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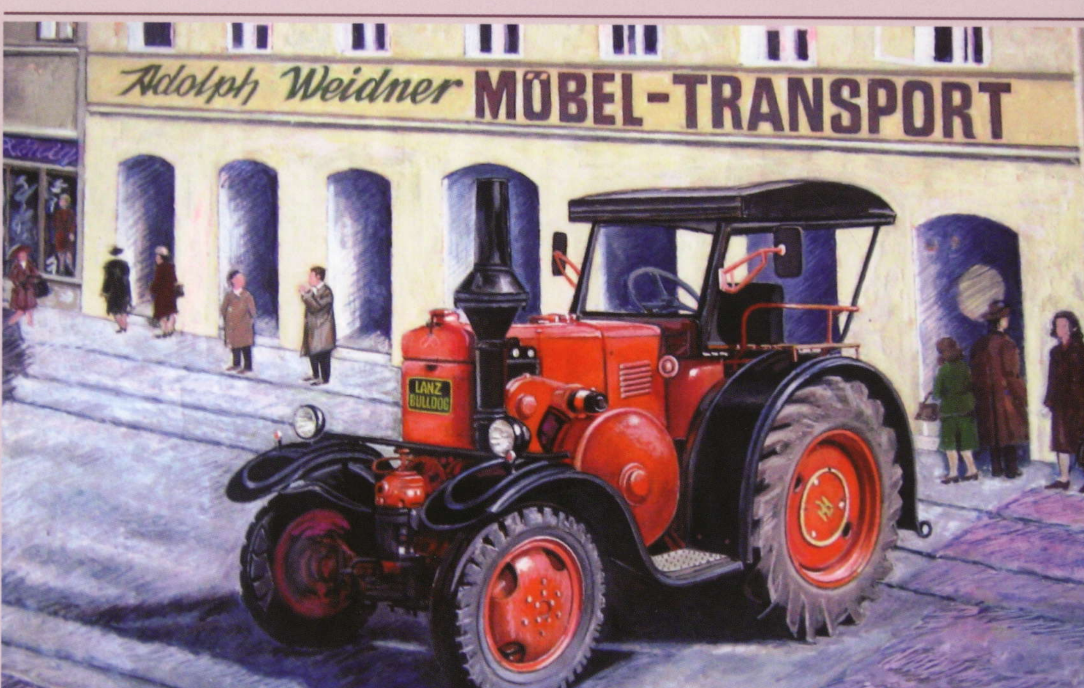
Actual Tasks on Agricultural Engineering

OPATIJA, CROATIA, 22. - 25. FEBRUARY 2011



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ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN BIOSISTEMSKE VEDE
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2010 godina je prošla, no gospodarske teškoće globalnih razmjera nisu i nažalost njihov trag će nas sve još dulje vrijeme pratiti. Stoga je i ovaj 39. simpozij osjetno skromnijeg iznosa ukupnih troškova, ali zahvaljujući stalnoj potpori kolega iz struke, strukovnih udruga (HUPT i HAD), trgovačkih kuća-predstavnika svjetskih proizvođača poljoprivrednih strojeva i opreme, Ministarstva znanosti obrazovanja i športa, te međunarodnih udruga Poljoprivredne tehnike (EurAgEng, CIGR, AAAE i AAESEE) ustrajali smo organizirati 39. Simpozij ”Aktualni zadaci mehanizacije poljoprivrede”. Ovaj 39. po redu Zbornik sadrži 48 radova od čega: Estonija, Islamska Republika Iran, Mađarska, Njemačka i Turska po (1), Italija (3), Hrvatska (5), Srbija (6), Slovenija (7) i Rumunjska (22) rada. Zahvaljujemo se svim sponzorima koji su svojom potporom omogućili održavanje ovog skupa, autorima referata, kao i svim učesnicima na interesu. Posebno se zahvaljujemo Ministarstvu znanosti i tehnologije Republike Hrvatske na stalnoj potpori. Svim učesnicima želimo ugodan boravak u Opatiji za vrijeme održavanja Simpozija.

Heavy burden of global economic crisis have marked the previous year 2010 while its influence unfortunately will follow all of us much more longer than we would like it. So, this 39th symposium is also urged to balance total expenses with much more skill than before but steady support of our colleagues, associations (CAES, CSA), commercial representatives of the world famous agricultural machinery and equipment producers, Ministry of sciences, education and sport and finally world known associations for agricultural engineering (EurAgEng, CIGR, AAAE and AAESEE) helped us and enabled organizer to carry out 39th symposium ”Actual tasks on Agricultural Engineering”. This proceedings contains 48 papers among them are: Estonia, Islamic Republic of Iran, Hungary, Germany and Turkey with (1), Italy (3), Croatia (5), Serbia (6), Slovenia (7) and Romania (22) papers. We would like to thank authors, reviewers, participants and especially sponsors for their contribution to organize the symposium. We especially emphasize sponsoring of Ministry of Sciences and technology of Republic of Croatia. Finally we wish all participants, our colleagues pleasant time, weather and company during symposium.

Chief Editor

Prof. dr. sc. Silvio Košutić

Zagreb, siječanj-January 2011.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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MATHEMATICAL MODELS FOR FLOOD AND DEBRIS FLOW ROUTING

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ABSTRACT

Floods and debris flows are among the most damaging of natural hazards, and are likely to become more frequent and more relevant in the future, due to the effects of increase in population, urbanization, land subsidence and the impacts of climate change, with the resulting increase in both annual average and peak intensity of rainfall.

During the period 1985-2003, the world experienced between 1700 and 2500 (major) flood events, while in Europe, from the Fifties to the Nineties, the number of floods in the river basins has risen from 11 to 64 per decade.

Knowledge and scientific tools play a role of paramount importance in the strain of coping with flooding problems. In this context, mathematical models represent the basis for effective flood mitigation. By using a model, an attempt is made to replace trial and error based strategies, as practised in the past, with more physically-based measures for flood management and control. Mathematical models are the best tools, nowadays available, for the design of efficient flood protection strategies and excellent supporters for decision-makers.

While in the past models were limited mainly to one dimension (1D), which is clearly not sufficient for the risk assessment of these hazards, now 2D or 3D codes are available and widely used for flood forecasting .

With reference to these issues, the paper provides a review and a general description of the main features of two new models that can be used in flood management along with the characteristics of the experimental data required for models' calibration.

Key words: *Flood risk management; Flood frequency analysis; Deterministic models.*

INTRODUCTION

Floods and debris flows are the most damaging of natural hazards, and are likely to become more frequent and more relevant in the future, due to the effects of many factors such as urbanization, land subsidence and the impact of climate change.

Within the European environment, the Flood Directive 2007/60/EC provides a framework for the assessment and management of flood risk across Member States (EC 2007). The Directive requires Member States to produce the first Flood Risk Management Plans (FRMPs) in 2015, whose core elements are: preliminary flood risk assessment, flood hazard and risk maps and flood risk management plans. In this context, mathematical models represent the basis for effective flood mitigation.

While in the past models were limited mainly to 1D, which is clearly not sufficient for the assessment of these hazards, now 2D or 3D codes are available and widely used for flood forecasting and mitigation.

With reference to these issues, the paper proposes two new models for both flood (clear-water) and debris flow routing.

RISK ASSESSMENT

Risk is an integral part of social and economic processes and is often increased by human interference with natural hydro-meteorological phenomena. The struggle against extreme events like floods and droughts is old as mankind. But in the last decades new challenges are likely to influence risk management measures and policies. These challenges can be summarized as follows (De Wrachien et al., 2010):

- climate change is likely to impact climate variability, making extreme events more severe and more frequent;
- increasing world population and economic growth lead to a more intense use of water and land resources;
- there is a rising awareness of the need of integrated water resources management, considering the river basin as the basic planning unit;
- due to the relentless urbanization process, at world wide level, hazards are increasingly transforming into disasters putting development at risk;
- there is a rising concern that damages resulting from water related disasters are growing disproportionately worldwide.

To cope with these challenges involves taking decisions and actions about appropriate levels of risks. These decisions and actions may be divided into the following two processes:

1. risk analysis procedure;
2. risk management cycle.

MATHEMATICAL MODELS

Types of Models

Research work on flood dynamics has traditionally specialized in different mathematical models. They can be roughly categorized into stochastic, deterministic and hybrid models.

Stochastic models are based on flood frequency analysis, defined as the means by which flood discharge magnitude is related to the probability of its being equalled or exceeded in any year or to its frequency of recurrence or return period.

Deterministic models are, generally, based on physical properties of elements that feature or influence the phenomenon under investigation, such as the catchment characteristics, the channel geometry, the rainfall-runoff process.

The recently proposed hybrid models offer the advantage of operationally combining the flood routing and the determination of the flood level. Moreover, this procedure opens up the potential for modelling more dynamic flood events such as ice jam release surges, which cannot be handled by traditional hydrologic or hydraulic modelling approaches.

Flood Routing

The River FLO-2D model is based on the Shallow Water (SW) equations that describe the free surface flow with a depth averaged approximation (Garcia-Martinez et al., 2009).

The resulting equations are as follows:

Continuity:

$$\frac{\partial \eta}{\partial t} + \frac{\partial UH}{\partial x} + \frac{\partial VH}{\partial y} = 0 \tag{1}$$

Momentum in *x*-direction:

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g\frac{\partial \eta}{\partial x} + \frac{\tau_{bx}}{\rho} = 0 \tag{2}$$

Momentum in *y*-direction:

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + g\frac{\partial \eta}{\partial y} + \frac{\tau_{by}}{\rho} = 0 \tag{3}$$

Sediment continuity:

$$(1-\lambda)\frac{\partial z_f}{\partial t} + \frac{\partial Q_{sx}}{\partial x} + \frac{\partial Q_{sy}}{\partial y} = 0 \tag{4}$$

where: x and y are the horizontal coordinates, t is the time, η is the water surface elevation, H is the water depth, U and V are the vertically averaged velocities in x and y directions respectively, ρ is the water density, g is the gravitational acceleration, z_f is the bed elevation, Q_{sx} , Q_{sy} are the sediment discharges in x and y directions respectively, λ is the soil porosity, τ_{bx} and τ_{by} are the bed friction terms defined as:

$$\tau_{bx} = \frac{gn^2 U \sqrt{U^2 + V^2}}{H^{4/3}} \tag{5}$$

$$\tau_{by} = \frac{gn^2 V \sqrt{U^2 + V^2}}{H^{4/3}} \tag{6}$$

and n is the Manning roughness coefficient.

The SW equations and the sediment continuity equation are discretized by the Galerkin finite element method using three-node triangular elements. To validate River FLO-2D the verification process recommended by ASCE Committee was followed (Wang et al., 2008). The process involves testing the model with analytical solutions, laboratory tests and comparisons with documented real cases, where field data are available.

Debris Flow Routing

Flood routing considers, mainly, situations of clear water surges. However, under natural conditions, a flood can generate extensive debris flows. Modelling these flows requires both a rheological model and constitutive equations for sediment-water mixtures.

Recently De Wrachien and Mambretti (2009, 2010) proposed a general 2D two-phase mathematical model suitable to analyse both non-stratified (mature) and stratified (immature) flows, i.e. when the solid/liquid mixture is present in the lower layer, while only water is present in the upper one (figure 1).

The 1D approach to debris flow routing is based on the De Saint Venant (SV) equations. This set of partial differential equations describes a system of hyperbolic conservation laws with source term (**S**) that can be written in compact vector for as:

$$\frac{\partial \mathbf{V}}{\partial t} + \frac{\partial \mathbf{F}}{\partial s} = \mathbf{S} \tag{7}$$

where:

$$\mathbf{V} = \begin{pmatrix} A \\ Q \end{pmatrix} \qquad \mathbf{F} = \begin{pmatrix} Q \\ \dfrac{Q^2}{A} + g \cdot I_1 \end{pmatrix} \qquad \mathbf{S} = \begin{pmatrix} 0 \\ g \cdot A \cdot (i - S_i) + g \cdot I_2 \end{pmatrix}$$

with $A(s,t)$: wetted cross – sectional area; $Q(s,t)$: flow rate; s and t: spatial and temporal coordinates; g: acceleration due to gravity; i: bed slope; S_i: bed resistance term or friction slope; I_1 and I_2: pressure forces, due to the longitudinal width variation.

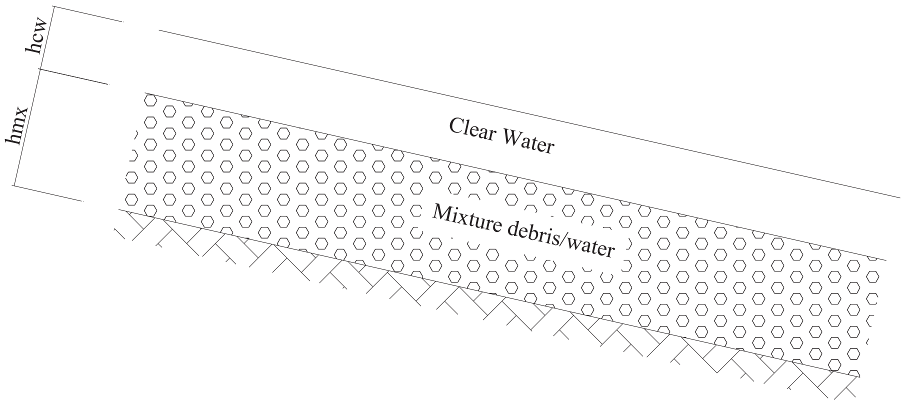

Figure 1 Scheme of the immature (stratified) debris flow.

To take into account erosion / deposition processes along the debris flow propagation path, a mass conservation equation for the solid phase and a erosion / deposition model have been introduced in the SV approach.

To extend the model to 2D, have been taken into account mass and momentum conservation balance for each phase and layer, and energy exchange between layers.

The level of maturity of the flow is assessed by an empirical, yet experimental based criterion (Larcan et al., 2006).

To validate the model comparisons have been made between its predictions and experimental results carried out at the Hydraulic Laboratory of Politecnico di Milano.

The 1D tests were performed with flows of water and homogeneous granular mixtures in a uniform geometry flume reproducing floods and debris flows triggered by dam failures. The 2D experiments were carried out utilizing a device consisting of a loading tank, a flume and a downstream basin with adjustable slope (De Wrachien and Mambretti, 2010).

DATA: REQUIREMENTS AND PROBLEMS

The most important question to be addressed when defining the quantity and quality of data to be used as input of a model is the purpose pursued.

Hydrologic models, based on empirical storage-flow relations, require only streamflow hydrographs as inputs. Hydraulic models require additional, physical and altimetric data describing the channel geometry and the floodplain morphology.

The topographic data resolution strongly affects the flood model efficiency.

Sound Digital Elevation Models (DEMs) must provide an accurate description of microtopography (e.g. levees, embankments, roads, buildings) to create a computational mesh in which all the elements that affect flow dynamics and flood propagation are included. The latest developments in airborne laser scanning make it feasible to produce high quality digital surface models (DSMs) with accuracies less than ± 25 *cm* depending on the land cover, slope, flight parameters and environmental conditions (Sole et al., 2008).

Hydrological/hydraulic flow characteristics are fundamental in flood modelling along with boundary conditions on depths and discharges.

The resistance to flow in a watercourse may be parameterized by the Manning, Chézy, Darcy friction coefficients which represent the effect of roughness elements of the channel bed and particles as well as losses mainly due to dynamic bed morphology and vegetation. Best results are obtained when the friction coefficients are adjusted (calibrated) to reproduce historical observation of stage and discharge.

CONCLUDING REMARKS

Floods and debris flows are among the most damaging of natural hazards, and are likely to become more relevant in the future due to the effects of increase in population, urbanization and land subsidence. These features, together with climate change, are changing the way flood risk is managed.

Within the European environment, the Flood Directive 2007/60/EC provides a framework for the assessment and management of flood risk across Member States. In this context, mathematical models represent the basis for effective flood forecasting, control and mitigation.

With reference to these issues, two new models for flood and debris flow routing are presented. The first model (River FLO-2D) is a 2D finite element river and dam-break flood code that uses a parallelized explicit time stepping scheme. The second model is a 2D, two-phase finite difference debris flow code suitable to analyse both non-stratified (mature) and stratified (immature) hyper-concentrated flows.

Both the models have been validated on the basis of laboratory tests and field data. With regard to the debris flow model, further research is in progress in order to feature the distribution of the material of different size of the solid phase (sorting): larger size material positioned in the front and in the top of the flood wave, and finer one in the bottom and in the tail.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ZADOVOLJSTVO ŽIVOTOM U RURALNOM PODRUČJU ZAGREBAČKE ŽUPANIJE

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SAŽETAK

Kvaliteta života osim uobičajenih pokazatelja često je rezultat i nemjerljivih subjektivnih vrijednosti, te je podložna promjenama tijekom određenog razdoblja.

Cilj ovog rada je utvrditi razinu zadovoljstva ispitanika životom u ruralnom području Zagrebačke županije. Istraživanje je provedeno metodom ankete na uzorku od 78 ispitanika u dobi između 25 i 45 godina.

Ispitanici su pokazali dosta kritičnosti spram ponuđenih obilježja kojima možemo označiti kvalitetu životnih uvjeta u njihovom naselju što je vidljivo i u najvišoj prosječnoj ocjeni od 3,45 za međuljudske odnose (ocjena od 1=nezadovoljavajuće do 5=odlično). Prometnu povezanost mjesta življenja sa općinskim/gradskim središtem u prosjeku ocjenjuju dobrom, nižom ocjenom uređenost stambenih objekata (2,71), zdravstvene usluge (2,27), uređenost javnih površina (2,18), socijalne usluge (2,05), zatim obrazovne usluge (1,78) te financijske i slične službe (1,73). Ruralna sredina je najčešće ograničena uskim spektrom izbora zanimanja (1,17) kao i mogućnošću zaposlenja u vlastitom mjestu (1,14) što je bitno ograničenje ostanka u njemu.

Ispitanici su svjesni boljih prirodnih uvjeta u svome mjestu u odnosu na grad, ali i nedostatka zabavnih i kulturnih sadržaja. U ruralnom prostoru veća je prisutnost vjere i vjerskog života, ali je manje kriminala, alkoholizma, narkomanije i sl te je prostor i manje onečišćen. Jače su obiteljske veze i veća je osobna sigurnost. U njihovom mjestu je manje odmora nego u gradu te manje slobodnog vremena. Općeniti dojam ispitanika je da njihov životni prostor humaniji za stanovanje nego u urbanim sredinama. Manje su mogućnosti za školovanje, ali i mogućnosti za politički i gospodarski uspjeh.

Ipak preko polovice ispitanika zadovoljno je svojim životom u selu (61,6%), četvrtina niti je zadovoljna niti nezadovoljna, a 15,4% ih je nezadovoljno.

Provedeno ispitivanje pokazuju da su najveći problemi života u ruralnom prostoru Zagrebačke županije ekonomske naravi tj. nedostatak posla, mali izbor zanimanja te niža zarada u odnosu na urbana središta posebno Grad Zagreb.

Ključne riječi: *Zagrebačka županija, ruralno područje, zadovoljstvo životom*

UVOD

Ruralni prostor posljednjih godina prolazi kroz nekoliko istodobnih promjena: smanjuje se zbog urbanizacije te industrijalizacije poljoprivrede, ali i dobiva na važnosti u strategijama ukupnog razvita pojedinih država ili užih lokalnih zajednica.

Zadovoljstvo odnosno nezadovoljstvo stanovnika životom u nekom prostoru često je rezultat nemjerljivih subjektivnih poimanja vrijednosti te podložno promjenama tijekom dužeg razdoblja.

Ruralni prostor Hrvatske dugo je značio demografski devastirano, kulturno i socijalno zaostalo, u gospodarskoj strukturi poljoprivredom dominantno područje (Bašić 2005). Autohtona različitost u proizvodnim djelatnostima i proizvodima, u građevinarstvu, kulturi i općenito načinu života uništavala se ubrzano (nakon ratova) ili postepeno u međuraću. Tek u posljednjih dvadesetak godina kod nas (kao i u Europi) ruralnom prostoru i ruralnom razvitku posvećuje se značajna pozornost sa željom očuvanja prostora uz uvažavanje njegovih različitosti.

Ruralni prostor Zagrebačke županije po nekim obilježjima je sličan ruralnom prostoru Hrvatske. Sličnost se ocrtava u njegovoj heterogenosti odnosno različitosti i to ekonomskoj, demografskoj, zemljopisnoj te u prosjeku se radi o području niske razine onečišćenosti. Posebnost prostora se očitava u njegovom „zagrljaju" najvećeg gospodarskog hrvatskog središta (Zagreba) što mu daje značajne pogodnosti u budućem razvitku, ali i njegova „naslonjenost" na Sloveniju što se može i treba iskoristiti naročito u razdoblju prije ulaska Hrvatske u EU (Juračak, J., Grgić, I., Kovačić, D. i sur. 2004).

CILJ ISTRAŽIVANJA

Cilj rada je utvrditi razinu zadovoljstva ispitanika životom u ruralnom području Zagrebačke županije kao jednog od bitnih preduvjeta gospodarske i demografske obnove prostora.

Zadovoljstvo i očekivanja ispitanika neizravno utječu na voljnost za dugoročnim ulaganjima kao što su ulaganja u strojeve i opremu te u poljoprivredne proizvodne objekte kojim bi se potaknuo rast dohotka i životnog standarda poljoprivrednog te s time i ukupnog ruralnog stanovništva.

METODE I MATERIJAL

Postoji nekoliko kriterija za određivanje ruralnosti, ali najčešće korištena definicija koju primjenjuju međunarodne organizacije za razdvajanje ruralnih i urbanih regija je ona razvijena u OECD-u. Ruralne regije su one u kojima gustoća naseljenosti iznosi manje od 150 stanovnika po km^2. Ukoliko je gustoća naseljenosti ispod 150 stanovnika po km^2, takva se zajednica smatra seoskom ili ruralnom.

U ovom istraživanju cijeli prostor Županije uzet je kao jedna regija Grgić i sur. (2007), Grgić i sur. (2008). Za gradove i općine izračunata je gustoća naseljenosti te su određeni kao ruralni odnosno urbani. Od ukupno 34 grada i općine u Županiji, primjenom ovakve podjele njih pet je svrstano u urbane, a dvadeset devet u ruralne zajednice. Prema Popisu 2001. godine na ruralnom prostoru živjelo je 182.961 osoba, odnosno 59,08% stanovništva Županije te se prostor Županije može svrstati u pretežito ruralne regije.

Istraživanje je provedeno metodom ankete na uzorku od 78 ispitanika. Jedinica anketiranja bila je kućanstvo, a unutar kućanstva jedan ispitanik u dobi između 25 i 45 godina.

Obrada je obavljena pomoću SPSS paketa 17.0 (Statistical Package for Social Sciences 17.0).

REZULTATI I DISKUSIJA

Neka sociodemografska obilježja ispitanika

Anketno istraživanje obuhvatilo je 79 osoba prosječne dobi od 33 godine. Najveći dio anketiranih je stalno zaposlen izvan gospodarstva (54,1%), manji dio nezaposlen (30,6%), poljoprivrednika je 12,5% te umirovljenika 2,8%.

Od stalno zaposlenih izvan gospodarstva najveći dio su radnici (82,0%), zatim službenici (12,8%) te poduzetnici (5,2%).

Prema stupnju obrazovanja, podjednaki dio ih je sa završenom srednjom trogodišnjom i srednjom četverogodišnjom školom (po 45,6%), 5,1% ispitanika ima osnovnu školu, 2,5% ima višu te 1,3% završen fakultet. Obrazovna struktura anketiranih je bolja od prosjeka Hrvatske s izuzetkom udjela osoba sa završenim fakultetom. Prema popisu iz 2001. godine u Republici Hrvatskoj bez škole je bilo 2,9% osoba starijih od 15 godina, sa osnovnom 37,5%, srednjom trogodišnjom 27,2%, srednjom četverogodišnjom 19,8%, višom školom 4,1% te sa fakultetom 7,8% .

Kvaliteta životnih uvjeta u naselju ispitanika

Kod bilo kakve procjene pred ispitanika se postavlja veliki problem: kako objektivno valorizirati kvalitetu pojave kroz osobni osjećaj vrijednosti i kako odabrati pojavu/kvalitetu sa kojom uspoređuje svoje viđenje. U konkretnom slučaju, radi se o životnim uvjetima u naselju ispitanika i njegovoj „skrivenoj usporedbi sa kako bi trebalo biti ili najčešće kako negdje i jest (u gradu)".

Vrlo često ispitanici kojima se ponude ovakva pitanja nesvjesno pokušavaju umanjiti nešto što je dobro «misleći da će na taj način zainteresiranu drugu stranu u istraživanju potaknuti da nešto i učini odnosno poboljša».

Uz sva navedene nedostatke, ispitanici su pokazali dosta kritičnosti spram ponuđenih obilježja kojima možemo označiti kvalitetu životnih uvjeta u njihovom naselju (najviša prosječna ocjena 3,45). Iako je teško povezati jakost veze između prosječne ocjene i možebitne njihove odluke o napuštanju naselja, ipak su dobar indikator za kvalitetno djelovanje lokalne samouprave i državne uprave.

Ruralnu sredinu zbog mnogo faktora, od kojih su najznačajniji brojnost stanovništva po naselju i rodbinska isprepletanost, karakteriziraju dobri međuljudski odnosi. Kod ocjene kvalitete životnih uvjeta kod ispitanika su na prvom mjestu i procijenjeni su između dobrih i vrlo dobrih (3,45).

Selo je sve bliže urbanim središtima pa je problem prometne povezanosti sve manje naglašen. Ispitanici prometnu povezanost svoga mjesta sa općinskim/gradskim središtem u prosjeku ocjenjuju dobrom.

Sve veća pozornost se posvećuje uređenosti stambenih objekata (prosječna ocjena 2,71), ali je opskrba mješovitom robom, po procjeni ispitanika, u prosjeku loša (2,40).

Tablica 1. Zadovoljstvo anketiranih nekim obilježjima života u ruralnom području 1 (Nezadovoljavajuće); 2 (Zadovoljavajuće); 3 (Dobro); 4 (Vrlo dobro) i 5 (Odlično)

	N	Min	Max	Mean	Std. Deviation
Međuljudski (susjedski) odnosi	78	1	5	3,45	0,784
Uređenost stambenih objekata i dvorišta	78	1	5	2,71	0,824
Prometna povezanost sa središtem	78	1	5	2,69	0,902
Opskrba mješovitom robom	78	1	5	2,40	1,303
Zdravstvene usluge	78	1	5	2,27	1,439
Uređenost javnih površina	78	1	4	2,18	0,818
Socijalne usluge	78	1	5	2,08	1,160
Komunalna infrastruktura	78	1	4	2,05	0,851
Obrazovne usluge	78	1	4	1,78	0,847
Financijske i slične službe	78	1	4	1,73	0,863
Mogućnost izbora zanimanja/posla	77	1	3	1,17	0,410
Mogućnost zaposlenja	78	1	3	1,14	0,386

Izvor: Anketa

Zdravstvene usluge (ambulanta, ljekarna) po procjeni ispitanika su nešto iznad zadovoljavajućeg (2,27). Dobna struktura ruralnog stanovništva (sve veći udio starih i nemoćnih koje su mlađi napustili odlaskom u gradove) i njihova potreba za zdravstvenim uslugama alarmiraju i ispitivani dio populacije je uspoređuje sa zdravstvenim uslugama u bližim ili češće u velikim središtima (posebice Zagrebu).

Sve veća pozornost se posvećuje uređenosti javnih površina i kritički se na to gleda (prosječna ocjena 2,18), pri čemu ih veliki postotak smatra u svojoj sredini nezadovoljavajuće uređenim.

U posljednje doba puno je učinjeno na izgradnji komunalne infrastrukture (vodovod, kanalizacija, plin, telefon i sl.) u pojedinim ruralnim područjima Županije, ali je ispitanici ipak procjenjuju prosječnom (od zadovoljavajuće do dobre). Jedna četvrtina je ocjenjuje nezadovoljavajućom.

Jedan od najvećih nedostataka ruralnih područja su socijalne usluge kao što su dječji vrtić, jaslice, starački dom i sl. Ispitanici ih ocjenjuju relativno skromnim tj. ispod zadovoljavajućih (prosječna ocjena 2,08).

Obrazovne usluge najčešće se svode na obavezno osnovno obrazovanje pa ispitanici tome daju ocjenu neznatno iznad zadovoljavajuće.

Financijske i slične službe (banke, bankomati, poštanski uredi i sl.) sve su prisutnije i dostupnije što prepoznaju i ispitanici i s obzirom na svoje potrebe oni ih u prosjeku smatraju zadovoljavajućim. Međutim, sve veće svakodnevne potrebe za njim kod velikog dijela ispitanika za posljedicu ima da ih oni smatraju nezadovoljavajućim.

Ruralna sredina je najčešće ograničena uskim spektrom svekolikih izbora pa tako i izbora zanimanja što su potvrdili i ovi ispitanici sa prosječnim zadovoljstvom bližim najnižoj ocjeni (1,17).

Mogućnost zaposlenja u vlastitom mjestu je u prosjeku mala (1,14) što je jedno od bitnih ograničenja ostanka u njemu.

Prednost i nedostaci života u naselju ispitanika

Procjena te usporedba «dobre i loše strane života u mjestu ispitanika u odnosu na život u gradu» susreće se sa dva značajna pitanja (1) koliko ispitanik kvalitetno/objektivno može procijeniti svoju sredinu i (2) koliko je općenito upoznat sa životom u gradu.

Za prvo (procjenu) bitan je njegov osobni osjećaj lošeg i dobrog što u konačnici određuje sve njegove buduće postupke te tako i želju za napuštanjem sadašnjeg mjesta življenja. Kako se u gradu živi, većina ispitanika je mogla u većoj ili manjoj mjeri i vidjeti/osjetiti zbog dosadašnjih intenzivnih migracija na relaciji selo-grad te ispitanici iz ove dobne skupine već imaju nekoga u gradu kod koga su i sami boravili i barem na kratko upoznali život u njemu (Ilišin 2006).

Odluka otići ili ostati osim značajnog utjecaja sreće, slučaja i sličnog najviše se temelji na dugogodišnjim osobnim ocjenama, procjenama i usporedbama kvalitete života u jednoj sredini. Najčešće, nedostaci života vrednuju se i ponderiraju većim ponderom od prednosti.

Ispitanicima je ponuđeno 26 prosudbi kojima smo procjenjivali dobre i loše strane života u njihovom mjestu pri čemu viša ocjena znači i njihovu veću suglasnost sa ponuđenom konstatacijom.

Selo u pravilu, u odnosu na grad, je hendikepirano sa zabavnim i kulturnim sadržajem (4,32). S time se slaže 43,6% te u potpunosti slaže 44,9% ispitanika. Međutim, ispitanici su svjesni boljih prirodnih uvjeta i većeg suživota sa prirodom u svome mjestu (4,31) pri čemu se čak 94,9% s time slaže i potpuno slaže. U ruralnom prostoru veća je prisutnost vjere i vjerskog života (4,3) što je mišljenje velikog dijela ispitanika (92,3%). Da je lošija komunalna opremljenost vlastitog sela u odnosu na grad slaže se i u potpunosti slaže dvije trećine ispitanika (92,3%), 3,8% o tome nema svoje mišljenje dok se njih 3,9% s time ne slaže.

Tablica 2. Dobre i loše strane života u mjestu ispitanika 1 (Uopće se ne slažem); 2 (Ne slažem se); 3 (Niti se slažem niti ne slažem); 4 (Slažem se); 5 (Potpuno se slažem)

	N	Min	Max	Mean	Std. Deviation
Manje zabavnih i kulturnih događaja	78	2	5	4,32	0,712
Bolji prirodni uvjeti	78	3	5	4,31	0,517
Veća prisutnost vjere i vjerskog života	78	1	5	4,29	0,74
Lošija komunalna opremljenost	78	1	5	4,29	0,824
Više se čuva tradicija	78	1	5	4,22	0,714
Manje onečišćenje	78	1	5	4,21	0,762
Manje kriminala, alkoholizma, narkomanije	78	1	5	4,17	0,780
Veća osobna sigurnost	78	1	5	4,15	0,774
Veći slobodan prostor	78	2	5	4,06	0,566
Manja zarada	78	2	5	4,05	0,788
Više fizičkog rada	78	3	5	4,04	0,612
Manje odmora	78	2	5	3,99	0,634
Manje slobodnog vremena	78	2	5	3,95	0,701
Humaniji prostor za stanovanje	78	2	5	3,94	0,709
Manje mogućnosti za polit. i gosp. uspjeh	78	2	5	3,83	0,780
Konzervativnija sredina	78	2	5	3,83	0,903
Manje mogućnosti za školovanje	78	1	5	3,81	0,774
Zdravija prehrana	78	2	5	3,79	0,858
Lošije uređen stambeni prostor	78	1	5	3,79	0,998
Jače obiteljske veze	78	1	5	3,77	0,737
Veća prometna izoliranost	78	2	5	3,68	0,655
Manja privatnost pojedinca	78	1	5	3,55	0,847
Bliskiji kontakti s mještanima	78	2	5	3,53	0,697
Manje socijalne razlike	78	1	5	3,06	0,958
Manje stresno	77	1	5	2,91	1,028
Manji troškovi života	78	1	5	2,31	1,177

Izvor: Anketa

U selu se više drži i čuva tradicija nego u gradu (4,22) s čime se slaže i u potpunosti slaže čak 92,3% ispitanika. Slična tome je i njihova percepcija prednosti manjeg onečišćenja (zagađenosti) prostora (4,21) s čime se slaže 62,8 te potpuno se slaže 32,1% ispitanika. Kriminal, alkoholizam, narkomanija i sl. nisu biljeg samo urbanog prostora, ali svoj prostor ispitanici još uvijek procjenjuju sigurnijim i manje «zatrovanim« (4,17). Sa tvrdnjom da je u selu manje kriminala, alkoholizma i narkomanije slaže se i u potpunosti slaže 85,9% ispitanika. Naglašena prisutnost obiteljskih veza daje i osjećaj veće osobne sigurnosti (4,15) s čime se slaže i u potpunosti slaže 91,1% ispitanika.

Veći slobodni prostor nego u gradu percipira značajan broj ispitanika (ocjena 4,06) s čime se slaže i u potpunosti slaže njih 92,3%. Oko tri četvrtine (78,0%) ispitanika slaže se i u potpunosti slaže sa tvrdnjom da je u selu u odnosu na grad manja zarada, njih 20,5% nema izraženo mišljenje te ih se 2,6% s time ne slaže.

Život u ruralnom prostoru često se percipira izrekom «radi se od jutra do sutra» te i ispitanici u visokom su suglasju sa njom u odnosu na život u gradu (4,04). Da je u selu više fizičkog rada slaže se 62,8 te u potpunosti se slaže 20,5% ispitanika. Shodno tome, sve pogodnosti prirodnog okruženja nisu i prostor «ljenčarenja» te ispitanici se slažu da je u njihovom mjestu manje odmora nego u gradu (3,99) s čime se slaže njih 64,1% te u potpunosti se slaže 17,9%. Manje odmora znači i manje slobodnog vremena (3,95) čime se slaže 59,0% te u potpunosti se slaže njih 19,2%. Ipak, općeniti dojam ispitanika je da njihov životni prostor humaniji za stanovanje nego u urbanim sredinama (3,94) s čime se slaže 61,5% te u potpunosti se slaže 17,9% ispitanika.

Nedostatak odgojno obrazovnih institucija kod ispitanika dovodi do procjene da su u njihovom mjestu značajno manje mogućnosti za školovanje (3,81) nego u gradu s čime se slaže i u potpunosti slaže 75,6% ispitanika, ali i da je značajno manja mogućnost za politički i gospodarski uspjeh (3,83) što je mišljenje čak 73,1% ispitanih osoba. Bez obzira na »industrijalizaciju sela» većina ispitanika prehranu procjenjuju zdravijom nego u gradu (3,79) s čime se slaže i u potpunosti slaže 77,6% ispitanika.

Da je u njihovom naselju lošije uređen stambeni prostor nije suglasno 10,3% ispitanika, petina ih o tome nema mišljenje, 41,0% ih se slaže te 25,6% se u potpunosti slaže. Prisutnost tradicionalnog u ruralnim sredinama temelji se i na jačim obiteljskim vezama nego onima u gradu (3,77) čime se slaže i u potpunosti se slaže 84,6% ispitanika.

Naglašenija prometna izoliranost je bliža procjeni «slažem se» (3,68) što misli 62,8% ispitanika te u potpunosti se slaže njih 5,1%.

Privatnost pojedinca u ruralnim sredinama je ograničena brojnošću, manjim životnim prostorom, familijarnim vezama, tradicijom i drugim. Čak 59,0% ispitanika smatra da je privatnost u selu manja nego u gradu što u konačnici ne mora imati loše posljedice za pojedinca.

Manja mjesta su često i mjesta naglašenijih međuljudskih kontakata sumještana što ispitanici navode kao značajnu prednost u odnosu na grad (3,53). S time se slaže 52,6% ispitanika te u potpunosti ih se slaže 3,8%.

Socijalne razlike su prisutne i zamjetne neovisno od područja te ih ispitanici ne valoriziraju kao prednost u odnosu na grad (3,06). Jedna trećina (28,2%) ih nema mišljenje o tome, 39,7% ih se slaže da su one manje nego u gradu te se u potpunosti s time slaže njih 1,3%.

Navedene prednosti nisu pogodovale i percepciji manje stresnog života (2,91) s čime se slaže 18,2 te u potpunosti se slaže 7,8% ispitanika, Jedna petina ispitanika o tome nema određeno mišljenje (niti se slaže niti ne slaže).

Sve veća količina kupljenih inputa za kućanstvo značaj troškova života približava onima u gradu (2,31). Sa tvrdnjom da su troškovi niži nego u gradu se slaže i u potpunosti slaže njih 21,8%, ne slaže se približno jedna trećina (58,9%), niti se slaže niti ne slaže 19,2%.

Motivi za napuštanje sadašnjeg naselja

Motivi za promjenu mjesta življenja su mnogobrojni. Najčešće se navode ekonomski razlozi kao što su nedostatak zaposlenja i niža razina dohotka. Nakon toga je niži standard življenja promatran kroz komunalnu i socijalnu infrastrukturu. Kao motiv za napuštanje mjesta življenja, u ovom slučaju ruralnog prostora – sela, bitan je i osobni doživljaj pojedinca kroz „društvenu skalu vrijednosti ako što je primjerice „selo=loše, nazadno, prljavo„ ili „selo= prihvatljivo, hit, opuštajuće, prirodno“).

Preko polovice ispitanika zadovoljno je svojim životom u selu (61,6%). Četvrtina ispitanika niti je zadovoljna niti nezadovoljna, a 15,4% ih je nezadovoljno.

Bez obzira na sve navedeno osjećaj zadovoljstva ili nezadovoljstva može se odrediti, ali rijetko i kvantificirati, prema određenoj skupini obilježja pri čemu stožer odrednice je osobna spoznaja o „boljem drugdje“ ili osjeća „negdje je bolje ili ovdje može i treba biti bolje“.

Bez obzira na osobni osjećaj zadovoljstva njih polovica kao najveći problem u svome selu vidi ukupnu infrastrukturu i nedovoljne komunalne usluge. Izgradnja putne mreže, razvitak javnog prijevoza te povećani broj osobnih prometala za posljedicu ima to da ih manji dio (28,8%) kao problem ističe prometnu povezanost svoga mjesta sa većim središtima. Posljedično tome ne ističu (ili ne primjećuju) nedostatak posla (13,7% ispitanika), loš društveni život (5,5%) odnosno standard (1,4%).

Sličan slijed je i kod percepcije vlastitih problema u mjestu stanovanja. Kao najveći osobni problem u mjestu stanovanja (33,7% ispitanika) ističu lošu infrastrukturu te prometnu povezanost (31,8%), nedostatak posla (16,8%), loše uvjete za mlade (7,9%), slab standard i društveni život (po 4,9%).

ZAKLJUČAK

Provedeno ispitivanje pokazuju da su najveći problemi života u ruralnom prostoru Zagrebačke županije ekonomske naravi tj. nedostatak radnih mjesta (posla), manja mogućnost izbora zanimanja i manja zarada u odnosu na urbana središta posebno Grad Zagreb. Ispitanici su također nezadovoljni socijalnim i zdravstvenim uslugama te slabo razvijena komunalna infrastruktura.

Stanovnici ruralnog prostora su svjesni i prednosti koje donosi život na selu u odnosu na život u gradu. To su: život u prirodom okruženju, manje zagađen prostor, bolje socijalne veze te manja stopa kriminaliteta.

Za potencijalne migrante najveći problem života na selu je nedostatak posla. Najveće prednosti života u gradu, prema njihovom, su veća mogućnost zaposlenja i dodatna zarada te puno veće mogućnosti za školovanje (njihove djece) i dodatno osobno usavršavanje.

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SATISFACTION OF LIFE IN A RURAL AREA OF ZAGREB COUNTY

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ABSTRACT

Quality of life, in addition to the usual indicators, is often the result of subjective and immeasurable values and it is also liable to changes during certain periods.

The aim of this study was to determine the level of satisfaction with life quality of informants in rural areas of the Zagreb County. The research was conducted a survey on a sample of 78 subjects aged between 25 and 45 years.

Informants showed a lot of criticism against the offered features that can mark the quality of living conditions in their neighborhood as it seen in the highest average rating of 3.45 for interpersonal relationships (scale of 1 = unsatisfied to 5 = excellent).

Traffic connection between place of living and the municipal center is well graded in the average, arrangement of housing is lower rated (2.71),also health services (2.27), decoration of public spaces (2.18), social services (2.05), than educational services (1.78) and financial and similar services (1.73).

Rural areas are often limited to a narrow spectrum of choice of professions (1.17) as well as the possibility of employment in our own place (1.14) which is essentially a limit to stay in it.

Informants are conscious of the better natural conditions in their place in relation to the town, but also of the lack of entertainment and cultural events. In rural areas it is increased presence of faith and religious life, but also there is less crime, alcoholism, drug addiction, etc, and the environment is less polluted. The family ties are stronger and personal safety is grater. In their place is less rest then it is in the city and it is also less free time. The overall impression of the informants is that their living space is more humane than same space in urban areas. There are fewer opportunities for schooling, but also opportunities for political and economic success. Over half of informants are still satisfied with their lives in the village (61.6%), quarter of them are neither satisfied nor dissatisfied, while 15.4% of them were dissatisfied.

Conducted examination showed that the greatest life problems in a rural area of the Zagreb County was economic nature, which refers to lack of work, a small selection of jobs and lower wages than in urban centers, particularly in the City of Zagreb.

Key words: *Zagreb county, rural area, satisfaction of life*

39.
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ABOUT THE NOISE ENERGY CONVERSION FROM AGRICULTURE TRACTOR ENGINES

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ABSTRACT

In this paper is presented the work carried out in the Department of Road Vehicles and Farm Machinery laboratories regarding the possibility of energy recovering from the pressure wave of the exhaust gasses and its conversion into electric energy.

The noise generated by the engine which equips farm tractors represents a factor of discomfort for the operators and a source of environment pollution. The analysis of this noises from an energetic point of view shows the fact that there is a possibility to capture the acoustic wave and convert it into electric energy with benefits on noise reduction.

The experimental results show conversion efficiency from noise into electric energy up to 75%. The tests were carried out using laboratory stands of self conception and acoustic piezoelectric sensors.

Key words*: energy, noise, engine, electric, harvest ratio.*

STATE OF THE ARTS

The acoustic energy is present all over the environment as a result of the evolution of other energies (thermodynamic energy, mechanical energy, electric energy, etc.). Considering another approach of the acoustic phenomena we can estimate that almost all energy transformations contain an acoustic fraction which in most cases is evaluated as a lost energy.

As an example we consider the transformation of the thermodynamic energy into mechanichal energy in the functioning conditions of the internal combustion engine. If we consider the energetic balance of this transformation described by the equation:

$$E_{th} = E_m + E_{lost} \ , \tag{1}$$

and if we detail the lost energy during the transformation (E_{lost}) considering the fact that a part of the energy is lost by friction and as a thermal lost energy, it is obvious that a part of the lost energy consists of acoustic energy described by the noise produced from the internal combustion function. In order to describe the source of this energy a basic approach was carried out considering the quantum energy of the acoustics: the phonon described in "The Theory of the Quantic Field" (Max Born and Jordan Pascual (1920) [2].

Along with the rise in concerns for the environment and the future of the planet, scientists have begun to seek alternative ways of obtaining energy, especially in the field of producing electric energy and thermal energy from renewable sources. The field of acoustics can be a real opportunity for the undergoing attempts to identify new forms of energy capable of covering the socio-economic needs.

The human ear, being as sensitive as it is, can overrun this entire power spectrum, from the audible border (10^{-12} W) to 10^{6} W (the feeling of pain appears over 100 W). Due to this considerable sensitivity acoustic noise is considered to be an agent of sound pollution.

The acoustic field from 120 dB to 160 dB (Table 1) might be explored in the future as a source of renewable energy.

Table 1 The characteristics of different typical sounds

Sound source	Sound power [W]	Acoustic sound power level [dB]	Sound pressure [Pa]	Sound intensity [W/m^2]
Racket	1.000.000	180	20.000	1.000.000
Turbo jet airplane engine	10.000	160	2.000	10.000
Buzzer	1.000	150	632	1000
Trucks	100	140	200	100
Gun machine	10	130	63	10
Pick hammer	1	120	20	1
Dog barking	0.1	110	6,3	0,1
Chopper	0.01	100	2	10^{-2}
Loud voice	0.001	90	0,63	0,001
Typewriting machine	10^{-5}	70	63x10^{-3}	10^{-5}
Refrigerator	10^{-7}	50	6,3x10^{-3}	10^{-7}
Hearing limit	10^{-12}	0	2x10^{-5}	10^{-12}

On the other hand, the green energy produced by the conversion of solar energy measures up to the same size. This way by using the solar energetic potential available in Romania (an average of 1275 kW/m^2/year), i.e. 146 W can be collected from 1m^2. Through the conversion with solar cells 25 W can be collected, provided that the sun is shining and there are no clouds. In spite of all this, solar systems tend to be used quite often for recovering energy.

We notice a systematic approach for the conversion of acoustic energy throughout the scientific literature. In the last 20 years several articles have been published which discuss the possibility of obtaining electric energy from the conversion of acoustic energy by using the Helmholz resonator [8].

The conversion of acoustic energy into electric energy with the use of piezoelectric transducers has received a patent in the United States. A problem that arises rather often is the issue of storing acoustic energy given that the mere possibilities of obtaining it are scarce by virtue if its content [7].

The noise which results from the functioning of engines with inner burning is regarded as a source of pollution, along with the chemical composition of exhaust fumes. The methods of reducing the noise are based on alleviation and not on conversion. Alleviation represents a way of dissipating energy, based on controlled losses of wave pressure.

THEORETICAL ASSUMPTIONS

There is a question for which we must find the answer: If the acoustic energy exists can we evaluate and store this kind of energy?

In accordance with the classic and quantum description of the mechanical phenomena the matter is characterized by a quasiparticle described by the quantification of the modes of lattice vibration of periodic, elastic crystal structures of solids so called phonon [1].

Considering a normal acoustic wave, the density of the energy is defined by the relation:

$$w = \frac{I}{c} \tag{2}$$

where:

w – is the density of the energy contained in the wave and measured in [J/m^3]

I – acoustic intensity [W/m^2]

c – acoustic wave speed [m/s].

Considering the sound intensity relation, the acoustic energy may be written with the formula [3]:

$$w = \frac{dE}{dV} = \frac{1}{2} \cdot \omega^2 \cdot A^2 \cdot \rho = \frac{p_{\max}^2}{2 \cdot \rho \cdot c \cdot c} = \frac{p_{\max}^2}{2 \cdot Z \cdot c} = \frac{I}{c} \tag{3}$$

where:

p – is the acoustic pressure in [N/m^2];

v – the speed of the acoustic wave [m/s];

ρ – the density of the propagation field [kg/m^3];

z_c – is the characteristic impedance [N·s/m^3];

c – is the sound velocity in [m/s].

The acoustic energy may be simulated for different sources and the shape of the density energy is similar with the shape of the impedance variation for different sources. The energy described with the relation 3 contains at the same time kinetic energy w_k and potential energy w_p, according to the equation:

$$w = w_k + w_p = \frac{1}{2 \cdot c} z \cdot v^2 + \frac{1}{2 \cdot c} \frac{p^2}{z} \tag{4}$$

In accordance with the equation 4, the impedance of the propagation environment and the impedance of the acoustic wave represent the key of noise harvest possibilities.

THE EXPERIMENTAL METHODOLOGY

The main option to describe the possibilities to harvest the noise and convert it into electrical energy stored or consumed is presented in the diagram from figure 1. Considering the mentioned diagram the noise measurement values of the noise harvest (see table 1) are important and so far it is not possible to increase the energy of the noise without any other added energy.

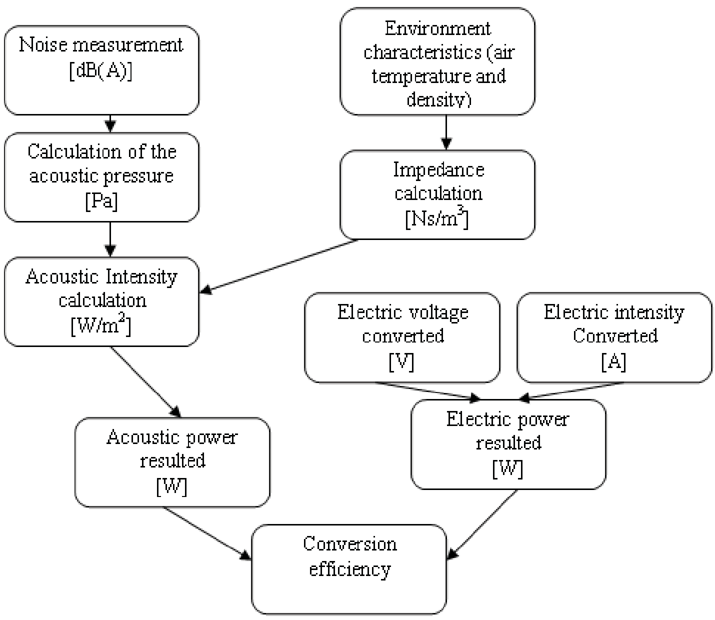

Figure 1 The diagram of the energy conversion efficiency evaluation

The main characteristic of the harvesting method is the sensitivity of the receiver which collects the noise depending on frequency and average intensity.

The final stage of the conversion represents the efficiency evaluation. In this respect the receiver area and its characteristics are important. To evaluate the efficiency an algorithm was developed by the authors and used as a software interface during the noise harvest evaluation.

According with this assumption an electronic device was designed to measure the electric energy delivered from the harvest noise (fig. 2).

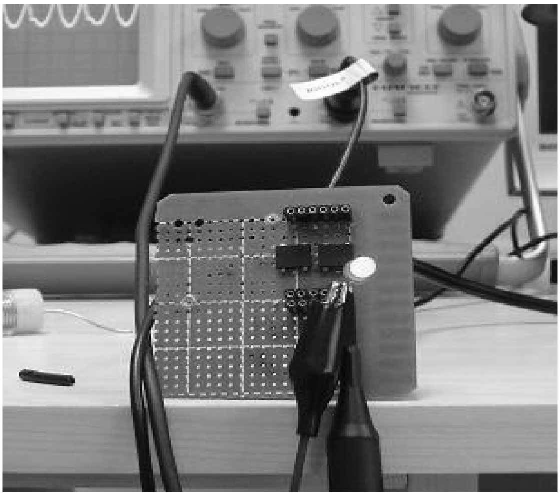

Figure 2 The electronic device designed to identify the presence of the delivered electric energy

In order to identify the most efficient receiver a few acoustic receiver types were analyzed. Finally the piezoelectric receiver type was used for experimental tests.

EXPERIMENTAL TESTS AND RESULTS

The aim of the research work carried out was to identify the energetic potential of the noise exhausted from a Diesel engine. In this respect an experimental stand was achieved (fig. 3).

The stand contains the Diesel engine D 30 with two cylinders and 30kW effective power and a few measurement instruments: noise analyzer, microphone, oscilloscope and an electric supply measurement instrument. To convert the energy of the noise a tweeter device was used.

We must mention the fact that the transducer high sensitivity is situated at 4 kHz frequency. In order to find the presence of the electric energy obtained from noise a new electronic device was designed.

Figure 3 The experimental stand for noise energy conversion evaluation; 1 – N 121 noise analyzer; 2- microphone; 3 – exhaust pipe; 4 – D 30 Diesel engine; 5 – oscilloscope; 6 – tweeter SAL KHS110 (acoustic transducer); 7 – energy supply measurement instrument

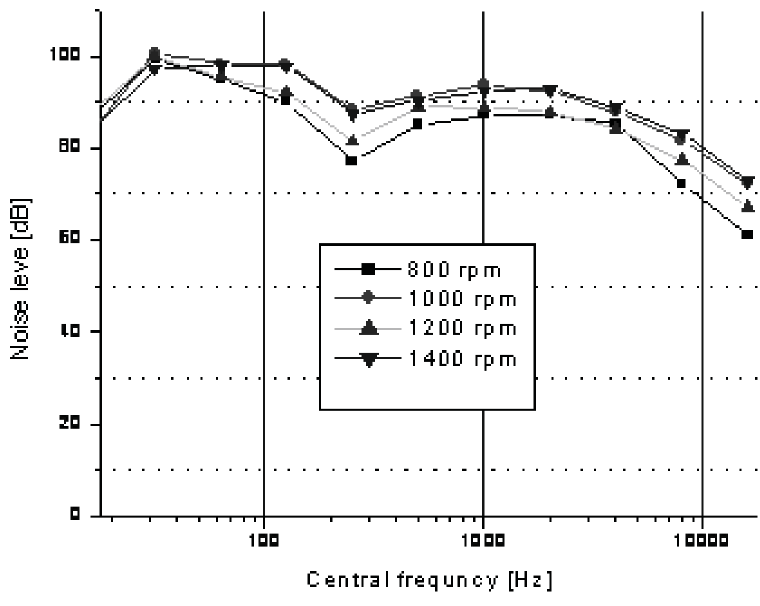

Figure 4 The noise level for different engine speed 1/1 octave bandwidth analyses

The noise produced in unload conditions for different engine speeds and measured in 1/1 octave frequency bandwidth is presented in figure 4.

An important aim of the research carried out was to evaluate the efficiency of the energy conversion. In this respect an algorithm was developed according to the diagram presented in the figure 1.

Table 2 The test results; acoustic and electric parameters

No of determination	Engine speed [rpm]	Acoustic pressure [dB(A)]	Electric parameters harvested	
			Electric supply [mV]	Electric current [mA]
1	800	104	21,0	8,7
2	1000	116	27,5	10,4
3	1200	110	28,9	11,6
4	1400	113	32,1	13,2
5	1600	114,5	35,1	14,6
6	1800	116	36,4	15,4

With the algorithm presented in figure 1 the efficiency of the noise conversion was calculated and the results are presented in figure 5. The rate of the conversion decreases over 130 dB due to the piezoelectric transducer limits.

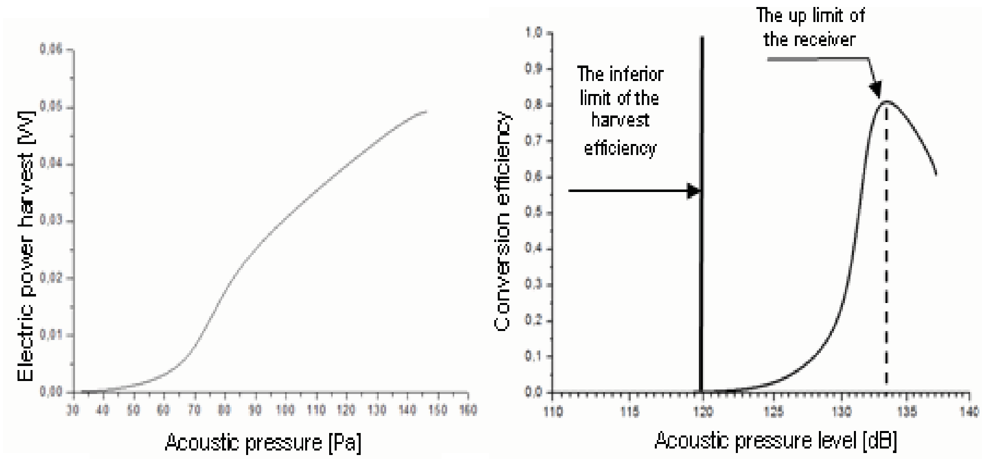

Figure 5 The noise conversion efficiency for Diesel engine: electric power harvested (left); conversion ratio (right)

We must mention the fact that this results were obtained using only one sensor with sensitivity around 4 kHz.

Consulting the noise diagram presented in figure 4, the maximum noise level corresponds to low frequency: 16 Hz, 31,5 Hz and 125 Hz. In this respect it is possible to obtain highest conversion efficiency if we use receivers with sensitivity in the mentioned domain.

CONCLUDING REMARKS

The noise produced by farm tractor engines is an important pollution source. So far this energetic result was analyzed only from an environmental point of view as a pollutant. The tests carried out by the research team offer information regarding the possibilities to harvest the noise as a choice to reconsider this inconvenient of internal combustion engine functioning conditions.

The noise produced by the internal combustion engine can be captured and converted into energy with an acceptable efficiency.

At the same time the noise captured reduces the pollution level behind the transducer. This result is important in order to re-evaluate the noise pollution environmental demands.

If an energetic conversion device is used it is not necessary to fix on the exhaust system an attenuator device and that has importance regarding the engine power loss due to the exhaust system attenuation muffler.

To increase the noise harvest efficiency a so - called “receiver matrix” must be used, able to capture the energy for different frequencies in accordance with the noise spectrum of the exhaust gases.

In the case of more piezoelectric transducers able to harvest the noise from a low frequency spectrum: from 16 Hz to 500 Hz the electric energy resulted will be significant. In this case we consider the receiver matrix located near the engine and close to the exhaust pipe.

The research team takes into consideration the possibility to extend the tests for stationary engine noises as a more efficient exploitation way of the work carried out.

The experiments show the fact that up to a limit we can not take into consideration the possibility to collect the noise and transform it into electric power (around 120 dB for the first tests and over 98 dB for the engine tested). In this respect it is necessary to find solutions to increase the noise level received by the transducers in order to harvest a significant electric power. In this case new nanometric technologies may be applied in order to improve the quality of the used transducers.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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RESEARCH ON THE IMPLEMENTATION OF ALTERNATIVE FUELS OBTAINED FROM POLYMERIC MATERIALS FOR AGRICULTURAL TRACTORS

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SUMMARY

The paper presents research developed in Laboratories of Bioengineering of the Department of Automotive Vehicles and Agricultural Machines to obtain fuel from waste polymeric materials derived from oil. It is known that these materials degrade very difficult in time, and storage and recycling is a problem in terms of environment.

Based on the chemical composition of these materials, similar to that of fossil fuels, has developed an experimental line of thermal decomposition of plastic waste, which gave rise to fractions solid, liquid and gaseous.

Instrumental analysis of liquid fraction revealed a composition very similar to Diesel fuel, also proved highly flammable gaseous fraction, which denote a thermal potential that can not be neglected.

Preliminary tests performed on DI D-30 engine fitted to the laboratory have demonstrated the energetic potential of hydrocarbon polymeric materials waste.

Key words *- recycling, pyrolysis, fuel, characterization, pollutants, engine*

INTRODUCTION

Almost all polymeric materials (such as Low Density Polyethylene - LDPE, High Density Polyethylene - HDPE) are obtained from hydrocarbons. In this case, we could by a heat process, named pyrolysis, the depolymerisation of some compounds with fuel properties.

If the pyrolysis process of Hydrocarbon Polymeric Materials (HPM) is carefully controlled, some polymers can undergo depolymerisation reactions. Depending on the nature of the initial compounds and pyrolysis conditions, polymers are broken down into molecules with lower molecular weight, reaching sometimes up to monomer.

The reactions that occur during pyrolysis can be considered:

- decomposition in monomers and other molecules with lower molecular weight;
- formation of unsaturated and aromatic compounds, of carbonization compounds.

At the end of this reaction are obtained - a gas mixture containing saturated and unsaturated compounds; a liquid containing saturated, unsaturated and aromatic compounds; solid residue that contains mainly carbon.

HPM degradation through various methods has been presented in scientific literature since the 80's, but a greater concern regarding this area appeared in the last ten years in Europe and Japan.

Thus Ohikita H., & all studied LDPE pyrolysis temperature of 400°C in the presence of a catalyst based on silica and alumina (SiO_2/Al_2O_3) [12].

Researches related to the obtaining and testing of fuels obtained from plastic waste were made starting 2000 [6,7,8,9,10].

Moriya et al [9] shown that cracked PE (polyethylene) can be used for engine as a 30-40% blended fuels with Diesel fuel.

Other studies involved a thermal recycling system of waste plastics, in which plastic waste is melted and mixed with heavy oil producing a fuel for Diesel engine generator systems [8,10].

Composition of the produced liquid, gaseous or solid waxes (in percent by weight) for pyrolysis of LDPE in the absence or presence of catalysts at a temperature of 430^{o}C was presented by Uddin A., & All [17] table 1.

Table 1 Percentage composition of liquid products, gas, waxy and solid residues from pyrolysis of LDPE [17]

Pyrolysis products	Pyrolysis products without catalyst [%]		Pyrolysis products in the presence of catalyst (SiO_2/Al_2O_3) [%]	
	HDPE	LDPE	HDPE	LDPE
Liquid	58,4	75,6	77,4	80,2
Waxy	26,3	8,70	0	0
Gas	6,30	8,20	11,6	10,8
Solid residues	9,00	7,50	11,0	9,0

Influence of pyrolysis temperature on the chemical composition of pyrolysis products of LDPE waste was highlighted in 1992 by K. Saito [15] table 2.

Temperature control for LDPE pyrolysis process leads to obtaining of valuable aromatic hydrocarbons (benzene, toluene and xylene) [4,16] with saturated and unsaturated hydrocarbons [2,11].

In all cases were obtained liquid pyrolysis products with close boiling points of the fuels used in internal combustion engines [1].

Table 2 Dependence of temperature and composition of pyrolysis products[15]

Pyrolysis products \ Temperature	Percentage composition of pyrolysis products					
	475ºC	500ºC	530ºC	560ºC	590ºC	650ºC
Methane	0,36	0,98	1,38	5,80	8,76	10,20
Eten	1,88	3,60	5,30	16,80	20,90	16,00
Propane	0,31	0,50	0,60	0,96	0,98	0,58
Propylene	0,57	1,15	1,55	6,30	7,50	6,30
Butane	0,50	0,50	0,50	0,30	0,30	0,20
Butene	0,33	0,30	0,46	1,76	0,80	0,80
Pentane	0,01	0,03	1,50	9,35	5,30	7,20
Pentenes	0,01	0,04	1,20	5,70	5,00	7,20
Methylpentane	0,01	0,03	0,80	4,10	3,50	4,16
Hexane	0,01	0,01	0,13	1,10	1,56	2,18
1- hexene	0,03	0,08	1,90	4,30	5,10	7,80
Benzene	3,27	2,38	0,92	0,29	3,50	6,52
Heptene	0,03	0,08	1,90	4,30	5,10	1,80
1- heptene	0,04	0,09	0,49	0,50	1,70	3,40
Toluene	7,20	5,35	0,71	0,03	0,50	1,34
Octene	0,01	0,01	0,04	0,04	0,20	0,41
1- decene	0,01	0,01	0,02	0,10	0,20	0,30

In a recent paper Mani and Nagarajan [6] studied the influence of injection timing on the performance, emission and combustion characteristics of a single cylinder, four stroke, direct injection Diesel engine has been experimentally investigated using waste plastic oil as a fuel. They concluded that the retarded injection timing of 14° BTDC (comparing to standard injection timing of 23° BTDC) resulted in decreased oxides of nitrogen, carbon monoxide and unburned hydrocarbon while the brake thermal efficiency, carbon dioxide and smoke increased under all the test conditions.

The same authors [7] studied waste plastic oil used as an alternate fuel in a DI Diesel engine without any modification. They showed that carbon dioxide and unburned hydrocarbon were marginally higher than that of the Diesel baseline. The toxic gas carbon monoxide emission of waste plastic oil was higher than Diesel. Smoke reduced by about 40% to 50% in waste plastic oil at all loads.

METHODS

A fuel has been obtained using a bench scale installation [13] starting from Low Density Polyethylene (LDPE) using a pyrolysis process. The obtained fuel has been characterized using UV-VIS spectroscopy using a Lambda 35 Perkin-Elmer spectrometer using quartz cuvettes with a path length of 1 cm, FT-IR spectroscopy using a Spectrum BX II Perkin-Elmer spectrometer, using a ATR device, and gas chromatography using a gas chromatograph (GC) system Agilent 7890A with flame ionization detector (FID).

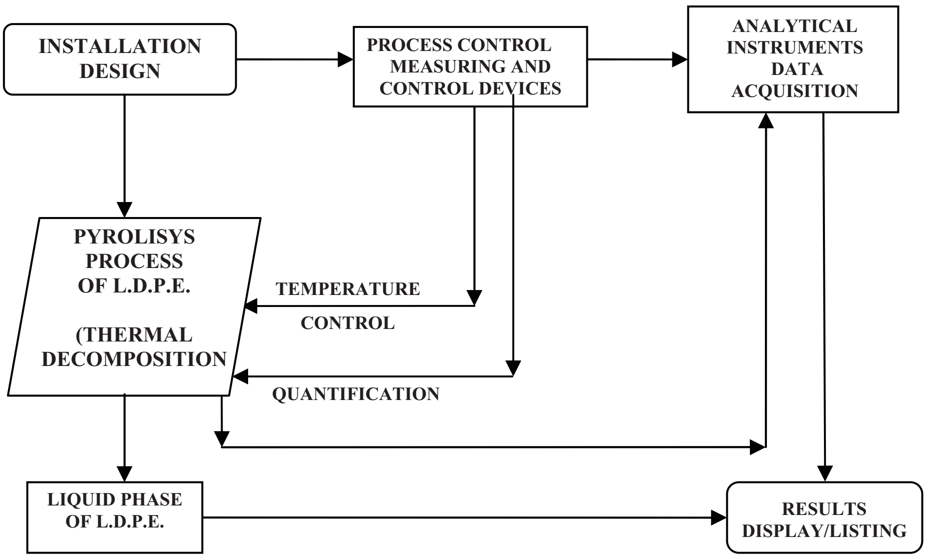

Fig. 1 Pyrolysis process diagram, its control, data acquisition and interpretation of results

The fuel waste derived tests were developed on a Diesel engine with the following features: model DI, D-30, 2 in line cylinders, water cooled;

A gas analyzer AGS 688 Brain Bee was used to determine the different gas concentration contained in exhaust gases.

The composition of the fuels used for tests are presented in table 3.

Table 3 The composition of the fuels used for experiments

Fuel composition			
Diesel fuel	Diesel fuel LDPE fuel	Diesel fuel LDPE fuel	LDPE fuel
100%	75%+25%	50%+50%	100 %

Following the experiments the engine speed, fuel consumption, the temperature and the concentration of pollutants from exhausted gasses were determined.

RESULTS AND DISCUSSION

UV-VIS spectroscopy measurements

Using UV-VIS spectrometer Lambda 35, the transmittances spectra were determined in a range between 350-900 nanometers for the liquid phase of pyrolysis, commercial gasoline and Diesel fuel, figure 2. Similarity between the spectra obtained was intended for the three substances under investigation [14].

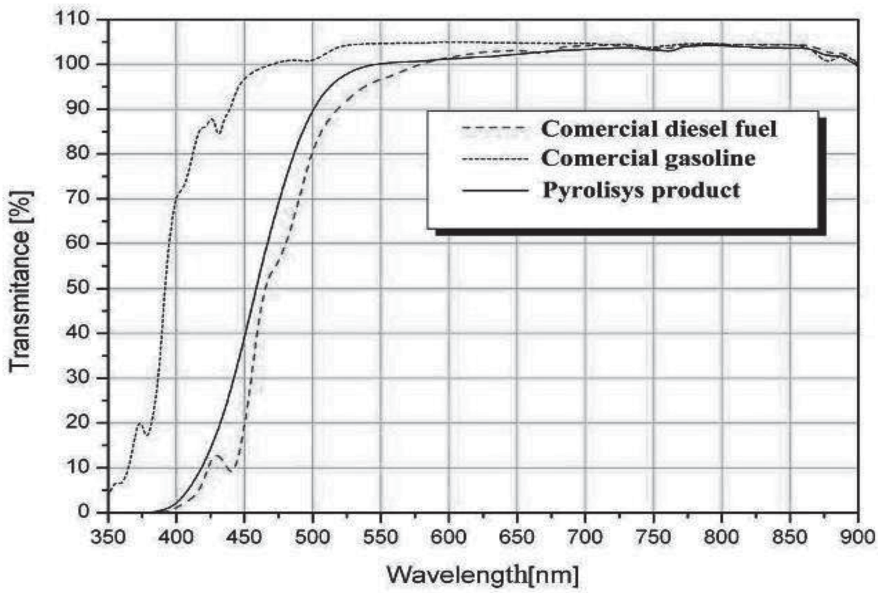

Fig. 2 Transmittances between 350-900 nanometers in UV-VIS light for the liquid phase from pyrolysis, commercial gasoline and Diesel

After plotting the spectra of the three substances subjected to comparative analysis one can be observed the similarity of the shape and slope of the obtained spectra, which entitles us to say that all products are seems to be similar in terms of chemical composition. A higher similarity between commercial Diesel and obtained liquid pyrolysis product can be noticed.

FT-IR spectroscopy

For better information related to the chemical composition of the fuels, the FT-IR spectra were recorded in order to identify the functional groups. FT-IR spectra of the commercial Diesel fuel and the pyrolysis product are presented in figure 3.

Using comparison program under "Spectrum software" the two fuels have been compared [3,5]. The used program concludes that the estimated correlation between the two considered spectra is of 0.9426, which means an overlap of 94.26%, figure 4.

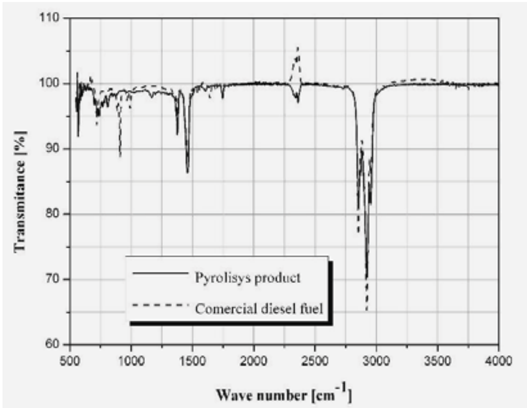

Fig. 3 FT-IR spectra of commercial Diesel fuel and pyrolysis product

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Compare - Produs de piroliza.dx

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             1,0000    1,0000 Pass ( >0,900000)
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Fig. 4 The correlation results using Spectrum software between the spectra of pyrolysis product and Diesel fuel

Gas chromatography

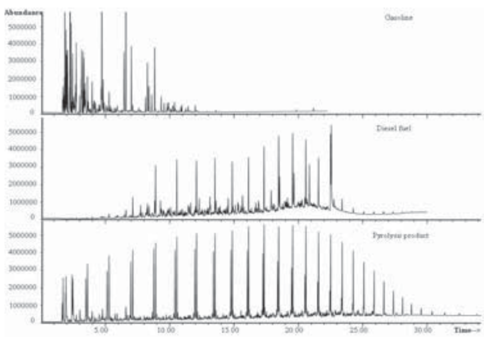

Fig. 5 Gas chromatograms for fuels under investigation

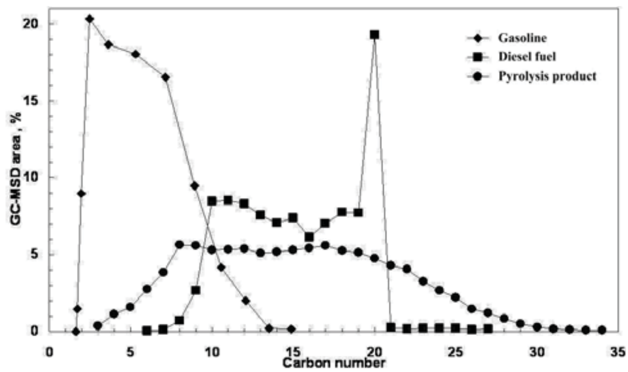

Fig. 6 Percentage composition of fuels depending on the number of carbon

Engine tests

The data obtained following the UV-VIS and IR spectroscopy and GC –FID chromatography analysis leads us to the conclusion that between the pyrolysis product and Diesel fuel there is enough similarities in order to proceed to use the pyrolysis product as fuel in a Diesel engine. Before using the fuel, the light and the heavy fraction from the pyrolysis products has been removed. During tests the fuel consumption, the temperature and the concentration of pollutants from exhausted gasses were determined as a function of engine's speed.

Figure 7 presents the fuel consumption as a function of engine speed. The introduction of pyrolysis product determined the decreasing of consumption for all the studied engine speeds. The lowest consumption was recorded for the pure pyrolysis product.

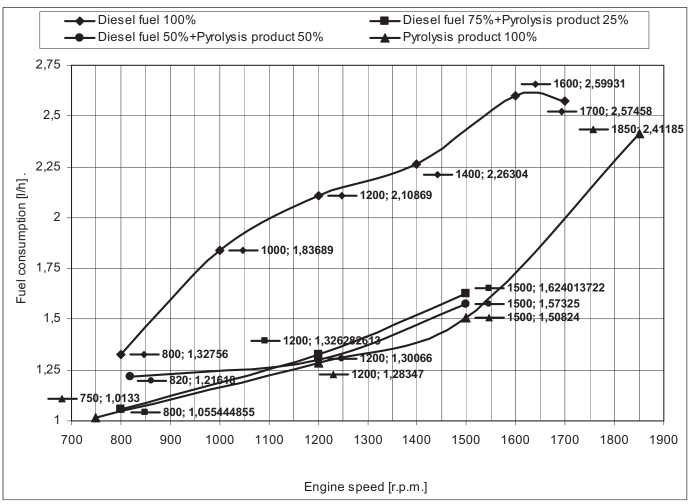

Fig. 7 Fuel consumption as a function of engine speed.

The variation of temperature of exhausted gases as a function of engine speed for the tested fuels is presented in figure 8.

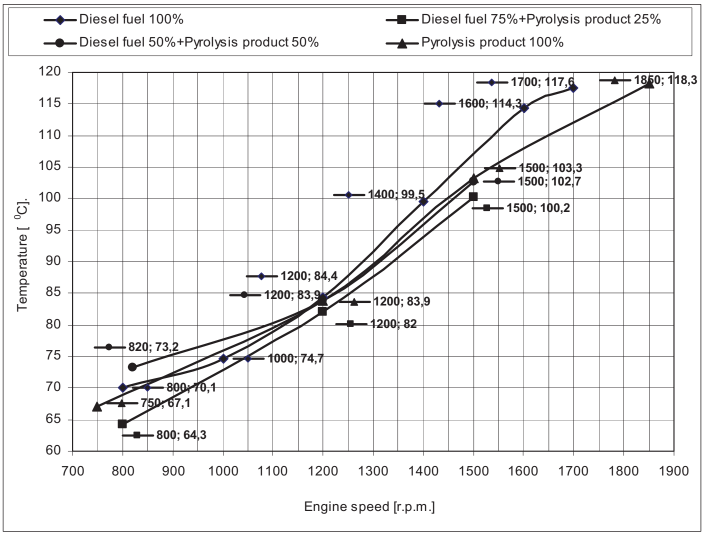

Fig. 8 The variation of temperature of exhausted gases as a function of engine speed

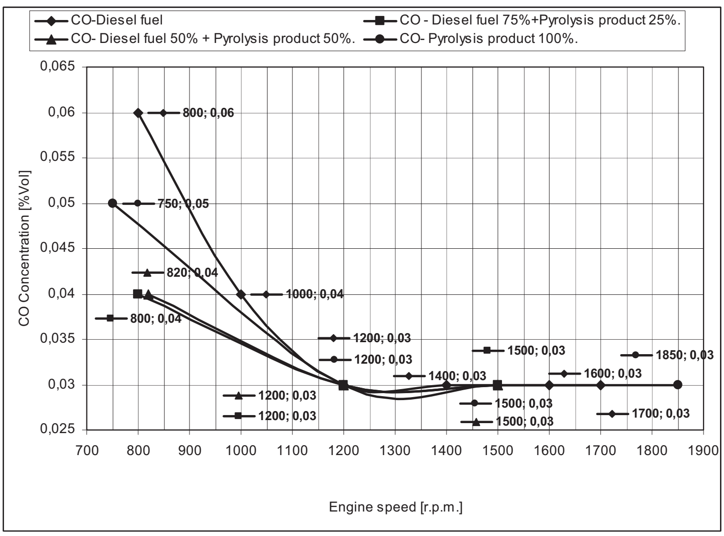

Fig. 9 The concentration of carbon monoxide as a function of engine speed

The difference of temperatures was smaller than 10^{o}C, for all engine speed. Increasing the rotation speed from 800 to 1500 r.p.m., the temperature increased almost linearly with the rotation speed. At a rotation speed of 1700 r.p.m., the highest temperature was reached using Diesel fuel.

The concentration of carbon monoxide, as a function of engine speed is presented in the figure 9.

The highest concentration of CO was recorded for 800 r.p.m. for all fuels. Increasing the speed a decreasing of CO emission was recorded. Comparing Diesel fuel with pyrolysis product, a decreasing of CO emission was observed when pyrolysis product or Diesel fuel containing pyrolysis products were tested.

The concentration of carbon dioxide, as a function of engine speed is presented in figure 10.

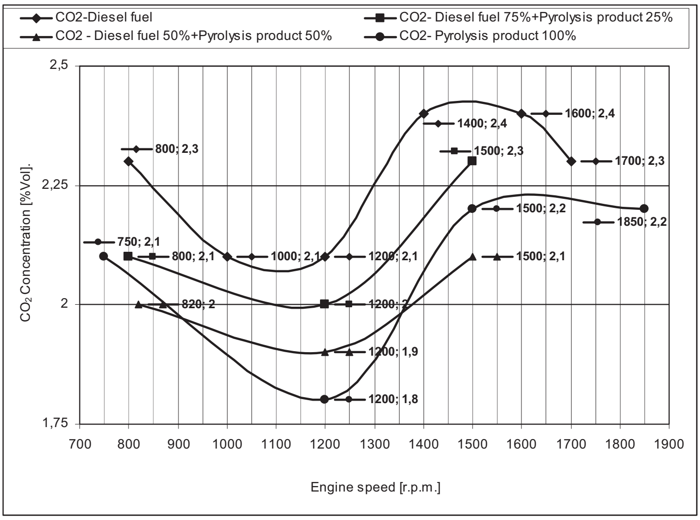

Fig. 10 The concentration of carbon dioxide as a function of engine speed

The increasing of engine speed from 800 to 1200 r.p.m. determined a decreasing of CO_2 concentration for all fuels. Increasing speed to 1500 r.p.m., the concentration of CO_2 in the exhausted gases increased to. The heist value for CO_2 has been obtained for Diesel fuel for all engine speed.

The concentration of hydrocarbons as a function of engine speed is presented in figure 11.

The concentrations of HC have a random variation with the engine speed.

The concentration of nitric oxide as a function of engine speed is presented in figure 12.

NO emissions decreased while engine speed increased up to 1200 r.p.m.. The Increase of engine speed leads to the increasing of NO emission.

Pyrolysis product has the lowest NO emissions compared with Diesel fuel. The mixture of Diesel fuel and pyrolysis product leads to a slight increase in NO emission for small engine speed, but the emission decreased for engine speed of 1050 r.p.m. below the emission of Diesel fuel.

The concentration of O_2 as a function of engine speed is presented in figure 13.

The concentration of oxygen follows the same shape as in the case of HC.

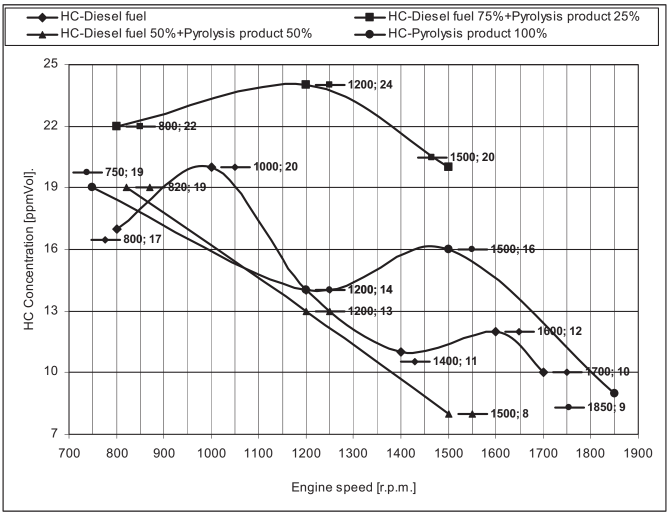

Fig. 11 The concentration of hydrocarbons as a function of engine speed

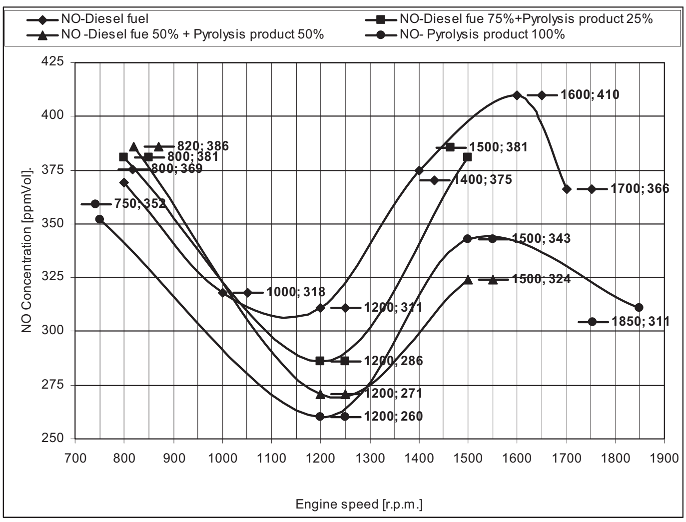

Fig. 12 The concentration of NO as a function of engine speed

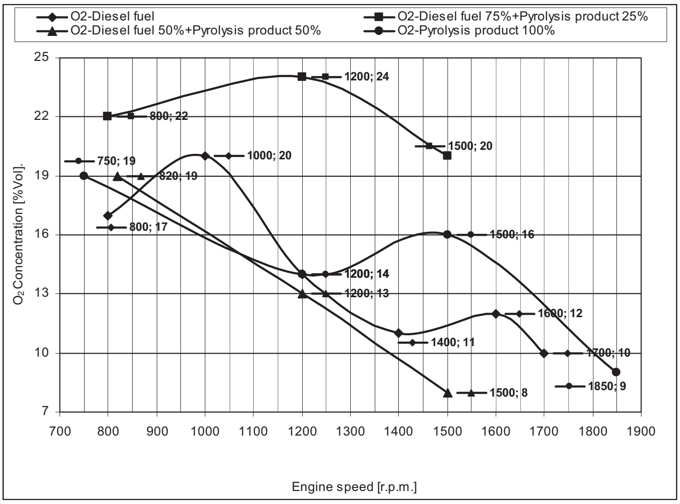

Fig. 13 The concentration of O_2 as a function of engine speed

CONCLUSIONS

- Was obtained a fuel from waste polymeric materials derived from oil with properties close to the properties of commercial Diesel fuel. It is known that these materials degrade very difficult in time and storage and recycling is a problem in terms of environment.
- The test carried out using the DI Diesel engine D-30, revealed that the both the pyrolysis product and the mixtures of Diesel fuel and pyrolysis product can be used as fuel. The emission of polluting gases such as CO, CO_2, NO and HC are smaller to the emissions resulted when Diesel fuel was used. Trend is that this alternative fuel reduces the pollutant emissions.
- Preliminary test leads us to the conclusion that the pyrolysis products obtained in laboratory can be used in Diesel engines. Further investigations are necessary in order to establish the influence of the pyrolysis product as a fuel on agricultural tractors.
- Due to the temperature high gradient, the supposition regarding the engine reliability must be considered.
- It can be seen a consumption decrease for both mixtures used and the pyrolysis product in the test.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.352.99
Stručni rad
Expert paper

TEHNOLOGIJA REZANJA ŽETVENIH OSTANKOV

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IZVLEČEK

Rastlinski material, ki se razkraja na površini, lahko več časa zadržuje ogljik vezan v njemu saj se tak material počasi razkraja in na ta način postopoma emitira CO_2 v atmosfero.

Pri direktni setvi v tla pokrita z rastlinskimi ostanki pa se pojavlja vprašanje pravilnega delovanja sejalnic oziroma vlagalnih elementov sejalnic, ki se v primeru velikih količin rastlinskega materiala začne kopičiti pred vlagalnimi elementi jih mašiti in preprečevati kakovostno setev.

Za raziskavo porabe energije in kakovosti razreza rastlinskih ostankov po žetvi smo uporabili novo razviti stroj za razrez žetvenih ostankov INO, Brežice. Stroj je po zasnovi hibrid med klasično krožno brano in poljedelskimi valjarji za tlačenje tal. V ekspolatacijskih pogojih (strnišče po spravilu koruze za zrnje) so opravljene meritve vlečne sile traktorja, porabe goriva traktorja in procesirane količine koruznice ter določen teoretičen delovni učinek stroja. Stroj je bil agregatiran s traktorjem Fend Vario 714 z močjo motorja 103 kW. Povprečna hitrost drobljenja je znašala 9,85 km/h. Iz povprečne vlečne sile in povprečne hitrosti drobljenja je izračunana vlečna moč, ki je znašala 50 kW oziroma 18,18 kW/m delovne širine stroja. Učinek razreza je bil dober v primeru majhne vlažnosti tal. Večina stebel koruznice je bila prerezana, ker so tla imela zadosten upor, da se stebla koruznice niso pogreznila v njih. V tem primeru so tudi potisni diski opravili svojo funkcijo, pritisnili so koruzna stebla ob tla, ki so delovala kot protirezilo in omogočila kakovosten razrez stebel.

Ključne besede: *rastlinski ostanki, stroj za razrez rastlinskih ostankov, poraba energije, kakovost dela*

UVOD

Vpliv kmetijstva na klimatske spremembe je dvojni, kot ponor in obenem vir ogljikovega dioksida. Ogljikov dioksid se veže iz atmosfere in pretvarja v ogljik vezan v rastlinah, ki se pri razkroju ponovno vrača v atmosfero. Rastline so sposobne vezati ogljikov dioksid iz atmosfere in ga uskladiščiti kot ogljik v strukturi rastline in v samih tleh.

Rastlinski material (žetveni ostanki), ki ostane na površini tal je podvržen počasnem razpadanju – razkroju zaradi različnih vremenskih vplivov in delovanja mikroorganizmov. Rastlinski material, ki se razkraja na površini lahko več časa zadržuje ogljik vezan v njemu saj se tak material počasi razkraja in na ta način postopoma emitira CO_2 v atmosfero. Zdrobljeni rastlinski ostanki se premešajo s površinsko plastjo tla, s tem se zapira površinski del tal zaradi ohranjanja vlage v tleh. S konzervacijsko obdelavo tal poskušamo tla porušiti v čim manjši meri, tako da se ohrani njihova naravna struktura, pusti maksimalni rastlinski pokrov in ustvari groba površina tal. S tem bodo tla zaščitena pred erozijo, evaporacija pa se lahko občutno zmanjša posebej v aridnih področjih. S konzervacijskim načinom obdelave tal se zmanjša talna erozija, manjši je vpliv na podtalnico zaradi vnosa mineralnih gnojil in pesticidov, manjše pa so tudi emisije CO_2. Izboljša se biološka aktivnost tal in biodiverziteta (biotska raznovrstnost). Konzervacijska obdelava, rastlinski pokrov, organska pridelava in kolobar lahko drastično povečajo količine ogljika uskladiščenega v tleh.

Gospodarna in ekološko naravnana pridelava, ki sedaj prihaja v ospredje pa postavlja še dodatne zahteve: zmanjšati stroške dela in energije za obdelavo tal (zmanjševanje emisij toplogrednih plinov, ki nastanejo, kot posledica delovanja kmetijske mehanizacije) ter skrčiti intenzivno obdelavo tal le na nujne ukrepe. Tehnike pri katerih se reducira intenziteta obdelave tla zaradi možnosti zmanjševanja emisij toplogrednih plinov postajajo vse bolj pomembne v svetu in Evropi.

Tendence pri setvi so v vse večjih delovnih širinah sejalnic, ki so primerne za setev v obdelana ali neobdelana tla (tla brez rastlinskih ostankov ali prekrita z rastlinskimi ostanki). Ravno tako sodobne tehnologije pri katerih se kombinira sočasna obdelava tal in setev imajo trend stalnega naraščanja in vse večjega umeščanja na trg Evrope. Pri direktni setvi (angl. »No till«) se vlagajo semena poljščin v neobdelana tla, na površini tal pa so žetveni ostanki prejšnjega posevka. Na takih tleh se ne opravlja nobena obdelava, za setev pa so namenjene posebne izvedbe sejalnic za setev v strnišče. Ta sistem omogoča izboljšavo strukture tal, zmanjšuje erozijo, povečuje količino organske snovi v tleh, zmanjšuje porabo goriva in časa, omogoča daljši časovni razpon za setev in žetev in zmanjšuje emisije ogljikovega dioksida v atmosfero. V primeru da bi se »No till« tehnologija uporabila v večjem obsegu v prihodnosti na obdelovalnih površinah Evrope in v svetu bi to pomenilo pomemben vpliv na zmanjševanje efekta steklenjaka (zmanjševanje emisije toplogrednih plinov), zmanjšano erozijo, izboljšano strukturo tal in kakovost vode, povečano biodiverziteto, povečane pridelke in izboljšano prehransko varnost. Pri direktni setvi v tla pokrita z rastlinskimi ostanki pa se pojavlja vprašanje pravilnega delovanja sejalnic oziroma vlagalnih elementov sejalnic, ki se v primeru velikih količin rastlinskega materiala začne kopičiti pred vlagalnimi elementi jih mašiti in preprečevati kakovostno setev.

PROBLEMATIKA

Sodobni kombajni so večinoma opremljeni s frezami za razrez rastlinske mase na izstopu iz čistilnega dela kombajna (v primeru kombajniranja poljščin za zrnje). Freza mora omogočiti kakovosten razrez rastlinskega materiala na izstopu in enakomerno porazdelitev po površini strnišča. V praksi pa se pri kombajniranju poljščin za zrnje dosti krat dogaja da zaradi visokega odreza kose ostanejo štrleči deli stebel rastlin (posebej izrazito pri koruzi), ki predstavljajo problem pri zaoravanju ali direktni setvi. Izvajalci storitev z mehanizacijo povečajo delovni učinek kombajna, ker manjša količina rastlinske mase gre skozi kombajn pri višjem odrezu stebel, poleg tega se zmanjša možnost poškodb kose kombajna. Kosa kombajna ob spravilu odreže nadzemno rastlino v določeni višini od tal. Ta je odvisna od vrste poljščine, razgibanosti terena in tehničnih karakteristik kombajna. Npr. kombajni, ki imajo žetveno napravo z avtomatskim kopiranjem reliefa terena imajo večji delovni učinek, zaradi psihofizične razbremenitve voznika stroja. Pri strnih žitih, oljni ogrščici in zrnatih stročnicah je ta višina med 15 in 25 cm, pri koruzi med 20 in 40 cm. Koruznica in slama strnih žit sta elastični in se med kombajniranjem skoraj ne drobita. Nasprotno je slama oljne ogrščice in večine zrnatih stročnic zelo krhke sestave, zato se jo velik del med potjo skozi kombajn zdrobi na tako majhne delce, da jih je s sedaj razširjenimi stroji težko pospraviti. Po grobi oceni v Sloveniji že sedaj pospravimo okoli dve tretjini žitne slame in jo namenimo za uporabo v kmetijstvu (nastilj za živino, prekrivke v zelenjadarstvu …) ali izven njega. Preostali del žitne slame se zaorje. V bodoče bo od cenovnih razmerij odvisno, za katere namene bodo kmetje uporabili žitno slamo. Slamo preostalih poljščin vključno s koruznico sedaj skoraj v celoti zaorjemo (Jejčič in sodelavci 2006).

Problematična je tudi razporeditev žetvenih ostankov po tleh po kombajniranju, posebej v letih, ko velik odstotek rastlin leži na tleh (Grosa 2008).

V Nemčiji so delali poskuse (Köller in Wiesehoff 2005) z različnimi elementi za setev v strnišče (elementi za razrez in za odstranjevanje rastlinskih ostankov). Elementi, ki odstranjujejo rastlinske ostanke so bili v delovanju primerjani z elementi, ki razrezujejo rastlinske ostanke. Elementi, ki razrezujejo rastlinske ostanke so se pokazali, kot boljši v primerjavi s prej omenjenimi elementi, ki odstranjujejo rastlinske ostanke. Glede erozije so tudi dosti primernejši, ker pustijo rastlinski pokrov praktično nedotaknjen (ni odstranjen), kar pomeni da pokrov ostane na površini tal in ščiti tla od vetrne in vodne erozije ter zmanjšuje vodno izparevanje. Glede kakovosti razreza rastlinskega pokrova (merjeno v laboratorijskih pogojih) se je izkazalo da sistem črtala in kolesa, ki pritiska rastlinsko maso ob tla lahko dosega 80 do 100 % razrez rastlinske mase. Kakovost razreza je boljša na bolj trdnih tleh in obratno (tla delujejo kot protirezilo).

Kotaleči rezalni diski se intenzivno uporabljajo za razrez rastlinskih ostankov na površini tal pri orodjih za obdelavo tal v reducirani obdelavi ali v direktni setvi. Štirje osnovni obliki teh diskov so na trgu: gladki (v uporabi na strniščih z manjšo količino žetvenih ostankov) ter nazobčeni, valoviti in rebrasti (trije omenjeni na strniščih z večjo količino žetvenih ostankov). Ti diski imajo probleme v delovanju in običajno ne prerežejo rastlinskih ostankov uspešno. Ko so tla suha potrebujejo visoko vertikalno obremenitev za prodiranje v tla, ko pa so tla mokra ne razrežejo rastlinskih ostankov uspešno (Magalhaes in sodelavci 2007).

V splošnem sile za razrez rastlinskih ostankov z Obodna hitrost rezalnega diska za razrez rastlinskih ostankov mora biti višja od njegove hitrosti gibanja naprej, zaradi možnosti drsnega rezanja na rezilu diska. Pri delovni globini, ki je enaka ničli, rezalni disk postane podoben vlečenem togem kolesu, ki se kotali na trdni podlagi. Ko delovna globina začne naraščati, obodna hitrost rezalnega diska v rotaciji postopoma narašča zaradi sile trenja (Desbiolles 2004).

Z uporabo klasične izvedbe krožnih bran, ki so trenutno večinoma v uporabi v kmetijstvu EU in so namenjene za drobljenje rastlinskih ostankov in njihovo delno inkorporacijo v tla, ni mogoče kakovostno opraviti razreza rastlinske mase – žetvenih ostankov. Slaba lastnost jim je da puščajo na površini veliko količino rastlinske mase, ki ni prerezana, kar pomeni veliko oviro za direktno setev.

MATERIAL IN METODA DELA

Za raziskavo porabe energije in kakovosti razreza rastlinskih ostankov po žetvi smo uporabili novo razviti stroj za razrez žetvenih ostankov INO, Brežice. Stroj je po zasnovi hibrid med klasično nošeno krožno brano in poljedelskimi valjarji za tlačenje tal. Za razliko od krožne brane, ki ima sferične diske postavljene pod določenim nastavnim kotom da lažje zajamejo tla (navadno 15 – 25° glede na os diskov), jih prerežejo in premešajo, stroj za razrez žetvene biomase ima diske nameščene pod pravim kotom (glede osi potisnih diskov). S tem je doseženo da se rastlinski ostanki maksimalno razrežejo.

Slika 1 Drobilnik žetvenih ostankov INO

Razrezu rastlinskih ostankov pomagajo potisni diski, ki v tem primeru potisnejo rastlinske ostanke ob tla – sama tla pa delujejo, kot proti rezilo da rezalni disk lahko opravi kakovostni razrez rastlinskih ostankov. Stroj ima na prednjem delu gred, na katero so pritrjena potisno - drobilna kolesa, ki delno zrežejo vzdolžno ležeče ostanke in poganjajo drugo gred preko verižnega prenosa z določenim prestavnim razmerjem. Na drugo gred pa so pritrjeni rezalni diski, ki se vrtijo hitreje od drobilnih koles in zrežejo ostanke ležeče v prečni smeri. Rezalni diski režejo globlje v tla kot drobilni valji in s tem omogočijo tudi delno prezračevanje tal in s tem lažjo inkorporacijo razrezanih rastlinskih ostankov v sama tla.

Stroj lahko kombiniramo s sejalnico za direktno setev in to tako da ga priključimo na prednje hidravlično dvigalo traktorja, sejalnico pa na zadnje hidravlično dvigalo traktorja. Ker stroj za razrez ni odvisen od pogona prek priključne gredi traktorja lahko dosega velike delovne hitrosti. Zaradi majhne dolžine razrezanih rastlinskih ostankov (posledica razreza zaradi majhne medsebojne razdalje med rezalnimi diski) je doseženo da sejalnica za direktno setev lahko nemoteno vlaga seme v tla – setveno plast. Krajši razrezani ostanki se brez problema umaknejo sejalnemu elementu po drugi strani pa je dosežen efekt da so tla prekrita z rastlinskimi ostanki, kar preprečuje rast plevelov, zmanjševanje izhlapevanja vode in zaščito tal od erozije.

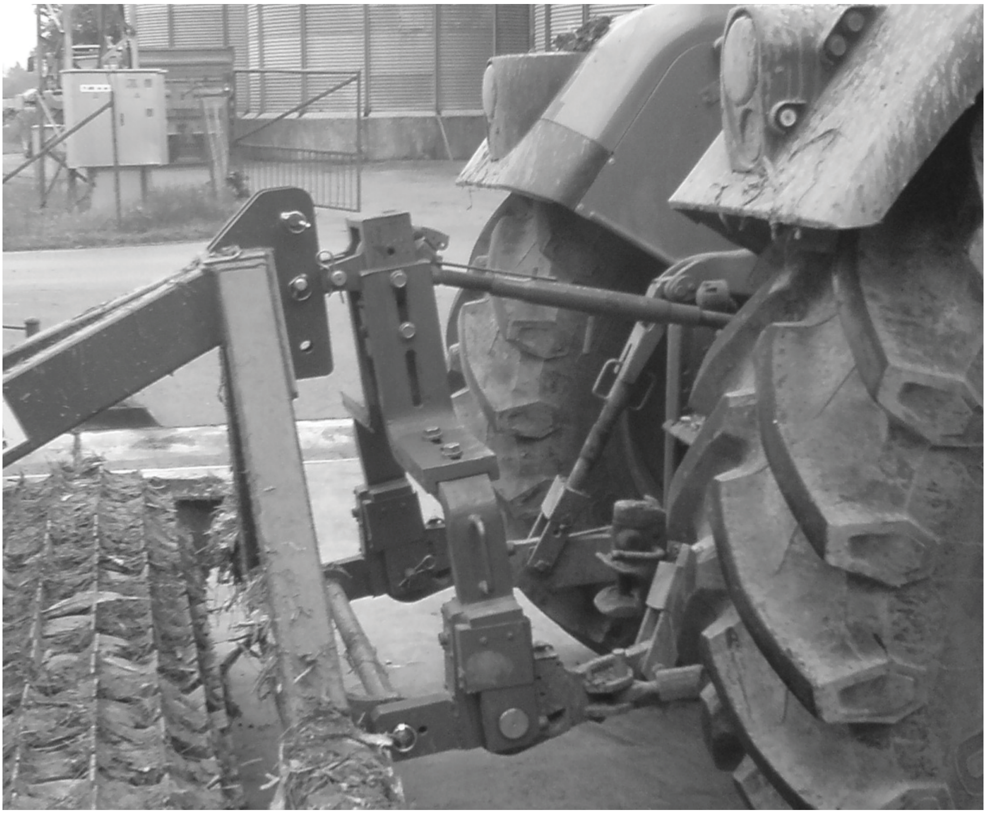
REZULTATI

Stroj smo preizkusili na koruznem strnišču po kombajniranju koruze za zrnje na lokaciji Jable pri Mengšu in Naklem. V Jablah pri Mengšu je stroj deloval na peščenih prodnatih tleh, v Naklem pa na glinasto ilovnatih tleh. Stroj je bil agregatiran s traktorjem Fend Vario 714 z močjo motorja 103 kW in brezstopenjskim menjalnikom (hidromehanska izvedba). Delovna širina stroja je znašala 2,75 m (merjeno od vertikalne ravni prvega do vertikalne ravni zadnjega diska za razrez), masa pa 1300 kg.

V ekspolatacijskih pogojih (strnišče po spravilu koruze za zrnje) so opravljene meritve vlečne sile traktorja, porabe goriva traktorja in procesirane količine koruznice ter določen teoretičen delovni učinek stroja.

V prvih preliminarnih preizkusih so pogoji za delovanje stroja bili dobri, tla so bila v stanju srednje vlažnosti. V času opravljanja meritev potreben vlečne sile za stroj pa so bila tla v stanju velike vlažnosti (jesen 2010 je bila z veliko dežja, obdelovalne površine pa v stanju prevelike vlažnosti oziroma celo poplavljene) tako da je prihajalo da prekomernega nabiranja zemlje na delovne elemente, kar je zmanjšalo učinek razreza in delovni učinek stroja.

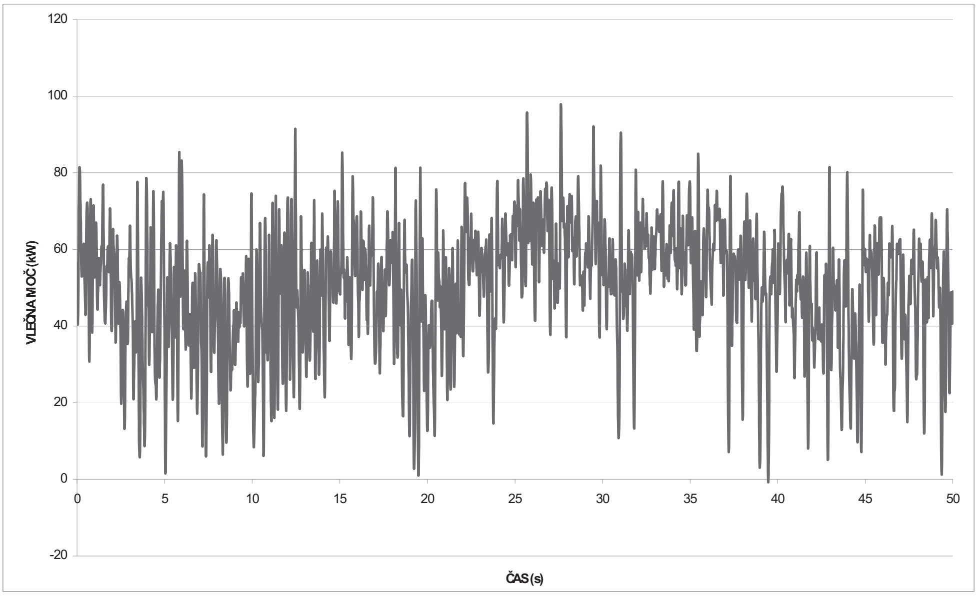
Za merjenje vlečne sile smo na tritočkovno priključno drogovje traktorja namestili dinamometrski okvir (II in III kategorija priključnega drogovja traktorskega hidravličnega dvigala) lastne zasnove in izdelave opremljen z elektrouporovnimi merilnimi lističi za merjenje raztezka materiala. Z omenjenim dinamometrskim okvirjem je možno ugotoviti celotno vlečno silo F_x v smeri vožnje traktorskega agregata iz izmerjenih vlečnih sil na obeh spodnjih ročicah (F_{x1}, F_{x2}) in zgornji ročici tritočkovnega priključnega drogovja (F_{x3}). Za določanje hitrosti vožnje v traktorskega agregata je bilo namenjeno peto kolo, ki je bilo opremljeno z inkrimentalnim dajalnikom. Dinamometrski okvir je bil povezan z merilnim ojačevalnikom Hottinger Baldwin Messtechnik, Spider 8, računalniško krmiljenim, ki je namenjen zajemu in obdelavi podatkov meritev. Frekvenca vzorčenja merilnega signala z omenjenim ojačevalnikom je znašala 10 Hz.



Slika 2 Dinamometrski okvir pritrjen na tritočkovno priključno drogovje traktorja moči 103 kW, na dinamometrski okvir je pripet drobilnik žetvenih ostankov INO delovne širine 2,75 m

Povprečna hitrost drobljenja je znašala 9,85 km/h. Omeniti je potrebno, da je možna večja hitrost drobljenja, tudi do 15 km/h, vendar so bila pri opravljanju meritev porabe goriva tla v stanju velike vlažnosti in je pri večji hitrosti zaradi lepljenja zemlje in napolnjenosti reber potisnih diskov z njo drobilnik tudi občasno drsel po tleh.

Iz povprečne vlečne sile in povprečne hitrosti drobljenja je izračunana vlečna moč, ki je znašala 50 kW oziroma 18,18 kW/m delovne širine stroja. Maksimalno določena vlečna sila pa je znašala 97,63 kW oziroma 35,5 kW/m delovne širine stroja. Ugotovljena povprečna potrebna moč je nižja v primerjavi s krožno brano, ki na srednje težkih tleh na delovni globini 7 – 10 cm rabi do 20 kW/m delovne širine in na težkih tleh od 20 – 40 kW/m delovne širine (Weise in Bourarach 1999).



Slika 3 Oscilogram vlečne moči drobilnika žetvenih ostankov INO delovne širine 2,75 m priključenega na traktor moči 103 kW

Slika 4 Na levi strani slike je vidna koruznica pred prehodom drobilnika INO (vidni so tudi kratki deli stebel, ki štrlijo iz tal in ostanejo neodrezani po prehodu kombajna), na desni po prehodu drobilnika INO in opravljenem drobljenu in skrajnje desno poorana tla po drobljenju

Merjenje porabe goriva je opravljeno z volumetrično metodo. Rezervoar traktorja je bil napolnjen do vrha. Po eno urni meritvi v poljskih pogojih je traktor na istem mestu, kjer je bil napolnjen rezervoar, ustavljen in rezervoar spet napolnjen do vrha. Iz količine dotočenega goriva do vrha rezervoarja je ugotovljena poraba goriva (povprečna poraba goriva 13,12 l/h).

Teoretični delovni urni učinek smo določili iz izmerjene hitrosti vožnje traktorskega agregata in delovne širine stroja. Omenjeni urni učinek je znašal 0,36 h/ha ali 2,7 ha/h. V tem primeru ni upoštevan čas za obračanje traktorskega agregata na koncu parcele, kjer je opravljeno drobljenje koruznice.

Ugotovili smo tudi količino razrezane koruznice, ki je procesirana s strojem na testni parceli na nekaj naključno izbranih mestih, kjer smo vzorčili (za vzorec smo vzeli kvadrat s stranicami 5 x 5 metrov). Povprečje treh vzorčnih mest je znašalo 19,9 kg/m^2 oziroma 7960 kg/ha.

Na suhih in trdih tleh rezalni diski težje vdirajo v tla. Ko so omenjena tla prekrita z rastlinskimi ostanki jih rezalni diski lažje prerežejo zaradi večje strižne trdnosti tal. V tem primeru tla delujejo, kot protirezilo.

ZAKLJUČEK

Poudarek pri današnji tehnologiji za obvladovanje žetvenih ostankov je v kakovostnem razrezu žetvenih ostankov ob zadovoljenih zahtevah po manjši porabi energije, visoki produktivnosti in zanesljivosti strojev.

Za raziskavo porabe energije in kakovosti razreza rastlinskih ostankov po žetvi smo uporabili novo razviti stroj za razrez žetvenih ostankov INO, Brežice. Stroj je po zasnovi hibrid med klasično krožno brano in poljedelskimi valjarji za tlačenje tal. Povprečna hitrost drobljenja je znašala 9,85 km/h. Omeniti je potrebno, da je možna večja hitrost drobljenja, tudi do 15 km/h, vendar so bila pri opravljanju meritev porabe goriva tla v stanju velike vlažnosti in je pri večji hitrosti zaradi lepljenja zemlje in napolnjenosti reber potisnih diskov z njo drobilnik tudi občasno drsel po tleh. V ekspolatacijskih pogojih (strnišče po spravilu koruze za zrnje) so opravljene meritve vlečne sile traktorja, porabe goriva traktorja in procesirane količine koruznice ter določen teoretičen delovni učinek stroja.

Iz povprečne vlečne sile in povprečne hitrosti drobljenja je izračunana vlečna moč, ki je znašala 50 kW oziroma 18,18 kW/m delovne širine stroja.

Učinek razreza je bil dober v primeru majhne vlažnosti tal. Večina stebel koruznice je bila prerezana, ker so tla imela zadosten upor, da se stebla koruznice niso pogreznila v njih. V tem primeru so tudi potisni diski opravili svojo funkcijo, pritisnili so koruzna stebla ob tla, ki so delovala kot protirezilo in omogočila kakovosten razrez stebel. Najboljši rezultat smo dosegali, ko so tla bila zmrznjena (lokacija Naklo). Takrat smo dosegali maksimalni razrez koruznih stebel, ker so tla imela največji odpor proti vtiskanju stebel v njih. V primeru prevelike vlažnosti tal pride do pojava potiskanja koruznice v tla na večjo globino, zdrsa rezalnih diskov prek stebel koruznice in dosti krat stebla koruznice ostanejo neprerezana ampak nalomljena. Učinek razreza koruznice se tudi zmanjša v pogojih prekomerne vlažnosti, ker so stebla bolj elastična. Ugotovljeno je, da je potrebno opraviti nekatere modifikacije geometrije odrivnih reber (imajo tudi drobilno funkcijo obenem) na potisnih valjih. Poleg tega bo potrebno preizkusiti novo geometrijo črtal za razrez oziroma nazobčene izvedbe črtal. Raziskave bomo nadaljevali v naslednji sezoni z modificirano izvedbo stroja na različnih strniščih in različnih stanjih vlažnosti tal.

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TECHNOLOGY OF POSTHARVEST RESIDUES CUTTING

SUMMARY

Plant material decomposing on the soil surface can keeps longer time carbon locked into it because such material is slowly decomposed, and thus gradually emit CO2 into the atmosphere. For direct sowing in soil covered with plant residues, the question arises as to the proper functioning of seed drills and seed drill elements, which in the case of large quantities of plant material begins to accumulate behind elements for seed deposition and prevent the sowing quality.For the study of energy consumption and cut quality of crop residues after harvest, we used a newly developed machine for cutting crop residues INO, Brežice. The machine design is a hybrid between the classic disk harrow and field rollers for soil compaction. In field condition (stubble after harvesting of grain maize) measurements of tractor pulling force, tractor fuel consumption and processed amount of maize stubble and a theoretical capacity of machine was estimated. Machine was connected on a tractor Fendt Vario 714 with an engine power of 103 kW. The average working speed was 9.85 km/h. From the average tractor pulling force and average working speed was calculated power, which is 50 kW or 18.18 kW/m of working width of the machine. The effect of cutting was good in the case of low soil moisture. Most of the stalk maize was cut because the soil has sufficient resistance which enabled that corn stalk did not penetrate deeper in soil. In this case, the pushing disks on machine made their function, pressing the corn stalks to the soil, which acted as counter knife and provides a quality cut of stems.

Key words: *plant residues, machine for plant residue cutting, energy consumption, quality of work*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 534.2:631.372
Prethodno priopćenje
Preliminary communication

MEASURING THE RADIAL ECCENTRICITY OF AGRICULTURAL TIRES FOR RIDE VIBRATION ASSESSMENT

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SUMMARY

The increasing speed on road surface of agricultural tractors has pointed out the attention on comfort and handling performance both for ergonomics and law requirements.

One of the main factors that could give the input to the vehicle is the tire geometry and, in particular, its eccentricity. This approach leads to consider a periodical solicitation that is equal or proportional to the amplitude of the eccentricity.

The CRA-ING Laboratory of Treviglio, Italy, has developed and compared different methodologies for evaluating the eccentricity of the tire based on the harmonic analysis of the tire's profile.

As the interest is focused on the typical speed of tractors (≤ 50 km/h) and the resonance of the tire influences above all the vertical movement and the pitch of the vehicle, the mathematical analysis is in this work carried out only on the first harmonic.

The position and the number of the reliefs is given from the treads. This requires the tire mounted on the rim and at a reference pressure, i.e. the nominal one. As the treads on the left and on the right side are not in phase, different methodologies to calculate the amplitude of the first harmonic and of the high and low peak of the tire have been considered and first conclusions have been pointed out to define a reference and comparable method.

The value of the eccentricity of the complete wheel, influencing directly comfort and handling, can be minimized matching the low spot of the tire with the high spot of the rim.

Key words: *Tractor, agricultural tire, comfort, eccentricity*

INTRODUCTION

The professional drivers are exposed at whole body vibrations (Okunribido, 2006) and, in particular, agricultural vehicle operators may be subject to risk of high levels of exposure (Scarlett et al., 2007).

The protection of workers from risks to their health and safety due to exposure to mechanical hand/arm vibrations and whole body vibration is reported in the European Parliament Directive 2002/44/EEC (EEC, 2002), that defines the minimum safety requirements. Moreover, in 2008, Italy adopted a specific national regulation (Decree no. 81/2008).

The increasing speed on road surface of agricultural tractors has pointed out the attention on comfort and handling performance both for ergonomics and law requirements.

This project, focused on whole body vibration (ISO 2631/1997), aims to define one of the factor affecting the evaluation of comfort during transport. In fact the tires' dumping effectiveness depends on factors such as eccentricity, load, pressure (Sherwin et al., 2004), resonance frequency, and elasticity characteristics (Taylor et al., 2000).

A first methodological approach on the role of the tires on the operator comfort was been developed by the CRA-ING Laboratory of Treviglio (Cutini et al., 2010) and allowed to focus the main boundary conditions (step forward speed, pressure and mass configuration) to use for the following of the research.

As agricultural tires can be considered like a system of springs and dumper, it is necessary, during tests on comfort, to take into account the factors that could affect the elastic behavior of the tires and to evaluate their influence on the results. These factors are the tractor mass distribution (impact on the value of resonance frequency), tire pressure (impact on tire stiffness), forward speed (which characterizes the solicitation frequency input) and amplitude of the solicitation.

One of the factors that influences the last parameter is the solicitation originating from tires caused from the passage of the revolution of the tires in their resonance frequency.

This means that also on a surface leveled, as asphalt, the tractor could have vibrations which source is not the soil profile.One of the main factors that could give the impulse input to the vehicle is the tire geometry and, in particular, its eccentricity. This last has a big influence on the handling of the tractor. The concept is to suppose that each complete rotation of the wheel induces a solicitation on the relevant axle. This approach leads to consider a periodical solicitation that is proportional to the amplitude of the eccentricity.

It becomes of fundamental importance to define a common methodology for evaluating and comparing this tire parameter.

The question has a particular importance considering the tractor with speed of 50 km/h or more.

To underline the importance of this aspect the EUWA, Association of European Wheel Manufacturer, has a specific standard for the rims: "3.21/2009".

This marking is used to match-mounting with tires on wheels to minimize the assembly radial force variation.

Beside, actually, there is not a standard focused on the tire, so the CRA-ING Laboratory of Treviglio, Italy, has identified and compared different methods for evaluating the eccentricity of the tire based on the harmonic analysis of the tire's profile.

METHODS

As the interest is focused on the typical speed (≤ 50 km/h) characteristic of the tractor and the resonance of the tire influences above all the vertical movement and the pitch of the vehicle, the mathematical analysis in this work is carried out only on the first harmonic. Beside the considerations are valid and easy to extend also to the superior harmonics.

The position and the number of the reliefs is given from the treads. This requires the tire mounted on the rim and at the desired pressure, i.e. the nominal.

The measure of the amplitude of the eccentricity of the tire (TI) will be that of the tire with rim, the wheel (WH), less that of the rim (RI). Each single data of the wheel is subtracted to the relevant of the rim so that TI=WH-RI.

As the treads on the left and on the right side are not in phase, different methodologies to calculate the amplitude of the first harmonic and of the high and low peak of the tire have been considered and first conclusions have been pointed out to define a reference method.

The value of the eccentricity of the complete wheel, influencing directly comfort and handling, can be minimized matching the low spot of the tire with the high spot of the rim.

The harmonic analysis has been used based on the concept that a function or a signal could be considered as a superposition of basic waves called harmonics.

The basic concept is based on the Fourier's theory: it is possible to form any function as a summation of a series of sine and cosine terms of increasing frequency.

According with the theory and considering A the amplitude, ω the pulsation and φ the phase, we have considered the follow:

$$y = A \cdot \sin(\omega x + \varphi) = A \cdot \sin\varphi \cdot \cos\omega x + A \cdot \cos\varphi \cdot \sin\omega x = a\cos\omega x + b\sin\omega x$$

If k is the -n harmonic, the amplitude A could be calculated as follows:

$$A_k \cdot \sin\varphi_k = a_k : A_k \cdot \cos\varphi_k = b_k \rightarrow A_k = \sqrt{a_k^2 + b_k^2}$$

$$a_k = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x) \cdot \cos kx \cdot dx; \quad b_k = \frac{1}{\pi}\int_{-\pi}^{\pi} f(x) \cdot \sin kx \cdot dx$$

where ω=2π/T (T is the period) for the first harmonic T=2π and ω=k=1.

The integral calculus becomes a summation of which has to be defined the number of reliefs and the measure of the amplitudes.

The number of reliefs is given from the treads and it is exactly the number of treads.

If the tire has R treads for each side, the number of reliefs will be 2R.

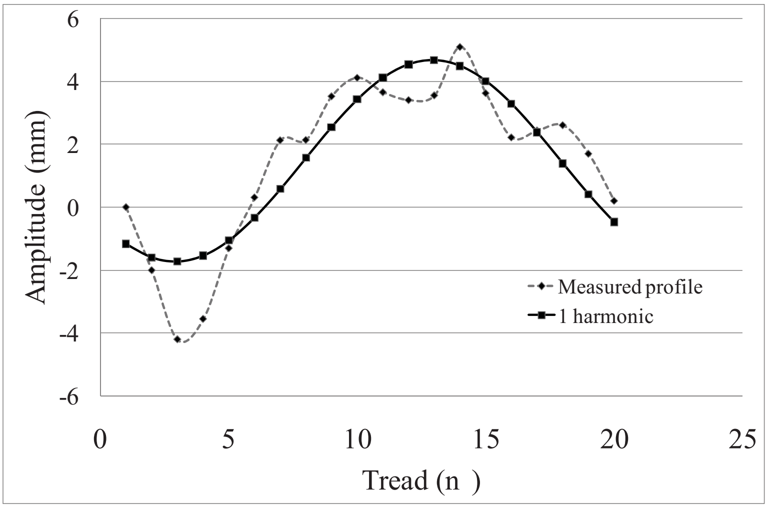

Fig.1 Example of a first harmonic of a measured profile

Before passing to the explanation of the methodologies, it's important to underline the definitions at the base of the research as reported in the EUWA standard.

1. *Radial run out* – Total Indicator reading (TIR) is taken simultaneously at the two bead seats, for a minimum of one revolution, with the wheel located on the specified equipment. From the starting point, it is so possible to run out trace of the two bead seats versus the degrees of rotation.
2. *Equipment* – The combination of physical features to locate the wheels during run out measurements. The rotation axis is defined by the centre of the bore and the disc mounting plane, for wheels which are centered by the central bore on the vehicle hub, and by the disc mounting plane and the centre of the bolt holes, for wheels which are located on the countersinks of the bolt holes.
3. *First harmonic* – The magnitude of the sinusoidal component of the radial run out, representing one cycle per revolution of a run out trace (dimension in mm).
4. *High point* – Experiences gained from the tractor manufacturers in cooperation with the wheel and tire manufacturers have defined two options for the value to be marked, depending on the tractor characteristics: the worse of the two bead seats first harmonic or, as an option, the first harmonic calculated from the average of two bead seats run out.
5. *Worse of the two bead seat first harmonic* – The location on a wheel at which the maximum value of the worse of the two bead seats first harmonic occurs.
6. *First harmonic of the vector average of the two beads run outs.* – The location on a wheel at which the maximum value of the first harmonic of the vector average of the two bead seats radial run out occurs.

Looking at the classic ellipsoidal shape of the footprint of a new tire, has been supposed that the load distribution on the ground is above all in the central part of the treads, so the relief will be at the center of the nose of the tread.

The amplitude of the relief will have to be that of the tire when ready to work.This will require a tire mounted on the rim and at the desired pressure, i.e. the nominal.

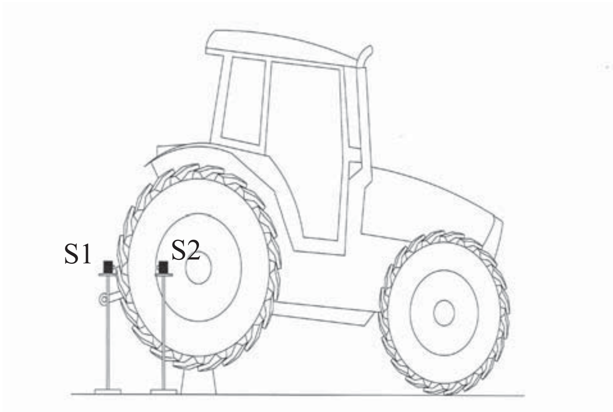

Fig.1 Layout of the position of the two sensors for the measurements at the wheel (S1) and at the rim (S2).

As TI=WH-RIthe amplitude of the eccentricity of the complete wheel (WH) and of the rim (RI) will be directly measured.

Two comparators are positioned on the same radius of the wheel, on the rim and of the relevant nose of the tread (fig. 1).

The tread n. 1 is conventionally that closest to the valve position.

As using comparators could be possible to move accidentally the sensor for positioning the feeler pin, a no contact sensor, such as a laser could be adopted.

The accuracy tolerance for both type of sensors was of 0.02 mm.

The versus of forwarding the tread number is that of designed forwarding of the wheel.

As the treads on the left and on the right side are not in phase, three methodologies could be considered:

- M1: considering the treads in phase and calculate the mean value between right and left side;
- M2: considering the wheel as a continuous alternating left and right measurement;
- M3: considering the wheel as a continuous alternating left and right measurement mean value.

Each single data of the rim is subtracted to the relevant of the rim so that:

TI=WH-RI

The results are the values of the tires that we can introduce in the formula for calculating tire eccentricity.

Four different tires (T1, T2, T3, T4) of 600/65R38 have been analyzed with the three different methods (M1, M2, M3).

At the end of the radial run out test the obtained values are:

1. First harmonic amplitude of the TI; RI; WH
2. Peak/peak of the TI; RI; WH

It's important to note that TI and WH are subject to the same error due to the assembly with the hub. This error is not present in the TI so the test is focused for the TI value.

As comparison have been reported also the values obtained analyzing only the left (LF) or only the right (RG) side of the wheel.

RESULTS AND DISCUSSION

The results of the values of the first harmonic (1H) and of the peak/peak (PP) are reported in tab. 1.

Table 1 the values of first harmonic and of peak/peak of four different tires

Tire	Amplitude (mm)									
	M1-1H	M2-1H	M3-1H	LF-1H	RG-1H	M1-PP	M2-PP	M3-PP	LF-PP	RG-PP
T1	2,43	2,41	2,40	1,64	3,23	5,12	7,18	5,28	4,1	7,18
T2	2,72	2,66	2,65	3,71	1,93	6,13	7,62	6,13	7,62	4,94
T3	1,83	1,83	1,82	1,73	1,92	4,31	5,51	4,47	4,99	4,25
T4	0,51	0,49	0,49	1,07	0,24	1,82	5,13	2,11	4,42	2,35

The following considerations can be reported:

- the difference of the first harmonic between the three methodologies of measurement is negligible;
- it's not enough to measure only one side of the wheel;
- it's necessary to check both side of the rim;
- the value of peak/peak is influenced from the chosen method.

As a tire has a footprint distributed on more treads and the interest is above all for preparing or checking comfort and handling tests, the M1 methodology of analysis is actually adopted from the CRA-ING of Treviglio. Beside if the test is carried out for analyzing tire uniformity the value of peak/peak of M2 gives always an higher accuracy because is not present a mean value.

The value of the first harmonic amplitude is important because influences directly comfort and handling and has possibility of being minimized.

In fact the setting could consider the following typologies:

Setting 1: Minimum of the tire (low spot) matched with the highest point of the rim (high spot)

Setting 2: Minimum of the tire matched 90° or 180° (worst case) out of phase with the rim's high spot.

Setting 1 is chosen as best fitting for an ideal behavior of the tractor while setting 2 is chosen for soliciting the tire for evaluating the tire behavior in comfort or handling at different speed.

As clarification an example is reported in figure 2 that shows the result on graph of the measurement of the rim and of the wheel on an other 600/65R38 tire. Their difference allows to calculate the data of the tire. The first harmonics of the rim, of the wheel and of the tire are reported.

treand n°	1			0		0,00			Peak/Peak	1,95
1° harmonic TI			0,59	1° harmonic WH (TI+RI)		1,56	1° harmonic RI			1,20

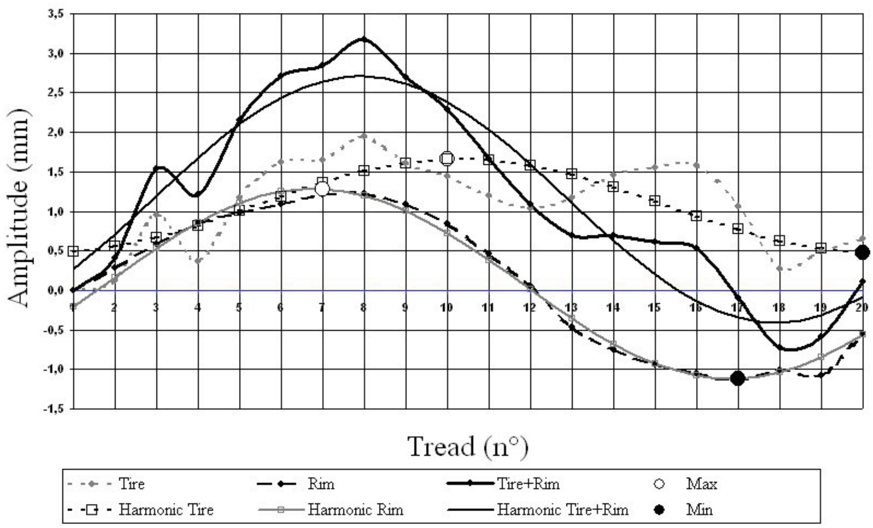

Fig. 2 Result in graphical form of the measurements on a tire

These results allow to simulate, and to define, the rotation between tire and rim that defines the fitting minimizing the value of the amplitude of the wheel. The value of the harmonic of the tire and of the rim doesn't change, instead the amplitude of the first harmonic of the wheel depends from the chosen position. As already said three positions are of particular interest, the best fitting is the ideal case for better comfort on tractor because minimizing the eccentricity value. This case is reported in figure 3 where is possible to note as the amplitude of the first harmonic of the wheel is passed from 1.56 to 0.62 mm.

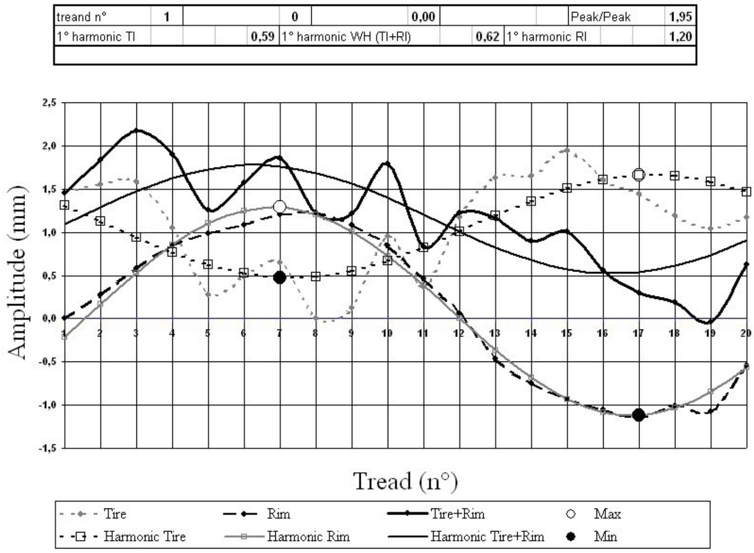

Fig. 3 Tire and rim best fitting scenario

The other cases of interest are reported in fig. 4 and 5 and are the fitting between tire and rim at 90° and 180° out of phase. This last is obviously the worst case scenario where the eccentricity of the wheel has became of 1.79 mm.

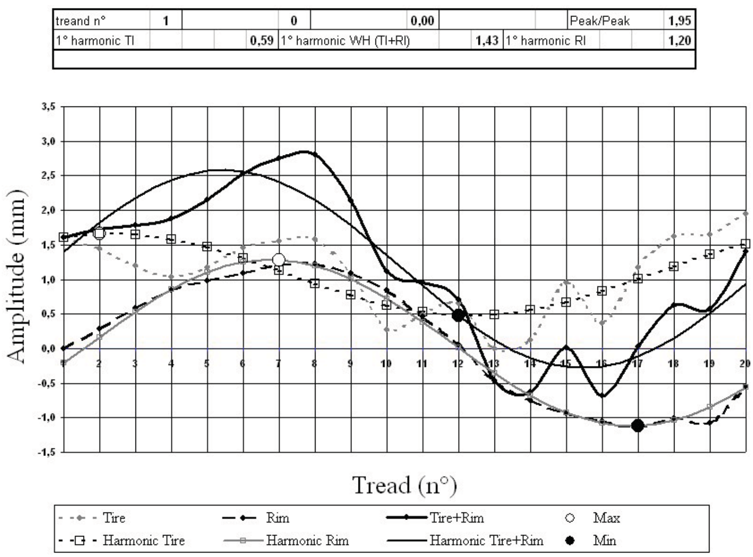

Fig. 4 Result of the tire and rim fitting with 90° out of phase

treand n°	1		0		0,00		Peak/Peak	1,95
1° harmonic TI		0,59	1° harmonic WH (TI+RI)		1,79	1° harmonic RI		1,20

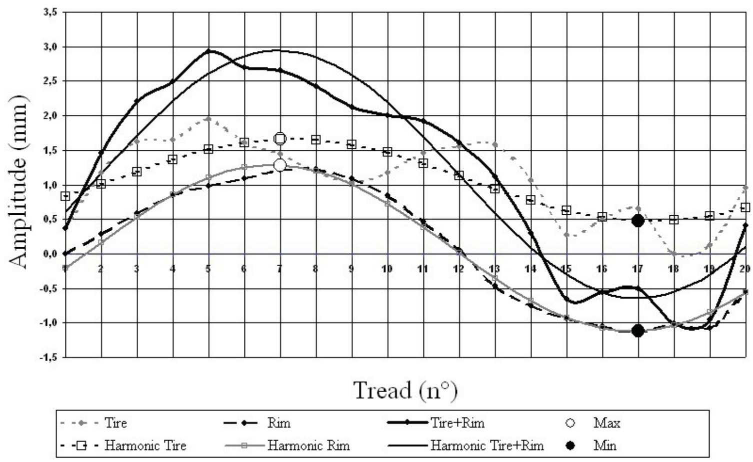

Fig. 5 Example of the worst case scenario with tire and rim fitted with 180° out of phase

CONCLUSIONS

Different methodologies for evaluating the eccentricity of the tire based on the harmonic analysis of the tire’s profilehavebeen analyzed and compared at the CRA-ING Laboratory of Treviglio, Italy. The methodology is based on the measurement of the profile enveloped from the treads and of the relevant radial point on the rim.

The measure of the amplitude of the point of the tire (TI) will be that of the tire with rim, the wheel (WH), less that of the rim (RI). Each single data of the wheel is subtracted to the relevant of the rim so that TI=WH-RI. The amplitude of the relevant first harmonic is the desired value of the eccentricity.

The results of the different methodologies of data analysis have not given difference in terms of first harmonic amplitude. Differences were found regarding peak/peak value. First harmonic analysis can be used for defining the best fitting between tire and rim for minimizing vibrations that could influence comfort and handling.

The evaluation of the influence of the eccentricity value on tractor’s operator comfort and in handling test will be the following step of the research.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

OSCILLATIONS OF SELF-STEERING WHEELS OF AGRICULTURAL SEMITRAILERS

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ABSTRACT

The continuous development of the agricultural semitrailers by increasing the transport capacity, has led to their equipment with rolling trains endowed with two and three axels, either the tandem or threedem type. This has required that at least one of them should be of the steering type so that it could be achieved a proper road curve with minimum skidding.

Therefore it has been performed the axle with self-steering wheel which allows a better and secure running at the road curves with direct implication in reducing the wear of tyres and rolling tracks.

During the operation and especially when they go over the road humps, the self-steering wheels have two oscillating movements, one in the crossing plan (shimmy) and the other in the vertical plan, that lead to the instability of the semitrailer.

In order to attenuate these oscillations, the rolling train presents within its structure some damping elements whose constructive, functional and assembling parameters depend on the characteristics and values which influence the self-steering wheel oscillations and which will be explained in the present paper.

Key words: *self-steering wheel, oscillations, secure running.*

INTRODUCTION

The transport development with high capacity agricultural semitrailers (10-30 tones), has led to their equipment with rolling trains endowed with two or three axles. This has required that at least, one of them, should be of the steering type so that it could be achieved a proper road curve with minimum skidding, with direct implication in reducing the wear of tyres, rolling track and the train component.

In order to assure a secure running and a high stability, the direction system must be as least as possible sensible at shocks, which imply a more rigid possible direction mechanism, but that must not affect in a high degree the system damping shocks. One of the more frequent oscillations which can appear at the self-steering wheel is the shimmy movement and thus consists in an angular oscillation of the wheel around the vertical axis pivot. Analysing the self-steering wheel movement, we have found the wheel can be canted with an angle β, figure 1, when it passes over the road humps or due to the vertical tyre elasticity.

At the same time, the axle can have a lateral displacement in comparison with the frame because of tyre or suspension lateral deformation. In this manner an elastic force can appear in spring suspensions, which tends to bring back the axle at the start position.

This work aims is to identifying the constructive and functional parameters of rolling track and self – steering trains which generate and influence the wheels oscillations, on one hand and, on the other hand the methods of attenuating or eliminating these oscillations influence all these being theoretical considerations and experimental tests.

At the present moment, many companies manufacturing agricultural trailers have modified their rolling wheels and suspensions in view of reducing or even eliminating the effect of horizontal and vertical oscillations of self - steering wheels in the system. Unfortunately, the theoretical researches and experiments on which these achievements are based are not published.

METHODS

The β angle movement is coupled with θ shimmy, figure 2, due to wheel gyroscopic action, the two movements having a reciprocal influence.

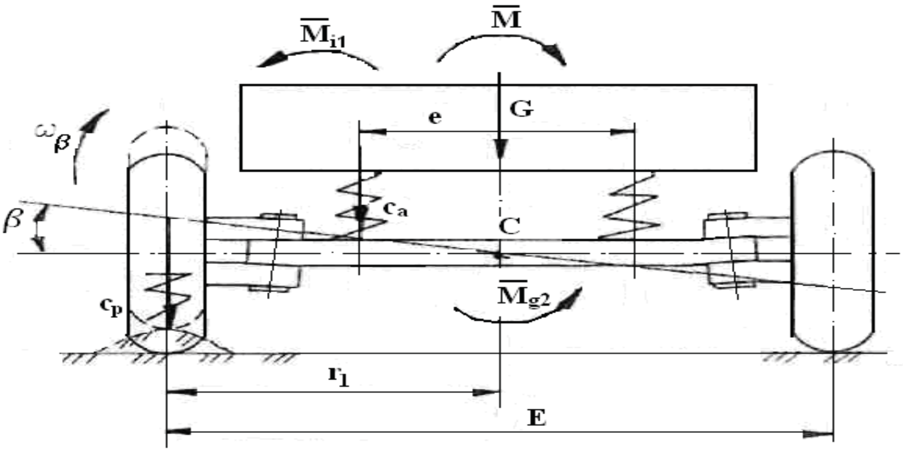

Fig. 1 The self-steering wheel oscillation in vertical plane, ”β“

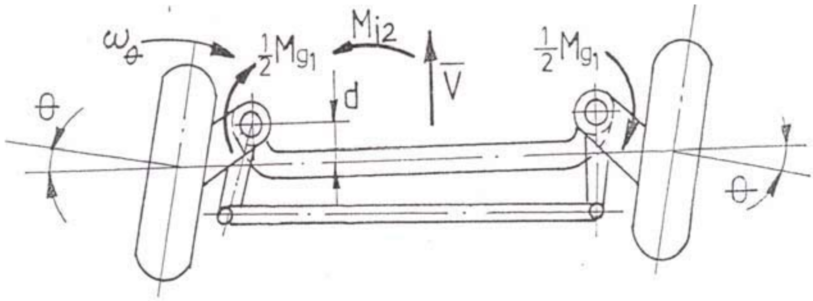

Fig. 2 The self-steering wheel oscillation in horizontal plane, "θ"

Using the notations from figures 1, 2, the wheel with inertial torque J_r and angular velocity ω_r, at passing over humps, will get a vertical impulse which creates the axle inclination with angle β. At the same time it springs up a gyroscopic torque M_{g1} relation (1), according [1, 4], due to the gyroscopic effect, which provokes wheel oscillations with angle β in horizontal plane. Using the kinetic torque theorem, it results in:

$$M_{g1} = J_r(\varpi_r x \varpi_\beta) = \pm J_r \omega_r \frac{d\beta}{dt} \tag{1}$$

The wheel oscillation with angle θ gives birth to the second gyroscopic torque M_{g2}, relation 2, which springs up loading-unloading of the wheel in vertical plane.

$$M_{g2} = J_r(\varpi_r x \varpi_\theta) = \pm J_r \omega_r \frac{d\theta}{dt} \tag{2}$$

The both motions are interdependent, the vertical oscillation with angle β gives birth to the horizontal oscillation around pivot with angle θ, which at the same time provokes and maintains the oscillation in vertical plane, β.

At the same time, during its movement on both directions, the axle is also driven by a resistent torque M_{i1} as against the longitudinal running axis, due to inertia of wheel-axle assembly, by J_1, which operates on M_{g2} direction and by the resistent torque M_{i2} regarding the pivot axis, due to the inertia of wheel-steering swivel-steering mechanism assembly, by J_2, which actuate on M_{g1} torque direction, according to relations (3).

$$M_{i1} = J_1 \frac{d^2\beta}{dt^2};\ M_{i2} = J_2 \frac{d^2\theta}{dt^2} \tag{3}$$

When the axle gets a vertical impulse, this is rotated with angle β in vertical plane around his weight centre C, figure 1, which provokes the suspension spring and tires deformation and gives birth to a re-establishment torque M_β formed from torque M_1, due to suspension respectivly torque M_2, due to tires for which at small angles, it results[2] in relations (4).

$$M_1 = 2c_a \frac{e}{2}\beta\frac{e}{2} = c_a \frac{e^2}{2}\beta;\ M_2 = c_p \frac{E^2}{2}\beta;\ M_\beta = M_1 + M_2 \qquad (4)$$

The pulsation of free angular oscillations ω_β of the axle, is:

$$\omega_\beta = \sqrt{\frac{c_\beta}{J_1}} \qquad (5)$$

where:

$$c_\beta = \frac{M_\beta}{\beta} = \frac{c_a e^2 + c_p E^2}{2};\ \omega_\beta = \sqrt{\frac{(c_a e^2 + c_p E^2)}{2J_1}}; \qquad (6)$$

where:

c_a - the elastic element rigidity

c_p – the tire rigidity

c_β – the vertical rigidity

From (6) relation it results that ω_β decreases at the same time with the own suspension and tyres rigidity decreasing, with disposing distances of those and with inertial torque increasing of the axle regarding oscillation axis.

Due to the transversal tyres elasticity, transversal soil reaction and the elastic elements which intervene in steering system, it gives birth to a re-establishment torque M_θ, relation (7).

$$M_\theta = c_\theta \theta \qquad (7)$$

where: c_θ – the horizontal rigidity.

The pulsation of free angular oscillations ω_θ of the wheel-steering swivel-steering mechanism, is (8).

The pulsation ω_θ decreases with rigidity decreasing c_θ and with the elastic system inertial torque increasing, regarding the pivot axis.

From (7) relation, using figure 3, it results in (9).

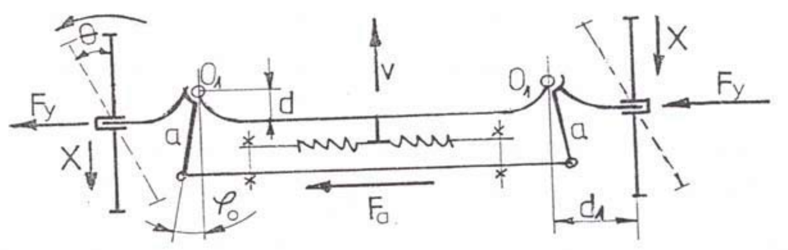

Fig. 3 Self-steering axle equilibrium

$$\omega_\theta = \sqrt{\frac{c_\theta}{J_2}} \tag{8}$$

$$c_\theta = \frac{\varphi G_0 d + F_a a \cos\varphi_0 \cos\alpha}{\theta} \tag{9}$$

where:

G_0-the weight sustain by self-steering axle

F_a –the force in hydraulic dampers

Therefore, the two re-establishment torque M_β, M_θ which appear during oscillation β, θ must equilibrate inertial and gyroscopical torques action, so that the self-steering axles came into equilibrium.

The damping in the system is of two kinds, natural damping which is given by the viscous behaviour of tyres and artificial damping, given by the telescopic hydraulic dampers, component parts of the assembly from figure 4.

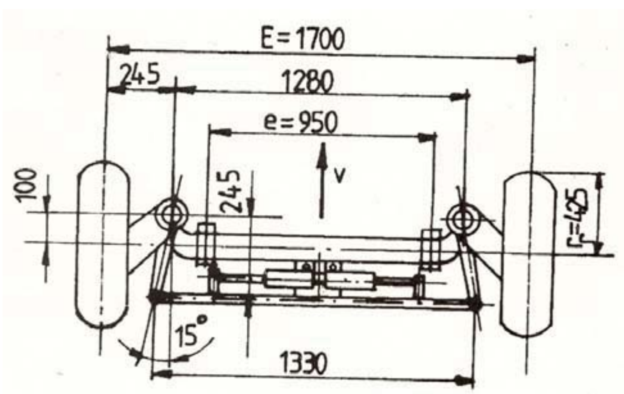

Fig. 4 The scheme of self-steering axle (the quotas are given in mm)

If we consider that the gyroscopic torque M_{g2} has a positive sign and using the torque of the damping forces, (the last therms of the equations), it results (10, 11).

$$J_1 \frac{d^2\beta}{dt^2} + J_r \omega_r \frac{d\theta}{dt} + c_\beta \beta + \mu_\beta \frac{d\beta}{dt} = 0 \tag{10}$$

$$J_2 \frac{d^2\theta}{dt^2} - J_r \omega_r \frac{d\beta}{dt} + c_\theta \theta + \mu_\theta \frac{d\theta}{dt} = 0 \tag{11}$$

The experimental researches have been performed on a self-directional wheel train endowed with two axles of agricultural bogie-type of 10 t maximum load mainly comprising a self –directional axle, a fix axle and two leaf-springs rigidly fixed on axles.

In order to register the experimental data two inductive displacement transducers and two strain gauges have been used .Their role is very clearly definite as it follows:

- the first transducer ,W-100 type ,of ±100 mm travel was used for registering the self directional wheel displacement in horizontal plan;
- the second transducer ,W 200 ,of ± 200 mm travel was used for axle's displacement in vertical plan ,during the passage over the field unevenness;
- two strain gauges, mounted on connecting bar for measuring this bar's strains;
- datas acquisition system DAP 2400 and amplifier Analog Devices 3B18.

The primary processing of registered data has been performed by means of NSOFT program ,and for solving equations (10 ,11) MATHCAD program has been used.

RESULTS AND DISCUSSION

Taking into account the fact that both the value of tire damping constant μ_β and telescopic absorbent constant μ_θ can not be expressed by known mathematical relations, so that we be able to give a precise interpretation of variation of damping forces according to speed ,equations (10,11) remain for the time being in author's attention

For the calculation necessary to design self-directional wheel train ,we can consider the displacement at steady speed –situation in which only angular displacements β θ and pulsation(angular displacements)dβ /dt , d θ/dt intervene, in this kind of situations β, θ can be determined through geometrical relations related to unevenness size, tire's characteristics, track and other constructive elements ,using fig .1,2,and dp/dt, d_θ/dt can be determined by using the wheel linear speeds on two directions, v_H and v_V, generated when the machine travels on humps road. In fact, the wheel train allows oscillations decrement β ,θ caused by tire and telescopic absorbers, intensified on connecting bar F_{bc} force and vertical and horizontal displacement of wheels x_v and x_h , after they have received the respective excitation, when passing over obstacles, fig. 5

Analysing (10, 11) relation it can notice that the J_1, J_2, J_r, c_θ,c_β, ω_r terms are known or can be determined, from the semitrailer and rolling train constructive and functional parameters, in this case, are:

J_1 =154 kgm^2; J_2=26 kgm^2; J_r=5 kgm^2 ; c_a=1.683 10^{6}N/m; c_p=0.395 10^6 N/m; c_β=1265000 Nm/rad and c_θ=32350 Nm/rad.

For the data of self-steering axle (fig.4), there were obtained, by numerical solving, the time graphic evolution in MATHCAD applications, of the angles β and θ, according to the figure 6, where the effects of damping can be seen.

The solution given in figure 6 corresponds to a given excitation by a non-null initial condition,(β =3.03^0), the other initial conditions being null.

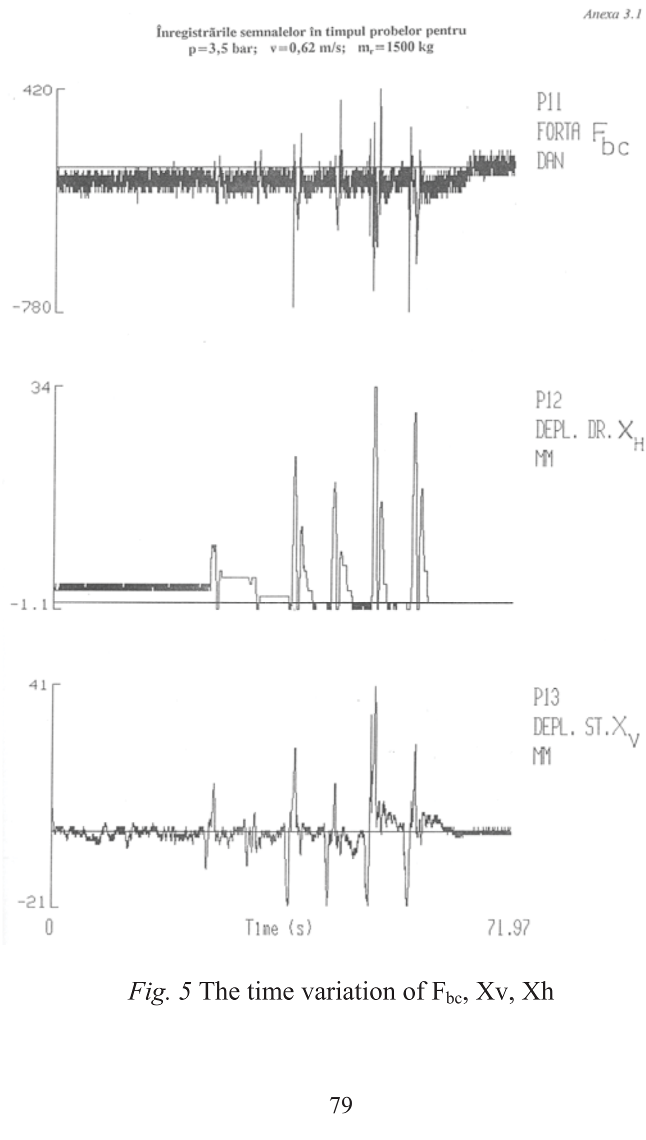

Fig. 5 The time variation of F_{bc}, Xv, Xh

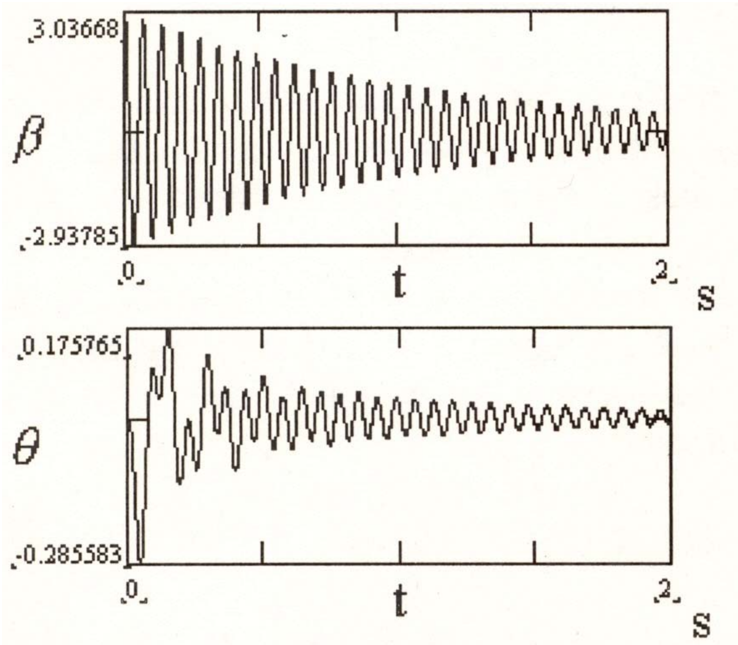

Fig. 6 The time variation of the angle oscillations

CONCLUSIONS

1. In order to ensure an appropriate running, without side slips, the agricultural trailers of high capacity should be equipped with self-steering rolling wheels;
2. The most dangerous phenomena appearing at self-steering wheels are their oscillations in horizontal(crossing) plan, known as "shimmy", which generate the instability of direction and trailer's behaviour on roads, as well as the excessive wear of rolling wheels components;
3. As a result of gyroscopic effects, the horizontal oscillations θ generate vertical oscillations β, they varying along with tire and suspension rigidity, as well as the wheel's components sizes and arrangement;
4. In order to attenuate the horizontal oscillations θ and their effects, within system are introduced damping elements (in the current stage)- telescopic damping elements;
5. When an agricultural trailer is going to be performed depending on compulsory parameters (mass, transport speed, overall dimensions) can be chosen the characteristics of suspension, tire and damping elements, as well as the positioning of constructive elements of a system, so that the rolling wheels more appropriately with a strong self – stability with direct influences on trailer's stability.

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CAB DAMPING DEVICE EVALUATION ON TRACTOR VIBRATION TRANSMISSION AND OPERATOR COMFORT USING A FOUR-POSTER TEST RIG

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SUMMARY

The comfort of tractors is currently considered to be one of the most important topics in tractor engineering. The main factors that define comfort are noise, dust, ergonomics, micro-climate and vibrations.

An important improvement in all these parameters was obtained with the introduction of the cab. Although there are some cases where the cab is attached to the rear axle, today almost all cabs are suspended, with the simplest and most common method being the use of rubber mounts, also commonly known as silent blocks (SBs).

In order to evaluate the impact of SBs on vibration transmission from the axles to the cab and on driver comfort, the Treviglio-based CRA-ING Laboratory has carried out an experimental test on a tractor incorporating a four-point suspended cab considering two kinds of SBs, with different degrees of hardness.

The results have confirmed a considerable difference in cab acceleration values of the order of 12% less the root mean square (RMS) and even higher if the peaks obtained from the adoption of two different damping devices are considered. The difference was smaller, but nevertheless present, in the case of driver comfort. The study has confirmed the need to investigate the elastic properties of rubber mounts to improve vibration damping behavior.

Key words:*vibration, rubber mounts, comfort, tractor cab, four-poster stand*

INTRODUCTION

Research on agricultural driver comfort is topical in all self-moving machines and it's oriented towards the five most important factors: vibration, noise, ergonomics, micro-climate and dust.

The efforts to optimize these parameters have resulted in continuous improvement after the introduction of cabs in tractors.

The simplest way of reducing vibration transmission is to suspend the cab. Although there are some solutions where the cab has been rigidly secured to the frame (or to the rear axle and gearbox), these cases are usually after-market structures that are mainly intended for ROPS (roll over protective structure) purposes. Several technical solutions have been adopted, but the simplest and most common is on rubber mounts (SBs).

Rubber mounts are devices made of rubber with a certain hardness whose task is to reduce vibrations from the ground and machine.

The isolation performance of the cab-mount depends on the damping and stiffness properties of the SB and the inertia properties of the cab (Cho et al., 2000). Consequently, the hardness of an SB and the load it has to bear characterize the amplification or damping of the input signal at the different frequencies and these define the transfer frequency response function (FRF). The FRF is the ratio of the Fast Fourier Transform (FFT) of the signal in the time domain between the points of interest, and it is useful (Braghin et al., 2007; Plunt, 2005) for engineering vibration damping in multi-body systems in order to reduce mechanical stress and noise as well as to optimize comfort.

A softer material usually reduces the amplitude of vibrations at high frequencies, although it results in higher resonance peaks. Therefore, the right choice of damping device is correlated to machine use, and is also related to the kind of solicitation on the vehicle (i.e. amplitude, frequency).

In order to evaluate the damping effect of SB, a four-wheel drive tractor with a suspended cab and two sets of four SBs of different hardness degrees was tested.

The effect of vibrations was evaluated as the root mean square (RMS) of the time history at the attachments of the cab to the frame and as the RMS of the time history filtered at the base of the cab and at the seat level, using comfort filters adopted from ISO 2631:1997 standard and from European Community Directive EEC 2002/44.

The tractor was tested with three different tire pressures (Ferhadbegovic B et al., 2006) to take into account the interactions with a second kind of damping device.

The tests were carried out in the vibration laboratory on a four-poster test plant capable of inducing both elementary curves, such as sinusoidal sweep and bump to characterize the vehicle or damping devices, and random time histories to reproduce use in the fields (Bisaglia et al., 2006).

METHODS

The tests were conducted to evaluate the difference, if any, in vibration damping between two rubber mounts. The tests were carried out at the Research Laboratory in Treviglio (BG), Italy, in April 2008. A four-wheel drive tractor with a suspended cab was used for the tests (Table 1).

The tire measurements were 380/85R28 (load and speed index: 133; A8) at the front and 420/85R38 (144; A8) at the rear respectively,. Two geometrically identical sets of four SBs

(SB1 and SB2; Figure 1), but with different hardness (declared Hardness Shore: SB1=50; SB2=40), were tested.

Table 1 Tractor specifications

Type	Engine		Mass (kg)		Dimensions (mm)	
4WD	Power (kW)	80	Front	2000	Wheelbase	2750
	Cylinder(n°)	6	Rear	3020	Trackwidth(front)	1930
	Capacity (cm^3)	6000	Total	5020	Trackwidth(rear)	1800

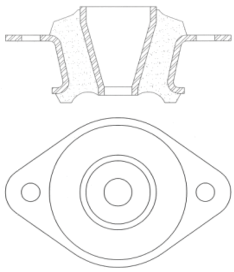

Figure 1 Rubber mount tipology

The experimental facility (Figure 2) was set up for full-scale trials with a vehicle mass of up to 15t. The test stand was a “four-poster” based plant provided by MTS™ Systems Corporation, Minnesota, USA.

Figure 2 The electro-hydraulic four poster plant

The system consists of a high-pressure hydraulic system, a reinforced concrete seismic mass and an electronic control unit (ECU). The main parts of the hydraulic system are the hydraulic power supply, the actuators, the servo valves and the hydraulic service manifold. The maximum force of each actuator was 160 kN and the allowed amplitude was equal to 250 mm. The dynamic characteristics were a speed of 1.6 ms^{-1} and an acceleration of 30 ms^{-2}, with a range of vibration reproduction of 0.1-100 Hz.

The acquired data pertained to the four actuators' displacement (LVDT), the four actuators' acceleration (Honeywell Sensotech JTF, +/-50g), the front and rear acceleration of the SB frame side, the front and rear acceleration (Figure 3) of the SB cab side (Honeywell Sensotech JTF, +/-10g shown in Figure 4; Lebow, +/-4g) and cab acceleration under the seat (Honeywell Sensotech JTF, +/-10g).

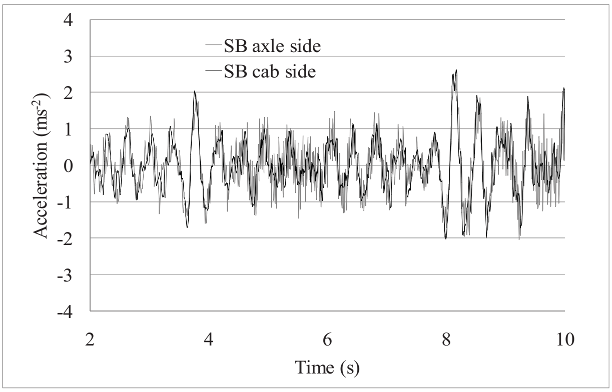

Figure 3 Example of the time history of the acceleration before and after the SB

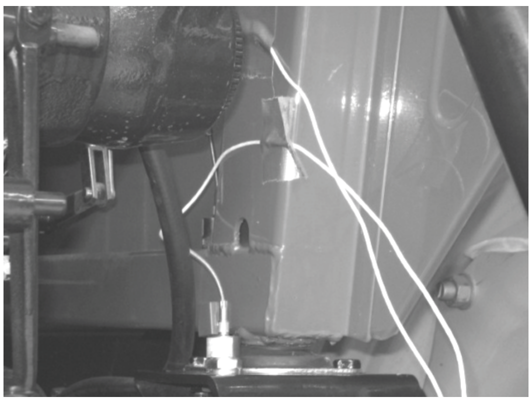

Figure 4 The accelerometers fitted in correspondence to a rear SB.

The evaluation investigated the transmission of stress solicitation to the cab in terms of mean and peak acceleration and of driver comfort. The RMS value of the accelerations time histories was measured and evaluated at the following points (Figure 5):

- SB at frame side;

- SB at cab side;
- in the cab, at the base of the seat;
- at the operator's seat.

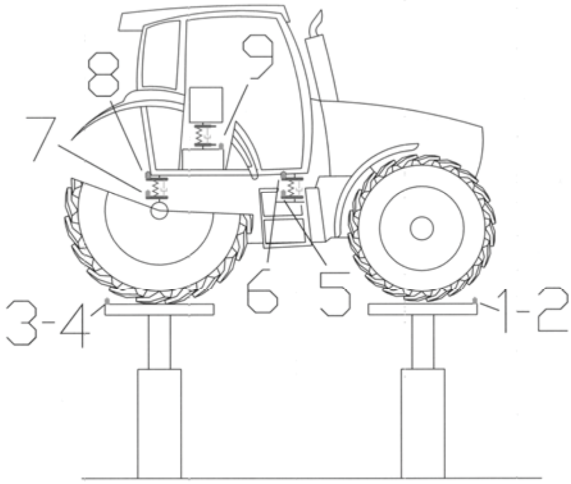

Figure 5 Test and accelerometers' position layout (1, 2: four-poster front acceleration; 3, 4: four-poster rear acceleration; 5, 6 front SB acceleration 7, 8 rear SB acceleration; 9: seat base acceleration)

The two different damping devices (SB1 and SB2) were evaluated at different steps by means of the following tests:

- T1: evaluation of the elastic constant;
- T2: evaluation of the FRF of the SB mounted onto the vehicle;
- T3: evaluation of the accelerations in the cab at reproduced normal vehicle use conditions;
- T4: evaluation of the solicitation on the seat and comfort evaluation.

T1 was carried out using a system consisting of a hydraulic cylinder, a load cell and a laser displacement sensor.

T2 provided the dynamic damping properties, such as the amplitude of amplification and the resonance frequency; the test was carried out with the SB mounted onto the vehicle, therefore the obtained FRF was that of the actual working condition of the SB. The solicitations to the four-poster on the tractor were of a vertical sweep (the four actuators in phase) and pitch response kind (the front actuators were at 180 deg in counter phase with the rear). The frequency and amplitude of the sweep were:

- vertical sweep of the actuators from 0.2 to 30 Hz;
- pitch response (from 0.2 to 25 Hz).

The T3 test was aimed at investigating the impact of the silent blocks on cab behavior. The vehicle was subjected to two different random actuator displacement time histories, that is the reproduction, at the four-poster, of solicitations obtained in the field from vehicles with similar mass and geometry. The replicated condition was driving on a grassy field at two different speeds:

- Field test 1 (FT1): 1.94 ms^{-1}
- Field test 2 (FT2): 2.78 ms^{-1}

The solicitation spectrum was filtered at 20 Hz, and the main amplitudes were concentrated under 5 Hz (the spectrums are listed in Figures 6 and 7).

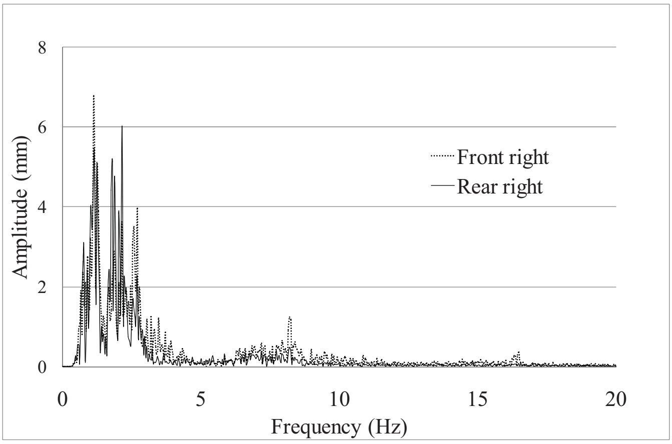

Figure 6 Field test 1 solicitation spectrum

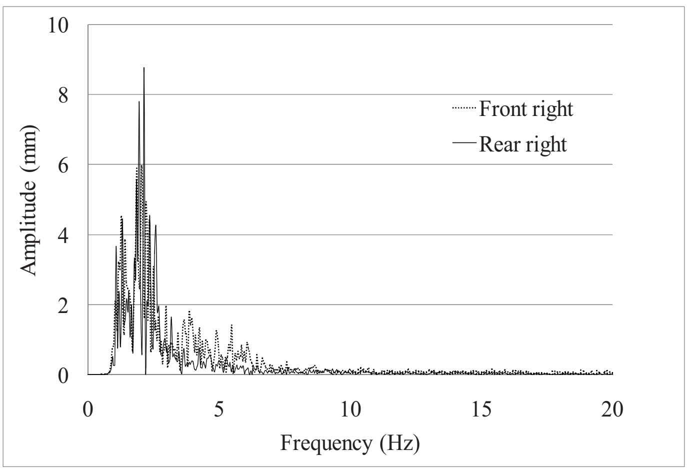

Figure 7 Field test 2 solicitation spectrum

The obtained values were:

- RMS of the time histories (Tables 2 and 3)
    - at the SB cab side (front and rear)
    - in the cab at the seat base
- Maximum and minimum acceleration peaks (Tables 4 and 5)
    - at the SB cab side (front and rear)
    - in the cab at the seat base

The four-poster test was repeated with different tire inflation pressures: 100, 160 and 250 kPa, in order to consider interaction of the elastic behavior of the SB with tires with different elastic characteristics.

Test T4, which was aimed at evaluating the comfort, was carried out in the cab (at the base of the seat) and at the seat as follows:

- acquisition of the cab acceleration time history at the base of the seat in tests FT1 and FT2;
- convolution of the obtained time histories with an FRF of a common pneumatic seat;
- filtering of the results with the ISO 2631/1997 filter of the vertical seat axis;
- evaluation of the RMS of the obtained time histories in order to calculate the comfort index (CI seat);
- filtering of the cab acceleration time history at the base of the seat with the ISO 2631/1997 filter of the vertical seat axle;
- evaluation of the RMS of the obtained time history in order to calculate the comfort index (CI cab).

RESULTS

T1 confirmed that the elastic constants (K) of SB1 were much higher than the elastic constants of SB2, suggesting a significantly higher stiffness. The test results are listed in Figure 8; the mean values obtained at compression in the range of interest are:

K_SB1= 512 N/mm

K_SB2=292 N/mm.

T2 indicated the frequency response of the rubber mounts; SB1 had a frequency resonance at 13.8 Hz, with an input signal amplification factor of 3.1. SB2 had a frequency resonance at 8.4 Hz, with an amplification factor of 3.8 (Figure 9). This data confirmed the higher stiffness of SB1.

T3 showed the following accelerations values in the field tests. In the FT1 test, the RMS values, obtained from different tire pressures and measurement points of the SB cab side ranged from 1.16 to 1.58 ms^{-2} for SB1 and from 1.32 to 1.77 ms^{-2} for SB2, with a mean RMS difference of 0.18 ms^{-2} (Table 2).

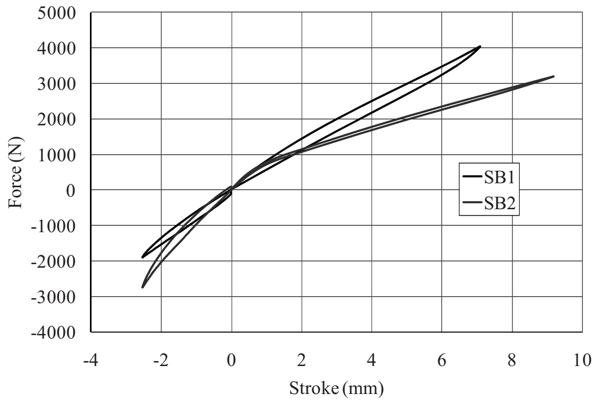

Figure 8 Force – displacement diagram of the SBs

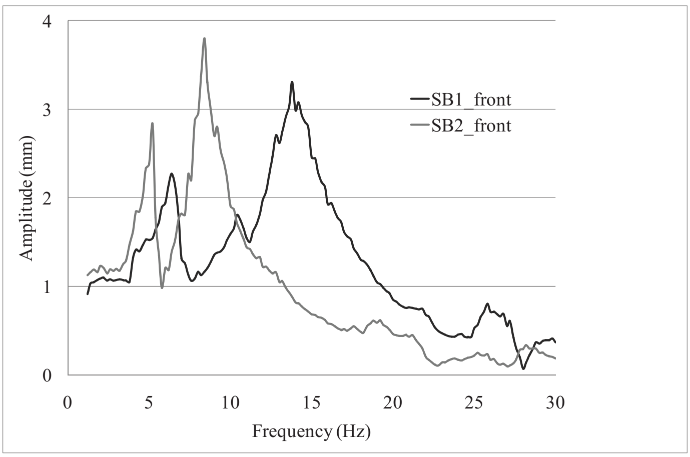

Figure 9 Response spectrum of the front SB at the cab side for the vertical sweep

Table 2 RMS of the accelerations time histories in FT1

FT1	RMS acceleration (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
Cab side – Front	1.52	1.38	1.46	1.24	1.66	1.45
Cab side - Rear	1.33	1.31	1.46	1.29	1.75	1.57
Cab – Seat base	1.32	1.16	1.44	1.18	1.77	1.58

The peak values were 7.06/-7.75 ms-2 for SB1 and 11.7/-12.75 ms-2 for SB2, with a mean difference between the maximum and minimum values of 3.13/-2.92 ms-2 (Table 3).

Table 3 RMS of the time histories of the accelerations in FT2

FT2	RMS acceleration (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
Cab side – Front	0.89	0.85	0.75	0.79	0.76	0.79
Cab side - Rear	1.02	0.83	0.97	0.84	1.1	1
Cab – Seat base	1.03	0.75	0.90	0.74	1	0.90

In the FT2 test the mean values were 0.74/1 ms^{-2} for SB1 and 0.75/1.1 ms^{-2} for SB2, with a mean difference of 0.102 ms^{-2} (Table 4).

Table 4 Maximum and minimum (peaks) of the accelerations in FT1

FT1	max/min acceleration (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
Cab side – Front	11.7/ -12.75	6.38/ -6.47	9.12/ -8.83	4.71/ -5	7.55/ -8.14	5.2/ -5.98
Cab side - Rear	8.14/ -6.87	5.2/ -5.49	8.83/ -7.36	5.3/ -6.18	8.93/ -8.44	6.47/ -7.55
Cab – Seat base	9.32/ -10.8	5.1/ -5.79	7.85/ -8.34	5.49/ -4.81	7.65/ -8.83	7.06/ -6.57

The peak values were 4.41/-4.31 ms^{-2} for SB1 and 5.4/-5.1 ms^{-2} for SB2, with a mean difference between the peaks of 0.58/-0.92 ms^{-2}, a less significant difference than in the previous tests (Table 5).

The results of both settings suggested that the differences obtained with tires at 100 kPa were lower than at 160 and 240 kPa. The results and differences were very similar in the latter conditions, suggesting that it was not necessary to test two "high" tire pressures.

Rubber mount 1 (SB1) showed lower RMS acceleration values in all the tested settings, considering both the two field tests and the different tire pressures. A larger difference was also found when the acceleration peaks were taken into account, especially in FT1.

The T4 results showed that CI was always lower (more comfortable) when SB1 was adopted.

The results obtained filtering the time history at the base of the seat with the FRF of the seat and with the ISO-2631 filter were very similar for the two devices, i.e. with tires at 100 kPa, the values of CI were (Table 6) 1.17 ms^{-2} for SB1 and 1.23 ms^{-2} for SB2 in FT1 and (Table 7) 0.72 ms^{-2} for SB1 and 0.75 ms^{-2} for SB2 in FT2.

Table 5 Maximum and minimum (peaks) of the accelerations in FT2

FT2	max/min acceleration (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
Cab side – Front	3.63/ -4.61	3.14/ -3.53	3.14/ -4.12	2.84/ -2.84	2.84/ -3.24	3.04/ -2.94
Cab side - Rear	4.71/ -4.12	3.83/ -3.53	5.3/ -2.94	3.92/ -3.63	5.4/ -4.41	4.41/ -4.31
Cab – Seat base	3.92/ -5.1	3.14/ -3.14	3.63/ -4.71	2.94/ -3.24	4.32/ -4.9	3.34/ -3.53

Table 6 Comfort index at the base of the cab and at the seat in FT1

FT1	Comfort index (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
CI_cab	1.2	1	1.05	0.79	1.09	0.87
CI_seat	1.23	1.17	0.95	0.86	0.92	0.86

Table 7 Comfort index at the base of the cab and at the seat in FT2

FT2	Comfort index (ms^{-2})					
Tire pressure (kPa)	100		160		250	
Rubber mount	SB2	SB1	SB2	SB1	SB2	SB1
CI_cab	0.772	0.663	0.765	0.595	0.977	0.66
CI_seat	0.752	0.721	0.573	0.508	0.519	0.45

These values suggested a low impact of the devices on the differences in comfort values. This was mainly due to the low input frequencies, when the rubber mounts have low damping and amplification effects. Furthermore, the adoption of SB1 also resulted to be more comfortable in all conditions.

CONCLUSIONS

Two sets of rubber mounts with different hardness degrees have been tested. The tests concerned the evaluation of the elastic constant of each of the rubber devices and their effects in dynamic conditions. Two random time histories, that reproduced field conditions at an electro-hydraulic four-poster test bench, were used to evaluate the response of the rubber mounts.

The solicitation to the cab was evaluated as the RMS and as acceleration peaks of the cab side rubber mounts. The impact on driver comfort was evaluated as the RMS at the seat and at the base of the seat. In all the tested configurations, SB1 resulted in lower acceleration values. This result is due to the greater stiffness of SB1 which gave a more distant frequency resonance from that of the tires than that of SB2 and to the fact that the higher damping effect of SB1 resulted to be more relevant than the filtering effect of the softer SB2.The measured difference of accelerations resulted significance in terms of peaks and suggests that an in-depth investigation of the characteristics of the rubber mounts is necessary in order to optimize their selection and use on agricultural machinery.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

FEM MODEL FOR THE STUDY OF THE INTERACTION BETWEEN THE DRIVING WHEEL AND THE ROLLING TRACK FOR AGRICULTURAL LAND VEHICLES

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SUMMARY

In Europe, most agricultural land vehicles (tractors and agricultural machinery) have to move on different types of rolling tracks: stubble, plough land, operation roads (forestry, industrial, petroleum), or public roads (highways and streets). To move easily on public roads, with minimum fuel consumption, tire air pressure must be as large as possible while the contact area between tires and the rolling track must be as small as possible. However, in these conditions, the pressure exerted by the rolling body (wheel) on the rolling track is larger and the stresses and strains transmitted to the rolling track are greater, thus giving the possibility to negatively affect the degree of compaction of agricultural land vehicles. This paper presents an analytical model using finite elements method, which allows the study of the distribution of stresses and strains that occur in different types of rolling paths (agricultural land, agricultural exploitation land and public land), for various values of tire pressure, for the same land vehicle. The paper has an interdisciplinary and multidisciplinary character, with contributions from the authors on soil behaviour modelling, public roads behaviour modelling (non-rigid or rigid road system) composed of multiple layers: wear, connection, base, resistance, foundation and sandy substratum. Conclusions emerged from this paper are particularly useful to those who design and operate agricultural land vehicles, giving the possibility to optimize tire air pressure so that the negative effect on the rolling track to be minimum and the traction and rolling parameters of the wheel to be as good as possible.

Key words. *Wheel, driving wheel, stress, tractor, finite element method*

INTRODUCTION

Most agricultural land vehicles (tractors and agricultural machinery) must travel both on agricultural land as well as on public roads. To travel on agricultural land, the rolling systems of land vehicles (wheeled or tracked) must exert a lowest pressure in the contact area. Thus, tire air pressure should be lower, leading to a higher adhesion. However, these requirements are not appropriate if the same land vehicle travels on public roads, where tire air pressure should be higher, in order to accomplish travel conditions with lower fuel consumption due to lower rolling resistances.

Figure 1 shows how the tire deforms, depending on its interior pressure. Thus, if tire pressure is too high, the contact area between the tire and the rolling path is lower (Fig. 1), the rolling resistance is also lower, but wheel adhesion is significantly reduced, and the compaction of the rolling path, especially for land vehicles, is increased. Figure 1 c shows the way tire deforms if tire air pressure is too low. In this case, the contact surface with the rolling path is higher, leading to higher adhesion, lower pressure on the contact area, but also a higher rolling resistance, which implies higher energy consumption for the travelling vehicle. Figure 1 b shows the case in which tire pressure is adequate.

a) b) c)

Fig. 1 Influence of tire pressure on its deformation

Figure 2 presents the road bed. Vehicle weight is transmitted through the structure by means of the wheels, thus, through the contact area between the wheels and the road.

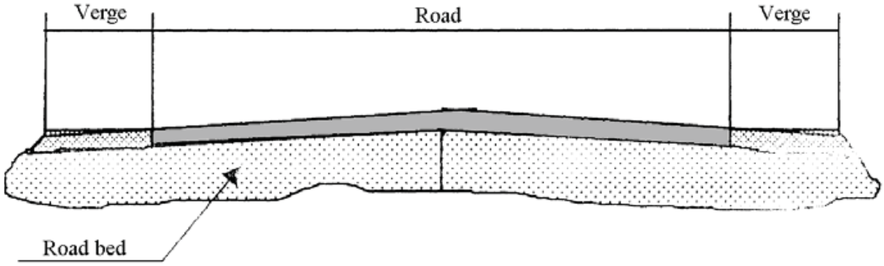


Fig. 2 The road bed

The road body is mainly meant to distribute the pressures transmitted by the wheels, so that, at the level of the bed, the pressures won't exceed the bearing capacity of the soil forming the embankment.

The layers forming the road system (Fig. 3) are grouped by their fulfilling role. Thus, clothing (1) represents the **top layer**, uniform and impermeable, whose role is to ensure vehicles turnover in optimal conditions, to protect the road system against the action of atmospheric agents, to transmit vertical loads and also to directly acquire the tangential shears produced by the wheels of the vehicle.

To reduce material consumption and to withstand the wear caused by road traffic, clothing consists of two layers: top layer (wear layer) and lower layer (connection layer).

Base layer (2) is made of resistant materials, as in its interior, high vertical pressures transmitted by the wheels, must be distributed and reduced so that they can be taken by the lower layer.

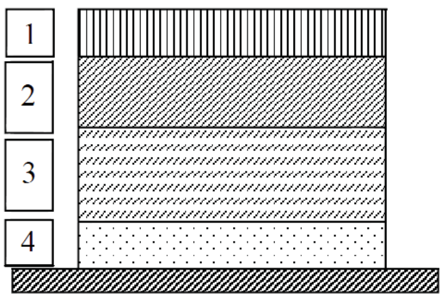


Fig. 3 Composition of the road system

Foundation layer (3) can be made of local materials and has the role of taking the pressures transmitted by the base layer, and further reducing them by distribution. It is calculated from the condition that the transmitted pressures must be smaller than the bearing capacity of the bed material.

Substrate (4), made of sand and ballast, is 7-10 cm thick after compaction, fulfilling drainage roles for rainwater that infiltrate in the road body, cutting the capillary rise of groundwater, preventing the mixing of the material from the foundation layer with the soil from road bed, increasing the total thickness of road system and also reducing the danger of freeze-thaw cycles of the soil forming the road bed.

Sizing and composition of road layers are made based on the intensity and composition of the traffic that the road system must bear. Depending on the behaviour under the action of traffic loads, are distinguished: **non-rigid road systems (flexible)** – consisting of granular materials, with or without binders and asphalt clothing, **rigid road systems** – consisting of one or more layers of cement, on granular material foundations, and **semi-rigid road systems** – consisting of semi-shaped stone pavements or road systems, containing stabilized layers of cement or ashes from thermo-power stations, or granular slag from blast furnaces.

Due to the fact that agricultural land vehicles are usually heavy machines, their movement can deform the layers of public roads, leaving ruts on the asphalt layer (Fig. 4).

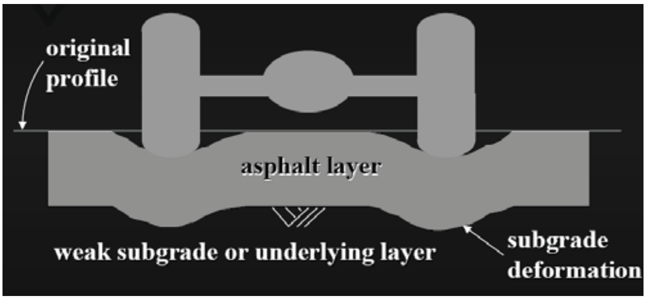


Fig. 4 Rutting in subgrade or base [9]

THEORETICAL ELEMENTS

When compute stresses and strains in pavement structures, three approaches can be used:

1. The layered elastic approach – divides the system into an arbitrary number of horizontal layers, each layer having variable thickness and material properties [9]. In each layer the material is considered to be homogeneous and linearly elastic. Due to these deficiencies it is difficult to simulate realistic scenarios. Strict limitations intervene in the implementation of the layered elastic method: materials must be homogeneous and linearly elastic within each layer. Also, wheel loads applied on the surface must be symmetrical to the axis. For example, it is difficult to rationally accommodate material non-linearity and to incorporate spatially varying tire contact pressures, which influence the behaviour of the pavement systems [9].

2. 2D finite element analysis – plane strain or axis-symmetric conditions are generally assumed. This method has larger practical applicability than the first method, as it can strictly handle the anisotropy and nonlinearity of the material and a variety of boundary conditions [9]. Though, there are some disadvantages in using 2D models, such as the incapability to capture with accurateness non-uniform tire contact pressure and multiple wheel loads.

3. 3D finite element analysis – this method overcomes the limitations in existing 2D models. By means of 3D finite element analysis, the response of flexible pavements under spatially varying tire pavement contact pressures can be studied.

Flexible and rigid pavements respond differently to loads (Fig. 6). Consequently, different theoretical models have been developed for both flexible and rigid pavements.

Boussinesq (1885) was the first to research the pavement's response to a load. He proposed a series of equations in order to determine stresses, strains, and deflections in a homogeneous, isotropic, linear elastic half space, with modulus E and Poisson’s ratio ν subjected to a static point load P (Fig. 7).

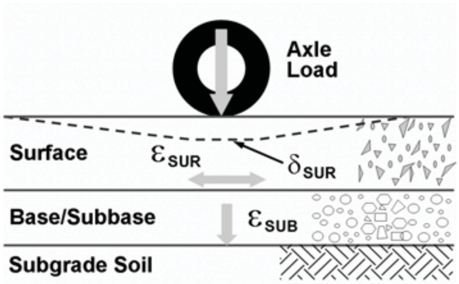


Fig. 6 Pavement responses under load [9]

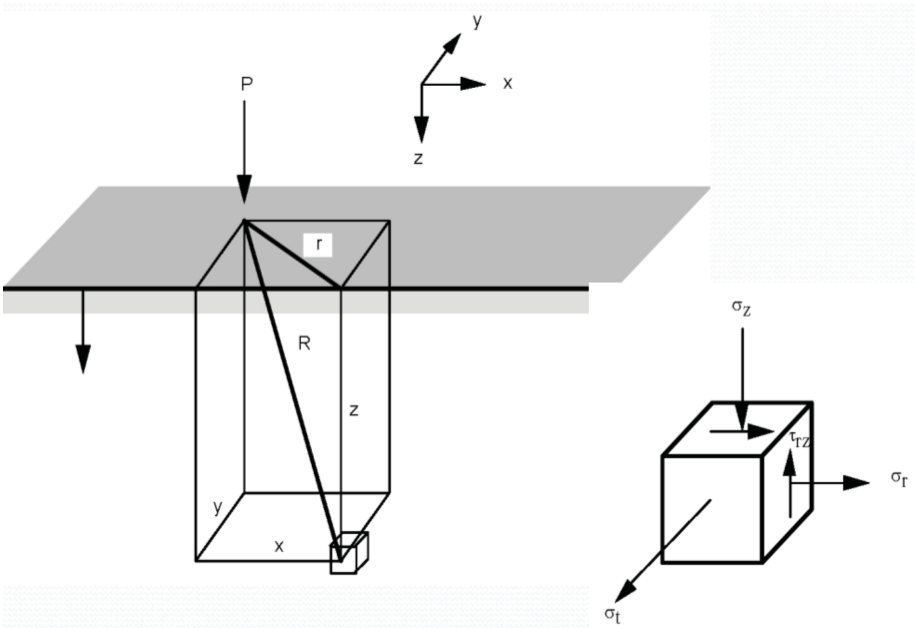


Fig. 7 One-layer system (static point load) (cylindrical coordinates)[9]

It can be noticed that the elastic modulus has no influence over any of the stresses and the vertical normal stress σ_z and shear stresses are independent from the elastic parameters. Originally, Boussinesq's equations were developed for a static point load.

Later, these equations were further extended by other researchers for a uniformly distributed load by integration (Fig. 8) [9], even though the original Boussinesq's equations are seldom used today as the main design theory. His theory is still considered a useful tool for pavement analysis and it provides the basis for several methods that are currently being used.

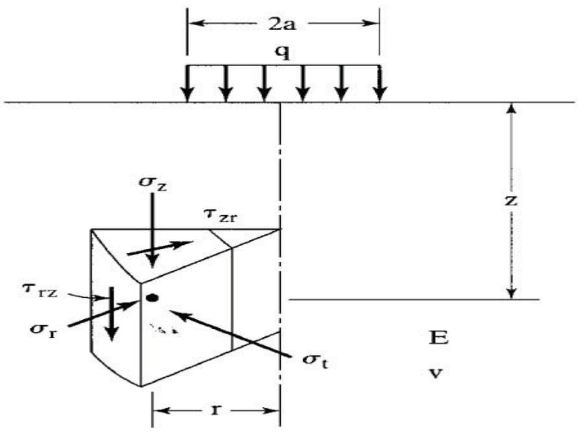


Fig. 8 One-layer system (uniformly distributed load) [9]

The stress levels are given in cylindrical coordinates as follows [9]:

Vertical stress:

$$\sigma_z = \frac{P}{2 \cdot \pi} \cdot \frac{3 \cdot z^3}{\left(r^2 + z^2\right)^{5/2}} \tag{1}$$

Radial stress:

$$\sigma_r = \frac{P}{2 \cdot \pi} \cdot \left[\frac{3 \cdot z \cdot r^2}{\left(r^2 + z^2\right)^{5/2}} - \frac{1 - 2 \cdot \mu}{r^2 + z^2 + z \cdot \sqrt{r^2 + z^2}} \right] \tag{2}$$

Tangential stress:

$$\sigma_t = -\frac{P \cdot (1 - 2 \cdot \mu)}{2 \cdot \pi} \cdot \left[\frac{z}{\left(r^2 + z^2\right)^{3/2}} - \frac{1}{r^2 + z^2 + z \cdot \sqrt{r^2 + z^2}} \right] \tag{3}$$

Shear stress:

$$\tau_{rz} = \frac{P}{2 \cdot \pi} \cdot \frac{3 \cdot r \cdot z^2}{\left(r^2 + z^2\right)^{5/2}} \tag{4}$$

where: P –is the point load, μ -Poisson's ratio, $\sigma_{z,r,t}$ –normal stress components.

[9] suggested that Boussinesq's theory can be used to estimate subgrade stresses, strains, and deflections, in cases when the base modulus and the subgrade are close. Pavement surface modulus, the equivalent "weighted mean modulus" calculated from the measured surface deflections, using Boussinesq's equations, can be used as an overall indicator of pavement stiffness [9].

A typical flexible pavement section can be idealized as a multi-layered system consisting of asphalt layers resting on soil layers with different material properties (Fig. 9).

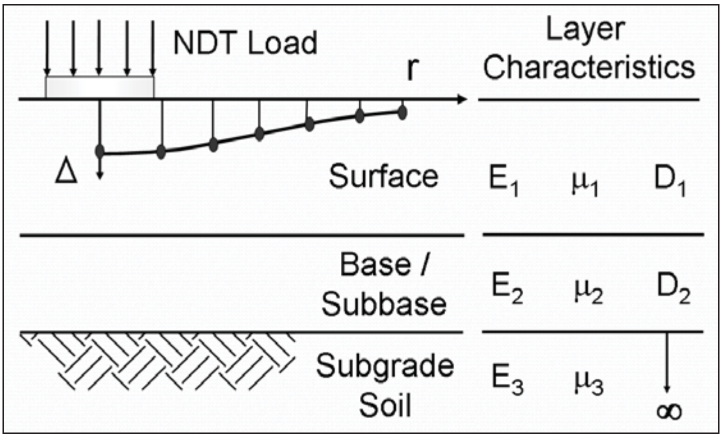


Fig. 9 The multi-layered system [9]

Most researchers considered the pavement to be either a 2 or 3 layer system, with a concentrated normal force or a uniformly distributed normal load. In their analysis, vehicle thrust (tangential loads) and nonuniform loads were not considered. In most cases, an Poisson's ratio of 0,5 was assumed.

Schiffman (1962) has developed a general solution for the analysis of stresses and displacements in an N-layer elastic system, providing an analytical theory for the determination of stresses and displacements in a multi-layer elastic system. Each layer has its separate properties, including elastic modulus (E_i), Poisson's ratio (μ_i), and thickness (h_i). The system is subjected to non-uniform normal surface loads, tangential surface loads, rigid, semi-rigid and also slightly inclined bearing loads.

MATERIAL AND METHODS

A 3D analysis model was developed for the road system (Fig. 11), over which were placed the contact areas with the wheels of a 65 HP tractor, in which was applied in vertical direction the constant pressure given by tractors weight. On the contact area with the driving wheels (rear wheels) it was also applied the horizontal component of the traction force. The road system model (Fig. 10), analyzed by means of ANSYS v12.1 has the following global dimensions: 5 m length, 3 m width, 1 m height. Over the soil having $E=3\cdot10^6$ Pa, it is placed the substrate (consisting of sand or ballast) having Young's modulus $E=13\cdot10^6$ Pa, and 100 mm height. The foundation layer, having $E=6\cdot10^7$ Pa, and 200 mm height, sustains the base layer with $E=13\cdot10^7$ Pa, and 100 mm height, and the clothing with $E=26\cdot10^7$ Pa, 70 mm height which consists of two layers (connection, respectively wear layers).

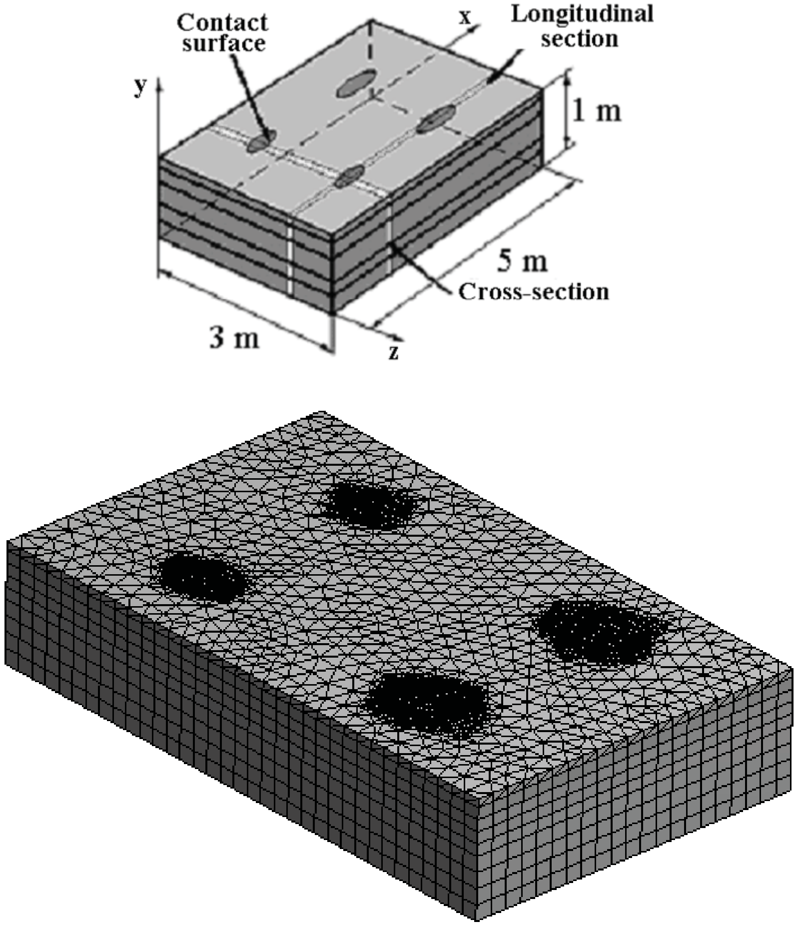
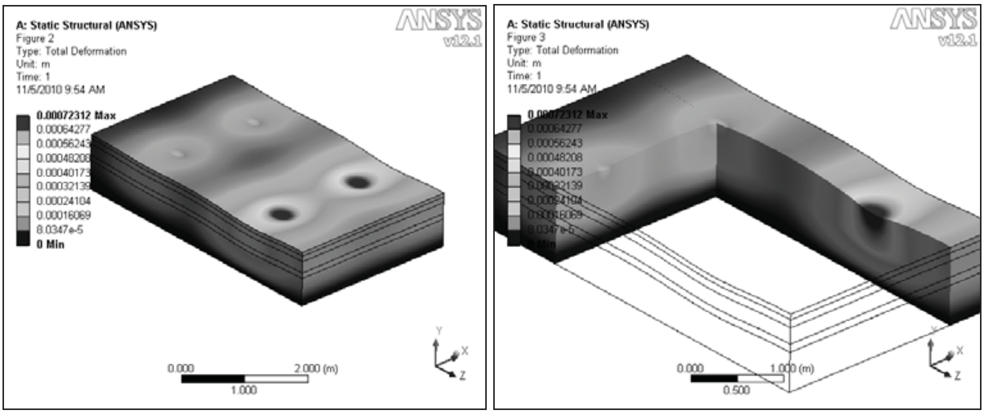


Fig. 10 Analyzed road system model

The meshed model consists of 3D finite elements for each layer. Nearby the contact area between wheels and the soil was applied a finer mesh, respectively a higher number of finite elements with smaller sizes, thus leading to an increased precision of the results.

RESULTS AND DISCUSSION

Figure 11 presents the strains distribution for the analyzed road system, of the whole block (Fig. 11.a) as well as in longitudinal-vertical and frontal plane (Fig. 11.b) from the contact area with the tractor wheels. It can be noticed that even though the normal pressure in the contact areas of the frontal wheels is higher, highest strains are obtained in the contact areas of the rear wheels due to an increased surface and also due to the horizontal component of the traction force exerted in this area.



a) b)

Fig. 11 Strains distribution in the road system

Figure 12 shows the distribution of the equivalent stresses, after Von-Mises criterion, for the block of the analyzed road system, and Figure 13 shows the distribution in longitudinal-vertical and frontal plane for the contact area with the rear wheels (Fig. 13.a), respectively with the front wheels (Fig. 13.b).

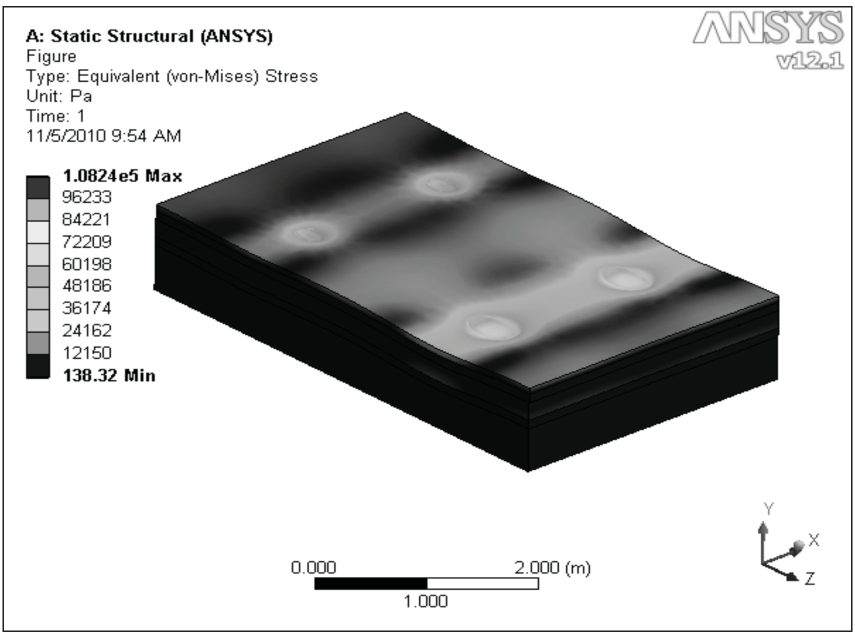
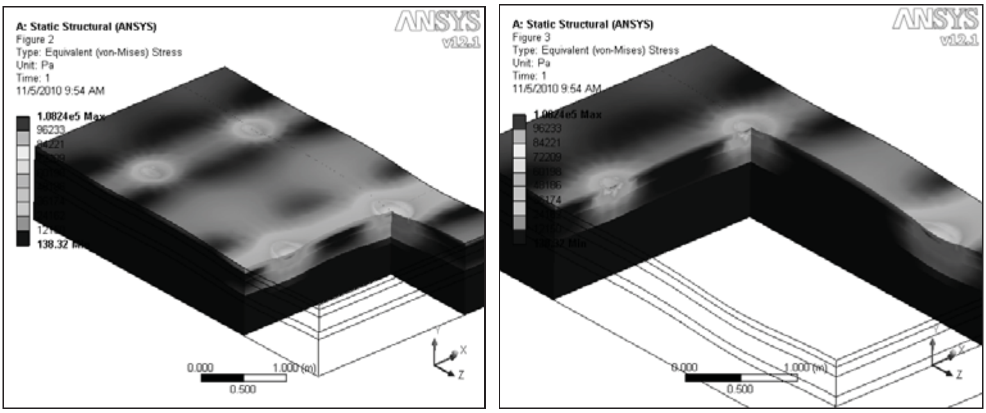


Fig. 12 Distribution of equivalent stresses in the road system



a) b)

Fig. 13 Distribution of equivalent stresses in the road system near the rear wheels (a) respectively the frontal wheels (b)

Highest equivalent stresses are found in the contact area with the tractors front wheel, due to a higher normal pressure in the contact area. It can be noticed that higher stresses are found in the superior layers of the road system (clothing and foundation layer) and it is lower than the maximum accepted stresses.

CONCLUSIONS

1. It can be stated that the Finite Element Method currently the most advanced mathematical tool, which can be used for the study of the interaction between the driving wheel and the rolling track for agricultural land vehicles. For mathematical modelling it is considered that the road system consists of overlapped layer, having specific physical-mechanical properties.
2. From this study it results that agricultural land vehicles can negatively affect the rolling path due to their increased weight and to higher pressures in the contact area. Even though travelling on public roads is easier when tire pressures are higher, it is recommended that their values should be lower to increase the contact area and the pressure distributed in these contact areas to have lower values.
3. Even though the simulation results have shown that highest stresses are found in the area of the front wheels of the analyzed 65 HP tractor, these values decrease by unloading the front deck when the tractor works in aggregate with carried agricultural vehicles.

Note: simulations were developed only for the 65 HP tractor, without being coupled to a working machine.

ACKNOWLEDGEMENT

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.1.02:631.373
Originalni znanstveni rad
Original scientific paper

ANALYSIS OF STRESS AND STRAIN DISTRIBUTION IN AN AGRICULTURAL VEHICLE WHEEL USING FINITE ELEMENT METHOD

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SUMMARY

Due to the complex geometry and the multitude of factors influencing the mechanical behaviour, modelling stresses and strains distribution in the tires of agricultural land vehicles is difficult. Proper exploitation of wheel tires of agricultural land vehicles is difficult and depends of many influence factors. A low pressure generates an exaggerated flexing of tire carcass. The consequences are tire heating, an increase of rolling resistance and also premature tire wear. In extreme cases, a low pressure may even cause tire destruction. Too large pressure causes the decrease of tire adhesion, irregular and faster wear, especially for driving wheels. This paper presents an analysis of a 65 HP tractor driving wheel tire, using Finite Element Method. A 3D model of the real tire is developed, for which were defined the parameters characterising the elastic behaviour of tire rubber. The study was developed for various tire air pressures and various normal loads acting on the wheel. Results and conclusions obtained from this study are useful in the identification of optimal operating parameters for driving wheels tires of agricultural land vehicles.

Key words: *Wheel, stress, strain, tractor, finite element method*

INTRODUCTION

Tire/rolling track interaction is a very complex research topic and has been considered a critical problem in the design of agricultural vehicles. Obtaining accurate solutions to tire/terrain interactions can directly help us in understanding how tire types and terrain conditions affect tire mobility and traction performance [1, 3].

Due to the wide diversity of shapes, sizes, material characteristics and operating conditions, lately have appeared more studies and researches regarding mathematical modelling and the analysis of stress and strain distribution in the tires of land vehicles. This is necessary in order to adopt a rapid and inexpensive procedure, capable to evaluate tire behaviour in different situations. With the great development of computers and numerical computation programs, came a natural opportunity to use these tools to simulate tire mechanical behaviour of land vehicles using Finite Element Method [6]. The biggest difficulty is to model accurately the nonlinear mechanical behaviour of the tires material (rubber reinforced with textile or metal).

Tires provide the following functions for a land vehicle: attenuate the shocks caused by uneven rolling tracks, ensure proper adhesion to the rolling track, and ensure safety and resistance to high-speed movement, takes the loads distributed on wheels, contributes to the comfort of passengers or operators [3].

Figure 1 presents the construction of land vehicles tires (without tube - a, with tube – b, of a 65 HP tractor). Tubeless tires are used for the wheels of passenger vehicles, with the tendency to use them for heavy vehicles too.

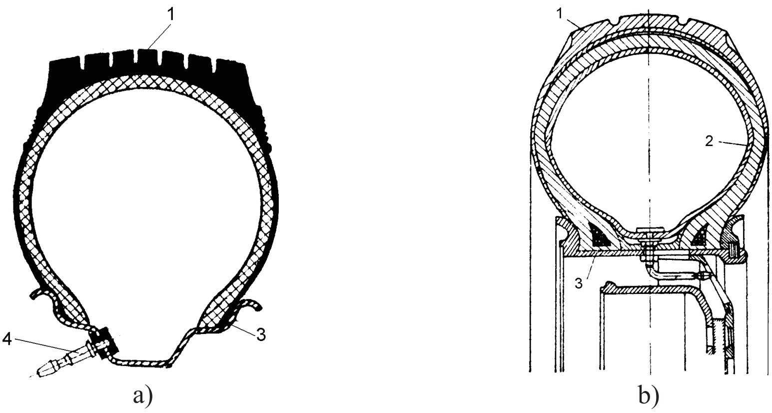


Fig. 1 Construction of land vehicle tires

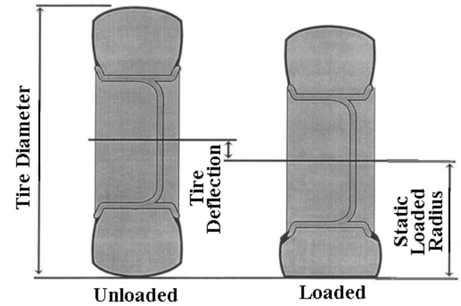


Fig. 2 Vehicle tire, unloaded and loaded

Fig. 3 Type R-1 drive wheel

Figure 2 illustrates the principal parameters of the tire. *Tire diameter* (overall diameter) is twice the section height of a new tire, including 24-hour inflation growth, plus the nominal rim diameter [7]. This overall unloaded diameter can be obtained from tire data handbooks, which are available from off-road tire manufacturers. *Tire static loaded radius* is the dimension measured from the axle centreline to the ground, when the tire is under the load. Figure 3 presents a type R-1 drive wheel of a 65 HP tractor used in Romania. For this type of tire, within this paper was conducted an analysis of stress and strain distribution using Finite Element Method.

THEORETICAL ELEMENTS

Tire normal force is calculated based on the normal deflection and velocity:

$$F_n = F_s - F_D \tag{1}$$

where: F_n - force on the normal direction; F_s - stiffness force due to normal deflection; F_D - damping force due to normal velocity.

Stiffness force due to normal deflection is:

$$F_s = k \cdot d_n \tag{2}$$

or:

$$F_s = f(d_n) \tag{3}$$

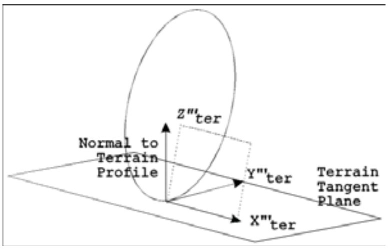
where: k - vertical stiffness coefficient; d_n - normal deflection; $f(d_n)$ - vertical stiffness force as a function of normal deflection (curve vertical).

Damping force due to normal velocity is:

$$F_D = C_D \cdot V_n \tag{4}$$

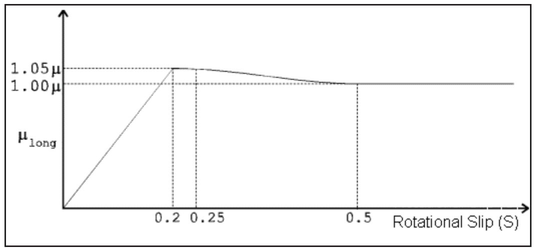
where: C_D - vertical damping constant; V_n - rate of change for normal deflection or normal velocity.

The terrain tangent plane is defined as the plane tangent to the terrain profile at the contact point between tire and terrain. It is assumed that the computed longitudinal and lateral forces are acting in this plane. The terrain tangent plane coordinate system is defined by these rules. Z-axis of the terrain tangent plane coordinate system is normal to the tangent plane, directed upwards. X-axis is located at the intersection between the terrain tangent plane and the plane of the tire disk. Y-axis is located in the terrain tangent plane, perpendicular to the X-axis, directed to result in a right-handed coordinates system.



a)

Fig. 4 Tire axis system [4]



b)

Fig. 5 Friction function [4]

Longitudinal force is computed based on rotational slip in the terrain tangent plane and is assumed to act in this plane. Two effects appear in the longitudinal direction: rolling resistance and traction/braking forces.

$$F_L = F_{rr} + F_{TB} \tag{5}$$

where: F_{rr} - rolling resistance force; F_{TB} - force due to traction/braking.

Rolling resistance represents the parasitic longitudinal force due to carcass deformation losses, bearing friction, etc., as a friction of normal force.

$$F_{rr} = -c_{rr} \cdot F_n \cdot sign[(V_c)_L] \tag{6}$$

where: c_{rr} - coefficient of rolling resistance; $(V_c)_L$ - forward velocity of the wheel centre obtained from the model state.

Traction/braking force can be modelled when the wheel rotational inertia is included (type full). If the rotational inertia is not included (type basic and intermediate) the traction/breaking force will be equal to zero. The ratio between the longitudinal force and the normal force (or longitudinal friction coefficient) is measured as a function of rotational slip. Thus, traction/breaking force can be written as:

$$F_{TB} = \mu_L \cdot F_n \tag{7}$$

where: μ_L - longitudinal force coefficient measured as a function of rotational slip.

The longitudinal friction coefficient is a piece-wise linear function of slip, based upon the nominal friction coefficient, and is shown in the following plot.

The rotational slip will be:

$$S = -\left|\frac{V_p}{(V_c)_L}\right| \cdot sign(V_p) \tag{8}$$

where: S - non-dimensional rotational slip; V_p - velocity of the bottom point of the tire.

The velocity of the bottom point of the tire is:

$$V_p = R_d \cdot \omega + (V_c)_L \tag{9}$$

where: R_d - deflected tire radius; ω - wheel rotational velocity obtained from the tire state.

Lateral force is computed as a function of normal force and slip angle analogous to the longitudinal force computation with rotational slip. Lateral force experimental data is typically known as a carpet plot because it varies with both the normal force and slip angle. The lateral force is approximated by a cubic polynomial determined from the following boundary conditions:

$$\alpha = 0 \Rightarrow \begin{cases} F_l = 0 \\ \dfrac{dF_l}{d\alpha} = C_\alpha \end{cases} \tag{10}$$

$$\alpha = \alpha_n \Rightarrow \begin{cases} F_l = (F_l)_{\max} \\ \dfrac{dF_l}{d\alpha} = 0 \end{cases} \tag{11}$$

where: α - slip angle; α_n - saturated slip angle; F_l - force acting on lateral direction; $\frac{dF_l}{d\alpha}$ - slope of the lateral force curve related to the slip angle; $(F_l)_{\max}$ -maximum force on the lateral side; C_α - cornering stiffness value.

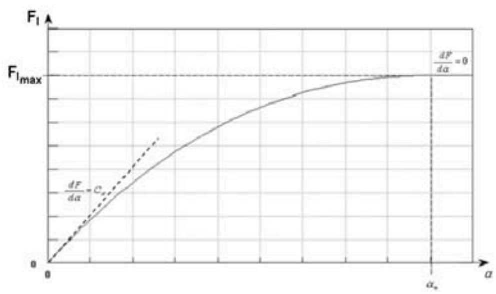


Fig. 6 Cornering stiffness [4]

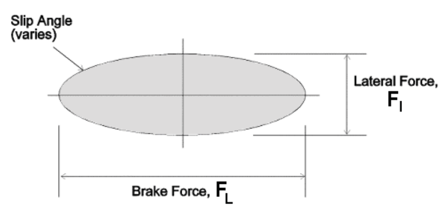


Fig 7 Friction Ellipse [4]

Slip angle is formed between the tire center heading vector and the projection of the velocity vector in the terrain tangent plane (as shown in figure 6). Due to the fact that slip angle is always acute, its sign depends on the sign of the lateral velocity component of tire center. Thus, slip angle can be defined as:

$$\alpha = \tan^{-1}\left|\frac{(V_c)_l}{(V_c)_L}\right| \cdot sign[(V_c)_l] \tag{12}$$

Saturated slip angle can be approximated by:

$$\alpha_n = 2.5 \cdot \frac{F_n}{C_\alpha} \tag{13}$$

Maximum lateral force is given by following relationship:

$$(F_l)_{\max} = \mu \cdot F_n \tag{14}$$

where: μ - nominal friction coefficient.

In longitudinal direction, as well as in lateral direction, proportionality coefficients between tangential and normal force are functions of a kinematic representation of slip. These forces are independently calculated, even though the two force components are not necessarily independent and their resultant is limited by the dimension of the friction force between tire and road. The friction ellipse, having the length of major axis $\mu_L \cdot F_n$ and the minor axis equal to $\mu_l \cdot F_n$, represents some possible values of this net force.

When computing the rotational slip, the applied frictional force is acting on the opposite direction of the velocity vector, with a dimension derived by intersecting the velocity vector with the friction ellipse. The dimension of this force is given by the length between the origin and the intersect point. This limiting condition is only taken into account for large slips, when the relationships for μ_L and μ_l reflect tire-road slippage as opposed to tire carcass stiffness. This limiting condition also shows the limitations in the applicability of the neglected wheel inertia model. The lateral force carpet plots are measured at zero rotational slip, so the presence of longitudinal forces tends to invalidate the use of this data (excepting the case when net vector slip is computed and a friction ellipse is used, as presented in case 2). Models with neglected wheel inertia should be used for simulations with relatively small longitudinal forces. Two cases are implemented to represent this description:

1) When using the neglected inertia model (type basic or intermediate), F_l is computed from the cubic approximation and:

$$\mu_{\max} \cdot F_n > \sqrt{F_L^2 + F_l^2} \tag{15}$$

then:

$$F_l < \sqrt{(\mu_{max} \cdot F_n)^2 - F_L^2} \quad (16)$$

where: μ_{max} - the maximum lateral force coefficient and it is understood that:

$$F_L < \mu_{max} \cdot F_n \quad (17)$$

This is a friction circle since the major axis of the friction ellipse (the longitudinal force F_L) cannot be determined without computing rotational slip.

2) When using wheel inertia model (type full), the longitudinal force is computed from the rotational slip and the lateral force from the steer slip. The following logic then imposes the friction ellipse limitation:

$$\mu_{max} \cdot F_n > \sqrt{(e \cdot F_L)^2 + F_l^2} \quad (18)$$

$$e = \begin{cases} \mu_L / \mu_{max} \\ 1.0 \end{cases} \text{for} \begin{cases} \mu_L > \mu_{max} \\ \mu_L < \mu_{max} \end{cases} \quad (19)$$

then:

$$F_l = -\mu_{max} \cdot F_n \cdot \frac{(V_c)_l}{|V|} \quad (20)$$

$$F_L = e \cdot \mu_{max} \cdot F_n \cdot \frac{V_p}{|V|} \quad (21)$$

where:

$$|V| = \sqrt{V_p^2 + (V_c)_l^2} \quad (22)$$

By simulating an agricultural vehicle driving over a discrete ditch it is obtained an example of tire force verification. These tests are part of a more comprehensive set of experiments in which the vehicle is driven over other obstacles, such as discrete bumps, and a concrete ISO test track. A perfect match was observed for the simulation and test accelerations at one location on the vehicle. The results were found to correlate well for high-pressure settings of the tires, but not as good for very low-pressure tires. For high tire pressures, the equations used to represent tire stiffness, damping, and friction characterize the real physical behaviour. Low-pressure tires act more complexly and the tire carcass nonlinear rubber behaviour becomes important. New development effort is underway to add capability to better represent the low-pressure tire case.

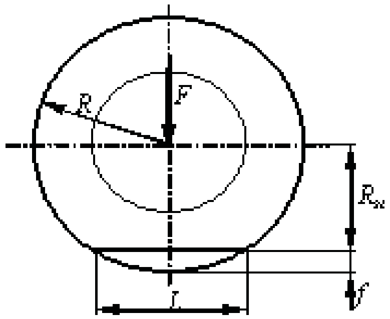


Fig. 8 Tire deformation under the action of an external load

Under the action of an external load (weight per wheel), a tire deforms as shown in Figure 8. According to Hedekel's equation, tire deformation is given by the following relationship:

$$f = \frac{F}{2 \cdot \pi \cdot p_i \cdot \sqrt{R \cdot r}} \text{ [mm]} \tag{23}$$

where: F – vertical load acting on the wheel, [N]; p_i – air pressure inside the tire, [MPa]; R – free radius of the wheel, [mm]; r – radius of tire running path in cross section, [mm].

Static tire radius is given by:

$$R_{st} = R - f \text{ [mm]} \tag{24}$$

and the lenght of the contact chord is:

$$L = 2 \cdot \sqrt{R^2 - R_{st}^2} \text{ [mm]} \tag{25}$$

MATERIALS AND METHODS

The analysis was developed for the tire of the rear wheel of the 65 HP Romanian tractors U-650, whose main characteristics are given in Table 1. The analyzed tire is symbolised as 14-38 R35. The tire is made of rubber, which is generally considered to be a non-linear, incompressible or nearly incompressible, hyper-elastic material, which often experiences very large deformations upon loading [6]. The element selected for analysing the rubber material was HYPER185, which was used in conjunction with the two-term Mooney-Rivlin material model [6]. ANSYS v12.1 program was used for the analysis of the 3D model, while Quick Field Students v5.6 program was used to analyze the plane model of tires section in „plane strain" mode.

Table 1 Main characteristics of U-650 tractor

Tractor	Soil interaction part	Gauge [mm]	Weight (total / per axle), [kg]		Contact patch width, [mm]
U-650 (65 HP)	Front tire	1600	3380	1170	180
	Rear tire			2210	367

Figure 9 illustrates the influence of tire pressure on the dimensional characteristics of the wheel (Figure 8), respectively tire deformation (Eq. 23), static radius R_{st} (Eq. 24) and the length of contact chord L (Eq. 25), for the rear wheel.

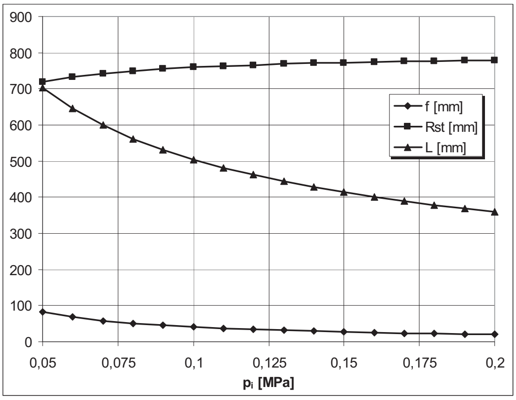


Fig. 9 Influence of tire pressure on the dimensional characteristics of the wheels

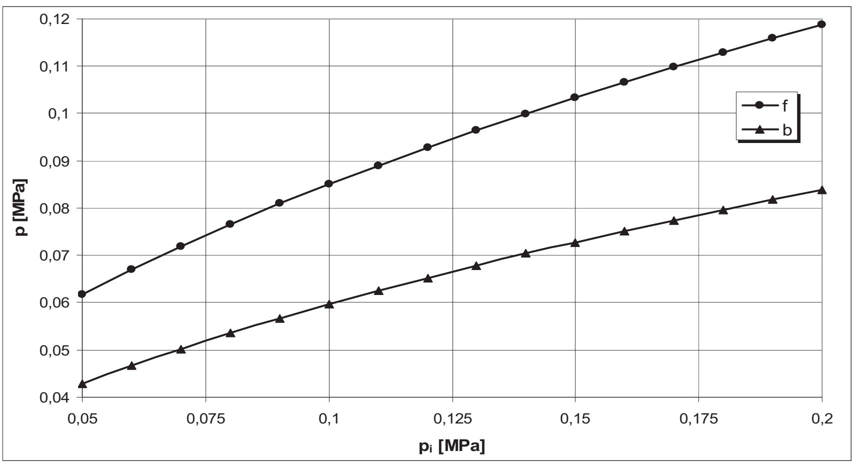


Fig. 10 Influence of tire pressure on the contact pressure

Tire air pressure influences the tire pressure applied on the soil. The dependency between tire air pressure (p_i) and the pressure applied on the soil by the tire (p) is illustrated in figure 10, for both front (f) and rear wheel (b) of the U-650 tractor.

RESULTS

Figure 11 illustrates the 3D physical model for the rear tire of the 65 HP tractors, developed by means of Solid Works program, which takes into consideration all the details on tire sizes. This geometrical model was imported in ANSYS v12.1, thus obtaining the meshed model of FEM analysis (Figure 12), which consists of three dimensional finite elements for both tire and rim, as well as for the rigid surface of the rolling track. In the contact area was developed a finer and more precisely meshing, using a higher number of finite elements having smaller sizes.

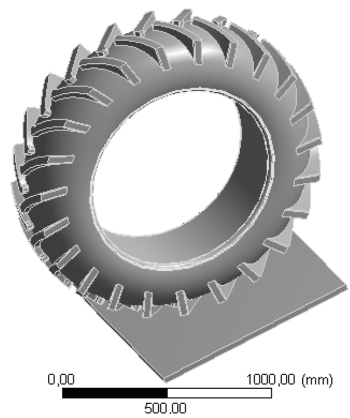


Fig. 11 Physical tire model

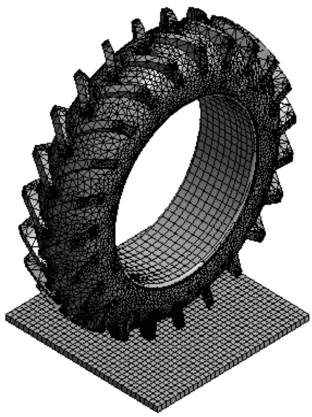


Fig. 12 Meshed tire model

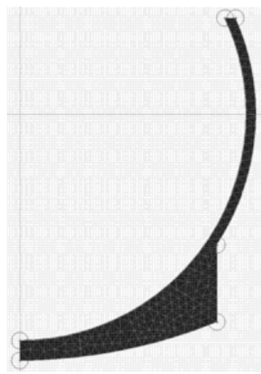


Fig. 13 Meshed tire model

For a simpler analysis it was also developed a plane, symmetric model for the tire in frontal plane, using Quick Field Students v5.6 program (Figure 13), for which tire air pressure and the load on the wheel were taken into account. According to the graphic presented in Figure 9, it was computed the tire strain on vertical direction for tire air pressure of 0.15 MPa.

Figure 14 shows the distribution of equivalent stresses by Von Mises criterion in the tire in the contact area with the rolling track and the graphical variation of those equivalent stresses on the outline. It is also traced the outline of the tire after the strain, due to the application of the external load. It can be noticed that the highest values of equivalent stresses are located in the joint area of the lug with tire carcass. Figure 15 shows the distribution of total displacement in the tire in the same section and the graphical variation of those displacements on the outline of the analyzed axis-symmetric model. Highest displacements appear in the mean area of tire carcass.

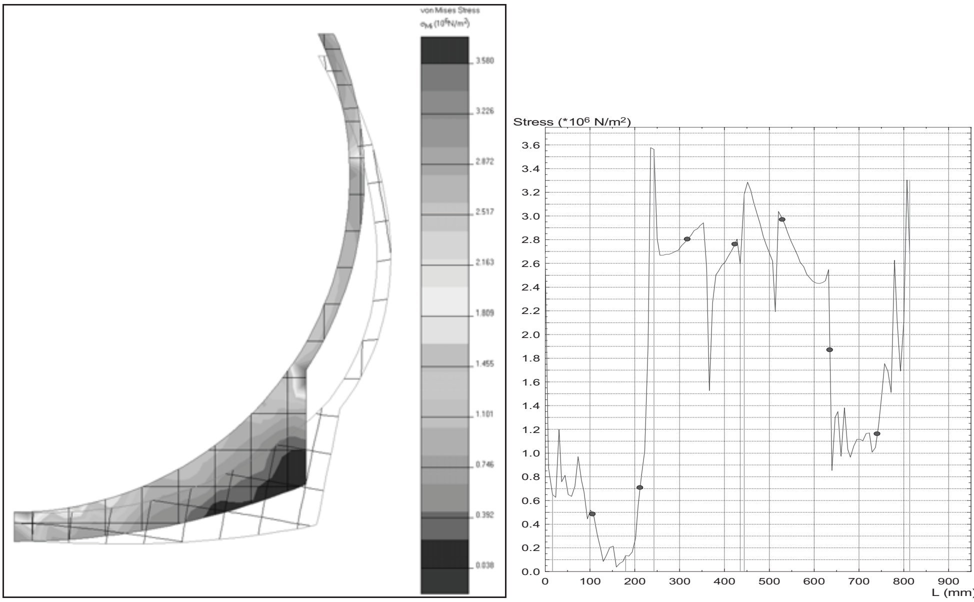


Fig. 14 Distribution of equivalent stresses in the tire in the contact area with the rolling track

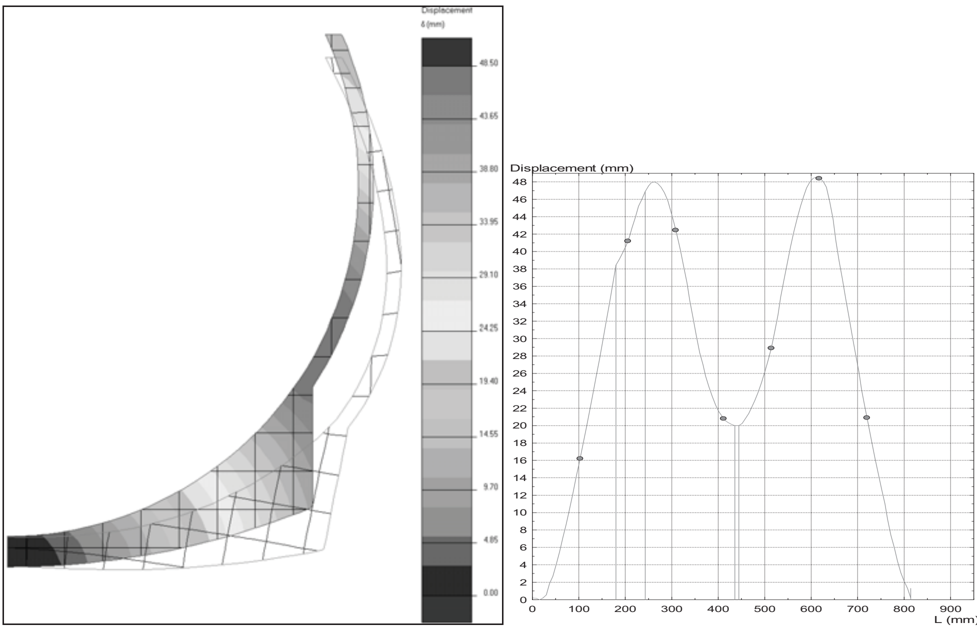


Fig. 15 Distribution of total displacements in the tire in the contact area with the rolling track

CONCLUSIONS

1. The Finite Element Method is currently the most advanced mathematical tool which can be used for the complex study of the interaction between the rolling bodies of land vehicles and the rolling track.
2. Highest difficulty for this study was modelling the nonlinear hyper-elastic behaviour of tire material – rubber, which included the cord angles in each layer, respectively the analysis of stress and strain distribution.
3. This study allows the highlight of some areas of the analyzed tire in which stresses are higher, as well as the fact that the mean area of tire carcass is subjected to the highest strains. This also leads to the highest danger of tire wear during depressurisation. This led to the conclusion that the thickness of carcass walls should be increased. For many speed vehicles was implemented the ”Runflat” system, to avoid the wear of tire carcass due to excessive strain during depressurisation.

ACKNOWLEDGEMENT

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

TEST FACILITY FOR INVESTIGATIONS OF TRACTOR TIRE DYNAMIC BEHAVIOR ON HARD SURFACES

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SUMMARY

A number of reasons can be named to investigate dynamic behavior of agricultural tractor tires on hard surfaces, one of the most important being increasing speed of contemporary tractors. It can be expected that a need for such investigations will increase in the future, hence also a need for appropriate test facilities. In the Laboratory for vehicles and engines at the Faculty of Technical Sciences in Novi Sad, there is a tractor tire test facility for terramechanical investigations. Recently a decision has been made to convert current tire test equipment to become appropriate for testing of tractor tire on hard surfaces. In this paper a significance of investigating and modeling of a tractor tire behavior on the hard surfaces is closer described. Basic conversion guidelines are named and initial stage of reconstruction is described.

Key words: *tractor tire, tire testing, tire & vehicle dynamics*

INTRODUCTION

Requirements for tractor tire design and exploitation properties are based above all on the needs of agrotechnical operations and motion on the soft terrain. Such requirements are: good tractive properties on agricultural terrains, low rolling resistance, protection of the soil from the compaction, low wear etc. On the other hand, tractors of today can travel at relatively high speeds when used for road transport, and there is a tendency for further speed increase. This brings into attention dynamic properties of tires on hard surfaces related to tractor performance characteristics such as handling and stability; as such properties are important factors of driving safety. Ride properties are also important because of their influence on the tractor body vibrations and realization of horizontal forces.

Tire design for appropriate behavior on hard surfaces requires different approach than that for the soft terrain, for which tractor tires are primarily developed. This fact leads to need for more intensive research and development activities in field of agricultural tire research and development, for which appropriate testing facilities are needed. Such facilities should enable investigation off all aspects of tire behavior, including longitudinal, lateral and vertical dynamics under different conditions on both hard and soft surfaces. These investigations are important because of the insight in the complex tire behavior they enable. Information acquired can, on one hand, be in function of tire development itself. On the other hand, tire model can be established to be used in virtual modeling and development of the tractor.

In the Laboratory for vehicles and engines on the Faculty of Technical Sciences in Novi Sad, a tractor tire test rig exists that has been developed in the mid-80's of the last century for the purpose of terramechanical investigations. Based on the previous considerations, decision has been made to undertake a reconstruction to adapt this facility for hard surface tire testing. The goal is to develop a test facility for overall investigations of tire dynamic behavior on the hard surfaces, retaining at the same time the possibility of terramechanical investigations. In this paper a need for reconstruction is explained, basic conversion guidelines are given, and the beginning stage of reconstruction is closer described.

SIGNIFICANCE OF INVESTIGATION AND MODELING OF TRACTOR TIRE BEHAVIOR ON HARD SURFACES

Tire behavior is considered separately in different directions of coordinate system, according to influence it has on the vehicle motion. Regarding tractor tire behavior on hard surfaces, attention was previously focused mostly on their characteristics in vertical direction, which governs ride properties. These properties are important because of their influence on the operator working conditions (vibrations), and for the conditions for realization of horizontal forces as well. Absence of elastic wheel suspension, distinctive for agricultural tractors, highlights importance of ride properties of the tire itself even more.

Tire behavior in longitudinal and transversal direction has earlier been investigated mainly on soft surfaces. Main subjects were tractive forces and transversal forces while working on the slope or when transversal force component from tractor implement is present. Recently, traveling speeds of tractors on public roads have been significantly increased, which leads to possibility of critical driving situations regarding handling and stability of the tractor. Transversal vehicle dynamics is the most influenced by tire cornering properties, which brings these into attention. Similar applies also for longitudinal (tractive and braking) tire properties. Increased traveling speeds and amounts of material in transportation distinctive for contemporary agricultural production [4] increase significance of vehicle braking performance characteristics. These facts indicate that a need exists for more detail investigation of tire dynamic behavior on hard surfaces. This need is even more expressed due to characteristic design properties of tractor tires that do not enable use of research experiences gained in intensive investigations of road vehicle tires.

Tire behavior in all three directions is quite complex. There are large deformations of the complex geometric structure, viscoelastic tire behavior, mechanics of composite materials, pressurized air within flexible body etc. Owing to this, tire behavior is characterized by pronounced non-linearity, frequency dependency and complex interactions of different outer influences. Although tire behavior has been subject of intensive investigations and theoretical basics exist for their analytical observation, a level of complexity is so high that such investigations still require experimental research [5]. Compared to ground vehicle tires, complexity level of tractor tire behavior is even bigger due to their complex geometry and low pressure causing bigger tire deflections.

According to these considerations, and bearing in mind influence tire has on overall dynamic tractor behavior, it is of interest to have a possibility of laboratory investigations of tire behavior under conditions that are as close to real as possible. Results of such investigations can be used for:

- Qualitative insight into tire properties and their influence on the vehicle dynamics, enabling conclusions about potentials for further tire improvement (development investigations), and
- Parameter identification for the implementation of the tire model in the frame of computer aided vehicle dynamics simulation.

Investigation of tire behavior on the hard surface can be of interest for one more reason, namely for gaining immediate insight into the properties of the tire itself, eliminating the need for analytical consideration of complex mechanism of its interaction with the surface. This approach can also be used for prediction of tire properties on the soft surfaces.

Due to the potential of computer aided simulation for improving efficiency and success of engineering systems design and development, they are nowadays unavoidable element of these activities. Their use contributes to the reduction of costs and efforts of development investigations. In vehicle dynamics, simulations enable identification of the possibility for appearance of unwanted forms of vehicle behavior under certain circumstances. Thus vehicle parameters can be adjusted in optimal way in order to reduce danger of unwanted outcomes as far as possible. Such approach significantly reduces time of development, since different concepts and design solutions can be evaluated and compared in early stage of development, before production of the real prototype. Figure 1 shows example of graphical representation of tractor dynamic model used in appropriate multi-body dynamics simulation software [1]. Such computer programs use numerical approach for computing forces and torques acting on the vehicle and its components, and appropriate accelerations accordingly. Final result is prediction of vehicle motion under given circumstances.

Figure 1 Graphical representation of the tractor modeled as multi-body dynamic system [1]

Tire has a substantial role in the realization of all functions of agricultural tractor. Availability of the tire model with appropriate performance characteristics therefore represents a basic condition for successful use of simulation. Appropriate testing capabilities are needed to develop such tire model.

CURRENT STATE IN THE FIELD OF TESTING TRACTOR TIRES ON HARD SURFACES

Nowadays there is a large number of well-equipped laboratories for tire testing and investigations. Though, regarding hard surfaces, test facilities are mostly provided for testing of passenger car and truck tires. Tractor tires are still mainly subject of considerations from terramechanical point of view, whilst facilities for their testing on hard surfaces are notably less represented. There are relatively few facilities that have capabilities to work with tires of such dimensions and working loads as it is a case with agricultural tractors. One of such facilities, based on the concept of measuring trailer (Figure 2) has been developed and applied on TU Hohenheim in Germany [6]. This single wheel tester can be used for investigation of tire performance characteristics in all three spatial directions, in steady-state and dynamic conditions, on both hard and soft surfaces. Besides apparent advantages of this test facility from the point of view of testing possibilities, its dimensions and complex structure require significant material resources for its production and exploitation.

Figure 2 Single wheel tester based on a measuring trailer [6]

There are also several facilities based on a flat belt test stands. One example also exists on the same university, Figure 3. Important feature of such test stand is plain tire-surface contact area, which is not the case with test stands with drums. Later are also not appropriate for most tractor tires due to tire dimensions. Plain contact area improves test conditions making them closer to the real situation. Concept is also characterized by compact dimensions and simple tire mounting. A drawback is intensive wear of the flat belt [7].

According to trends in development and use of tractors and other off-road vehicles, it is valid to expect that in context of their development a need for appropriate tire test facilities will raise. This expectation justifies further innovation activities in this field.

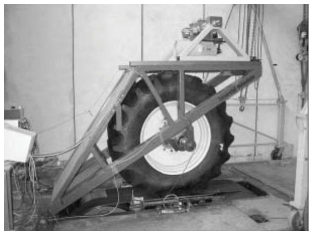

Figure 3 Flat belt tire test stand with mounted shaker device [2]

BRIEF DESCRIPTION OF TERRAMECHANICAL TEST FACILITY ORIGINAL CONFIGURATION

As already mentioned, in the Laboratory for vehicles and engines at Faculty of Technical Sciences in Novi Sad, a test facility for terramechanical investigations of tractor tire has been developed earlier. A conversion of this facility, which should enable tractor tire testing on the hard surfaces, is in progress. Here a brief description of original configuration is provided, Figure 4. Tested wheel (1) with its axle is attached to the frame that can move in vertical direction. Frame guides (3) are mounted on the cart (2) guided on 13.6m long rails. The cart is 2.2m long, which gives a testing lain approximately 11m long. According to its purpose, it was necessary to shape test lane as a tub filled with appropriate kind of soil (7). Cart was driven by a driving chain (5), through driving system consisting of electric motor and continuously variable transmission located on one end of the test lane (8).

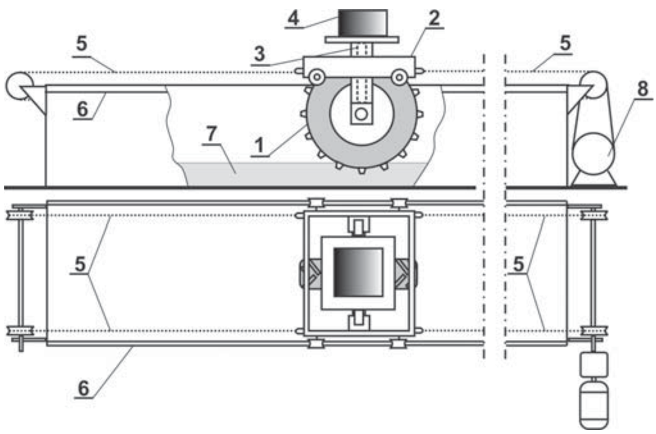

Figure 4 Original concept of the terramechanic test facility: 1-tested tire, 2-guiding cart, 3-vertical guides, 4-weight, 5-driving chain, 6-cart guiding rail, 7-soil, 8-driving system

Concept analysis reveals some drawbacks. Some of them are related to deviation of testing conditions from real, such as:

- Too slow motion of the wheel (velocities of order ≈0,01 – 0,05 m/s)

- Absence of driving torque on the tested wheel.

There is also a group of features that, bearing in mind that this facility represents testing and measurement system, can be regarded as drawbacks. These are:

- Besides rolling, a wheel has just one more degree of freedom (vertical motion)
- Missing integration of measuring, control and actuating equipment
- It can be assessed that structure parts of the facility are quite oversized[1].

BASIC CONVERSION GUIDELINES

A main goal of the test facility conversion is enabling of testing of wide spectrum of tire behavior aspects on hard surfaces. In order to fulfill such requirement, conversion should comprise as much as possible the following:

- integration of measuring system for acquisition of all relevant kinematic and dynamic parameters of motion;
- incorporation of electronic controlled actuating system for tire excitation;
- incorporation of driving and/or braking system of the wheel itself;
- conversion of the wheel guiding system enabling additional degrees of freedom for slip and castor angles, for testing of steady-state and dynamic cornering tire properties;
- Integration of controls of cart drive and wheel drive, enabling introduction of longitudinal wheel slip in controlled manner; etc.

Development of the facility that matches all named requirements would require material resources in amount that significantly exceeds current capabilities of the Laboratory. This difficulty can be eliminated or mitigated by introduction of the concept that divides development into separate stages. This also contributes to the systematic approach and gradual gain of experience and knowledge needed to shape facility which can be successfully used for practical testing tasks. Facility development under restricted budget has also imposed a need to use parts and components that were already present in the Laboratory. Taking into account adopted concept of the development divided into stages, a modular design solutions should be used in order to make future conversions simpler and cheaper to realize.

BEGINNING STAGE OF THE CONVERSION

Initiated beginning conversion stage comprises incorporation of drive system for transmission of the driving torque to the wheel and setting up of the system for the excitation of the wheel vertical vibrations. Following the principle of cost reduction a

[1] This contributes to the reliability in facility exploitation, but deteriorates accelerating properties, hence reducing available path and time for measurements

hydrostatic system has been chosen as driving unit, whose components were already present in the Laboratory. System consists of the hydrostatic motor and the assembly of hydraulic pump and 2kW electric motor.

Power is transmitted from hydraulic motor to the wheel via belt drive. In the beginning stage, also from the reason of costs reduction, wheel drive is realized without a possibility for speed regulation. As most economic option for testing tire on different speeds a change of driven belt wheel is possible. Due to the lack of hydrostatic system controls, a way has to be found to protect its parts from overload in a braking phase. To solve this, a mechanism for automatic disengage of the belt drive by reducing belt tension and contact angle during braking is provided.

Table 1 Approximate assessment of test facility kinematic parameters for different speeds of motion *(m ≈ 1000 kg – mass of moving parts, P_{MAX} = 2 kW – drive motor maximum power, $\varphi \approx 0{,}7$ – adhesion coefficient, s_{TOT} = 10m – total test path length)*

Velocity [m/s]	Acceleration time [s]	Acceleration path length [m]	Braking path length [m] ($v_0 = v$)	Path length available for measurement [m]	Time available for measurement [s]
v	$t_A \approx \frac{m \cdot v^2}{P_{MAX}}$	$s_A \approx \frac{2}{3} \cdot v \cdot t_A$	$s_B \approx \frac{v_0^2}{2 g \varphi}$	$s_M = s_{TOT} - s_A - s_B$	$t_M = \frac{s_M}{v}$
0.5	0.1	0.04	0.02	9.94	19.9
0.75	0.3	0.14	0.04	9.82	13.1
1	0.5	0.33	0.07	9.59	9.6
1.25	0.8	0.65	0.11	9.24	7.4
1.5	1.1	1.13	0.16	8.71	5.8
1.75	1.5	1.79	0.22	7.99	4.6
2	2.0	2.67	0.29	7.04	3.5
2.25	2.5	3.80	0.37	5.83	2.6
2.5	3.1	5.21	0.46	4.34	1.7
2.75	3.8	6.93	0.55	2.52	0.9
3	4.5	9.00	0.66	0.34	0.1

For the choice of a belt drive ratio an assessment of the optimal wheel velocity had to be made. This was conducted taking into account total test path length and lengths needed for acceleration and braking. Acceleration performance characteristics can be approximately estimated on the basis of accelerating mass and available power as explained in [3]. For this approximation all resistance forces during acceleration are neglected, and assumption is introduced that a constant power is continually available, that equals one half of the maximum power installed. Acceleration time is than calculated on the basis of the kinetic energy introduced to the system through the action of the constant power. Acceleration path length was calculated on the basis of another approximation, according to which acceleration decreases from maximum value to zero linearly. Braking path length is determined according to well-known theoretical dependency on initial velocity and adhesion coefficient φ whose value amounts to approximately $\varphi \approx 0.7$ as determined in previously conducted measurements. Appropriate formulas and numerical values are given in Table 1.

From the Table 1 it is obvious that with given parameters a choice of velocities greater than 2m/s can hardly make sense, and the optimal values are probably between 1 and 2m/s. According to that assumption, it was decided that for the initial phase of conversion wheel velocity should come to approximately 1m/s or slightly less. Such value – relatively low – was chosen because of the need to firstly gain practical insight into dynamic behavior of the whole system. This way a danger of the drive system overload during acceleration is mitigated. Further, insight is enabled into requirements for design of appropriate braking system, which will be needed for the measurements with greater velocities. At last, such decision is justified by not knowing characteristics of rail system geometry inaccuracies, which can lead to significant dynamic loads, and what could not come to expression in earlier period of use because of too small velocities.

For wheel vertical vibration excitation in the first stage appropriate surface profile geometry is provided. Different shapes can be used such as ramp, single obstacle, pothole, triangle, semi-circle etc. For harmonic excitation an inertial excitation device can be used. An example of the profile geometry shape used as excitation source is shown on the Figure 5. For investigation of tire vibrational behavior a measurements of vertical acceleration and displacement is provided. Due to the fact that configuration represents one-mass vibrational system, acceleration is proportional to the reaction force between the wheel and surface, hence this can also be calculated accordingly. Taking into account tire velocity, excitation can be represented as vertical displacement of the contact area in the time domain, so that appropriate transfer functions can be established. These results can then be in the function of further analysis and modeling of the tire vibrational behavior.

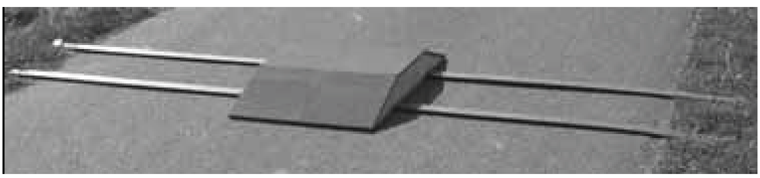

Figure 5 Example of the profile geometry shape used as excitation source [6]

CONCLUSIONS

Importance of investigation and modeling of tractor tire behavior on the hard surfaces is explained in the paper. Related to this, a need for development of appropriate test facilities is justified. Basic guidelines and requirements for the conversion of existing terramechanical test facility for tractor tire testing on the hard surfaces are briefly introduced. It has been concluded that dividing development into separate stages can contribute to the quality and success of the conversion, and mitigate a problem of restricted financial resources at the same time. In the following period, possible design solutions for practical realization of these guidelines are to be found. Detailed technical and economical analysis of the possibilities and conditions for their realization is to be conducted. Possibility of the cooperation with other research institutions in the country and abroad, or with manufacturers of tractors and tractor tires as well, could greatly contribute to improvement of the conditions for the realization of the conversion. This would also strengthen usefulness and practical applicability of investigation results.

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EXPERIMENTAL RESEARCHES CONCERNING THE INFLUENCE OF THE INERTIAL BRAKING EQUIPMENT COMPONENTS CHARACTERISTICS ON THE BRAKING PERFORMANCE OF THE TRACTOR – TRAILER SYSTEM

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SUMMARY

This paper presents the results of the experimental researches concerning the influence of the constructive and functional parameters of the inertial braking systems on the braking efficiency of the tractor –trailer transport system. Based on the obtained results, practical proposals are made for functionally and constructively improving the inertial braking systems.

Key words: *tractor–trailer system, inertial braking systems, braking performances*

INTRODUCTION

The construction of the braking systems for agricultural trailers comprises an important aspect: decreasing the price of the product but keeping the functional performances of the braking process by using an inertial braking system instead of pneumatic system, which is not so expensive. For this purpose, it is necessary to study the influence of the inertial braking equipment components on the braking performance of the tractor – trailer system. These are the researches which are made and the results will be present in this paper.

METHODS

The experimental researches performed have aimed at studying the influence of certain components of inertial braking system (fig. 1) on braking efficiency, namely:

- Ratio of transmission of actuating level (i_T=m/n);

- Length of cam actuating level (l);
- Brake diameter (D);
- Brake shoes width (b).

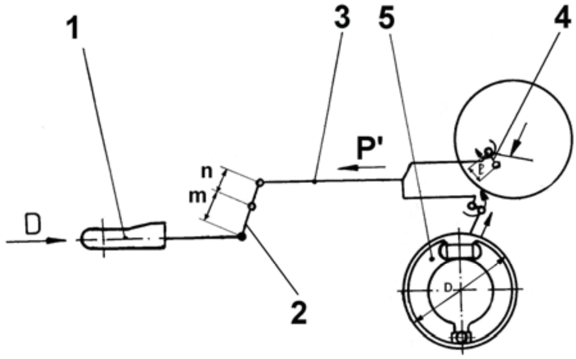
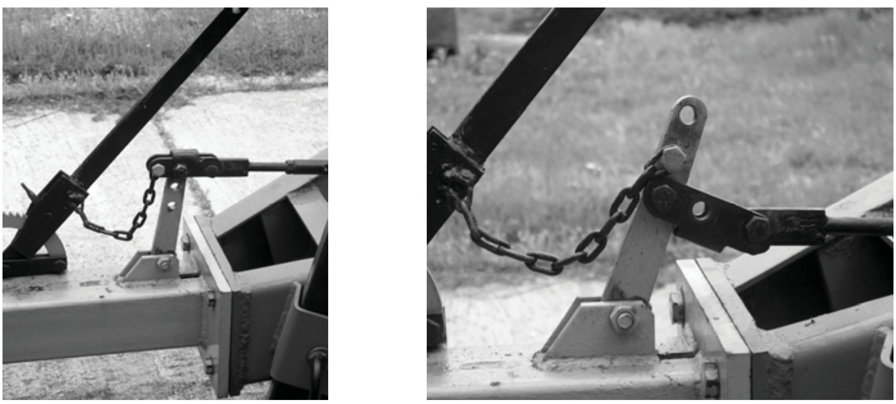


Fig. 1 Diagram of inertial braking system 1-actuating unit; 2-actuating device lever ; 3-intermediate lever; 4-cam actuating lever; 5-proper brakes

In order to perform this analysis, these elements have been designed and manufactured as following dimensional versions:

- Transmission ratio of actuating lever (fig.1): i_{T1}=0.66; i_{T2}=0.88.



a) *DSC 1 version*: n_1=120 mm   b) *DSC 2 version*: n_2= 90 mm

Fig. 2 The two coupling positions of actuating device lever; m=80 mm; *DSC 1 version*: n_1=120 mm; *DSC 2 version*: n_2=90 mm

- length of cam actuating lever (l);

a) PC 1: l_2 =210 mm

b) PC 2: l_1 =170 mm

Fig. 3 The two coupling positions of cam actuating lever - *brake's dimensions: (Dxb)*
D_1xb_1 : Ø300x80; D_2xb_2 Ø 300x60; D_3xb_3 Ø 250x60

In figure 4 is shown the proper brake, which has been tested, and in figure 5 are presented two pairs of brake shoes of Ø300x60 and respectively Ø250x60, the third pair of brake shoes Ø300x80 being already set on semi-trailer which has been performed for experimental tests.

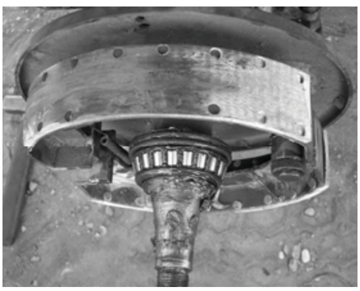


Fig. 4 Drum and shoes brake

Fig. 5 Two brakes' dimensions, 300x80 şi Ø 250x60

For each of the three proper brake dimensions, the transmission components were mounted (lever of operating device and cam actuating lever) as 4 possible versions and three braking tests for each combination were performed, being totally performed 36 braking tests with 45HP tractor – semi-trailer aggregate and three braking tests only with 45HP tractor, for analyzing the aggregate's braking performances in comparison with single tractor.

Within experimental researches, the following parameters have been determined through measurements:

- initial speed from which the braking process starts;
- deceleration;
- braking space;
- braking time;
- pressure force on pedal;
- forces of semi-trailer's coupling mechanism to tractor.

Fig. 6 Photo of registering apparatus calibration

Fig. 7 Photos taken during the tests; traces at adhesion limit

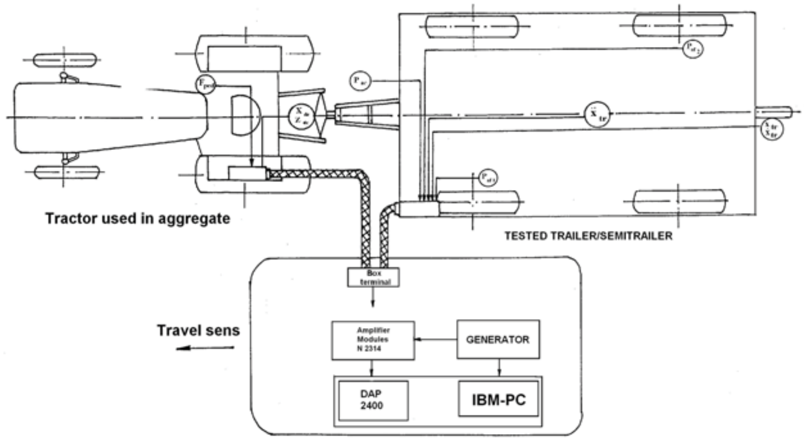


Fig. 8 Schematic representation of measurement equipment used for experimental research in service conditions

The measuring apparatus used for performing experimental research records during the operation type is the transmission of signals by wire, information is collected by the equipment mounted on the trailer, tractor respectively, consisting of strain gauges and pressure transducers, transmission cables acquisition card mounted recording on a tractor and laptop computer.

The process for measuring data transmission by cable is shown schematically in fig.8.

RESULTS AND DISCUSSIONS

Influence of cam actuating lever length

In view of studying the length of cam's actuating lever, a lever with two holes different spaced related to joint have been designed and performed, fig.2, allowing to the transmission rod to be suitably coupled to two lengths of cam actuating lever arm PC 1: l_1 = 210 mm and respectively, PC 2: l_2 =170 mm.

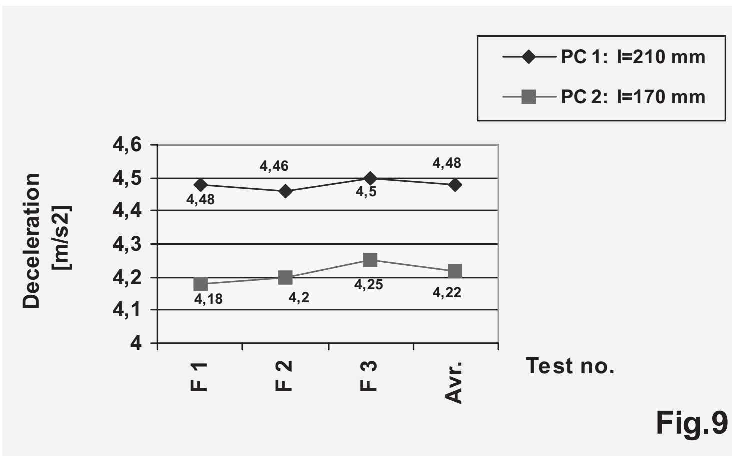


Fig. 9 Influence of cam actuating arm length on deceleration when mounting version is DSC1: n=120 mm and brake Ø 300 x 80

There has been noticed that length of cam actuating lever arm has an effect upon the braking performances of all three variants of inertial braking system, equipped with proper brakes of three different sizes: Ø300x80, Ø300x60 and Ø250x60.

At the first braking system comprising a brake of Ø 300 x 80 it can be noticed that for about 23% increase of cam actuating lever arm length, the braking performances raised, which was expressed by a 4% greater deceleration, at Ø 300 x 60 brake - a 7% deceleration increment and at Ø 250 x 60 brake, the deceleration increment was of de 9%. These values are differentiated because of different values of action forces, being impossible to obtain identical forces in exploitation conditions.

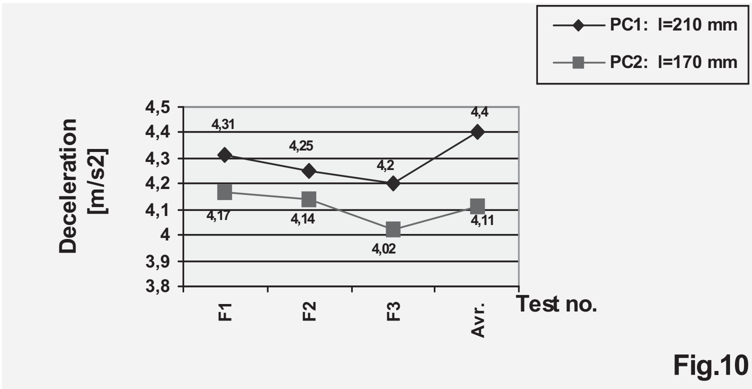


Fig. 10 Influence of cam actuating lever arm length on deceleration when mounting version DSC1: n=120mm and brake Ø 300 x 60

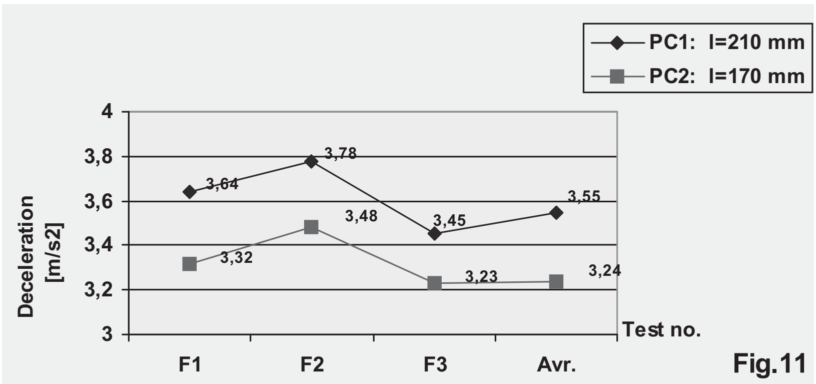


Fig. 11 Influence of cam actuating lever arm length on deceleration when mounting version DSC1: n=120mm and brake Ø 250x60

Influence of brake dimensions: shoes diameter and width

Within the experimental researches, performed with inertial braking system, the influence of main brake parameters, namely shoes diameter and width have been also intended to demonstrate.

Influence of brake shoes width. Analyzing the influence of brake width upon braking performances, we can notice that for 33% increase of shoes width when mounting transmission version DSC1: n_1 = 120 mm and PC 1: l_1 = 210 mm, 1.8 % deceleration increment has been registered. This growth is not spectacular, viewing the fact that the increment of friction surface itself is not so big.

The graphic of figure 12 synthesizes the influence of shoes width upon deceleration, in case of presented assemblage.

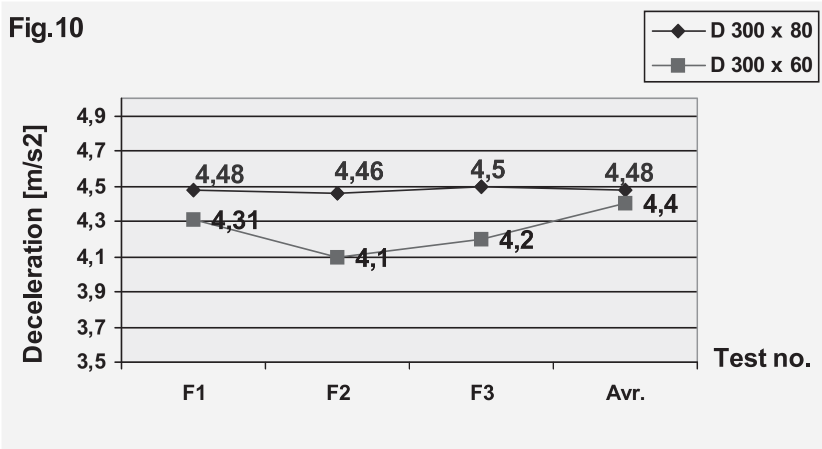


Fig. 12 Influence of shoes width when transmission is mounted DSC 1 version: n=120mm; PC1: l=210mm, upon deceleration

In case of the second assemblage tested (DSC1+PC2), where the cam actuation lever was set in a lower position, we can notice the fact that, for a shoes width of 33% bigger, a deceleration increment of about 2.7% has been obtained.

Table 1 Influence of proper brake shoes width; comparison between ϕ 300 x 80 brake and ϕ 300 x 60 brake; actuation and transmission: DSC 1: n1=120 mm=ct.; PC 2: l2=170 mm=ct

Brake size (Dxb) [mm]	Ø 300 x 80				Ø 300 x 60			
TEST NO.	F 4	F 5	F 6	Average	F 4	F 5	F 6	Average
Deceleration [m/s^2]	4.18	4.15	4.25	4.22	4.17	4.14	4.02	4.11
Braking space [m]	7.71	7.84	7.66	7.74	7.62	7.84	7.98	7.81
Speed from which the braking process starts [km/h]	27.1	26.9	27.1	27.03	26.9	27.1	27.1	27.03
Action force of coupling device [N]	13720	13010	15260	14000	10090	11630	10250	10660

The values of deceleration, in this case too, are higher than the limit imposed by regulations in force (min.3.5 m/s2).

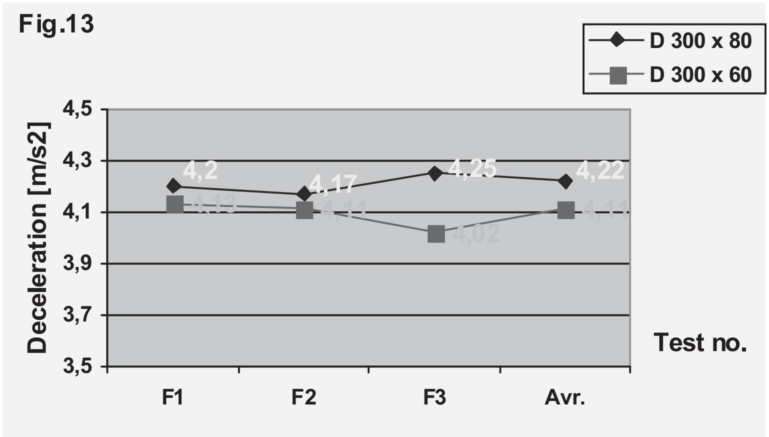


Fig. 13 Influence of shoes width when mounting the transmission DSC 1: n=120mm; PC 2: l=170 mm, upon deceleration

Influence of brake diameter. In table 2 is shown the influence of brake diameter variation in case of two brake dimensional versions: Ø300 and, respectively Ø250, for a shoes width b=60 mm and an assemblage appropriate to transmission version DSC1: n_1=120 mm and PC1: l_1=210 mm.

Table 2 Influence of proper brake diameter; comparison between Ø 300 x 60 brake and Ø 250 x 60 brake; Actuation and transmission: DSC 1: n_1 = 120 mm=ct.; PC 1: l_1 = 210 mm=ct

Brake size (Dxb) [mm]	Ø 300 x 60				Ø 250 x 60			
TEST NO.	F 1	F 2	F 3	Average	F 1	F 2	F 3	Average
Deceleration [m/s^2]	4.31	4.10	4.20	4.40	3.64	3.78	3.24	3.55
Braking space [m]	7.41	7.90	7.61	7.64	8.48	7.90	8.81	8.40
Speed from which the brake starts [km/h]	27.2	27.3	27.5	27.1	27.8	27.3	27.5	27.5
Action force of coupling device [N]	13430	13150	12840	13140	21390	23580	19960	21640

The graphic of brake diameter influence on deceleration is shown, for case presented in table 2, in figure 14.

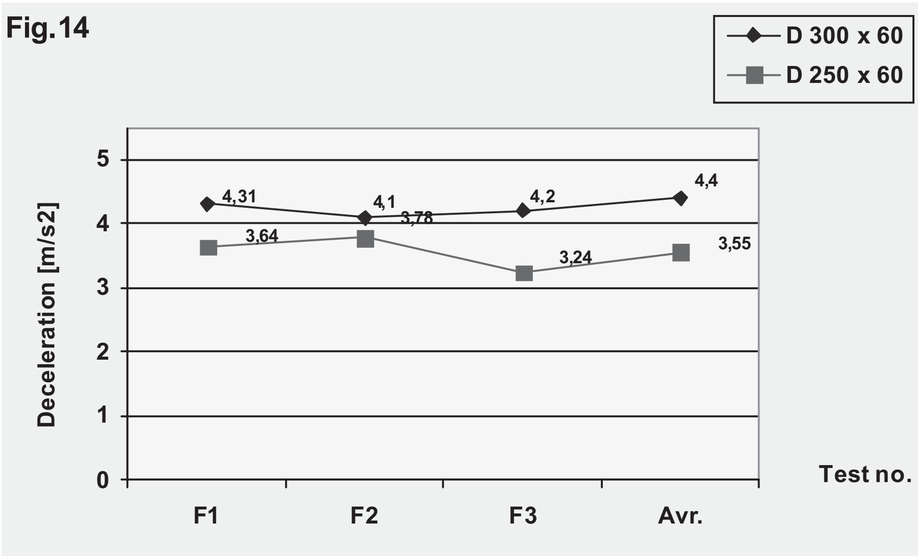


Fig. 14 Influence of brake diameter when mounting the transmission DSC 1=120mm; PC1=210mm upon deceleration

Table 3 Influence of proper brake diameter; comparison between ϕ 300 x 60 brake and ϕ 250 x 60 brake; control and transmisssion: DSC 1 = 120 mm=ct.; PC 2 = 170 mm=ct

Brake size	ϕ 300 x 60				ϕ 250 x 60			
TEST NO.	F 1	F 2	F 3	Average	F 1	F 2	F 3	Average
Deceleration [m/s^2]	4.17	4.14	4.02	4.11	3.32	3.48	3.23	3.24
Braking space [m]	7.62	7.84	7.98	7.81	8.39	8.62	9.31	8.77
Speed from which the brake starts [km/s]	26.9	27.1	27.1	27.03	26.9	27.1	27.1	27.03
Action force of coupling system [N]	10090	11630	10250	10660	31150	30900	28710	30250

The researches performed for emphasizing the influence of brake diameter on braking performances have demonstrated that , when the brake diameter is 20% bigger, as transmission assemblage version DSC1=120mm, PC1=210mm, the deceleration has increased by 24%, which is rather important if this dimension can be increased, ensuring this way better braking performances, concretized as deceleration and braking space.

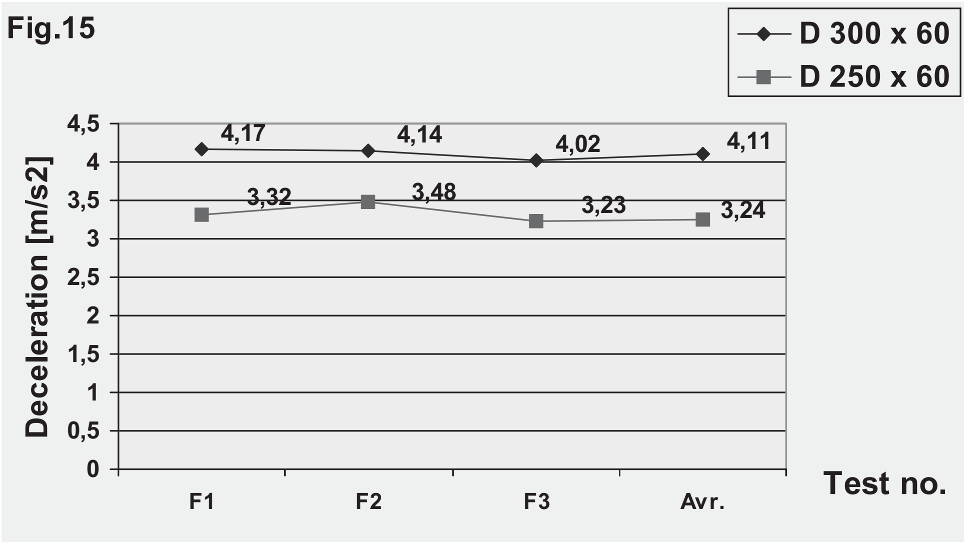


Fig. 15 Influence of brake diameter when mounting the transmission SC 1: n=120 mm; PC 2: l=170 mm upon deceleration

Braking performances of U 445 tractor (45 HP) as single unit. In order to compare the braking results of aggregate comprising U445 (45HP) tractor and semi-trailer, the braking performances of single tractor have been also registered.

Table 4 Braking performances of U 445 single tractor + semi-trailer

Performances obtained for:	U 445 single tractor(45 HP)				Brake Ø 300x80 PC1: l_1=210 mm; DSC2: n_2=90 mm			
TEST NO.	F 1	F 2	F 3	Average	F1	F 2	F 3	Average
Deceleration [m/s^2]	3.67	3.48	3.70	3.62	4.54	4.51	4.56	4.54
Braking space [m]	8.39	8.09	8.97	8.48	7.06	7.09	7.02	7.06
Speed from which the brake starts [km/h]	26.7	27.6	25,9	26.7	27.3	27.2	27.2	27.2
Force of coupling device [N]	-				1406	1358	1426	1397

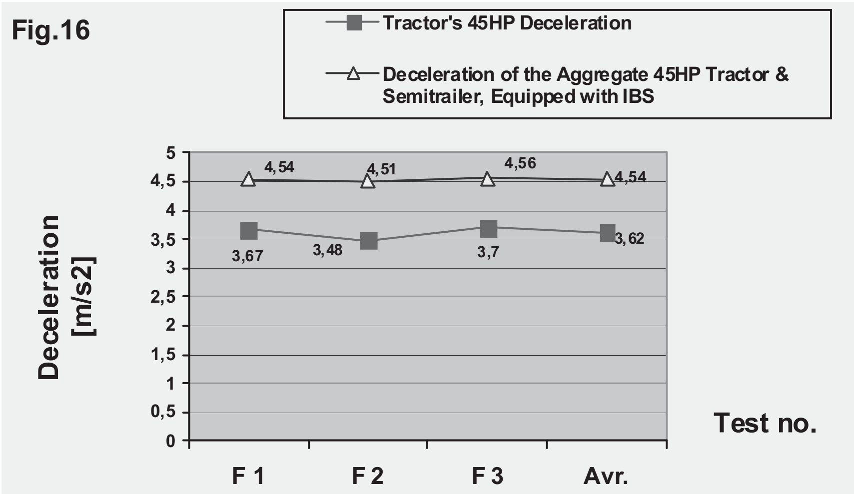


Fig. 16 Deceleration of 45HP single tractor and aggregate 45HP tractor&semitrailer, equipped with Inertial Braking System (IBS)

CONCLUSIONS

Conclusions of experimental researches of inertial braking system with mechanical transmission:

- The experimental researches performed have emphasized the *importance of an appropriate dimensioning* of inertial braking with mechanical transmission in order to obtain the braking performances required (deceleration and braking space) according to regulations in force;
- If tyre dimensions are pre-established by allowable load per tyre, the braking performances can be improved by *intervening on the two levers* of mechanical inertial braking system transmission, *related to operating device stroke and gap between drum and brake shoes*;
- After analyzing the brake's dimensions (Dxb), there has been found that *increasing brake's diameter, D, is more efficient than modifying brake shoes width, b*;
- Following the experimental researches performed it has resulted that braking performances of tractor + semi-trailer aggregate, equipped with inertial braking system are similar to those obtained for a tractor-semi-trailer aggregate, endowed with pneumatic braking system, but at a *much smaller price.* Therefore, the version of inertial braking system is considered to be *more advantageous in economic and financial terms* than pneumatic braking variant, under the same conditions of braking performances.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

PURE PLANT OIL - A SOURCE OF ALTERNATIVE ENERGY

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SUMMARY

The necessity of using bio-fuels for Diesel engines from tractors and agricultural machines, and the necessity of extracting oil from specific plant seeds in the purpose of using it as bio-fuel represent an important opportunity for rural development. The paper presents the main oleaginous plants, the characteristics of produced oils and the methods of yielding them, the main equipments used for extracting vegetable oil, sizing of the main elements for an extraction press at cold, purification methods for the produced oils and an installation designed so that it satisfies the demand in bio-fuel for an agricultural farm's (600-900 ha) tractor park. Using a cold pressed plant consists of three modules was obtained by pressing an average separation of oil from seeds of over 33% at an average yield of 401.87 kg / h. The results obtained from experimentations outlined the importance of using vegetable oils as an alternative energy source for tractors and agricultural machinery Diesel engines and the method for use of raw vegetable oil as a long term bio-fuel.

Key words: *alternative energy, plant oil, tractors, agricultural machinery*

INTRODUCTION

Given that energy requirements are increasing and that fossil fuel reserves are being depleted, taking into consideration their catastrophic polluting effects on the ecosystem, it became imperative to find new ways of producing energy from alternative sources to replace these classics fuels. Increasingly serious pollution of air, water and soil, contributing to health deterioration, global warming of the Earth, already causing catastrophic weather changes and threatens to completely change the conditions that make life possible on our planet. The increasing pollution and high prices of the fossil fuels bring to the forefront the biofuels and sources that produce biofuels.

Because the known reserves of natural gas, oil and coal are close to exhaustion, this led to continuous and rapid price rises in the last thirty years. Their world market price will make over several decades to disappear some of the economic branches.

The capitalization of agriculture potential by encouraging the alternative crops of technical plants (such as rape, sun-flower, soy etc.) in order to provide an alternative energy source of fuel for tractors and self-propelled agricultural machines, is a current energy desideratum with broad prospects for development of field crops in Romania.

In recent years, took a special development the cultivation of plants with high energy potential as: rape, soy, sunflower, sweet sorghum etc. on growing areas. Following negotiations with the EU and implementing the acquis communitarian on arable crops (cereals, oilseeds, protein crops, etc.) each member state of the Union has received a share of the total area smaller than the existing, important areas remaining available to be used for cultivation of plants with high energy potential to provide the necessary energy for own consumption on farms, micro farms, etc. (alternative energy sources) [6], [7], [8], [9].

The raw materials processed in Romania are sunflower seed, soy, flax, rapeseed, castor seed, corn germ, wheat germ.

The obtained oils will be used to determine the energy efficiency for each type of oil derived from seeds of different plants. The vegetable oil extracted from rapeseed has two main uses in food and biofuels.

Suitability and culture efficiency is reported differently to these uses and possibilities for recovery of the finished product.

An advantage of cold oil plants pressing is that in addition to producing cold pressed vegetable oil are valuable cake fodder, used successfully in animal husbandry.

The seed production level is very important to determined the profitability of the whole system by the amount of seed produced per hectare, by the percentage of oil that can be extracted and by the possibility to use the cake resulting from feeding extraction in zooculture.

By cold pressing the seed it obtain oil and pellets containing 5% and about 33% protein, and by hot pressing it obtain seed with 19% more oil and grist.

The cakes and groats of rape are very nutritious for animals and can be successfully replace the soy or sunflower.

On the European level is normally obtained around 3 tons per hectare of rape seed, from which can be extract a tone of raw rapeseed oil. Crude oil extracted from rapeseed can be used directly in engines up to 100% during the summer, with the addition of 40% in autumn and winter in a lower concentration [4].

Ways of purifying crude oil:

- *mechanical path of separation by collecting in decantation* - sedimentation vessels where there is the decantation - sedimentation phenomenon of mechanical components and suspension in the mixture. Samples are taken after decantation – sedimentation, they are analyzed, is passing through two filters: one coarse and one fine, then the samples are again analyzed and is considering whether oil composition it is appropriate and can be used per se;

- *chemical path*: crude oil is passed through a centrifugal separator, through a derubber coating-neutralization reactor where there is neutralization and separation of unsaturated fats FFA, then passes through a centrifugal separator where glycerin resulted from the reaction of transesterification is separated and through a polymer separator where resulting biodiesel is dried;
- *mixed-path*: the crude oil that has passed the stage of filtration and has not the necessary composition follows the chemical steps [4].

MATERIAL AND METHODS

The methods for obtaining the vegetable oils are by pressing and cold extraction or pressing and hot extraction. Seed pressing process has two phases: in the first phase of training the seeds are dried and ready and in the second phase the seeds are pressed to the cold or hot. By pressing at cold were obtained oil and cakes or pellets.

After pressing, the oil was filtered and deposited in barrels. Oil has many uses: energy for vehicles and heating, feedstock for biodiesel, animal feed oil. By cold pressing of the seeds it obtained oil and cakes or pellets containing 5% oil and about 33% protein. Filtered oil was very pure, with only 120 mg / kg of impurities. About 80% of total quantity of oil turned into biodiesel by esterification process and the rest was pure glycerine. Pure vegetable oil was defined as crude or refined oil but not chemically modified, produced by pressing, extraction or comparable procedures from oleaginous seed, being compatible with the type of engine that is used and meets the requirements of emissions into the environment.

Pure vegetable oil was the cheapest of all those listed. Raw vegetable oil is neutral in terms of air pollution with sulfur oxides, nitrogen and carbon. The product was in train, produced by a verified technology well-known by specialists. Currently are available all necessary equipment. It is not flammable and can be stored anywhere in drums, underground or on the ground, do not pollute the soil or groundwater in the event of leakage and can be stored over a year without damaging its quality.

Cold pressing may be achieved at an average level in a private farm located somewhere near the crops, directly or indirectly connected to agricultural production, being necessary reduced prices of investment.

This technology never use chemical solvents or thermal conditioning of the seeds. The cold pressing process has logistics costs and reduced security measures, low energy, increased flexibility, faster process of adjusting for oleaginous seed and without water consumption.

Fatty materials processing is somewhat different, depending on their type. Depending on the oil content of seeds and oleaginous germs, the oil extraction can be done only by cold or hot pressing or only by solvent extraction.

Grinding and flattening operations are preparatory operations of material before pressing. Since the content in water and shells is different at the processing of different oilseed, the preliminary operations before extraction is different for different kinds of seeds and in case of some fruits (olives, cocoa) even the extraction methods are different.

Testing methodology

After mounting the vegetable oil extraction installation before starting were made a series of checks on the proper functioning of the main components:

- checking the possibility of supplying the product to make good test;
- check the tightness of housings at: screw conveyors (inclined and horizontal), simply lift ES 100, rotary separator, chain and components conveyor TRK 90;
- static balance of the oil collector mixer;
- verification trough normal rotation of the agitator without hanging or blocking of it;
- verify the way on how products is collected: oil is extracted in oil collector and pellet are extracted in pellets collector, aiming them to be collected under optimum conditions.

Equipment and machinery used for testing: Roulette: 0-8 m

Caliper	0-1000 mm
Centrifugal tachometer:	60-24000 min^{-1}
Digital thermometer	0-50 C
Balance	0-150 kg
Laboratory balance	0-6 kg
Triphase network analyzer	0-345 w

RESULTS AND DISCUSSIONS

Calculation of power and the force necessary to press

Calculation of required power [1], [2] to drive the screw is made by using the relationship [5]:

$$P = \frac{M_t \times n}{95,500} \quad (1)$$

where:

M_t - twisting moment applied to shaft screw [daNcm];

N - frequency of rotation [rpm].

P - driving necessary power [kW]

Twisting moment is evaluated considering that on snail is acting the resultant force F of the screw pressure applied on the oily material (fig. 1, a), which is calculated with:

$$F = \frac{\pi}{4}(D^2 - d^2)p \tag{2}$$

where:

p -is the pressure to extract the values in the range 25-28 MPa and 40-200 MPa, depending on the type of press – with one or with two sections;

D - outer diameter of the screw coil in the press area;

d - inner diameter in the pressing zone.

Normal force acting on screw coil (fig. 1, b) at the angle α_m.

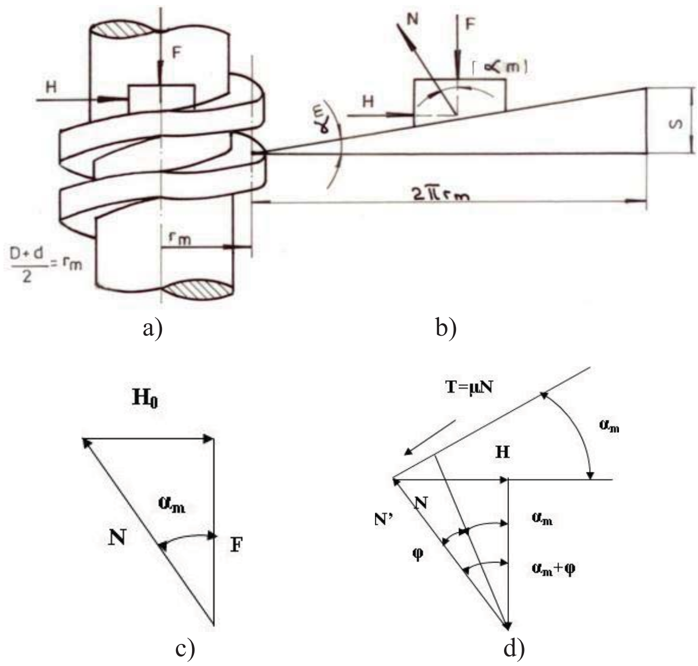

Fig. 1 The forces created by the oily material on spiral screw

The force required to push the material along the screw coil is denoted by H. As a result of material movement by the force H, occurs its pressing developing the resultant axial force F of pressure forces, so that in the no friction case

$$H = H_0 = Ftg\alpha_m \tag{3}$$

as shown in Figure 1c where N is the normal reaction to the spiral screw.

Friction force has as an effect a deviation of the normal reaction with the friction angle φ taking birth the resultant N' (Fig. 1, d). In this case, between the acting forces can be written the relation:

$$H = Ftg(\alpha_m + \varphi) \tag{4}$$

Therefore, to achieve the act of pressing the material it is acting with moment of twisting.

$$M_t = Hr_m tg(\alpha_m + \varphi) \tag{5}$$

given the relationship or (2)

$$M_t = \frac{\pi}{4}\left(D^2 - d^2\right) pr_m tg\left(\alpha_m + \varphi\right) \tag{6}$$

The drive shaft is the shaft on which is mounted the snail segments. Through it, the movement is transmitted to a snail.

Loading snail when operating is presented schematically in figure 2. The following acts on snail:

- twisting moment created by the driving system
- snail weight evenly distributed along the length L
- axial load due to transport pressure, p_a.

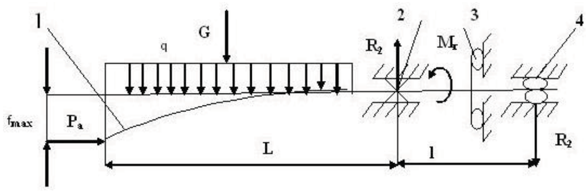

Fig. 2 Shaft load diagram; 1 - elastic line of the shaft, 2 - prop shaft, 3 - thrust bearing, 4 - radial bearing

Twisting moment created by the driving system;

- Snail weight evenly distributed along the length L;
- Axial load transport due to pressure, $p_{a.}$

The weight of the snail could be calculated with:

$$G = qL \tag{7}$$

where *q* is the linear load and L is the length of the snail screw located on the console.

Axial load is calculated with:

$$p_a = \frac{\pi}{4}\left(D_s^2 - d^2\right)\Delta p \tag{8}$$

where:

D_s - the outer diameter of the spiral snail in the supply area;

d, - inner diameter of spiral snail;

Δp - pressure at the end of the snail.

Calculation of the buckling of the snail [1]**.** Critical buckling load for the embedded bar with length L is given by the relation:

$$p_{cr} = 2.467\frac{EI}{L^2} \tag{9}$$

where "*I*" is the moment of inertia of the shaft and *E* is the modulus of elasticity of the material. Moment of inertia is calculated with:

$$I = \frac{\pi d_a^4}{4} \tag{10}$$

where d_a is the diameter of driving shaft.

Actual safety factor is calculated with the equation:

$$c_{ef} = \frac{p_{cr}}{p} \tag{11}$$

At a rational dimensioning,

$$c_{ef} = c_a\left(1 \div 0.1\right) \tag{12}$$

where c_a is the safety coefficient admissible to buckling.

Calculation of maximum arrow of the snail. For an embedded at one end bar with a uniformly distributed load at the free end the top arrow is:

$$f_{max} = \frac{ql^2}{8EI} \tag{13}$$

It is necessary that

$$f_{max} < \delta \tag{14}$$

where δ is radial play of the snail in the cylinder.

The snail is considered a bar subjected to bending and twisting. In these circumstances arise normal and tangential unit loadings.

Maximum bending stress. Maximum bending moment is calculated with the equation:

$$M_{i\,max} = \frac{GL}{2} + p_a\delta \tag{15}$$

$$f_{max} = \delta \tag{16}$$

Maximum unit load is determined with relation

$$\sigma_{max} = \frac{p_a}{A} + \frac{M_{i\,max}}{W} \tag{17}$$

where A is the shaft plan area and W is the shaft resisting moment

Torsional stress. The torsional stress is determined with relation:

$$\tau_{max} = \frac{M_t}{W_p} \tag{18}$$

where M_t is the maximum torsional moment and W_p is the polar resisting moment of the shaft.

Equivalent stress. For the equivalent stress, using the theory of maximum tangential unified effort it is calculated with the relation:

$$\sigma_e = \sqrt{\sigma_{max}^2 + 4\tau_{max}^2} \tag{19}$$

The equivalent stress is compared with the allowable unified effort, respectively

$$\sigma_e \le \sigma_a \tag{20}$$

The duration of pressing τ, must be large enough to allow the flow of the oil. The overtaking of duration does not significantly increase the pressing return, but significantly reduces the productivity.

The duration of pressing, as an amount of pressing durations on each section (step), is given by the relation:

$$T_s = \frac{V_s E}{Q_v\left(1-\beta_s\right)} \ \text{[s]} \tag{21}$$

where:

V_s - the volume of the open space from the press section, in m^3;

E_s - the degree of pressure in that section

Q_v - volume flow of the grist in the press, m^3/s

β_s - correction coefficient related to the grist amount eliminated from the press along with the oil, up to the analyzed section.

Installation for obtaining vegetable oils (fig. 3) has a processing capacity of 450 kg seeds per hour. The equipment is intended for medium-sized farms with arable land area 600÷900 hectares and consists of three modules: seed preparation module (a), oil extraction module (b) and oil purification module (c).

a) Seed preparation module (fig. 4) consist of: inclined conveyor, receiving hopper, horizontal screw conveyor, bucket elevator, magnetic separator, rotary separator and intermediate hopper.
b) Oil extraction module (fig. 5) consist of: frame, feeder conveyor with chains and nodes, seeds preheater, oil press (3 pcs.), oil collector.
c) Oil purification module (fig. 6) consist of a battery of 4 decantation – sedimentation vessels and a plate filter.

Fig. 3 Installation for obtaining vegetable oils

Fig. 4 Seed preparation module

Fig. 5 Oil extraction module

Fig. 6 Oil purification module

Performance: Seeds are bring in bulk or in bags and stored in the storage bunker. Its power will be made with the inclined screw conveyer.

The mixture of seed from the storage bunker is taken from an horizontal screw conveyor and is placed in the elevator base then it is raised, passed through magnetic separator where metal impurities are separated, through the rotary separator where coarse impurities are separated and the clean seeds are stored in an intermediate hopper.

The product is taken from the intermediate bunker with a conveyor with chains and nodes and is placed in the preheating hopper. Some of the hot air temperature passing through serpentine is transmitted to plant seed oil (rape, sunflower, soybean, castor, in etc.) which will be preheat helping to accelerate the process of pressing. From the preheating hopper through a cylindrical tube the seed are feeding every three seed presses. Depending on the quantity of seed that must be processed it is used one or even all three presses.

Once the seed reached the admission hopper of the press they are taken from the feed segment of the admission space. Before feeding the press is imperative that it be heated, in particular the extrusion head. The press will run this gap between 3 and 5 hours depending the temperature of the working medium. The press is prepared by taking into account the type of seed to be processed, specific adjustments are made for each type of seed.

The seeds from the admission space are taken from the feed screw and placed in the press room. Pressing occurs gradually. In the first segment takes place seed breakage and elimination of some smaller oil parts and after that takes place crumbling and even grinding of the seeds and oil removal. A small amount of oil will remain in the mass of groats which may vary between 5-8% depending on the type of seeds and adjustments made. Sunflower pellets is eliminated as pellets (rape, flax) or as cakes (Soya, sunflower). It can be obtained also only pellets but with assurance of a strict control.

The advantage to obtain pellets is that it is easier to store and easier to use as fuel. In use the press will work with lateral shields mounted the danger of scattering the oil being eliminated. The oil is discharged from the press through a funnel which collects oil from all compression segments and oil is introduced into the oil collector.

To not settle the phospholipids on the walls, the oil collector is equipped with an agitator which is driven by a gear motor providing a rotational frequency of about 20 rpm.

The oil collector has a capacity chosen to ensure the collection of oil extracted from three presses in 24 hours. The pellets discharged from the extrusion head of the press fall into the pellets collector, where when it is almost full the pellets collector is emptied, the pellets being collected in a specially arranged place. In the table 1 are listed the results obtained from experiments.

From the pellets discharge chamber, the temperature obtained from processing of seeds is taken from each press by a flexible plastic tube with insert metal. The warm air absorbed by a radial-axial fan thrust is sent to the preheat seed hopper.

From the oil collector through the connections provided at its base and with a centrifugal pump the oil will decant in the decantation-sedimentation vessels. They form a battery, the first powered the second by an overflow etc.

Table 1 –Results

No.	Determined parameter	MU	Press I				Press II				Press III				On installation
			Sample I	Sample II	Sample III	Average	Sample I	Sample II	Sample III	Average	Sample I	Sample II	Sample III	Average	
1	Proof mass	kg	5	5	5	**5**	5	5	5	**5**	5	5	5	**5**	**15**
2	Sample processing time	s	131	142	136	**136,33**	126	138	137	**133,67**	139	132	130	**133,67**	**134,56**
3	Working capacity	kg/h	137,4	126,8	132,4	**132,2**	142,9	130,4	131,4	**134,9**	129,5	136,36	138,46	**134,77**	**401,87**
4	Quantity of oil extracted	kg	1,85	1,99	1,93	**1,92**	1,62	1,77	1,76	**1,72**	1,645	1,698	1,719	**1,69**	**5,33**
5	Extraction grade	%	37	39,8	38,6	**38,47**	32,4	35,4	35,2	**34,33**	32,9	33,96	34,38	**33,75**	**35,52**
6	Current intensity	A	13,1	13,2	13,2	**13,17**	13,2	13,3	13,3	**13,27**	13,3	13,4	13,4	**13,37**	**13,27**
7	Current Voltage	V	380	380	380	**380**	380	380	380	**380**	380	380	380	**380**	**380**
8	cos φ	-	0,78	0,78	0,78	**0,78**	0,78	0,78	0,78	**0,78**	0,78	0,78	0,78	**0,78**	**0,78**
9	Power	kw	6,725	6,776	6,776	**6,759**	6,776	6,827	6,827	**6,81**	6,828	6,879	6,879	**6,86**	**6,81**
10	Specific energy consumption	kwh/t	48,94	53,45	51,2	**51,2**	47,43	52,34	51,96	**50,58**	52,73	50,45	49,68	**50,95**	**50,91**

The coarse product deposited at the bottom of the vessel is discharged on their base. The product decanted from the vessels is taken from a filter pump and placed into horizontal filter plates where are retained the unseparated coarse impurities in decantation-sedimentation vessels. The filtered product is collected in reservoirs if necessary cleaning. Otherwise it becomes a fine filter with vertical filters.

CONCLUSIONS

Following the results obtained (Table 1), we notice the following conclusions:

- average working capacity (productivity) of the three presses that form the pressing plant was: 132.2, 134.9 and 134.77 kg seeds per hour, which corresponds to a total processing capacity of 401.87 kg seeds per hour;
- The total amount of oil extracted by cold pressing installation was 142.53 l/h, representing:
  - 50.7 l/h (at an extraction degree of 38.47%), in the first press;
  - 46.32 l/h (at an extraction degree of 34.33%), in the second press;
  - 45.51 l/h (at an extraction degree of 33.75%), in the third press;
- average power consumed for processing the amount of 401.87 kg seeds and extraction of 142.53 l of oil in one hour was 6.81 kW;
- Average specific consumption of energy consumption was 50.94 kWh/t;
- oils obtained by cold pressing produces no pollution effects after use;
- technical equipments coming into contact with the oil obtained is made from austenitic stainless steel (alimentary);
- the installation, by proper endowment, ensures obtaining of vegetable oil from several types of seeds: soybean, sunflower, flax, ricinus etc. The adjustment of the oil drain distance among the segments of the sieve is done with special plates spacers with thicknesses specific to each seed species, from 0.1 mm to 0.8 mm.

- Vegetable oils are a safe alternative energy source;
- The installation ensure environmental protection, the method being clean, because it works only with natural products

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

RESEARCHES REGARDING MISCANTHUS STALK BEHAVIOUR DURING CRUSHING STRESS UNDER SMALL LOADS

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ABSTRACT

For grinding energy consumption determination, and also during other biomass mechanical preparation operations for bio-fuel use, it is necessary to determine behaviour under mechanical stress to which the vegetal material is subjected. In this paper, Miscanthus stalk behaviour to compression stress for relatively low load values (≤ 2.5 daN) is presented. Sample materials were used, taken from the zone between nods, but also from node areas of Miscanthus stalks, of different diameters, with approximately 20mm length, from plant base, that have been subjected to increasing value compression stresses until a limit value, followed by a drop of the same values, including stress mechanical hysteresis, for determining the energy gained during sample stress. On these results, appreciations on Mischantus plant mechanical properties have been made.

Key words: *miscanthus stalk, compression, load – deformation, deformation energy, elasticity*

INTRODUCTION

During biomass preparation process for combustible briquettes and pellets obtainment, the vegetal material is subjected to grinding, drying, milling briquetting, operations.

Miscanthus X Giganteus stalk can also be used as biomass for combustible pellets and briquettes production, starting from harvesting in the third year of plantation.

Milling the grinded biomass for obtaining a higher density material is made with hammer mills and also special disintegrators that transform grinded particles into dust material. Inside the grinding apparatus, but also inside the milling machines, stalks and stalk fragments are subjected to complex mechanical stresses, combined by crushing, shearing, bending, torsion, simple cutting or slide cutting, etc, the result of which being a particle mixture that goes back into the technological flow.

Mohsenin in his study concluded the fact that the majority of the grinding process required energy is wasted as heat, the required energy for material grinding being from 0.06 to 1% out of the total process energy requirement, [8].

High material volume, biomass low bulk density resulted from agricultural materials represents a significant impediment during its use as raw material for many processes, including bio-energy production, [10]. Thus reducing Miscanthus stalk dimensions requires an important energy value depending on a large number of milling machine functional and constructive parameters. Also required energy for densification process depends on parameters such as material particle size, moisture content, material properties, [6].

Material hardness depends largely on its microstructure, and the mechanical processes at which the material is subjected can alter its microstructure [4]. Dynamic load effect is the most used method for material hardness modification. Through repeated stresses application (stresses, pressure) to Miscanthus stalk, cracks in material structure appear, respectively at Miscanthus stalks, cracks that grow in size until rupture taking into account also the materials moisture content.

Generally biomass is composed out of hard materials, the behaviour of which could be classified between elastic-plastic and elastic-viscous at low temperatures and high stresses. It can be noted that stress decreases with constant strain (relaxation) or strain increases under constant stress (creeping), [9].

Dry biomass is generally a uniform constant, for briquetting adding small water content for easier pressing with the extruder. It has been concluded that for vegetal plants used the moisture content must be of approximately 14.87%, temperature of 115^{o}C, pressure of 32.99 MPa in order for an optimum process, [1]. Briquettes are used for industrial room heating, and pellets are used in smaller heating systems.

Through the process of briquetting, material density rises [2,7] and so it offers the possibility of an easy handling of the material than in it's original state. In [5], were used different compaction speeds for the oak sawdust in the limits 0.24–5.0 MPa/s. It was concluded that the density of compacted dry material measured at 2 min after compression decreases with the increasing compaction rate up to 3 MPa/s, above this value of the compression speed there are not detected any significant influences regarding the density of the compacted material.

Vegetal material behaviour during mechanical operations of the transformation technological process into combustible briquettes depends on the size and type of applied tests. For deformation and plant transformation into material particles with small dimensions subjected to densification process different energy consumptions are assumed. The paper presents results of experimental researches on Miscanthus energetic plant stalks.

MATERIAL, METHODS AND PROCEDURES

In order to determine the compaction behaviour of Miscanthus stalks under relatively small strains, under 2.5 daN, samples from the lower part of the plant's strain of approximately 20mm in the space between nods were used (12 samples), but also nod samples (2 samples.) Miscanthus stalks were harvested in March 2010, from experimental field of the National Institute of Agricultural Machinery Bucharest. Miscanthus crop was planted in 2008 and is currently in its second year.

Tests consisted of subjecting Miscanthus probes to progressive compression stresses, starting from 0.5 kg, until a value of 2.35 kg, determining the load and deformation each time (a total of 15 values of load masses). After maximum load, a decrease of the same values followed, taking notes of deformation.

Principle sketch of the apparatus in use for tests is presented in figure 1, weight loads with known masses (10^{-1} g measuring precision) were used, sample deformation being registered with an exterior comparator (10^{-2} mm precision).

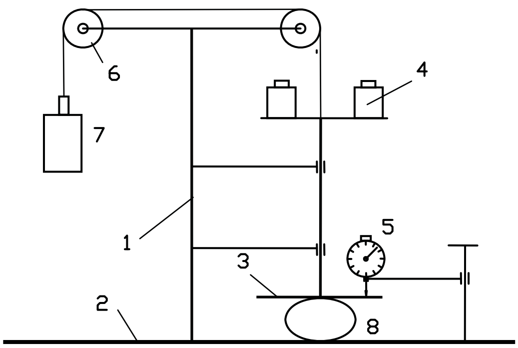

Fig. 1 Experimentation apparatus scheme (1.support, 2.support plate, 3.superior plate, 4.load masses, 5.measuring device – comparator, 6.roles, 7.counterweight, 8.sample)

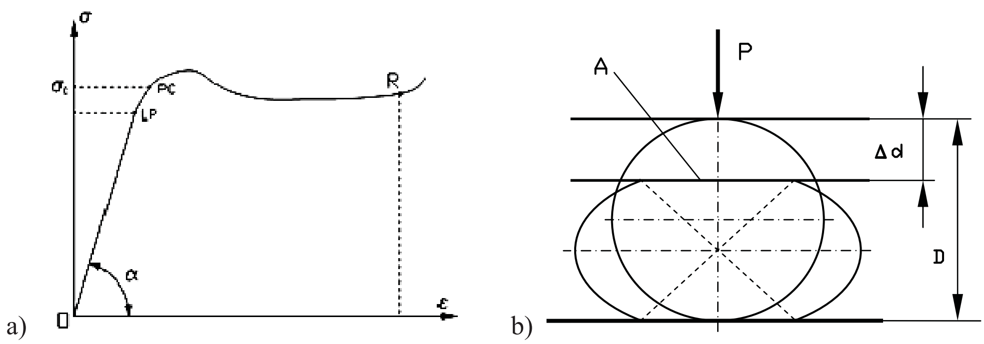

Fig. 2 Load – deformation curve specific for biological solid bodies (a), and transversal strain of miscanthus stalks (b)

For energy consumption determination in the material sample during compression test and its behaviour analysis, compression tests assumed both sample weight loads, and its discharge. Taking in consideration biological material behaviour under compression loads, like in fig. 2, the sizes that enter in elasticity module relation E of the material (in small deformation domain), respectively relative deformation ε and compression tension σ.

In fig. 2, a it can be observed, [3]:

- LP – proportionality limit until the σ – ε variation becomes linear, in the domain of small deformation, the bent of this portion is the elasticity module E (Young module), this characteristic (E) can be added as a measure of material texture strength called rigidity;
- PC – bio-flow point, when linear variation disappears, deformations have significant rises at insignificant σ tension rise, σ - ε variation becoming non-linear – here we can see the first crushing effects – cell destruction;
- R – flow point at which the fissures propagated onto all product mass and its rupture occurred., in PC – R area, at insignificant tension rises high deformations occur, until rupture.

In fig. 2, b, material sample deformation is presented for compression stress where σ = P/A (P – compression force, A – transversal section area) in Pa, ε - strain (Δd – absolute strain, D – undamaged sample diameter).

Unitary strain at which samples are subjected have been determined with the relation:

$$\sigma = E \cdot \varepsilon \tag{1}$$

According to figure (2), the elasticity module is:

$$E = \tan\alpha = \frac{\sigma}{\varepsilon} \quad [\text{N/m}^2] \tag{2}$$

Relative stalk deformation under loads has been determined with the relation:

$$\varepsilon = \frac{\Delta d}{D} \tag{3}$$

where: D is materials sample average diameter (measured at the two ends on perpendicular directions) [mm], and Δd is absolute strain (mm).

At sample deformation under load forces, the contact surface between apparatus mass and sample, respectively the press plate and sample, was considered rectangular and was determined on the basis of sample geometrical characteristics at different loads. Knowing the load force and the contact surface the compression tension σ was determined for each load force (2 square surfaces were considered, superior and inferior, equal at sample contact with the apparatus mass and pressure plate).

Knowing the deformation force and contact surface the compression tension σ was determined, after which drawing the relative tension-deformation curves were done. From these graphs through linear regression (with the help of Microsoft Excel) lines of correlation between compression tension and relative deformation were drawn, and the elasticity module of Miscanthus stalk was determined.

Geometrical characteristics of the samples: absolute deformation (Δd), relative deformation (ε), contact surface (S), compression tension (σ) and the elasticity module (E) have had values presented in table 1.

Table 1 Main mechanical characteristics of tested samples

No. sample	Diameter, mm	Length, mm	Deformation Δd, mm	Strain ε, mm	Contact area, mm^2	Stress σ, N/m^2	Young module, N/m^2
1	6.68	20.10	0.39	0.058	90.464	254.953	4616
2	6.23	20.55	0.11	0.018	47.903	481.469	28283
3	6.50	20.45	0.17	0.261	60.438	381.614	15236
4	6.68	21.10	0.11	0.016	51.115	451.216	31004
5	6.46	20.06	0.33	0.051	81.776	282.039	6284
6	6.54	20.28	0.34	0.050	85.991	268.217	5089
7	6.40	20.45	0.39	0.061	90.033	256.174	4868
8	6.35	21.05	0.45	0.009	98.845	233.337	3892
9	6.23	20.19	0.29	0.047	75.875	303.976	8489
10	6.62	20.44	0.2	0.030	66.031	382.775	18862
11	7.25	23.94	0.21	0.027	85.655	269.267	10106
12	7.72	25.11	0.29	0.038	105.264	219.107	6318
13*	6.07	21.51	0.16	0.026	-	-	-
14*	8.35	23.88	0.22	0.026	-	-	-

* nod material probes

RESULTS AND DISCUSSION

Taking account of compression load masses and sample absolute deformation under each force, the curves of load-deformation have been drawn (through points), both for load and sample discharge, including mechanical stress hysteresis for consumed energy determination during compression tests.

For some of the analyzed samples these curves are presented in fig. 3

Using linear regression analysis and Excel program force- deformation variation regression lines were drawn during load tests and discharge tests. Equation form, its coefficient and the value of correlation coefficient for each of the two lines (load-discharge) are presented in table 2, in which consumed energy values are also present for each sample during load-discharge testing. This energy shows elastic-plastic behaviour of samples and thus of Miscanthus stalks during stresses inside mechanical preparation operations.

Table 2 Regression equations and the hysterezis area resulted

No.	Loading		Unloading		Hysterezis area		
Sample	Linear equation	R^2	Linear equation	R^2	(kg·mm)	($J \cdot 10^{-3}$)	(J/m)
1	y = 5.607·x	0.977	y = 21.842·x – 6.469	0.959	0.334	3.277	0.163
2	y = 19.615·x	0.978	y = 34.926·x – 1.662	0.969	0.053	0.520	0.025
3	y = 12.584·x	0.839	y = 54.996·x – 7.048	0.932	0.136	1.334	0.065
4	y = 20.739·x	0.947	y = 44.197·x – 2.556	0.930	0.068	0.667	0.031
5	y = 6.959·x	0.971	y = 19.247·x – 4.014	0.970	0.239	2.345	0.116
6	y = 5.950·x	0.906	y = 14.862·x – 3.240	0.728	0.226	2.217	0.109
7	y = 5.990·x	0.983	y = 15.987·x – 4.246	0.859	0.326	3.198	0.156
8	y = 5.268·x	0.999	y = 18.656·x – 6.018	0.939	0.379	3.718	0.176
9	y = 8.716·x	0.979	y = 14.206·x – 2.008	0.942	0.208	2.040	0.101
10	y = 14.659·x	0.847	y = 19.498·x – 1.805	0.947	0.181	1.776	0.086
11	y = 10.044·x	0.854	y = 16.902·x – 1.450	0.956	0.091	0.893	0.037
12	y = 7.639·x	0.951	y = 13.097·x – 1.591	0.961	0.135	1.324	0.052
13*	y = 14.534·x	0.991	y = 22.159·x – 1.445	0.908	0.086	0.844	0.039
14*	y = 9.504·x	0.969	y = 23.510·x – 3.216	0.858	0.149	1.462	0.061

* nod samples

Regression lines correlation degree with the experimental values for the 14 probes is between the limits of R^2 = 0.839...0.999 at loading, for the majority of probes the correlation coefficient was $R^2 \geq 0.95$, and at discharge the correlation degree was between the limit of R^2 = 0.728...0.970, for the majority of probes the correlation coefficient being $R^2 \geq 0.93$.

From the table value analysis we can see that the stored energy inside the samples for the 14 probes of material is between the limits of 0.025–0.177 [J/m] under smaller than 2.3 daN load forces.

CONCLUSIONS

Following our research we drew the conclusion that for Mischantus plant deformation to crushing at transversal compression stresses, static tests larger than 2.5 daN are necessary.

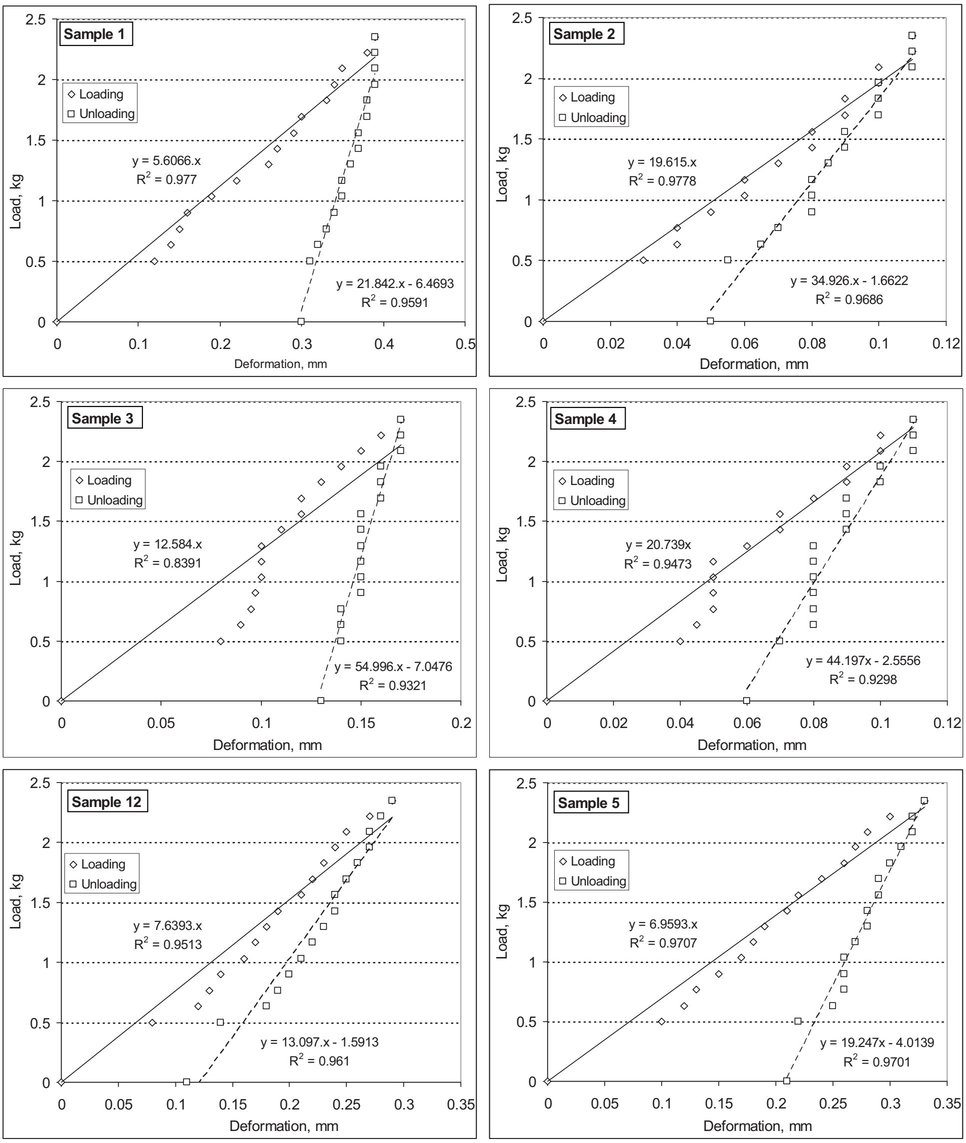

Fig. 3 Experimental data and regression curves for the some experimental samples

During the transversal compression process the plant disintegrates, deformation that relatively keeps its value after removing the load force. So it can be concluded that Miscanthus plant stalks have a plastic-elastic behaviour during the compression process that assumes a cumulated energy quantity in the plant without transforming it into smaller particles, so without being crushed until rupture. From the presented graphs and data a plant elasticity module result of values between 4284 – 31004 N/m^2, the energy lost at compression through load-discharge depending on the plant mechanical properties. These mechanical properties vary on plant height, with its diameter and width of exterior lignin; also they are different for plant nod portions. Through regression analysis done in the paper, the correlation of regression lines with measured data was at relatively high values that assumes the chosen model credibility.

Obtained values and the data presented in the paper are of real use to specialists and biomass processing equipment designers.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.234:662.63
Prethodno priopćenje
Preliminary communication

ENERGETSKA UČINKOVITOST DVEH TIPOV RASTLINJAKOV OGREVANIH Z LESNO BIOMASO

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POVZETEK

Lesna biomasa postaja pomemben vir energije tudi v intenzivni kmetijski pridelavi v zaprtih prostorih. Namen raziskave je podrobneje proučiti toplotne izgube, ki se pojavljajo v plastenjakih in steklenjakih ter izračunati potrebno količino goriva ter primerjati rezultate z dejansko porabo lesnih sekancev na dveh vrtnarijah v novembru in decembru. S pomočjo meritev temperature in izračunov toplotnih izgub smo prišli do naslednjih ugotovitev: toplotne izgube na enoto prostornine vrtnarije 1 so bile 1,12 kW/m^3, medtem kot so na vrtnariji 2 znašale 1,22 kW/m^3. Izračunana poraba goriva na enoto prostornine je znašala 6,78 kg/m^3 na vrtnariji 1 in 7,36 kg/m^3 na vrtnariji 2, kar je primerljivo z dejansko porabo lesne biomase (7,17 kg/m^3 na vrtnariji 1, 7,58 kg/m^3 na vrtnariji 2). Če zraven vseh parametrov upoštevamo še višji temperaturni primanjkljaj na vrtnariji 2, lahko zaključimo, da so energetsko učinkovitejši steklenjaki vrtnarije 2.

Ključne besede: *lesna biomasa, plastenjak, steklenjak, toplotne izgube, porabljena količina goriva*

UVOD

Ogrevanje zaprtih prostorov predstavlja visok strošek v procesu gojenja rastlin, zato je izbira ogrevalnega sistema ključnega pomena pri zmanjševanju stroškov proizvodnje. Ogrevanje na lesno biomaso pomeni enega izmed optimalnih sistemov ogrevanja, ki zaradi izrabe domačih lesnih proizvodov pridobiva na pomenu. Pomembno je dejstvo, da pri pravilnem kurjenju z lesom praktično ne onesnažujemo zraka (v zrak spuščamo le CO_2 in H_2O) in da z izkoriščanjem lesnih ostankov vplivamo na boljše vzdrževanje gozdov. Včasih je kurjenje lesa spadalo med časovno potratne postopke, kar ni bilo sprejemljivo za današnji vse hitrejši življenjski ritem. V zadnjih desetletjih je na področju ogrevanja z lesom tehnika naredila velik korak naprej. Vendar pa kljub napredku v tehnologiji, pri ogrevanju prostorov prihaja do toplotnih izgub (Krajnc in Kopše, 2005).

Lesna biomasa je les, uporaben v energetske namene. Ko govorimo o učinkoviti rabi lesne biomase v energetske namene, govorimo o učinkoviti in sodobni rabi vseh oblik lesa za ogrevanje in segrevanje sanitarne vode. Lesna biomasa se uporablja v zelo različnih oblikah od tradicionalnih polen do sekancev in različnih oblik stiskalcev (briketi in peleti). Les uporabljen v energetske namene je okrogel les slabše kakovosti, droben les, vejevina, lesni ostanki, žagovina, lesni prah in neonesnažen odpadni les (Kopše in Krajnc, 2005).

Toplotne izgube, preračunane na enoto bruto prostornine zgradbe, so vsota transmisijskih toplotnih izgub, kjer toplota prehaja zaradi višjih notranjih temperatur skozi zidove, okna, strop na prosto in toplotnih izgub zaradi prezračevanja. Pri slednjem pride do izgube toplote potrebne za ogretje zraka, ki teče skozi stavbo. Transmisijske toplotne izgube lahko določimo razmeroma natančno (pri znanih izolacijskih vrednostih zunanjih zidov, oken, stropov) na osnovi gradbenih načrtov, določevanje prezračevalnih izgub je približno in je seštevek izgub, ki nastanejo zaradi v našem primeru naravnega prezračevanja in izgub zaradi netesnosti oken, vrat in vpliva vetra. Slednje smo v našem izračunu zanemarili ter tako upoštevali samo izgube nastale s prezračevanjem. Skupna potrebna toplota za ogrevanje objekta je tako sestavljena iz transmisijske toplote in ter prezračevalnih izgub, medtem ko smo v izračunu zanemarili ostale dodatne izgube, kot so dodatek zaradi prekinitve ogrevanja, dodatek zaradi izenačitve temperature hladnih površin, dodatek za strani neba itd.

METODE

V raziskavo sta zajeti dve vrtnariji (v nadaljevanju vrtnarija 1 in vrtnarija 2) na katerih uporabljajo za ogrevanje lesne sekance.

Vrtnarija 1 se nahaja v Kamnici pri Mariboru. Imajo 1693 m^2 pokritih površin, kjer v sedmih plastenjakih vzgajajo in pridelujejo okrasne rastline. Njihovi plastenjaki so različnih proizvajalce, v osnovi so vsi sestavljeni iz pocinkane železne konstrukcije, aluminijastih profilov in cevi, polikarbonatnih plošč za čelne stranice rastlinjakov in polietilenske UV folije, s katero je prekrita streha in bočne stranice. V vrtnariji so v začetku leta 2009 pričeli z ogrevanjem na lesne sekance, kar se je že pokazalo kot dobra investicija. Količina skladiščene biomase je 150-200 m^3, predvidena poraba je 10-20 m^3 na mesec. Za ogrevanje uporabljajo smrekov les. V vrtnariji 1 imajo kurilno napravo avstrijskega proizvajalca Fröling, katere glavne karakteristike so podane v preglednici 1.

Vrtnarija 2 se nahaja v Sv. Juriju ob Ščavnici. Danes ima vrtnarija 4200 m^2 površine, od tega približno 1600 m^2 steklenjakov. V vrtnariji se ukvarjajo z vzgojo in pridelavo najrazličnejših vrst okrasnih rastlin, v svoji ponudbi imajo tudi urejanje okolice in grobov. Njihovi steklenjaki so nizozemskega proizvajalca Venlo, sestavljeni iz vroče pocinkane železne konstrukcije, aluminijastih profilov in kaljenega stekla za streho ter navadnega stekla za stene steklenjaka. Na ogrevanjem z lesnimi sekanci so prešli leta 2007, kar se je že pokazalo za dobro investicijo. Za ogrevanje steklenjakov uporabljajo smrekov les. Količina skladiščene biomase je 70 m^3, predvidena poraba je približno 15 m^3 na mesec. Imajo kurilno napravo italijanskega proizvajalca D'Alessandro Termomeccanica, katere glavne karakteristike so podane v preglednici 1.

Preglednica 1 Podatki o kurilni napravi vrtnarije 1 in vrtnarije 2

	Kurilna naprava vrtnarije 1	Kurilna naprava vrtnarije 2
Tip kurilne naprave	Fröling Turbomat	D'alessandro termomeccanica CSA
Leto izdelave	2009	2007
Nazivna moč kotla	220 kW	180 kW
Max. dovoljen tlak	3 bar	3 bar
Toplotna moč goriva	240 kW	218 kW
Max. dovoljena delovna temperatura	95 °C	90 °C
Max. dovoljena temperatura	110 °C	120 °C
Količina vode	570 l	500 l

Enačbe za izračun toplotnih izgub po SIST EN 832

Za izračun toplotnih izgub smo si pomagali s Pravilnikom o toplotni zaščiti in učinkoviti rabi energije v stavbah (UL RS št.42/2002) in enačbami za izračun toplotnih izgub po SIST EN 832.

Izračun koeficienta transmisijskih toplotnih izgub H_T zaradi prehoda toplote skozi ovoj stavbe:

$$H_T=L_D+L_S \text{ [W/K]} \quad (1)$$

kjer je:

L_D [W/K] – neposredne specifične toplotne izgube skozi ovoj stavbe iz ogrevanega prostora v zunanjost,

L_S [W/K] – specifične toplotne izgube skozi tla.

Izračun neposrednih specifičnih toplotnih izgub skozi ovoj objekta:

$$L_D=\sum_i A_i*U_i \text{ [W/K]} \quad (2)$$

kjer je:

A_i [m^2] – površina elementa i, ki je del ovoja stavbe,

U_i [W/m^2K] – toplotna prehodnost elementa i.

V primeru, da je $T1<T2$, je toplotni tok negativen, kar pomeni, da toplota prehaja iz zunanjosti v objekt; torej imamo dobitek in ne primanjkljaj.

Ekvivalentno toplotno prevodnost izračunamo s pomočjo enačbe:

$$U_{eq}=U - G*S \text{ [W/m}^2\text{K]} \quad (3)$$

kjer je:

U_{eq} [W/m^2K] – ekvivalentna toplotna prehodnost zasteklitve in folije, U [W/m^{2}K] – toplotna prehodnost zasteklitve,

G – skupni prehod sončne energije (faktor sončnega sevanja),

S [W/m^{2}K] – koeficient pridobljene sončne energije v odvisnosti od smeri, v katero je obrnjen objekt (Jug: 2,4 W/m^{2}K; Vzhod/Zahod: 1,65 W/m^{2}K; Sever: 0,95 W/m^{2}K).

Celotno transmisivnost sončne energije dobimo z enačbo:

$$g=F_w * g_T \quad (4)$$

kjer je:

g_T – transmisivnost sončne energije za sevanje, ki je pravokotno na zasteklitev,

F_w – korekcijski faktor,

g – celotna transmisivnost sončne energije.

V primeru plastenjakov in steklenjakov za izračun neposrednih specifičnih toplotnih izgub skozi ovoj objekta tako uporabimo prilagojeno enačbo z upoštevanimi toplotnimi dobitki zaradi sončnega sevanja.

$$L_D=\sum_i A_i * U_{ieq} \text{ [W/K]} \quad (6)$$

kjer je:

A_i [m^2] – površina elementa i, ki je del ovoja stavbe,

U_{ieq} [W/m^{2}K] – ekvivalentna toplotna prehodnost elementa i.

Poleg toplotnih izgub skozi stene predstavlja zelo pomembne toplotne izgube transmisija skozi tla. Izračunamo jo s pomočjo enačbe:

$$L_S=A*U \text{ [W/K]} \quad (7)$$

kjer je:

A [m^2] – površina tal,

U [W/m^{2}K] – toplotna prehodnost tal ($U_{beton(10\ cm)}$=2 W/m^{2}K, U_{zemlja}=1,5 W/m^{2}K).

Postopek izračuna koeficienta toplotnih izgub zaradi prezračevanja, HV, je podan v z izrazom:

$$HV= V_Z * \rho_a * c_a \quad (8)$$

kjer je:

V_Z [m^3/h] – stopnja zračnega toka skozi stavbo, upoštevaje zračni tok skozi neogrevane prostore,

$\rho_a * c_a$ [J/m^{3}K] – prostorninska toplotna kapaciteta zraka (ρa* ca = 1200 J/m^{3}K).

Stopnjo zračnega toka VZ, lahko izračunamo s pomočjo predvidene stopnje izmenjave zraka n, ki je v našem primeru 0,1 izmenjave zraka na uro:

$$V_Z = n * V * 24 \quad (9)$$

kjer je:

$V[m^3]$ – prostornina ogrevanega prostora, izračunanega z upoštevanjem notranjih dimenzij,

n $[h^{-1}]$ – predvidena stopnja izmenjave zraka na uro.

24 – časovni faktor.

Koeficient skupnih toplotnih izgub H ogrevanega prostora je vsota koeficienta transmisijskih toplotnih izgub HT in koeficienta toplotnih izgub zaradi prezračevanja HV.

$$H=H_T+H_V \text{ [W/K]} \quad (10)$$

kjer je:

H_T [W/K] – koeficienta transmisijskih toplotnih izgub,

H_V [W/K] – koeficienta toplotnih izgub zaradi prezračevanja.

Toplotni primanjkljaj je vsota razlik zunanje temperature zraka in izbrane temperature v ogrevanem prostoru in ga izračunamo po enačbi:

$$DD=N*T_{i,p} - T_{(e,sezona)} \text{ [K]} \quad (11)$$

kjer je:

N – število dni v ogrevalni sezoni,

$T_{i,\,p}$ – projektna temperatura ogrevanih prostorov v zgradbi,

$T_{e,\,sezona}$ – povprečna temperatura okolice v ogrevalni sezoni.

Za potrebe raziskave smo spremljali zunanje temperature v obdobju dveh mesecev, zato je potrebno enačbo za izračun temperaturnega primanjkljaja nekoliko prilagoditi. Temperaturni primanjkljaj smo izračunali za vsak dan in za vsak plastenjak oz. steklenjak posebej.

$$DD=\sum_i (T_{i,p} - T_{e,o}) \text{ [K]} \quad (12)$$

kjer je:

$T_{e,o}$ – povprečna dnevna temperatura okolice,

i – dnevi meritev.

Celotne toplotne izgube objekta so tako odvisne od koeficienta skupnih toplotnih izgub objekta in temperaturnega primanjkljaja in jih izračunamo s pomočjo enačbe:

$$Q_l=H*DD \text{ [kWh]} \quad (13)$$

kjer je:

H [W/K] – koeficient skupnih toplotnih izgub objekta,

DD [K] – temperaturni primanjkljaj.

Toplotne izgube vseh plastenjakov oz. steklenjakov vrtnarije so vsota toplotnih izgub posameznih plastenjakov oz. steklenjakov. Izračunamo jih z enačbo:

$$Q=\sum Q_I \text{ [kWh]} \tag{14}$$

kjer je:

Q_I [kWh] – celotne toplotne izgube objekta.

Izračun porabe goriva za ogrevanje izračunamo s pomočjo enačbe:

$$m_g=Q*(3,6*\tau)/(H_i*\eta) \text{ [kg]} \tag{15}$$

kjer je:

3,6 – pretvorni faktor,

τ [h/dan] – število ur kurjenja v dnevu (običajno 24 h/dan),

H_i [kJ/kg] – spodnja kurilnost goriva,

η – izkoristek kurilne naprave.

Celotne toplotne izgube na enoto prostornine posameznih rastlinjakov izračunamo s pomočjo enačbe:

$$EK=Q_I/V \text{ [kW/m}^3\text{]} \tag{16}$$

kjer je:

Q_I [kWh] – celotne toplotne izgube objekta,

V [m^3] – prostornina rastlinjaka.

Porabo goriva na enoto prostornine izračunamo s pomočjo enačbe:

$$M_g=m_g/V \text{ [kg/m}^3\text{]} \tag{17}$$

kjer je:

m_g [kg] – porabljeno gorivo za ogrevanje,

V [m^3] - prostornina rastlinjaka.

REZULTATI Z RAZPRAVO

Izračun toplotnih izgub posameznih plastenjakov vrtnarije 1

Zaradi velike količine podatkov smo predstavili rezultate vrtnarije 1 ter primerjavo energetske učinkovitosti obeh tipov rastlinjakov. V preglednici 2 je prikazan izračun toplotnih izgub vrtnarije 1.

Preglednica 2 Toplotne izgube plastenjakov vrtnarije 1

Vrsta rastlinjaka	L_D [W/K]	L_S [W/K]	H_T [W/K]	H_V [W/K]	H [W/K]	$\sum A$ [m^2]
Plastenjak 1	/	/	/	/	/	
Plastenjak 2	2881,02	315,00	3196,02	29,77	3225,79	
Plastenjak 3	2524,09	283.50	2807,59	25,20	2832,79	
Plastenjak 4	2524,09	283.50	2807,59	25,20	2832,79	
Plastenjak 5	/	/	/	/	/	
Plastenjak 6	/	/	/	/	/	
Plastenjak 7	1248,64	150,00	1398,64	14,17	1412,81	
Plastenjak 1-7						688

Kot je razvidno iz preglednice 2 je bil največji skupni koeficient toplotni izgub na vrtnariji 1 v plastenjaku 2, saj ima ta med vsemi ogrevanimi plastenjaki največjo površino, in je znašal 3225,79 W/K. Skupna ogrevana površina plastenjakov je znašala 688 m^2.

Izračun celotnih toplotnih izgub vrtnarije 1

V preglednici 3 so prikazane celotne toplotne izgube vrtnarije 1 v mesecih november in december 2009.

Preglednica 3 Celotne toplotne izgube vrtnarije 1

Vrsta rastlinjaka	Q_I [kW]
Plastenjak 2	364,84
Plastenjak 3	1237,36
Plastenjak 4	891,76
Plastenjak 7	703,30
$Q = \sum Q_I$	3197,26

Celotne toplotne izgube na vrtnariji 1 so znašale 3197,26 kW. Kot je razvidno iz preglednice 3 so bile največje toplotne izgube v plastenjaku 3, kjer je bil poleg velike površine tudi veliki temperaturni primanjkljaj.

Izračun porabe goriva za ogrevanje

Iz izračunanih celotnih toplotnih izgub smo izračunali porabljeno količino goriva za ogrevanje, v našem primeru lesnih sekancev. Izkoristek peči za ogrevanje je po podatkih proizvajalca najmanj 90 %. Spodnja kurilnost lesnih sekancev je po podatkih iz literature med 14700 in 16700 kJ/kg (Medved, 1997; Senegačnik, 2005). Pri izračunu porabljene količine goriva smo uporabili vrednost 16000 kJ/kg. Na podlagi gostote lesnih sekancev, ki zanaša 700 kg/m^3 (Kopše in Krajnc, 2005), smo izračunali volumen (m^3) porabljene biomase. V preglednici 4 so prikazani izračuni porabe goriva v vrtnariji 1.

Preglednica 4 Poraba lesne biomase v vrtnariji 1

Poraba lesnih sekancev [kg]	Poraba lesnih sekancev [m^3]
19.183,56	27,40

Izračun celotnih toplotnih izgub na enoto prostornine v plastenjakih vrtnarije 1

V preglednici 5 so prikazani izračuni celotnih toplotnih izgub na enoto prostornine v plastenjakih vrtnarije 1 za obdobje dveh mesecev.

Preglednica 5 Celotne toplotne izgube na enoto prostornine posameznih plastenjakov vrtnarije 1

Vrsta rastlinjaka	Prostornina [m^3]	Celotne toplotne izgube [kW]	Celotne toplotne izgube na enoto prostornine [kW/m^3]
Plastenjak 2	893	364,84	0,41
Plastenjak 3	756	1237,36	1,64
Plastenjak 4	756	891,76	1,18
Plastenjak 7	425	703,30	1,65

Iz preglednice 5 je razvidno, da so bile največje toplotne izgube na enoto prostornine v plastenjakih 3 in 7, ker je bil tam največji temperaturni primanjkljaj. Najnižje toplotne izgube na enoto prostornine so bile v plastenjaku 2.

Izračun porabe goriva na enoto prostornine v vrtnariji 1

Iz preglednice 6 je razvidno, da je bila izračunana poraba goriva na enoto prostornine, ki je znašala 6,78 kg/m^3, manjša od dejansko porabljene, ki je znašala 7,17 kg/m^3. Dejanska poraba goriva v času meritev je znašala 29 m^3.

Preglednica 6 Poraba goriva na enoto prostornine

Vrste rastlinjaka	Skupna prostornina [m^3]	Izračunana poraba goriva [kg]	Dejanska poraba goriva [kg]	Izračunana poraba goriva/enoto prostornine [kg/m^3]	Dejanska poraba goriva/enoto prostornine [kg/m^3]
Plastenjak	2830,00	19.183,56	20.300,00	6,78	7,17

Primerjava energetske učinkovitosti obeh tipov rastlinjakov

V preglednicah 7 in 8 je prikazana primerjava najpomembnejših izračunanih in dejanskih parametrov, ki smo jih izračunali s pomočjo enačb predstavljenih enačb.

Preglednica 7 Primerjava celotnih toplotnih izgub na enoto prostornine v obeh vrtnarijah

Vrste rastlinjaka	V [m3]	Q [kW]	EK [kW/m3]
Vrtnarija 1	2830	3.197,26	1,12
Vrtnarija 2	6555	8.045,60	1,22

Iz preglednice 7 je razvidno, da so toplotne izgube na enoto prostornine večje na vrtnariji 2, torej v steklenjakih. Pričakovali smo da bodo večje toplotne izgube v plastenjakih, zaradi večje toplotne prehodnosti materialov iz katerih so izdelani, vendar so te večje v steklenjakih predvsem zaradi nižje povprečne zunanje temperature v novembru in decembru.

Preglednica 8 Primerjava porabljene lesne biomase v kilogramih in kubičnih metrih v obeh vrtnarijah

Vrste rastlinjaka	m_g [kg]	m_p [kg]	M_g [kg/m^3]	M_p [kg/m^3]	Izračunana poraba goriva [m^3]	Dejanska poraba goriva [m^3]
Vrtnarija 1	19.183,56	20.300,00	6,78	7,17	27,40	29,00
Vrtnarija 2	48.273,58	49.700,00	7,36	7,58	68,97	71,00

Iz preglednice 8 je razvidno, da je izračunana poraba goriva tako v kilogramih kot v kubičnih metrih manjša od dejanske porabe, kar je bilo pričakovano, saj smo pri toplotnih izgubah nekatere parametre kot so dodatki za prekinitev ogrevanja, izenačitev temperature hladnih površin in strani neba ter izgube, ki nastajajo zaradi netesnosti oken in vrat ter vpliv vetra zanemarili.

SKLEPI

Cilj raziskave je bil ugotoviti energetsko učinkovitost obeh tipov rastlinjakov. Na osnovi meritev, ocen in izračunov smo prišli do nekaterih zanimivih zaključkov.

Celotne toplotne izgube na enoto prostornine so bile večje v vrtnariji 2, torej v steklenjakih. Glede na to, da so toplotne izgube odvisne predvsem od koeficientov prehoda toplote in temperaturnega primanjkljaja smo pričakovali, da bodo večje toplotne izgube pri plastenjakih. Vendar so nižje zunanje temperature (predvsem v decembru) in višje zahtevane projektne temperature v steklenjakih (torej večji temperaturni primanjkljaj) ključno vplivale na višje toplotne izgube v steklenjakih. Posledično je tudi poraba goriva večja v steklenjakih, saj je ta odvisna tudi od celotnih toplotnih izgub.

Izračunana poraba goriva je po pričakovanjih v obeh tipih rastlinjakov manjša od dejanske porabe. Vzrok so dodatne izgube toplote, ki se pojavijo nepričakovano (npr. zaradi čezmernega odpiranja vrat) in jih v naših izračunih nismo upoštevali.

Ob upoštevanju vseh parametrov lahko zaključimo, da so energetsko učinkovitejši steklenjaki, vendar se ljudje še vedno večinoma odločajo za postavitve plastenjakov, saj so ti predvsem cenovno ugodnejši.

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ENERGY EFFICIENCY OF TWO TYPES OF GREENHOUSES HEATED BY WOOD BIOMASS

SUMMARY

Wood biomass is becoming an important source of energy in the intensive agricultural production in greenhouses. The aim of the research was to discuss the heat losses occurring in plastic greenhouses comparing to glasshou ses. Furthermore, we calculated the required amount of fuel and compare the results with the actual biomass consumption during two months period (November and December). Using temperature measurements and heat loss calculations we can conclude that there was no difference between two types of greenhouse since in gardening 1 heat loss per unit of volume was 1.12 kW/m^3 comparing to gardening 2 where heat loss per unit of volume reached 1.22 kW/m^3. Calculated fuel consumption per unit of volume was 6.78 kg/m^3 in gardening 1 and 7.36 kg/m^3 in gardening 2, which is also comparable to actual biomass consumption (7.17 kg/m^3 in gardening 1 and 7.58 kg/m^3 in gardening 2). Considering higher degree days in the gardening 2 and other parameters we can conclude that glasshouses in gardening 2 are more energy efficient.

Key words: *wood biomass, plastic greenhouse, glasshouse, heat loss, fuel consumption*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.95:633.584.3
Stručni rad
Expert paper

ANALYZE OF OPPORTUNITIES FOR WILLOW'S CULTURE AS BIOMASS RESSOURCES IN BANAT REGION

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SUMMARY

This paper presents one analyze of opportunities for short rotation coppice (SRC) culture in Banat region, in order to ensure a coherent approach between energy and environment policies and to avoid the additional costs to business and the environmental incoherence that would be associated with an inconsistent approach. For these reasons, it was necessary to provide sustainability criteria ensuring that energy, biofuels and bioliquids can qualify for the incentives only when it can be guaranteed that they do not originate in biodiverse areas or, in the case of areas designated for nature protection purposes or for the protection of rare, threatened or endangered ecosystems or species, the relevant competent authority demonstrates that the production of the raw material does not interfere with those purposes. There were considered agricultural criteria, economical criteria, social criteria, soil and clime conditions. A lot of species were considered, the most important criteria for analyze was the risk of production. The results of researches was used in decision for develop an important SRC culture in optimum area.

Those criteria also have an important part to play in promoting the security of energy supply, promoting technological development and innovation and providing opportunities for employment and regional development, especially in rural and isolated areas. Also, production of energy from renewable sources often depends on local or regional small and medium-sized enterprises (SMEs).

The final conclusion was that willow is the opportune culture for Banat region and creates conditions for cross-border cooperation programs.

***Key words**: Short rotation coppice (SRC), optimization, biomass, willow "salix viminalis", agriculture, opportunities*

INTRODUCTION

Energy demand is complex and supposes a lot of conditions, risks, costs, disparities, constraints etc. Nowadays energy demand increase and imposes special solutions to avoid environmental influences and insures low general costs (economic, social etc.).

For European Union, according to Directive 2009/28/EC of the European Parliament and of the Council of April 23th, 2009, the strategy will be considered more criteria focused on the control of European energy consumption and the increase of the use of energy from renewable sources (the target of 20% share of renewable energy by 2020), together with energy savings and increasing of energy efficiency, as important parts of the complex package of measures needed to reduce GHG emissions. In the same time same the ensuring of the energetic security, promoting technological development and innovation and providing opportunities for employment and regional development (especially in rural and isolated areas) is also most important (Directive EU, 2009). According to the same document it is necessary that increasing demand for biofuels and bioliquids do not have the effect of encouraging the destruction of biodiverse lands. For these reasons will be promote that agricultural cultures which not originate in biodiverse areas or, in the cases of environmental protected areas, the promoters must demonstrate that the production of such raw material does not interfere with those purposes (Directive EU, 2009).

Based on such considerations and others technical and optimal, the paper analyzes the opportunity for Salix cultivation in Romania, Banat region, by identifying the optimum areas.

The decision has considered all criteria (technical, economical, social, environmental etc.), by developing a specifically analysis.

METHODS

Opportunities and conditions

The principal opportunities for SRC in Europe are:

- arable land in European Countries (EC) is 101 million Ha
- all EC Countries have to fulfill the same directives (both general and specific national) like: “Biomass Action Plan”,”Green Growth” (this plan establish only for Denmark 50000 – 100000 ha with perennial crops in 2020) etc.
- the biomass production is therefore needed
- the farmers need new solutions for efficiency in condition of European Accords in Agriculture
- the farmers could be part of “the solution”, not part of “the problem”

As European country Romania needs to consider these aspects and develops a national plan in this area. Also, in specific regions as the west of the country, such systems must be integrated at regional cross-border level, according with the similarly agricultural potential.

Actually, if we refer only at Salix, more than 50 000 ha are cultivated in Sweden, Hungary already proposed by its national energetic plan to create more 36 000 ha plantation till 2013 using only uncultivated land (Hollerbach et all, 2009).

Plant species analysis

The first decision was establishing of most adequate species for Banat region, in conditions of optimize upon the aggregated criteria.

There were considered for analyze next species: Salix Viminalis Energo, Robinia Pseudoacacia, Paulownia Tomentosa, Rubus sp. and Hamamelis Virgiliana. Less interests were considered also Ailanthus Altissima, Elaeagnus Angustifolia, Juglans Nigra, Lycium Barbarum, Prunus Spinosa (porumbarul), Acer Platanoides, Ononis Spinosa and Gleditsia Triacanthos.

After a SWOT analyze and economicity was decided the option for biomass specie which will be cultivated..

Location analyzing and description

The most important influence for willow culture is the soil both in productivity and life time of the culture in production (Tahvanainen L., 1999).

First step was the analyzing of soil map, by using of data base compilation as part of Soil profile Database (PROFISOL- Romanian Soil Data Base System) for typical soil survey activities which have carried out soil in three fields: general soil resource inventory, agricultural land and forest land (Florea N., 1999, Munteanu D., 2007).

Depending on soil, climate and specifically conditions, chemical compounds etc. (expressed by groundwater and surface water gleying, salinity/sodicity, topsoil texture, soil pollution, slope, landslides, groundwater depth, liability to inundation, total porosity, CaCO3, soil reaction, physiologically useful volume, humus reserve, excess of moisture etc.) together with economical criteria (land concession price, grouping of areas for insuring minimum 150 ha, price of local workforce etc.) and accessibility criteria was located the optimum area.

Optimization of cultivating technology and future use

For establishing the cultivating technology firstly must consider that biomass production depends on several factors, the most important of which are: site conditions, and presence of pollutants (Heller M.C., 2004, Mleczeka M., 2010, Noronha-Sannervik A., 2003, Souch C.A., 2003, Volk T.A., 2004). Even the significance of biomass is the most important thing and the demand for Salix materials as an energy source is increasing, the use of such biomass has some limitations connected with the way of exploiting it (Helby P., 2006, Hoffmann D. 2005, Mleczeka M., 2010, Tharakan P.J., 2003).

An important advantage was found at some willow species which are efficient in absorbing: heavy metal ions, organic compounds (PAH, PCB, TPH) and even selected explosives (Mleczeka M., 2010, Volk T.A., 2006).

There was determined at different Salix clones wide differences in metal accumulation dependent on structure as well as amounts of metals available in the soil (Mleczeka M., 2010).

Also, environmental studies show that phytoremediation by selected Salix clones can be a useful tool in technical replenishment methods in soil remediation (Dos Santos Utmazian M.N., 2007).

Based on analyze conditions and economical criteria was established cultivating technology and agricultural machineries which are necessary.

Important part was allowed to use of fertilization as important part for cultures start-up.

Also, for future use, an important application of willows is in sewage sludge treatment (Labrecque M., 1997, Kocika Agnieszka, 2007).

Final step was the economical analyzing by the help of the business plan realized considering all conditions and criteria presented. For the most interesting culture there was elaborated an economic model for costs calculation per hectare, for the first seven years of the culture.

Also in different scenarios were considered threads and weaknesses and principal problems against extending the plantation.

RESULTS AND DISCUSSION

SWOT analysis

It is presented an example of SOWT analysis for willow. Particularly for Banat region could be presented some opportunities as follows (Hollerbach et all, 2009):

- Willow can grow (recommended) on permanent wetlands or periodical, evapotranspiration has a capacity of 15-20 l water/day; this advantage gives an undisputed place as the plant used to make thousands of hectares of land;
- The annual reception capacity of 20-30 tons / ha of sludge from the waste water treatment;
- Cultivation of willow creates new jobs for unskilled people and for unused machines, because harvesting is done during the break crop after the fall leaves (used as fertilizer), in the months from November to March, a period when agricultural machinery is not used for anything else;
- Willow can be a reliable alternative energy sources (heating) for localities, being used as biomass (hash) briquettes or pellets; the pelleting equipment units - briquetting of different capacity transform minced willow in briquettes or pellets, and these products are used for heating localities (at least the schools, clinics, kindergartens etc.);
- Willow Salix Viminalis Energo - is highly resistant to different weather conditions;
- Results after 3 years of experience in Hungary (neighbored country in cross-border area), show that willow performed extremely well on sandy soil and heat much higher, resulting in a higher yield by 45% (in Hungary cca.60t/ha front of 40-45 t / ha in Sweden).

In the same time, the expanding the plantation encounter next problems:

a) Lack of information about the existence and benefits of these varieties

b) Lack of regulation in achieving plantations.

The lack of regulation in achieving plantations includes special steps for Romania:

- clarification to areas include - plant species of agricultural or forest (because energy willow is planted with a duration of spring - fall so in a crop year were cases in which falling in the category of agricultural plants and modest annual grants-in, like agricultural production; in recent years the EU has decided that to be subsidized energy plants separately, and was left to each member country in part to determine how employment);
- which is subject to the regulation of agricultural plants or the forest (in all countries where energy willow plantations have a significant scale - are classified in category "special" timber species, forest regulations in so far as plantation, but special collection on them (do not require permits for harvesting))?
- determining how the grant operates economical (the grant was initially set at 200 EUR/ha - (in Sweden and Hungary) in each year after harvest; it means that a plantation is 25-30 years of life, but in the first year of life production is negligible, about 10t/ha (in this period grows roots) and in subsequent years is the annual production of 40-45 t/ha (after the Swedish records and 50-60 t/ha in Hungary); this crop provides a considerable income growers (cca.1.400 EUR/ha) and no annual subsidy, but to date further development has been slow due to large costs of plantation (about 2000 EUR/ha); in 2006 - most states went to subsidies by 50% the cost of plantation, giving the annual subsidy; following this measure, in Hungary in autumn 2006 - requests for cuttings and registration of land for plantation increased by over 50% and in Sweden is considered the most viable solution for achieving the EU requirements, as each member country to cover 12% of unconventional sources of energy consumption);
- terms for the grant, if grant conditions are clearly, and apply a standard method
- coverage of various national programs of the cultivation, and processing biomass (currently, Romania has bought both companies licensed in Sweden and in Hungary, there are steps initiated for approval of nurseries, but without some national programs competing to expand their plantations throughout the country and no national programs to spur the development of regional investment from use of biomass plantations (briquetting plant, pelleting) can not extend Salix crops).

Plant options

More than 200 variants (species) of willow from Sweden were selected firstly, final option was for varieties that has a very large increase (3-3.5 cm / day) a high content of salicylic acid which gives the properties a number of very favorable - high calorific value (greater than beech or oak), resistance to weathering, resistance to degradation during storage in the form of mince (raw material for pelleting for briquetting).

Strain, may be knots, bark with cracks, reaching a height more than 3-4 meters, but some of elected species can reach up to 10-15 meters.

Location analyzing and description

The above lead us to conclude that in Romania there are all the right conditions to grow them (the whites of rivers, floodplains unused).

By extending the energy willow plantations, besides being a source of renewable energy put into use unused land, it avoids (or reduces considerably) destroying of the forest generated by the increasing demand for cheaper fuel.

In figure 1 is presented the soil repartition in Romania based on reliability classes (Cernescu N., 1989), one of the bases in area establishing.

Final decision was for adopted for 150 ha polder area in Ghilad, near Timis river, position marked by black circle in figure 1.

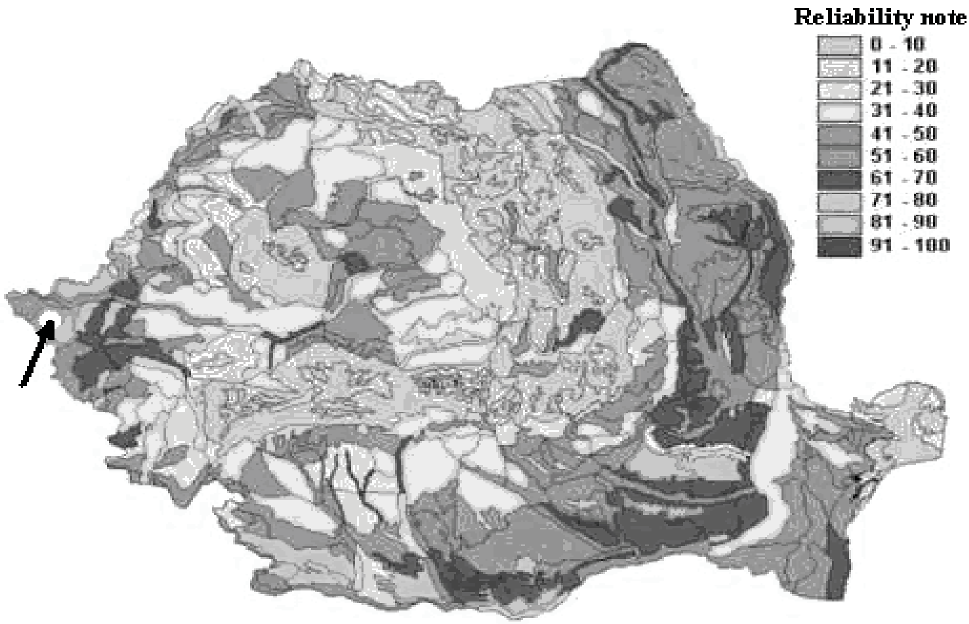

Figure 1 The soil repartition in Romania based on reliability classes (Cernescu N., 1989)

Analysis of economical needs

Based on agro technical activities, in table no. 1 are presented principal costs per hectare, per each activity and year of culture. “Year0” was the year before founding of the culture, because such areas were usually not cultivated before and needs special tillage.

All costs were calculated based on condition of minimum grouped 40 ha land surface, in conditions of local workforce prices in Ghilad, and fuel prices in 2009 year, in conditions of external use of mechanization equipment, considering also, subvention given from agricultural activities in Romania.

Table 1 Estimated costs for 1 ha willow culture for firstly six years

No.	Agrotechnics works	Costs [EUR/ha]	Year0 [EUR]	Year1 [EUR]	Year2 [EUR]	Year3 [EUR]	Year4 [EUR]	Year5 [EUR]	Year6 [EUR]
				I. Soil preparation					
1.	Tilling	76,00	76,00						
2.	Herbicide	50,00	50,00						
3.	Cultivation	20,00	20,00						
4.	Herbicide	50,00	50,00						
5.	Cultivation	20,00	20,00						
				II. Plantation					
6.	Cutting pl.	1200,00		1200,00					
7.	Plantation	120,00		120,00					
				III. Maintenance					
8.	Herbicide	50,00		50,00					
9.	Cultivation	180,00		30,00	30,00	30,00	30,00	30,00	30,00
10.	Fertilization	225,00		135,00	45,00	45,00			
11.	Harvesting	400,00			80,00	80,00	80,00	80,00	80,00
12.	Transport	100,00			20,00	20,00	20,00	20,00	20,00
	TOTAL	2491,00	216,00	1535,00	175,00	175,00	130,00	130,00	130,00

The costs could be seriously improved if there is considered the possibility of investme-nts by the help of European grants.

CONCLUSIONS

As result from international practice, and analysis of local conditions, for Banat region, Salix Viminalis Energo is the most suitable species of economically, the other SRC being the additional species that should be planted in areas that are restricted (and stuffing).

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 620.9
Stručni rad
Expert paper

INTEGRATION OF RENEWABLE SOURCES OF ENERGY IN AN INDEPENDENT FARM

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ABSTRACT

This paper presents the concept of integrating renewable sources of energy into the grid. Firstly the principles of power injection into the grids are detailed. Then, the integration of multiple sources into a microgrid is covered and three types of electrical buses for integration or renewable energy sources are reviewed (DC, AC, HFAC). Based on these is given a solution for the supply of an independent cow farm with multiple renewable energy sources and different consumers. The solution is based on practical determination of electrical consume after statistical proceeding.

Such a solution offers the advantage of losses, investment costs and the use optimization and should improve the power quality, boost the energy system reliability and reduce energy costs.

If the integration of multiple renewable energy sources is considered there are three possible solutions that should be taken in consideration: DC link, AC link and HFAC link. Each of them has advantages and disadvantages and should be chosen depending on the local situation, still the most common used are DC and AC integration methods.

***Key words**: renewable energy sources integration, distributed generation, microgrid, independent farm, AC, DC, HFAC*

INTRODUCTION

Presently a challenge in the integration of renewable energy sources (RES) appears because their output is variable and the energy consumption is differs, so it must be stored for later use – when there is demand.

One solution could be the integration of renewable and fossil fuel-based energy sources into networks for distributed generation (DG) or even energy systems that consist only of renewable energy sources. These solutions require on-site, small scale technologies located in the vicinity of the loads to be served.

If only one energy source is taken in consideration, it can be connected to a storage system to deliver energy on demand or interconnected with the grid. But if there are multiple RES in use, the electric power system is more complex and a **microgrid** is formed. The microgrid is defined as a cluster of loads and DG units that operate in order to improve the quality and reliability of the power system in a controlled manner (Farret F.A., et. al., 2006).

There are many small islanded sites that could benefit from such energy systems (residential areas, industrial sites, agro-sites, farms etc.). Each of them has different demands and must be analyzed individually to determine the optimum solution in every different case. When capacities are small, RES can be more valuable than conventional sources (Grubb M.J., 1991).

METHODS

There are two classes of electrical systems that need to be taken into consideration when applying electrical energy conversion technology to renewable energy systems: **stationary** and **rotatory**. Fuel cells and photovoltaic arrays are the main RES in the stationary group. These produce usually direct current (DC).
In the other group – rotatory, that provides alternating current (AC) – there can be found hydropower wind and gas turbine energy sources.

Converting technologies

In Table 1 are presented some examples of energy conversion processes or devices currently in use organized according to the output energy form after the conversion (***, 2009).

There are also many devices that perform a number of energy conversion steps. For example, a power plant performs a chain conversion process between different energy forms: solar → chemical → heat → mechanical → electrical.

Table 1 Examples of energy conversion processes (***, 2009)

Initial energy form	Converted energy form				
	Chemical	**Radiant**	**Electrical**	**Mechanical**	**Heat**
Nuclear					Reactor
Chemical			Fuel cell		Burner, boiler
Radiant	Photolysis		Photovoltaic cell		Absorber
Electrical	Electrolysis	Lamp, laser		Electric motor	Heat pump
Mechanical			Electric generator	Turbines	Friction
Heat			Thermionic generators	Thermodynamic engines	Convector radiator

There are different technologies that are used to incorporate renewable energy power into the grid. The main technologies are illustrated in Figure 1. In the case of fuel cell and photovoltaic systems, a DC link bus could be used to aggregate them. Otherwise, if wind or hydro power is used, a variable-frequency AC voltage control must be aggregated into an AC link through an AC-AC conversion system. Other energy sources such as gas or diesel can also be integrated with RES. In the case of biogas microturbines the solution that is commonly used is the implementation with a power electronic inverter-based technology.

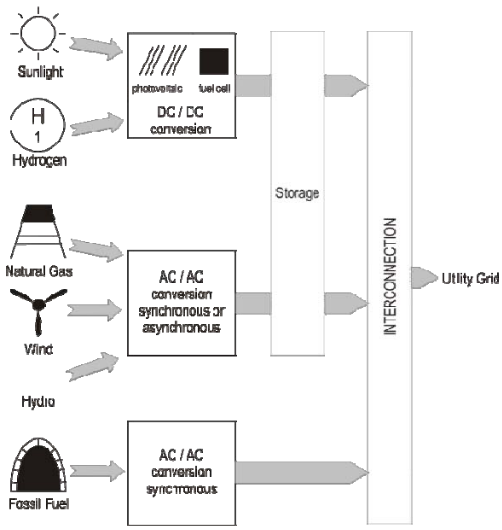

Fig. 1 Alternative energy conversion technologies for injection of alternative energy power to the grid

Storage systems

The future of intermittent energy sources, as RES are, depends on the flexibility of the systems. Increasing this flexibility is done by introducing storage and relocation options (Skoglund A., 2010). Storage systems need to be included in the design of microgrids. These systems have to incorporate energy storage with continuous control and integration of source, storage, and allow the system to interconnect with other systems. Storage systems will have a significant impact in the small scale integration or RES into small sites (Nair C N-K, et. al., 2009).

The storage system can be stationary or rotatory. Magnetic coils, supercapacitators and batteries are stationary and generators, flywheels and pumping hydro are rotator storage systems.

The static systems consist of a DC input converted to a DC or AC output and unidirectional power flow. The rotating systems consist of an AC input converted to a DC or AC output and bidirectional power flow. Storage systems are bidirectional systems with requirements of AC and DC conversion. The power generated by wind power generators, photovoltaic generators and fuel cells cannot be connected straight to the grid, so there is a need for systems that can transform and store the energy produced by these sources.

Integration of multiple RES

The integration of multiple RES implies the use distributed generation systems, consisting in small generators. The generation systems are spread throughout the system to provide electrical and sometimes as cogeneration heat energy to consumers. When these modular generation technologies are interconnected with distribution systems, they form a new type of power systems – the microgrid.

DC-Link integration. The first type of electrical energy integration was by using a DC link as illustrated in Figure 2. The most common example consists of a connection between a DC source and a battery and load scheme. The most representative examples are the first cars that used this type of integration.

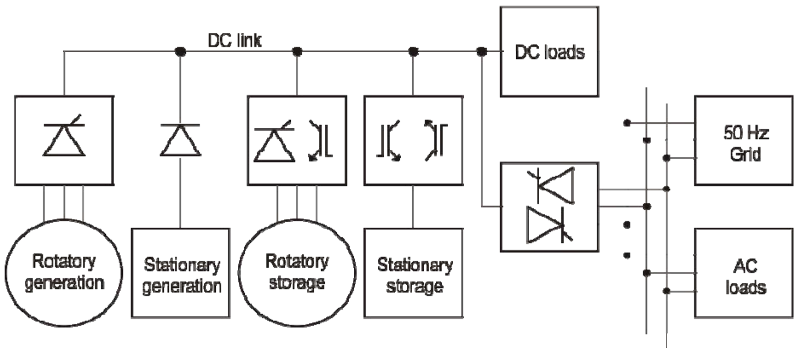

Fig. 2 DC-Link integration of RES (Farret F.A., et. al., 2006)

Table 2 Advantages and disadvantages of DC-Link integration of RES (Farret F.A., et. al., 2006)

	Advantages	**Disadvantages**
1	Synchronism is not required.	The need for careful compatibility of voltage levels to avoid current recirculation between the input sources.
2	There are lower distribution and transmission losses than with AC link.	The need for robust forced commutation capabilities in circuits at high power levels.
3	It has high reliability because of the parallel sources.	Corrosion concerns with the electrodes.
4	Although the terminal needs of a DC link are more complex, the DC transmission infrastructure per kilometer is simpler and cheaper than in AC links.	A large number of components and controls.
5	Long distance transmission is possible	More complex galvanic isolation.
6	The converters required are easily available.	Higher costs of terminal equipment.
7	Single wired connections allow balanced terminal AC systems	Difficulties with multiterminal or multi-voltage-level operation for transmission and distribution.

AC-Link integration. The second type of electrical energy integration is the AC-link bus operating at 50 Hz, as displayed in Figure 3. This bus can be the public grid or a local grid for islanded operation. The stationary generation needs a DC-AC inverter.

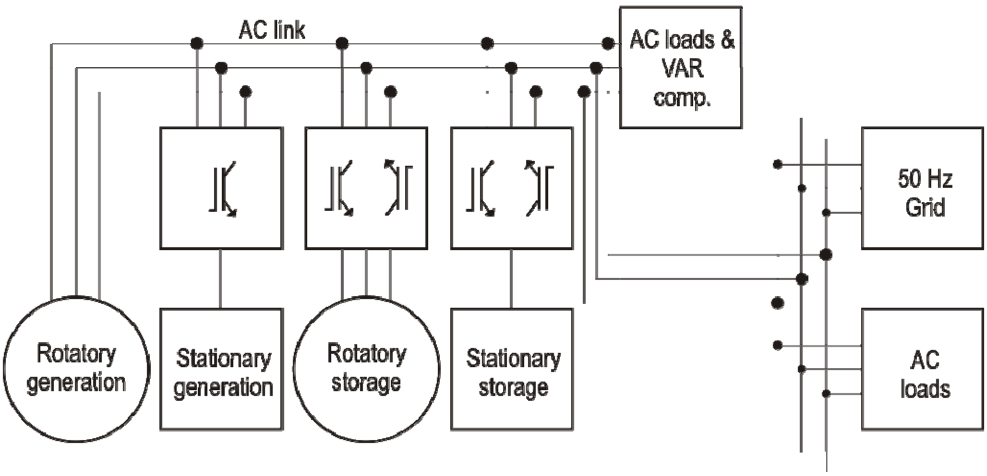

Fig. 3 AC-Link integration of RES (Farret F.A., et. al., 2006)

Table 3 Advantages and disadvantages of AC-Link integration of RES (Farret F.A., et. al., 2006)

	Advantages	**Disadvantages**
1	Utility regulation and maintenance of the operational voltage.	The need for rigorous synchronism during interconnection as well as during operation.
2	The possibility, in some cases, of eliminating the electronic converters.	Leakage inductances and capacitances.
3	Easy multivoltage and multiterminal matching.	Electromagnetic compatibility concerns.
4	Easy galvanic isolation.	The possibility of current recirculation between sources.
5	Well established scale economy for consumers and existing utilities.	The need for power factor and harmonic distortion correction.
6		Low limits for transmission and distribution.

HFAC-Link integration. The HFAC link is displayed in Figure 4. This system is a power electronics solution that is promising as an interface for the utility grid and stand alone operation. It has fault protection, is of small dimensions and has a configuration to serve a large variety of power quality functions.

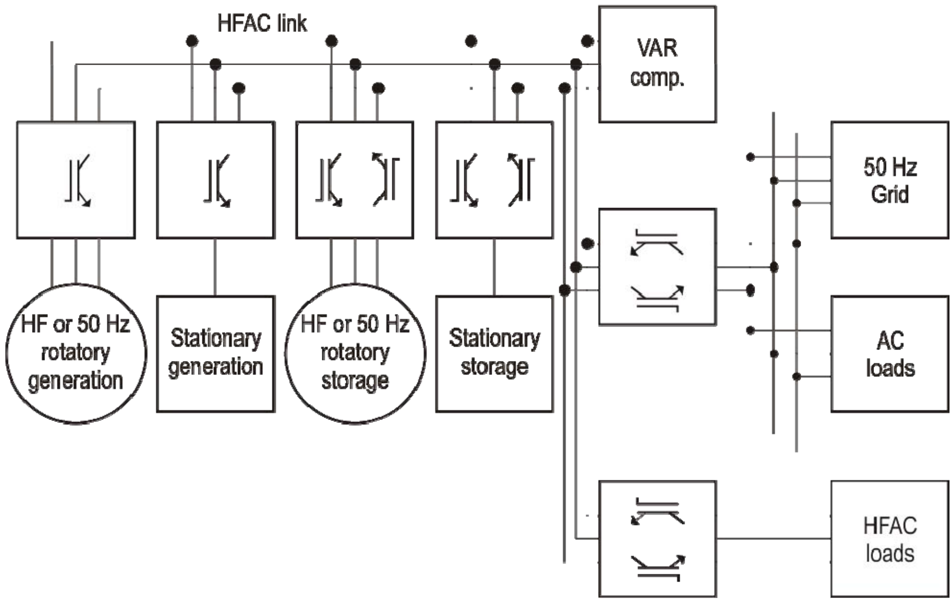

Fig. 4 HFAC-Link integration of RES (Farret F.A., et. al., 2006)

Table 4 Advantages and disadvantages of HFAC-Link integration of RES (Farret F.A., et. al., 2006)

	Advantages	Disadvantages
1	The harmonics are of higher orders and are easily filtered out.	High costs of transformers.
2	Fluorescent lighting will experience improvement because, with higher frequency, the luminous efficiency is improved.	The large number of devices.
3	High-frequency induction motors can be used for compressors, high-pressure pumps, high speed applications and turbines.	Very complex control.
4	Harmonic ripple current in electric machines will decrease, improving efficiency.	The dependence on future advances of power electronic components.
5	High frequency power transformers, harmonic filters for batteries, and other passive circuits become smaller.	Concerns about electromagnetic compatibility.
6	Auxiliary power supply units are easily available by tapping the AC link. They would be smaller with higher efficiencies.	Extremely reduced limits and technological problems for transmission and distribution at high frequencies.
7	Dynamic storage is an alternative to batteries	

RESULTS AND DISCUSSION

The previous analysis had the purpose to identify the optimum solution for supplying a small cow farm specialized in milk production with electrical energy in an integrated manner. Based on the methods described above the DC-Link integration method was chosen.

The characteristics of the farm are the following:

- the capacity of the farm is 25 cows, all living in the same stable;
- the average annual milk production is 3500 milk per foddered cow;
- the feeding is done at the stable (with green mass being brought there);
- the water supply for drinking is mechanized;
- the milking and dejection evacuation is also done mechanized;

In order to accurately dimension the elements of the energy system, the first step was to identify the main consumers and then to measure and determine the energy consumption for each device. The devices that use electrical energy are the following: *1 milking machine, 1 scraper machine* for waste disposal, *1 foddering machine* for preparing the needed food, *1 hydrophore* for the water supply and *12 light bulbs*. The statistical results are presented in Table 5.

Table 5 The energy consumptions for the devices supplied with electrical energy

Consumer	Units	Device/Hour (KWh)	Hours/day	Days	Total/device (KWh)
Milking device	1	2,2	2	365	1606
Scraping device	1	9	¼	365	821,25
Foddering device	1	20	1	365	7300
Hydrophore	1	10	1	365	3650
Light bulbs	12	0,11	5	365	589,6
				Total/year (KWh)	13966,5

Based on these results and on the description of the DC-Link integration model form the previous chapter, the solution in Figure 5 was proposed. The system consists of the following components:

- sources: 6-10 photovoltaic panels; 1 wind micro-turbine 1 biogas generator (fueled with the biowaste from the farm and from surroundings)
- a DC bus and DC consumers
- an AC bus, inverter and AC consumers;
- one controller in order to monitor and control the system.

The nominal powers of the sources are not mentioned, as they depend on the manufacturers and on the economic resources of the farm owner. Choosing the right power to the specific conditions at the site is very important for the optimization of the energy outcome and economic income (Blarke M.B., et. al., 2008).

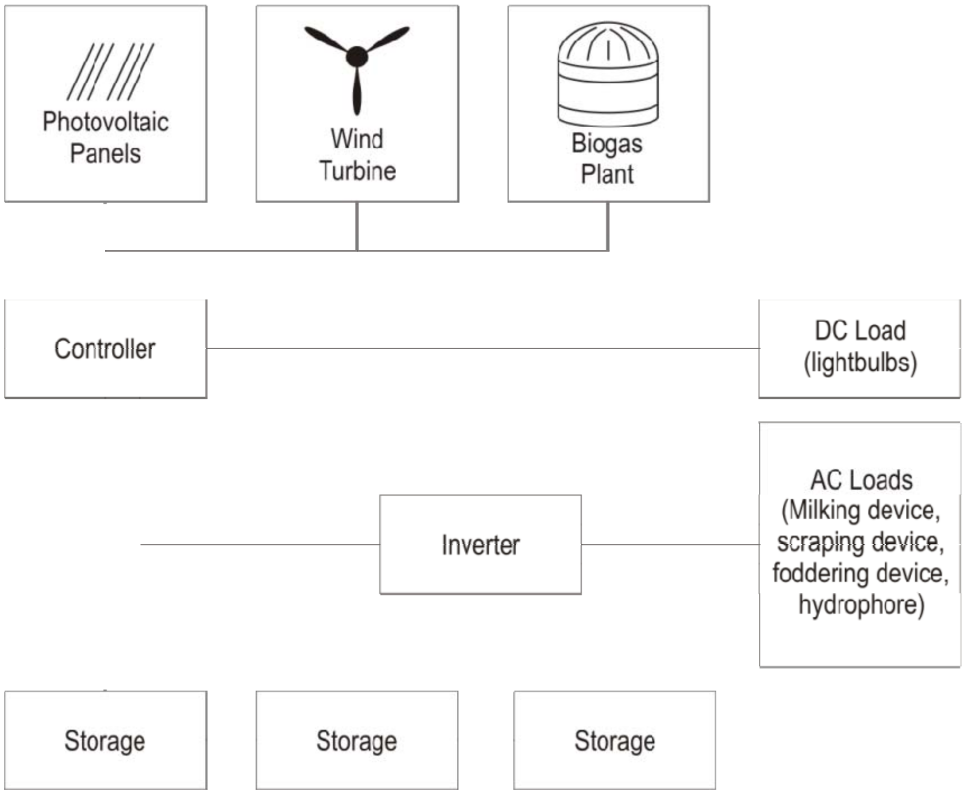

Fig.5. Energy supply system – solution for a small cow farm

CONCLUSIONS

Actual distributed generation technologies should improve the power quality, boost the energy system reliability and reduce energy costs. Each of the integration solutions for RES has advantages and disadvantages and should be chosen depending on the local situation, still the most common used are DC and AC integration methods.

The integration of multiple RES is a good, simple solution for small, islanded sites that have available renewable energy sources. All available sources may be integrated in such a system, but the optimum design of the system (from an economic and technological point of view) must be done in accordance with the needs of the consumers.

ACKNOWLEDGMENTS

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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ANALYSIS OF ENERGY EFFICIENCY FOR SAWDUST BRIQUETTING PROCESS

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SUMMARY

Romania has a high potential of raw material for sawdust. It is used mainly as an unprocessed thermal energy sources with a low efficiency. This is due to the changing in physical properties as a function of climate condition, as well as, transportation, storage, manipulation and conversion. Energy efficiency of sawdust conversion in thermal energy may be improved by compacting in the form of briquettes. The paper aims to develop an energy analysis of sawdust briquetting process in order to expresses in a quantitative sense the energy consumption associated to each activities carried out in the process. A mathematical model, based on systemic analysis, is developed to quantify the structure of the energy consumption in the briquetting process and energy embodied in the briquette, as a final biofuel. An application was developed and the structure of the energy consumption was determined. The energy efficiency was calculated as a ratio between the total energy embodied in a mass unit of briquettes and the total energy consumed in the process per mass unit. The method permits a complete study of sawdust conversion in thermal energy, thus optimization of the process may be possible.

Key words: *energy efficiency, mathematical method, sawdust briquettes, systemic analysis.*

INTRODUCTION

In the context of technology development, the energy becomes an essential element for the most human activity. Increasing energy demands involve an increase of importance of renewable energy sources. The biomass is an important renewable energy resource in Romania. It has a high available potential and its conversion is characterized like a non polluting process.

In our country, the main source of bio-energy from biomass is agriculture, forestry and the wood processing industry. The sawdust is the main source of bio-energy from biomass coming from wood processing industry and forestry.

According to Eurostat statistical dates [1], annually in Romania, 1500000m^3 of sawdust is produce. In 2006 [10] from total Romanian area 26,7 % (6382,2 thousand ha) was covered by forests. The energy potential of wood waste (forestry biomass and wood waste) was estimated at 0,069673 EJ.

According to the regional distribution of wood exploitation, the Romanian energy potential of wood waste has a regional distribution (table 1).

In the last period this quantity was increased in concordance with the total exploited wood quantity. In the Romanian West Mountains there is located an important percent from national forestry fund, thus sawdust become a viable renewable energy sources in this region.

In this context, researches regarding the energy efficiency of sawdust conversion process are very important. Thus, the main objective of the research is to develop an analysis of the energy efficiency of the sawdust briquetting process using a method based on the systemic analysis.

Table 1 The regional distribution of energy potential of woody biomass [11]

No.	The Romanian Region	Forestry biomass	Wood wastes
		[Thousand tones/year] [EJ]	[Thousand tones/year] [EJ]
I	Dobrogea	54	19
		0,000451	0,000269
II	Moldovian Plateau	166	58
		0,001728	0,000802
III	Carpatian Mountains	1873	583
		0,019552	0,008049
IV	Transylvanian Plateau	835	252
		0,00721	0,003482
V	Western Plain	347	116
		0,003622	0,001603
VI	Subcarpatian Area	1248	388
		0,013034	0,005366
VII	South Plain	204	62
		0,002133	0,000861
Total		4727	1478
		0,049241	**0,020432**

The sawdust briquetting process, using the classical technology, is a complex activity. This involves energy consume in all stage of the process: pretreatment, processing and manipulation.

Thus, in order to determinate the efficiency of sawdust briquetting process is necessary to determinate the quantity of energy consummated in the sawdust pretreatment and processing activities and the sawdust briquettes resulted at the end of the process embodied a high quantity of the energy.

The systemic analysis was used for determinate the consumption of energy involved in the sawdust briquetting process.

The method of systemic analysis applied in the analysis of sawdust briquetting process has permitted to quantify the process variables. Thus, the sawdust processing operation was assimilated with an independent system. In the next stage this system was divided in subsystems described through explicit mathematical relations.

METHODS

In the context of systemic analysis, the independent system, generic called „PRETRAT" was assimilated with the sawdust briquetting process. The specific stages of the briquetting process were considered subsystems of the independent system.

The input variables (I) represent the total energy consumptions (W_I) associated to activities of the subsystems.

The output variables (O) represent the total energy embodied in sawdust briquettes (WO), obtained at the end of the briquetting process.

The external factors (S_f) have an influence on the considered system. The influence of this factors can't be eliminated. The main external factors are weather, origin place of sawdust, collecting conditions.

The schematic representation of the "PRETRAT" System is presented in fig 1.

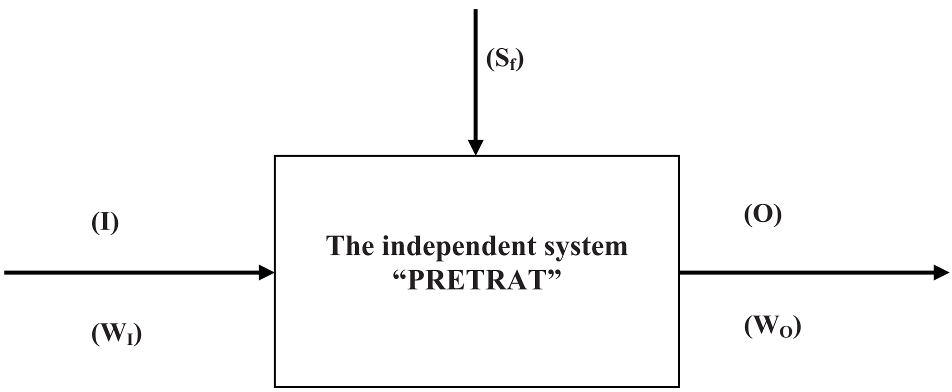

Figure 1 Schematic representation of „PRETRAT" System

According to the schematic representation of "PRETRAT" System (figure 1), the energy efficiency of the sawdust briquetting process can be determinate using relation (1):

$$E_{pretrat} = f(I, O, S_f) \tag{1}$$

where $E_{pretrat}$ represents the energy efficiency of the sawdust briquetting process, [%].

The equation (1) is considered the compartmental equation of the "PRETRAT" System. The quantitative determination of the input variables (I), output variables (O) and correlations between these, involve determination an explicit mathematical expression. This explicit mathematical expression is used for determination the energy efficiency of the sawdust briquetting process. The total quantity of input energy (W_I) was determinate using the partial energy associated to component activities of the sawdust processing operation (equation 2):

$$W_I = \sum_{i=1}^{n} \sum_{j=1}^{m} W_{I,j}^{i,k} \tag{2}$$

where I represent the input variables; k is the order of input variables subdivision, k = 1,2,3,...,l; i identify the sawdust category, i =1,2,3,...,n (e.g.. i=1 represent the beech sawdust); j identify the analyzed activity, j = 1,2,3,...,9; $W_{I,1}^{i,1}, W_{I,2}^{i,1}, W_{I,3}^{i,1}, ..., W_{I,m}^{i,1}$ represent the total energy consummated associated to each activities of the process.

External factors S_f are analyzed using the same method, systemic analysis. S_f , are considerated discret variables because they can't be quantify by explicit mathematical equations, but in the analysis of the systems the external factors must be considered distinct terms. So, S_f is considered the functional elements of the system and is determinate using a functional relation (equation 3):

$$S_f = f(S_c, S_{c_1}, S_s, ..., S_{mg}), \tag{3}$$

where S_c is distinct term associated to weather condition from sawdust collected area; S_{c1} is the distinct term associated to weather condition from sawdust processing area; S_s is the distinct term associated to soil characteristics from sawdust collected area; S_{mg} is the distinct term associated to heavy metals content of soil from sawdust collected area.

The output variables (O) can be analyzed using the same method. Thus, the total output energy (W_O) is determinted using equation (4).

$$W_O = W_{bios}^{i} \tag{4}$$

W^{i}_{bios} represents the total energy embodied in sawdust solid biofuels at the end of the sawdust processing.

The partial energy associated to component activities of the sawdust processing operation $W^{i,1}_{I,1}, W^{i,1}_{I,2}, W^{i,1}_{I,3}, ..., W^{i,1}_{I,m}$ was divided in inferior order terms, using the same algorithm.

Thus, using the flow energy chart of the process, was determinate the explicit mathematical equations used for energy consumption evaluation of each activities of the considered subsystems. These equations are developed based on energy consumption of the specific equipments and machine used in the process.

The results offer the possibility to make the energy balance of the process and calculation of the energy efficiency of the process.

APPLICATION

The sawdust briquetting process incorporates a several stages and activities identified using the systemic analysis. Thus, the sawdust briquetting process was considered an independent system "PRETRAT" and the main stages of the process were considered subsystems of the independent system.

According to developed analysis method, calculation of energy efficiency of the process involves the analysis of energy consumption associate to each stage and activity of the process. Thus, the analysis involves start from flow chart of the main subsystems and activities of the process (figure 2).

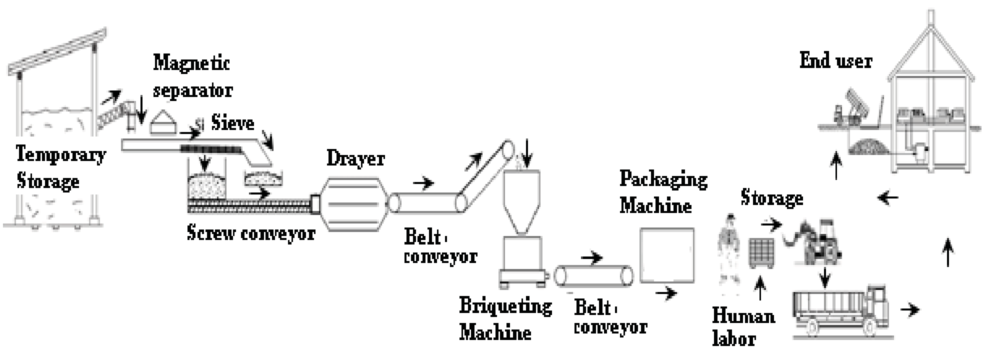

Figure 2 The flow chart of main subsystems and activities of sawdust briquetting process

The main identified activities of the process and the specific machines used are: the temporary storage of raw sawdust using natural aeration silos; the transport of sawdust at magnetic separation using a screw conveyor; the sawdust cleaning and sorting operations using a combined system (a magnetic separator and a rotary drum sieve); the transport of sawdust at dryer using a horizontal screw conveyor; the dry of sawdust using a rotary dryer;

the transport of sawdust at briquetting machine using belt conveyors; the sawdust briquetting operation; the transport of sawdust briquettes at packaging machine using a horizontal belt conveyor; the briquettes packaging activity; the transport of briquettes packages at intermediate storage using the human labour; the load briquettes packages in transport vehicles using a loading vehicle; the transport of sawdust briquettes at end user using a truck with 30 m^3 maximum load capacity.

All activities involve an energy consume which was calculated using the technical characteristics and maximum energy consumption of the specific machines. The input variables, necessary for energy efficiency determination, according to activities flow chart are shows in table 2.

Table 2 The input variables of the "PRETRAT" System

The input variable	Value
The "Human labor" subsystem [5]	
The number of workers	n_{mn} := 2 in 8 hours
The worker energy consume in 8 hours	W_{mn} := 1200 [MJ/zi]
The total quantity of manipulated material in 8 hours	m^2_{mr} := 1000 [kg]
The „Processing" subsystem [8]	
The "Sorting" Activity	
The hourly processing capacity of the magnetic separator	c^1_{se} := 7090.9 [kg]
The hourly energy consumption of the magnetic separator.	E^1_{se} := 1.5 [kW]
The hourly processing capacity of the sieves sorting system.	c^1_s := 7090.9 [kg]
The hourly energy consumption of the sieves sorting system.	E^1_s := 5.5 [kW]
The "Dry" Activity	
The sawdust calorific value at the end of dry activity.	$H^1_{r,s}$:= 12.8 [MJ/kg]
The sawdust quantity hourly processed.	c^1_u := 3567 [kg/h]
The efficiency of dryer.	η^1_u := 98
The hourly electricity consumption of the dryer.	E_u:= 110 [kW]
The „Briquetting" Activity.	
The hourly energy consumption of the briquetting machine.	E^2_c := 22 [kW]
The sawdust quantity hourly processed by the briquetting machine.	c^2_c := 600 [kg/h]
The „Packaging" Activity.	
The hourly energy consumption of the packaging machine.	E^2_a:= 0,75 [kW]
The briquettes quantity hourly processed by the packaging machine.	c^2_a := 1000 [kg/h]
The "Intermediate Transport" subsystem.	
The hourly energy consumption of screw conveyor used between temporary	$E^{1,1}_{man}$:= 0,55 [kW]

storage and magnetic separator (pine sawdust W_t = 55%, ρ = 709.09 [kg/m^3]),[8]	
The sawdust quantity hourly transported by the screw conveyor between temporary storage and magnetic separator[8].	$c^{1,1,1}{}_{man}$:= 7090.9[kg]
The hourly energy consumption of horizontal screw conveyor used between sorting system and dryer[8].	$E^{1,1}{}_{man}$:= 0,37[kW]
The sawdust quantity hourly transported by the horizontal screw conveyor between sorting system and dryer[8].	$c^{1,2,1}{}_{man}$:= 7090.9[kg]
The hourly energy consumption of transport combine system (1 horizontal belt conveyor and 1 inclined belt conveyor) used between dryer system and briquetting machine (pine sawdust W_t = 10%, ρ = 433.33 [kg/m^3]),[8].	$E^{1,2}{}_{man}$:= 0,92 [kW]
The sawdust quantity hourly transported by the combine system between dryer system and briquetting machine[8].	$c^{1,3,2}{}_{man}$:= 6933,28 [kg]
The hourly energy consumption of belt conveyor used between briquetting machine and packaging machine[8].	$E^{2,2}{}_{man}$:= 0,37[kW]
The sawdust quantity hourly transported by the belt conveyor between briquetting machine and packaging machine [1].	$c^{2,3,2}{}_{man}$:= 3376 [kg]
The fuel used by the loading vehicle [1].	Diesel
The hourly medium fuel consume of the loading vehicle [1].	$c^{4,3}{}_{man}$:= 25[l/h]
The hourly medium quantity of briquettes manipulated by the loading vehicle. [1]	$c^{2,4,3}$:= 3300 [kg/h]
The "Final Transport" subsystem [1]	
The quantity of fuel consumed by the transport vehicle[l/100km].	$c^{2,2,1}{}_{cb,auto}$:= 30
The fuel used by the transport vehicle.	Diesel
The distance between the processing place and end user.	$D^{2,2,1}{}_{trans}$:= 50 [km]
The load capacity of the transport vehicle.	$V^{2,2,1}{}_{auto}$:= 30 [m^3]
Bulk density of the sawdust briquettes.	$\gamma^2{}_r$:= 422 [kg/m^3]
The „Output Energy" subsystem.	
The total quantity of briquettes hourly processing.	$c^2{}_b$:= 3300 [kg]
The calorific value of the briquettes.	$H^2{}_{cb}$:= 17.3 [MJ/kg]
The calorific value of raw sawdust (pine sawdust, w_{ti} = 55%).	H_r := 8,3 [MJ/kg]

RESULTS AND DISCUSSION

The absolute value of energy consumptions divided into the subsystems of "PRETRAT" system was obtained using the input dates and the developed analysis method [Table 3].

The analysis of energy consumption divided into the subsystems of "PRETRAT" System (figure 3) identify the subsystems with the highest energy consumption – "Human labor"

Subsystem (33,356%), “Intermediate Transport” Subsystem (32,73 %) and “Final Transp-ort” Subsystem (5,096 %).

The high energy consumption in “Intermediate Transport” Subsystem is due to the energy consumed by loading material in transport vehicles, respectively the energy consu-mption of the loading vehicle (99,547 % of total energy consummated in “Intermediate Transport” Subsystem), (figure 4).

Table 3 The absolute value of energy consumptions divided on the subsystems of "PRETRAT" system

The consumption energy associated to human labor [MJ/kg]	0,3
The energy consumed in the magnetic separation activity [MJ/kg]	0,00076
The energy consumed in the sieve sorting activity [MJ/kg]	0,00279
The total energy consumed in sorting activity (magnetic separation and sieve sorting) [MJ/kg]	0,00355
The energy consumed in the drying activity [MJ/kg]	0,1110
The energy consumed in the briquetting activity [MJ/kg]	0,132
The energy consumed in the packaging activity [MJ/kg]	0,0027
The total energy consumed in the “Processing” subsystem [MJ/kg]	0,24825
The energy consumed in the transport activity between temporary storage and magnetic separator [MJ/kg]	0,00027
The energy consumed in the transport activity between sorting system and dryer [MJ/kg]	0,00018
The energy consumed in the transport activity between dryer and briquetting machine [MJ/kg]	0,00047
The energy consumed in the transport activity between briquetting machine and packaging machine [MJ/kg]	0,00039
The energy consumed by loading material in transport vehicles [MJ/kg]	0,28787
The total energy consumed in the “Intermediate Transport” subsystem [MJ/kg].	0,289218
The total energy consumed in the “Final Transport” subsystem. [MJ/kg]	0,045023
The total energy consumed in sawdust briquetting process (“PRETRAT” System)	0,88351
The total energy embodied in raw sawdust (pine sawdust, w_{ti} = 55%) [MJ/kg]	8,3
The total energy embodied in sawdust briquettes [MJ/kg]	17,3
Energy balance [MJ/kg]	8,11649

The analysis of the energy consumptions divided into the activities of „Processing” Subsystem (figure 5) identify the high energy consume associated to briquetting activity (52,959%). This situation is due to the low quantity of sawdust hourly processed (600 kg) and to the high electrical energy consumption of the briquetting machine (22kW/h).

The high energy consumption in drying activity is due to the energy (110 kW) used for decreasing sawdust moisture content from 55% to 10%.

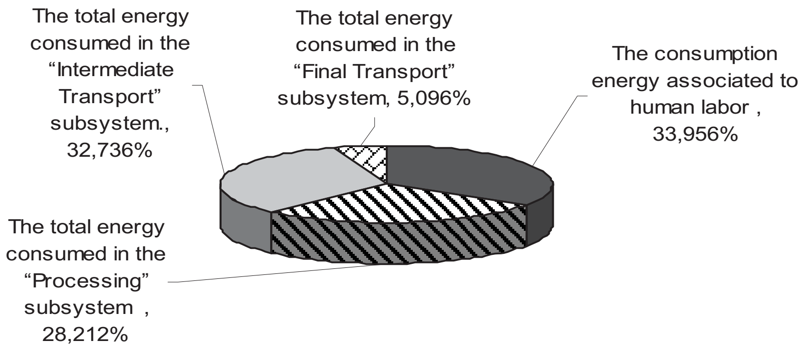

Figure 3 The structure of energy consumption divided on the subsystems of "PRETRAT" System

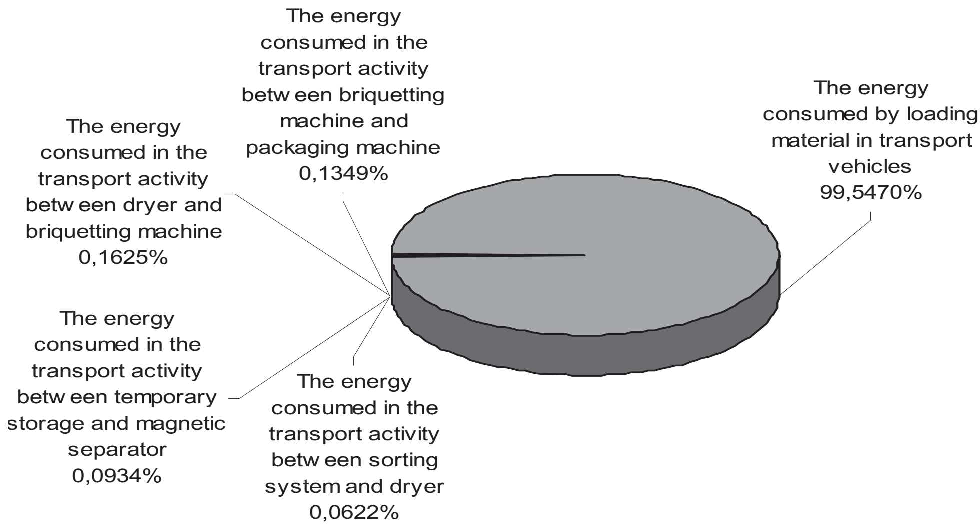

Figure 4 The structure of energy consumption divided on activities of "Intermediate Transport" Subsystem

Although, the dryer energy consumption is five time higher than energy consumption of the briquetting machine, the energy consumption per mass unit of biofuel is lower, because the hourly processing capacity of dryer is about 9,4 time higher than hourly processing capacity of briquetting machine.

The energy consumed in other activities from the „Processing" Subsystem are comparable (1,42% sorting activity and 1,083% packaging activity).

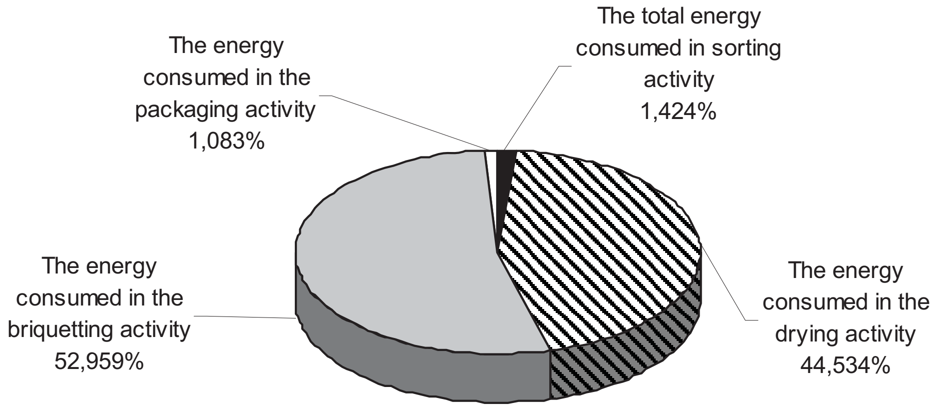

Figure 5 The structure of energy consumption divided on activities of „Processing" Subsystem

The analysis of energetic balance shows that the energy consumption in the sawdust briquetting process is lower then energy embodied in the sawdust briquettes resulted at the end of the process.

Thus, the energy resulted (8,11649 [MJ/kg]) is about 9,18 time higher than energy consumed in the briquetting process (0,88351 [MJ/kg]). The higher energy quantity is due to increasing of energy density of the solid biofuel and to final transport activity efficiency.

In accordance to the results of the energy balance and the developed analysis method, the energy efficiency of the process can be calculated as the ratio between the total energy embodied in mass unit of briquettes and the sum of the energy embodied in the raw sawdust and total energy consumed in the process per mass unit. The energy efficiency of the process is about 188,831%. Thus, we can conclude that sawdust briquetting process has a high energetic efficiency.

CONCLUSIONS

This article presents an approach to analyze the energy efficiency in the briquetting process of sawdust.

A mathematical model, based on systemic analysis, was developed to quantify the structure of the energy consumption in the briquetting process and energy embodied in the briquette, as a final biofuel.

Calculation of energy efficiency of sawdust briquetting and conversion processes requires the evaluation of all elementary energy associated to each activity of the sawdust briquetting process, as well as, the total energy embodied in the last form of the sawdust, respectively sawdust briquettes.

An application was developed and the structure of the energy consumption was determined. The energy efficiency was calculated as a ratio between the total energy embodied in a mass unit of briquettes and the total energy consumed in the process per mass unit.

The method permits a complete study of sawdust conversion in thermal energy, thus optimization of the process may be possible.

The method of energy analysis may be extended to other energy processes evaluation and optimization.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

MONITORING AND ASSESSING THE PERFORMANCE OF AGRICULTURAL BIOGAS PLANTS

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ABSTRACT

Germany is a leading European country in biogas production with currently around 5,000 agricultural biogas plants in operation. There is a recognized need for assessment, comparison and performance improvement of biogas plants. Prerequisites for a reliable assessment include: 1) Detailed and reliable performance data, 2) defined assessment criteria, and 3) a comprehensive assessment approach. Data from thorough monitoring of ten Bavarian agricultural biogas plants are presented. Various performance figures were derived from the collected data to enable comparison of different biogas plants. Four aspects of a biogas plant performance were considered: 1) Biogas production, 2) biogas utilization, 3) environmental impact, and 4) socio-economic impact. Eight pertinent performance figures were selected and used as assessment criteria. To assess the performance of the ten biogas plants, three different approaches were applied and compared based on their limitations and capabilities. In the first approach, which is based on Data Envelopment Analysis (DEA), it was impossible to involve experts in the assessment. In the second approach, two Multi Criteria Decision Making (MCDM) methods were combined and experts determined criteria weights, i.e. importance of criteria in the assessment. The third approach is based on fuzzy mathematics, which enabled experts to determine criteria weights and qualitative evaluation of biogas plant performance. Also, "weak points" in operation were identified, where the operator of a biogas plant could improve the performance of his installation. When necessary, this approach may be adjusted to technological developments or changes in political and economical framework conditions. It was concluded that the third proposed approach is the most appropriate for the assessment of biogas plants. The approach should be methodologically extended to include more assessment criteria and to improve the reliability by consulting a larger number of experts.

Key words: *biogas plant, agriculture, performance, monitoring, assessment*

INTRODUCTION

Germany is a leading European country in biogas production with currently around 1.7 GW of installed electrical capacity distributed over 5,000 biogas installations. Electricity production from biogas accounted for 1.7% of the total electricity demand in 2009 (BMU, 2009). The number of biogas plants has grown rapidly since specific feed-in tariffs for "green" electricity were defined in the Renewable Energy Law (EEG) from 2001 and its amended versions from 2004 and 2009. Biogas production has become an important branch of agriculture, mainly due to continuously growing usage of agricultural raw materials for anaerobic digestion (AD).

Amongst others, data on actual performance of biogas plants are available from FNR (2009), Effenberger et al. (2009a) and Schöftner et al. (2006). Assessment of environmental impact of operating biogas plants has been reported by Bachmaier et al. (2009). These studies showed that the performance of biogas plants may be described with manifold performance figures. Therefore, the assessment of "overall" biogas plant efficiency requires multi-criteria methods.

To date, such an overall performance assessment of biogas plants has been seldom reported. Madlener et al. (2009) used a combination of Multi Criteria Decision Making (MCDM) and Data Envelopment Analysis (DEA) for assessing biogas plants with respect to economic, environmental and social criteria. In Braun et al. (2007) DEA was used as a benchmarking tool to identify the most efficient biogas plants and nominate them as "Best Biogas Practice". A shortcoming of these approaches is that the used assessment criteria were primarily chosen to fit the applied method, while no clear definition was provided about the performance indicators of biogas plants. Detailed performance figures for agricultural biogas plants have been presented and discussed by Strobl & Keymer (2006) and Effenberger et al. (2009b).

Contemporary agricultural biogas plants are characterized by their diversity in terms of site conditions, capacities, designs, input materials, material and energy flows. Consequently, considerable differences in their performance can occur. Therefore, there is a need for comprehensive assessment of biogas plants in agriculture.

The objective of this paper was to present monitoring results of ten agricultural biogas plants and their performance assessment using three different approaches. Further objective is to compare the three approaches, to recognize their limitations and to define tasks for future research.

MATERIALS AND METHODS

Description of biogas plants

Ten contemporary farm-scale biogas plants were monitored over a period of two years (Table 1). The plants reflect the diversity of geographical locations and designs of biogas installations in Bavaria. They represent agricultural biogas plants, since only animal manure and energy crops were used as input materials for biogas production.

Table 1 Basic characteristics of the ten monitored biogas plants (Effenberger et al., 2009a)

Plant ID		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Average daily input[1]	$t \cdot d^{-1}$	22.3	20.3	18.9	18.5	17.8	28.2	18.6	10.9	11.4	26.2
Proportion of animal manure	% (m/m)	8	3	7	0	28	15	28	0	41	38
Type of animal manure		LCM, SCM, SPM	SCM	LCM	–	SPM	SPM	LHM, LCM, SCM	–	LCM	LCM, SCM
Type of energy crops		MS, GS, GR, CCS	CGS, MS, CCM, CCS	MS, GS, CCS, CCM	MS, WW, GS, WR, GR	MS	MS, MK, CCS, GS, GN	MS, CCS, GS, SG, RGS	MS, GR, SG, LC	GN, MK, MS, SB	MS, GS, CCS, GN
Year of commissioning		2005	2005	2004	2004	2005	2002	2005	2004	2005	2001
Total digester volume[2]	m^3	3,015	2,605	3,676	2,290	2,487	3,740	1,540	1,778	1,095	3,413
Storage of digested residue		collect	open	collect	open	collect	open	collect	open	open	collect
CGU engine type		G	G	G	G	G	G	PI	PI	G	G
Rated electrical capacity	kW	329	333	380	420	347	526	280	250	324	380
Rated thermal capacity	kW	447	232	486	472	432	566	300	262	250	486

[1]) Animal manure and energy crops, not including added water; [2]) Sum of the usable volume of all process stages of the biogas plant excluding digested residue storage; Collect: Gas collection; G: Gas engine; PI: Pilot-injection engine; CCM: Corn-Cob-Mix; CCS: Cereal crop silage; CGS: Clover grass silage; GN: Grain; GR: Green rye crop silage; GS: Grass silage; LC: Lawn-clippings; LCM: Liquid cattle manure; LHM: Liquid hog manure; MK: Crushed maize kernels; MS: Maize crop silage; RGS: Rye grass silage; SB: Sugar beats; SCM: Solid cattle manure; SG: Sudan grass silage; SPM: Solid poultry manure; TC: Triticale silage; WR: Winter rye crop silage; WW: Winter wheat crop silage.

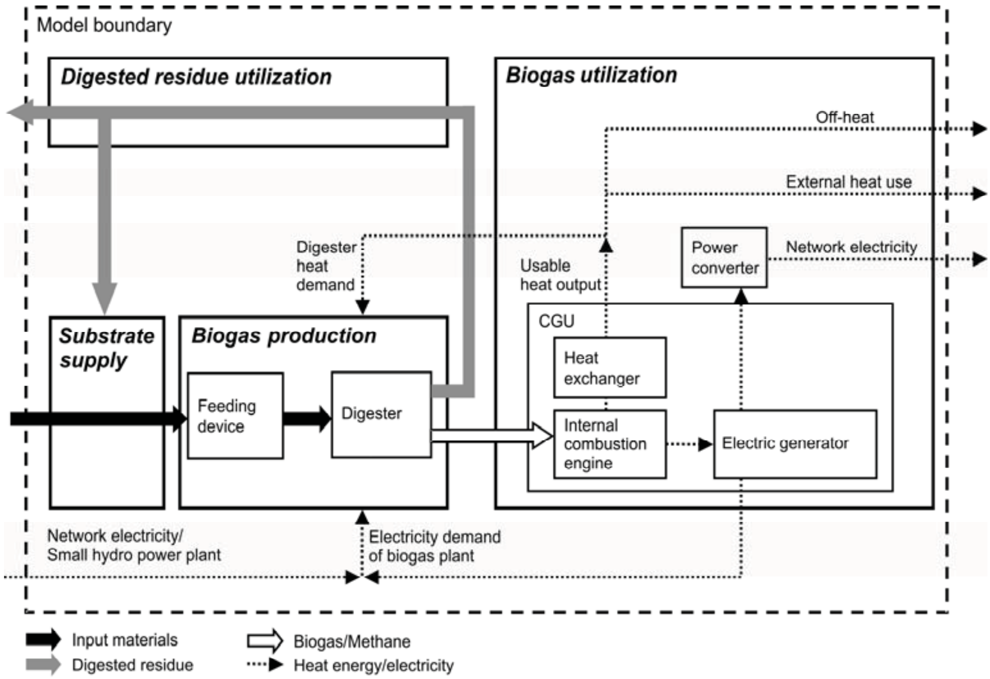

Figure 1 General scheme of the process chain for the ten monitored biogas plants

A general scheme of the process chain with material and energy flows for the ten biogas plants is given in Fig. 1. As in the vast majority of biogas plants in Germany, biogas produced in these plants was utilized in a co-generation unit (CGU) with internal combustion engine, to produce electricity and heat. Electricity was fed into the public electricity network. Own electricity demand of the biogas plants was covered either by network electricity, by own production or by production in a small hydropower plant. A certain amount of heat energy was consumed for heating the digesters. Surplus heat energy was utilized externally for district heating or drying processes. Unutilized heat energy ("off-heat") was wasted in the atmosphere.

The digested residue was used as fertilizer. In three cases, the residue was subjected to solid-liquid-separation. The storage tanks for the digested residue were either open or covered and connected to the biogas collection system (Table 1).

Monitoring procedures

The data required for the assessment were either logged manually by the operator or automatically by upgrading the biogas plants with measuring devices. Additionally, samples of input materials and digester contents were analyzed to calculate material and energy flows. Overall, up to 100 parameters per plant were collected in different intervals. The database for storing the monitored data and software for calculation of performance figures were developed at the Institute for Agricultural Engineering and Animal Husbandry in Freising.

Performance figures and assessment criteria

After monitoring, numerous performance figures were derived from the collected data. These figures were calculated by combining several working parameters. In most cases, the figures were related to electricity production, which often is the primary objective of biogas production. To describe the overall performance of biogas plants, eight pertinent performance figures were selected and used as assessment criteria (C1-C8, see Table 2). These eight criteria determine four aspects of biogas plant performance, such that each aspect was described by two corresponding assessment criteria: 1) Biogas production (C1, C2), 2) biogas utilization (C3, C4), 3) environmental impact (C5, C6), and 4) socio-economic efficiency (C7, C8).

Assessment approaches

Data Envelopment Analysis (DEA) approach. DEA is a method commonly used for assessing the relative efficiency (performance) of a set of 'units' that are commonly called decision making units (DMUs). Within the DEA procedure, a linear program is applied and solved for each DMU under evaluation (Charnes et al., 1978). The performance measure takes a value between 0 and 1, where the DMUs (in this case biogas plants) with the "best" performance reach a value of 1. Biogas plants with the "worst" performance reach the lowest value (larger than zero). In this paper, a Super-CCR DEA model was applied that is able to distinguish further between efficient biogas plants, by allowing the measure of relative performance to take a value greater than 1 (Cooper et al., 2006). In order to improve the efficiency of a biogas plant, inputs (I_s) should be decreased and outputs (O_s) should be increased. Therefore, three assessment criteria were determined as I_s (C5, C6 and C8) and five of them as O_s for the DEA model (C1, C2, C3, C4 and C7). DEA is a non-parametric approach, since no functional relationships are required between I_s and O_s.

General DEA procedures have been discussed in Dyson et al. (2001). For assessing the performance of biogas plants, DEA was applied in Djatkov & Effenberger (2010) and Madlener et al. (2009).

Table 2 Description of selected assessment criteria

Criterion	Title	Unit	Weight	Formulae	Remark
C1	Relative biogas yield	%	2.8	$Y_r = \frac{Y_m}{Y_t}$	Relative biogas yield (Y_r) was computed as the ratio of measured biogas yield (Y_m) and theoretical biogas yield (Y_t) based on animal feed value analysis (Keymer and Schilcher, 2003). It is an indicator of the microbiological degradation ratio of the input materials.
C2	Methane productivity	$m^3 \cdot (m^3 \cdot d)^{-1}$	2.9	$P_M = \frac{M_p}{V_d}$	Methane productivity describes the volumetric productivity of the digester and as such is equivalent to specific power output. It is the ratio of methane production rate (M_p) and usable digester volume (V_d).
C3	Utilization ratio of CGU	%	3.2	$U_{CGU} = \frac{E_p}{E_t}$	Utilization ratio of the co-generation unit (U_{CGU}) describes the efficiency of utilizing the nominal electrical capacity of the CGU. It is the ratio of total electricity production (E_p) and theoretical electricity production given 100% availability (E_t) over a specific time period.
C4	Methane utilization ratio	%	7.2	$U_M = \frac{E_p - E_d + Q_{ext}}{H_m}$	Methane utilization ratio is the sum of produced electricity (E_p) minus the electricity demand of the biogas plant (E_d), plus external heat utilization (Q_{ext}), related to the net heating value of methane output (H_m). If a pilot injection engine is used, the amount of electricity produced from diesel fuel must be subtracted from E_p. This figure describes the efficiency of utilizing the fuel value of produced methane.
C5	Specific GHG emissions	$g\ CO_{2,eq} \cdot kWh_{el}^{-1}$	10.8	$E_{GHG} = \frac{E_e - E_a}{E_p}$	Specific greenhouse gas emissions (E_{GHG}) of electricity production from biogas are determined as the difference between emitted (E_e) and avoided amounts of GHG (E_a) from the entire process chain (see Fig. 1), specified to electricity output (E_p). Values include emissions of CO_2, CH_4 and N_2O and were obtained from Bachmaier et al. (2009).
C6	Cumulated energy demand	$kWh \cdot kWh_{el}^{-1}$	2.7	$CED = \frac{ED_c + ED_o + ED_r - ED_a}{E_p}$	Cumulated energy demand (CED) is the sum of energy input from fossil resources for the construction (ED_c), operation (ED_o) and removal (ED_r) of the biogas plant minus substituted heat energy from fossil fuels for external users and avoided energy input for fertilizer production (ED_a), related to electricity output (E_p). Values were obtained from Bachmaier et al. (2009).
C7	Profit	$€ \cdot (kW_{el} \cdot a)^{-1}$	58.8	$P = \frac{I - C}{P_e}$	Profit was calculated as the difference between total yearly income (I) and yearly cost (C) of agricultural biogas production, related to average electrical capacity (P_e).
C8	Labor input	$Lh \cdot kW_{el}^{-1}$	11.6	$E = \frac{L_o + L_m + L_r}{P_n}$	Labor input (L) is the sum of human labor hours spent for operation (L_o), maintenance (L_m) and repairs (L_r) of the biogas plant, related to nominal electrical capacity (P_n).

Multi Criteria Decision Making (MCDM) approach. In this approach, two MCDM methods were combined: Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW). AHP was originally developed by Thomas Saaty (Saaty, 1980). In the assessment of biogas plants, AHP was used for deriving weights, *i.e.* relative importance of assessment criteria by consulting an expert panel (Table 2, the fourth column). SAW is a commonly used method to combine multiple assessment criteria with unequal weights. For assessment of biogas plants an overall utility value (U_i) was calculated. Derived criteria weights (w_j) were directly applied to criteria values (x_{ij}) as presented in Eq. 1 (n is the number of biogas plants to be assessed, while m represents the number of assessment criteria). Biogas plants were ranked in descending order with the best-performing biogas plants having the highest utility value. A detailed description of the MCDM approach is given by Djatkov et al. (2009).

$$U_i = \sum_{j=1}^{m} w_j x_{ij} \qquad i = 1...n \tag{1}$$

Fuzzy mathematical approach (FMA). FMA was developed using the theory of fuzzy sets and fuzzy logic (Klir and Yuan, 1995). In this approach, the same criteria weights as in MCDM were used. These weights were firstly fuzzified to construct appropriate fuzzy numbers ($\tilde{W}_i$) on the scale between 0 and 100. Fuzzy numbers were constructed from criteria values as well ($\tilde{C}_i$). Fuzzy weights and fuzzy criteria values were combined in Fuzzy Weighted Average (FWA, Eq. 2), to obtain the overall performance assessment. FMA is a fuzzy extension of traditional methods, *e.g.* SAW, to combine multiple criteria with unequal weights. Beside determination of criteria weights, experts took part in qualitative determination of efficiency states. Five efficiency states, which are fuzzy numbers, were defined for each criterion and for overall performance ("unacceptable", "poor", "acceptable", "good" and "excellent"). After the assessment, biogas plants were assigned to one of the defined efficiency states. The assignment was facilitated by calculating the Euclidean distance between the fuzzy overall performance value of the individual biogas plants ($\tilde{R}$) and the respective fuzzy numbers for the five efficiency states ($\tilde{S}$). Biogas plants were assigned to the efficiency state with the shortest Euclidean distance. In order to rank assessed biogas plants, centroid defuzzification method was applied (Eq 3). From the resulting fuzzy number, a crisp value (real number) between 0 and 100 was obtained which represents the overall performance of a biogas plant.

$$\tilde{R} = \frac{\sum_{i=1}^{n} \tilde{W}_i \tilde{C}_i}{\sum_{i=1}^{n} \tilde{W}_i} \tag{2}$$

$$d(\tilde{R}) = \frac{\sum_{x=0}^{100} \tilde{R}(x) * x}{\sum_{x=0}^{100} \tilde{R}(x)} \tag{3}$$

RESULTS AND DISCUSSION

Performance figures for the ten monitored agricultural biogas plants are given in Table 3. Six of these performance figures were selected (C1-C6) and used as assessment criteria (Table 2). Individual economic performance figures are confidential and therefore not reported. Compared to similar studies (FNR, 2009; Schöftner et al., 2006), fewer biogas plants were investigated, but the necessary parameters were collected exhaustively and continually. Therefore, the quality of the data pool is considered a particular strength of this study.

Table 4 presents the results of performance assessments using three different approaches. Biogas plants were ranked with respect to calculated overall performance on different scales. In FMA, qualitative assessment is provided with letters in parenthesis. Ten plants were assigned "poor", "average" or "good" overall performance.

Table 3 Performance figures for the ten monitored agricultural biogas plants

Parameter	Unit	A	B	C	D	E	F	G	H	I	J
Evaluation period	d	639	672	305	865	793	823	609	488	640	609
Organic loading rate[1]	kg ODM•(m^3•d)$^{-1}$	2.0	1.9	2.0	2.6	2.7	3.0	3.0	1.9	3.1	1.9
Overall HRT	d	120	126	131	110	78	141	84	127	96	131
Biogas yield/ODM input	L•kg ODM^{-1}	696	681	709	737	676	519	714	754	729	700
Potential biogas yield/ODM input	L•kg ODM^{-1}	541	480	542	534	537	578	550	530	453	526
Relative biogas yield	%	129	142	131	138	126	90	130	142	161	133
Methane productivity	m^3•(m^3•d)$^{-1}$	0.79	0.71	0.78	0.98	0.97	0.76	1.0	0.74	1.2	0.65
Electricity yield/ODM input	kWh•t ODM^{-1}	1,280	1,277	1,549	1,506	1,191	1,077	1,535	1,648	1,362	1,263
Utilization ratio CHPU	%	97.8	82.4	93.7	79.3	97.1	91.3	96.1	92.2	58.6	89.0
Share of own electricity demand[2]	%	9.1	17.4	3.7	5.8	8.3	7.3	4.5	10.3	11.1	6.2
Engine electrical utilization ratio	%	32.4	35.6	39.4	40.4	33.6	40.5	38.4	38.4	34.7	36.6
External heat utilization ratio[3]	%	2.8	2.1	n.a.	37.9	50.3	58.0	19.3	39.7	60.0	n.a.
Methane utilization ratio	%	30.4	30.0	65.2	49.4	49.0	58.2	42.2	50.9	42.8	42.4
Specific GHG emissions	g $CO_{2,eq}$•kWh_{el}^{-1}	251	207	16	163	-85	29	177	223	216	164
Cumulated energy demand	kWh•kWh_{el}^{-1}	0.22	0.24	-0.42	-0.13	-0.62	-0.53	0.24	0.19	-0.22	0.06

[1]) Related to total digester volume (see Table 1); [2]) Electricity demand of biogas plant related to electricity output; [3]) Related to surplus heat output; FM: Fresh matter; HRT: Hydraulic retention time; n.a.: Not available; ODM: Organic dry matter.

Table 4 Performance assessment for the ten monitored biogas plants using three different approaches

Plant ID	DEA		MCDM		FMA	
	Performance	**Ranking**	**Performance**	**Ranking**	**Performance**	**Ranking**
A	0.526	10	0.559	9	33.60 (P)	9
B	0.779	7	0.189	10	21.14 (P)	10
C	1.522	3	0.983	3	74.49 (G)	3
D	1.938	2	0.989	2	83.14 (G)	2
E	126.8	1	1.000	1	84.93 (G)	1
F	1.317	4	0.902	4	66.82 (G)	4
G	0.608	9	0.798	6	59.54 (A)	6
H	0.618	8	0.632	7	36.15 (P)	8
I	1.292	5	0.613	8	38.91 (P)	7
J	0.826	6	0.848	5	65.44 (G)	5

P: poor; A: average; G: good.

Since it was impossible to involve experts in the assessment with DEA, results obtained from this approach are considered least reliable. MCDM facilitated a more reliable assessment, since experts determined criteria weights. FMA is deemed most reliable, since experts determined criteria weights and efficiency states. Due to methodological similarity in the calculation of overall performance values, ranking orders for MCDM and FMA are almost identical. The advantage of FMA is the possibility for an absolute assessment whereas in DEA and MCDM the assessment is relative among a set of biogas plants. In the latter cases, the best biogas plant attains the highest value on the respective scale, although its performance may not be excellent in absolute terms. This is the case with plant E, which attained the highest value in DEA and MCDM, but only a “good” rating in FMA.

In FMA, qualitative assessment of each individual aspect of biogas plant performance is possible as well. For example, if one aspect is assessed as “poor”, it can be identified as a “weak point”. The respective plant should then be compared with others that obtained a better rating with respect to that particular aspect. In this way, biogas plant operators receive a good indication of where they should preferably start to improve the performance of their installation.

The FMA approach was developed based on collected data and current state-of-the-art of biogas technology in Germany. However, it can be easily adjusted to assess biogas plants in any other geographical region.

CONCLUSIONS

The thorough monitoring of ten agricultural biogas plants illustrated manifold performance figures that may be used for performance assessment. So far, eight pertinent figures were selected and used as criteria to assess four aspects of biogas plant performance: Biogas production, biogas utilization, environmental impact and socio-economic impact. The overall performance of a biogas plant was described by combining these four aspects.

In this paper, three different approaches were applied to assess the overall performance of ten biogas plants in agriculture. DEA and MCDM approaches may be used to rank a set of biogas plants. FMA is considered superior to the other approaches, since experts knowledge was included in the assessment and an absolute assessment was provided. We propose this approach for assessing (overall) performance of biogas plants. It can serve for indicating starting points for improvement of existing installations and pre-assessment of biogas plants in planning phase.

Further research should focus on developing an approach that is capable of handling compensation between individual criteria. The approach should be methodologically extended to enable consulting a larger number of experts to improve reliability. Furthermore, more assessment criteria might be included, but it should not overburden the assessment.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RAZVOJ NA PODROČJU KMETIJSKIH BIOPLINSKIH NAPRAV V SLOVENIJI

TOMAŽ POJE

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IZVLEČEK

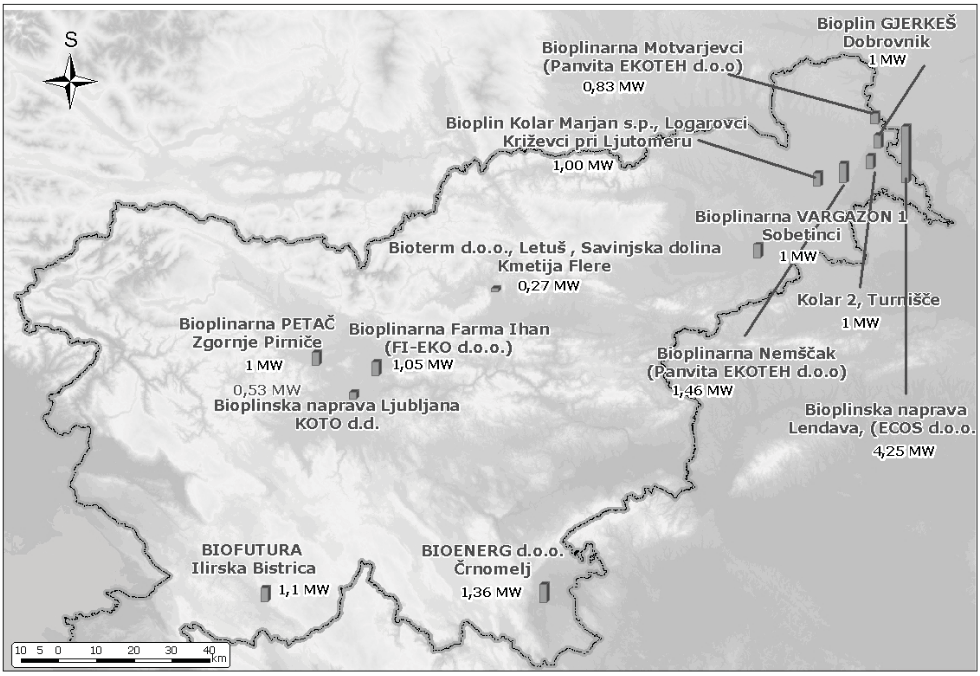
Število bioplinskih naprav v Sloveniji narašča predvsem zaradi relativno ugodnega sistema za odkup električne energije. Rigorozne spremembe na področju podpor lahko bistveno zmanjšajo zanimanje investitorjev. V naslednjih letih pričakujemo razvoj malih bioplinskih naprava, kjer se bodo morala vzpostaviti tudi različna partnerstva za uspešno delovanje bioplinskih naprav.

Ključne besede: *bioplin, stanje, podpore, male bioplinske naprave, partnerstva, Slovenija*

UVOD

Kljub gospodarski recesiji je področje kmetijskih bioplinskih naprav v Sloveniji v zadnjih letih napredovalo. Obstoječim bioplinskim napravam sta se v letu 2010 pridružili dve novi bioplinski napravi, trenutno pa se jih nekaj tudi še gradi. Na sliki 1 so prikazane kmetijske bioplinske naprave konec leta 2010 v Sloveniji. Največja bioplinska naprava je bioplinska naprava ECOS d.o.o. v Lendavi, velika 4,2 MW_e. Dejansko gre že za industrijski tip bioplinske naprave. Najmanjša bioplinska naprava je bioplinska naprava Bioterm d.o.o. na kmetijski Flere v Savinjski dolini. Na začetku delovanja je imela 120 kW_e, sedaj pa je razširjena na 270 kW_e. Nekatere od prikazanih bioplinskih naprav so pogojno kmetijske, ker uporabljajo tudi substrate, ki ne izvirajo iz kmetijstva (2).

Tak strm razvoj bioplinskih naprava je dejansko posledica ustrezne odkupne cene za elektriko proizvedeno iz bioplina. Odkupna cena je določena z Uredbo o podporah električni energiji proizvedeni iz obnovljivih virov energije, ki jo je Vlada RS sprejela v letu 2009 (3, 4).



Slika 1: Karta (kmetijskih) bioplinskih naprav v Sloveniji, december 2010

KMETIJSKI POTENCIAL ZA PROIZVODNJO BIOPLINA V SLOVENIJI

V zadnjih letih (desetletjih) je bilo v Sloveniji izdelano že nekaj potencialov za bioplin iz kmetijstva. Zadnji tak potencial je bil izdelan aprila 2010 (Pšaker, Lobe 2010). Njena avtorja sta Peter Pšaker in Barbara Lobe iz Kmetijsko gozdarske zbornice Slovenije, Zavoda Celje. Potencial za proizvodnjo bioplina v Sloveniji sta izračunala iz živinskih gnojil in rastlinske biomase. Izdelala sta tri različne scenarije potenciala. Po prvem scenariju, ki dejansko najmanj posega v primarno kmetijsko pridelavo, je kmetijski potencial za bioplin 86 MW_e. V tem scenariju je 16 % bioplina proizvedenega iz živinskih gnojil. Za pridelavo rastlinske biomase pa bi po tem scenariju namenili 9906 ha njiv (kar predstavlja 5,9 % vseh njiv v Sloveniji), 12958 ha strnišč (26 % vseh strnišč v Sloveniji) in 9047 ha trajnih travnikov (3,6 % vseh trajnih travnikov v Sloveniji). Po tretjem scenariju je za kmetijsko gospodarstvo ugodneje prodati rastlinsko biomaso za bioplin kot za hrano ljudi ali kot krmo za živali (tu znaša kmetijski potencial 147 MW_e). Pri tem scenariju bi rastlinsko biomaso za potrebe bioplinskih naprav pridelovali na 23457 ha njiv, 14917 ha strnišč in 17150 ha trajnih travnikov.

AKTIVNOSTI MINISTRSTVA ZA KMETIJSTVO NA PODROČJU BIOPLINA

Kljub temu da obstoječe bioplinske naprave uporabljajo vhodne substrate za pridobivanje bioplina, ki izvirajo iz kmetijstva (gnojevka, energetske rastline, stranski kmetijski proizvodi itd.) se do jeseni 2010 Ministrstvo za kmetijstvo, gozdarstvo in prehrano (MKGP) ni aktivneje vključevalo v usmerjanje razvoja bioplinskih naprav. Razvoj bioplinskih naprav je dejansko potekal na temelju podjetniških pobud. Večjo vlogo pri razvoju booplinskih naprav je predstavnik MKGP prvič javno najavil septembra 2010 na seminarju o bioplinu, ki ga je organiziral Kmetijski inštitut Slovenije v okviru IEE projekta Biogas Regions. Najavil je, da na MKGP razmišljajo o uvedbi ukrepov v smeri zmanjšanja uporabe glavnih posevkov na njivskih površinah v substratih bioplinskih naprav. Na MKGP so mnenja, da bi bilo potrebno v bioplinskih napravah zagotoviti večji delež gnoja in gnojevke in ostalih odpadkov iz kmetijstva. Pretežni del energetskih rastlin pa naj bi se pridelal kot strniščni posevek (5).

Kot posledica takega stališča MKGP je bila v Uradnem listu RS, št. 94 / 26. 11. 2010 objavljena Uredba o spremembah in dopolnitvah Uredbe o podporah električni energiji, proizvedeni iz obnovljivih virov energije (1). Njen 7. člen se glasi takole: »V 13. členu se doda novi drugi odstavek, ki se glasi:

»Proizvodne naprave na bioplin, ki za proizvodnjo bioplina uporabljajo substrat, ki vsebuje več kot 40 prostorninskih odstotkov zrnja oziroma silaže koruze in drugih žitaric, niso upravičene do podpore po tej uredbi.««.

Taka rigorozna sprememba obstoječe uredbe med lastniki bioplinskih naprav, sedanjimi investitorji v bioplinske naprave in potencialnim investitorji v bioplinske naprave ni bila sprejeta z odobravanjem. Po tej spremembi bi bili še v najslabšem položaju tisti investitorji v bioplinske naprave, ki so kalkulacije delali na večjem deležu energetskih rastlin. Investicije v bioplinsko napravo namreč niso majhne, spremembe na področju odkupnih cen elektrike proizvedene iz bioplina pa lahko popolnoma spremeni ekonomičnost investicije.

Tudi v Državnem zboru RS (parlamentu) večkrat razpravljajo o pomenu kmetijske pridelave za hrano ali za energijo. 9.12.2010 je bila v Državnem zboru RS 25. seja Odbora za kmetijstvo DZ. Na njej so imeli tudi razpravo**:** Ali zelena energija ogroža prehransko varnost? Poslanci tega Odbora in vabljeni gostje so razpravljali o dilemi kmetijstva ali pridelovati za hrano ali tudi za energijo. Predstavniki Ministrstva za gospodarstvo so najavili novo sprememba Uredbe o podporah, ki se dotika bioplina v smislu prehodnega obdobja za tiste, ki že imajo gradbeno dovoljenje in gradijo bioplinske naprave. Nadalje je bilo najavljeno znižanje spremenljivega dela odkupne cene, kakor tudi upoštevanja 40 % energetskih rastlin (koruza, žita) v vhodnem substratu. Ta predlog je sedaj v usklajevanju po različnih ministrstvih.

Minister za kmetijstvo, gozdarstvo in prehrano RS g. Dejan Židan je 23.11.2010 imenoval strokovno skupino za pripravo strategije o uporabi kmetijske biomase v energetske namene. V njej so strokovnjaki iz različnih institucij. Namen skupine je priprava strategije uporabe kmetijskih surovin za proizvodnjo bioenergije in umestitev uporabe biomase v okvir strateških usmeritev za zagotavljanje trajnostne izrabe kmetijskih zemljišč in gozdov. Sprejeta strategija bo osnova za nove spremembe Uredbe o podporah električni energiji pridobljeni iz OVE.

RAZVOJ MIKRO IN MALIH BIOPLINSKIH NAPRAV

Država Slovenija oziroma Ministrstvo za gospodarstvo načeloma podpira gradnjo mikro in malih bioplinskih naprav z višjimi odkupnimi cenami za elektriko proizvedeno na mikro in malih bioplinskih napravah. Kljub temu je v Sloveniji do sedaj le ena majhna bioplinska naprav in sicer na kmetiji Flere z velikostjo 270 kW_e. Glede na trenutne investicije, ki potekajo na področju bioplina se predvideva, da bo segment relativno velikih bioplinskih naprava velikost reda 1 MW_e hitro zapolnjen. Nato pa bodo sledile investicije v manjše bioplinske naprave. To je nekako logično tudi zaradi velikostne strukture slovenskih kmetij. Ta je relativno majhna, povprečna velikost znaša 6,3 ha. Ravno zaradi te velikostne strukture se bodo tudi na področju bioplina morala vzpostaviti različne oblike partnerstev.

PARTNERSTVA

Nekatere od obstoječih bioplinskih naprav so samozadostne pri zagotavljanju vhodnih substratov in načeloma same skrbijo za kvaliteto in količino potrebne biomase. V osnovi ne potrebujejo posebnih partnerjev za zagotavljanje osnovnih substratov. Dobave substratov so le bolj kot dopolnila za boljši izplen bioplina (npr. glicerin, kot stranski proizvod pri proizvodnji biodizla v tovarni PINUS Rače). Pri dobavi glicerina gre za tako imenovani tehnični glicerin, kjer je več kot 50 % glicerina, po navadi pa med 82 in 88 %. Načeloma gre v tem primeru za letne pogodbe oziroma naročila. Ker imajo v osnovi na voljo dovolj površin za pridelavo kmetijske biomase, potem načeloma tudi ni ovir za raztros predelanega substrata, kot gnojila na njihovih obdelovalnih površinah.

Slika 2 Bioplinska naprava Petač velikosti 1 MW_e se nahaja v Zgornjih Pirničah pri Ljubljani

Obstajajo tudi bioplinske naprave, ki si substrate morajo deloma ali večji del zagotoviti od drugih dobaviteljev kmetijske biomase. V primeru, da substrat bioplinskim napravam dobavljajo kmetje (predvsem gnojevko ali energetske rastline, npr. koruzo) potem med lastnikom in ponudniki substrata običajno ni kakšnih pisnih pogodb (veljajo ustni dogovori). Vprašanje pa je, kaj se zgodi, ko tak dogovor ni več ustrezen za eno od pogodbenih strank. Običajno se pri omenjenih dogovorih tudi ne spremlja vseh potrebnih parametrov, ki določajo pravilno razmerje med strankami. Tako partnerstva bi morala biti vzpostavljena preko dolgoletnih pogodb, kjer morajo biti definirani številni parametri (kot so kvaliteta substrata, usklajevanje cen itd.). Le s takim načinom pogodbenega partnerstva imata obe strani (ponudnik in kupec biomase) zadovoljiv medsebojni odnos, saj so definirani (in v naprej določeni) medsebojni odnosi. V primeru, da se substrat nabavlja od drugih pravnih oseb, potem je ta medsebojni odnos med dobaviteljem substrata in lastnikom bioplinske naprave rešen pogodbeno.

Marca 2010 je bil v Mariboru ustanovljen GIZ Bioplin, s celim imenom «Proizvajalci električne energije bioplinskih elektrarn, gospodarsko interesno združenje». V njem so vključene že deluječe bioplinske naprave ali pa bioplinske naprave v končnem stadiju gradnje enega od največjih ponudnikov bioplinske tehnologije v Sloveniji. Ena izmed nalog GIZ Bioplin bo tudi usklajevanje na področju zagotavljanja substratov za svoje članice (kakovost substrata, cena substrata).

ZAKLJUČEK

Na področju kmetijskih bioplinskih naprav je Slovenija v zadnjih letih doživela razcvet kljub gospodarski recesiji. Zasluga je v državnih podporah obnovljivim virom energije, kamor spada tudi elektrika proizvedena iz bioplina. Te podpore morajo biti stalne na daljše obdobje, rigorozne spremembe kot so bile v letu 2010 pa zmanjšujejo interes investitorjev v bioplinske naprave. Po novih študijah je kmetijski potencial za proizvodnjo bioplina v Sloveniji za 86 MW_e, ne da bi bistveno posegali v primarno kmetijsko pridelavo. Po scenariju kjer je za kmeta bolj ugodno prodati pridelek bioplinskim napravam pa za 147 MW_e. Glede na posestno strukturo v Sloveniji se bodo slej ali prej začele graditi tudi manjše bioplinske naprave, kjer bodo za njihovo uspešno delovanje zlasti pomembna vzpostavljena partnerstva pri zagotavljanju substratov.

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DEVELOPMENT ON THE FIELD OF AGRICULTURAL BIOGAS PLANTS IN SLOVENIA

ABSTRACT

The number of biogas plants in Slovenia recently increase mainly due to relatively favorable system of buying electricity produced from biogas. Rigorous change in support for biogas can significantly reduce the interest of investors in construction. In coming years we expect the development of small biogas plants. For the successful operation of them the different partnerships will be established.

Key words*: biogas, biogas plants, state, support, small-scale biogas plant, partnership, Slovenia*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

A STUDY ON THE DETERMINATION OF ANIMAL-BASED BIOGAS ENERGY POTENTIAL OF TURKEY

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ABSTRACT

Energy is the basic input of social and economic development in Turkey and throughout the world. Global energy need is gradually increasing with population growth and industrialization. The widespread use of renewable energy sources in meeting this need is of great importance in economic and environmental terms. Due to its advantages of sustainability, availability and environmental friendliness, animal and plant based biogas production has been analyzed intensively in recent years.

This study determined the number of large ruminants, small ruminants and poultry animals within Turkish provinces in 2009. Animal based biogas potential was calculated and the current status of this technology was analyzed. The electrical energy and natural gas energy equivalent of biogas production potential for 2009 was determined. It was found that 9.4% of total electrical consumption and 4.4% of natural gas consumption of Turkey could be supplied from biogas. In addition, the animal based biogas potential of Turkey during the last 19 years was determined and, based on this data, future biogas potential was analyzed.

Key words: *biogas, animal, churn*

INTRODUCTION

Global energy requirements are increasing in parallel with human development. This increase in energy need has led some international organizations and companies to make research in energy production, energy efficiency and new energy sources. Recent studies indicated that fossil energy sources will be exhausted by the year 2030 (Kaya, 2006; Tricase and Lombardi 2009). The distribution of energy utilization in the world according to types of energy is given in Figure 1 (Anon, 2008).

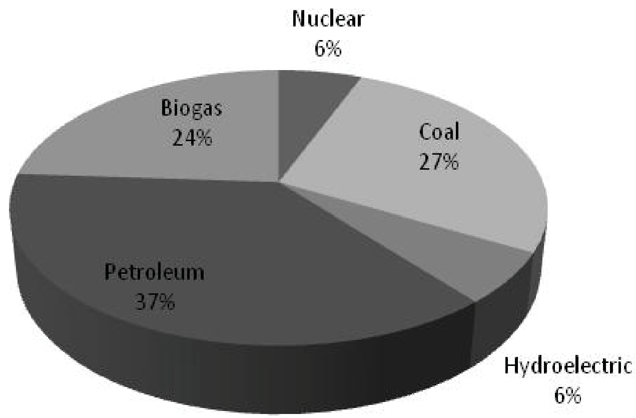

Figure 1 Global Energy Utilization according to Types of Energy

The fact that fossil energy sources are non-renewable and the high cost of investment in renewable energy sources such as wind, solar, hydraulic and geothermal etc. suggests that biogas should be utilized as a source of energy. Biogas is produced by the breakdown of organic matter (manure, plants, waste, food waste, chemical wastes) under anaerobic conditions as a result of biochemical fermentation and microbiological activity. Biogas is a mixture of inflammable gas, composed of 40–75% CH_4, 25–40% CO_2, 1-3% H, 0.5-2.5% N, and 2% H_2S, O, NH_3, and CO. Biogas has a calorific value of 20 MJ/m^3 and is 20% lighter than air (Salomon and Lora, 2009).

In many countries, biogas facilities are built using different technologies, according to the planned objective. There are three types of biogas facilities: family type (6–12 m^3 capacity), farm type (50–150 m^3 capacity) and village type (100–200 m^3 capacity). In developing countries, biogas may account for up to 38% of energy use. In China, resident-type bioreactors produce 2 billion m^3 of biogas per year and a total of 25 million people use the gas supplied by biogas facilities for a significant part of the year. China has 800 biogas facilities, capable of producing 7800 kWh of electricity. 80% of the facilities established for obtaining biogas from animal waste are located in China, and 10% are located in India.

Germany is one of the countries which use biogas technology most efficiently. Germany had a total of 850 facilities in 1999, due to incentives implemented by the government; by the year 2006, the number of facilities increased to 3500 and currently stands at 4000. The majority of these facilities first refines the biogas and then uses the produced biogas for electricity production. Germany plans to increase the number of biogas facilities to 43000 by the year 2020. There are more than 70 facilities in Russia and around 30 facilities in Kazakhstan. In addition, small sized (3-10 m^3) resident-type biogas facilities are also used in Russia. There are approximately 75 biogas facilities in England. The volume of biogas facilities designed in developed countries is gradually increasing (Deublein and Steinhauser, 2008; Turker, 2008).

Biogas potential, production and utilization have been analyzed by many researchers. Heegde and Sonder. (2007) analyzed resident-type biogas facility potential and need in Africa and determined the technical biogas potentials of African countries. Lantz et al.

(2007) determined future potentials of biogas facilities in Sweden and evaluated the political barriers against establishment of these facilities. To analyze biogas production potential from cotton waste, Isci et al. (2008) determined the methane production potential of three different cotton wastes (cotton stalk, cotton seed shell and cotton pulp) and found that cotton waste has significant effects on biogas production. Omer et al. (2002) evaluated biogas technologies in Sudan in ecological, social, cultural and economic terms, and emphasized that biogas facilities should be encouraged, particularly in rural areas. Igone et al. (2008) designed an anaerobic digester to enhance biogas production performance from solid waste and found that biogas production increased.

This study analyzes potential animal waste based biogas production and the amount of energy that may be obtained in Turkey. Firstly, the number of large ruminant (cattle, horse, donkey, and camel), small ruminant (sheep, goat) and poultry (hen, turkey, goose, duck) animals was determined, for each province, for the year 2009. Then, potential biogas production, depending on type of animal, was determined for regions. Energy potential was determined based on the biogas amount, and animal waste based biogas production potential was analyzed In addition, by determining the biogas potential in Turkey between the years 1991-2009, the changes in biogas potential in the past and possible changes in the future were interpreted and suggestions were made.

MATERIAL AND METHOD

The material of the study consisted of data on the number of large ruminants, small ruminants and poultry animals in 81 provinces of Turkey in the year 2009. These figures were obtained from The Ministry of Agriculture and Village Affairs, Provincial Directorate of Agriculture. Animal potential of Turkey between the years 1991-2008 was obtained from the Turkey Statistical Institute. Based on the obtained data, the biogas capacity of Turkey for these years and future potential was evaluated and suggestions were made.

The following figures were used to calculate the amount of manure produced: 10-20 kg/day (wet) manure yield or 5-6% of live weight for large ruminants; 2 kg/day (wet) manure or 4-5% of live weight for small ruminants; 0.08–0.1 kg/day (wet) or 3-4% of live weight for poultry. According to another approach, the amount of manure obtained from the animals varies according to the type of animals (Berkes and Kislalioglu, 1993; Kocer et al. 2006).

According to this data:

- 3.6 ton/year wet manure is produced from 1 Large ruminant.
- 0.7 ton /year wet manure is produced from 1 small ruminant.
- 0.022 ton/year wet manure is produced from one poultry animal.

Based on these values,

- 1 ton of cattle manure produces 33 m^3/year biogas,
- 1 ton of sheep manure produces 58 m^3/year biogas,

1 ton of poultry manure produces 78m^3/year biogas (Berkes and Kislalioglu, 1993; Kocer et al. 2006).

RESULTS AND SUGGESTIONS

To determine the biogas potential of Turkey according to regions, the number of large ruminant, small ruminant and poultry animals in 81 provinces of Turkey were determined. These figures were supplied form the Provincial Directorate of Agriculture. The data was interpreted according to regions and the number of animals is presented in Figures 2-4.

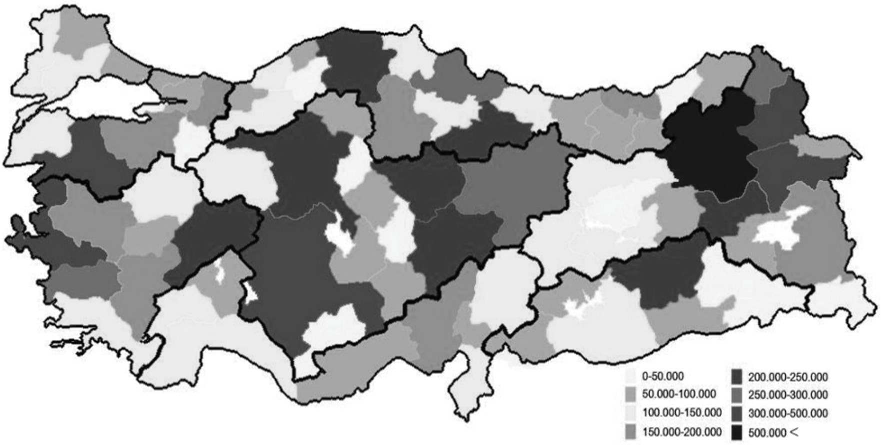

Figure 2 Large Ruminant Potential of Turkey according to Provinces

Figure 3 indicates number of large ruminant in Turkey according to regions. The data indicates that 24% of large ruminants in Turkey are in Eastern Anatolia Region. 18% of the animals are in the Black Sea Region and 16% of the animals are in the Central Anatolia Region. The Southeastern Anatolia Region has the lowest number (6%) of animals among all the regions.

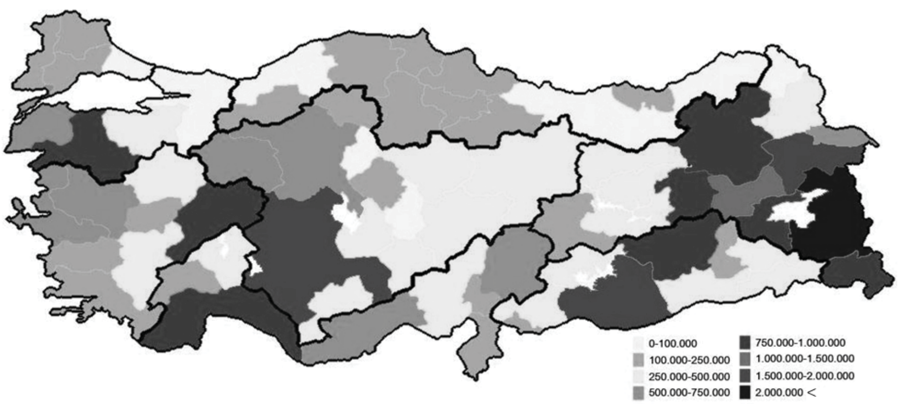

Figure 3 Small Ruminant Potential of Turkey according to Provinces

Figure 3 indicates the number of small ruminants according to the regions of Turkey. From the figure, it can be seen that 33% of small ruminants are within the Eastern Anatolia Region. This region is followed by the Central Anatolia Region (17%) and Southeastern Anatolia Region (16%), respectively. The Black Sea Region had the lowest number of small ruminants.

Figure 4 shows number of poultry animals in Turkey according to regions. The Figure indicates that, 36% of all poultry animals are within the Marmara Region. This region is followed by the Black Sea (23%) and Aegean (16%) regions, respectively. The Southeastern Anatolia Region had the lowest number (2%) of large ruminants

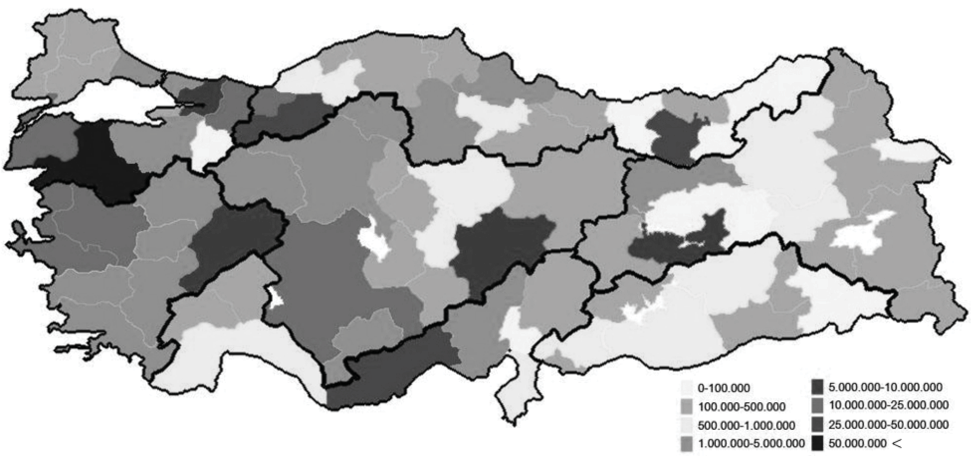

Figure 4 Poultry Animal Potential of Turkey according to Provinces

Table 1 Animal Based Biogas Potential of Turkey

Regions	Large ruminant Animal based Biogas Potential (m^3/year)	Small ruminant Animal Based Biogas Potential (m^3/year)	Poultry Animal Based Biogas Potential (m^3/year)
Mediterranean	104.397.665	131.179.905	56.119.845
Eastern Anatolia	310.963.940	454.047.590	18.994.235
Aegean	186.875.620	135.978.195	93.071.715
Southeastern Anatolia	77.214.290	192.347.335	65.953.310
Central Anatolia	221.206.790	221.309.720	54.426.245
Black Sea	242.472.420	61.971.160	138.494.140
Marmara	165.238.420	107.652.370	201.395.685

Based on the number of animals given in Figures 2-4, the annual biogas potential that can be obtained from the wastes of large ruminants, small ruminants and poultry animals, are shown in Table 1.

Table 2 shows annual electric energy consumption and electrical energy equivalent which can be obtained using biogas energy and the proportion of biogas potential in electrical energy. The biogas energy potential of Eastern Anatolia Region corresponds to 72.7% of total electric consumption. This Region is followed by Black Sea (17.3%) and Southeastern Anatolia (5.8%) regions. Among the regions, Marmara Region has the lowest biogas energy potential. It was found that although the electric energy equivalent of biogas energy potential of Marmara Region is high, it corresponds to 3.5% of the total, due to high electricity consumption in the region.

Table 2 Electricity Consumption and Biogas Potential of Turkey

Regions	Electricity Consumption Amount (MWh/year) 14]	Electric Energy Equivalent of Total Biogas (MWh/year)	The Ratio of Biogas Potential in Electric Consumption (%)
Mediterranean	21.434.383	1.370.940	6.4
Eastern Anatolia	5.068.562	3.684.675	72.7
Aegean	27.182.333	1.953.845	7.2
Southeastern Anatolia	9.930.688	1.576.800	15.8
Central Anatolia	22.131.446	2.335.270	10.5
Black Sea	12.014.146	2.081.595	17.3
Marmara	63.639.985	2.229.055	3.5

Natural gas consumption of Turkey during the year 2008 was 36 billion m^3. The total biogas potential of Turkey was 3.24 billion m^3/year, which is equal to 2.04 billion m^3/year of natural gas. The electrical energy equivalent of the determined biogas potential was 15.232.180 MWh/year. This value can meet 4.4% of total natural gas consumption of Turkey. In addition, the biogas potential of Turkey is equal to the energy produced from 2.78 million ton/year of coal; 11.24 million ton/year of wood; 2.13 million m^3/year diesel of or 2.43 million m^3/year of petrol.

Figure 5 indicates the annual biogas potential of Turkey between the years 1991-2009. The significant decrease shown in the number of large ruminants and small ruminants between the years of 1991-2003 resulted in almost a 25% decrease in 3.89 m^3/year biogas potential to 2.99 billion m^3/year. Between the years 2003-2006, the number of large ruminants increased by 2.5%; poultry animals increased by 6% and the number of poultry animals remained approximately constant. Accordingly, biogas potential increased by approximately 5.5%. As indicated in Figure 5, if the observed change in Turkey's biogas potential continues, this potential will decrease significantly in the future.

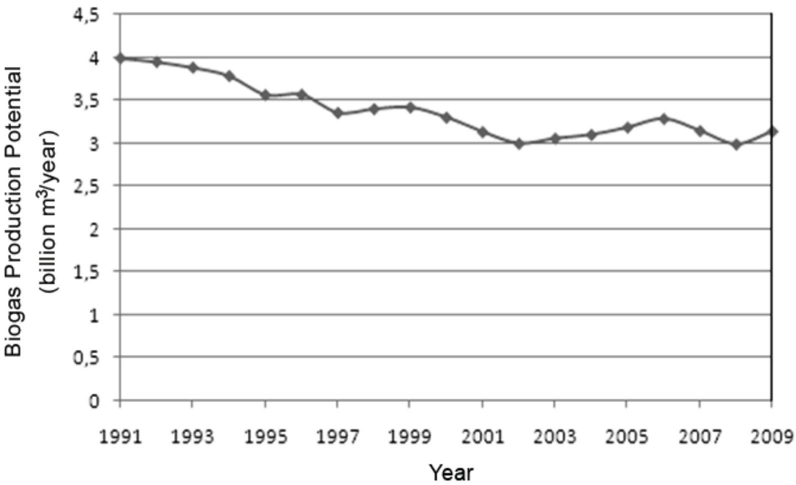

Figure 5 Change in Biogas Production Potential of Turkey

RESULT

In meeting Turkey's general energy needs, maximizing the use of renewable energy sources will provide a considerable amount of energy input. Obtaining biogas from biomass is technically feasible and has significant potential. Therefore, it is a form of energy that can be used in the regions which need energy. However, the changes observed in Turkey's biogas potential between the years 1991-2009 indicates that, in future, this potential may decrease significantly.

Studies should be carried out to establish biogas facilities, particularly in the regions where animal husbandry is common, and to make use of the significant biogas potential of Turkey. Furthermore, it should be taken into account that the amount of high-quality manure be obtained after biogas production was 5.740.711 tons for the year 2009, and this by-product can be used effectively in agricultural areas.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

ENERGETSKE KULTURE I KRMNI KOMBAJN

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SAŽETAK

U 21. stoljeću proizvodnja biomase kao energenta pokazuje sve značajniju tendenciju porasta. Veći udio energetskih usjeva u proizvodnji bioplina, rast broja bioplinskih postrojenja, razvoj biogoriva druge generacije dobivenih iz lignoceluloznih materijala, primjena biomase brzorastućeg drveća kao goriva postavljaju nove tehničke zahtjeve proizvođačima krmnih kombajna, pa stoga i utječu na korištenje i razvoj krmnog kombajna. Osnovne značajke razvoja su: povećanje snage motora, radnog zahvata hedera a samim time i mase krmnog kombajna. Za manju duljinu sječke potrebni su bubnjevi-sječkare posebne izvedbe, s većim brojem noževa. Podizanje energetskih nasada brzorastućeg drveća, odnosno kultura kratke ophodnje – KKO na poljoprivrednim površinama dobiva sve veći značaj. Za ubiranje-sječu vrba i topola koristi se standardni krmni kombajni s posebnim hederom za KKO koji ima dvije ili jednu kružnu pilu.

Ključne riječi: *energetski usjev, brzorastuće drveće, krmni kombajn, tzv. bioplinski bubanj-sječka, heder za KKO*

UVOD

U Europi je poslijednjih dvadesetak godina vidljiv značajan porast korištenja biomase kao izvora energije. Posebno je to izraženo u proizvodnji bioplina procesom anaerobne digestije. Osim što biogoriva dobivena iz biomase mogu zamijeniti fosilna goriva, njihovo korištenje ublažuje efekt staklenika, jer za rast koriste postojeći ugljični dioksid iz atmosfere, a pri izgaranju u atmosferu emitiraju ”isti” CO_2. Uz povećanje potreba za biomasom kao energentom, povećava se i potreba za biomasom kao hranom. Naime, intenzivnije korištenje zrna žitarica i uljarica u proizvodnji biogoriva uzrokuje rast cijene hrane za ljude i životinje, prenamjenu zemljišta, a stvara i ozbiljan etički konflikt spram gotovo 1/3 svjetske populacije gladnih. Pretpostavka je da će u narednom periodu rasti značaj proizvodnje i pretvorbe biomase u energiju i to one koja nije izravno namijenjena ljudskoj prehrani. EU u 2020. godini planira 20% udjela iz obnovljivih izvora od ukupno proizvedene energije, a sredinom stoljeća očekuju povećanje na čak 50%. Royal Commission on Environmental Pollution (RCEP) u svojem dvadeset drugom izvještaju iz 2000. godine zauzima se za značajno smanjenje emisije stakleničkih plinova u UK do 2050. godine u čemu bi značajnu ulogu imala biomasa biljnog podrijetla kao izvor energije. Takva strategija podrazumijeva prenamjenu značajnijeg dijela poljoprivrednog zemljišta i u UK se u te svrhe planira do 2020. godine doseći proizvodnja energetskih usjeva na 1.000.000 ha, a do 2050. godine na 5.500.000 ha (Royal Commission on Environmental Pollution, 2004). Prema podacima iz 2007. godine to je oko 30% od korištenih poljoprivrednih površina u UK kojih je oko 17.500.000 ha od čega su 6.000.000 ha oranice. Prema procjenama Europske udruge za biomasu (European Biomass Association - AEBIOM) od 20 do 40 Mha (milijuna hektara) zemljišta u EU27 bi se moglo koristiti za proizvodnju energije, bez utjecaja na opskrbu hranom u EU (Al Seadi at al., 2008). EU27 ima oko 190 Mha korištenih poljoprivrednih površina od čega su 108,6 Mha oranice, a u 2007. godini je 4,0 Mha oranica bilo zasijano energetskim usjevima od kojih je s gotovo 3,0 Mha dominirala uljana repica. Za 2020. godinu se planira proizvodnja energetskih kultura na 20 Mha, od čega bi na 15 Mha bio uzgoj usjeva za proizvodnju tekućeg biogoriva, na 3 Mha uzgoj usjeva za proizvodnju bioplina (kukuruz, trave itd.) i na 2 Mha proizvodnja čvrste biomase (vrba, kineski šaš itd).

POTENCIJALI ENERGETSKIH KULTURA

Biomasa, kao skraćenica pojma biološka masa predstavlja biorazgradivi dio proizvoda, otpada i ostataka proizvedenih u poljoprivredi (uključujući tvari biljnoga i životinjskoga podrijetla), šumarstvu i srodnim industrijama, kao i biorazgradivi dio industrijskoga i komunalnoga otpada. Biljke proizvedene i namjenjene isključivo kao izvor energije definiraju se kao energetski usjevi, odnosno energetski nasadi i to mogu biti jednogodišnje biljke (vrste iz porodice trava, kukuruz i dr.) ili višegodišnji nasadi drvenastih kultura (vrba, topola i dr.). Poželjno je da su im što niži troškovi proizvodnje, visoki prinosi s manjim sadržajem vode, dobre karakteristike kao biogorivo (energetska vrijednost i iskoristivost) i da su bezopasne za okoliš.

Bioplin kao biogorivo prve generacije proizvodi se iz animalnih ekskremenata-gnoja, organskog otpada i energetskog usjeva. Weiland (2006) navodi da je u Njemačkoj u proizvodnji bioplina udio energetskih usjeva bio iznad 46%, a životinjskog gnoja oko 24%. Porastom broja bioplinskih postrojenja povećavaju se zahtjevi u proizvodnji energetskih usjeva, kako u količini tako i raznolikosti. Za proizvodnju bioplina pogodne su biljke bogate lako razgradivim ugljikohidratima, kao što su šećer i proteini, a s manjim sadržajem slabo razgradive hemiceluloze i lignina. Kao sirovina za proizvodnju bioplina koristi se pšenica (*Triticum aestivum* (L) *em.* Fiori et Paol.), kukuruz (*Zea mays* L.), sirak (*Sorghum bicolor* (L.) Moench), uljana repica (*Brassica napus* L. (Partim)), različite vrste trava (*Poaceae, Gramineae)*, djetelina (*Trifolium*) i ostale kulture, kao i sve vrste poljoprivrednih ostataka. Drvenaste kulture koje imaju visok sadržaj lignina, celuloze i hemiceluloze mogu se koristiti u anaerobnoj digestiji za proizvodnju bioplina, no potrebno ih je prethodno obraditi radi povećanja mogućnosti digestije.

Najčešće se uzgajaju žitarice od kojih se i dobiva najveća količina bioplina, također se silira lucerna (*Medicago sativa* L.), konoplja (*Cannabis sativa* L.), čičoka tj. jeruzalemska artičoka (*Helianthus tuberosus* L.). Lucerna ima dobar potencijal za proizvodnju metana u procesu anaerobne digestije i to uz manji utrošak energije za uzgoj spram dobivene električne energije. Silirana biljna masa daje veću količinu bioplina s većim volumnim udjelom metana u odnosu na svježe ubranu i nesiliranu masu. Količina metana ovisi o trenutku ubiranja, sadržaju vode, vrsti kulture i siliranju, zato treba postići dobar kompromis između visine prinosa (sadržaja suhe tvari) i kvalitete usjeva.

Proizvodnja električna energija iz bioplina stvara manju emisiju stakleničkih plinova u odnosu na proizvodnju iste količine električne energije iz fosilnih goriva. Osim emisije stakleničkih plinova treba razmotriti i količinu energije potrebnu za proizvodnju, transport i skladištenje energetskih usjeva. Proizvodnjom električne energije iz bioplina dobiva se više energije u odnosu na energiju potrebnu za uzgoj energetskih usjeva koji se koriste u anaerobnoj digestiji bioplinskog postrojenja. Velika količina te energije može se racionalizirati korištenjem digestata iz bioplinskih postrojenja umjesto mineralnog gnoja, pošto energija potrebna za proizvodnju mineralnog gnoja zauzima i do 80% od ukupno utrošene energije u uzgoju bioplinskih energetskih usjeva (Plöchl at al., 2009).

Blještac (*Phalaris arundinacea* L.), kukuruz (*Zea Mays* L.) zasijan sa suncokretom (*Helianthus annuus* L.) ili bijela slatka lupina (*Lupinus albus* L.) s ječmom (Hordeum vulgare L.) su isto zastupljeni kao energetski usjevi Od C_4 biljaka podrijetlom iz podneblja s visokim temperaturama kao energetski usjev najpoznatiji je kukuruz, koristi se kineski šaš tj. rogoz (*Miscanthus x giganteus* Greef et Deu.) s kojim su pokusi za potrebe proizvodnje bioenergije započeli 1983. godine u Danskoj, zatim u Njemačkoj 1987. godine, a potom se proširili Europom (Huisman, 2003), uzgaja se sudanska trava (*Sorghum sudanense* (Piper) Stapf.), divlji proso (*Panicum virgatum* L.) i ostale kulture.

Druga faza razvoja biogoriva, definirana EU Strategijom o biogorivima (2006) u okvirima srednjoročnog razvoja za period 2010. – 2020. godine navodi slijedeće ciljeve:

- proizvodnja biogoriva druge generacije,
- izrada koncepta biorafinerije,
- istraživanja biogoriva druge generacije iz lignoceluloznih materijala,
- razvoj energetskih kultura i održive poljoprivrede.

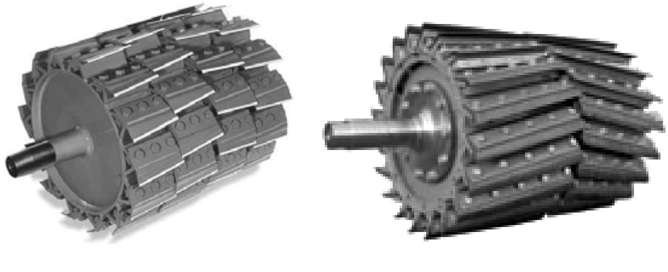
Biogoriva druge generacije kao što su sintetska biogoriva, celulozni bioetanol, prirodni sintetski plin (SNG) i biovodik koriste kao sirovinu lignocelulozni materijal (LCM), te se mogu koristiti sirovine koje nisu namijenjene ljudskoj ishrani. Intenzivno se istražuje proces prevođenja čvrste biomase u tekuću, tzv. BtL (Biomass to Liquid) i očekivanja industrije su velika, no vrijeme dovođenja na razinu primjenljivosti u praksi se stalno odgađa (Martinov at al., 2010). Za BtL kao sintetsko biogorivo veliki je izbor sirovina, od drveta, brzorastućog drveća (topola ili vrba) preko slame do cijelih biljaka žitarica ili trava (Krička at al., 2007). Lignocelulozni materijal za proizvodnju celuloznog bioetanola mogu biti brzorastuće drvenaste kulture, ostaci kukuruznih biljaka nakon žetve i sl. (Jukić at al., 2007). Biorazgradiva plastika kao ambalaža postaje sve interesantnija, tako je u Europi smješteno 60% proizvodnje biopolimera. Japanska vlada je donijela plan (Biomass Nippon Strategy) po kojem do 2020. godine iz obnovljivih izvora energije mora biti proizvedeno 20% plastike korištene u Japanu (Živković, 2009). Izvor ugljika u proizvodnji biopolimera mogu biti i sirovine iz poljoprivrede, šumarstva i drvne industrije kao što su lignocelulozni materijali ili škrob. Kod lignoceluloznog materijala problem je skuplji postupak hidrolize i njegova voluminoznost koja uzrokuje veće troškove u transportu, dok je kod škroba upitno korištenje ljudske hrane u proizvodnji biopolimera. Razvojem se očekuje konkurentna cijena i šira primjena biopolimera.

Republika Hrvatska spada u zemlje s velikim potencijalom biomase, raspolaže s 2.688.687 ha šuma i šumskog zemljišta, te 2.955.728 ha poljoprivrednih površina od kojih je 806.328 ha trajno nepogodno za poljoprivrednu proizvodnju (Tomić at al., 2008). Cilj je povećati prinos i obradive površine zasijane poljoprivrednim kulturama koje su sirovina za proizvodnju biogoriva. Za cilj je postavljeno podmirivanje potrošnje biogoriva u 2020. godini iz vlastitih sirovina. Od 2.150.000 ha potencijalno obradivih površina u Hrvatskoj čak je 947.080 ha neiskorišteno gdje bi se uz primjenu manje ili više intenzivnih melioracijskih mjera na jednom dijelu mogao proširiti uzgoj poljoprivrednih kultura za proizvodnju hrane i biogoriva (Tomić at al., 2008). Hrvatska također raspolaže s 181.659 ha neobraslog proizvodnog šumskog zemljišta koje bi se u jednom dijelu moglo iskoristiti za podizanje energetskih nasada s brzorastućim drvećem (Matić, 2007).

KRMNI KOMBAJN
RAZVOJ I PRILAGODBE ZA ENERGETSKE USJEVE-KULTURE

Povećanjem proizvodnje različitih energetskih usjeva odnosno nasada, povećava se i značaj krmnog kombajna. Kontinuirani rast prodaje krmnih kombajna na njemačkom tržištu se tijekom 2007./2008. godine nastavio, prvenstveno zbog porasta proizvodnje kukuruza za potrebe bioplinskih postrojenja. Prema podacima VDMA Fachverband Landtechnik (2009) prezentirani grafikonom u Jahrbuch Agrartechnik (2010) prodaja krmnih kombajna u sezoni 2002./2003. godine je bila iznad 300 komada da bi u sezoni 2007./2008. godine porasla na preko 500 komada. Njemačko tržište krmnih kombajna je najveće tržište u Europi s udjelom od 40%. (Brüser, 2008).

Korištenje travne silaže za bioplinska postrojenja uvjetuje manu duljinu sječke i u nekim slučajevima korištenje krmnih kombajna sa specijalnim tzv. bioplinskim bubnjevima koji s većim brojem noževa osiguravaju kraću duljinu sječke. Ovisno o proizvođaču, najveći broj noževa na bubnju je u rasponu 32 (2x16) - 56 (4x14), dajući najmanju duljinu sječke od 3,0 mm (tablica 1 i sl. 1).

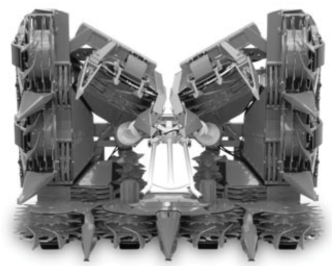


Sl. 1 Bubanj s 56 nožava (4x14) proizvođača John Deere (lijevo) i bubanj s 40 noževa (2x20) proizvođača Krone (desno)
Fig. 1 Drum with 56 knives (4x14) from John Deere (left) and drum with 40 knives (2x20) from Krone (right)

Trend je povećanja radnog zahvata krmnog kombajna kao i snage motora, što uzrokuje povećanu masu strojeva a samim time i veće osovinsko opterećenje (tablica 1). U tom smislu rješenje je u smanjivanju mase konstrukcije kombajna i izvedbi hedera koji rasterećuju stražnju ili prednju osovinu položajem težišta ili primjenom potpornog kotača (sl. 2) što omogućuje cestovni prijevoz s 40 km/h gdje je ograničen osovinskim opterećenjem (Wiedermann, 2010).

Tablica 1 Tehnički podaci samokretnih krmnih kombajna velike snage motora
Table 1 High engine power self-propelled forage harvesters specifications

Opis/Model	Claas Jaguar 980	John Deere JD 7950 SAEJ 1995	Krone BiG X 800 i 1000	New Holland FR 9090
Najveća snaga motora (kW)	610	597	607 750	606
Najveći radni zahvat beračkog uređaja-hedera:				
- univerzalni (br. red./m)	12 / 9,0	12 / 9,0	14 /10,5	10 / 7,5
- pickup (m)	3,8	4,5	3,8	3,0
- diskosna kosilica (m)	6,1	5,6	6,2	5,5
Bubanj:				
- širina (mm)	750	830	800	900
- promjer (mm)	630	805	600	710
- najveći br. noževa	36	56	40	32
- način postavljanja noževa	2x18	4x14	2x20	2x16
- najmanja duljina sječke s najvećim br. noževa (mm)	3,0	4,0	3,5	3,0
Masa (kg)	13.180	14.550	14.800 14.900	13.100




Sl. 2 Kemper Champion 375 heder (lijevo), krmni kombajn Claas Jaguar s beračkim uređajem za kukuruz ORBIS 900 s potpornim kotačem (desno)
Fig. 2 Kemper Champion 375 header (left), forage harvester Claas Jaguar and maize header ORBIS 900 with a support wheel (right)

Bitna značajka kombajna je i usavršeni sustav istovremenog mjerenja protok mase i njenog sadržaja vode, odnosno sadržaja suhe tvari, a što omogućuje podešavanje optimalne duljine sječke s obzirom na uvjete ubiranja. Proizvođači u razvoju kombajna također poklanjaju veliku pažnju smanjenju vremena potrebnog za održavanje i popravak strojeva, što omogućuje nadzorno-upravljački elektronički sustav kombajna.

Pretovar ubrane biomase

U ukupnoj emisiji stakleničkih plinova nastalih u proizvodnji energetskih usjeva za proizvodnju bioplina transport je zastupljen s 5%, pod pretpostavkom da je udaljenost do silosa 10 km, u slučaju kada ta udaljenost iznosi 100 km, udio transporta u emisiji stakleničkih plinova može iznositi trećinu od ukupne emisije plinova (Plöchl at al., 2009). Koncept pretovara može povećati učinak transporta veće količine biomase s polja na udaljenija mjesta skladištenja, odnosno siliranja. Takvim postupkom se odvaja silažni lanac „krmni kombajn - prikolica" od daljnjeg transporta s polja i tako ga čini neovisnim. U primjeni su dva sustava od kojih se u prvom ubrana i usitnjena biomasa silažnim prikolicama istovaruje na rub polja gdje daljnji pretovar u velike prikolice obavlja poseban stroj. Utovarni kapacitet stroja ROPA NawaRo-Maus (sl. 3) je od 10 do 15 m^2 u minuti, a pužnica koja izuzima biomasu s polja ima radni zahvat od 8 m. U drugom sustav je direktni pretovar iz silažnih prikolica u velike prikolice uz rub polja, a bez istovara na polje. Navedene koncepcije pretovara biomase s polja u velike cestovne prikolice zasada nemaju veći značaj (Wiedermann, 2010).

Kod silažnih prikolica se osim povećanja utovarnog kapaciteta proširuje i njihova primjena, tako se izvedbe s prednjim pick-up uređajem koriste i kao samoutovarne prikolice. Povećanje utovarnog kapaciteta se ne ostvaruje prvenstveno povećanjem volumena prikolice već i sustavom sabijanja utovarene silažne mase, odnosno povećanjem njene gustoće.

Sl. 3 ROPA NawaRo-Maus stroj za pretovar krme s polja u velike prikolice
Fig. 3 ROPA NawaRo-Maus machine for loading silage from field to trailers

BRZORASTUĆE DRVEĆE I SJEČA KRMNIM KOMBAJNOM

Podizanje energetskih nasada brzorastućeg drveća na poljoprivrednim površinama dobiva na značaju kao alternativa (Brüser, 2008). Na sjeveru Italije poljoprivrednici se sve više usmjeruju prema energetskim usjevima i osnivanju plantaža brzorastućeg drveća koje se sijeku prilagođenim krmnim kombajnima (Spinelli at al., 2008). Intenzivni uzgoj brzorastućih vrsta drveća poput vrbe (*Salix* L.), topole (*Populus* L.), johe crne (*Alnus glutinosa* L.), breze (*Betula pendula* Roth.), bagrema (*Robinia pseudoacacia* L.) i dr. poznat je pod nazivom „kulture kratke ophodnje“ - KKO, odnosno engl. SRC (Short Rotation Coppice/Crop/Culture) ili SRF (Short Rotation Forestry). Tehnologija ubiranja i sagorijevanja brzorastućeg drveća je poznata, u Njemačkoj je u pravilu to visokovlažni iver, primjenljiv samo u velikim postrojenjima (Martinov at al., 2010).

Specifičan način uzgajanja drveća u pravilnom rasporedu na kultiviranom tlu sličniji je uzgoju poljoprivrednih kultura nego klasičnom šumarstvu, te se primjenjuje i na poljoprivrednom zemljištu (Christhersson and Senneby-Forsse, 1994). Brzorastuće vrste drveća mogu biti i zamjena za uzgoj poljoprivrednih kultura na površinama gdje poljoprivredna proizvodnja nije rentabilna odnosno na lošijim staništima, npr. na „podvodnim“ tlima koja treba meliorirati. Brzorastuće drveće također, pridonosi raznolikosti u uzgoju kultura na poljoprivrednom zemljištu, a može se koristiti za pročišćavanje otpadnih voda i tla, kao i vezivanje povećane količine atmosferskog ugljika. Ova proizvodnja je manje zahtjevna spram konvencionalnih kultura, a uz značajno smanjeno korištenje pesticida, ekološke prednosti su i veća zastupljenost insekata, ptica itd. Neki od nedostataka su veći troškovi u podizanju nasada i sječi, skladištenju i mogućem dodatnom sušenju biomase, i tek se nakon par godina ostvaruje financijska dobit.

Najčešći je uzgoj vrba i topola koje se sijeku svake druge do pete godine ili nakon svake treće do osme godine, zatim izbijaju novi izbojci koji se opet sijeku nakon istog intervala. Poslije šest do osam ophodnji (razmak između sječe) produkcija biomase opada i nasad je potrebno iskrčiti i zamijeniti novim sadnim materijalom, što može biti i nakon 30 godina.

Gustoća sadnje varira od 10.000 do 20.000 biljaka po hektaru, a razmak sadnje se prilagođava strojevima za ubiranje. U Europi je uobičajena sadnja u dvostrukim redovima s razmakom od 75 cm između redova, te razmakom od 150 cm između dvostrukih redova, a razmak unutar reda varira od 50 do 57 cm (Handler and Blumauer, 2010). Nakon osam godina promjer stabla je od 10 do 15 cm, a visina može biti do osam i više metara. Prinosi su različiti, a ovise o starosti nasada, tlu, gnojidbi i klimatskim uvjetima. U Hrvatskoj su postavljene pokusne proizvodnje vrbe uglavnom u nizinskom panonskom području (Darda i Čazma) na marginalnim tlima, napuštenim od poljoprivredne proizvodnje. Klonovi stablastih vrba pokazali su najveći potencijal produkcije biomase u kratkim ophodnjama, prosječna produkcija suhe biomase kod treće dvogodišnje ophodnje, u dobi od 2/7 godina, iznosila je 9,3 t/ha (Kajba at al., 2007), no prinosi mogu biti veći.

Poželjni uvjeti sječe i transporta su kada je tlo smrznuto ili suho. Da bi se osigurao visoki sadržaj suhe tvari najbolje je sječu obaviti krajem zime kada je sadržaj vode u biljci od 50 do 55%, no mogu biti povećani rizici zbog vremenskih uvjeta, također vlažno tlo može stvarati probleme u korištenju strojeva veće mase. Sječu treba obaviti kada je biljka u fazi mirovanja, a uz visinu reza između 10 i 15 cm od tla.

Dvije su osnovne koncepcije ubiranja odnosno sječe brzorastućeg drveća:

- sječa stabljika s istovremenim usitnjavanjem (sjeckanjem) ili
- sječa stabljika koje se mogu sušiti prirodnim putem i naknadno usitniti.

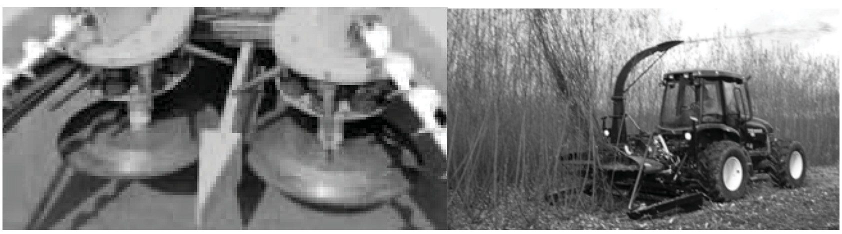
Strojevi za sječu brzorastućeg drveća mogu biti: pogonjeni traktorom (izvedba: vučeni ili nošeni) i samokretni s vlastitim pogonom. Krmnim kombajnom se masa istovremeno sječe-ubire i usitnjava što je jednostavnije, no ovisno o namjeni nedostatak može biti visoki sadržaj vode koji uzrokuje truljenje, te je potrebno dosušivanje biomase u sušarama. Prednost ovakovog ubiranja je potpunije, odnosno bolje iskorištenje krmnog kombajna tijekom godine.

Samokretni krmni kombajni na sl. 4 imaju posebne hedere sa sustavom za sječu brzorastućog drveća s dvije kružne pile, hidraulički pogonjene što omogućuje jednostavnije priključivanja na standardne kombajne različitih proizvođača (CRL), osim modela Wood Cut 1500 koji ima jednu kružnu pilu promjera 180 cm pogonjenu lančanim i remenskim prijenosom. U jednom prohodu se sijeku oba reda vrba, a ovisno o modelu hedera najveći sječni promjer može biti 7 cm ili više, a za Wood Cut 1500 i do 15 cm.

a b c

Sl. 4 Krmni kombajni s hederom za sječu brzorastućeg drveća: a) John Deere s Coppice Resources Ltd SRC harvester, b) Krone s Wood Cut 1500 HTM GmbH i c) New Holland s 130 FB CNH

Fig. 4 Forage harvesters with SRF/SRC header: a) John Deere with Coppice Resources Ltd SRC harvester, b) Krone with Wood Cut 1500 HTM GmbH and c) New Holland with 130 FB CNH



a b

Sl. 5 a) Heder za sječu brzorastućeg drveća HS 2 Claas i b) traktorski nošeni priključak za sječu i usitnjavanje brzorastućeg drveća Bender Salix Maskiner AB

Fig. 5 a) SRF/SRC harvesting header HS 2 Claas and b) tractor mounted unit for SRF/SRC harvesting and chipping Bender Salix Maskiner AB

ZAKLJUČAK

Veća proizvodnja raznih energetskih kultura, porast broja bioplinskih postrojenja, zatim razvoj biogoriva druge generacije dobivenog iz lignoceluloznih materijala utjecat će na povećanje poljoprivrednih površina namijenjenih proizvodnji biomase kao izvora energije. U Hrvatskoj bi se trebale povećati površine za uzgoj energetskih usjeva i nasada koji nisu direktno namijenjeni ljudskoj prehrani, pogotovo korištenjem poljoprivrednih površina koje su manje pogodne za uzgoj glavnih kultura. Korištenje krmnog kombajna u spremanju energetskih kultura je sve značajnije kao i strojeva namijenjenih za spremanje krme. Iskoristivost krmnog kombajna se povećava njegovim dodatnim korištenjem za sječu brzorastućeg drveća. Važan segment je transport voluminozne biomase sa stanovišta troškova i bitna je udaljenost polja od mjesta skladištenja odnosno postrojenja za proizvodnju biogoriva. Daljnji porast zastupljenosti energetskih usjeva u proizvodnji bioplina, primjena biomase brzorastućeg drveća kao goriva i razvoj biogoriva druge generacije utjecat će na razvoj i zastupljenost krmnog kombajna i strojeva za spremanje krme u proizvodnji biogoriva.

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ENERGY CROPS AND FORAGE HARVESTER

SUMMARY

In the 21st century, there has been an increase in production of biomass as an energy source. A higher proportion of energy crops in the production of biogas, biogas plant growth and development of second generation biofuels obtained from lignocellulosic materials, utilisation of fast-growing trees as a fuel set new technical demands on the producers of forage harvesters, and hence affect the use and development of forage harvesters. New developments are based on: the increased engine power, the expanded working width of header and thus increasing the mass of forage harvesters. Specially made cutter drums, with a larger number of knives are needed for smaller length of cut. Increase in establishment of energy plantations of fast-growing trees, short rotation crops – SRC on agricultural land is becoming increasingly important. To harvest willow and poplar with standard forage harvester equipped with a special header for CSR with one or two circular saws is used.

***Key words**: energy crops, fast-growing tree, forage harvester, biogas drum, SRC header*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.313.1:621.548.3
Prethodno priopćenje
Preliminary communication

SIZING SMALL WIND GENERATORS ACCORDING TO PROBABILISTIC INFORMATION OF WIND CONDITIONS

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ABSTRACT

A system consisting of a small wind generator with an electricity and heat storage system is analyzed in the current article. We presume that the wind generator works in autonomous mode. Systems of the given configuration are used mainly in remote sites or islands, where it is not economically reasonable to establish an electrical grid. Existing wind generator systems are mostly overdesigned to get maximum energy supply reliability, hence their high cost as a rule. Wind conditions are unique for any certain area - not only wind speed, but also specific length and quantity of wind lulls. If 100% reliability is aimed at, then it is necessary to guarantee certain capacity of electrical storage. Making compromises in reliability might result in the decrease of electrical storage capacity, which makes the system cheaper. In our paper we have not targeted for an economical analysis, but we will give the methodology for sizing and optimizing the components of a wind energy system according to certain wind conditions.

Key words*: wind energy, capacity, energy supply probability, heat storage*

INTRODUCTION

Wind generators are located in uninhabited or sparsely inhabited places mostly. They may be switched to network (grid-connected systems) or work autonomously. According to the Estonian experience the establishment of big wind generators is becoming more and more complicated. The sites available for setting up wind generators are far from the sufficient configuration electrical networks, which often require big investments comparable to the cost of the wind generator (Landsberg *et al*., 2005). At the same time the financial support system is being questioned. Wind energetic developers have been claimed to get too big profits from the support system. The development of small wind energetics is just starting. The increased interest in small wind generators has been shown both by producers of generators and by developers. The world experience shows that for small wind generator developers special financial support mechanisms have been created that are not so costly for the society. By standard a small wind generator has an impeller circle area not bigger than 200 m^2 and the corresponding capacity of up to 50 kW (Estonian Standard, 2005). Also network construction problems are less acute even if the wind generator is grid-connected, as the installed capacities are not big and networks are mostly designed with extra reserve for possible new consumer´.

Wind generators as one kind of energy conversion equipment have the shortest energy payback time, less than 0.5 year (Mathew, 2006). But the main disadvantage of wind generators is the stochastic output power. To a certain extent it is possible to predict the output power of wind generators for up to 24 hours ahead, but with limited accuracy of about 20%. Stochastic wind power curve is not correlated with the supply power curve required by consumers. The energy not produced by wind generators has to be supplied from other sources, which is mostly expensive and hazardous to environment (Palu *et al*., 2009). The necessary capacity can be bought from an energy market (for example NordPool in Nordic countries), which is mostly remarkably more expensive compared with the custom tariff. In the case of autonomous wind generators the need to balance the output power is inevitable, but it is increasingly more important to guarantee as stable balance of power as possible in grid-connected wind generators as well. When installing small wind generators, we have to bear in mind that fluctuating output power must not cause problems of network control. Therefore it is important that the produced capacity flows are balanced not far from the wind generator or are consumed nearby. In our study we look at the methodology of evaluating the capacities of an autonomous wind generator and its storage equipment and the possibilities of balancing the energy flows depending on probabilistic parameters of wind.

METHODS

Annual energy production, calculated according to wind data and generator capacity and considering consumption, might not guarantee the necessary energy supply reliability. Oversize generator and storage systems probably make the cost rise remarkably. The prediction of annual energy production according to the power curve of the generator and average wind speed is not sufficient. There might be relatively long periods without wind (energy lulls) in Estonia, during which the system must still guarantee energy supply. The problem has not been researched from this angle. The calculation of the installed capacity of a wind turbine and the storage device is appropriate when there is no sufficient wind data available about the selected location (Oidram *et al*., 2007). There are different methods for optimization of generator capacities in energy systems in case of partial information (Keel *et al*., 2005), in case of cogeneration (Keel *et al*., 2005) and for cooperation of wind turbines with oil shale plants (Liik *et al*., 2005). These methods are developed according to continuous power production and consumption schedules and the possibility of a storage device is not considered. Models of LOLP (Loss of Load Probability) and EENS (Expected Energy Not Supplied) have been used for the estimation of reliability of a hybrid system (wind generator+diesel generator+storage device) but this model does not include the capacity of a storage device (Liu & Islam, 2006). LOLP model has been used for the research of a similar system (wind generator+diesel generator+storage) but the average wind speed 7.5 m/s was used and longer periods without wind were not taken into consideration (Kaldellis, 2007).

Wind measurement data from EMHI (Estonian Meteorological and Hydrological Institute) was analyzed where the average wind speed for 1 h had been measured at the height of 10 m above ground during a 5 years' period, 2004-2008. The data was processed using Scilab. Definite locations were selected: Jõgeva, Viljandi, Tõravere for the inland area and Virtsu, Pakri and Tiirikoja (near Lake Peipsi) for the coastal area.

The data was transposed to higher height values using Hellman equation with the coefficient k_H = 0.25 for seashore (Tomson & Annuk, 2005) and k_H = 0.29 for inland (Annuk & Tomson, 2005).Wind energy amount could be estimated on the basis of the wind generator power curve $P = f(v)$ where v is the average speed of wind for 1 h time periods and P is the corresponding power output. In our calculations, we use the normalized power curve averaged from a group of typical small WTG-s. Normalised wind generator power curves (Fig. 1) could be described as (Annuk *et al.*, 2008)

$$P^* = \frac{P}{P_N} \rightarrow P^* = \{0...1\}$$

$$0 < v < 2.5 \text{ m/s} \rightarrow P^* = 0 \qquad (1)$$

$$2.5 \leq v \leq 12 \text{ m/s} \rightarrow P^* = 0.0078 \cdot v^2 - 0.0229 \cdot v + 0.00866022$$

$$v > 12 \text{ m/s} \rightarrow P^* = \text{const} ,$$

where

P^* – relative output power,

P – hourly average power output, kW

P_N – rated power, kW.

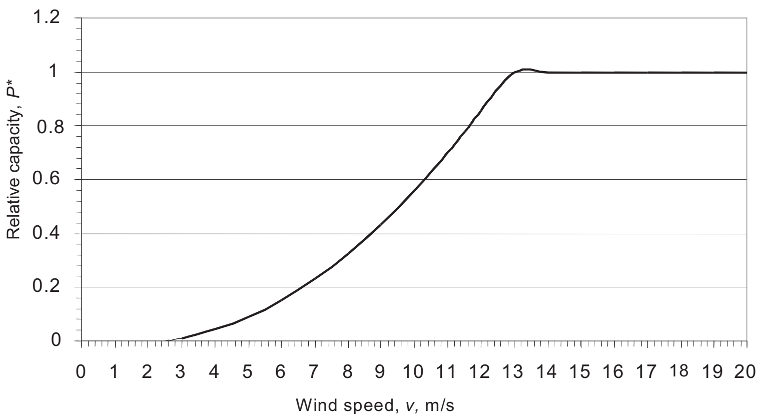

Fig. 1 Normalized power curve of wind turbine generator

In the study (Põder *et al.*, 2009) the above mentioned five years' period wind data from different places of Estonian territory, transposed to the height 30 m above ground, is analyzed. Table 1 show that the maximum average duration of energy lulls T_m a year is usually bigger by one standard deviation than the following average energy lull. Energy lull is defined as a period when wind speed remains below 2.5 m/s. The maximum length of energy lull T_m increases quickly with the reduction of average wind speed. The standard deviation of all 5-year annual average wind speed in all locations is near 5%. The standard deviation of 5-year average capacity is between 6…14% (smaller values near higher average wind speed).

Tab. 1 The values of five years: average wind speeds v, capacities P^*, maximum durations of energy lulls T_m and the following size of energy lulls with the standard deviations on the height of 30 m

Location	Wind speed, v, m/s	Capacity, P^*	Max. lull, T_m, h	Std. dev, δ, h	Next lull, h	Std. dev, δ, h
Viljandi	3.0	0.0363	93.0	17.7	71.6	13.5
Pakri	6.09	0.2263	24.2	6.2	17.8	1.6
Virtsu	4.84	0.1296	39.4	9.9	29.6	5.5
Jõgeva	3.61	0.0649	53.4	8.6	46.8	8.2
Tõravere	3.66	0.0626	49.0	6.7	43.4	2.5
Tiirikoja	3.0	0.0389	86.2	28.7	60.0	9.6

By data of Table 1 the duration of a period of energy lull may be up to 93 hours in unfavourable conditions and in good conditions up to 24.2 hours on the height of 30 m above ground. Such long time-lags, possibly also preceded by low energy periods, forecasted once every five years, have their definite role to the reliability of energy supply.

The continuity of energy supply is estimated by the theory of reliability. Reliability is the probability that a device will perform its intended function during a specified period of time under stated conditions. Mathematically, this may be expressed as:

$$R(t) = \Pr\{T > t\} = \int_t^{\infty} f(x)\,dx, \qquad (2)$$

where

f(x) - the failure probability density function,

t - the length of the period of time.

For evaluating energy supply reliability we use value as availability of the integrated wind system, used for evaluating reliability of power stations (Suik & Pihu, 2009). The availability A of the integrated wind energy system is defined as follows:

$$A = ((T_a - T_l)/T_a), \qquad (3)$$

where

T_a – total hours of availability period,

T_l – total hours of outage due to energy lulls.

Nowadays automatically registered trustworthy wind data for longer periods are increasingly available. Therefore it is possible to use wind time series data for evaluating the reliability of an integrated wind energy system and determining the capacities of equipment. The longer the period, the more trustworthy is the results of the analysis. We use five years' series data with the abovementioned properties.

We evaluate the system: generator, consumer, electricity and heat storage. Heat storage is used as an additional equipment balancing energy flows. Therefore the energy balance of the system in five years' period may be expressed as follows:

$$W_g = \beta \cdot W_c + W_h + W_l, \tag{4}$$

where

W_g – energy produced by generator,

β – energy consumption factor (0...1),

W_c – energy consumed for energy supply,

W_h – energy to heat storage (including other losses),

W_l – losses in electricity storage (efficiency of storage as 75%).

In any moment the system must correspond to the following conditions:

$$P_{gi} = P_{ci} = P^*, \tag{5}$$

where

P_{gi} – capacity from the generator, any time point ,

P_{ci} – consumed capacity by system of consumer and storages.

Consumer capacity P_c as a constant that can be expressed by following expression:

$$P_c = \frac{\sum_{i=1}^{n} w_{gi}}{n}, \tag{6}$$

where

W_{gi} – hourly amount of generated energy,

n – amount of hours.

In calculations we consider the following conditions:

$$W_s < \beta \sum_{i=1}^{n} W_{ci},$$

$$\text{if } W_s = 0\text{, then } P_{ci} = 0\text{; if , then } W_{hi} > 0 \tag{7}$$

where

W_s – capacity of electricity storage.

The time interval, when $P_{ci} = 0$, is accounted as interruption time of energy supply.

RESULTS AND DISCUSSIONS

In the calculations we used Pakri wind data from 2004-2009, transposed to 30 m above ground. The site is one of the windiest coastal locations in Estonia. According to the data of Table 1 the five year average wind speed is 6.09 m/s 30 m above ground and correspondingly the unit generator produced energy is 9917.28 kWh. In case we did not need to accumulate energy and β=1, the stable consumed capacity would be 0.2263 kW.

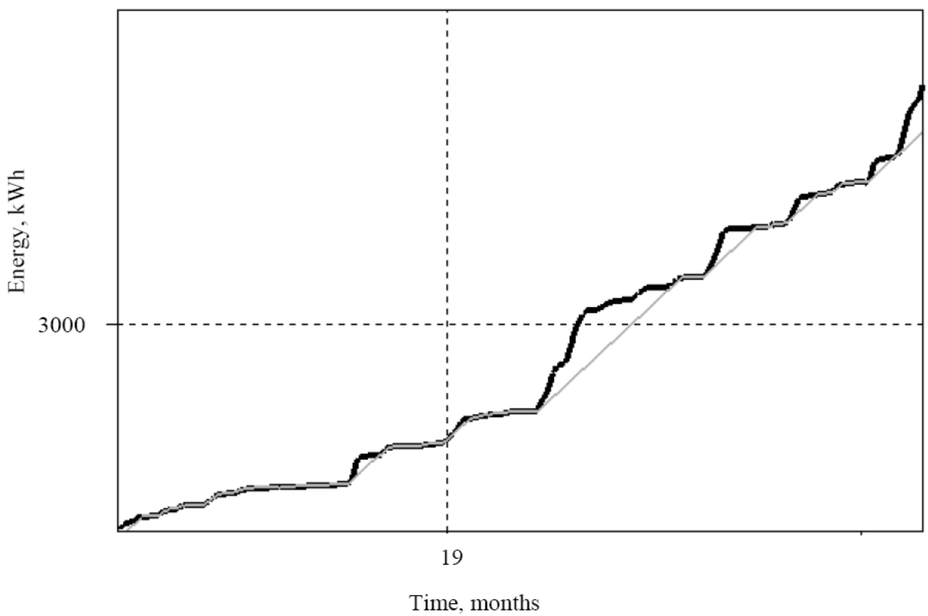

Fig. 1 Share of the cumulative curves of production (upper) and consumption (lower) of the system of a wind generator - electricity storage - heat storage

As seen on graph (Fig.1) it is clearly recognizable when the storage is empty and consumption has stopped. There the production and consumption curves overlap.

For better illustration we calculated (Tab. 2) total annual interruption time T_{ia} and the ratio of heat energy to the total produced energy. Here it is clearly seen, that the amount of heat energy depends on consumption factor β and in the given case may exceed 25% from produced energy by β = 0.75.

Tab. 2 Dependencies on availability A to capacity of electricity storage and heat energy amount during five years' evaluation period

Availability A	Storage capacity W_s, kWh		To heat W_h, kWh (%)		Annual interruption time T_{ia}, h
	$\beta = 1$	$\beta = 0.75$	$\beta = 1$	$\beta = 0.75$	
0.95	160	23.3	491 (4.95)	2841(28.6)	438
0.96	211	28	377 (3.80)	2766(27.9)	350.4
0.97	286	34	252 (2.54)	2689(27.1)	262.8
0.98	371	46	125 (1.26)	2612(26.3)	175.2
0.99	470	69.5	0 (0)	2529(25.5)	87.6
1.00	569	101	0 (0)	2445(24.7)	0

From Fig. 2 and 3 it can be seen that the necessary storage capacity is in inverse correlation from amount of heat energy. Keeping both values in minimum is essential. But finding the minimum of storage capacity is primary, as storages are expensive and of relatively short working age. It is possible to get heat energy with cheaper methods than using the current configuration of a wind generator system, thus excessive heat energy amount decreases the system's economy efficiency by expanding equipment capacities. From graphs it is seen that decreasing consumption factor increases the availability influence about values near 1 to values of storage capacity. At the same time the amount of heat energy remains relatively stable in lower consumption factors, but has a high value.

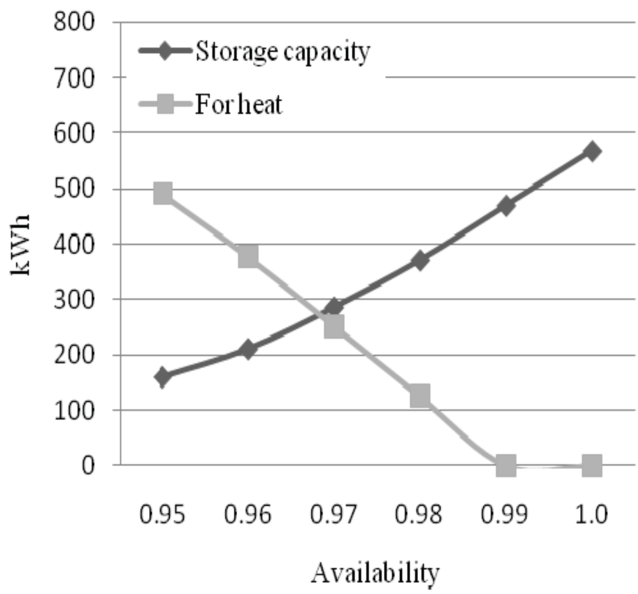

Fig. 2 Needed storage capacity and heat energy accordingly to availability when $\beta = 1$

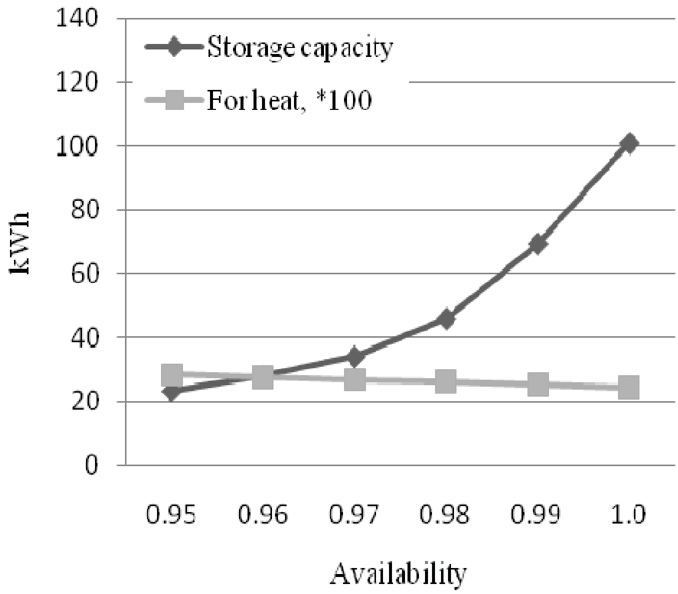

Fig. 3 Needed storage capacity and heat energy according to availability when β = 0.75

CONCLUSIONS

1. The given evaluation is a methodological survey of the options for the choice of a storage device capacity, which has currently become possible due to reliable wind speed data available for longer periods. The longer the time series data, the higher the reliability of calculations.
2. Even with relatively high average wind speeds the necessary values of storage capacities proved to be very high. In the given example, when the average capacity consumed per unit generator is 0.2263 kW, the value of necessary storage capacities in favourable conditions is over 100 kWh. If we need to provide a bigger consumer with an energy supply of reasonable reliability, we multiply the capacity of a unit generator by the necessary coefficient. The value of storage capacity will change accordingly.
3. According to the previous conclusion it is reasonable to use such kind of wind energy systems only for low consumption demands, up to about twenty watts.
4. The storage capacity needs decreases quickly if the reliability of supply is reduced, and could even be four times with the value of availability 0.95. The question arises if the consumer agrees to have such long power interruption periods (annually 438 h). By availability level 0.99 it is 0.7 times smaller, which means 87.6 h of energy supply interruption a year.
5. The given methodology enables to add energy producers, consumers and storage equipments to the system in order to study the influence on the necessary value of storage capacity or the amount of heat energy.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 620.9:621.3
Stručni rad
Expert paper

FOTOVOLTAIKA V SLOVENIJI

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POVZETEK

Fotovoltaika je proces direktne pretvorbe sončne energije v električno. Sonce je edini potreben vir energije. Uporaba sončne energije ima številne prednosti, saj je sonce stalen vir in na voljo v izobilju. Najdemo se veliko informacij o ugodnosti sončne energije, vendar je premalo informacij o dejanskih izračunih uporabnosti solarnih tehnologij za prihodnje uporabnike.

Ker se države vse bolj zavzemajo za kakovostnejše okolje, se v razvitih delih sveta na veliko uveljavljajo obnovljivi viri energije. Velik pomen dosega tudi fotovoltaika. Zato smo se v prispevku osredotočili na možnosti uporabe solarne tehnologije na različnih lokacijah v Sloveniji.

Obenem smo prikazali tudi izračun proizvedene električne energije s pomočjo fotovoltaike in seveda tudi približno oceno stroškov. Ugotovili smo, da ima Slovenija veliki energijski potencial. Do teh ugotovitev smo prišli s pomočjo spletne aplikacije PV Potential Estimation Utility.

Rezultat izračuna predvidene letne proizvodnje in stroškov za malo sončno elektrarno je bil izjemno ugoden. Na podlagi podatkov, ki smo jih dobili o fotovoltaični tehnologiji menimo, da je to vsekakor ena boljših alternativnih možnosti, ki lahko veliko prispevala k ohranjanju naravnega okolja v katerem živimo.

Ključne besede: *obnovljivi viri energije, fotovoltaika, sončna elektrarna, globalno sončno obsevanje*

UVOD

Alternativna energija je energija pridobljena iz obnovljivih virov energije, ki praviloma manj onesnažujejo okolje. Obnovljivi viri so naravne snovi, ki vsebujejo energijo v različnih oblikah. Ti viri se uporabljajo za pridobivanje energije ali pa za prenos energije. Poznamo primarne in sekundarne energijske vire. Primarni energijski viri se uporabljajo za direktno pridobivanje energije. Zajemanje obnovljivih virov energije ne izčrpa vira (Babuder, 2009).

Človekov razvoj je bil vedno odvisen od virov energije, ti pa so se z razvojem korenito spreminjali. Približujemo se trenutku, ko bomo z obstoječimi viri prišli do limita. Zato bo potrebno izkoristiti vse vire, ki so na razpolago in racionalizirati porabo. Alternativni viri lahko pomagajo popravljati energetsko bilanco. Po drugi strani pa je ravno poraba energetskih virov načela naše okolje. Pojavil se je efekt tople grede, zaradi tega se ozračje ogreva to pa vodi do izrednih vremenskih pojavov, ki ogrožajo človeka in ravno alternativni viri lahko ublažijo ta pojav (Topič, 2004).

METODE

Če se odločimo, da bomo na svoj dom ali gospodarsko poslopje namestili sončno elektrarno, je potrebno najprej razmisliti, kje se nahajamo in koliko sončnega obsevanja je na lokaciji, kjer želimo postaviti panele (Bezjak, 2009). Najprej je smiselno pogledati spletno stran Hidrometeorološkega zavoda Republike Slovenije, saj na tej strani najdemo klimatološke karte za vsak letni čas.

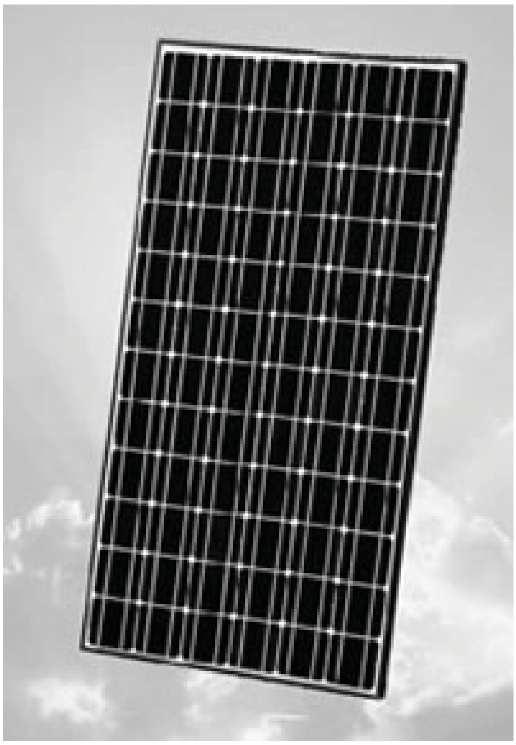
Globalno sončno obsevanje je definirano kot celotno sončno obsevanje, ki pade vodoravno na ploskev. Energija globalnega sončnega obsevanja je odvisna od meteoroloških dejavnikov (oblačnost, vlaga, prepustnost ozračja za sevanje), od reliefnih dejavnikov (nadmorska višina) in astronomskih dejavnikov (Agencija RS za okolje). Letno globalno sončno obsevanje je najbolj bistven podatek, ki pove, koliko energije lahko proizvedemo iz sonca. Merimo ga v kWh/m^2. Tudi podatke o globalnem obsevanju najdemo na strani Agencije RS za okolje.

Slika 1 Heliogram (Ketiš, 2010)

Trajanje sončnega obsevanja so v Sloveniji začeli meriti leta 1947 v Mariboru, leto kasneje pa v Ljubljani. Leta 2004 so trajanje sončnega obsevanja merili že na 22 meteoroloških postajah. Trajanje sončnega obsevanja merimo z optično pripravo, heliografom, ki je sestavljen iz krogelne leče in podstavka, na katerem je pritrjen registrirni trak – heliogram. Krogelna vreča zbira sončne žarke v svojem gorišču in izžiga na sled heliogramu. Na sliki 1 je heliogram.

Izračun, koliko energije bi lahko proizvedli na neki lokaciji, je možen na več načinov. Prvi je, da izberemo pot preko površine globalnega obsevanja in izkoristka panela. Drugi način je s pomočjo spletne strani, kjer vpišemo lokacijo (zemljepisno širino in dolžino) ter tako dobimo pričakovani rezultat letne proizvodnje.

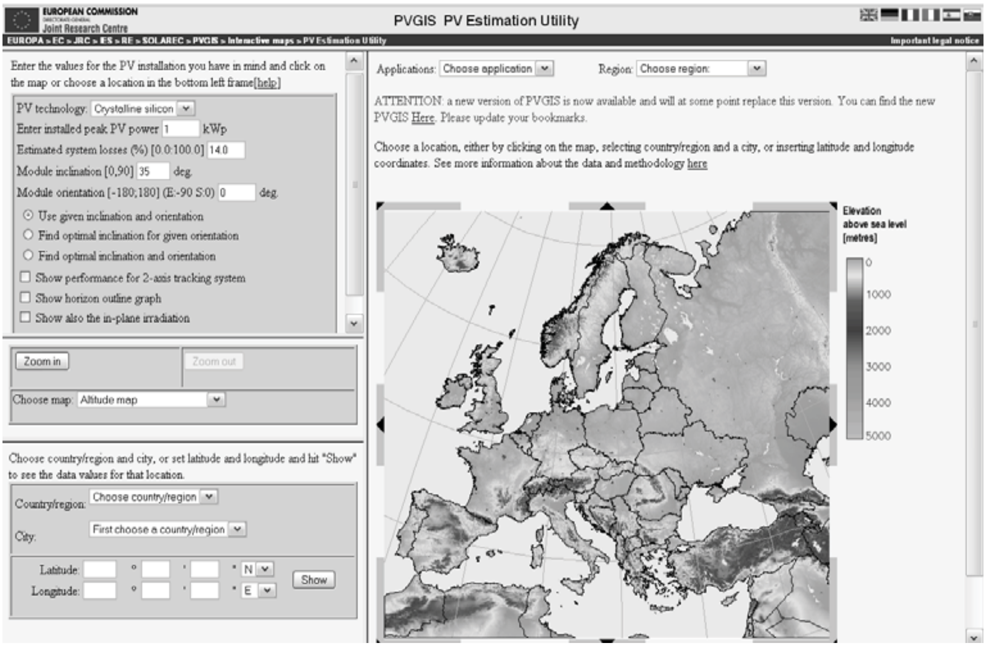
V prvem primeru, s pomočjo letnega globalnega obsevanja in površine panelov ter izkoristkov je bil uporabljen primer panela Sanyo HIP – 210 NKHE, ki je na sliki 2. Ta panel ima dimenzije 1580 mm ali 798 mm.



Slika 2 Panel Sanyo HIP - 210 NKHE (Ketiš, 2010)

Drugi način ugotavljanja predvidene letne proizvodnje je s pomočjo spletne strani Sunbird. Izberemo tip in naklon panelov, predvidene izgube sistema (v našem primeru 0 %, saj nas zanima produkcija panelov in ne celotnega sistema) in lokacijo (Slovenija, Maribor). Spletna storitev sama izriše predvideno proizvodnjo po letih ali mesecih, ter tabelo s seštevkom proizvodne energije, ki je v našem primeru 1176 kWh na leto. Za lokacijo Maribora določimo nadmorsko višino in geografsko širino. Nato spletna stran izriše tabelo.

Na sliki 3 je spletna aplikacija, na levi strani se vpišejo podatki, na desni strani, kjer se vidi zemljevid pa se izbere lokacija.



Slika 3 Spletna stran Sunbird (Sunbird, 2010)

Izračun predvidene nazivne moči

Izračuna predvidene nazivne moči fotonapetostnega generatorja se lotimo tako, da razpoložljivo površino strehe, kjer bomo postavili module, delimo s površino, ki jo potrebujemo za 1 kWp.

Površina razpoložljive površine strehe: A [m^2]

Površina, ki jo potrebujemo za 1 panel: B [m^2]

Nazivna moč fotonapetostnega generatorja: P

Iz tega sledi, da površina enega panela, ki je B = 8 m^2 zadošča za 1 kWp nazivne moči.

B……….1 kWp

A……….? kWp (P) (1)

Izračun količine kWh, ki pade v letu na module

Bistven izračun je, koliko kWh pade na letnem nivoju na module. Tega se lotimo tako, da množimo razpoložljivo površino z letno energijo globalnega sončnega obsevanja na izbrani lokaciji.

Energija letnega globalnega sončnega obsevanja na lokaciji: G [kWh/m^2]

Količina kWh, ki pade na znano površino modula: M [kWh]

$$M = A * G \quad (2)$$

Izračun največje možne proizvodnje

Znano je dejstvo, da v Sloveniji dobimo med 1050 in 1100 kWh/kWp. Največjo možno proizvodnjo dobimo, če pomnožimo število kWh/kWp v Sloveniji s predvideno nazivno močjo, ki jo imamo na voljo.

Največja možna proizvodnja: I [kWh]

Skupna količina energije: S [kWh/kWp]

Predvidena nazivna moč: P [kWp]

$$I = P * S \quad (3)$$

Stroški

Stroški, potrebni za 1 kWp, so cca 3.000 €.

Odkupne cene se razlikujejo glede na nazivne moči elektrarn. Mikro (manj kot 50 kWp), mala (od 50 kWp do 1 MWp), srednja in velika (do 125 MWP). V našem primeru gre za mikro elektrarno, cena letnega odkupa znaša 0,386 € za 1 kWp. Večja je nazivna moč, manjše so odkupne cene.

Izračun za določeno elektrarno

Izračun investicije izračunamo z množenjem cene za 1 kWp in predvidene nazivne moči.

Cena za 1 kWp: D [€/kWp]

Cena investicije: Y [€]

$$Y = D * P \quad (4)$$

Izračun letnega odkupa

Letni odkup izračunamo tako, da ceno za letni odkup na izbrani lokaciji za leto 2010 (vsako leto se namreč cene spreminjajo) množimo z največjo možno proizvodnjo.

Cena za letni odkup: O [€/kWh]

Letni odkup: L [€]

$$L = O * I \quad (5)$$

Povračilo investicijskih stroškov se izračuna z deljenjem cene celotne investicije z letnim prihodkom oziroma odkupno ceno.

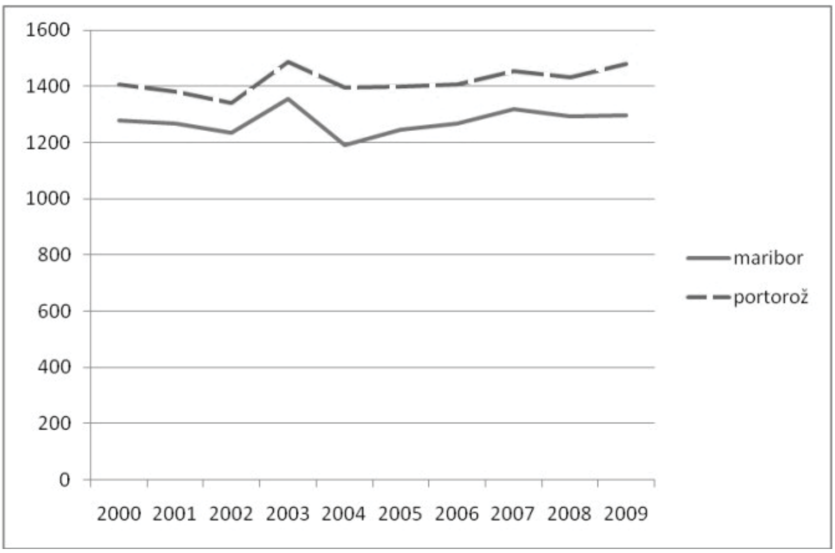
Povračilo investicijskih stroškov: U [leta]

$$U = Y/L \tag{6}$$

Referenčni stroški novo zgrajenih elektrarn, in s tem odkupne cene, bodo od navedenih v naslednjih letih nižje, zaradi padanja cene silicija.

REZULTATI Z RAZPRAVO

Grafikon 1, kjer so primerjani podatki o globalnem sončnem obsevanju med leti 2000 in 2009 na lokacijah Portorož in Maribor nazorno kaže, da je letno globalno sončno obsevanje v Portorožu okrog 1400 kWh/m^2, v Mariboru pa je približno 92 % letnega obsevanja v Portorožu, saj je sončnega obsevanja 1288 kWh/m^2. Na Ptuju, ki ima letnega globalnega sončnega obsevanja 1215 kWh/m^2, pa je v primerjavi s Portorožem na 86 % letnega globalnega sončnega obsevanja. To je številka direktnega globalnega obsevanja, brez obsevanja od odbojev do razpršitve. Amorfna tehnologija bolje izkorišča še difuzno obsevanje, kar pa za monokristalne in polikristalne silicijeve sončne celice ne velja.



Grafikon 1 Globalno sončno obsevanje v Mariboru in Portorožu

Rezultati izračunov za postavitev fotovoltaike na stanovanjski hiši

Na osnovi podatkov o površini in inklinaciji strehe, smo ugotovili, da je v našem primeru razpoložljiva površina 98 m^2. Na spletni strani Agencije RS za okolje smo poiskali podatek energije globalnega sončnega obsevanja za Ptuj.

Nazivna moč male elektrarne. Energija letnega globalnega sončnega obsevanja na Ptuju je G = 1215 kWh/m^2.

Po enačbi (1) izračunamo nazivno moč P = A/B = 98/8. Za razpoložljivo površino strehe smo dobili 13 kWp nazivne moči.

Izračun količine energije. Sledi izračun količine kWh, ki v enem letu pade na module. S pomočjo enačbe (2) in podatka o globalnem sončnem obsevanju smo dobili M = A * G = 98 * 1215 = 119070 kWh.

Izračun največje možne proizvodnje s pomočjo enačbe (3) je I = P * S = 13 kWp * 1100 kWh/kWp = 14300 kWh

Rezultat je 14300 kWh proizvedene električne moči v enem letu na 13 kWp inštalirane moči.

Cena investicije s pomočjo enačbe (4) smo dobili vrednost investicije Y = D * P = 3.000 * 13 = 39.000 €.

Izračun letnega odkupa. Ceno letnega odkupa za mikro elektrarno pomnožimo z izkoristkom s pomočjo enačbe (5) L = O * I = 0,386 * 14300 = 5.519,80 €.

Povračilo investicijskih stroškov smo dobili tako, da smo delili ceno celotne investicije z letnim prihodkom oz. odkupno ceno za električno energijo po enačbi (6).

U = Y/L = 39.000 € / 5.519,80 € = 7,06 let

Stroški potrebni za celotno investicijo se povrnejo približno v 7 letih. Vendar pa moramo vedeti, da je to primer za najboljši možni scenarij. K ceni investicije moramo prišteti še fiksne stroške (čiščenje, zavarovanje, gradbeno dovoljenje, morebitna popravila). Na podlagi tega lahko ugotovimo, da bi se nam vsi stroški, fiksni in investicijski, povrnili približno v 9 letih.

Rezultat izračuna za panel Sanyo HIP - 210 NKHE

Omenjeni panel ima nazivno moč 210 Wp. Celice v panelu dosežejo izkoristek 18,7 %, cel modul 16,8 %. Iz računa lahko izračunamo površino za 1 kWp. Potrebna je površina 6 m^2. Na Agenciji RS za okolje smo dobili podatke, da je v Mariboru letnega globalnega obsevanja nekje 1300 kWh/m^2. Za 1 kWp potrebujemo površino 6 m^2. Iz tega sledi, da na te panele na letnem nivoju pade 6 m^2 * 1300 kWh/m^2 = 7800 kWh. Ob upoštevanju izkoristka panela, ki je 16,8 %, dobimo rezultat 1310,4 kWh proizvedene električne energije v enem letu na 1 kWp inštalirane moči.

SKLEPI

Slovenija ima sorazmerno veliko energetsko intenzivnost, tako pri oskrbi kot pri rabi energije. Ima zelo ugodne naravne pogoje. Problem, s katerim bi se morali soočiti, je ustvariti primeren plan, ki bi ohranil energetsko odvisnost države in seveda zmanjšanje škodljivih vplivov na okolje. Tudi zakonodajo bi morali nekoliko spremeniti, tako da bi povzročala čim manj ovir bodočim investitorjem pri priključitvi elektrarn na električno omrežje, in zagotoviti fiksno odkupno ceno. Osnovni namen prispevka je bil prikazati, kje v Slovenije je smiselna uporaba fotovoltaike, ter prikaz izračuna primer enodružinske hiše na Ptuju. Izračun za postavitev male sončne elektrarne, ki smo ga naredila za streho na Ptuju je pokazal, da je na površino strehe 98 m^2 možno inštalirati 13 kWp nazivne moči. Največja možna proizvodnja električne energije bi znašala 14300 kWh.

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PHOTOVOLTAICS IN SLOVENIA

SUMMARY

Photovoltaics is the process of conversion of solar energy into electric energy. The sun is the sole necessary energy source. The use of solar energy has many advantages, since the sun is a permanent source and is available in abundance. There is much information about the advantages of solar technologies for future users.

As more and more countries are in favour of high-quality environment, renewable energy sources become widely popular in the developed areas of the world. Therefore, our paper focuses on the possibility of use of solar technology at different locations in Slovenia.

In the same time, the calculation of electric energy produced by the use of photovoltaics and the approximate estimate of costs have been shown. It has been found that Slovenia has a great energy potential. These findings have been reached by means of the internet application PV Potential Estimation Utility.

The result of the anticipated annual output and costs of a small solar power station was highly favourable. According to the information obtained about the photovoltaic technology our opinion is that this is one of good alternative options likely to contribute a lot to conservation of our natural environment.

Key words: *renewable energy sources, photovoltaics, solar power station, global solar radiation*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.43
Stručni rad
Expert paper

A COMPARISON OF GREEN PLANT AND TREES EFFICIENCY IN PHYTOREMEDIATION

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SUMMARY

Phytoremediation is friendly environmental technology for pollutants mitigation from soil, water and air. It is effective, economic and simple technology. The aim of this work is in comparison of green plants and trees efficiency in heavy metal phytoremediation. The efficiency is determined by coefficients, which are calculated as ratio of plant accumulation ability and soil concentration. The concentrations data were sampled and selected from international publisher science Springer and Elsevier. The results shown that green plants have higher accumulation abilities than trees, but they have very small biomass than trees. Trees are chosen as best choice, because of theirs huge biomass, and easier breeding, treatment, harvest, and later manipulation.

Key words: *phytoremediation, green plants effects, trees effects, comparison, biomass productivity*

INTRODUCTION

Phytoremediation is `green technology` consist of pollutants mitigation in soil, water and air. This technology appplies plants able to accumulate, degrade or eliminate metals, pesticides, solvents, explosives, crude oil and various other contaminants, from the environment that contain them.

Heavy metals are important environmental pollutants and many of them are poisonous even at low concentrations. Environmental pollution by heavy metals has accelerated since industrial evolution. Plants that accumulate more than 100 ppm Cd, 1000 ppm As, Co, Cu and Pb, 10000 ppm Zn and Ni are considered as hyper accumulators. (Baker and Brooks, 1989, Baker et al, 2000). These ratios are 10 - 500 times higher than the amounts that ordinary plants accumulate. Phytoremediation may be applied wherever the soil or static water environment has become polluted. This technology is considered a clean, cost - effective and non - environmentally disruptive method. Over the past 20 years, phytoremediation has become increasingly popular and has been employed at sites with soils contaminated with heavy metals lead, uranium, and arsenic. (www.wikipedia.org).

The aim of this paper is in comparison effects of green plants and trees in phytoremediation and choose the best solution for environment which must be economic and simple technology.

MATERIAL AND METHOD

The most literature was sampled from experiments and papers from publisher's journal base: Springer and Elsevier. The paper accent is in comparison effects of green plants and trees in phytoremediation, based on present results. There were sampled heavy metal concentrations data from soil and plant accumulation. Then, there were calculated the coefficients as plant and soil concentration ratio. These coefficients are used as plant efficiency indicator in phytoremediation and were the base of comparison and plant biomass.

RESULTS AND DISCUSSION

Green plants as remediators

As a plant - based technology, the success of phytoremediation is inherently dependent on several plant characteristics. The two most important being the ability to accumulate large quantities of biomass rapidly and the capacity to accumulate large quantities of environmentally important metals in the shoot tissue (Kumar et al., 1995; McGrath, 1998) Several green plant species have huge bioaccumulation capacity. (Tab. 1)

Table 1 Several metal hyper accumulator species and their bioaccumulation potential

Plant species	Metal	Leaf content (ppm= mg / kg)	Reference
Thlaspi caerulescens	Zn:Cd	39,600:1,800	Reeves&Brooks(1983) Baker&Walker(1990)
Ipomea alpina	Cu	12,300	Baker&Walker (1990)
Haumaniastrum robertii	Co	10,200	Brooks (1977)
Astragalus racemosus	Se	14,900	Beath et al. (1937)
Sebertia acuminata	Ni	25% by wt dried sap	Jaffre et al. (1976)

The green plants, characterized as hyperaccumulators, absorb unusually large amounts of metals compared to other plants and did not show any toxic effects. These plants can accumulate and tolerate greater metal concentrations in shoots and roots than those usually found in non – accumulators. At present, at least 45 plant families are known to contain metal -accumulating species (Reeves and Baker, 2000). A number of these species are members of *Brassicaceae* family (Reeves and Backer, 2000). Some species are adequate for some metals and hyperaccumulates only one or two heavy metals in higher concentrations. (Tab. 2)

Table 2 Green plants – hyperaccumulators

Num.	Hyperaccumulator	Metals in plant	Reference
1.	*Thlaspi caerulescens*	Zn, Cd	Reeves and Brooks (1983); Baker and Walker (1990)
2.	*Ipomea alpina*	Cu	Baker and Walker (1990)
3.	*Sebertia acuminata*	Ni	Jaffre et al. (1976)
4.	*Haumaniastrum robertii*	Co	Brooks (1977)
5.	*Astragalus racemosus*	Se	Beath et al. (2002)
6.	*Arabidopsis thaliana*	Zn,Cu,Pb,Mn,P	Lasat (2002b)
7.	*Thlaspi goesingens*	Ni	Kramer et al. (2000)
8.	*Brassica oleracea*	Cd	Salt et al. (1995b)
9.	*Arabidopsis halleri*	Zn, Cd	Reeves and Baker (2000); Cosio et al. (2004)
10.	*Sonchus asper*	Pb, Zn	Yanqun et al. (2005)
11.	*Corydalis pterygopetala*	Zn, Cd	Yanqun et al. (2005)
12.	*Alyssum bertolonii*	Ni	Li et al. (2003); Chaney et al. (2000)
13.	*Astragalus bisulcatus*	Se	Vallini et al. (2005)
14.	*Stackhousia tryonii*	Ni	Bhatia et al. (2005)
15.	*Hemidesmus indicus*	Pb	Chandra Sekhar et al. (2005)
16.	*Salsola kali*	Cd	de la Rosa et al. (2004)
17.	*Sedum alfredii*	Pb, Zn	Li et al. (2005)
18.	*Pteris vittata*	As	Ma et al. (2001); Zhang et al. (2004); Tu and Ma (2005)
19.	*Helianthus anus*	Cd, Cr, Ni	Turgut et al. (2004)
20.	*Amaranthus*	Pb, Fe	Oyelola O. et al (2009)
21.	*Tomato*	Pb, Fe, Cu, Zn	Oyelola O. et al (2009)
22.	*Artemisia*	As	Shahraki A. S.
23.	*Ferula Oopoda*	As	Shahraki A. S.
24.	*Gundelia tournefortii*	As	Shahraki A. S.

Thlaspi c. is most used green plant in phytoremediation. Leon Kochian, American scientist found the molecular way of Thlaspi remediation in it shoots and root. Tipical plant may accumulate 100 ppm Zn and 1 ppm Cd. Thlaspi may accumulate 30000 ppm Zn and 1500 ppm Cd in its shoots and does not show any toxic effect. The simple plant may be toxic with 1000 ppm Zn or 20 – 50 ppm Cd in its shoots.

Trees as phytoremediators

The poplars and wilows are species which are often use in phytoremediation. They are no hyperaccumulators but they posses positive characteristics to grow very fast, grow on low fertility soils, have good developed root system, which may reach the underground water and have high transpiration coefficient. (Aitchison et al., 2000). The trees have huge biomass what is important in remediation. They may grow on sediments and near the rivers and have long life, 25 – 30 years. Nowdays, the results have shown that the poplar use in heavy metals phytoremediation is succesful. (Pilipović et al., 2002, Kališova - Špirochova et al., 2003; Bojarczuk, 2004; Pilipović, 2005, Pilipović et al., 2005, 2006, Katanić et al., 2006).

The comparison effects between green plants and trees in phytoremediation

Plants were selected from two groups: hyperaccumulators -Arabidopsis halleri and Thlaspi caerulescens and accumulator trees with a great biomass production - Salix smithiana, Salix dasyclados, Salix caprea, Populus trichocarpa and Populus nigra maximowiczii (Fischerova Z., 2006), Salix Pentandra (Maxted A. P., 1999), Larch and Populus (Wang X. et al., 2010), Artemisia aucheri, Astragalus myriacanthus, Ferula oopoda, Gundelia tournefortii, Rumex crispus (Shahraki A. S.).

It was compared accumulation ability of tested plant species. Both hyperaccumulators confirmed their extremely high trace element accumulation capacity compare to other species

Table 3 Heavy metal - Cd concentrations in plants, soil and their coefficients

Plant	Heavy metal	Plant concentration mg/kg	Soil concentration mg/kg	Coefficient	Reference
S. Pentandra	Cd	0.80 0.60	0.20 0.10	4.00 6.00	Maxted A. P. (1999)
Populus	Cd	1.60 1.35	0.13 0.13	12.30 10.38	Wang X. et al (2010)
Larch	Cd	1.75 1.20	0.13 0.13	13.46 9.23	Wang X. et al (2010)
Thlaspi c.	Cd	271	5.46	49.63	Fischerova Z. (2006)
A halleri	Cd	82.3	5.46	15.07	Fischerova Z. (2006)
S. Smithiana	Cd	23.6	5.46	4.32	Fischerova Z. (2006)
S. dasyclados	Cd	41.1	5.46	7.53	Fischerova Z. (2006)
S. caprea	Cd	32.8	5.46	6.00	Fischerova Z. (2006)
P. trichocarpa	Cd	20.4	5.46	3.73	Fischerova Z. (2006)
P. nigra	Cd	17.3	5.46	3.17	Fischerova Z.

The coefficient comparison results have shown that *Thlaspi c.* has the highest accumulation ability in Cd remediation. It accumulated 15.65 times higher Cd concentration than *P. nigra*, 13.31 times higher Cd concentration than *P. .trichocarpa*, 12.4 times higher Cd concentration than S. *Pentandra*, 11.48 times higher Cd concentration than *S. Smithiana*, 8.27 times higher Cd concentration than *S. caprea*, 6.59 times higher Cd concentration than *S. dasyclados*, 4 times higher Cd concentration than *Populus*, 3.68 than *Larch* and 3.29 than *A. halleri*.

Thlaspi c. is green plant. It has great and high accumulation abilities, but it has 3.03 t / ha aboveground biomass. (Zhao F. J. et al, 2003.) *A. halleri* has also about 3 – 5 t / ha low biomass. This is the main disadvantage of all green plants as remediators.

Trees like *Salix, Poplar* and *Larch* familiy has lower accumulation abilities than green hyperaccumulators. The advantage of tree species is their greater harvestable biomass compared to most hyperaccumulators with only small aboveground biomass. The *S. dasyclados* has great aboveground biomass about 31.53 t / ha. (Maxted et al,), larch has about 13,86 t / ha biomass and poplars have about 20 t /ha biomass.

If the coefficients are compared and experiment included informations about plant biomass, it is concluded that the best remediator for Cd is *Salix family*, than *Larch* and *Thlaspi*, than *Populu*s and *A. halleri*.

Table 4 Heavy metal - Zn concentrations in plants, soil and their coefficients

Plant	Heavy metal	Plant concentration mg/kg	Soil concentration mg/kg	Coefficient	Reference
S. Pentandra	Zn	180.0	350.0	0.51	Maxted A. P. (1999)
		100.0	375.0	0.27	
Populus	Zn	90.0	263.4	0.34	Wang X. et al (2010)
		165.0	263.4	0.63	
Larch	Zn	70.0	263.4	0.26	Wang X. et al (2010)
		58.0	263.4	0.22	
Thlaspi c.	Zn	1500.0	279.0	5.38	Fischerova Z. (2006)
A halleri	Zn	2746.0	279.0	9.84	Fischerova Z. (2006)
S. Smithiana	Zn	432.0	279.0	1.54	Fischerova Z. (2006)
S. dasyclados	Zn	591.0	279.0	2.12	Fischerova Z. (2006)
S. caprea	Zn	475.0	279.0	1.70	Fischerova Z. (2006)
P. trichocarpa	Zn	337.0	279.0	1.21	Fischerova Z. (2006)
P. nigra	Zn	344.0	279.0	1.23	Fischerova Z. (2006)

The coefficient comparison results have shown that *Arabidopsis halleri* has the highest accumulation ability in Zn remediation. The greatest biomass has *Salix* (about 30 t / ha), *Populus* (20 t / ha), *Larch* (13 t / ha) and the smallest has *A. halleri* 4 t / ha and *Thlaspi c.* 3 t / ha. With respect the coefficient results and biomass productivity the best remediator for Zn was *Salix family* and *A. halleri*, than *Populus* family and *Thlaspi.c.* and the worst was *Larch* family.

Table 5 Heavy metal concentrations in plants, soil and their coefficients

Plant	Heavy metal	Plant concentration mg/kg	Soil concentration mg/kg	Coefficient	Reference
Thlaspi c	As	6.07	28	0.22	Fischerova Z. (2006)
A halleri	As	5.30	28	0.19	Fischerova Z. (2006)
S. Smithiana	As	1.25	28	0.04	Fischerova Z. (2006)
S. dasyclados	As	0.96	28	0.03	Fischerova Z. (2006)
S. caprea	As	1.08	28	0.04	Fischerova Z. (2006)
P.trichocarpa	As	0.82	28	0.03	Fischerova Z. (2006)
P. nigra	As	0.92	28	0.03	Fischerova Z. (2006)
Artemisia aucheri	As	41.6	149	0.27	Shahraki A. S.
Astragalus myriacanthus	As	107	300	0.36	Shahraki A. S.
Ferula oopoda	As	38.1	102	0.37	Shahraki A. S.
Gundelia tournefortii	As	36.0	146	0.25	Shahraki A. S.
Rumex crispus	As	32.0	127	0.25	Shahraki A. S.

The coefficient comparison results have shown that Ferula oopoda has the highest accumulation ability in As remediation. The greatest biomass has Salix (about 30 t / ha), and the smallest has A. halleri 4 t / ha and Thlaspi c. 3 t / ha and all selected green plants has biomass from 2,5 – 3 t / ha. With respect the coefficient results and biomass productivity the best remediator for As was Salix family and Astragalus m. and Ferula o., than Thlaspi c. A, halleri and other green plants and Populus family.

CONCLUSIONS

In comparison experiment, the tree plant species with lower metal accumulated concentration in shoots, compensated the remediation effectiveness by great biomass production, compared to green plant species with higher element concentration and low biomass production. There was practically no difference in remediation efficiency between hyperaccumulators and selected trees. Some varieties of *Salix spp*. have a higher remediation efficiency than hyperaccumulators (*T. caerulescens, A. halleri*) due to the high biomass production and transport of Cd and Zn to shoots.

From the breeding practical point, it is easier to use trees because of their greater biomass production and easier treatment, harvest, and later manipulation with biomass compared to small hyperaccumulators.

Tree utilization in soil remediation has more advantages than green plants. Trees, such as poplars, are able to transpire more water, they can get water from deeper soil horizons. Poplars have better regeneration capability than green plants (most of hyperaccumulator species), especially in spring revegetation.

After remediation trees may be used in paper industry, or burned and have use as bioenergy. When the trees are part of burning process, there must be some filters for ash, because the heavy metals especially exists in part of light ash. The dangerous ash is going to the landfill for toxic waste. In the future, there will be interest in trees after remediation process. The scientists have some ideas how to extract heavy metals from plants and reuse them in industry.

Nowdays, phytoremediation is simple, cost – effective, clean and environmentaly great technology. It may be useful in any contaminated soil, or water, as sediment remediation technology. There are many places which needs remediation and there be many more, because of the growth of industry, traffic, fabrics,…

Phytoremediation needs some time to remediate the area, because it is natural process and biomass is physiology limited, but it is more environmental effective, and low cost than mechanic methods. Mechanic methods may disorganize enviroment and biological balance. In soil lives plants, microorganisms, and small animals and insects and many years will be past till the biological balance will reached again.

Phytoremediation is process which has been researched for many years and this technology will be better, when all experiments will included many more factors, like genetic and physiology resources, soil Ph values, acids for better metal accumulation, many other plant genotypes. There are some experiments like this above mentioned, but many of them not included all these parameters, and in the near future there will be experiments like in the laboratory and environmet in the same time, and than scientists will say which parameter the most affect in remediation process and how to choose the best parameters options for the most effective technology.

Phytoremediation is a best choice for the fields which may be used later in sustainable agriculture practice.

Also, it may be used in city and around city areas. The trees will be the best choice for that remediation, because of great naturally look and efficiency in the same time.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

FINITE ELEMENTS ANALYSIS OF A HARROW'S DISC TRAIN DURING THE WORKING PROCESS

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SUMMARY

Disk harrows are widely used as independent agricultural machines for soil processing, namely for germinating layer preparation. They are also found as subassemblies within more complex units used for single pass full soil preparation, these machines being subjected to higly complex loads during the working process. In this paper the authors line out the usefulness of the finite elements analysis when used in the design process of disk harrows.

As a result of the analysis, there are emphasized equivalent stresses, total deformation, maximum displacement and safety factor distributions affecting a disk train's frame under working conditions. This method is advantageous due to the fact that eventual design deficiencies can be eliminated when the project is still on the drawing board.

Key words: *disk harrow, agricultural machines, finite element method*

INTRODUCTION

Agricultural machinery for soil perparation, equipped with working tools with concave discs (spherical shape), successfully replace moldboard plows and other similar agricultural machinery in certain climatic conditions, correcting some of their disadvantages.

The work process of the disc consists of the soil cutting by means of its peripheral sharp cutting edge. By rotating around its major axis and in an inclined plane in comparison with the machine forward direction, the soil is displaced, chopped and partially loose and overturned. During the working process, disc harrows are subjected to very complex loads. Therefore, the finite elements analysis becomes a very usefull tool for the designers.

THEORETICAL BACKGROUND

During this process, the disk cuts the soil with the edge from its periphery, furrow beeing displaced by the segment bounded by the depth of penetration into the soil. The disc must be in equilibrium under the ground reaction forces, which can be reduced to two:

- Reaction force R which acts in a plane tangent to the disc edge (is the resultant of reaction forces acting on the cutting edge's circle segment that enters the soil).
- The reactions resultant R_n acting on the circle sector which detaches the furrow.

The R force intersects the disc's axis of rotation. The Rn force application point is the center of a circle sector delimited by the depth limits and is considered parallel to the disc axis (Fig. 1). The bearings friction and disc inertia are neglected. As R and Rn forces are acting on different planes, they do not intersect and can not have a resultant, but they wil generate a torsor. In order to analyze the action of these forces, their projections Rx, Ry and Rz on coordinate axes will be considered, and also the disc weight: Gd = Rz.

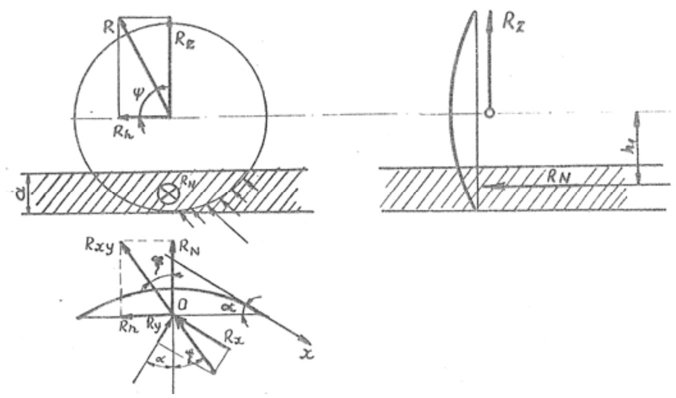

Figure 1 Forces on one disc

The *R* force has a vertical component R_z and and a horizontal one R_h [2,3]. According to figure 1:

$$R_z = R \cdot \sin\psi$$
$$R_h = R \cdot \cos\psi \tag{1}$$

The composition of horizontal forces R_h and R_n gives the R_{xy} resultant, which has two projections on the *x* and *y* axes:

$$R_x = R_{xy} \cdot \sin(\alpha + \xi)$$
$$R_y = R_{xy} \cdot \cos(\alpha + \xi) \tag{2}$$

The three components R_x, R_y and R_z does not give a rezultant because R_x and R_y are in different horizontal planes.

Analytical calculation of the components after the three axes can be achieved only after a prior use of dynamometer on the unit, after which one can determine the R_x component which is distributed by the forward direction. The other components are calculated based on them.

$$R_y = R_x \cdot ctg(\alpha + \xi) \tag{3}$$

because:

$$R_z = R_h \cdot tg\,\Psi$$

$$R_h = R_{xy} \cdot \sin\xi$$

$$R_{xy} = R_x \cdot \frac{1}{\sin(\alpha + \xi)}$$

So it results:

$$R_z = R_x \cdot \frac{\sin\xi}{\sin(\alpha + \xi)} \cdot tg\,\psi \tag{4}$$

Using the following notations:

$$A = ctg(\alpha + \xi)$$

$$B = \frac{\sin\xi}{\sin(\alpha + \xi)} \cdot tg\,\psi$$

the next mathematical relations are derived:

$$\begin{aligned} R_y &= A \cdot R_x \\ R_z &= B \cdot R_x \end{aligned} \tag{5}$$

Coefficients *A* and *B* were obtained on an experimental basis (dynamometer measureme-nts). The values of these coefficients are:

A=0.5…1.4

B=0.9…1.6

for an α angle between 15 and 20° (0.262...0.349 rad).

Starting from the forces acting on a disc, the equilibrium conditions of a free disc train without support wheels are analized. It is supposed that it is equipped with coupling device on the harrow’s frame (Fig. 2). Assuming the soil is homogeneous, we can consider that the resultant of vertical components R_z acts in a vertical plane, while R_n and R_h are acting in a horizontal plane, all beeing applied on the central disc.

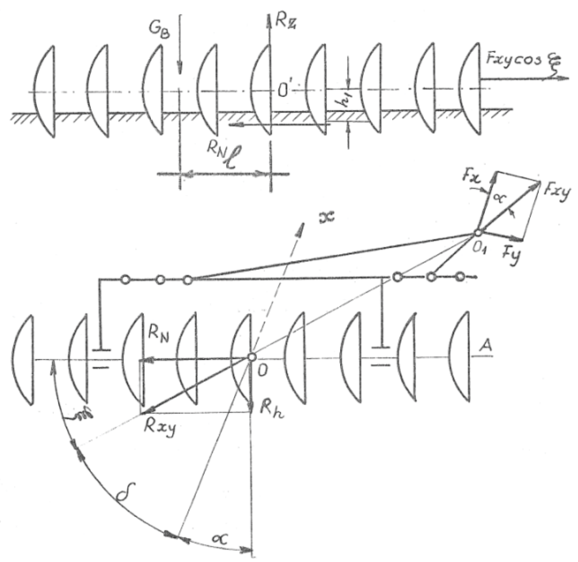

Figure 2 Forces acting on a disc train attached to the frame of the harrow

To maintain a constant angle α (which means a constant depth of work), the R_{xy} resultant must have the same direction as the direction of traction OO_1, which means that R_{xy} must have the same direction with the traction force F_{xy}.

In the O_1 point of traction, there are transmitted the traction reaction force $F_x = R_x$ and the component $F_y = R_y$ (F_y beeing perpendicular on F_x). Any change of the tractor's direction of travel will cause the disc train's turning around O_1, due to the resultant torque induced by R_{xy} and F_{xy}, until these forces will have again the same support. The disc train will always tend to get a stable equilibrium position in horizontal plane, canceling the torque formed by the two resultant forces. The angle between the traction direction and the forward direction is δ (Fig. 2).

The following forces act in a vertical plane: disc train's force of gravity, the ground reaction force R_z, the axial force R_n, and the projection of the traction force on the OA direction (which is equal to R_n).

$$R_N = F_{xy} \cdot \cos \xi$$

For balance, the following condition is required:

$$R_N \cdot \frac{D - a}{2} = G_B \cdot l \tag{6}$$

where GB is the disc train weight.

In case the moment arm *l* is zero, the disc train wil rotate due to the moment *M*, changing the working depth. The front discs will work deeper than the rear ones.

$$M = R_N \cdot \frac{D - a}{2}$$

To maintain a balanced movement of the disc train without support wheels, it requires that its center of mass to be placed closer to the rear discs. Due to the nonhomogeneity of soil and working conditions, the R_{xy} and R_x component values are changing continuously, which gives an unsteady disc train movement. Therefore, the disc trains are required to be equipped with support wheels, which improves balance.

FINITE ELEMENT APPROACH

The analyzed section was modeled in SolidWorks (Fig. 3). The overall dimensions of the model, measured in terms of global coordinate system of the program, are 0.35 x 0.652 x 2.94 m. As a result of specifying the materials used for different parts of the frame, a total model's weight of 188.4 kg was calculated.

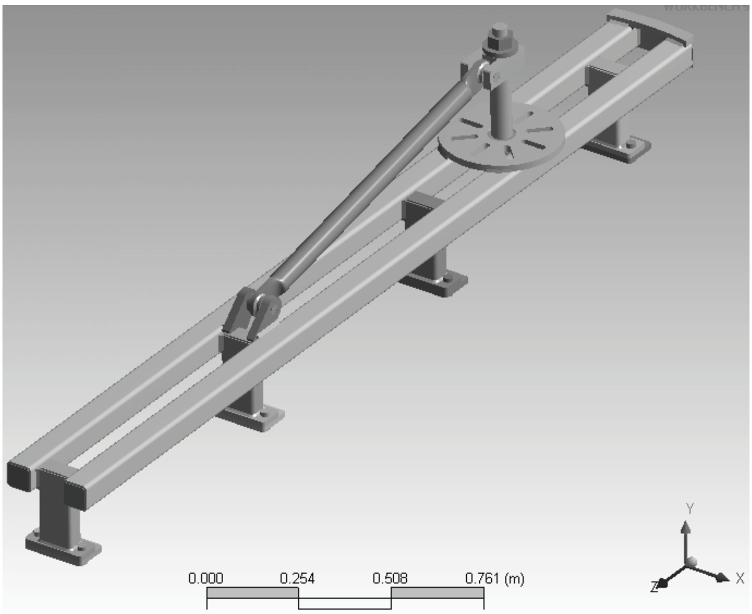

Figure 3 3D model of the disc train's frame

The aim was to model as fair as possible the real structure. The assembly is comprised of 89 pieces, of which 44 are welds. Static analysis performed in ANSYS Workbench -

Mechanical application, took into account the worst case (the forces acting on the frame that occur during the working process are maximum). 104 links between the component parts were made by modeling welds, contacts between welds and parts beeing declared as "bonded" (contact without relative movement between the components).

The remaining 39 contacts in the assembly have been declared as "No Separation" (very small movements between components) in order to avoid nonlinear iterative procedures specific to other possible types, consuming significant computational resources.

FINITE ELEMENT MESHING

In the contact zone the "Part Proximity" property was used, which automatically and gradually reduces the elements' size, in order to improve the accuracy of results. It has been used a proximity relevance coefficient of 40. A stronger refinement would lead to a higher number of elements, with corresponding increase in computing resources required. The elements type selection was left to the discretion of the program. It automatically placed higher order elements in critical areas. The final model contains 70,027 elements and 165,706 nodes. Figure 4 shows an overview of the global mesh and two details.

WORKING ENVIRONMENT

Working environment contains all loading conditions and boundaries of the model. In addition to structural loads, the influence of mass was taken into account, by placing an acceleration equal to the acceleration of gravity and with an opposite direction.

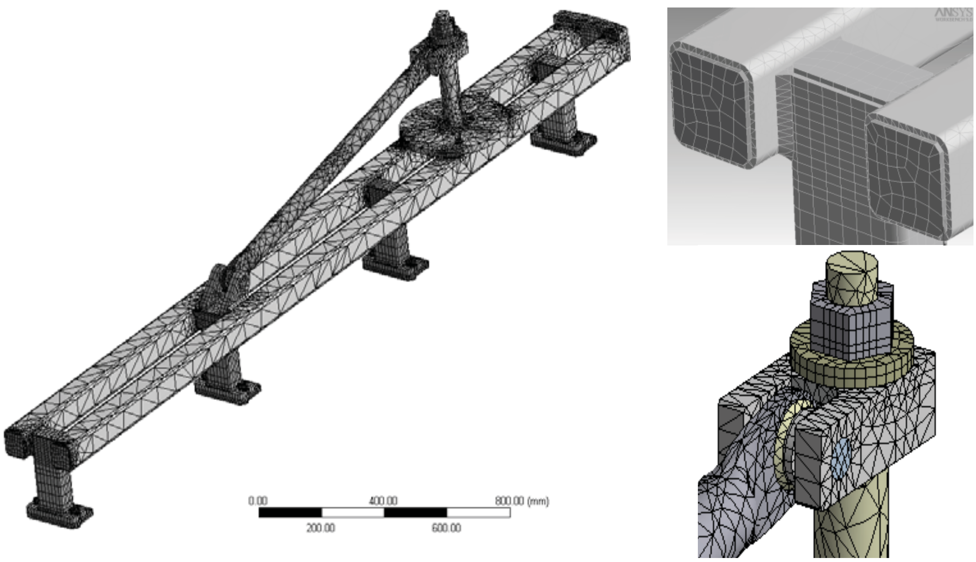

Figure 4 Meshed assembly

Maximum forces that can be transmitted by the 16 discs on the four mountings welded on the frame, are of the "Remote Force" type (Figure 5). The reason was to avoid the modeling of discs and their axles. Each force was defined by three components in relation to a user-defined coordinate system and was applied four times - once for each mounting. The values of the three components are F_x = 746 N, F_y = 207 N, F_z = 115 N, the resultant having a magnitude of 782.68 N.

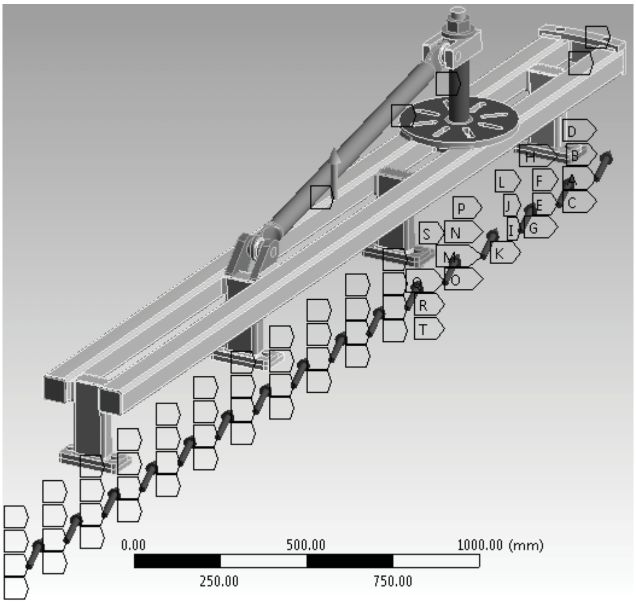

Figure 5 Remote forces exerted by the 16 discs

In order to model the coupling of the disc train to the harrow's frame, displacement restrictions of the following types have been specified: "Given Displacement" (with zero displacement on one of the coordinate system's axes), "Fixed Support" and "Cylindrical Support".

The model was solved with default values and settings implemented for the solver.

RESULTS

Visual representation of the equivalent stresses was done in two colors, thus clearly differentiating the areas where the material has an elastic behaviour of the zones of plasticity. It was found that, in this particular case of the maximum forces action, there are localized areas belonging to some welds and their surroundings, where the elastic limit and, in two cases, the ultimate strength are exceeded (Fig. 6, 7).

Total maximum displacement occurs at the outer end of the harrow and has a value of 1.42 cm, which shows a good rigidity of the assembly.

Figure 6 Yield strength (3.7×10^8 Pa) exceeded

Figure 7 Ultimate strength (6.4×10^8 Pa) exceeded

The safety factor was calculated in relation to yield limit [1,5]. Figure 8 shows that there are small welded areas on the 1-st and 2-nd mountings, where the safety factor has values under 1. This confirms the plastic behaviour of the material in these areas. A minimum safety factor of 0.179 was calculated.

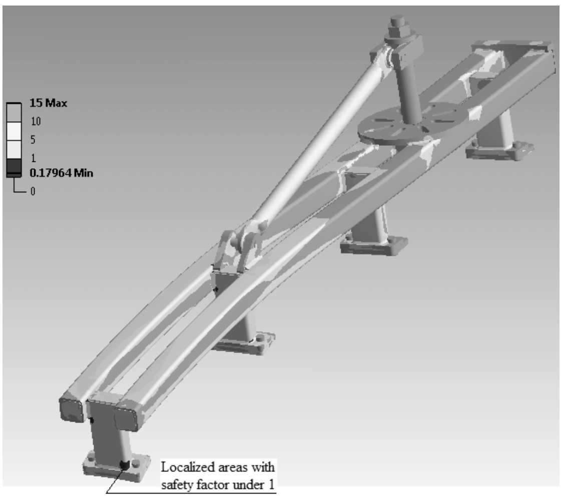

Figure 8 Safety factor distribution

CONCLUSIONS

1. Mesh refinements have been made in localized areas to determine more accurate stress values.
2. The reduced deflection of the free outer end of the frame (1.42 cm) relative to its length reveals a very good stiffness of the frame, which translates into high working precision.

3. The analysis of the disc train's frame showed that the part displayed signs of localized yield under the given loading condition. Even if the yielding is very localized (which means some permanent deformation of the part and possibly some small misalignment of the frame), danger of small cracks is present. This can lead in time to permanent failure as they act as fatigue-stress concentrators.
4. Based on the given results, improvements on the design can be made in order for the frame to be more than capable of carrying the load under maximum loading conditions. For example, an increase of the weldments' thickness would be the simplest solution.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

ECONOMIC EFFICIENCY OF NON-CONVENTIONAL SOIL TILLAGE SYSTEMS IN OIL SEED RAPE AND WINTER BARLEY PRODUCTION

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ABSTRACT

The paper presents results of the two years experiment in oil seed rape (Brassica napus L) and winter barley (Hordeum vulgare L) production with five different soil tillage systems carried out in Western Slavonia, at agricultural company "PK Nova Gradiška" in village Staro Petrovo Selo, located 150 km south-east from Zagreb (45° 10' N, 17° 30' E). Energy requirement comparison showed that CT system in both crops production had the highest fuel consumption of 47.36 L ha^{-1} (oil seed rape) and 50.93 L ha^{-1} (winter barley). Also, the best energy saving system in both crops production was RT1 with 32.60 L ha^{-1} in oil seed rape and 33.03 L ha^{-1} in winter barley production, which is decrease of 31.2 % and 35.1 % respectively. Soil tillage systems comparison regarding labour requirement unveiled that conventional tillage required 2.04 h ha^{-1} and 0.45 h Mg^{-1} in oil seed rape, while in winter barley production required 2.14 h ha^{-1} and 0.52 h Mg^{-1}. The highest average yields were obtained by CT system in oil seed rape (3.85 Mg ha^{-1}) and RT3 in winter barley production (4.42 Mg ha^{-1}), while the lowest yields were with RT1 in both crops production, 3.21 Mg ha^{-1} in oil seed rape and 3.71 Mg ha^{-1} in winter barley.

Key words: *soil tillage, energy and labour requirement, income/costs ratio*

INTRODUCTION

Soil tillage aims to create favourable conditions for seed germination and plant growth and is considered an indispensable part of arable crop production. The intensification of tillage, along with fertilization, crop protection and selection, has enabled a significant increase in yields, but also caused soil degradation, increased risk of erosion and rise of production costs. Greatest possibility for production rationalization offers tillage reduction, mainly by substitution of mouldboard ploughing as most energy and time-demanding task with conservation tillage systems.

Oil seed rape (*Brassica napus* L) and Winter Barley (*Hordeum vulgare* L.) are among the most important arable crops in Croatia. The mainly utilised soil tillage system in these crops production is conventional system, based on mouldboard ploughing as primary tillage operation, followed with secondary tillage performed by disc harrow and seed-bed implement. This tillage technology is, from one side, the most expensive, organisationally slow, with high fuel consumption and labour requirement, and, from another side, ecologically unfavourable *(Zugec et al., 2000)*. *Pellizzi et al. (1988)* reported that 55-65% of direct field energy consumption could be accounted to soil tillage. According to researches conducted in EU *(Tebrügge et al., 1998)* the conventional tillage system requires 434 kWh ha^{-1} of energy and 4.1 h ha^{-1} of human-machine work. In contrast, reduced tillage systems can achieve saving 30% -50% of energy and human-machine work, and direct sowing as much as 70%, compared with conventional tillage. It should be noticed that *Košutić et. al. (1995)* after experimenting with different reduced tillage methods concluded that soil tillage systems which included mouldboard plough and PTO driven implements like rotary harrow or rotary cultivator were often equally or more demanding in energy consumption as conventional tillage system, but more favourable regarding human labour and soil compaction.

Stroppel (1997) reported that by the end of the last century about 85% of the arable land of central Europe was under conventional tillage systems. The implementation of reduced tillage systems has not significantly increased to date, and it is estimated that there are still less than 20% *(ECAF, 2010)*. The world leading agricultures in substitution of conventional soil tillage systems with different variations of the reduced tillage and direct sowing are United States and Canada in North America and Brazil, Argentina, Uruguay and Paraguay on the South, where conservation tillage and no-tillage systems applied to more than half of total arable crop area *(Derpsch and Friedrich, 2009)*. Despite the mentioned trends, it is estimated that over 90 percent of the fields in Croatia are still being tilled with the conventional tillage system *(Zimmer et al., 2002)*.

MATERIAL AND METHODS

The experiment was performed at agricultural company "PK Nova Gradiska" in village Staro Petrovo Selo, located 150 km south-east from Zagreb (45° 10' N, 17° 30' E). Experimental field was consisted of 12 plots with dimension length 250 m x width 56 m each, organized as randomized blocks with three replications. The tillage with different systems was performed on the Hypogley-vertic type of soil, *(Anonymous, 1998)*. Its texture in ploughed layer according to *Anonymous (1975)* belongs to the silty clay loam (Table 1). Implements, which were included in different tillage systems, are as follows:

1. Conventional tillage - plough, disc harrow, seed-bed implement, drill (CT);
2. Conservation tillage 1- chisel plough, disc harrow, seed-bed implement, drill (RT 1);

3. Conservation tillage 2 - chisel plough, rotary harrow + drill (RT 2);
4. Conservation tillage 3 - plough, rotary harrow + drill (RT 3).

In conservation tillage systems RT2 and RT3 an integrated implement consisted of rotary harrow and drill was used. The energy requirement of each tillage system was determined by tractor's fuel consumption measurement for each implement in each tillage system applying volumetric method. Energy equivalent of 38.7 MJ L^{-1} *(Cervinka, 1980)* was presumed. In this experiment 4WD tractor with engine power of 136 kW was used. The working width of the tillage implements was chosen according to the pulling capacity of the tractor. The labour requirement was determined by measuring the time for finishing single tillage operation at each plot of the known area (14.000 m^2). The yields were determined by weighing grain mass of each harvested plot, and recalculated according to grain moisture content in storage conditions afterwards.

Table 1 Soil particle size distribution and soil type (Hypogley-vertic)

Soil layer (cm)	0.2-2 µm (%)	0.05-0.2 µm (%)	0.002-0.05 µm (%)	<0.002 µm (%)	Soil type*
0-35	16.0	28.0	22.0	34. 0	SCL
36-55	13.0	32.0	26.0	29.0	SCL-SL
56-85	13.0	31.0	28.0	28.0	SCL
86-170	16.0	31.0	24.0	29.0	SCL

*SCL=Silty clay loam, SL=Silty loam

Air temperatures in cropping period 2008-2010 were generally within twenty year's average with no significant deviations recorded (Figure 1). Total precipitation during cropping period of oil seed rape was within twenty years average but the distribution of precipitation was irregular (Figure 2). The significant lack of precipitation occurred in August 2008, so the sowing of oil seed rape was delayed until 18th September. Also the 2009 spring was very dry, so weather conditions regarding precipitation weren't favourable for oil seed rape production. On the contrary, during winter barley growing period the great excess of precipitation occurred in May and June 2010 (more than double of average). Although there was stagnating water over experimental plots, the obtained yield of winter barley was slightly lower than expected.

Schedule of the field operations (tillage, fertilizing, sowing, crop protection, harvesting) and soil moisture content at the moment of tillage are shown in Table 2. On the experimental field previous crop was winter wheat. Working conditions regarding soil moisture content, soil compaction and post-harvest residues at the beginning of experiment were equal for all tillage treatments.

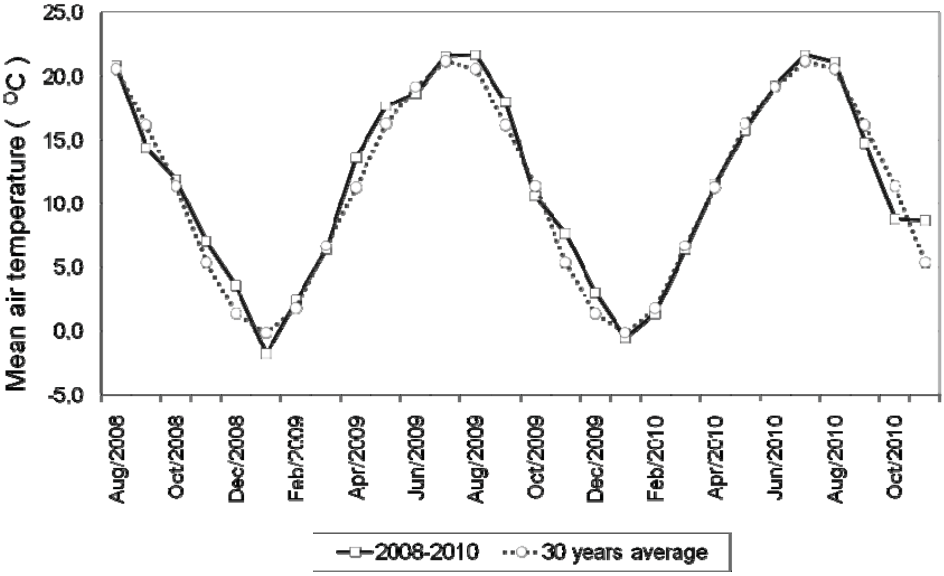

Figure 1 Mean air temperature during cropping period

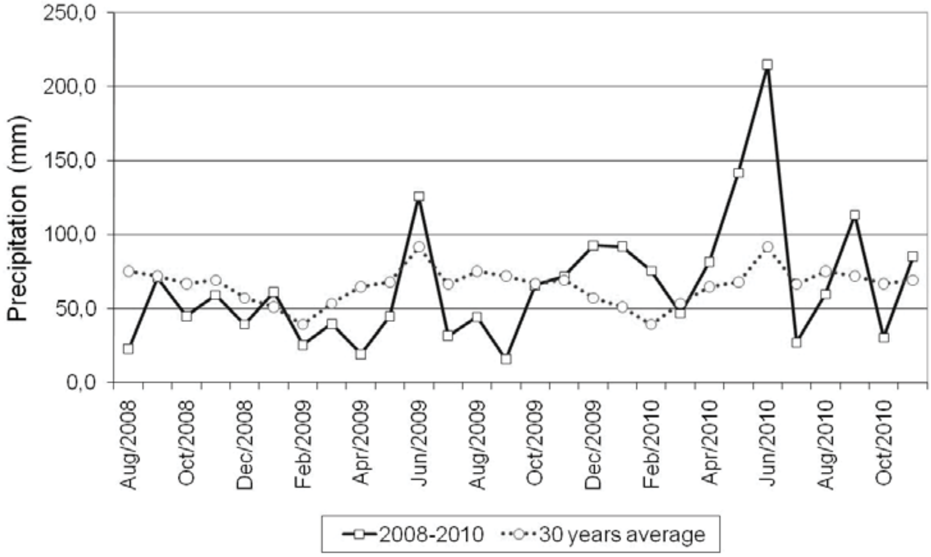

Figure 2 Precipitation during cropping period

Table 2 Date of field operations, soil moistures and application rates

Description	Oil seed rape 2008/2009	Winter barley 2009/2010
Tillage & Sowing		
Primary tillage	30th July 2008	1st November 2009
Soil moisture (%) at 5; 15; 30 cm depth	29.4; 33.6; 37.9	18.8; 28.7; 33.2
Secondary tillage	6th August 2008	15th October 2009
Soil moisture (%) at 5; 15; 30 cm depth	28.0; 31.3; 36.3	30.1; 29.7; 31.0
Sowing date	18th September 2008	15th October 2009
Crop-cultivar (kg ha^{-1})	Elvis (3.5)	Mombasa (210)
Fertilizing		
Application date	29th July 2008	14th October 2009
Fertilizer-rate (kg ha^{-1})	NPK 10:30:20 (100)	Urea 46% (100)
Application date	7th March 2008	2nd March 2010
Fertilizer-rate (kg ha^{-1})	CAN 27% (250)	CAN 27% (150)
Application date	24th March 2008	
Fertilizer-rate (kg ha^{-1})	Urea 46% (300)	
Crop protection		
Application date	19th September 2008	27th November 2009
Chemical-rate (l ha^{-1})	metazachlor (1.7)	cyhalothrin (0.15) triasulfuron (45 g ha^{-1})
Application date	10th October 2008	15th April 2010
Chemical-rate (l ha^{-1})	cyhalothrin (0.15) methiocarb gr. (5 kg ha^{-1})	azoxistrobin (0.033)
Application date	9th April 2009	21th April 2010
Chemical-rate (l ha^{-1})	chlorpyrifos + cypermethrin (0.9)	epoxichonazol + crezoxim-metil (0.8)
Application date	3rd July 2008	12th May 2010
Chemical-rate (l ha^{-1})	dimoxistrobin + boscalid (0.5)	prothioconazole (0.9)
Harvest		
Harvesting date	4th July 2009	12th July 2010

RESULTS AND DISCUSSION

Yield

In the first experimental season the greatest average oil seed rape yield of 3.85Mg ha^{-1} achieved CT system followed by RT3 system which obtained average yield of 3.76 Mg ha^{-1} and RT2 system with 3.63 Mg ha^{-1}. RT1 system had the lowest average yield of 3.21 Mg ha^{-1}. According to noticed average yield differences, statistical analysis showed that tillage system RT1 achieves statistically significant lower yield than other tillage systems. *Košutić et al. (1997)* reported that the highest yield was obtained with energetically most favourable tillage system consisted of rotary cultivator with integrated drill, while other reduced tillage systems achieved lower yields than conventional system.

In winter barley production RT3 achieved the greatest average yield of 4.42 Mg ha^{-1} followed by CT with average yield of 4.14 Mg ha^{-1} and RT2 with 4.04 Mg ha^{-1}. The lowest average yield obtained RT1 with 3.71 Mg ha^{-1}. According to ANOVA differences of average winter barley yields obtained by different soil tillage systems were statistically significant between RT3 and RT1, at probability level of $p<0.05$. CT and RT2 yields were not significantly different to other tillage systems. While *Chatskikh and Olesen (2007)* reported that spring barley dry matter grain yields were reduced by 14% for RT and 27% for DD (direct drill) compared to CT, *Moret and Arrue (2007)* experimenting with different tillage systems in winter barley production during three consecutive cropping seasons reported that no clear differences in crop yield were observed among the tillage treatments in the study period.

Energy requirement

The conventional tillage system (CT) was expectantly the greatest fuel consumer with 47.36 L ha^{-1} in oil seed rape and 50.93 L ha^{-1} in winter barley production. RT3 system enabled saving of 9.7 % of energy per hectare in oil seed rape and 10.3 % in winter barley production. RT2 system enabled saving of 20.3 % and 20.1 % of energy per hectare in oil seed rape and winter barley production respectively. The greatest energy saving per hectare in oil seed rape production of 31.2 % was obtained by RT1 system, while in winter barley production it was 35.1 % by the same tillage system. *Bowers (1992)* showed a composite of average fuel consumption and energy expended, based on data from different countries around the world and reported that average fuel consumption for mouldboard ploughing is 17.49±2.06 L ha^{-1}, chisel ploughing 10.20±1.50 L ha^{-1}, while no-till planter required 4.02±1.03 L ha^{-1}. In comparing these data to other sources, wide variations can be expected due to soil types, field conditions, working depth, etc. On the other hand, *Köller (1996)* reported that the fuel consumption was 49.40 L ha^{-1} for mouldboard ploughing, 31.30 L ha^{-1} for chisel ploughing and 13.40 L ha^{-1} for no-till. *Hernanz and Ortiz-Cañavate (1999)* presented data that coincide between previously mentioned results.

Table 3 Energy and labour requirement of different soil tillage systems

	Oil seed rape 2008/2009				Winter barley 2009/2010			
Tillage system	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	Productivity h Mg^{-1}	Fuel L ha^{-1}	Energy MJ Mg^{-1}	Productivity h ha^{-1}	Productivity h Mg^{-1}
CT	Average yield = 3,85 Mg ha^{-1} a[(1)]				Average yield = 4,14 Mg ha^{-1} ab			
Plough	29,51	296,3	1,10	0,24	33,4	312,3	1,21	0,29
Disc harrow	10,21	102,5	0,31	0,07	9,95	93,0	0,28	0,07
Seed-bed implement	5,07	50,9	0,18	0,04	4,95	46,3	0,24	0,06
Drill	2,57	25,8	0,45	0,10	2,63	24,6	0,41	0,10
Total	47,36	475,6	2,04	0,45	50,93	476,2	2,14	0,52
RT 1	Average yield = 3,21 Mg ha^{-1} b				Average yield = 3,71 Mg ha^{-1} b			
Chisel	17,67	213,2	0,49	0,12	18,42	192,4	0,58	0,16
Disc harrow	7,29	88,0	0,31	0,07	7,03	73,4	0,26	0,07
Seed-bed implement	5,07	61,2	0,18	0,04	4,95	51,7	0,24	0,06
Drill	2,57	31,0	0,45	0,11	2,63	27,5	0,41	0,11
Total	32,6	393,4	1,43	0,34	33,03	344,9	1,49	0,40
RT 2	Average yield = 3,63 Mg ha^{-1} a				Average yield = 4,04 Mg ha^{-1} ab			
Chisel	17,67	188,3	0,49	0,12	18,42	176,4	0,58	0,14
Rotary harrow + drill	20,07	213,9	0,74	0,17	22,26	213,2	0,78	0,19
Total	37,74	402,2	1,23	0,29	40,68	389,6	1,36	0,34
RT 3	Average yield = 3,76 Mg ha^{-1} a				Average yield = 4,42 Mg ha^{-1} a			
Plough	29,51	304,1	1,10	0,24	28,86	252,9	1,23	0,28
Rotary harrow + drill	13,25	136,6	0,75	0,17	16,83	147,5	0,76	0,17
Total	42,76	440,7	1,85	0,41	45,69	400,4	1,99	0,45

(1) Different letters indicate significant ($p \leq 0.05$) differences

Economic analysis

Total costs include all the inputs (labour, machine costs, seed, fertiliser and plant protection chemicals) from soil tillage to harvest, including grain transport within field. Storage and handling costs weren't taken into account since its great variability.

In both seasons CT system resulted in the highest costs with 688 € ha^{-1} (oil seed rape) and 564 € ha^{-1} (winter barley). In oil seed rape production the income/costs ratio differences showed that RT2 system obtained the best economic result but only RT1 system had statistically significant lower ratio among tested tillage systems (Table 4). In winter barley production the ANOVA unveiled that RT2 and RT3 tillage systems were significantly better considering the income/costs ratio than CT and RT1 systems (at probability level $p<0.05$).

Table 4 Total cost, gross income and gross margin

Tillage	Oil seed rape				Winter Barley			
	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio	Gross income € ha^{-1}	Total costs € ha^{-1}	Gross margin € ha^{-1}	Income/ Costs ratio
CT	1222	688	534	1,78 a[(1)]	875	564	311	1,55 b
RT 1	1068	660	408	1,62 b	816	537	279	1,52 b
RT 2	1169	619	550	1,89 a	862	496	366	1,74 a
RT 3	1198	647	552	1,85 a	913	523	390	1,75 a

[(1)] Different letters indicate significant ($p\leq 0.05$) differences

CONCLUSIONS

Summarizing results of short term experiment results together with previously acquired experience following could be concluded:

1. In comparison to conventional tillage (CT) the greatest energy saving per hectare of 31.2 % in oil seed rape and 35.1 % in winter barley production was obtained by RT1 system.
2. The lowest labour consuming soil tillage system in both cropping seasons was RT2, enabled savings of 39.6 % in oil seed rape and 36.5 % in winter barley production.
3. Since there weren't statistically significant yield differences between three soil tillage systems in oil seed rape production, the system with the best income/costs ratio (RT2) could be right choice, due to its lowest total costs.
4. In winter barley production RT3 tillage system could be the best solution due to its significantly highest yield and best income/costs ratio obtained.

This short-term experiment showed that non-conventional tillage systems, due to their lower energy and labour requirement, could be economically important tool to decrease production costs.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

EFFICIENT METHODS FOR LAND DRAINAGE DESIGN USING COMPUTERIZED NON STEADY-STATE METHODS

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ABSTRACT

Drainage is a vital part of water resources integrated management. The integrated management of water resources represents a process which promotes the coordination of water, soils and other resources management and development in order to maximize the economic and social sectors in an equitable manner and without compromising the sustainability of vital ecosystems.

During the last decades many researchers created specialized software, with different levels of complexity, in the field of land drainage. This paper will analyze applications as Espadren (from Costa Rica), Drainspace (from United Kingdom) and GDZ RoDrain (from Romania) which are using the non steady-state equations in computing the spaces between drains and will present a study case from Romania.

Key words: *drainage, Espadren, Drainspace, GDZ RoDrain*

INTRODUCTION

The approach of non-permanent regime, in the process of designing drainage systems, describes only a simplified relation, constant, between water-table and flow. In reality, water-table recharge is function of time and as a consequence the underground flow to the drains is not constant. In order to describe the water-table fluctuations as function of time designers are using the non-permanent regime of flow.

The equations which are describing this process are based on the differential equations of non-permanent flow. The both approaches (permanent and non-permanent) are based on Dupuit-Forchheimer assumptions. The only difference is represented by recharge which in the case of non-permanent regime is variable in time.

Equations which are describing the non-permanent regime were proposed by Glover-Dumm, De Zeeuw-Hellinga, Jenab, Guyon, Kraijenhoff van der Leur Maasland and others.

The equations of Glover-Dumm, De Zeeuw-Hellinga, Jenab, Guyon, Kraijenhoff van der Leur Maasland had a large applicability being used in many countries with different climate and soil characteristics.

The calculations were realized for Margina area from Timis County, western Romania.

METHODS

Actual researches in the frame of non-permanent regime of drainage are based especially on Glover-Dumm equation.

Glover-Dumm equation is used for describing a water-table level with a decreasing tendency after a sudden rise due to an instantaneous recharge. This situation is typical for irrigated areas where the water-table level is rising usually very sudden during water applications in order to decrease subsequently in a slow way.

Glover-Dumm equation has the following form:

$$L = \pi \left(\frac{Kdt}{\mu} \right)^{\frac{1}{2}} \left(\ln 1{,}16 \frac{h_0}{h_t} \right)^{-\frac{1}{2}}$$

where L is the distance between drains, K is the hydraulic conductivity, μ is the drainable porosity, d_r represents equivalent depth of the soil layer below drain level, t represents the necessary period (in days) to decrease the water table level from h_0 to h_t, h_0 is the initial height of water table level, h_t is the desired height of water table level.

The original equation is based only on the horizontal flow and doesn't take in consideration the radial resistance of flow, to the drains, which doesn't reach the impermeable layer. By similarity with the approach of permanent regime, in any situation, with the introduction of Hooghoudt's concept regarding the equivalent soil layer, the resistance caused by convergent flow to the drains will be considered in calculations.

De Zeeuw-Hellinga equations are used for describing a fluctuant water-table. In this approach, a non-uniform recharge is divided in small periods of time in order to accept this recharge as being constant on these small periods. This situation is specific for humid areas with a high intensity of precipitations, concentrated in storms.

We can use the following equations:

$$q_t = q_{t-1} e^{-\alpha \Delta t} + R\left(1 - e^{-\alpha \Delta t}\right)$$

and

$$h_t = h_{t-1} e^{-\alpha \Delta t} + \frac{R}{0{,}8\mu\alpha}\left(1 - e^{-\alpha \Delta t}\right)$$

for simulating drains discharge and the water-table fluctuations basing on a critical distribution of precipitation intensity obtained from records from archives.

In the Kraijenhoff-Maasland equation, the recharge has been considered constant over any time period t instead of instantaneous recharge which was assumed in Glover-Dumm equation.

The height of the water-table midway parallel drains (where x = 0,5L) at any time is given by the following equation:

$$h_t = \frac{4}{\pi} \cdot \frac{R}{S} j \sum_{n=1,3,5}^{\alpha} \frac{1}{n^3}\left(1 - e^{-n^2 t / j}\right)$$

where:

$$j = \frac{SL^2}{\pi^2 KD} = \frac{1}{\alpha}$$

called reservoir coefficient.

We can also compute the discharge intensity, q_t, with the following formula:

$$q_t = \frac{8}{\pi^2} R \sum_{n=1,3,5}^{\alpha} \frac{1}{n^2}\left(1 - e^{-n^2 t / j}\right)$$

To account for the convergence of stream lines in the vicinity of drains not reaching impermeable layer D is replaced by d for Hooghoudt and:

$$j = \frac{SL^2}{\pi^2 Kd}$$

Other two equations which are used in the analyses of non-permanent regime belong to Guyon and Jenab.

Guyon's method explains water table depletion by fictive, wider drain spacing, but it is less precise compared with Glover'Dumm's, even though they are basically similar. This property of Guyon's method limits its application.

Guyon’s method is based on the following equation:

$$L^2 = \frac{32Kdt}{\pi\mu}\left[\ln\frac{(2d + h_t)h_0}{(2d + h_0)h_t}\right]^{-1}$$

where: *K* – soil permeability (m/day); *d* – equivalent drain depth (m); *t* – time of drainage (days); μ - drainage porosity; *h0* – maximal groundwater table depth; *ht*- minimal level of depression curve at the end of depletion process (m).

Jenab proposed a formula for calculation of distances between drains in non-permanent regime considering the following assumptions:

- The soil is homogenous;
- The flow is horizontal and radial, in the formula for calculation of distances between drains being used the equivalent soil depth;
- The formula for calculation between drains is based on heat flux equation;
- The equation's solution describes the decrease of water-table level as function of time, distance between drains and soil's properties.

A graphical solution of Jenab formula can be expressed as it follows:

$$L = \frac{1}{C}\sqrt{\frac{4tKD_h}{\phi}}$$

which can also be written as:

$$L = \frac{1}{C}\sqrt{\frac{4tK}{\phi}\left(d + \frac{h_0 + h_t}{4}\right)}$$

where L – distance between drains; K – hydraulic conductivity; D_h – thickness of the soil layer where appears the horizontal flow; d – Hooghoudt's equivalent soil layer; D – depth from drains line to impermeable layer; h_0 – initial height of water-table level above drains; h_t – final height of water-table level above drains after t period; C – value obtained with the help of graph as function of $D(U_n)=h_t/h_0$; t – necessary time to decrease the level of water-table from h_0 to h_t; Φ – drainable porosity.

Jenab proposes the following formula for the equivalent soil layer:

$$d = \frac{D}{\frac{8}{\pi}\cdot\frac{D}{L}\ln\left(\frac{D}{\phi}\right) + 1}$$

In the frame of this paper I used a number of 3 different software's: DrainSpace, Espadren and GDZ RoDrain, each of them based on Glover-Dumm formula. With their help I calculated the distance between drains for Margina area, affected by humidity excess and located in Timis County, western Romania. Espadren also offers the opportunity to compute the distance between drains with the help of Jenab formula while GDZ RoDrain also includes applications based on Guyon and De Zeeuw-Heillinga formulas.

RESULTS

For Margina area we have the following information: H_{drain} (drain's depth) = 1,4 m; K = 0,16 m/day; Φ = 0,04; r (drain radius) = 0,04 m; h_0 = 0,8 m; h_t = 0,6 m; t = 2 days.

I also mention that for Margina area, in permanent regime using Ernst formula, we obtained a distance between drains equal with 9 m.

The results are presented in tables.

Table 1 Results obtained in computing the distances between drains for Margina area using Glover-Dumm formula in the frame of DrainSpace, Espadren and GDZ RoDrain applications

t (days)	Drain Space L (m)	Espadren L (m)	GDZ RoDrain L(m)
2	5,77	15,38	14,07
3	7,71	19,46	17,23
4	9,4	22,93	19,9

As it can be seen from the previous table and graph, DrainSpace offers lower values than Espadren and GDZ RoDrain which presents similar results. On the other side, we can say that Espadren and GDZ RoDrain are presenting much „economical" solutions that DrainSpace but we must verify if these solutions are technical acceptable.

In table 2 I will present a comparison between the results obtained with Glover-Dumm and Jenab formulas in the frame of Espadren program.

Table 2 Results obtained in computing the distances between drains for Margina area using Glover-Dumm and Jenab formulas in the frame of Espadren application

t (days)	L (m) (Glover-Dumm)	L (m) (Jenab)
2	15,38	13,93
3	19,46	17,66
4	22,93	20,84

Jenab formula is not a very used method being introduced only at the beginning of 2010 in Romanian technical literature. We can compare the results obtained with this method with other results but only at theoretical level due to the less experience in applying Jenab method in Romania.

In table 3 I will present a comparison between the results obtained with Glover-Dumm and Guyon formulas in the frame of GDZ RoDrain application.

Guyon formula it seems to be much economical than Glover-Dumm for a period of time longer than 4 days but due to its less precision we must verify its results and from technical point of view.

Table 3 Results obtained in computing the distances between drains for Margina area using Glover-Dumm and Guyon formulas in the frame of GDZ RoDrain application

t (days)	L (m) (Glover-Dumm)	L (m) (Guyon)
2	14,07	13,22
3	17,23	16,65
4	19,9	19,62

Anyway, we can observe from the last two graphs that Espadren and GDZ RoDrain are presenting relative similar results, with small differences between them.

Using the average of the 4 series of results I verify how will function the drainage system if I will adopt a distance between drains of 14 m and I will impose a period of 2 days for decreasing the water table level from 0,8 to 0,6 m knowing that for Margina area, in April, we have 94,2 mm of precipitation. I used De Zeeuw-Heillinga method in the frame of GDZ RoDrain application.

H_{drain} (drain's depth) = 1,4 m; K = 0,16 m/day; Φ = 0,04; r (drain radius) = 0,04 m; h_0 = 0,8 m; h_t = 0,6 m; t = 2 days; d = 0,97; α (reaction factor) = 0,195; q_0 (initial discharged flow) = 0,003 m/day.

We can observe that the drain system, with a distance of 14 m between drains, will be able to decrease the water-table level from 0,8 m to 0,6 m in 2 days so we can conclude that the obtained values correspond from technical point of view.

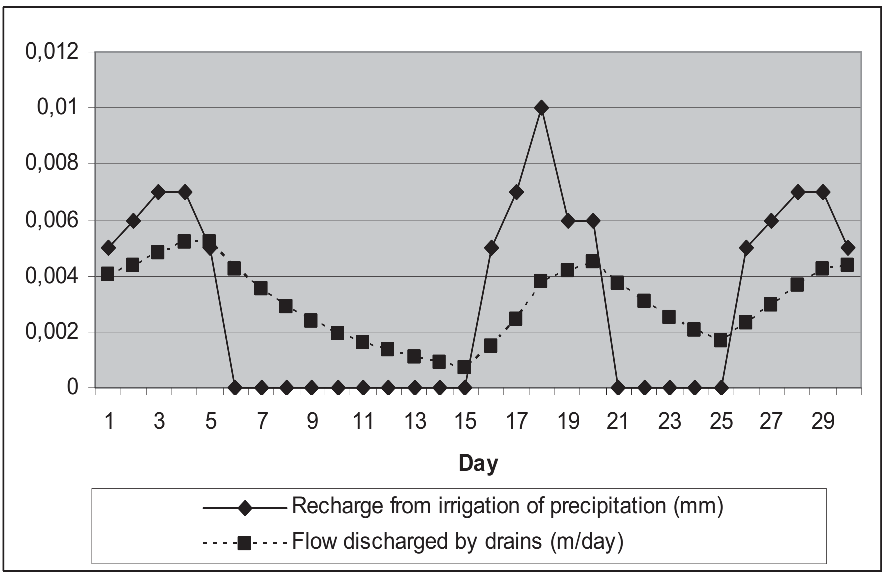

Figure 5 Graphical representation of recharge and discharged flow

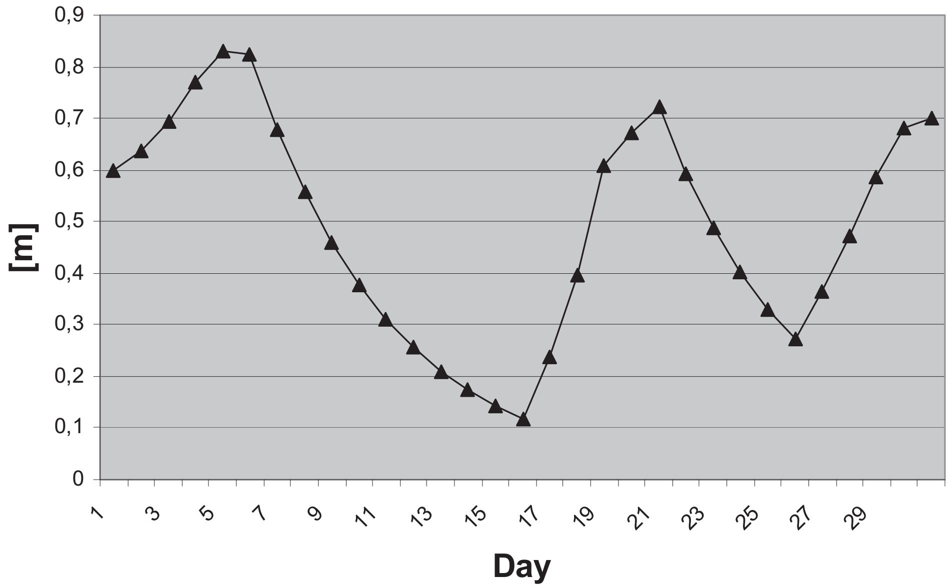

Figure 6 Graphical representation of water-table level variation

CONCLUSIONS

The non-permanent regime, which reflects the reality in the frame of drainage systems, was analyzed by many researchers which presented different equations, many of them transposed in computerized applications.

Due to the numerous essential decisions which must be taken in designing and implementing a drainage system, the researchers and designers must used specialized applications in order to obtain accurate results and to eliminate different types of errors which can appear in manual calculations.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

DIFFERENT SOFTWARE FOR AGRICULTURE WATER MANAGEMENT IN ROMANIA

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ABSTRACT

An efficient agriculture in Romania's climatic conditions can be practiced only with the help of performant land reclamation and improvement systems.

Due to the numerous and different situations which can appear in trying to ameliorate the lands affected by humidity excess or water scarcity, Romanian researchers developed different methods for an efficient water management in agriculture. Unfortunately, these methods were not transposed in computer programs and their resolving processes suppose long time and predisposition to errors. Computerized methods allow us to easy identify errors and to correct them before launching the calculations.

This paper will present different Romanian and international computer programs specialized on agriculture water management used by Romanian researchers and results which were obtained with these programs.

Key words: *agriculture water management, software*

INTRODUCTION

The effects of climatic changes, during the last years, request a better management of water resources from agriculture.

Irrigation and drainage (the most important land reclamation and improvement measures) arrangements must be focused on water conservation by applying efficiently the watering volumes and by managing and using efficiently the water-table and the drained water.

In order to reach these targets, irrigation and drainage engineers must know very well the designated area, the soil conditions, crops necessities, climate features and many other relevant factors. All the factors imply elaborated calculations, many of them requesting computerized methods.

Among the most important computer programs specialized on agriculture's water resources management I can mention DrenVSubIr (Romania), GDZ RoDrain (Romania) and Drainmod (USA), Espadren (Costa Rica) and EnDrain (Netherland) for drainage issues and Netafim (Israel) for irrigation issues.

These programs can be applied in different parts of this world. Their characteristics allow the user to apply the program's procedures in different climatic conditions, on different soils and for specific purposes.

Romanian researchers are using with success programs from different parts of the world: USA, Europe, Middle East, Central America.

METHODS

First Romanian software's for agriculture's water resources management were realized for drainage projects design at the beginning of 1990's.

They had a simple interface and calculate only the distance between drains by using Ernst formula.

$$h=\frac{q\cdot D_v}{K_l}+\frac{q\cdot L^2}{8\cdot K_l\cdot T_e}+\frac{q\cdot L}{K_l}\cdot \ln\frac{\alpha\cdot D_0}{U}+\frac{q\cdot L}{K_l}\cdot \zeta_{if}$$

Even Romanian researchers developed different methods for an efficient water management in agriculture, unfortunately, these methods were not transposed in computer programs and their resolving processes suppose long time and predisposition to errors.

Only in 2007 appeared a new program, DrenVSubIr, with a friendly interface, program which calculate the distance between drains and also verify the possibilities for applying the subirrigation.

The disadvantages of this software are:

- The calculations are realized only for permanent flow regime without verifying the results in non-permanent situation;
- The results can't be saved on magnetic support and can't be printed;
- The program has only Romanian version and can't be used by foreign users without a correct translation being know that, at this hour, are many differences between Romanian specific drainage terminology and the drainage terminology used in other countries.

In 2010 I write a new application, GDZ RoDrain, for drainage projects design, application which uses Glover-Dumm, De Zeeuw-Heillinga and Guyon equations (for non-permanent flow regime), the results being comparative with programs from other countries (e.g. Espadren from Costa Rica).

$$L = \pi\left(\frac{Kd_r t}{\mu}\right)^{\frac{1}{2}}\left(\ln 1{,}16\frac{h_0}{h_t}\right)^{-\frac{1}{2}}$$

where L is the distance between drains, K is the hydraulic conductivity, μ is the drainable porosity, d_r represents equivalent depth of the soil layer below drain level, t represents the necessary period (in days) to decrease the water table level from h_0 to h_t, h_0 is the initial height of water table level, h_t is the desired height of water table level.

GDZ RoDrain also offers the possibility to analyze the water-table variation as function of: percolations from irrigation and/or precipitations, distance between drains, time imposed for decreasing the water-table level from h_0 to h_t.

GDZ RoDrain has an interface written in Romanian and was also translated in English.

The results obtained with GDZ RoDrain can be saved and printed.

Unfortunately, at this hour, in Romania we don't have specialized software for irrigations systems design.

In other countries, with a large experience and an old tradition in land reclamation and improvement, many researchers developed important and valuable software for agriculture's water resources management.

First software were written in Fortran or Basic and they had simple interfaces but with the possibility to calculate a significant number of variables and they also allow the user to view and save different suggestive graphs.

One of the most important drainage programs used by Romanian researchers and imported from Holland is EnDrain, software created by Prof. Oosterbaan from Wageningen University.

EnDrain does calculations on horizontal subsurface drainage systems in agriculture, hydraulic head, depth and level of water-table in agricultural land, and drain spacing using the energy balance of groundwater flow but also the Darcy and continuity equation (mass balance/budget of water). It includes drain entrance resistance and soil anisotropy of hydraulic conductivity (soil permeability for water), i.e. the horizontal and vertical hydraulic conductivity are different. EnDrain is applicable to pipe/tile drains (drain pipes) and open ditches.

Another program used by Romanian researches is Wasim, especially the DrainSpace module.

Developed by HR Wallingford and Cranfield University (with support from the UK Department for International Development), WaSim is a computer-based training package for the teaching and demonstration of issues involved in irrigation, drainage and salinity management. WaSim is a daily water balance model that simulates the soil water/ salinity relationships in response to different management strategies (e.g. drainage designs and water management practices) and environmental scenarios (e.g. weather data, soil types, cropping patterns).

DrainSpace module, which is included in Wasim program, allows the computation of distances between drains in steady-state approach (with the help of Hooghoudt equation) and also to verify the results which were obtained using unsteady-state equations (Glover-Dumm equation).

Espadren is an application developed in Costa Rica by Prof. M.V. Bejar for simplifying the computation of distances between drains using steady-state equations (Donnan, Hooghoudt, Dagan, Ernst) but also non steady-state equations (Glover-Dumm and Jenab) for open channels and buried drains. Espadren was realized using Visual Basic environment (Villón, 1985).

Jenab formula was introduced with this occasion in Romanian technical literature regarding the calculation of distances between drains in non-permanent regime.

$$L = \frac{1}{C}\sqrt{\frac{4tK}{\phi}\left(d + \frac{h_0 + h_t}{4}\right)}$$

where L represents distance between drains, K is the hydraulic conductivity, D_h is the thickness of the layer were appears the horizontal flow, d is equivalent depth of the soil layer below drain level, D represents the distance from drains level to impermeable layer, h_0 represents the initial height of water-table above drains level, h_t represents the final height of water-table above drains level after t period, C is a value which can be obtained with the help of a graph as function of $D(U_n) = h_t/h_0$, t represents the necessary period to decrease water-table level from h_0 to h_t, Φ represents drainable porosity.

Regarding the irrigation systems design, Netafim, an application developed in Israel, is designed to help the user to define the parameters of his irrigation system. The user will be able to run the program with any suitable parameters, review the output, and change input data in order to match it to the appropriate irrigation system set up. Some parameters may be selected from a system list; whereas other is entered by the user according to their own needs so they do not conflict with the program's limitations.

The software package includes an opening main window, five calculation programs, one language setting window and a database that can be modified and updated by the user.

The most used formula, for the calculation of distance between drain in the case of non permanent regime, is the Glover-Dumm formula.

The term which must be analyzed in detail is d_r (also noted with d). On the basis of the method of 'mirror images', Hooghoudt derived a relationship between the equivalent depth (d) and, respectively, the spacing (L), the depth to the impervious layer (D), and the radius of the drain (r). This relationship, which is in the form of infinite series, is rather complex. Hooghoudt therefore prepared tables for the most common sizes of drain pipes, from which the equivalent depth (d) can be read directly. The value of d increases with D until

$$D \cong \frac{1}{4}L\,.$$

If the impervious layer is even deeper, the equivalent depth remains approximately constant; apparently the flow pattern is then no longer affected by the depth of the impervious layer. With computers readily available, the Hooghoudt approximation method of calculating the equivalent depth can be replaced by exact solutions.

Van der Molen and Wesseling analyzed the flow problem by the method of „mirror images" (as Hooghoudt and Dagan), resulting in an exact solution for *d*:

$$d = \frac{\frac{\pi L}{8}}{\ln \frac{L}{\pi \cdot r_0} + F(x)}$$

where:

$$x = \frac{2\pi D}{L}$$

and

$$F(x) = 2\sum_{n=1}^{\infty} \ln \coth(nx)$$

$F(x)$ represents an infinite series of logarithms and can be modified to:

$$F(x) = \sum_{n=1}^{\infty} \frac{4e^{-2nx}}{n(1-e^{-2nx})} \qquad (n = 1,3,5,...)$$

This function converges rapidly for $x>1$. If $x<<1$ then the convergence is slow. When $x<=0.5$, a comparison with Dagan's formula results in an approximation that is accurate.

$$F(x) = \frac{\pi^2}{4x} + \ln \frac{x}{2\pi}$$

The exact solution presented in equations

$$d = \frac{\frac{\pi L}{8}}{\ln \frac{L}{\pi \cdot r_0} + F(x)}$$

and

$$F(x) = \frac{\pi^2}{4x} + \ln \frac{x}{2\pi}$$

can be easily used in computer calculations. For this solution it was realized a flow chart presented in figure 1.

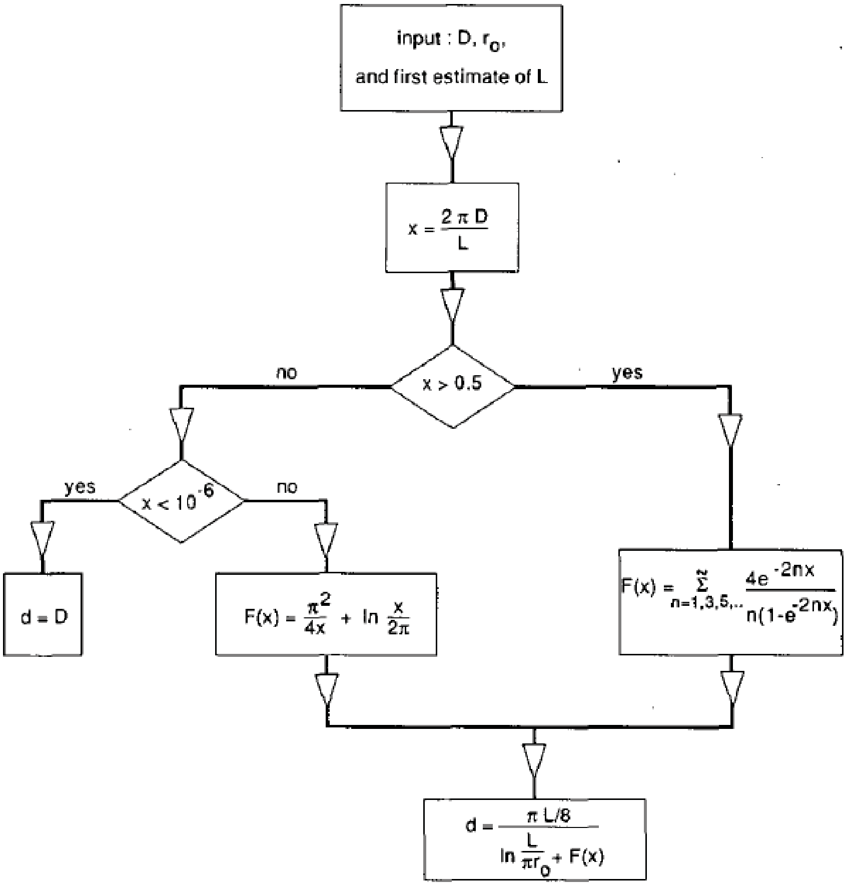

Fig. 1 Flow chart for the calculation of Hooghoudt's equivalent depth [Ritzema, 1994]

M.V. Bejar from Costa Rica proposes another formula for *d*.

$$d = \frac{D}{\frac{8}{\pi} \cdot \frac{D}{L} \ln \frac{D}{u} + 1}$$

This equation takes in consideration the drain radius by introducing the wetted perimeter u where:

$$u = r_0 \cdot \pi$$

Smedema and Rycroft in "Land drainage" (1983) are proposing other equations for *d* as function of the values of D/L.

If D/L > 0.25 then:

$$d = \frac{D}{1 + \frac{8D}{\pi L} \ln \frac{D}{u}}$$

and if D/L<0.25 then:

$$d = \frac{\pi L}{8 \ln \frac{L}{u}}$$

It can be observed that Bejar and Smedema and Rycroft adopted similar equations for d with the observation that the last two authors are proposing two different cases function of D/L values.

The Romanian program, GDZ RoDrain, was constructed basing on the Bejar formulas but the results were not exactly the same.

Unfortunately, at this hour, Romanian researchers do not dispose of any programme based on Van der Molen and Wesseling solution, in this case being impossible to present relevant comparison between different methods and approaches.

RESULTS

In the last period (2009 – 2010) the author realized a series of tests and subsequently several comparisons with different Romanian and international drainage programs for the case of non-permanent regime.

During these tests were used the following programs: GDZ RoDrain, Espadren and DrainSpace, all of them having included in their procedures the case of non-permanent regime.

I mention again that GDZ RoDrain and Espadren were build on similar formulas (for the calculation of distance between drains and for the calculation of equivalent depth of the soil layer below drain level) while DrainSpace has a different approach regarding the calculation of d (equivalent depth of the soil layer below drain level).

The calculations were conducted for Ticvanu Mare, a commune affected by humidity excess from Caras-Severin County, western Romania. For this area we know the following data: K = 1,99 m/day, μ = 14%, h_0 = 0,8m, h_t = 0,6 m, H_{drain} = 1,4 m (drains depth), H_{imp} = 3m (depth of impermeable layer), u = 0,13 m (wetted perimeter), r = 0,04 m (drain radius). We also know that in the case of permanent regime we obtained a distance between drains (by using Ernst formula) of 45 m. The results obtained with these 3 programs are presented in the figure 2.

Romanian technical literature imposes to decrease the water table level in a period of maximum 2 days. On the other side, the usual procedure in designing drainage systems includes 2 stages:

- In the first stage we calculate the distance between drains by using the formulas of permanent regime;
- In the second stage we are verifying the results obtained in the frame of the first stage by using non-permanent regime formulas.

We can observe from the figure 2 that Espadren and GDZ RoDrain programs are providing similar results (but not the same) even they are based on the same formulas.

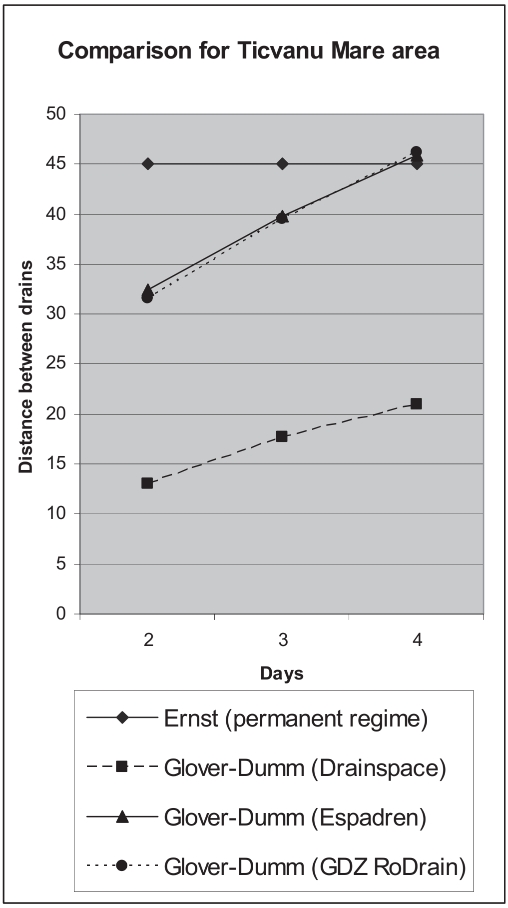

Fig. 2 Comparison between the results obtained in calculation of distance between drains (with Glover-Dumm formula – non-permanent regime) by using 3 different programs: DrainSpace, Espadren and GDZ RoDrain and the comparison between the results obtained in permanent and non-permanent regime

We can also observe that the water-table level will reach the desired depth only at the end of day 4 (which doesn't correspond with the technical conditions but it is an acceptable period).

DrainSpace provides very different results, at a first view these results presenting a very expensive solution. Because only one test doesn't presents accurate and relevant comparisons, I analyzed another one area, this time with a small K (=0,3 m/day). This time we observed a different situation which is presented in figure 3.

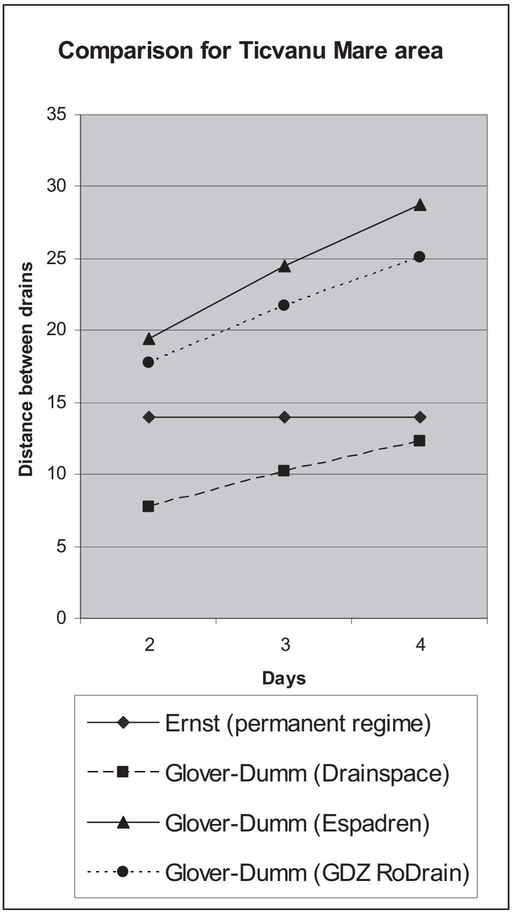

Fig. 3 Comparison between the results obtained in calculation of distance between drains (K=0,3 m/day)

In conditions of a small K, Espadren and GDZ RoDrain are providing much economical solution in comparison with the permanent regime and in the same time increase the differences between their results. DrainSpace results are much closer to the permanent regime results but they are continued to be less economical. Only if K is smaller than 0,1 m/day, the results provided by DrainSpace will verify the results obtained in permanent regime but with the mention that in this situation, a very small K, the results provided by this program don't present a satisfactory accuracy.

Unfortunately, due to the lack of irrigation software in Romanian technical literature we can't present relevant results, the only existent program, Netafim, being in the stage of acknowledge.

CONCLUSIONS

In the field of drainage, the most important programs used at this hour in Romania are: DrainSpace, Espadren, GDZ RoDrain, EnDrain, SaltMod and DrenVSubIr, each of them having its advantages and disadvantages, part of them presented in this paper. The only program used in irrigation systems design is Netafim. The programs presented in this paper were proposed in order to serve as tools for integrated drainage planning and design, giving due consideration to sustainability, and to environmental and socioeconomic factors. This applications have a large applicability, existing the possibility to be used in research stages and also in design stages.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.347:631.67
Pregledni rad
Review paper

ENERGY AND DISTRIBUTION PARAMETERS OF THE MOBILE WHEEL LINE SPRINKLER SYSTEM

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ABSTRACT

The paper presents a synthesis of several years long research on sprinkler irrigation systems with the mobile wheel line sprinkler system, in some arable crops and vegetables. The research program included analysis of parameters that influence water distribution uniformity. The aim of the research was to define the energetic indicators, as well as indicators of function quality, and their influence on defining of irrigation uniformity according to the predefined irrigation rate.

Key words: *irrigation, self-propelled wheel line sprinkler system, energy consumption, uniformity, irrigation rate.*

INTRODUCTION

The utilization of water for crop production has been recognized as essential since agricultural practices began to be developed. Irrigation was practiced in old civilizations, mainly in the Orient and the Mediterranean basin (Pereira and Allen, 1999). Until the 20th century, all irrigation depended on gravity to deliver water to the fields and to spread water across the surface of the land. Development of efficient engines, pumps, and impact sprinklers in the first half of this century allowed farmers to mimic rainfall with sprinkler irrigation.

Irrigation performance often is described in terms of the water application efficiency and water distribution uniformity. Because there are many aspects to irrigation and several irrigation methods, a wide range of performance parameters have been proposed but there is no consensus for standardization (Pereira and Trout, 1999).

In the paste decades, it was the goal of industry and research to develop irrigation systems with the distribution as evenly as possible (Sourell and Sommer, 2003). Uniformity of distribution is one of the most important factors that influence the quality of the irrigation system performance. This parameter is important in sense of ecology (uniform soil watering, plants responding), economy (time of harvesting and yield) and energy stable production with higher yields and better energy utilization). If adequate, irrigation systems distribution uniformity leads to the concept of “precision” irrigation that will further make agricultural production energy, ecology and economy beneficial (Sourell and Sommer, 2000).

The mobile irrigation systems can be considered the final product of the oldest and longest development process in the history of irrigation technology.

The aim of this paper was to analyze uniformity of mobile irrigation system water distribution in order to evaluate the work quality of the system in sense of energy and water consumption regarding the given irrigation rate.

MATERIAL AND METHOD

The aim of the research was filed testing of various sprinkler irrigation systems for evaluating their performance in sense of water distribution uniformity, energy consumption and overall irrigation effects on the crop yield and quality.

The research was carried out in 2008. on the fields of Agricultural corporation Belgrade. One part of the research was determination of the water distribution uniformity for the self-propelled wheel line sprinkler system. For that purpose the Eijkelkapm rainmeter was used. There were 36 rainmeters on the 400 m long system. For the easier data processing and analyzing the system was “divided” on left and right side. The tested system consisted of a self-propelled 400 m long wheel line sprinkler system (Fig. 1). The wheel engine was Lombardini with 3 kW power supply. As for the water supply an 31 kW Agro 1/II pump was used. Its capacity was 1350 l/min.

Figure 1 A self-propelled wheel line sprinkler system

Statistical analysis was based on the variance analysis. Beside the water distribution patterns, energy consumption and system productivity were evaluated.

RESULTS AND DISCUSSION

On of the parameters that affect mobile irrigation system productivity is wheel slippage. Results show that the energy consumption will increase linearly with the slippage and that productivity will not change much (Fig. 2).

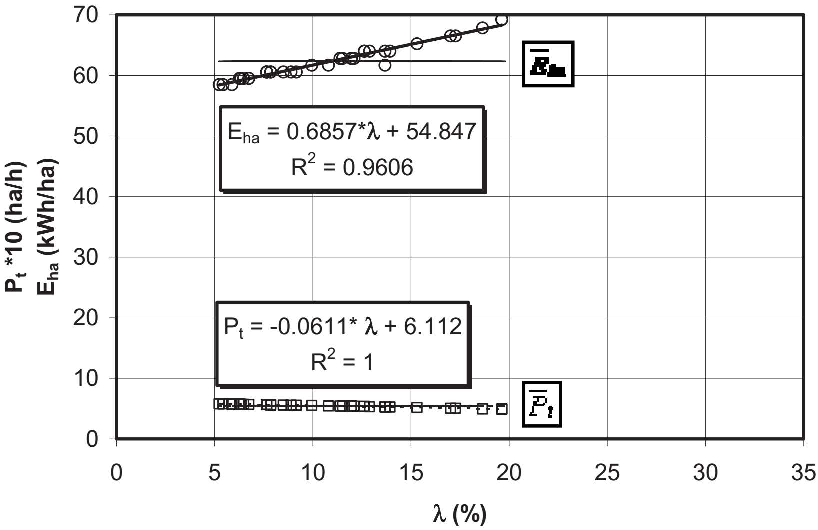

Figure 2 Energy and productivity of the self-propelled wheel line sprinkler system

The results also show a very high determination coefficient that leads to conclusion that water distribution is not uniform along the system. The average energy consumption was 62.02 kWh/ha. The maximum consumption was 69.21 kWh/ha in the conditions of 19.63% slippage. The average productivity was 0.55 ha/h and the slippage was 10.87% in average.

When data obtained from rainmeters are analyzed and compared to mean and nominal irrigation rate, it can be seen that the uniformity of the system is low (Fig. 3). The mean value of the irrigation rate was 13.12 mm and was 12% lower than nominal irrigation rate (15 mm).

So, apart from the uneven distribution, system, in some of its parts, didn't achieve the nominal irrigation rate. There is an obvious asymmetry in left and right side distribution uniformity. Even on the same side it can be seen that there are differences in applied irrigation rates. The calculated standard deviation was 7.69 mm which is close to the half of the given nominal value of irrigation rate. The upper and the lower quartile (19.3 mm and 7.62 mm) are placed asymmetrically to the mean value as well as to the median (10.89 mm) that divides the sample in two equally numbered groups. The same case is with the percentile 10% and 90% (Fig. 4) that are 3.22% and 23.33% respectively.

Within this interval 80% of the obtained values are placed. It can be seen that in the middle of the system and to the left side the applied irrigation rates are higher than the nominal one and go out of the given upper percentile range. On the right side, most of the values of applied irrigation rate are lower than the mean value and only few of them are out of the given lower percentile range.

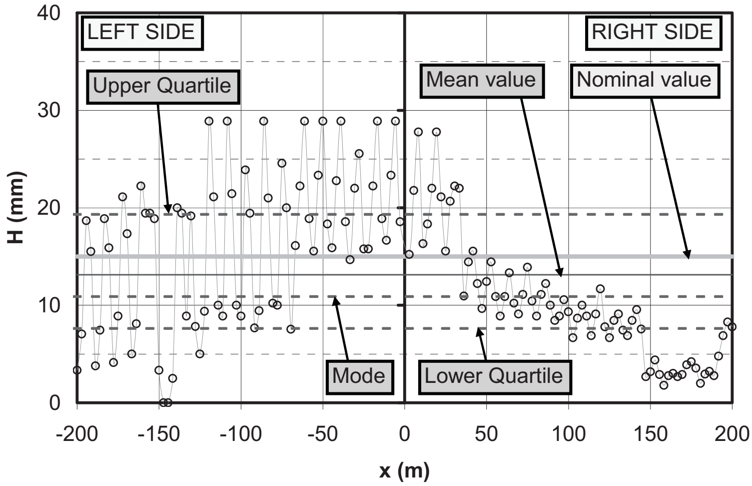

Figure 3 Water distribution patterns along the system

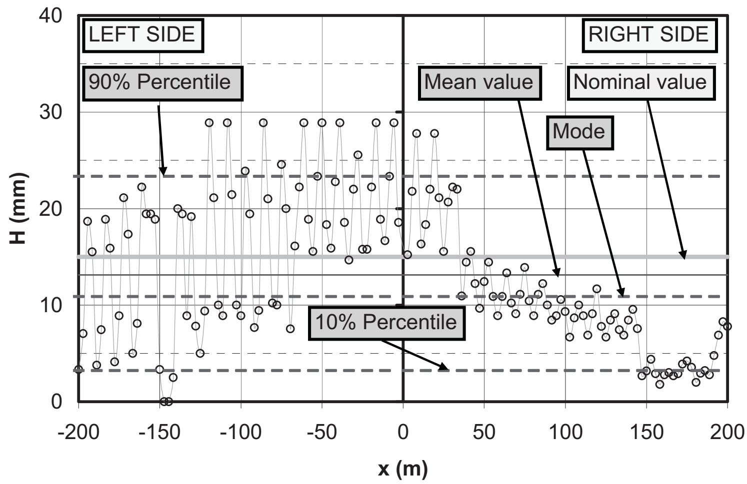

Figure 4 Percentile 10%, median and percentile 90%

The water distribution pattern can also be seen on the 3D surface chart (Fig. 5). It can be seen that the left side of the system has high peaks with non-uniform values higher than the nominal irrigation rate. On the right side, values are more uniform, lower and closer to the given application rate.

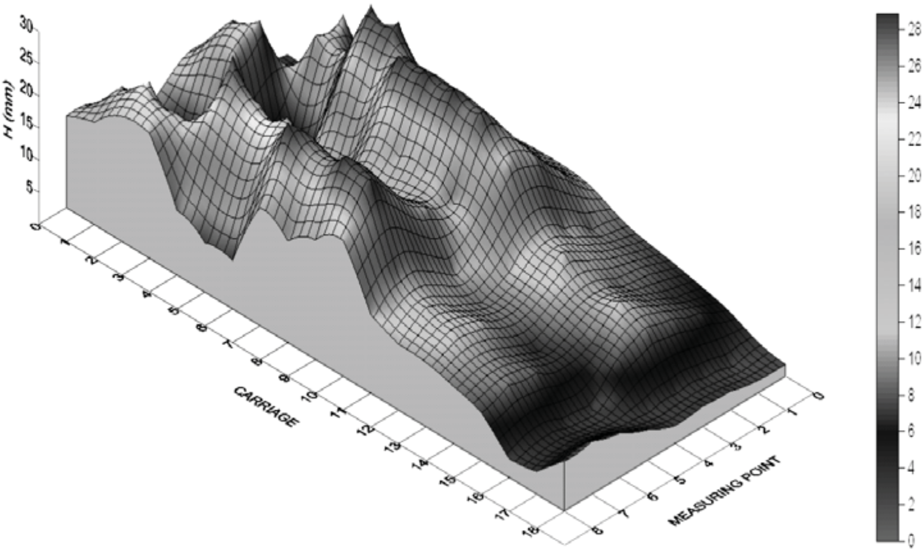

Figure 5 The water distribution along and normal to the self-propelled wheel line sprinkler system

Obtained results in form of uneven distribution along the system can be explained by the fact that some of the sprinkler were not managed well in the previous exploitation and needed replacement.

If the obtained values are classified in groups by the applied irrigation rate (Fig 6) the distribution histogram tends to have a Normal distribution pattern. The estimated skewness factor (factor that describes symmetry) is 0.4 and the Kurtosis factor is –0.81.

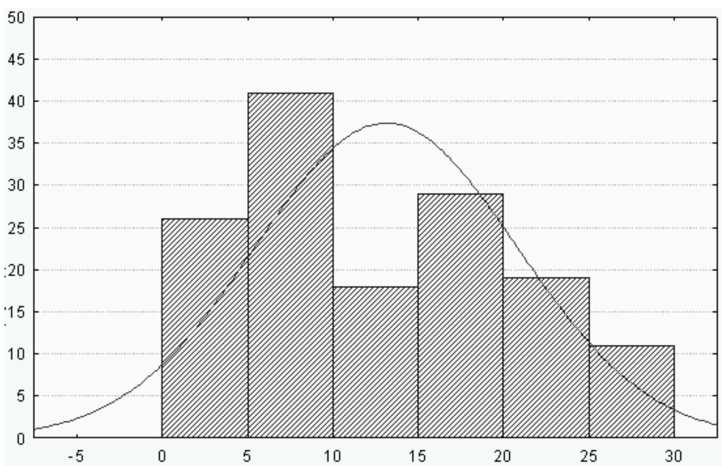

Figure 6 The water distribution histogram

For the case of Normal distribution both of these values should be equal 0. So, these values further confirm previously given conclusion that the self-propelled mobile wheel line sprinkler system does not have an adequate water distribution uniformity.

CONCLUSIONS

A few centuries ago, agricultural production changed, mainly because new crops began to be cultivated and agricultural production became progressively oriented toward the market. Farmers soon recognized that yields could be increased when water was applied in larger amounts. Sprinkler irrigation in agriculture began with the development of impact sprinklers and lightweight steel pipe with quick couplers. Additional sprinkler innovations are continually being introduced that reduce labor, increase the efficiency of sprinkling, and adapt the method to a wider range of soils, topographies, and crops. Shortages of labor and water are resulting in more widespread use of mechanization and automation, including self- propelled sprinkler systems, automatic valves, and computer monitoring and control.

In this paper self-propelled wheel line sprinkler system was analyzed concerning the energy consumption, productivity and water distribution uniformity. Results show that the average energy consumption was 62.02 kWh/ha. System productivity was 0.55 ha/h and average wheels slippage was 10.87%. Concerning the uniformity of distribution results show that there are differences in irrigation rate in the center of the system and to the both sides. The nominal irrigation rate was 15 mm while average achieved rate was 13.12 mm. The results lead to conclusion that constant surveillance and maintenance of each sprinkler is needed as well as care in organization and management of the systems in the filed in order to have an uniform water distribution and to fulfill the nominal irrigation rate.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

COMPARISON OF A SPRINKLER'S TRANSVERSE DISTRIBUTION WITH USED AND NEW NOZZLES

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SUMMARY

Reducing the environment pollution (soil, water) through rational use of phyto-sanitary treatment substances constitutes one of the methods that enable the practice of a sustainable agriculture. The main increasing direction of plant protection machine precision is represented by its constructive improvement (including the measuring and control equipment) for automated control of liquid quantity distributed per hectare, raising the treatments quality and reducing the remnant soil pollution through maintaining its initial technical characteristics. In the present paper researches regarding distribution uniformity comparative analysis of both new and used nozzles (which were used on approximately 500 ha) of a herbicide machine were made, using specific trial procedures on the basis of SR EN 13790-1: 2004; outlining the necessity of trial stages every cycle of minimum 2 years for sprinkling equipment, due to the fact that over time nozzles decalibrate.

Key words: *equipment, nozzle, protection, soil, uniformity*

INTRODUCTION

An important link of the technological process of plants growing is fighting against pests and diseases, using new plant varieties and applying new technologies within the preparation of the germinating bed, but they would not give the results without the application of appropriate phyto-sanitary treatments. Performing this work with superior quality indices influences decisively the production obtained per hectare, wherever possible, chemical fertilizers will be replaced by organic fertilizers, respectively well fermented manure [3], [4].

In Romania, within the phyto-sanitary treatments or some stages in the fertilization works are used only liquid products prepared with water or conditioned with some particular organic ingredients, to be applied as such. Installations designed at phyto-sanitary treatments perform these works by the method of spraying and should meet some general and / or special requirements [1]:

- should dose products specifically for each unit area treated;
- should keep the adjustments made during work on installation parameters;
- should be fitted with equipment of control and automation during the work;
- should perform a fragmentation as uniform as possible at a drops/cm2 density consistent with the agro-technical requirements;
- should have multiple and rigorous adjustment possibilities, and be able to perform treatments with a wide range of products within a diverse range of volumes;
- should have a simple, robust, construction, made of appropriate materials;
- should be light, easy to handle and set, have a good protection of labor;
- should be standardized and the safety of use be guaranteed;
- should have low cost manufacturing for achieving the investment pay off;
- should allow the achievement of high productivity;
- should have pleasant design and setting and dismantling facilities;
- should have low energy consumption and high working efficiency.

Performance can be expected only by respecting the conditions referring to the quality / quantity ratio. Homogenous distribution of phyto-sanitary solutions on target objects surfaces, along with strict dosage respecting, which ensures necessary biological effects means ensuring the suitable quality, and depends on the following factors [2]:

- jet flow of liquid sprayed, essential component of the working rate;
- degree of fineness of the sprayed liquid flow;
- weather conditions;
- degree of coverage and penetration of plant mass (homogeneity of deposit);
- uniformity of distribution in space of jet fluid, related to performance of spraying heads;
- spatial arrangement of target objects or areas to be covered.

The considerations above have shown that the factors responsible for work quality are the spraying heads, therefore they represent the main components of any spraying machines. This explains the wide variety of spraying systems. Sprayers improperly called nozzles perform the spraying, which is a physical phenomenon of liquids spraying division in drops of various diameters, which are then projected on target object surface. The main direction for improving the plant protection machinery is the improvement of their design (including control and measuring equipment) for automatically adjust the quantity of liquid per hectare, increase the quality of treatment and reduce residual soil pollution by keeping the original technical features [5].

Within monitoring system of spraying machines the following aspects are checked: pump operation (speed, flow, pressure), the substance level in the tank, nozzles functioning. In case of state-of-the art equipment, these controls do not have spectacular effects, but for other equipment upgrading work is necessary for improving qualitative indicators and thus, reducing the amount of pesticide applied, diminishing the cost of work and, not least, reducing environment pollution.

Establishing a centralized system of monitoring and warning for plant protection spraying machines aims at watching their functioning for ensuring uniformity of spraying as a compulsory requirement and reducing the risk of pollution of soil and agricultural products due to persistence in soil of phyto-sanitary substances improperly applied [2].

TESTING METHODOLOGY

Tests regarding comparative determination of transversal distribution uniformity at a transported machine for field crops herbicide administration JET 4(6), with the two types of nozzles, were carried out in conformity with specific testing procedures and work instructions, credited and SR EN 13790-1:2004.

Test Conditions

In order to test the spraying / herbicide machine, with nozzles subjected to comparative analysis, there were performed the following operations for the preparation of the tests:

- the herbicide machine was coupled to the tractor and was verified its linkage system;
- it was checked the folding and extension mechanism of herbicide ramps ;
- it was checked the telescopic rod overlapping of the transmission shaft;
- it was checked the existence and proper installation of safety guards
- the hydraulic installation tightness was verified;
- the manometer functioning was verified;
- assembly organs tightness and security were verified.

On the machine new nozzles type ALBUZ AVI 11004, that were later replaced with used nozzles ALBUZ AVI 11004 type, taken from a machine that was used for herbicide spreading on 4200ha of land.

The measurement equipment used is formed out of:

- measuring tape: 3m and 8m;
- caliper: 150mm;
- manometer: 0÷8 bar;
- electronic tachymeter;
- stand for transversal distribution uniformity determination;
- laptop with data acquisition system.

RESULTS AND DISCUSSIONS

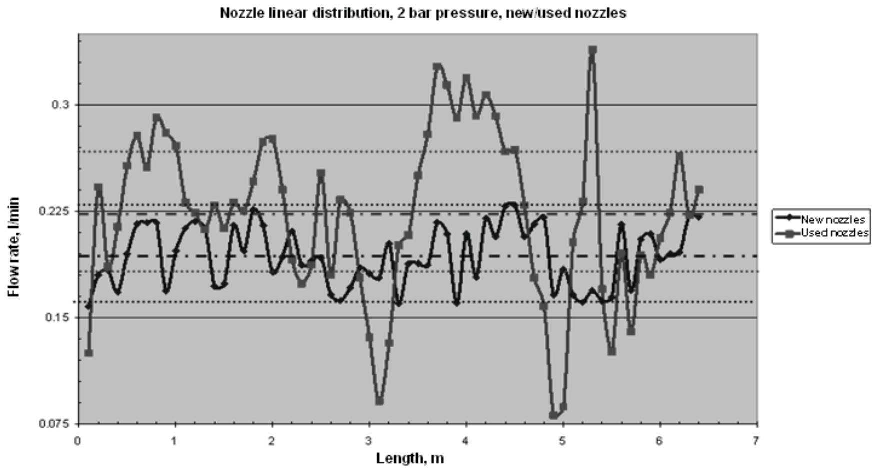

Fig. 1 Distribution uniformity at 2 bar pressure, new/used nozzles

Legend

Used nozzle arithmetic average;
New nozzle arithmetic average;
Used nozzle deviation ±10%;
New nozzle deviation ±10%.

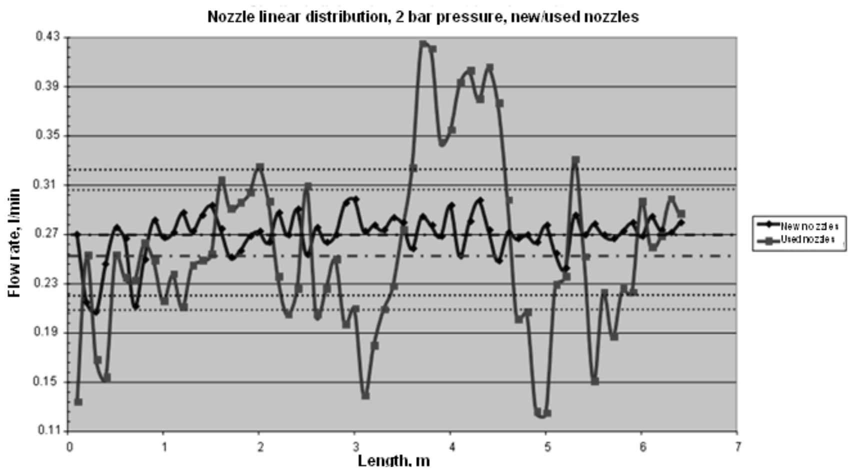

Fig. 2 Distribution uniformity at 4 bar pressure, new/old nozzles

Legend

Used nozzle arithmetic average;
New nozzle arithmetic average;
Used nozzle deviation ±10%;
New nozzle deviation ±10%.

Tests for transversal uniformity determination have been made on a mounted machine for herbicide administration in field crops, JET 4(6), equipped with:

- new nozzles ALBUZ AVI 11004 type;
- used nozzles ALBUZ AVI 11004 type (used for herbicide sprinkling on to 4200ha).

The work pressures for which the measurements were made were of 2, respectively 4 bar, three repetitions per pressure. Results are presented in fig. 1 (for new nozzles ALBUZ AVI 11004 type), respectively in fig. 2 (for used nozzles ALBUZ AVI 11004 type).

Fig. 3 Transversal distribution uniformity determination for new/used nozzles - aspects during measurements

Fig. 4 Command, data acquisition and parameter monitoring during transversal distribution uniformity determination for new/used nozzles

CONCLUSIONS

Comparative analysis of distribution uniformity for a sprinkling machine with new, respectively used nozzles (decalibrated), used to administer herbicide for field crops, was done for a field crop herbicide administration mounted machine, JET 4(6), with the purpose of finding large deviations regarding distribution uniformity (according to SR EN 13790-2004) that appear following long term use, and the necessity for their examination, at a certain period of time (max. 2÷3 years) and recalibration/replacement.

Obtained results following this comparative analysis outline breakage of the ±20% limit to the average of all chamfers by the quantity of liquid from each chamfer, in the portion where the nozzle jets cover completely, respectively ±10% of the variability coefficient, in the case of used nozzles, both for 2 and 4 bar pressure.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

UTJECAJ PROVJERAVANJA APARATA ZA ZAŠTITU BILJA NA STANJE APARATA I POBOLJŠANO RASPOREĐIVANJE PESTICIDA

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SAŽETAK

Zadatak ispitivanja aparata za zaštitu bilja je održavati takvo stanje aprata, da se može primjena maksimalno smanjit i da je još uvijek efektivna količina pesticida, i da je primjena pesticida ravnomjerna. Rad obuhvača neobavezno provjeravanje aparata za zaštitu bilja 1989-1994 godine i obavezno provjeravanje aparata za zaštitu bilja od 1995-2010 godine grupe za provjeravanje ŠC Šentjur u celjskoj regiji. Provjeravanje je provedeno u 6704 aparatih za zaštitu bilja, od toga 849 u vrijeme neobaveznega provjeravanja i 5855 aparata za vrijeme zakonsko obaveznog provjeravanja. Istraživanja su pokazala, da je bilo stanje aparata za zaštitu bilja vrlo loše za vrijeme neobaveznog provjeravanja iako se poboljšavalo. Poslije neobaveznog provjeravanja bilo je 16% - 27% ispravnih aparata za zaštitu bilja, a između 73% i 84% aparata, kod kojih bilo je loše razpoređivanje fitofarmacevtskih sredstava. Za vrijeme obaveznog provjeravanje se je stanje znatno poboljšalo. Kod provjeravanja utvrđuje se sve manje kvarova, Ispravnost aparata za zaštitu bilja se je poboljšala između 80% - 100% i značajno poboljšala zaštita okoline.

Ključne riječi: *zaštita bilja, provjeravanje, kvarovi, stanje aprata, zaštita okoline*

UVOD

Ustrezna izbira strojev za varstvo rastlin in izvajanje rednih pregledov je edini način, ki lahko pripomore k bolj kvalitetnim in zdravim pridelkom. Temeljni namen je ugotoviti stanje parametrov eksploatacijskega potenciala stroja, tehnične hibe ali pomanjkljivosti, le-te odpraviti in dati uporabniku stroja posebna strokovna navodila za pravilno upravljanje strojev in tehnično vzdrževanje. Pri strojih za varstvo rastlin je pomemben pravilno nastavljen tlak, pravilna razporeditev pripravka, pravilni pretoki, ustrezna kapaciteta črpalke in varnost pri delu. Vse te parametre pa lahko preverimo z naslednjimi napravami:

- manotest,
- dositest,
- merilcem pretoka,
- merilcem vrtljajev.

Vsi ti parametri vplivajo na stanje strojev za varstvo rastlin, na kar smo dali velik poudarek v tej kratki nalogi. Rezultati prikazujejo predvsem podatke o stanju strojev za varstvo rastlin in posredno kvaliteto nanašanja fitofarmacevtskih sredstev. Samo z ustreznimi stroji za varstvo rastlin in znanjem (poznavanje uporabe in delovanja) se lahko izvede kvalitetno nanašanje fitofarmacevtskih sredstev.

Z uvedbo zakonsko obveznega testiranja strojev za varstvo rastlin se je stanje teh strojev bistveno izboljšalo, kar omogoča bolj kvalitetno nanašanje pripravkov, manjše odtekanje pripravka na tla ter manjše porabe pripravkov.

METODE RADA

Postopek terenskega testiranja izpravnosti strojev obsega:

- zunanji vizualni pregled stroja za varstvo rastlin in pripravo za merjenje;
- merjenje osnovnih tehničnih parametrov, kateri omogočajo pravilno delovanje stroja.

Cilj spremljanja objektivnih in natančnih rezultatov eksploatacijskih značilnosti je, da izmerimo in ugotovimo parametre predpisanih tehničnih značilnosti, od katerih je odvisno pravilno delo s stroji za varstvo rastlin. Sem spadajo naslednje meritve:

- meritev števila vrtljajev priključne gredi (min^{-1}), (Merjenje števila vrtljajev priključne gredi se opravi z elektronskim merilcem vrtljajev, kar je pomembno zaradi preverjanja obremenjenosti črpalke v času vključitve vseh porabnikov).
- preverjanje zračnega tlaka v tlačni komori črpalke,
- preverjanje natančnosti delovanja instrumentov za merjenje in prikazovanje delovnega tlaka (manometri, Quantometri),
- merjenje parametrov eksploatacijskih potencialov.

Po opravljenem vizualnem pregledu aparatov za varstvo rastlin ter po izmerjenih tehničnih parametrih, kateri omogočajo pravilno delovanje strojev za varstvo rastlin, so zajete tudi meritve parametrov eksploatacijskih potencialov.

Postopek obsega naslednje:

- merjenje skupnega pretoka (kapaciteta) črpalke Qp(l/min.),
- merjenje pretoka na vseh porabnikih strojev za varstvo rastlin in ugotovitev njihove medsebojne usklajenosti.

Postopek obsega meritve naslednjih parametrov- skupni pretok vseh šob,- pretok posameznih segmentov naprave za škropljenje,- pretok namenjen za hidravlično mešanje zaščitnih sredstev in posamezni pretok šob.

Vse meritve količine pretoka pri terenskem testiranju so opravljena z elektronskimi merilcem pretoka, t. j.

- meritev količine povratne tekočine (l/min) z namenom ugotovitve hidravličnega mešanja,
- meritev enakomernosti površinske razporeditve zaščitnega sredstva.

REZULTATI I DISKUSIJA

Stanje strojev za varstvo rastlin

Preglednica 1 Stanje strojev- prostovoljno testiranje

Leta testiranja	Testirani agreg. Kom %	Izpravnih Kom %	Neizpravnih Kom %
1989	181 100	30 16,6	151 83,4
1994	143 100	39 27,3	104 72,2

Preglednica 2 Stanje strojev v letih 1995 – 2010 – zakonsko obvezno testiranje

Leta testiranja	Testirani agregati Kom. %	Izpravnih Kom. %	Neizpravnih Kom. %
1995	128 100	103 80,47	25 19,53
1996	105 100	96 91,43	9 8,57
1997	164 100	159 96,95	5 3,05
1998	59 100	56 94,91	3 5,09
1999	95 100	95 100	0 0
2000	97 100	94 96,91	3 3,09
2003	101 100	101 100	0 0
2004	935 100	934 99,89	1 0,11
2005	583 100	583 100	0 0
2006	571 100	571 100	0 0
2007	767 100	767 100	0 0
2008	688 100	688 100	0 0
2009	788 100	788 100	0 0
2010	774 100	774 100	0 0

Najpogostejše okvare po elementih strojev za varstvo rastlin izraženi v deležih

Preglednica 3 Okvare po elementih strojev za varstvo rastlin

Vrste elementov	1989 - 1994	1995 - 2000	2003 - 2010
MANOMETRI	38,74	19,26	61,64
ŠOBE	22,52	16,70	4,26
REGULATORJI	21,37	14,55	7,00
ČRPALKE	12,07	4,30	5,93
ARMATURE	5,30	1,33	0,15
PIPE, VENTILI	/	16,70	15,23
PROTIKAPNI MEHANIZEM	/	14,55	2,74
OSTALO	/	12,61	3,05
SKUPAJ (%)	100	100	100

Razprava rezultatov

Iz predstavljene problematike je razvidno, da ima testiranje strojev za varstvo rastlin neposreden vpliv na stanje strojev za varstvo rastlin in na natančnost uporabe pesticidov. S testiranjem strojev za varstvo rastlin se je ugotovilo, da se uporaba pesticidov ni izvajala dovolj kvalitetno, vendar se je s testiranjem strojev stanje bistveno izboljšalo. Vzroki za nekvalitetno aplikacijo pesticidov se lahko na podlagi ugotovitev, razdelijo na:

- nepoznavanje strojev za varstvo rastlin,
- velik % okvar na strojih za varstvo rastlin,
- sprememba tehničnih parametrov strojev za varstvo rastlin, do katerih prihaja pri večletni uporabi,
- premajhno poznavanje vseh zahtev in predpisov.

S testiranjem se opravlja kontrola najpomembnejših tehničnih parametrov posameznega stroja za varstvo rastlin, od katerih je odvisno maksimalno koriščenje eksploatacijskega potencijala.

S testiranjem je ugotovljeno, da je bilo stanje strojev za varstvo rastlin na našem področju, zelo slabo, čeprav se je izboljševalo. V letih testiranja 1989 – 1994 je bilo povprečno 19,32 % strojev za varstvo rastlin izpravnih, 80,68 % pa neizpravnih oziroma tehnično nepopolnih;

Od tega:

- 38,74 % okvar na manometrih
- 22,52 % okvar na šobah
- 21,37 % okvar na regulatorjih
- 12,07 % okvar na črpalkah
- 5,30 % okvar na armaturah

V letih zakonsko obveznega testiranja 1995 – 2000 se je stanje bistveno izboljšalo, povprečno 93 % aparatov je bilo izpravnih, 7% pa neizpravnih.

Od tega :

- 19,26 % okvar na manometrih
- 4,30 % okvar na črpalkah
- 14,55 % okvar na regulatorjih
- 16,70 % okvar na šobah
- 1,33 % okvar na armaturah
- 16,70 % okvar na pipah, ventilih
- 14,55 % okvar na protikapnih mehanizmih
- 12,61 % ostale okvare

V letih zakonsko obveznega testiranja 2003 – 2010 se je stanje še izboljšalo,povprečno 99,89 % aparatov je bilo izpravnih, 0,11% pa neizpravnih po odhodu iz testiranja. Okvare pred testiranjem pa so se pojavljale na naslednih elementih:

- 19,26 % okvar na manometrih
- 4,30 % okvar na črpalkah
- 14,55 % okvar na regulatorjih
- 16,70 % okvar na šobah
- 1,33 % okvar na armaturah
- 16,70 % okvar na pipah, ventilih
- 14,55 % okvar na protikapnih mehanizmih
- 12,61 % ostale okvare

Stanje strojev je prikazano po odhodu iz testiranja, kar pomeni, da je bilo stanje ob prihodu bistveno slabše, vendar so uporabniki okvare in napake odpravili.

Kljub temu pa se stanje strojev in poznavanje tehnike bistveno izboljšuje

ZAKLJUČAK

Osnovni namen raziskave vpliva testiranja strojev za varstvo rastlin na ustreznejše razporeditev pripravkov pri pridelavi je bilo ugotavljanje stanja strojev za varstvo rastlin. Stroji bistveno vplivajo na kvaliteto nanosa in količino uporabe pripravka. Z neustreznimi stroji ne moremo doseči kvalitetnega nanosa ob istočasni zahtevi čim manjše uporabe pesticidov. S testiranjem najpomembnejših tehničnih parametrov strojev za varstvo rastlin je ugotovljen njihov neposredni vpliv na natančnost delovanja strojev, s tem pa tudi nivo kvalitete uporabe pesticidov.

Na osnovi rezultatov terenskega testiranja, opravljenega v letih 1989 – 2000, lahko izvlečemo nakatere osnovne sklepe :

- Vsako leto se zmanjšuje število manometrov brez glicerinskega polnjena, povečuje pa se število manometrov z glicerinskim polnjenem.
- Zmanjšuje se število neizpravnih manometrov (1989 - 45,56%, 1994 - 16,78%, 1999 - 0%).
- Zmanjšuje se delež starih izvedb šob
- Izboljšuje se stanje strojev za varstvo rastlin, v letu 1989 je bilo izpravnih 16,6%, v letu 1994 27,3%, v letu 1999 100%, v letu 2000 96,91% .

Na osnovi rezultatov terenskega testiranja, opravljenega v letih 2003 – 2010, ugotavljamo, da se je stanje strojev uredilo ter da se okvare pred ali v času testiranja odpravijo.

Z uvedbo subvencij se bistveno tudi povečalo število testiranih strojev za varstvo rastlin, ker je pogoj pri pridobivanju le teh.

S tem se dosega namen boljšega varovanja okolja ter pridelave bolj zdrava hrane.

Z zakonsko obveznim testiranjem strojev za varstvo rastlin se je izboljšalo stanje strojev, kar pa ima pomembno vlogo v proizvodnji zdrave hrane.

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IMPACT OF PLANT PROTECTION MACHINERY TESTING ON ITS STATE OF AND APPROPRIATE ALLOCATION OF PREPARATIONS IN PRODUCTION

ABSTRACT

The task of testing the sprinklers is to keep the machinery for plant protection in such state that we can minimize the amount of products for plant protection and that the application of preparations is as even as possible. The work includes the non-obligatory testing of machines for protection of plants during the years1989-1994 and the obligatory testing of machines during the years 1995-2010 within Celje region. The testing has been done on 6704 plant – protecting machines, among which there were 849 done during the period of non – obligatory testing and 5855 during the period of obligatory testing. The researches have shown, that a lot of machines were out of order, but the faults weren't abolished within the period of non – obligatory testing. After finishing the tests there were only 16 – 27 % of machines without any faults, which means that, within the non – obligatory testing period there were between 73% and 84% of all machines, where there was found a bad disposition of fito – pharmaceutical agents. In the period of obligatory testing the technical condition of the machines for protecting plants has improved. Within testing less and less faults have been found. What is more, the technical condition of machines for protecting plants has improved from 80% - 100% and thereby the protection of the environment has significantly improved as well.

Key words*: protection of plants, testing, technical faults, technical condition of machines*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

REALIZATION OF AGRICULTURAL MAPS EXPERIMENTAL MODELS BY DETERMINING THE ELECTRO-CONDUCTIVITY IN CONCEPT OF PRECISION AGRICULTURE

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SUMMARY

Precision farming involves the collection of detailed information about the characteristics of agricultural operations. Electro-conductivity (EC) of soil is one of the most easy tests and less costly for agriculture, which can be performed today. Electro-conductivity (EC) is the ability of a material to transmit (conduct) an electrical current and is usually expressed in miliSiemens / meter. Electro-conductivity (EC) of soil is a measur and that characterizes many soil properties which affect the productivity of crops. These include the water content, soil texture, soil organic matter (OM), depth to clay layer, the capacity of cation exchange (CEC), salinity, calcium, magnesium. Measurements of electro-conductivity (EC) of soil can add value to agricultural operations if they can be used to help explain variations in agricultural production. Article shows electro-conductivity maps models made on different soil and in different locations in Romania and electro-conductivity correlation with the physico-chemical properties of these soils.

Key words: *soil, electro-conductivity, precision agriculture, soil properties, soil quality, maps*

INTRODUCTION

Precision Agriculture (PA) - is a model that is about to be applied in all developed countries and seeks a modulated management of inputs (seeds, irrigation water, fertilizers, fungicides, herbicides, insecticides) by adapting the work of soil, the sowing, the fertilizers to the characteristics of heterogeneity of the parcel. Precision farming, being the agriculture seen as an application of mechatronics, make way for a new methodology (which aims to a new farming system) that may be key to many problems. Opportunities favorable to development of precision agriculture are:

- Ability to understand the complexity of agricultural systems - a systemic and holistic approach;
- Ability to monitor the phenomena and systems - computer - controlled data acquisition;
- Achievements in the field of computer technology: hardware, software, fireware and databases;
- Improvements to the interpretation and calculation methods-statistics, modeling, simulation, decision support systems - DSS;
- Development of geographic information systems - GIS;
- The emergence and development of spatial analysis and statistics - Geostatistică;
- Progress of space technology - remote sensing, GPS;
- Technical developments in automation and improvement of agricultural machinery - agricultural mechatronics.

A necessary requirement for production costs is that they are as low as possible to ensure market competitiveness. Achieving these goals involves the use of complex management and control systems to regulate in an effective, large amount of interactive physical variables. Recent advances in hardware and software such as microprocessors and microcontrollers, drive to the integration of complex control and management tasks in farms sites.

Farmers who practice precision farming can now collect more detailed information than ever, about the spatial characteristics of agricultural operations. In addition to the map of culture, border and attributes of the field, a wide range of electronic sensors, mechanical and chemical were developed to measure and chart many of soil and plant properties.

Soil EC is one of the simplest and least expensive measurement available to farmers who practice precision farming today. Soil EC is a measurand that integrates many of its properties that influence crop productivity. These include soil texture, soil water content, organic matter, CEC - cation exchange capacity, salinity and cation change (Mg and Ca)

Measurements of soil EC value can be added to agricultural operations that can be used to explain changes in culture. This increased understanding should then lead to enhanced management opportunities which or improve crops, reduce input costs or accurately predict the benefits that can be obtained from weeding, irrigation, or other works to improve the field.

So precision farming is based on geospatial information to facilitate the treatment of small portions of the field as individual units. Although farmers know much that land is heterogeneous only recently became available technologies that allow productive practice to take this variability into account efficiently. Key technologies include GPS, GIS, electronic sensors and computers for field data acquisition and control. Though it is relatively easy to collect geo-spatial data for precision farming it is more difficult to know how better to use these data in culture management decisions. An important step is to understand the management decision on a basis of spatial productivity agronomic crops by the multitude of factors that may cause variations of culture.

MATERIALS AND METHODS

There are two techniques used to measure soil EC, by electromagnetic induction-without soil contact (EM) and direct contact with the soil. EM measurements are achieved by introducing electromagnetic energy into the soil using a power source that runs over the earth but with which does not make physical contact. An electromagnetic field sensor of the device measures the resulting electromagnetic field that this current induces it. Contact electrode method involves a device that directs electricity in the soil through insulated metal electrodes that penetrate the soil surface. These devices directly measures the voltage drop between source and sensor electrode. Measurement of soil EC both through direct contact method and method EM (electromagnetic induction) have comparable results as values. Contact method using a type of sensor which is composed of typical electrodes in the form of discs which make contact with the ground to measure the EC. In this approach two to three pairs of discs are mounted on a metal frame. A pair applies electrical current into the soil while the other two pairs measures the voltage drop between them as in figure 1. Electro-conductivity information is recorded in a data recorder together with location data. A global positioning system GPS provides geographic location information. Direct contact method is more popular for precision farmers applications because it is easier to cover a larger area and is less susceptible to the interference with external factors. The disadvantage of the system is usually given the fact that it is slow and can not be used in small farms. [1,2,3,9]

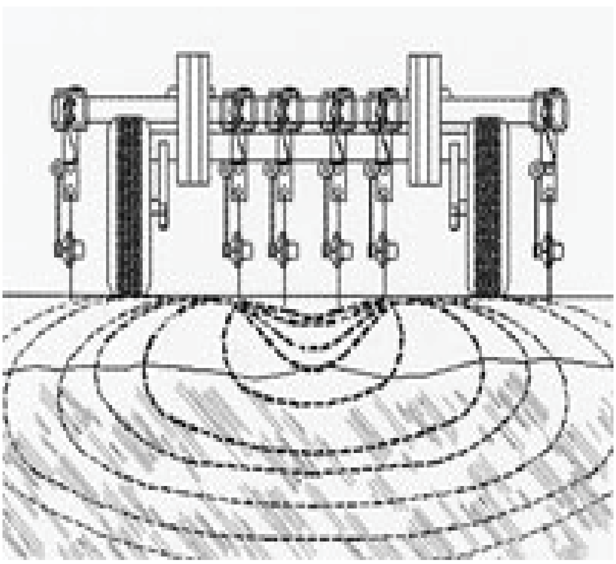

Fig. 1 The functioning principle of the VERIS 3150 system

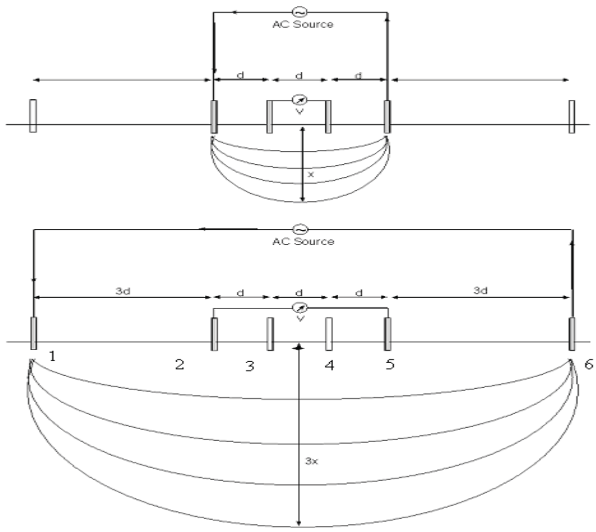

Fig. 2 Configuration scheme for A-surfaceEC <30 cm (top) and B-depth EC <90 cm (down)

Electro-conductivity soil sensor manufactured by Veris Technologies is used to detect the ability of soil to conduct electricity. In the Veris system of electro-conductivity soil mapping, electrodes are represented by rotating discs placed 6 cm deep in soil. While the frame is moved along the ground, a pair of electrodes send electric current into the soil, while the other 2 pairs of electrodes measure the voltage drop. The system is set to switch between the 2 configurations A (shallow, determines electro-conductivity of the surface) and B (deep - is determined the depth electro-conductivity) - as shown in Figure 2. Configuration A uses the 4 internal disks (2, 3, 4 and 5), the voltage is measured between the two discs placed in the interior (3 and 4). In configuration B the 4 disks located on the outside (1, 2, 5 and 6) are used and the voltage is measured between discs 2 and 5 [9].

To create maps of electro-conductivity, the user must provide one or more universal tools of mathematical calculation software such as Excel, Mathcad, Matlab, etc.. There is also a fairly wide range of specialized software, aimed at creating maps with three or more dimensions, such as Surfer, Farmworks, MZA - Zone Management Analyst, etc.. Electro-conductivity maps are three-dimensional maps containing on the abscissa and on the ordinate information concerning the location of the charted terrain, and the third dimension is represented by the electro-conductivity values recorded. Data about the location of the charted terrain can be represented in the form of measured values towards a particular reference system, having as a measuring unit the meter multiples or sub-multiples or can be represented as geographic coordinates having as measuring unit the grade. Electro-conductivity of soil measured by Veris 3150 platform can be of surface (0 to 30 cm) or deep (0 to 90 cm or 0 to 110 cm depending on the configuration chosen) and expressed in mSiemens / meters. In our case the electro-conductivity maps have on the abscissa the latitude expressed in centesimal degrees and on the ordinate the longitude expressed also in centesimal degrees. The third dimension is represented by the electro-conductivity measured values corresponding to the pairs (latitude, longitude) above. The electro-conductivity can be both of surface or deep or can be represented as a mathematical function of both. The measured values are expressed in mS / m but are figured graphical under the form of constant-diameter filled circles and whose color varies in proportion to the numerical value along a spectrum of colors, beginning with dark blue, through blue, cyan, green, yellow and red and ending with red, so that the minimum numerical values corresponds to dark blue and the maximum values correspond to dark red color. The map created this way contains raw data of electro-conductivity, without processing them through different methods. Veris 3150 platform manufacturer recommends use of such raw data, particularly for applications for soil sampling, because the processing thereof may lose valuable information. Another approach of electro-conductivity data is the creation of histograms containing on the abscissa the maximum recorded electro-conductivity value on the terrain, value which is divided into 10 intervals and on the ordinate is found the number of values of electro-conductivity from each interval, so that the user to make an opinion about the prevalent electro-conductivity value of soil in question. Thus, to identify different levels of electro-conductivity and to identify areas containing these values will interpret diagrams created (map of electro-conductivity and electro-conductivity histogram). In those areas will take samples of soil for analysis, then by mathematical regression calculations, grouping the electro-conductivity values with the analysis results one can create maps which reflect the properties of land all over the mapped area [8].

RESULTS AND DISCUSSION

The study was conducted in five different locations to determine the electro-conductivity (EC) for different soil textures and soil types in Romania. The objective was to evaluate in a first phase the relations between the electro-conductivity (EC) and soil properties (soil water content, pH, temperature, porosity, cation exchange capacity-CEC) before sowing, care being taken that next year to observe the correlation EC with productivity obtained on the terrains subjected to analysis. Such tests were performed with Veris 3150 mobile platform for determining electro-conductivity of soil in the following locations:

1. INCD. Fundulea-soil type : Brown red forest, the analyzed area was of 7.5 ha and was represented by a processed parcel and a 0.5 ha parcel unprocessed.
2. Agricultural resort Simnic-Craiova - soil type: luvic reddish brown, the analyzed surface analysis was of 5 ha unprocessed soil and 0,3 ha processed soil.
3. UASVM Timisoara- soil type: bill mold, the analyzed analysis was represented by the two parcels of processed land totaling a mapped area of 15 hectares.
4. Valul lui Traian agricultural Resort - soil type: vermic mold, the analyzed surface was of 14.3 ha.
5. Polygon INMA Bucharest - soil type: red brown forest, the mapped area was of 1.2 ha processed soil.

The Veris Mobile Platform 3150 (Fig. 3) was carried by a tractor U 650 (65CP) at an approximate speed of 8 km / h. The used method for obtaining the data was the grid, and it was achieved a normal grid with spacing of 5 to 20 meters. At the same time soil samples were taken for physico-chemical laboratory analysis (the soil water, pH, temperature, porosity, cation exchange capacity-CEC), for correlating these data with those of electro-conductivity (EC) obtained with the Veris 3150 mobile platform needed to make the electro-conductivity maps.

Data can be recorded every second through a GPS (GPS V-connection used was NMEA 0183 VERSION 2.30) connected to the Veris 3150, required absolute condition for recording of electro-conductivity data in memory card of the machine. Data will be transferred later in a notebook to generate maps using various mapping programs.

Fig. 3 Veris 3150 mobile platform working

Thus based on these data were made two models of electro-conductivity map for each chosen location:

a) a map of soil electro-conductivity according to surface EC (electro-conductivity determined at a depth of 0-30 cm)

b) a map of soil electro-conductivity according to deep EC (electro-conductivity determined at a depth of 0-90 cm).

Experimental models of electro-conductivity map obtained are:

1. INCDA FUNDULEA, reddish brown forest soil type, processed soil is represented in Figure 4.

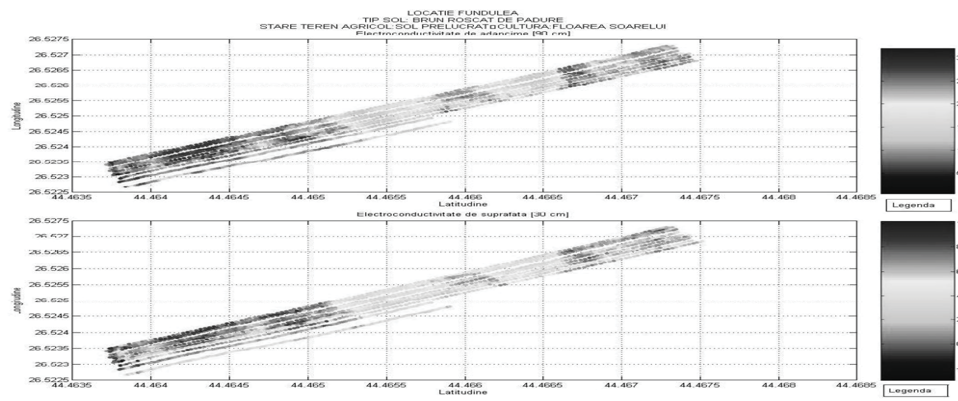

Fig. 4 Experimental model of agricultural maps based on soil EC (INCDA Fundulea - processed soil)

There have also been made a series of histograms which can be seen the dominating domain of electro-conductivity for each map obtained both for the deep and surface EC, making also a ratio of the two distinct types of electro-conductivity by creating a new map of EC.

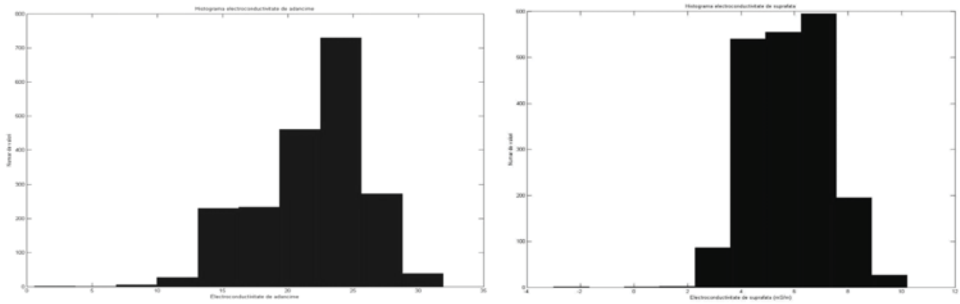

Fig. 5 Histogram of deep EC, surface EC (INCDA Fundulea - processed soil)

2. SCDA SIMNIC - Craiova luvic reddish brown soil type, soil unprocessed.

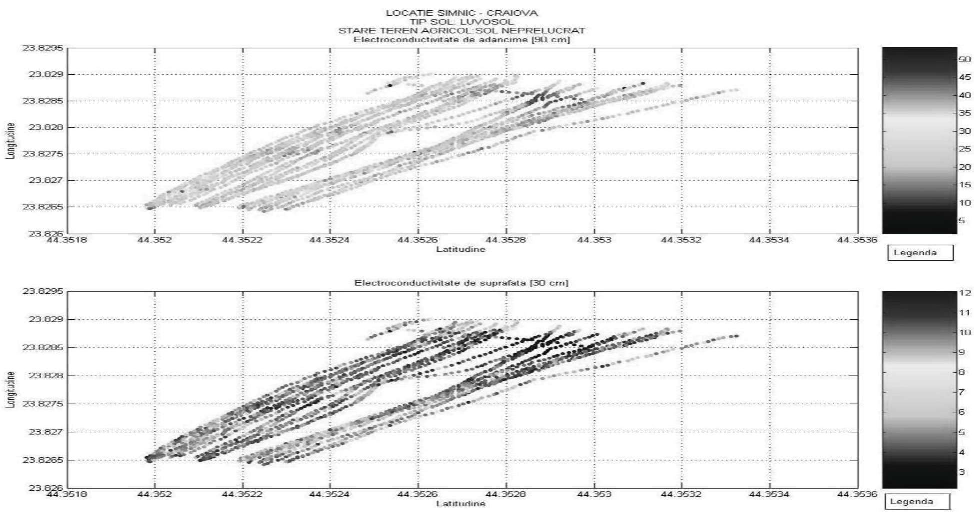

Fig. 6 Experimental model of agricultural maps based on soil EC (unprocessed soil)

Histograms in which can be seen the predominantly electro-conductivity domain for each map obtained both for the deep and surface EC are shown in Figure 7.

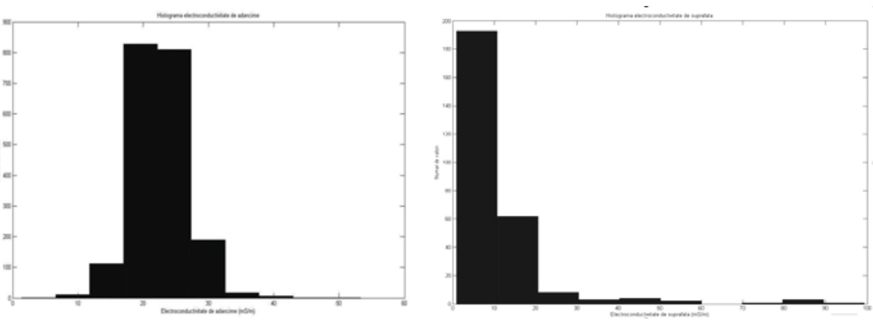

Fig. 7 Histogram of deep EC, surface EC (unprocessed soil SCDA feel-Craiova)

3. USAMV Timisoara, soil type bill mold, unprocessed soil

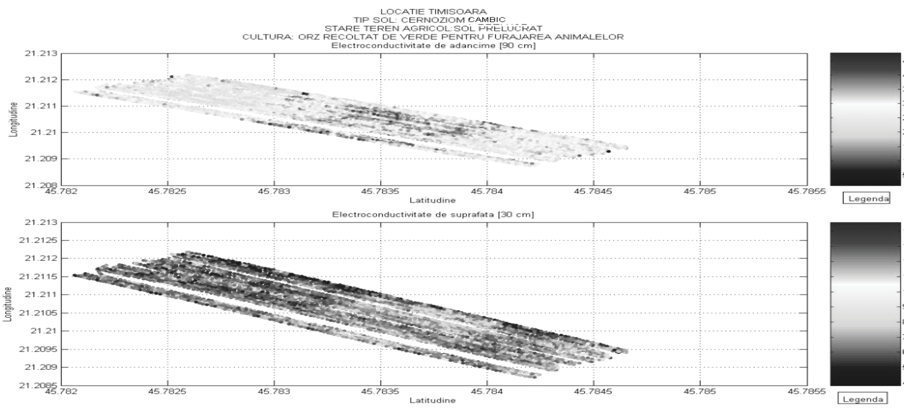

Fig. 8 Experimental model of agricultural maps based on soil EC

Histograms in which can be seen predominantly electro-conductivity domain for each map produced both for the deep and surface EC are shown in Figure 9.

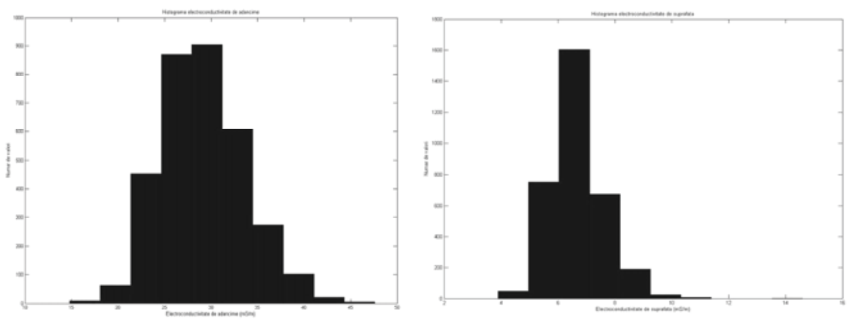

Fig. 9 Histogram of deep EC, surface EC (unprocessed soil UASVM Timisoara)

4. SCDA Valul lui Traian, soil type vermic mold, processed soil.

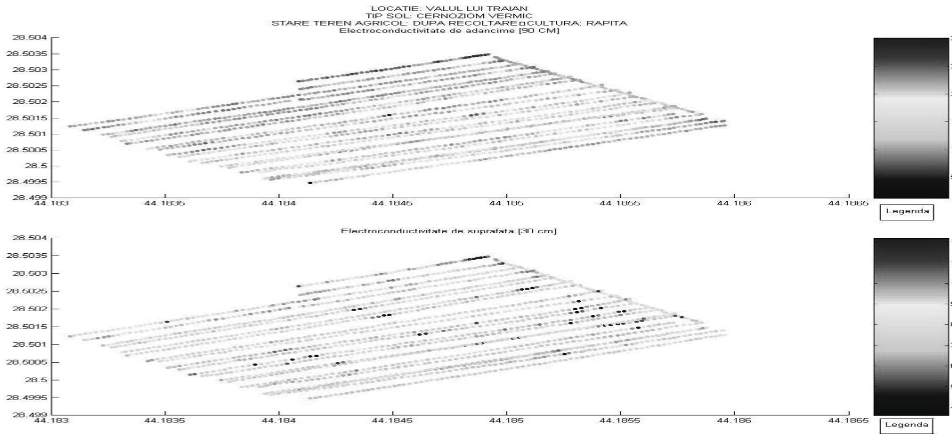

Fig. 10 Experimental model of agricultural maps based on soil EC

Histograms in which can be seen predominantly electro-conductivity domain for each map produced both for the deep and surface EC are shown in Figure 11.

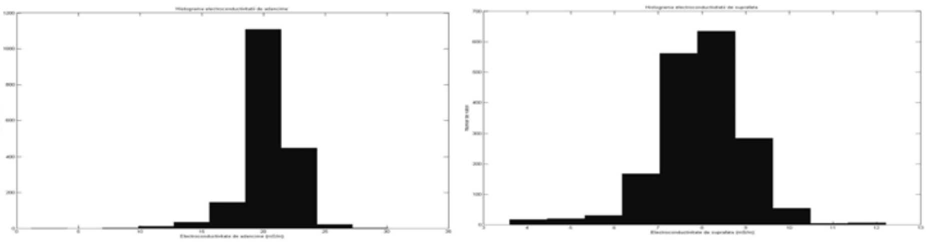

Fig. 11 Histogram of deep EC, surface EC (unprocessed soil Valul lui Traian)

5. Polygon INMA Bucharest, reddish brown forest soil type

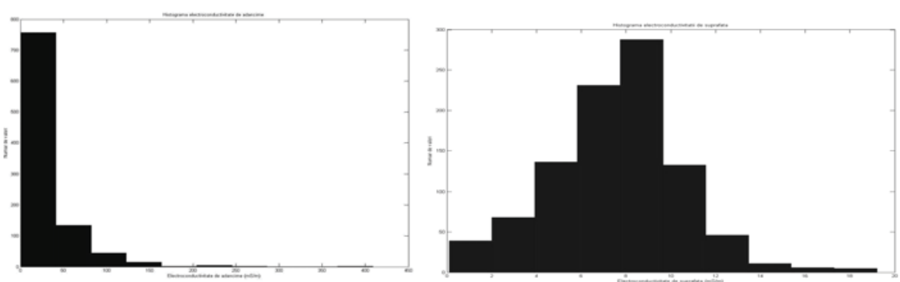

Fig. 13 Histogram of deep EC, surface EC surface (ground processed polygon INMA Bucharest)

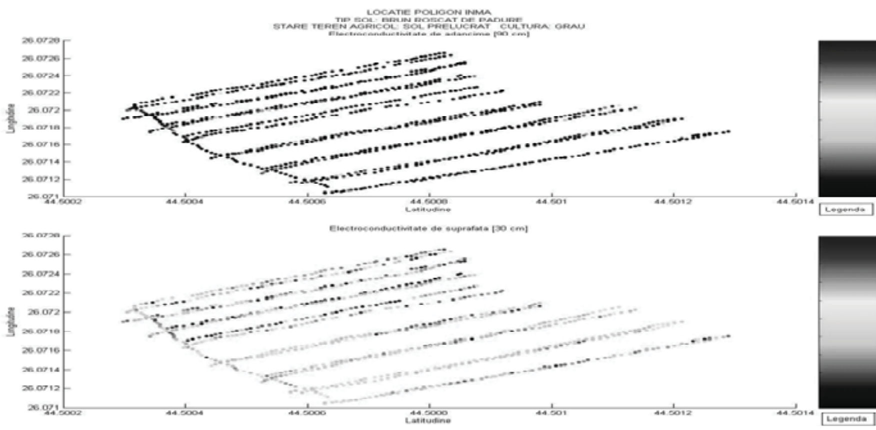

Fig. 12 Experimental model of agricultural maps based on soil EC

CONCLUSIONS

So for the development of experimental models of agricultural maps of electro-conductivity (EC) were selected five different locations within the country, sites being chosen so that it contained all types of soils representative of Romania (easy – SCDA SIMIC-Craiova, Dolj County, medium - INCDA FUNDULEA, County ILVOF and SCDA Valul lui Traian, Constanta county, hard - INMA Bucharest, Ilfov County, very hard - USAMV Timisoara, Timis county, where using a Veris 3150 mobile platforms were obtained the electro-conductivity data necessary for the EC model maps.

Following the examination of all patterns of agricultural map of electro-conductivity and the corresponding histogram results the next conclusions:

- average deep electro-conductivity measured between 0÷90 cm deep, is located in the EC parcels tested in the range of values between 0÷50 mS / m;
- average surface electro-conductivity measured between 0÷30 cm stands for the analyzed parcels between 0÷10 mS/m depth.
- regarding the behavior of soil EC review finds that there aren't significant differences between surface EC and deep EC between the processed terrains (ploughed, cultivated or state of being cultivated) and unprocessed terrains.
- depending on analyzed soil type is established that the predominant values of electro-conductivity are:

Soil: reddish brown forest:

- The deep electro-conductivity values are situated between a predominant interval of 20÷25 mS/m;
- The surface electro-conductivity values are situated between a predominant interval of 6÷8 mS/m

Soill: reddish brown luvic:

- The deep electro-conductivity values are situated between a predominant interval of 20÷30 mS/m;
- The surface electro-conductivity values are situated between a predominant interval of 0÷10 mS/m

Soil bill mold:

- The deep electro-conductivity values are situated between a predominant interval of 22÷28 mS/m;
- The surface electro-conductivity values are situated between a predominant interval of 6÷7 mS/m

Soil: vermic mold:

- The deep electro-conductivity values are situated between a predominant interval of 38÷45 mS/m;
- The surface electro-conductivity values are situated between a predominant interval of 7÷9 mS/m

However these values can not be regarded as referential for that soil type and even for the same parcel of land considered as EC may change over the years and even over the same year as climatic conditions and in particular precipitations regime is very different, which makes the determinations of electro-conductivity abroad takes place on at least three years.

Regarding the influence of physicochemical properties on the values of conductivity obtained was found that moisture or water content of the soil, has a constant degree of influence. Thus soils with a high water content have higher EC values (eg farm land assessed in Valul lui Traian location were measured high electro-conductivity values correlated with higher soil moisture). To the opposite pole are Simnic-Craiova location where the water content in soil was lower so the electro-conductivity measured was lower compared with the rest of the locations.

For soil porosity was found that a higher porosity results in a higher electro-conductivity, this can be explained simply by the fact that soils with a higher content of clay in their structure have a higher porosity than sandy soils, so electro -conductivity increases with clay content of a soil. This was demonstrated in the three locations analyzed INCDA FUNDULEA, SCDA Simic-Craiova, UASVM Timisoara on soil types reddish brown forest, red brown and cernoziom cambic, where data demonstrates the theory above. However in the case of cernoziom vermic soil from -jud.Constanța Valul lui Traian, although the analysis carried out showed a lower soil porosity, so the containing clay in the soil structure is below the percentage amount of sand present, the EC data obtained were higher than in other locations. This is explained by higher soil moisture in case of Valul lui Traian location, over than 35% compared with a maximum humidity of 20% for Fundulea, Timisoara and Craiova locations, thereby showing that soil moisture is the property of which the electro-conductivity is closely linked.

Low soil temperature determine an electro-conductivity of the respective soil smaller than normal

Cation exchange capacity represented by the presence of positive ions from the soil as Ca^{2+}, Mg^{2+}, Na^{+}, $NH4^{+}$ and H^{+} increase soil electro-conductivity resulting the fact that humus-rich soils have a high electro-conductivity [8].

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

EXPERIMENTAL MODELS OF AGRICULTURAL PRODUCTIVITY MAPS OBTAINED WITH THE HELP OF AN INFORMATION AND SATELLITE MEASUREMENT SYSTEM ADAPTABLE FOR DIFFERENT TYPES OF COMBINES

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SUMMARY

The article presents productivity agricultural map models, created on the basis of production data obtained through MICRO TRAK type cereal production monitoring system, mounted on different types of combines that where used in the locations where experiments took place. Locations were picked so that all of Romania's geographical regions were covered (with different climate and precipitation regimes), with varied soil texture (INCDA FUNDULEA, forest brown-red type soil, USAMV TIMISOARA – cambic cernoziom type soil, INMA BUCHAREST polygon forest brown-red type soil). Productivity maps are tridimensional containing information about charted terrain localization, third dimension being reserved by registered productivity values.

Key words: *agriculture, precision, system, maps, productivity*

INTRODUCTION

In agriculture, even the slightest difference in terrain properties can lead to large variations in quality and productivity. Presently, in the field of precision agriculture these slight differences can be taken into consideration. Worldwide precision agriculture is implemented at farm management level or associations of agricultural farms. Precision agriculture permits the farmer to modify in good time his harvesting techniques for the specific crops. Also, besides achieving good crops, ecologically sensible areas are included in environmental friendly harvesting plans.

Soil properties and quality differs in a considerable way even for short surfaces. These field properties that vary locally are influenced by the natural characteristics of each area. The main purpose of precision agriculture is to exploit the arable terrain as economically as possible and at the same time to harvest in an environmental friendly manner.

Terrain administration gives larger benefits if it is adapted to terrain properties and to plant necessity at a low scale. Fertilizers and pesticides are applied in an ecological and economical manner in optimal quantities, reducing to eliminating the ecological problems caused by agriculture, as dissolving nutrient substances or polluting water with pesticides.

Field harvesting must be made more carefully now in the ecologically sensible areas. Successfully implementing and applying on a large scale the precision agriculture needs clarifying problems regarding efficiency and interactions between geology, geography, climate and crop growth.

Enhancing crop quality and productivity is necessary in modern agriculture systems. A necessity for production costs is that they must be kept as low as possible in order to guarantee market competitiveness. Achieving these objectives implies the use of complex management and the control of systems to efficiently regulate a large quantity of interactive physical variables. [2]

Thus in order to obtain higher productivity and implicitly a larger profit coefficient, taking into consideration the high demands from EU market regarding quantity and quality of products obtained following agricultural terrain harvesting, it has become a priority to find new ways and methods, resulting in gathering a series of data on soil properties, its texture and electro-conductivity, data that will help Romania's agriculture to fit in the concept of precision agriculture. So, in the last few years obtaining crop maps that can reflect productivity on different agricultural parcels, and in some cases even on the same parcel.[4]

In the countries with developed agriculture there are advanced methods of determining productivity of an agriculture parcel, through the use of powerful technical equipment, that lead to identifying and optimizing solutions regarding mechanization techniques and creating agricultural crops as productive as possible. [1]

Types of flow measurement sensors, used worldwide:

- *Caterpillar CEBIS System* (fig. 1) – measures cereal flow using light barrier;
- *Fieldstar AGCO System* (European version) (fig. 2) – measures cereal flow using pallet spin;
- *Fieldstar AGCO System* (European version) (fig. 3) – measures cereal flow using radiation detector;
- *AG-Leader & Case IH AFS System* (fig. 4) – mass sensor that measures flow with a force transducer;
- *Micro-Trak Grain-Trak & AGCO FieldStar System* (fig. 5) (American version) – measures flow with a force transducer with fingers;
- *John Deere Greenstar System* (fig. 6) – measures flow with a potentiometer.

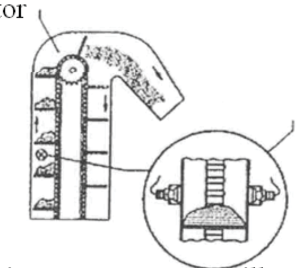

Fig. 1 CEBIS Caterpillar System

CEBIS Caterpillar System (fig.1) uses a volumetric measurement mechanism. This means the transported cereal volume on each pedal. In order to achieve this we use a single type of light barrier, as it is presented in figure 1.

The sensor works almost like a solar cell. When pedals are empty, a high frequency constant signal is sent to the sensor, because there is no break in the light source. As the pedals are with cereal, a pulse is sent to the sensor. This happens because the light is interrupted by the pauses in mass from cereal. Through measuring the time of low frequency signal we can calculate the volume of cereal.

Through combining information from flow sensors and humidity a precise measurement of productivity is achieved.

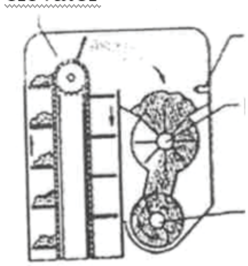

Fig. 2 AGCO FieldStar System

Class Yield-o-Meter System (fig.2) uses a different type of volumetric measurement. The sensor is placed at threshing/ cleaned cereal elevator exit. Cereals must pass through the wheel pedals. Pedal spinning is accompanied by a sensor that measures rotations per minute. The rotations are combined with the known volume of cereal that passes with each rotation at calculating the cereal volume. The rotations per minute take account of the known volume of seeds that passes through at each rotation for calculating the cereal volume. Comparing this number with the recordings from a humidity sensor, results a correct productivity measurement.

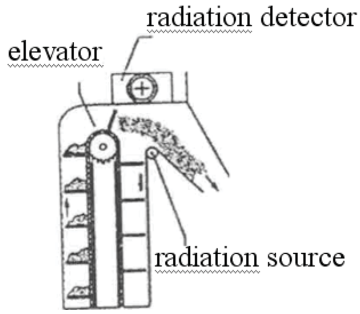

Fig. 3 AGCO FieldStar System

AGCO's European FieldStar System (fig.3) availible on Gleaner combines and Massey Ferguson uses a detector to measure cereal quantities. The sensor is placed at the exit from the threshed stems elevator. A radiation sensor placed over the elevator exit of clean stems measures the quantity of radiations it reaches. At the time the stems pass directly through these radiations, some of them are absorbed. The quantity that touches the radiation sensor is reverse proportional with the quantity of cereal that flows through the passing surface.

By combining the two measurements (from the flow sensor and the humidity sensor) the production is calculated.

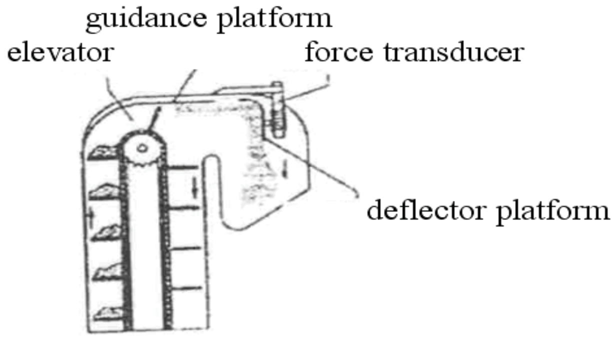

Fig.4 Ag-Leader& Case IH AFS System

In the case of **Case AFS Systems** (fig. 5) and **Ag. Leader** (fig. 6) used by the *CASE-IH* firm, uses a force transducer almost identical for measuring cereal mass in the threshed cereal elevator. These sensors resolve this task by using a curved deflector plate. The pan is positioned in the way of cereals from the elevator. The force transducer measures the force with which the cereals hit the deflector plate. The transducer converts the data into a signal that is sent to the monitor. This measurement of mass is combined with the information gathered by the humidity sensor for productivity measurement.

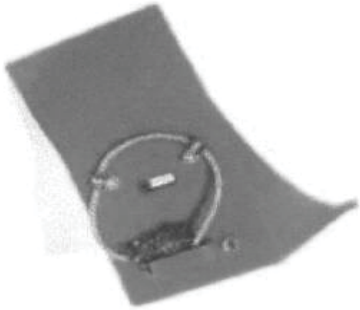

Fig.5 Case IH AFS flow senzor system

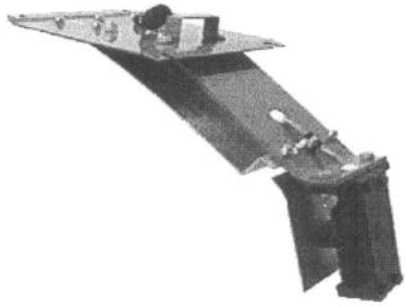

Fig.6 Ag Leader flow senzor system

John Deere's GreenStar System (fig.7) uses a completely different sensor, at least for measuring cereal flow from the elevator. Instead of a force transducer as in the case of Ag Leader and Case IH AFS, John Deere uses a potentiometer attached at the curved deflector plate. The plate is placed in the direction of cereal flow as it is at the Ag Leader and Case IH AFS. The potentiometer records a signal proportional with the force placed on the flat deflector from the way of cereal flow. The GreenStar monitor combines the signal from the potentiometer with the signal from the humidity sensor for calculating production values. [3]

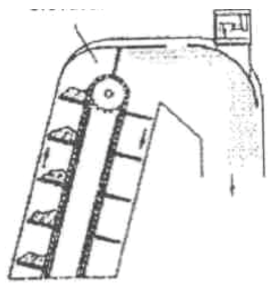

Fig. 7 John Deere Greenstar System

METHODS

The fundamental component of a production monitoring system is a production sensor that measures the cereal flow from the harvesting machine's cereal gatherer and displays the information at the driver position. When a humidity sensor is used the system has the capacity to deliver data as hectare optimum humidity, average humidity, etc. This information is updated continuously, usually once or twice a second. When this productivity sensors and the humidity are combined with a GPS (global positioning system), data about the local production can be achieved for generating production maps. These maps graphically illustrate the variation of field production and permit the farmer to take the right decisions.

The main components of a productivity monitoring system are:

- productivity sensor – measures cereal flow in time;
- speed sensor – indicates the work speed in order to calculate the crop after the surface taken into consideration;
- humidity sensor – measures the cereal humidity, the value obtained being an average of humidity values obtained during harvesting;
- GPS receptor - signal receptor and satellite positions from the global positioning system;
- Correcting differential receptor – GPS signals are corrected, giving more precise information about location;
- Operating interface – receives data from the combine operator and displays the processed information in the dashboard computer;
- Tipping sensor – sensors from the combine platform at the furrow edge in order to stop the double recording of production;
- Dashboard computer – placed in the combine cabin, receives output data from different sensors and input data from the operator, processes and/or information regarding the production on a specialized memory card (flash memory).

As in the case of Ag Leader and Case IH, the **Micro-Trak's Grain-Trak & AGCO FieldStar** (figure 8), used in the case of experimentation presented in the paper, uses a force transducer for measuring cereal flow from the elevator. The two systems are still different. Instead of curves from a flat deflector attached at a transducer, the operator console uses a set of „measuring fingers" that are attached to the transducer.

These measuring fingers are placed in the way of cereal passing at the exit from the elevator. Following the reaction, the fingers are being pushed. The created force is transformed into an electric signal by the transducer. As in other systems, this signal is transmitted to the monitor and combined with the humidity sensor information achieves a production measurement. [5]

Fig.8 Sistem Micro-Trak Grain-Trak & AGCO FieldStar

The study was established in three different locations in order to determine the production capacity of some parcels that have been analyzed a year earlier for soil properties. So, there have been gathered probes with the Micro-Trak Grain-Trak & AGCO FieldStar System in order to determined soil productivity in the following locations:

- INCDA. Fundulea – soil type: FOREST BROWN RED, analyzed surface 0,8 ha, seed wheat crop;
- USAMV Timisoara – soil type: CERNOZIOM ALCALIN, analyzed surface 3 ha, wheat crop;
- INMA Bucureşti - soil type FOREST BROWN RED, analyzed surface 4 ha, rape crop;

The productivity monitoring system Micro-Trak Grain-Trak & AGCO FieldStar was mounted on different types of combines (C110H, MDW 527 STS, experimental combine WINTERSEIGR – fig.9). Data can be recorded every second, with the GPS (GPS V-connection used NMEA 0183 Version 2.30 data) connected to the main system, an absolute necessary condition for recording productivity data in the PCMIA card. Data will be transformed later on in a notebook for generating maps using MATLAB. [6]

Fig. 9 Images during experimentation

RESULTS AND DISCUSSION

Following experiments in the three locations the following productivity maps were achieved:

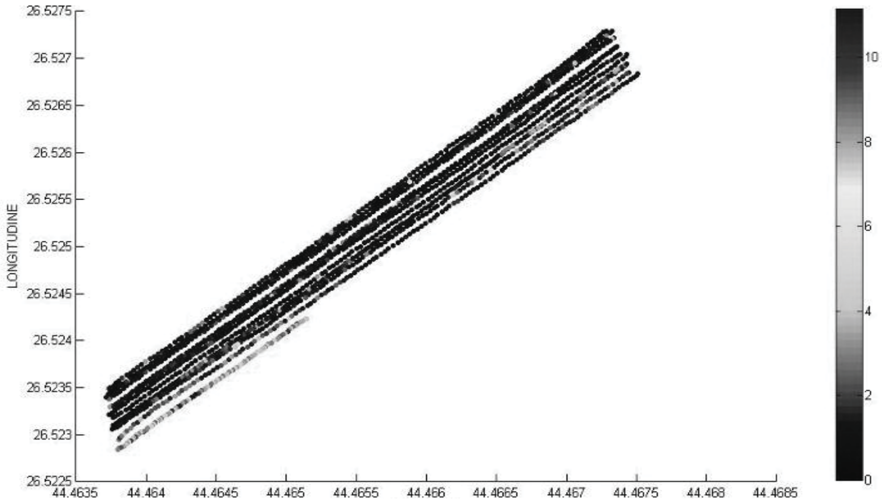

Fig. 10 Experimental model of agricultural maps acording to soil productivity (INCDA Fundulea – seed wheat crop)

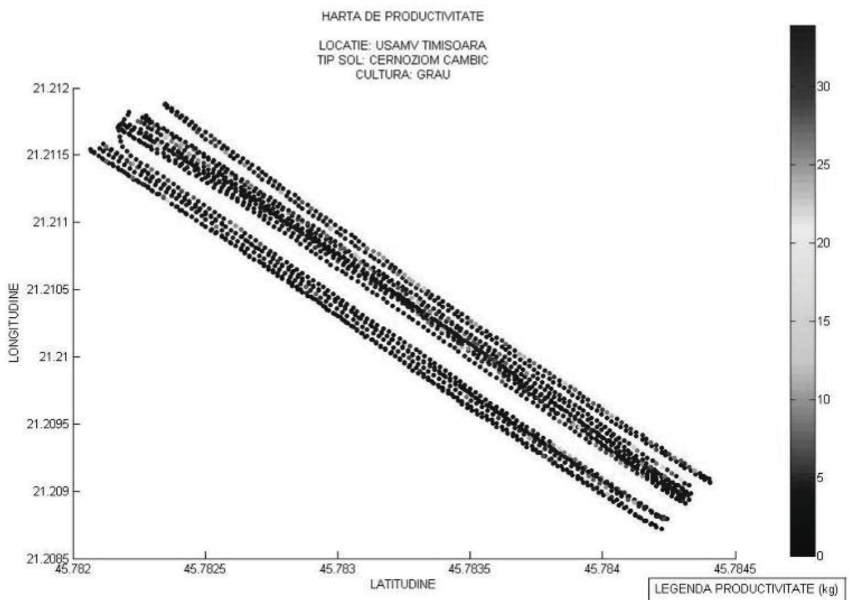

Fig. 11 Experimental model of agricultural maps acording to soil productivity (USAMV Timisoara, – cambic cernoziom soil type, wheat crop)

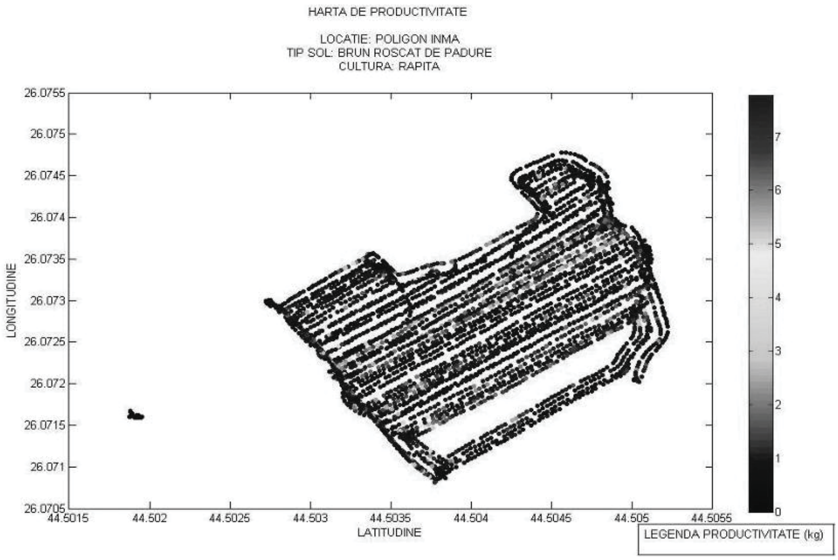

Fig. 12 Experimental model of agricultural maps according to soil productivity (INMA Bucharest, soil type FOREST BROWN RED, rape crop)

CONCLUSIONS

Agricultural productivity maps show the production variation in an agricultural terrain an represents an important source for the farmer. The production monitor is just a part of the informatics system in precision agriculture, with the help of which we can make comparisons of productivity values on more periods of time. Adopting a decision regarding a crop must not be made with rash action from the farmer, at least three years being needed for characterizing an agricultural terrain from a productivity point of view. The farmer must not jump to conclusions, long term conclusions being more solid. The most complicated situation is when in some agricultural parcels following many years of mapping productivity there is no difference from year to year.

In order to make experimental models of agricultural productivity maps three different locations were chosen from Romania, that represented the three main soil types from this country (medium soil – INCDA Fundulea, Ilfov, heavy – INMA Bucharest, Ilfov and very heavy – USAMV Timisoara, Timis), where with the help of a productivity monitoring system, MICRO TRAK type, mounted on different types of combines used for experimentation productivity data necessary for creating productivity map models where obtained.

Following analysis of all productivity agricultural map models the following conclusions were drawn.

- in the case of parcel I from INCDA Fundulea, FOREST BROWN RED soil type, seed wheat crop, after an analysis of the productivity map model the production was of 4200 kg per hectare. Also from the points, the average productivity / m^2 was similar for the entire parcel because it was treated with herbicide during the agricultural year.

- In the case of parcel II, from USAMV Timisoara, CERNOZIOM CAMBIC soil type, wheat crop, after analysis of the map model, we can say that the hectare production was of 3259 kg. Also we can say that the average productivity / m^2 was similar, because it was treated with herbicide;
- In the case of parcel III from INMA Bucharest, FOREST BROWN RED soil type, rape crop, we can say after analysis that the production was of 800 kg. This is due to the fact that the parcel was not treated with herbicide; this was also visible on the points from the map model. So, we can see the interference of some points from specific areas from the parcel with a lower productivity.

Regarding the monitoring system behavior used, MICRO TRAK GRAIN, there were no significant differences between the recordings of total productivity and mass of cereal harvested on a parcel and weighed with an electronic scale, adjustments being made during probing. Also adjustments were made for the harvested cereal humidity that was compared with the humidity displayed with the humidity sensor from the monitoring system mounted at the cabin bunker level.

Making decisions on the basis of productivity maps is not an easy action. The type, quantity, and quality of some data obtained at a farm dramatically modify. Farmers will be forced to choose between these data and decide which information is relevant for their objectives. Farmers must select priorities, the steps in making decisions stimulates the process to include: data gathering, data interpretation, making decisions, plan implementing, evaluation. [6]

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 634.11:621.317.7
Prethodno priopćenje
Preliminary communication

DEVELOPMENT OF APPLE FORECAST REGISTER BASED ON VISUALISATION OF TREE GROWING VOLUME AND GLOBAL POSITIONING SYSTEM

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ABSTRACT

The paper describes the development of an algorithm for the early estimation of apple and pear yield based on the global positioning system and collection of information on the number and diameter of fruits in the orchards through the 'method of image analysis'. The system consists of an application on a personal computer (PC), from which the user create a daily journey through the plantations and export the data to a navigation device; a mobile application with GPS receiver (ASUS 565), which enables to capture positions of plantation and images and to store them into a database. Processing of all collected data runs on a PC, which requires a synchronization of all new, changed or updated data stored in the mobile device database with the database on the PC.

***Key words**: apple, forecast, image analysis, register, GPS*

INTRODUCTION

Early prediction of the annual harvest of apples and pears is essential for the organization of harvesting and storage of harvested crops, and pricing. During 1989-1999, in Slovenia improved method of Winter (l986), so called Bavendorf method based on time consuming counting and measuring of fruits diameter in sample orchards was used (Stajnko et al, 2001). Due to time-consuming counting, the lack of experts and inaccurate forecasts, Slovenia in 2002 moved to a methodology applied to the SURS (www. surs.si, 2009). In this procedure agricultural experts in the field assessed the future yield by counting the fruit crop in the selected tree plantation. Later by statistically methods, through collected data from the Ministry of Agriculture, Forestry and Food, the forecast was made for the entire country. Due to the small number of samples, this forecast was rather vague, thus in individual years the forecast differed from the actual production from 12 to 55 %.

Recently, also in the fruit forecast, it does not go without modern technology, thus Stajnko et al. (2004), developed a system for capturing images of the tree and subsequent automatic processing of images. The advantage of such data acquisition is that it is possible to capture a lot of samples of different apple and pear varieties at various farmers in a short time in order to improve forecast accuracy.

Since our method for predicting yield based on past forecasts and compare it later with actual production, it is desirable that each year the images of the same trees are captured.

The paper describes a system that enables a satellite control guiding of the user to the selected orchard for locating and capturing the tree image as quickly as possible, especially if we process the tree from the previous calendar year. It provides the data acquisition with minimal equipment and efficient access to the information contained on the ground for further processing. Besides, a converting of a GPS coordinate system into the horizontal state coordinate system D48, implemented in the procedure is described.

METHODS

Taking samples in the orchard requires a lot of walking, so it is very important that the researcher use as little devices as possible, preferably only one, which can help the user to locate and record the tree position automatically. A suitable device is a PDA or smart phone with built-in GPS receiver and camera. Since we need to store previously information on the owners and their orchards, a larger amount of additional memory is required.

Slovenian Ministry of Agricultural formed a graphics database of agricultural land use called GERK (Uradni list RS, 2006) for all farmers in 2005. GERK is completed unit of agricultural land, and usually consist of more orchards with several different apple varieties. Data on the geographical position are held by the Ministry and was also a source for our application.

After examining the project requirements, we have decided that a preparation to departure on the ground should start already at the personal computer (PC).

First, the user makes a daily plan by selecting GERKs or indirectly orchards, from which he will collect data for forecast. Then positions of GERKs are exported to the mobile device in GPX file, which is loaded on Garmin (www. garmin.si, 2009) application, which was originally intended to road navigation. Additionally, our application also provides an overview of all producers of agricultural land, GERKs, orchards and varieties.

The central part of the system represents the mobile device with the wireless device and installed Garmin, which leads the user selected GERK or orchard. Using the GPS receiver and camera together can help the user to easily capture the current tree position and its image and store them in the database of mobile devices.

As seen in Figure 1, a full system uses two instances of the database. The first is stored on a PC and the other on the mobile device. Since the data recorded on the ground are located to the mobile base, two bases no longer have the same content. Therefore the application has got to be synchronized after each recording in the orchard.

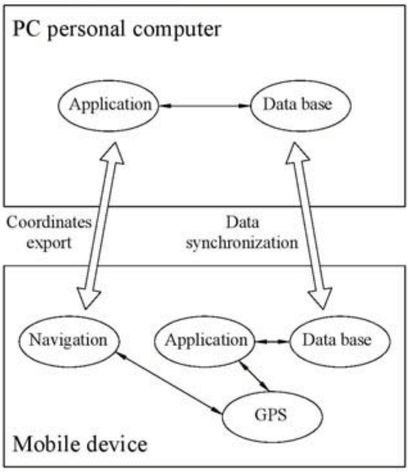

Figure 1 System Architecture

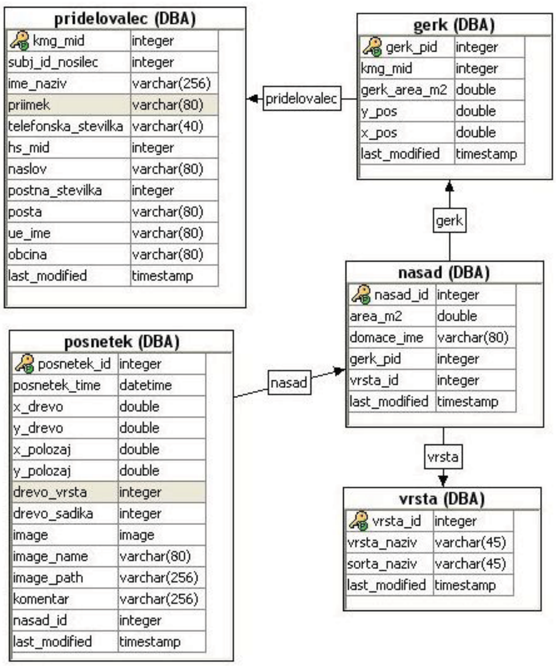

Figure 2 Diagram of the database

The structure of the database

Figure 2 shows all database tables applied in our application. It consists of five tables: farmers (pridelovalec), image (posnetek) GERK, orchard (nasad) and row (vrsta). A table of farmers contains information such as name, company name, address and post office, for all owners of orchards. GERK contains x and y-coordinate as D48/GK (http://prostor.gov.si, 2009) and the area. Each GERK usually consists of one or more orchards, thus a Table 'gerk' contain information about the area of orchard and variety of trees. Table 'posnetek' contains information that the user of mobile applications can capture on the ground: the position of trees and recording, photograph, date and time, commentary and of course the identifier of the orchard in which the recording was made. The file row contains data about the row from which the image was captured.

Coordinate systems

Because the Slovenian public administration is still using the D48 coordinate system, the application performs the conversion of coordinates between a WGS84, used by GPS satellite navigation, and D48. Basically, WGS84-coordinates are the geographical coordinates, while the D48 are planar (map) coordinates. Figure 3 shows the conversion between coordinate systems. As seen, first WGS84 geographical coordinates are converted into geocentric coordinates to WGS84-ellipsoid, and then into the geocentric coordinates of the Bessel ellipsoid. Bessel transforms geocentric coordinates into the geographic coordinates, which are finally the geographical coordinates of the plane D48 (Zgonc, 2006).

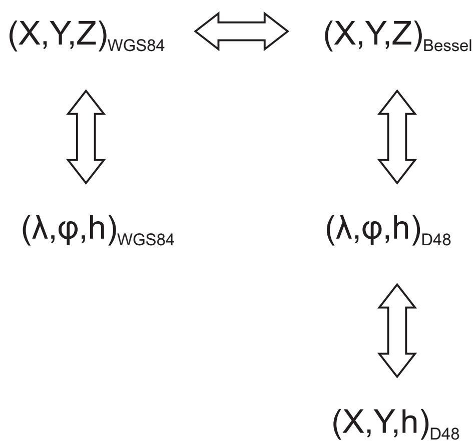

Figure 3 Conversion of WGS84 coordinate system and D48

Global guiding

With the help of our applications on the PC the daily path is pre-prepare by choosing GERKs or their owners, we want to visit. Then data is transferred via USB in the navigation software on the mobile device through the GPX file format, since for guiding the user to the desired orchard on the ground a Garmin navigation system is used.

Field data capture

The user captures data in the field by a mobile application. First a mobile application shows all GERK-e in a 5 km radius assorted by distance according to the position conveyed by the GPS device. The user has to choose a GERK and orchard which is currently located. Additionally the user can check the variety on each tree plantation, since there is a label with information on species and variety. Finally, (Figure 4) the following data can be stored in the database:

- contact details of the owner of the selected GERK,
- local name of the plantation, which is defined by the owner of the orchard,
- the position of trees, which will be photographed,
- the position from which the photo will be taken,
- any comment and
- image of the tree.

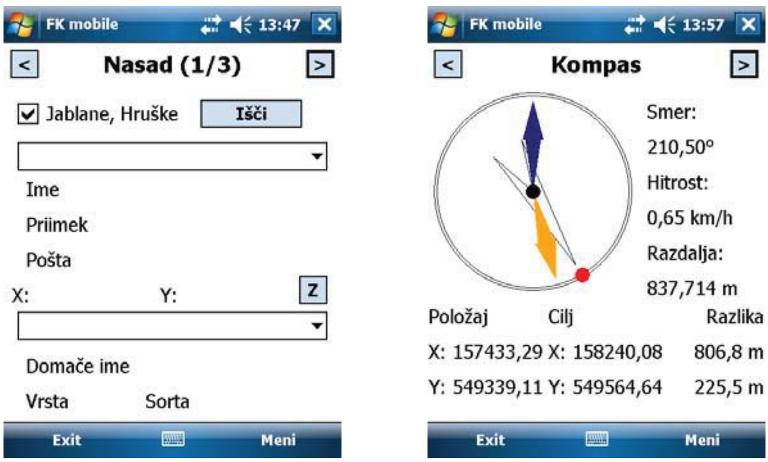

Figure 4 The window for capturing data on site (left) and compass (right)

The application allows viewing of data, which were noted in previous recordings. One can also find all information about the current situation and all near-recorded positions in the recent past. Relevant information, like GERK, plantation, manufacturing date of recording, the position of the tree and image, will be retrieved from the database of mobile devices. The user can press a button with labeled tree position taken in the past year, and open a separate navigation window for local control - a compass that leads him to the selected tree.

Local governance

The mobile application is able to guide user to local position by built-in compass (Figure 4 right). Different situations, like the center of each GERK, tree or position captured in the past year, are stored in the database. In the graphical interface called compass the user can mark this point and run the application to the finish point. Figure 4 right shows three of the compass directions:

- movement (dark arrow), which represents the direction of movement and still shows up
- north (empty arrow with a red dot), which points towards the north, and
- target (a bright arrow), which points towards the selected target.

Textual part (below) shows the current situation and the targets chosen in D48-coordinates, direction and current speed of movement and three distances: Euclidean distance, the distance in x direction and distance in the y direction between the current position and destination. However, a major shortcoming of all compasses is based on GPS technology, which does not work if the user is stationary. So the user should be aware that the speed and direction are correct, only if they move, and also that the accuracy of direction and velocity increase at a rate of movement.

RESULTS

From the register of intensive crops 245 positions of the orchards were selected in 2009 according to the apple varieties, planting year and growing form. In 23 cases (9.6 %) errors of measurements occurred in 2009, due to wrong choice of GERK (8 cases), GPS error (9 cases) and error register GERK (6 cases). One year later the system was upgraded with GERK polygon coordinates and tested on the same positions again. The accuracy of the sampling was 100 %, whenever properly entered into the 20 m belt of the orchard.

CONCLUSIONS

This paper describes a system for capturing, processing and storage of tree images required for forecasting the future yields on a new GPS supported way. The new approach for random selection of parcels and autonomous guiding into the orchards was shown to be very efficient and precise. Thus it enables a good basis for more accurate apple and pear yield forecast. The user-friendly PC application allows easy data transfer from the central databases and scheduling daily routes, which is needed for sampling the same trees each year. A guideless on a daily path over the GPS mobile device and a program for street navigation led us to the selected orchards on a quickest way, which spared a lot time, especially whenever attempting the plantation without the owners.

In 2009 the information on the tree position captured by the image camera was tested on 245 samples (22 apple and 6 pear varieties). Postpone manual comparison between the stored data in a mobile device and those from GARK base showed that in 23 cases (9.6 %) errors of measurements occurred due to the incorrect positioning or incomplete data in the GERK base. In 2010 all samples were positioned correctly, so the system can be directly transferred into the practice.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

DETECTING NATURAL OBJECTS BY USING TEXTURE ANALYSIS

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ABSTRACT

This paper describes different approaches to detect natural objects based on texture properties. It starts with texture analysis in spatial domain, where it uses structural, statistical and spectral approach to calculate texture properties such as contrast, uniformity, entropy and others. It continues with texture analysis based on frequency representation, its advantages and its drawbacks. The paper concludes with spatial-frequency approach to analyse textures of natural objects n order to detect them. It introduces a pre-processing step using Homomorphic filtering, 2D smoothed pseudo Wigner-Ville distribution and a support vector machines approach as an classification tool. The results prove that the approach successfully classifies a colour segmented region with coverage of up to 66 %.

Key words: *texture analysis, colour segmentation, Homomorphic filtering, spatial-frequency representation, support vector machines*

INTRODUCTION

Object detection algorithms represent an important part of more complex systems, such as fruit picking robots (Juste et al., 1991, Tanigaki, 2008, Van Henten, 2003) or harvest prognosis systems (Stajnko, 2009) and even quality control systems (López-García, 2010). In all cases we can use digitised snapshots of natural scenes, captured by a common digital camera. By using 2D digitised representations of a given natural scene, we can detect regions that represent fruit and draw conclusions about quantity, quality and location. In general, object detection algorithms include colour segmentation step (Gonzales et al., 2001) that produces a binarised result, disclosing potential areas we are looking for. These areas are then analysed by looking at different properties of an object, in some cases even its textures (Stajnko et al., 2009).

Various distributions of colour shades produce different patterns we call textures. In order to detect them, we can apply one of the following three approaches. The first and the simples is structural approach that describes repeating patterns. The key step in structural approach is to find the representative unit of a texture and mark/measure its occurrences. A bit more complex is statistical approach, based on statistical moments, and measures properties such as skewness and flatness of a histogram. The third is spectral approach that uses Fourier transform and analyses familiar frequency components of a texture. The first approach is rarely used due to its simplicity which demands clear and whole repeating patterns which we cannot guarantee on images of natural scenes, that is why we will continue with the statistical and spectral approaches.

One of the most straightforward approaches is to analyse the colour histograms of an entire image or a histogram of an image part. The histograms are then used to calculate statistical moments (Gonzales et al., 2001). First two moments (zero and first) are discarded, as they produce constant values of 1 and 0, respectively. More useful prove to be the second, third and fourth moments that correspond to variance, skewness and flatness of a histogram. Based on each statistical measurement a decision can be made on classification of the describing texture. However, a statistical approach has a serious disadvantage as it does not take into consideration relative positions of pixels in relation to each other.

In order to include the location of each occurrence of intensity value a different approach was devised by using a co-occurrence matrix (Gonzales et al., 2001). With its help we define the relation between the occurrences of each intensity in relation to other intensities of an image. By using a co-occurrence matrix different characteristic measurements can be computed, such as contrast, uniformity, homogeneity and entropy that can serve as classification properties.

The third approach to describe and detect familiar texture patterns is spectral approach. By using a 2D Fourier transform (Gonzales et al., 2001) an image is converted from spatial to frequency domain. The frequency domain representation is made up of frequencies that describe an image. If a given set of frequencies for selected texture is prominent enough it can serve as a classification tool. The problem of the spectral approach described is that it does not reveal the location of occurrence for each texture. That is way short-time (windowed) 2D Fourier transform is usually used or, as we will see in the following subsections, a spatial-frequency distribution can seriously be considered.

TEXTURE ANALYSIS

Texture analysis is made of three crucial steps. The first removes uneven illumination from the scene, which can affect the analysis, the second calculates a spatial–frequency representation of a given image, while the third looks for familiar patterns by using support vector machine (SVM) as an classification tool.

HOMOMORPHIC FILTERING

When using images of natural scenes, captured in uncontrolled environment, we must take into account they include over and under illuminated areas. Over illuminated areas are caused by direct sunshine which can even produce areas that are almost completely white, where the colour information is almost lost. On the other hand, we often encounter under illuminated areas that are in the shade which is caused by other objects, such as branches, levees and fruits that cover an object from a direct sunshine. These situations are unavoidable and must be taken into account.

One approach in trying to correct the unevenly illuminated images is to fix their histograms. We do so by applying histogram equalization step (Gonzales et al., 2001) or use other similar but a bit more advance approaches such as adaptive histogram equalization (Bovik, 2005, Seul, 2000) or even contrast limited adaptive histogram equalization (Pisano et al, 1998). With their help we increase the contrast, but we also increase the noise, which takes its toll on the quality of the analysis. In order to make our detection method as robust as possible, we decided not to correct the histograms but rather to introduce a preliminary step of Homomorphic filtering (Delac et al., 2006). With its help we eliminate the light from the images and preserve the textures.

Homomorphic filtering is based on the illumination-reflectance model (Delac et al., 2006). If we describe our input image of a natural scene as *I* we can define it as a product as shown by the following equation:

$$I = RL \tag{1}$$

where *R* represents reflectance and *L* illumination. As we already explained, the illumination is not constant and changes on an image, which can be described with a set of low frequencies. In order to eliminate its influence we can apply Homomorphic filtering that eliminates the changes in illumination and promotes the reflectance. However, the illumination and reflectance define an image as a product and cannot be simply separated. In order to define a linear form we can use logarithms as shown by Eq. (2):

$$z(x,y) = \ln\left[i(x,y)\right] = \ln\left[r(x,y)\,l(x,y)\right] = \ln\left[r(x,y)\right] + \ln\left[l(x,y)\right] \tag{2}$$

We then transform the expression from Eq. (3) to frequency domain:

$$F\left\{z(x,y)\right\} = F\left\{\ln\left[r(x,y)\right]\right\} + F\left\{\ln\left[l(x,y)\right]\right\} \tag{3}$$

In order to eliminate lower frequencies that make up the illumination we apply a high pass filter (for instance Butterworth filter) which we describe as *H* and use it as:

$$S = HF\left\{Z\right\} = h(u,v)\,F\left\{\ln\left[l(x,y)\right]\right\} \tag{4}$$

We then use inverse 2D Fourier transform to transform the result to the spatial domain:

$$S' = F^{-1}\{S\} = F^{-1}\left\{h(u,v)F\left\{\ln\left[r(x,y)\right]\right\}\right\} + F^{-1}\left\langle h(u,v)F\left\{\ln\left[l(x,y)\right]\right\}\right\rangle \quad (5)$$

and apply antilogarithm that produces the final result:

$$I' = (x,y) = e^{s'(x,y)} \quad (6)$$

where I' designates a corrected image from which we removed low frequencies that make up the illumination, but we preserved higher ones that describe texture patterns. The whole step is summarized using a data chart on Fig. *1*.

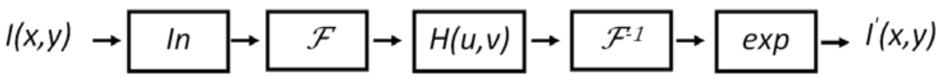

Figure 1 Homomorphic filtering flow chart

Fig. 2 depicts an example of Homomorphic filtering for one selected example. Image on the left of Fig. 2 represents our test example. It includes a lot of regions that are unevenly illuminated. The left image of Fig. 2 on the other hand represents the result of Homomorphic filtering. The result is not perfect, but we managed to illuminate the majority of situations with uneven illumination and preserved the textures we need in the following step.

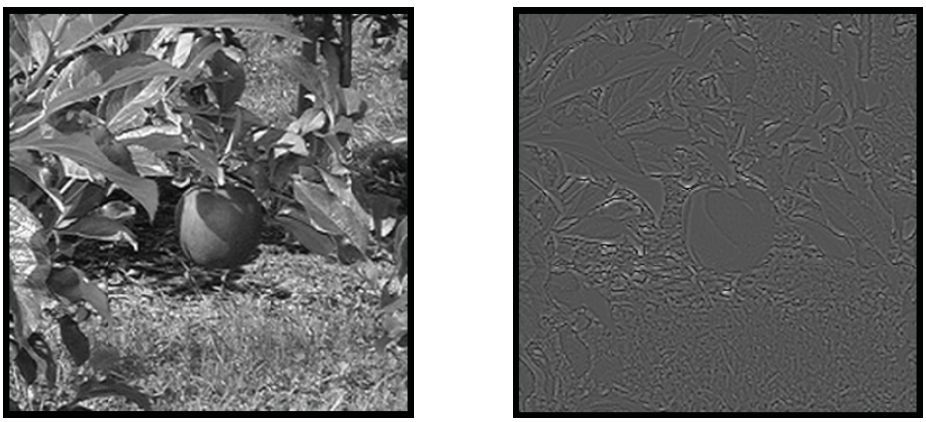

Figure 2 An example of Homomorphic filtering: the left image represents an example snapshot of a natural scene while image on the right its Homomorphic filtered image

SPATIAL – FREQUENCY REPRESENTATION

In contrast to frequency representation, the time–frequency domain (Carranza, 2006, Baraniuk et al., 1995, Greitans, 2008) proves to be a better choice as it is not limited for non-stationary signals that change with time/location. We could use a short-time Fourier transform, but it is sensitive to the chosen window size. Instead we used Wigner-Ville representation that offers good resolution in time as well as in frequency domain and its result is not affected by the size of the window.

As described by Wigner (1932) and Ville (1948), the Wigner-Ville distribution is defined as an auto-correlation function. Its result is time-frequency representation for every point in time and is calculated as show by Eq. (7).

$$\mathrm{WV}_{1\mathrm{D}}(t,u) = \sum_{\tau=-N/2}^{N/2} f(t+\frac{\tau}{2}) f^{*}(t-\frac{\tau}{2}) e^{(-2j\pi u\tau)}, \quad (7)$$

where t and u represent time and frequency components, f^* the complex conjugate of the original signal and N its length. As we are working with images, the 2D version of Eq. (7) can be formulated in the following manner:

$$\mathrm{WV}_{2\mathrm{D}}(n_1,n_2,k_1,k_2) = \sum_{\tau_1=-N/2}^{N/2} \sum_{\tau_2=-M/2}^{M/2} I(n_1+\tau_1, n_2+\tau_2) I^{*}(n_1-\tau_1, n_2-\tau_2) e^{-2j\pi/N\left[k_1(\tau_1-\frac{n_1}{2})+k_1(\tau_2-\frac{n_2}{2})\right]}, \quad (8)$$

by introducing parameters n_1 and n_2 as a spatial domain coordinates, coordinates k_1 and k_2 for frequency domain representation, I as an input image, I^* its 2D complex conjugate and parameters M and N for image size.

A closer look at Eq. (7) and Eq. (8) reveals that the 1D version produces a 2D result while for 2D version of the Wigner-Ville distribution produces a 4D solution. As the amount of data needed to be processed soon gets overwhelming it is advisable to consider a sub-sampling approach and compute the distribution to every n-th point, where n is selected according to the Nyquist criteria.

The Wigner-Ville distribution is, in contrast the period of 2π of the Fourier transform, periodic at π. The result of Eq. (8) is therefore sampled at twice the frequency. It is however impossible to escape the aliasing in time as well as in frequency domain, but we can use two different approaches to minimize this property. The first approach consists of zero padding a signal in the time/spatial domain, while the second splits the frequency band. This can be done in one of two ways; to oversample (sample at four times the frequency) or to compute the analytic version of the input signal using Hilbert transforms (Zhua et al., 1990). It is not uncommon to use both approaches; especially for the 2D signal as the 2D Hilbert transform only computes an approximation of the analytic signal.

The property of the Wigner-Ville distribution has however a drawback that must be accounted for. It produces so called cross-terms (Greitans, 2008, Debnath, 2002) between time-frequency or spatial-frequency responses that can affect the detection. They can be minimised by smoothing the signal in frequency as well as in frequency domain. Based on the recommendations we can formulate the smoothed pseudo Wigner-Ville distribution as:

$$PW_{2D}\left(n_1,n_2,k_1,k_2\right)=4\sum_{u=-P_2+1}^{P_2-1}\sum_{v=-P_1+1}^{P_1-1}h_{P_1,P_2}\left(u,v\right)$$
$$\sum_{r=-Q_2+1}^{Q_2-1}\sum_{s=-Q_1+1}^{Q_1-1}g_{Q_1,Q_2}\left(r,s\right)I\left(n_1+r+u,n_2+s+v\right) \tag{9}$$
$$I^*\left(n_1+r-u,n_2+s-v\right)e^{j\left(\frac{2\pi uk_1}{M}+\frac{2\pi vk_2}{N}\right)}$$

where we introduce the window functions H_{P_1,P_2} and G_{Q_1,Q_2} , parameters P_1 and P_2 that designate one half of the dimensions size of the first window, Q_1 and Q_2 one half of the dimensions second window and we use M and N for signal dimensions.

SUPPORT VECTOR MACHINES

The computed Wigner-Ville distribution produces different responses for different textures and they must be analysed. To do so, we have chosen a support vector machines (or SVM) as described by Vapnik, (1999), Haykin (1999) and Ivanciuc (2007). The SVM approach can be used for linear regression analysis or pattern classification, as in our case. To analyse an image, we use spatial-frequency distribution for each of the pixels and, based on the spatial-frequency response, conclude if the pixel belongs to an area with the texture we are trying to detect or not. This in affect produces a binarized image, revealing pixels that make up a familiar texture pattern.

SVM works by applying directed neural network in order to estimate a hyperplane that separates one group from the other. The process starts with a learning step that initializes the weights of the neural network in a way that the hyperplane is able to classify a member in one of two groups. Every group member is therefore presented with a help of *n*-dimensional feature vector and based on its contents it is separated with the help of a liner classifier or (*n*-1) dimensional hyperplane.

SVM can be defined according to Haykin (1999) in the following way. We use $\mathbf{x}_i$ to represent a feature vector, for which we select a response d_i, with values of 1 or -1 that classify the object according to the features in one of two groups. A hyperplane can then be written as:

$$w^T x_i+\beta=0 \tag{10}$$

where w represents a weight vector, β a bias and **x** an input feature vector. For an unknown feature vector $\mathbf{x}_i$ the equation (10) changes to:

$$w^T x_i + \beta \geq 0 \tag{11}$$

and

$$w^T x_i + \beta < 0 \tag{12}$$

The vectors that comply with Eq. (11) and Eq. (12) fit the hyperplane perfectly and we name them support vectors. In order to make a classification we need to calculate the weight parameter w and a bias β. To do so, we use a quadratic optimization (Haykin, 1999) and Lagrange multiplayer approach (Haykin, 1999) that are covered elsewhere and will not be recapitulated here.

Once the support vectors are know, we can proceed with a classification of an unknown object, based on its feature vector. In our case the object is represented as a pixel in spatial domain, while its feature vector is made of spatial-frequency responses of the 2D smoothed pseudo Wigner-Ville distribution. However, the classification on an object will only be as good as it is the learning set of objects defined by its feature vectors used during the learning step.

RESULTS

As we are limited with space, the validation of the method will be summarized with one of the examples, depicted on Fig. *3*, while at the end of the section an average estimate will be given for our whole test pool.

Figure 3 An example snapshots of a natural scene of an object (apple fruit) we are trying to detect

For the texture validation step we will use the image from Fig. 3 and a new, similar image that will serve as a learning set. The training set image is depicted on Fig. 4 (left). As described, we first compute their spatial-frequency representation, where we use the training set to learn the SVM.

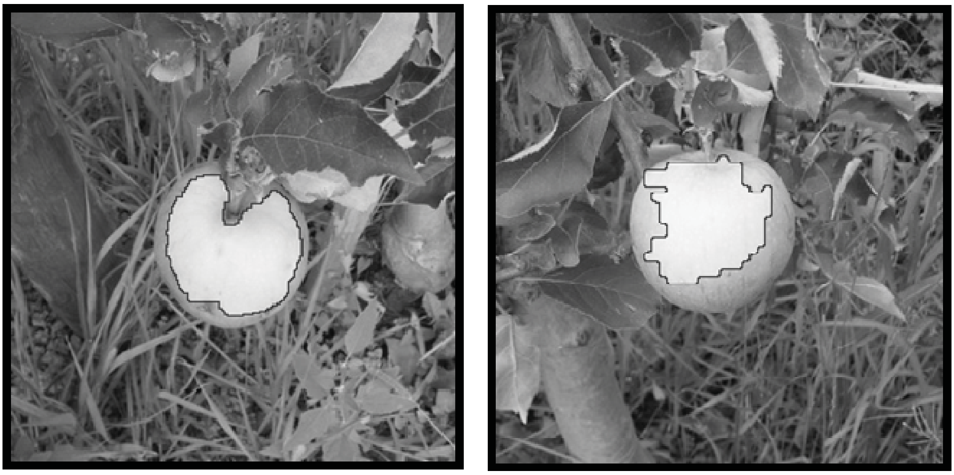

Figure 4 Two similar images; where the left serves as a learning set and the right shows the result of SVM classification.

Area marked with partly transparent white colour and circled with red serves as one, while the rest of an image serves as the other learning set. Based on the learning sets a classification of a new image can be done as shown by the right image of Fig. *4*. The classification in this case was successful, where we note that we do not expect to detect the whole area we are looking for but partial detection is enough to confirm a region produced by colour segmentation.

For the final subsection we have selected 4 random examples each from a different representative test group, tested them and summarised the results in Tab. 1. Image from the first group represents colourful objects, the second colourful object with partial occlusions caused by other objects on the scene, the third less colourful objects and the fourth less colourful objects with partial occlusions. The training set consisted of two different objects, one for the first two sets, while the other for the third and fourth step.

The results of texture analysis are summarized in Tab. 1, where average results for all our test cases are summarized. It should be noted that the results are influenced by the used (as it happened to the second example) training set. If the learning set is not representative enough the texture analysis may miss. However, only a small positive response of texture analysis is enough to prove or disprove a region. Based on the measurements we can conclude that texture analysis based on Wigner-Ville distribution and SVM works as an additional verification step.

Table 1 Average texture analysis measurements for 4 randomly selected examples

	Group 1 / example 1	Group 2 / example 2	Group 3 / example 3	Group 4 / example 4
Average fruit coverage	4 %	0 %	66 %	33 %

CONCLUSIONS

In this paper we presented an approach to detect natural object based on its textures. It consists of a pre-processing step, spatial-frequency representation as well as classification based on support vector machines. The approach could be used as a preliminary step to detect natural objects, such as apples, of the fruit prognosis system.

Texture analysis based on Wigner-Ville distribution and SVM offers a reliable tool for image segmentation or, as in our case, region confirmation. Once the neural network of the SVM is trained with well representative examples it offers a quick classification tool for spatial-frequency responses of the input signal. The only drawback is the space requirements of the 2D Wigner-Ville distribution that can quickly consume much of the memory available on the workstation. It is therefore advisable to limit the number of pixels in spatial domain for which we compute its spatial-frequency representations.

There are many things that could be improved or added to the object detection system. For one, the texture analysis could also be used to determine the quality of the harvest with a set of known defects and illnesses that would confirm damaged or ill fruits.

ACKNOWLEDGEMENTS

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

MACHINE VISION RECOGNITION ALGORITHM DEVELOPMENT AS THE FIRST STAGE OF APPLE ROBOTIC HARVESTING

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ABSTRACT

Machine vision application in mechanized tree fruits harvesting operations can be implemented by image processing algorithms. In this paper, a combination of color and shape processing was used to segment the red apples images in order to detect an apple fruit in each image and to determine its location. Thirty images had been taken, randomly. Images were filtered, converted to binary images, and noise reduced. The algorithm was finally assessed. The algorithm could detect apple fruits in the 83.33% of images and determined apple locations with precision of 85.17%.

***Key words**: machine vision, image processing algorithm, fruit detection, apple harvesting.*

INTRODUCTION

Iran is the 4th apple producer in the world (Food and Agriculture Organization, 2009) which indicates the need for mechanization and implementation of appropriate technologies.

Tree fruits harvesting is a susceptible operation. Its profitability may be influenced by labor inaptitude, costs and unavailability, low quality harvesting, and operation untimeliness. So, mechanized harvesting operation may solve the problems.

Mechanized fruit harvesting may be mechanically or automatically. Mechanical fruit harvesting methods have been studied for decades (Shepardson et al, 1970; Peterson et al, 1994; Erdogan et al, 2003) and robotic harvesting has also a long history (Schertz and Brown, 1968; Jimenez et al, 2000; Bulanon and Kataoka, 2010).

Apples mechanical harvesting by mass removal techniques makes damages due to excessive apple movement during detachment, apple-to-branch, and apple-to-apple contacts (Peterson, 2005). These damages are in the form of splits, punctures and bruises (Singh and Reddy, 2006).

Problems accompanying with mechanical harvesting resulted in development of robotic methods.

Prototype machine vision based harvesters are increasingly being developed. Apple (Parrish and Goksel, 1977; Bulanon and Kataoka, 2010) and other fresh fruits and vegetables (Levi et al, 1988; Satish Mehta, 2007) have been worked on for decades.

The automated harvesting system should perform the following operations: (1) recognize and locate the fruit; (2) reach for the fruit; (3) detach the fruit without causing damage both to the fruit and the tree; and (4) move easily in the orchard (Sarig, 1990).

The first operation needs development of appropriate methods to detect and locate the fruits. Using photometric information based (Schertz and Brown, 1968) and infrared laser range finding (Jimenez et al, 2000) methods were developed. While, image processing based methods have been used to detect and located the fruits (Bulanon and Kataoka, 2010; Satish Mehta, 2007; Slaughter and Harrell, 1989).

"Both intensity/color pixel-based and shape-based analysis methods were appropriate strategies for the recognition of fruits, but some problems arose from the variability of the sensed image itself when using CCD cameras, which are very sensitive to changes in sunlight intensity as well as shadows produced by the leaves" (Jemenez et al, 2000).

Since no research has been reported on robotic apple harvesting in Iran, this paper focuses on recognition of apples, as the first stage of apple robotic harvesting.

Recognition of apple fruits using machine vision under natural daylight conditions was the objective of this study. Thirty images of Red Delicious apple canopy were selected randomly from photos taken of apple trees. The images were taken from Hamedan groves, in Iran.

MATERIALS AND METHODS

Image acquisition

Thirty digital images were obtained under the uncontrolled daylight conditions. Image frames were 3072 × 2304 pixels in the JPEG format. A digital camera (*Sony, DSC-H5, Color CCD Camera*) was used to acquire the RGB images.

Image processing algorithm

The goal was finding and locating an apple in each image obtained in uncontrolled lighting conditions. In order to segment the acquired images, a color-shape based algorithm was developed to decline luminance variety.

The algorithm was developed by MATLAB (*R2007a*) and a laptop (*Dell, Vostro 1510*) was used to process the images.

The algorithm was implemented based on the following steps:

1. The images were first enhanced. A Gaussian low-pass filter was used to reduce the noise as much as possible. Noise portends unequal color intensity distribution in the original images that formed shades and shiny regions in the images.

   The Gaussian filter was a 250 × 250 pixel matrix with standard deviations of 200 which limit image frequencies to less than 200 Mega Hertz (MHz). Filtered images were noise-reduced by removing high frequencies (more than 200 MHz). Filtering the image caused blurring.
2. Filtered images were then converted to binary form in order to be processed.
3. Binary images were processed to reduce the existing noise after converting images. In this stage, noise was defined as the areas detected as features other than apples. This stage of the project is shape-based processing of color-based processed images.
4. Binary, noise-removed images were then labeled in order to extract apple fruit feature.

RESULTS AND DISCUSSION

Since the images were acquired under uncontrolled natural daylight conditions, they included tree branches, leaves, fruits, sky, etc. Each object of the image had its own properties, making image set of features which the apple fruit was just on of them.

First stage of the algorithm was color processing. Filtering the images made them blurred (Figure 1-b). Objects of the filtered images were less than of the original images. Consequently the blurred image, obtained from Gaussian filter, included less noise.

Converting the image to binary form and shape-based analysis made the noise as low as possible (Figure 1-c, 1-d). Labeling image features resulted in showing image objects as separate images (Figure 1-e).

Errors caused by uncontrolled lighting conditions in this algorithm made it generalizable under various lighting. Color-shape based algorithm could detect the apples in 25 of 30 images. In other words, the accuracy of the algorithm was 83.33%.

The precision of the algorithm was defined as its ability to locate the apple fruits. So, the overlap between a rectangular surrounded apple in the original image and a same sized rectangular, focused on detected apple feature center in the binary image, was calculated. Pixels included in the coverage area were assumed as overlap. Figure 2-b shows the overlap area.

The algorithm could locate the apple fruits with precision of 85.17%, whereby the maximum precision measure was 99.71% and the minimum was 54.43% (Table 1).

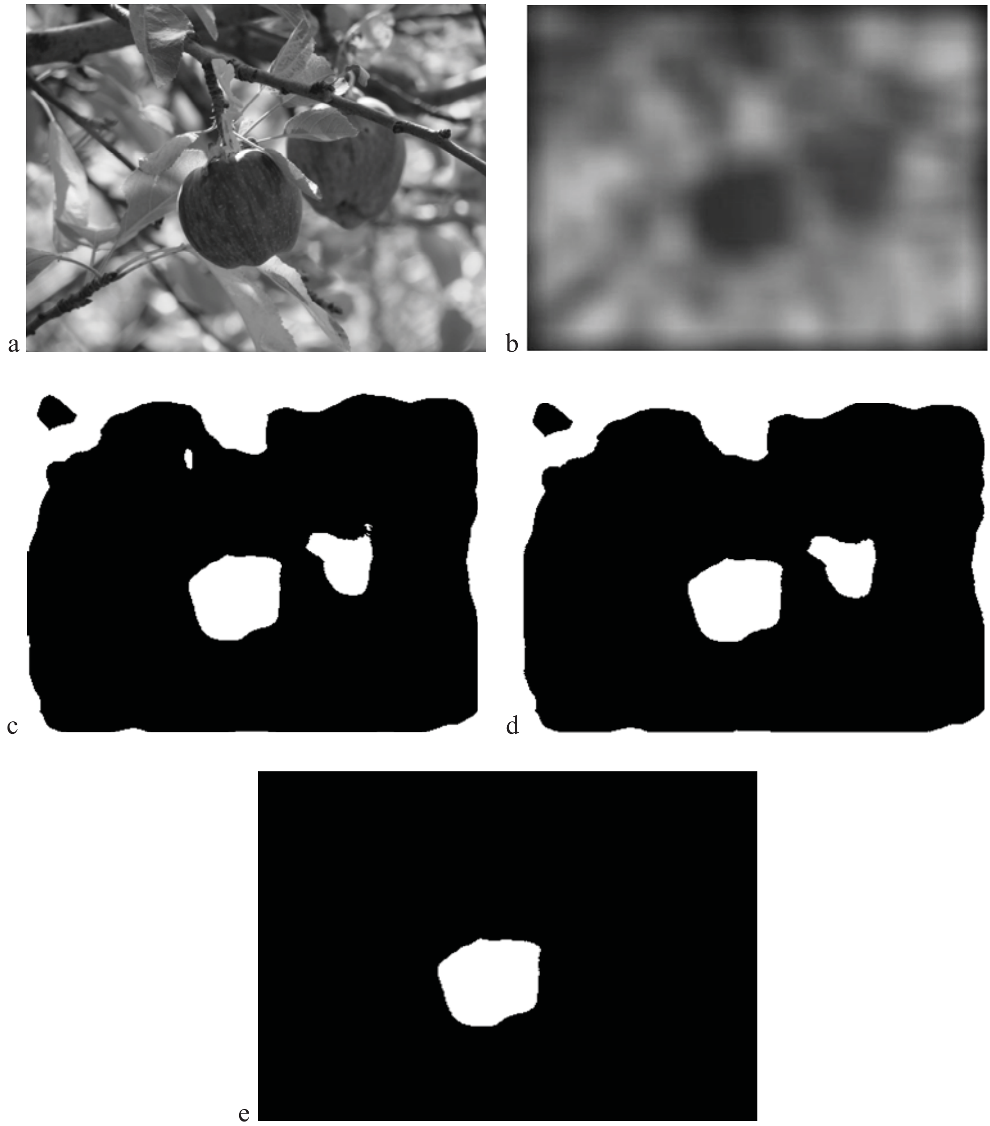

Figure 1 Color-shape based algorithm, a) Original image, b) Filtered image, c) Binary image, d) Noise-reduced binary image, e) Labeled image

Table 1 Algorithm precision descriptive statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Precision	25	0.4528	0.5443	0.9971	0.8517	0.1095	0.0120

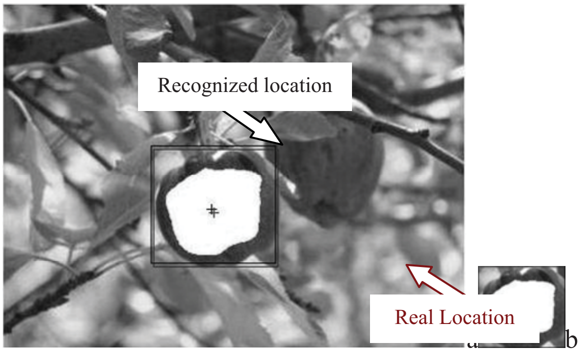

Figure 2 Overlap between recognized and real location of apple, a) Relative position of recognized and real locations, b) Overlap area

CONCLUSIONS

The main idea was to develop an algorithm be able to be generalized under various natural lighting conditions. A color-shape based algorithm was developed and assessed to detect one apple in each image. No control was applied to standardize the acquired images lighting. The algorithm was able to detect apple by accuracy of 83.33%. Its precision was 85.17% ranged from 54.43% to 99.71%.

Errors caused by uncontrolled conditions in this algorithm made it generalizeble under various lightings.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

CONSIDERATIONS ON OPTIMIZING THE PALLETIZING SYSTEMS OF AGRICULTURAL PRODUCTS USING ROBOTICS ELEMENTS

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SUMMARY

The paper analyzes the functional structure of the main palletizing systems of agricultural products that are prepackaged or are in primary packages (boxes, bottles, bags, pieces). The analysis of the system's component parts is made starting from the elementary functional blocks, working diagrams and temporary efficiency. The performances are evaluated in function of working capacity, number of rejected products and energy consumption.

The practical application was made for a system used for palletizing liquid products packed in plastic bottles or for milk packed in brick packages.

The results can be used for the immediate integration of products from the agricultural farms in commercial networks and of the reduction of financial and fiscal circuits, including the decrease of economical circuits for agricultural farms.

Key words: *packaging, palletizing agricultural products, risk, efficiency, productivity*

INTRODUCTION

The paper analyzes the functional structure of the main palletizing systems of agricultural products that are prepackaged or are in primary packages (boxes, bottles, bags, pieces). The analysis of the system's component parts is made starting from the elementary functional blocks, working diagrams and temporary efficiency. The performances are evaluated in function of working capacity, number of rejected products and energy consumption.

The goal of this work is the application of robotics elements in the manufacturing process. The manufacturing process consists of the conveyor belts, robots and wrapping system. The robotic solution was chosen to obtain real time analyses of the product position on the moving conveyor, the position is then sent to the robot controller, which relocates the product from the moving conveyor to the wrapping system. To decrease the time delay, there was a robotic element solution developed, based on the use of simple and cheap to manufacture grippers working together as a pattern system that offers short time response (Stas O. et al., 2009).

Robotics-logistics can be understood as the field of activities in which applications of industrial robot-technologies are offered and demanded in order to ensure the optimization of internal material flows. Activities can be classified in several scenarios as unloading / loading of agricultural products and palletizing / depalletizing of agricultural products (Echelmeyer W. et al., 2008).

The layout of the production line is arranged by the reachable workspace of the robots with the followed goal of achieving the minimum footprint. A pneumatic gripper is proposed under the constraints of joint velocity and acceleration to achieve higher productivity and easier implementation (Zhang LA. et al., 2008).

A case study for realizing low cost solution for distributed production line automation with control networking technology is presented. PLC and control network technology are used to automate this food packaging cell (Mahalik N.P. et al., 2008). The practical application was made for a system used for palletizing liquid products packed in plastic bottles or for milk packed in brick packages.

METHODS

Palletizing tasks are necessary to promote the efficient storage and shipping of boxed products. These tasks, however, involve some of the most monotonous and physically demanding tasks in the factory. To integrate these tasks and to define the position of the boxes, the robot and its peripherals, as well as the system layout and its coordinates, are defined (Yu S.N. et al., 2008).

The palletizing system is composed of 2 conveyors which bring the prepackaged products on 2 separate lines. From there 2 robots grip and transport the products on a euro pallet, which is brought by other conveyors between the 2 robots. After the established number of products is positioned on the pallet, the conveyor transports the loaded pallet to the wrapping system, and after the wrapping procedure it awaits to be further transported in the factory’s warehouse.

The main problem is to design and manufacture the grippers, which should be able to handle agricultural products with a mass of m=4kg prepackaged in plastic or cardboard. The shape of the prepackaged product is cylindrical or parallelepiped. The grippers should center the product after its axis, they should have presence sensors, compliance should also exist, but with no micro movement elements needed. A number of the fingers for each gripper should be enough to center the products after their axis. They should have a flange to mount on a KUKA robot, KR 15 SL, which is able to handle object with a total mass of 15kg. The robot’s flange has 8 holes, 7xM6 and 1xØ6mm, placed at 45° one from another, on a Ø50mm circle. The Ø6mm is positioned so that the gripper can be properly aligned with the robot’s arm.

To calculate the squeezing force the following data was considered:

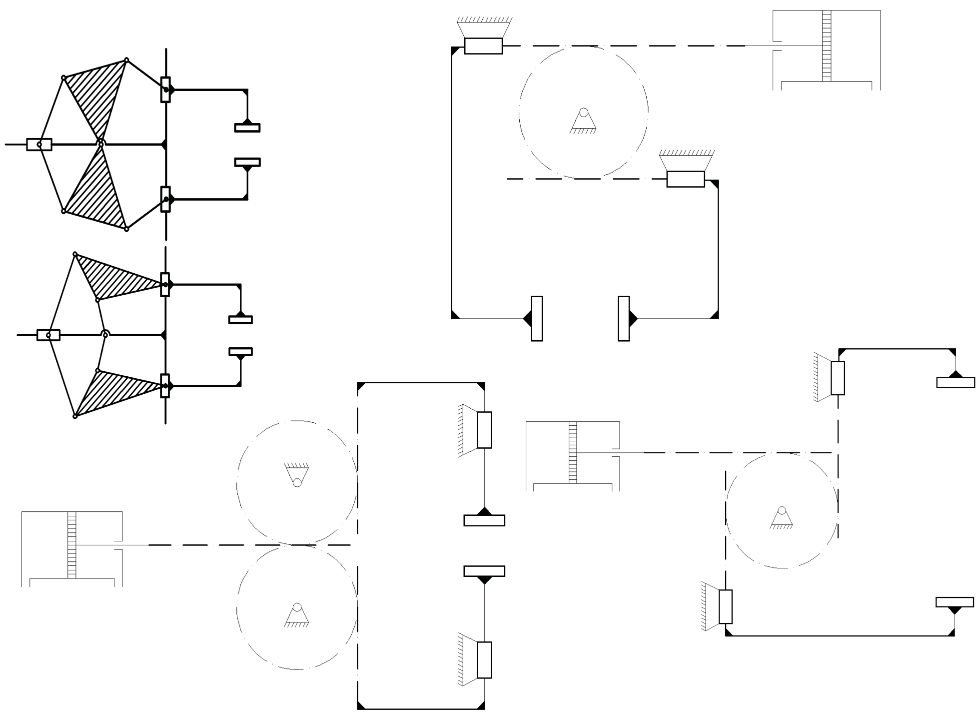
- safety coefficient c = 1,5
- number of fingers n = 2
- gravitational acceleration $g = 10\ m/s^2$
- product's acceleration $a = 15 \cdot g = 150\ m/s^2$ (Mesaros-Anghel V., 1991)
- friction coefficient for dry surfaces and small sliding speeds (for steel on plastic) μ = 0,4 (Hutte, 1995).

For the normal force on the gripper's surface the following calculus was obtained (Mesaros-Anghel V., 1991):

$$F_N = m \cdot (g+a) / n \cdot \mu \quad => \quad F_N = 800\ N \qquad (2.1)$$

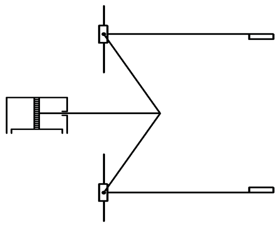
For the gripper's squeezing force the following data was obtained (Mesaros-Anghel V., 1991):

$$F_S = c \cdot F_N \quad => \quad F_S = 1.2 \cdot 10^3\ N \qquad (2.2)$$



Picture 1 Proposed kinematic schemes for the gripper (Mesaros-Anghel V., 1991)

Several kinematic schemes were proposed (picture 1), the simplest, the safest and the cheapest to build was chosen (picture 2).

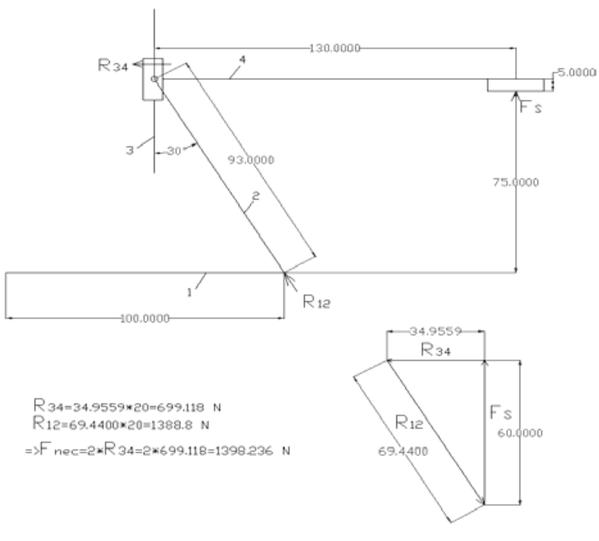


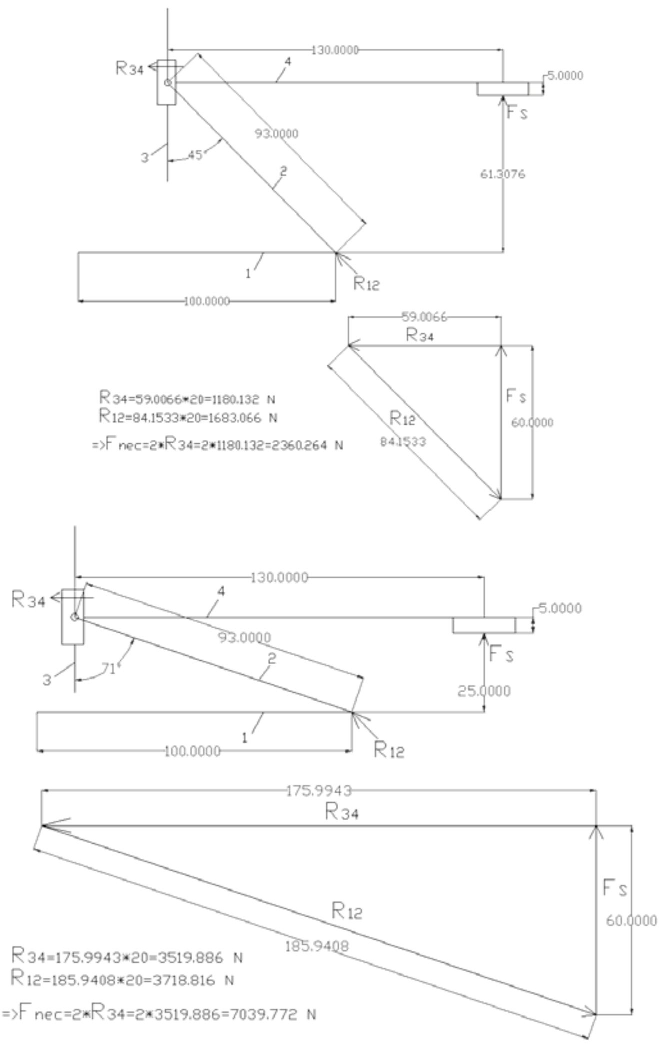
Picture 2 Chosen kinematic scheme for the gripper

The motor pushes and pulls a bar to which two other bars are connected. These two bars are also connected on the other ends to two sliding parts, on which the fingers are mounted. When the motor pulls, the fingers release the product, and when it pushes, the fingers grip the product. On the tip of the fingers presence sensors are mounted so when the product is gripped, the motor's power is interrupted without damaging the package or the product itself. By using the sensors no rubber or other soft contact surface with the handled product is needed. It represents a very simple solution, easy to manufacture and to program.

The material from which every main part of the system should be made is OL50, because it is cheap and the products that the device has to handle are prepackaged or are in primary packages, so there is no risk of food contamination.

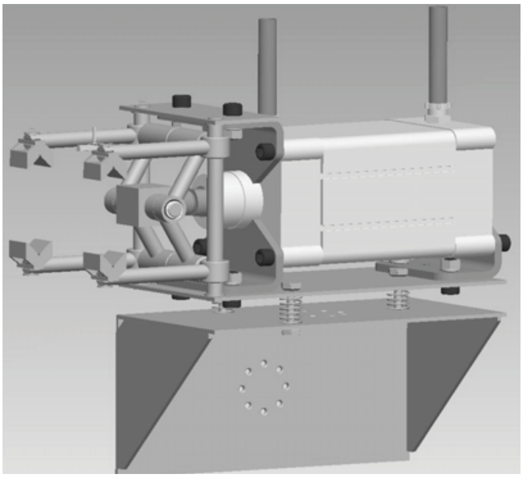
Working in the agro-food industry, a hydraulic motor is forbidden due to the safety of products. Consequently, a pneumatic motor from FESTO for example, Standard Cylinder DNC to ISO15552, with specific code DNC-125-80-PPV-A – 163500, was chosen, after the following calculations were made:





The calculations represent the necessary force for the motor so the device can grip the widest package (150mm), the thinnest (50mm) but also a package of intermediate dimension.

The algorithm used presumes determining the forces' distribution in the mechanism's schema. Known data are represented by the squeezing force, the mechanism's schema and the main dimensions (elements' length and angle between them). The forces' reactions are calculated using a scaled (1:20) 2D representation: knowing F_S's scaled value, the angle between F_S and R_{12} (force's reaction between the 1st and the 2nd element), that R_{34} (force's reaction between the 3rd and the 4th element) is horizontal, and that the two forces' reactions are intersecting, their value can be determined by measuring the length of each resulted segment. After measuring them, the multiplication with the scaling factor (20) is needed in order to obtain the values of the forces. The gripper having two fingers, the necessary force is double the force's reaction between the 3rd and the 4th element.



Picture 3 The working version of the gripper

In picture 3 a working version of the gripper is presented. The flange has two mounting positions, so the device can be adapted to different tasks. The gripper is attached to the flange using screws and springs, so the compliance function is accomplished. The connections to the compressed air system are mounted on top of the device, thus avoiding the occurrence of accidents during operations.

CONCLUSIONS

The final effectors can be easily changed to adapt the device to different agro-food products, thus making this palletizing system more efficient and increasing the chances to implement it in different packaging lines and also elevating the productivity.

The results can be used for the immediate integration of products from the agricultural farms in commercial networks and of the reduction of financial and fiscal circuits, including the decrease of economical circuits for agricultural farms.

ACKNOWLEDGEMENT

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39.
SIMPOZIJ
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Originalni znanstveni rad
Original scientific paper

MECHANISATION COSTS OF SWEET SORGHUM PRODUCTION, CONSIDERING THE WHOLE PLANT PRODUCTION TECHNOLOGY OF THE GIVEN FARM

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SUMMARY

Our work is a comprehensive examination that analyses the machine fleet formation and machine use of plant production farms that grow sweet sorghum too by using computer aided modelling. It considers the characteristics of machines used at the production technologies of different plants and it especially focuses on the appliance of machines with the convenient capacity and level from the side of costs at different farm sizes.

The total production cost of sweet sorghum per hectare in case of small-scale farm size is minimum 715 EUR. Examining the large-scale production the costs reduce, but they can not be reduced under the 610 EUR/hectare level.

Keywords*: mechanisation of different branches of plant production, mechanisation of different sized farms, machine fleet planning, machine utilisation, low cost machine fleet*

INTRODUCTION

The goal of the research is the technical-economical analysis of the production-technology system of the sweet sorghum that is known as energy plant and nowadays as a promising base material of biotechnological industries.

Work done *by an efficiently developed machine system* is a significant condition of the fruitfulness of farming. The machine prices and the cost of their utilization are extremely high and all these result in extraordinarily high production costs. *Rational machine utilization* is a definitive factor of the efficiency of venture-farming [4].

We have accomplished the examinations by taking power-machines from different quality and cost levels as base. Through this we will show that not only the size of the farms effects the amount of the operational costs, but the standard of mechanization too.

METHOD

The sweet sorghum (Sorghum vulgare saccharatum) - Introduction

The sweet sorghum is one of Hungary's plants that is capable to produce the greatest amount of biomass and it's production can be fitted in the conventional alternation of the cereals and industrial plants and the outstanding yields can be ensured at lower costs than other cultures. From the point of view of energetic use, the component of the sweet sorghum that is classed as secondary product, the high sugar content solution that can be pressed from the spears, that is a suitable base material for bioconversion methods. The amount of the productable sugar reaches or exceeds the amount of the glucose that can be produced from cereals grown on a land with the same size. The complex use of the components that can be obtained from the sweet sorghum can significantly increase the reachable profitableness of agriculture.

The plant is subtropical, needs hot weather and takes drought significantly. It is also called durra or sweet-cane. It was grown in a higher amount between the two world wars. After the II. World War, until the start of the sugar production, the sugar containing syrup pressed and condensed from the plant was used instead of sugar. Nowadays it is mainly used to produce silage fodder, planted with silage corn The growing conditions are very advantageous, because the sweet sorghum gives a stable yield even in case of poor water supply (60-70 tonns/hectare) (**Kocsis** 2009). [5]

The surveyed crops

The surveys can be conducted by *modelling* the machine working processes of agricultural production. On the base of field crop production a crop plan including cereal plants for human consumption, *sweet sorghum* for animal breeding and for *energy* production purposes and oil seeds – as sunflower and the nowadays very popular crucifer - appropriate for human consumption and energy production as well and reflecting the special features of production in Hungary has been applied. Depending on venture size the proportion of the crop area of the individual plants has been stipulated in view of the agronomical and production technological conditions.

The significance of machine utilization, the machine families applied, the parameters of model calculations

In the utilization costs of the more and more up-to-date and expensive power machines the proportion of *fixed costs*, especially depreciation and maintenance is very high. This expense can be decreased by increasing *utilization*. If the applied means are coupled to the individual field work operations at their effective operation cost – i.e. taking the rate of utilization into account – the effect of ***working-hour performance*** on costs will become measurable [7].

Basically the cheapest power machine families used in Hungary on the one hand, and the ones with the highest possible investment cost demand available on the market of agricultural machinery on the other have been the subject of the survey [6].

The basic figures of machine utilization have been determined with the help of the data base of the Hungarian Institute of Agricultural Engineering of Ministry of Rural Development [3].

The *model-calculations* have affected the farm size points of machine stock development in a farm size of 30 and 1000 ha. On this basis we can come to statements affecting a wider segment of the agricultural property structure, resp. to conclusions concerning mechanization and machine utilization.

RESULTS

The constitution of the machine system in case of the examined operating sizes

The power-machine system that can be ordered to serve the examined operating size of 30 hectares to finish the soil preparation in a good quality consists of the minimal 40 kW output piece and the attachable soil tilling, nutritive spreading and insecticide process machines. In case of the 1000 hectare farm size that is the base of the large-scale examination, the minimum is the tractors with 60-120 kW of output that can be the base of the machine works. The different output-categories are represented by two power-machines in each case. The easier nutritive supply and insecticide tasks are done by the machines with smaller output and the heavier tasks are done by the machines with higher output. The *materials handling to the depot* can also be done by these tractors by using tow-cars to increase the exploitive of the machines.

In case of farm size of 30 hectares, the finishing of the harvesting works as wage work is the most efficient. According to the calculations, on a 1000 hectare sized farm, to reach the acceptable capacity-utilization, one *cereal combine-harvester machine* can be operated as the property of the farm. The appliance of the self-propelled silo harvester that does the gathering of the sorghum as a property, highly increases the machine costs of the farm, therefore it can be seen in the chapter *results* in details that it is more advantage out to use a self-propelled silo harvester for commission work.

The number of the executed working-hours in function of the power-machine category, the mechanical level and the farm size

The number of the executable working-hours of the power-machines in case of different farm sizes determines the composition to each category of the power-machine system;

In case of the examined *smaller sized farm* (**30 hectares**) based on our calculations *low exploitive* can be reached to the tractors: maximum 435 working-hours/year.

In case of large estate sizes (**1000 hectares**) the executed machine working-hours of the farms power-machine fleet, based on our model calculations is 6650 working-hours, from which the tractors represent a major (1100 working-hours/year (power-machine with 60 kW output) and 1700 working-hours/year (power-machine with 120 kW output)) part.

With a clever-chosen cereal harvesting machine at ***one thousand hectare*** farm size executing about 450-500 working-hours it reaches *significant* exploitage, that results in *acceptable* operational cost. The annual capacity exploitage of the self-propelled silo combine in case of own property is only 150 working-hours, that makes the idea of purchasing the machine as property to think it over.

The number of the working-hours at *unity area* will *decrease* by the increasing of the estate size. *In case of 30 hectare* farm *size*s ***14,4 working-hours/hectare/year*** materializes. In case of the 1000 hectare farm size about ***6,6 working-hours/hectare/year*** can be measured annually.

These values characterize the power-machine usage with low investment costs and slightly change in case of using power-machine ranges with high investment costs. The modern power-machine implement connections finish their work in a shorter time, that can also be seen in the mentioned specifical indicator too. Annually, depending on the estate size, the use of machines with higher price and technical level mean 0,2-0,6 working-hours per hectare preference. However, assuming only inner, private working, this preference is disadvantageous, because the annual working-hour execution of the different machines decrease, that increases their specifical usage costs.

In case of a **30 hectare sized farm** the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 120 working-hours, that is 14,8 working-hours/hectare. This value is slightly higher than the economic average. In case of a **1000 hectare sized farm** the machine work demand of sweet sorghum that's production is fitted in the rotation of crops is 1675 working-hours, that is 6,7 working-hours/hectare. This marks well that the production of sweet sorghum is a labour-intensive activity, because this value is also higher than the value that is specific to the whole farm. By using ***modern machines*** the shown working-hour execution parameters will decrease with 4-5 %.

With the increasing of the farm size, the specific number of the needed machine working-hours for a unity of area decreases and the values almost half in case of using high output machines at large-scale production.

In case of small-scale production the significant number of shift-hours increases the living work outlay, thereby ***increases the employment***. (**Takács et al.** 2008) In the farms with this size the use of small output machines is reasonable. However the proper usage of the small capacity machines is not ensured either, so the significant constant costs induce *higher operational costs*. [8]

The analysis of the machine usage and machine investment costs

Applying ***low-level*** power-machine fleet, the annual machine use cost of a **30 hectare** farm that produces sweet sorghum too is 11.785 EUR, that is 393 EUR per hectare. The specific machine cost of the produced crops is the following: wheat 365 EUR/hectare, sunflower 375 EUR/hectare, rape 395 EUR/hectare, sweet sorghum 440 EUR/hectare. In the sowing plan the ratio of the plants is the following: wheat 40%, sunflower 25%, sweet sorghum 25%, rape 10%.

The whole machine investment cost in case of a **30 hectare** plant production farm is 37.145 EUR, that is 1235 EUR per hectare. The whole investment cost of the machines applied in the production of the sweet sorghum is 23.570 EUR, that is 2975 EUR per hectare.

Applying ***modern power-machines*** the annual machine use cost is 14.645 EUR, that is 491 EUR per hectare. In case of the produced plants the machine costs are the following: wheat 460 EUR/hectare, sunflower 475 EUR/hectare, rape 500 EUR/hectare, sweet sorghum 540 EUR/hectare.

In this case the whole cost of machine investment is 63.930 EUR, that is 2130 EUR per hectare. The whole investment cost of the machines applied in the production of the sweet sorghum is 47.860 EUR, that is 5965 EUR per hectare.

Those who work on **small sized** farm can count with low power-machine utilization, that also has effects on the use costs per working-hour of the tractors. This value is 19 EUR/working-hours in case of the 40 kW tractors that are usually used in small works. At this production size, the calculated cost of the borrowed used cereal harvester and self-propelled silo combine is 52,5 EUR/working-hours and 72,7 EUR/working-hours. In case of ***modern machines*** the specific cost of the mentioned tractor to a time unit is 24 EUR. The cost of the cereal combine is 73,6 EUR/working-hours. In case of an ensilage cutter, we can also count with the given values, because in the database that we used for the calculations we haven't found two different technical levels from the harvesting machines with these functions.

Considering a **1000 hectare sized farm** in case of ***low level*** mechanization, taking the above mentioned sowing plan ratios the annual use cost of the machines is 303,5 thousand EUR, that is 303,5 EUR/hectare. The machine cultivation cost per hectare to each of the plants: wheat: 240 EUR, sunflower 270 EUR, rape 245 EUR, sweet sorghum 465 EUR.

Basically the machine investment costs are 814,3 thousand EUR, that is 814,3 EUR calculated for area unit. For the mechanization of the sweet sorghum production itself, 623,2 thousand EUR is needed, that means specifically 2500 EUR/hectare.

If the use of the self-propelled ensilage cutter machine is not as an own property, than it is ***leased work***, the machine use cost of the whole farm is 267,8 thousand EUR. The specific value for a hectare is 267,8 EUR. And the specific machine cost of the sweet sorghum production is the advantageous level of ***320 EUR/hectare***.

The machine investment costs also decrease to 596,4 thousand EUR (596,4 EUR/hectare). In this case the price of the machines that are in close connection with the production of sweet sorghum is 428,6 thousand EUR (1718 EUR/hectare).

With the appliance of ***high level*** power-machines the annual machine use cost projected to the whole farm is 339 thousand EUR, specifically 339 EUR/hectare. In case of wheat it is 275 EUR/hectare, sunflower 305 EUR/hectare, rape 275 EUR/hectare and sweet sorghum 505 EUR.

It can be observed that the machine cost of sweet sorghum is the highest in every case, compared to the other plant cultures. This is mostly because great volume of the harvesting and crop transporting tasks: at least 60-80 t/hectare of crop has to be harvested and transported to the processing plant.

The machine investment costs are the following: The costs to the whole farm is 1050 thousand EUR, that is 1050 EUR/hectare. The purchasing of the machines that are needed for the sweet sorghum production cost 810 thousand EUR. The projection of this to one hectare is 3245 EUR.

If the ensilage cutter machine does it's tasks as ***leased work***, the costs decrease. As a result of the calculations, the total machine use cost of the whole farm is 303,5 thousand EUR. Specifically it is 303,5 EUR/hectare. The machine work cost of the sweet sorghum production is ***365 EUR/hectare***.

The machine investment costs decrease to 832 thousand EUR (832 EUR/hectare) in this case too. With this, the purchasing price of the machines that are part of the sweet sorghum production is 615 thousand EUR (2465 EUR/hectare).

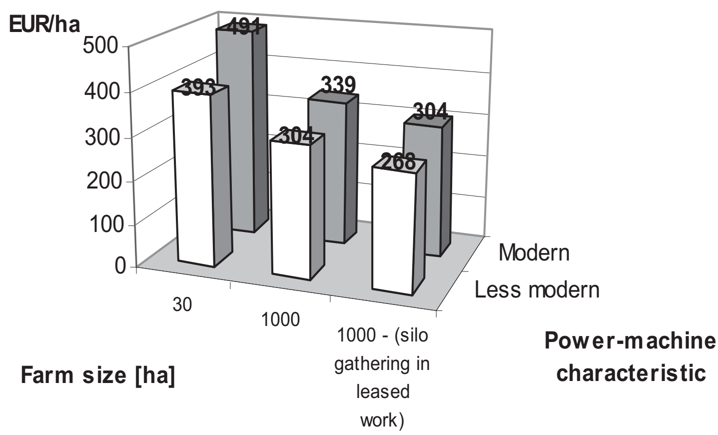

Figure 1 The specific machine use costs in case of different mechanization levels at farms with the investigated sizes

The **Figure 1** also shows the previously introduced things, where the upper and lower limit of the machine use costs are shown in function of the farm size, that are determined considering the use of low level power-machines and implements and the expensive power-machines that represent the modern machine technologies.

In large-scale production the exploitage of the power-machines is more advantageous. The tractor with 60 kW output works 1100 working-hours and the medium sized universal power-machine with 120 kW output works 1750 working-hours annually. The use cost of them to one working-hour is 15,7 EUR, and 27,3 EUR. According to our calculations the use cost of the cereal harvester and self-propelled silo combine as own property is 83 EUR/working-hour, and 243,2 EUR/working-hour. If we borrow the ensilage cutter for work, the cost reduces significantly to 97,4 EUR/working-hour. In case of ***modern power-machines*** the specific cost of the mentioned tractors to a time unit are 19,7 EUR and 31,4 EUR. The cost of the cereal combine is 93,4 EUR/working-hours. In case of an ensilage cutter as we have mentioned, we can calculate with the above given values.

Tab 1 The direct machine operation costs of the work processes of the sweet sorghum production

	In case of using low cost power-machine		**In case of applying modern power-machines**	
Farm size	**30 ha**	**1000 ha**	**30 ha**	**1000 ha**
Dimensional unit	EUR/ha	EUR /ha	EUR /ha	EUR /ha
Stubble ploughing	23	15,4	28,6	17,6
Fertilizer distribution	11,8	8	14,8	8,3
Muck-spreading		34,9		39,8
Stubble care	23	15,4	28,6	17,6
Deep ploughing	69,4	33,8	78,9	37,5
Plough levelling	23	15,4	28,6	17,6
Herbicide spraying	10,9	7	13,4	7,8
Chemical pouring	15,5	10,6	19,2	12,1
Preparation of seedbed	15,5	10,6	19,2	12,1
Sowing	22,3	18	25,9	19,8
Chemical plant protection	10,9	7,0	13,4	7,8
Within-the-row cultivation	19,6	7,7	23,8	9
Harvesting	*(65,2)*	171 *(64,1)*	*(65,2)*	171 *(64,1)*
Crop transportation to depot	*(57,1)*	32,9	*(65,3)*	38,5

The operational costs of the work processes of the sweet sorghum production calculated after the computer modelling can be seen on Table 1.

The marked costs in the chart show the direct costs of the machine operation, plus the accessory costs (farm level costs) that increase the discussed values with almost 20%.

The difference between the costs of the small and the large-scale farm size is well-marked. This all can be explained with the efficiency of the machine exploitage. In the field of costs there is also a difference between the use of modern and less modern machines. In case of small-scale farm size, with using less modern power-machines a more advantageous cost level can be reached, although the quality of the work and the circumstances of the working must be considered. In case of large-scale farm size the difference between the operational costs of the less modern and modern machines decrease significantly, because the operation of the less modern machines is more expensive at larger strain and the high level constant costs of the modern machines significantly decrease, according to their better exploitage, considering one unit of work.

The values in brackets show the first-cost of the leased work.

The introduced operational costs can slightly modificated with the spatial distribution, because for example in a more undeveloped region the lower wages have a decreasing effects on the operational costs, compared to the regions where the wages are higher and the job market is more efficient. Furthermore the feature of the ground, the soil and other factors can slightly have influence on the costs.

It can be established that apart from the level of mechanization, the person who works even on a 30 hectare sized farm using own property machines must face higher specific investment cost than the lower cost level that can be experienced at a 1000 hectare sized farm. If some production technological compulsion forces to do so, the owner should try to increase the exploitage of the machines by offering leased work to others in order to keep the costs at an acceptable level. With this the specific machine use costs can be reduced.

CONCLUSIONS

Besides the introduced machine costs we must count with the prices of the input materials of the sweet sorghum production to know the whole cost of the production of the plant. For the nutrient supply we can count with about 150 EUR per hectare. The cost of the seeds is around 40-55 EUR/hectare, the cost of the pesticide reaches 60 EUR to each area unit. Adding all these, we face a minimal input material cost is 250 EUR/hectare. Beside this we must not forget about the cost of the insurance and other supplemental expenses that is connected to the production.

Adding everything, the total production cost of the studied plant per hectare in case of small-scale farm size is minimum 715 EUR. Examining the large-scale industrial production the costs reduce, but they can not be reduced under the 610 EUR/hectare level.

The aim of our research work and the exposition of its results is the professional support of the machine investment decisions and the machine utilization practice of the different size ventures promoting hereby the creation of the conditions of fruitful farming and rational machine investment decisions.

ACKNOWLEDGEMENT

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

UČINKOVITOST STROJEVA ZA SPREMANJE SJENAŽE U VALJKASTE BALE

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SAŽETAK

Ispitivanje učinkovitosti strojeva za spremanje sjenaže u valjkaste bale ovijene plastičnom folijom provedeno je na pokusnom dobru Agronomskog fakulteta Sveučilišta u Zagrebu u mjesecu lipnju 2008. godine. Na parceli površine 7,5 ha je bila lucerna koja je pokošena prvog dana pokusa, dok je sakupljanje pokošene mase i baliranje, te ovijanje bala plastičnom folijom obavljeno drugi dan. Rotacijskom kosilicom zahvata 2,4 m je ostvaren učinak od 2,0 ha/h, skupljačem otkosa s horizontalnim rotorom 2,5 ha/h, dok je prešom skupljačicom s tlačnom komorom stalnog volumena ostvaren učinak od 2,3 ha/h odnosno 18,3 bala na sat. Ovijačem bala s okretnim postoljem je ostvaren učinak od 37,5 bala na sat.

Ključne riječi: *sjenaža, lucerna, valjkaste bale, ovijanje, učinak*

UVOD

Spremanje sjenaže u bale ovijene plastičnom folijom je već niz godina vrlo popularna tehnika konzerviranja zelene krme u mnogim zemljama (Wilkinson i Toivonen, 2003). Počeci takvog načina spremanja zelene krme datiraju od početka sedamdesetih godina prošlog stoljeća, da bi se osamdesetih godina usavršili strojevi i počela šira primjena u razvijenim europskim zemljama. Do prije nekih petnaestak godina u Hrvatskoj nije bilo ovakvog načina spremanja zelene krme, a poljoprivrednici su koristili najstariji način spremanja krmnog bilja, a to je u obliku sijena. Kod takvog načina spremanja je problem da zbog loših klimatskih uvjeta (obilne kiše i niske temperature) za vrijeme proljeća većina poljoprivrednika s košnjom čeka do početka lipnja, neki čak i do početka srpnja, a do tada su livade već pune korova. Sijeno dobiveno s takvih livada većinom je loše kvalitete, pa se može reći da su livade vrlo slabo iskorištene (Katalinić i sur., 2000). Kod spremanja sjenaže trava se može početi kositi u vlatanju, a djetelina u početku pupanja, tako da se prva košnja može obaviti već koncem travnja ili početkom svibnja, te se na tim livadama može dobiti najmanje četiri, pa čak i pet otkosa tijekom godine (Zimmer i sur., 2009). Osim toga, sadržaj vode u krmnom bilju kod spremanja sijena treba svesti ispod 20%, dok se kod spremanja sjenaže krma samo provene da sadržaj vode bude oko 60%, tako da provenjavanje pokošene mase u polju traje 3 do 4 puta manje vremena u odnosu na vrijeme potrebno za sušenje sijena što znači da je i znatno manji rizik od loših vremenskih prilika (Zimmer i sur., 1997). Upravo iz gore navedenih razloga spremanje sjenaže predstavlja znatno fleksibilniji sustav u odnosu na spremanje sijena s obzirom na vrijeme košnje i manju ovisnost o vremenskim prilikama (Savoie i Jofriet, 2003). U odnosu na klasični način spremanja silaže u silose velika prednost spremanja silaže u bale ovijene plastičnom folijom je eliminacija visokih troškova podizanja silosa (Shinners i sur., 2009). Svaka bala koja je ovijena plastičnom folijom predstavlja zaseban silos gdje se odvijaju procesi siliranja. Sjenaža konzervirana u plastične bale može se koristiti pojedinačno prema kvaliteti i hranidbenoj vrijednosti spremljene stočne hrane, za razliku od spremanja sjenaže u silose i trapove u koje se često miješa i sprema zajedno stočna hrana različite hranidbene vrijednosti. Očuvanje visoke hranjive vrijednosti i kvalitete sjenaže glavna je svrha konzerviranja i uskladištenja zelene mase koja može služiti za ishranu stoke tijekom cijele godine, a posebno onog dijela godine kada krave ne mogu na ispašu.

Da bi se postupak spremanja sjenaže obavio na zadovoljavajući način, potrebno je raspolagati strojevima koji imaju visoki učinak kako bi se radovi obavili u što kraćem agrotehničkom roku (Štorman i sur., 1994). Iz tog je razloga provedeno ispitivanje učinkovitosti strojeva potrebnih za spremanje sjenaže u valjkaste bale ovijene plastičnom folijom.

MATERIJAL I METODE

Istraživanje učinkovitosti strojeva u postupku spremanja sjenaže provedeno je dana 22 i 23. lipnja 2008. godine na pokusnom dobru Agronomskog fakulteta Sveučilišta u Zagrebu na lokaciji Svetošimunska cesta (45°53'N, 16°02'E, n.v. 152 m). Na parceli površine cca 7,5 hektara (340 x 222) je bila lucerna koja je pokošena prvog dana, dok je sakupljanje pokošene mase i baliranje, te ovijanje bala u plastičnu foliju obavljeno drugi dan. Vrijeme je oba dana bilo sunčano, vruće i sparno, s prosječnom temperaturom zraka 32°C, a relativna vlaga zraka mjerena u 07 sati ujutro bila je 65%, a ona mjerena u 14 sati bila je 39%. Zbog takvih vremenskih uvjeta nije bilo potrebno dodatno prevrtanje zelene mase radi bržeg provenjavanja. Da se kojim slučajem išlo u postupak prevrtanja zelene mase, postigao bi se negativan učinak, jer bi sa stabljika lucerne ispadalo lišće u kojem je najveća koncentracija hranjivih tvari. Pokusna parcela je podijeljena na dva dijela, tako da se prilikom skupljanja pokošene i provenute mase u zbojeve radilo dvije vrste zbojeva, veći i manji, kako bi se utvrdilo koji je učinkovitiji način.

U pokusu su korišteni slijedeći strojevi:

- rotacijska tanjurasta kosilica radnog zahvata 2,4 m u agregatu s traktorom snage 84,5 kW
- skupljač otkosa s horizontalnim rotorom radnog zahvata 3,4 m u agregatu s traktorom snage 28,7 kW

- preša skupljačica s tlačnom komorom stalnog volumena radnog zahvata sakupljačkog uređaja 1,8 m u agregatu s traktorom snage 84,5 kW
- ovijač bala s okretnim postoljem u agregatu s traktorom snage 55,1 kW

Elektroničkom štopericom Casio mjereno je vrijeme obavljanja pojedinih operacija, uključivo i vrijeme okretanja na uvratinama i to svaka operacija u pet (5) ponavljanja. Za određivanje sadržaja vode u lucerni uzeti su uzorci koji su vagani prije i nakon sušenja na preciznoj vagi Precia Molen maksimalne nosivosti 8 kg i točnosti ± 0,2 g. Ista vaga korištena je i za određivanje mase zbojeva po jednom metru. Masa bala je proračunata na osnovi izmjerene duljine zboja potrebne za formiranje jedne bale i izvaganih uzoraka s jednog metra zboja u pet ponavljanja. Nakon vaganja uzorci su vraćeni u zbojeve.

REZULTATI I RASPRAVA

Košnja je obavljena rotacijskom kosilicom radnog zahvata 2,4 m prosječnom brzinom kretanja od 9,5 km/h uz prosječno vrijeme okretanja na uvratini od 11,4 sekunde. Shodno tim izmjerama, ukupno vrijeme potrošeno na košnju parcele površine 7,5 hektara iznosilo je 3,76 sati. Kvaliteta košnje je bila zadovoljavajuća, jer je visina reza bila prilično ujednačena i kretala se u granicama 6-8 cm. Otkosi su bili pravilni, širine u prosjeku 128 cm, pri čemu je razmak od sredine do sredine otkosa iznosio u prosjeku 217 cm.

Drugog dana istraživanja je nakon pregleda pokošene mase zaključeno da nije potrebno dodatno prevrtanje radi prosušivanja, te se odmah prišlo skupljanju mase u zbojeve rotacijskim sakupljačem radnog zahvata 3,4 m. Prosječna brzina kretanja iznosila je 8,6 km/h uz prosječno vrijeme okretanja na uvratini od 14,6 sekunde, tako da je ukupno vrijeme potrošeno na sakupljanja pokošene biljne mase iznosilo 2,98 sati. Zbojevi su skupljani od 3 ili 4 otkosa, pa je samim time bilo dvije vrste zbojeva, veći i manji. Ukupno je napravljeno 42 zboja, od čega 24 manja i 18 većih, pri čemu je ukupna duljina manjih zbojeva iznosila 5328 m, a većih 3996 m. Izvršeno je mjerenje osnovnih značajki - karakteristika i jedne i druge vrste zboja, a prikazani su u tablici 1.

Tablica 1 Prosječne karakteristike manjih i većih zbojeva
Table 1 Average characteristics of smaller and larger swaths

Vrsta zboja Swath type	Širina zboja Swath width (cm)	Visina zboja Swath height (cm)	Razmak zbojeva Swaths distance (m)	Sadržaj vode Water content (%)	Masa po 1 m Mass per 1 m (kg/m)
Manji zboj Smaller swath	83	40	7,2	39,0	2,2
Veći zboj Larger swath	96	46	9,5	41,0	3,0

Nakon formiranja zbojeva, pregleda parcele i uzetih uzoraka može se zaključiti da je bolja kvaliteta rada postignuta kod većih zbojeva, jer su ti zbojevi bili ujednačenije širine i visine, sadržavali su veći postotak vlage što je povoljnije za sjenažu, a ostvareni su i manji gubici, pa je na tom dijelu parcele prikupljena nešto veća količina biljne mase po jedinici površine. Iako većina autora za spremanje sjenaže u bale preporučuju sadržaj vode u rasponu između 50% i 60% (Lingvall, 1995; Garthe i Hall, 1996), neki autori navode da se sjenaža može uspješno spremati u bale ovijene plastičnom folijom i sa sadržajem vode između 30% i 45% (Huhnke i sur., 1997) kao što je bilo prilikom ovih istraživanja.

Nakon sakupljanja pokošene biljne mase u zbojeve pristupilo se baliranju. Ukupno je napravljen 60 bala, po 30 na dijelovima parcele s manjim i većim zbojevima. Izmjereni parametri bala formiranih od manjih i većih zbojeva prikazani su u tablici 2.

Tablica 2 Prosječne karakteristike bala od manjih i većih zbojeva
Table 2 Average characteristics of bales from smaller and larger swaths

Vrsta zboja Swath type	Duljina za 1 balu Lenght for 1 bale (m)	Masa bale Bale mass (kg)	Specifična gustoća Specific density (kg/m^3)
Manji zboj Smaller swath	177,3	390	274,6
Veći zboj Larger swath	135,1	405	285,2

Na dijelu parcele s manjim zbojevima traktor u agregatu s prešom se kretao prosječnom brzinom od 3,75 km/h i za formiranje jedne bale bilo je potrebno u prosjeku 2 minute i 50 sekundi. Bale su omatane mrežom, a prosječno vrijeme omatanja je iznosilo 12 sekundi, pa je ukupno vrijeme potrebno za dobivanje gotove bale iz manjih zbojeva u prosjeku iznosilo 3 minute i 2 sekunde. Za omatanje bala je korištena mreža širine 1,23 m. Za okretanje traktora s prešom na uvratini bilo je potrebno u prosjeku 30,2 sekundi, odnosno za 24 zboja je potrebno 23 okretanja pa to ukupno iznosi 11 minuta i 35 sekundi. Na osnovi tih podataka proizlazi da je ukupno vrijeme potrebno za dobivanje 30 bala iz manjih zbojeva iznosilo 1 sat, 43 minute i 35 sekundi.

Na dijelu parcele s većim zbojevima traktor u agregatu s prešom se kretao manjom prosječnom brzinom od 3,08 km/h, ali zbog veće količine biljne mase po dužnom metru za formiranje jedne bale bilo je potrebno kraće vrijeme, u prosjeku 2 minute i 38 sekundi. Budući da se radilo prešom s tlačnom komorom stalnog volumena sve bale su bile približno istih dimenzija, a prosječne dimenzije bala su bile promjer 125 cm i duljina 116 cm.. Pri tome su bale formirane od većih zbojeva bile su u prosjeku teže za 3,8%, što znači da je kod njih ostvarena nešto veća specifična gustoća odnosno zbijenost bala. Zbijenost biljne mase je inače jedan od signifikantnih parametara koji karakteriziraju rad preše (Waszkiewicz i Kostyra, 2003). Zbog nešto veće prosječne mase bala prosječno vrijeme omatanja mrežom je iznosilo 13 sekundi, pa je ukupno vrijeme potrebno za formiranje jedne bale iz većih zbojeva u prosjeku iznosilo 2 minute i 51 sekundu. Zbog većeg razmaka između zbojeva bilo je nešto lakše okretanje na uvratini pa je potrebno vrijeme za okretanje u prosjeku iznosilo 28,5 sekundi, odnosno za 18 zbojeva je potrebno 17 okretanja pa to ukupno iznosi 8 minuta i 5 sekundi. Na osnovi tih podataka proizlazi da je ukupno vrijeme potrebno za dobivanje 30 bala iz većih zbojeva iznosilo 1 sat, 33 minute i 5 sekundi.

Slika 1 Ovijanje bale u plastičnu foliju

Ovijanje bala je vršeno na mjestu spuštanja iz preše, a prosječno vrijeme podizanja bale na postolje ovijača je iznosilo 26 sekundi. Prosječno vrijeme ovijanja bale u plastičnu foliju je iznosilo jednu minutu i 10 sekundi, pa je ukupno vrijeme ovijanja s utovarom iznosilo 96 sekundi. Iz toga proizlazi da je ukupno potrebno vrijeme za ovijanje 60 bala iznosilo 1 sat i 36 minuta. Za ovijanje je korištena folija dimenzija 750 mm x 0,025 mm x 1500 m, a utrošeno je tri namotaja folije. Plastična odnosno polietilenska folija se već godinama koristi za ovijanje bala zbog odgovarajućih mehaničkih svojstava i prihvatljive cijene (Borreani i Tabacco, 2008). U početku su se bale ovijale u četiri sloja, ali zbog propusnosti folije se broj slojeva povećao na šest ili čak osam slojeva kako bi se što bolje sačuvala kvaliteta sjenaže (Keller i sur., 1998; Müller, 2005), Međutim, time se povećalo potrebno vrijeme za ovijanje, kao i dodatni troškovi nabave i kasnijeg zbrinjavanja folije (Lingvall, 1995). Iz tog razloga se u novije vrijeme koriste nove rastezljive folije koje imaju smanjenu propusnost i tada broj slojeva može biti manji (Borreani i Tabacco, 2010).

Ukupno vrijeme utrošeno za spremanje sjenaže u valjkaste bale ovijene plastičnom folijom s parcele od 7,5 hektara iznosilo je 11 sati, 36 minuta i 36 sekundi. Prvi dan ispitivanja strojeva obavljena je košnja cijele parcele u trajanju od 3 sata, 45 minuta i 49 sekundi, dok su drugi dan obavljene ostale operacije, sakupljanje u zbojeve, baliranje i ovijanje bala za što je utrošeno 7 sati, 51 minuta i 35 sekundi. Od ukupno utrošenog vremena, na košnju otpada 32,4%, na skupljanje u zbojeve 25,6%, na baliranje 28,2% i na ovijanje bala 13,8%. Ostvareni učinci pojedinih strojeva su prikazani u tablici 3.

Tablica 3 Vrijeme obavljanja pojedinih operacija i učinak strojeva
Table 3 Times for specific operations and machines efficiency

Stroj Machine	Ukupno vrijeme Total time (h)	Vrijeme po hektaru Time per hectare (h/ha)	Učinak Efficiency (ha/h)
Kosilica Mower	3,76	0,50	2,0
Sakupljač Windrower	2,98	0,40	2,5
Preša Baler	3,28	0,44	2,3
Ovijač Wrapper	1,60	0,21	4.8
Ukupno Total	11,62	1,55	-

Ako se ostvareni učinci strojeva usporede s rezultatima drugih autora, vidljivo je da su korištena rotacijska kosilica i sakupljač s horizontalnim rotorom ostvarili manje učinke zbog manjeg radnog zahvata. Rotacijske kosilice ostvaruju znatno veći učinak u odnosu na ostale tipove kosilica, ali bi za veće parcele trebalo koristiti kosilice većeg radnog zahvata (Potkonjak i sur., 2009). Učinak preše sakupljačice je vrlo dobar jer Potkonjak i sur. (2010) ispitujući učinak tri tipa preša za valjkaste bale navode da su ostvareni učinci u rasponu od 1,40 do 1,87 ha/h, pri čemu je najveći učinak ostvaren prešom s tlačnom komorom stalnog volumena kakva je korištena i u ovim istraživanjima. Ukoliko se uzima u obzir broj napravljenih bala po satu, Taylor (1995) navodi da je učinak preše za valjkaste bale s omatanjem u mrežu bio 16,8 do 22,8 bala na sat. U ovim je ispitivanjima učinak preše bio 18,3 bale na sat. Ostvareni učinak ovijača bala je također vrlo dobar jer je za 1,6 sati ovijeno 60 bala iz čega proizlazi učinak od 37,5 ovijanja na sat. Borreani i sur. (2007) navode da je konvencionalni ovijač s okretnim postoljem ostvario učinak od 25 bala na sat, dok je ovijač nove izvedbe s dvosmjernom rotacijom aplikatora folije ostvario učinak od čak 55 bala na sat.

ZAKLJUČAK

Na temelju provedenih ispitivanja može se zaključiti da je ukupno vrijeme utrošeno za spremanje sjenaže u valjkaste bale ovijene plastičnom folijom s parcele od 7,5 hektara iznosilo 11 sati, 36 minuta i 36 sekundi. Prvi dan ispitivanja strojeva obavljena je košnja cijele parcele u trajanju od 3 sata, 45 minuta i 49 sekundi, dok su drugi dan obavljene ostale operacije, sakupljanje u zbojeve, baliranje i ovijanje bala za što je utrošeno 7 sati, 51 minuta i 35 sekundi. Od ukupno utrošenog vremena, na košnju otpada 32,4%, na skupljanje u zbojeve 25,6%, na baliranje 28,2% i na ovijanje bala 13,8%. Ispitivanja su pokazala da je nakon košnje i prosušivanja biljne mase bolje raditi veće zbojeve jer su ti zbojevi bili ujednačenije širine i visine, a sadržavali su veći postotak vlage što je povoljnije za sjenažu. Ovakav način spremanje sjenaže se može preporučiti obiteljskim poljoprivrednim gospodarstvima u Hrvatskoj, jer će se stoka hraniti kvalitetnom voluminoznom hranom što bi trebalo dati zadovoljavajuće rezultate u proizvodnji mlijeka i mesa.

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EFFICIENCY OF THE MACHINES FOR MAKING GRASS SILAGE IN ROUND BALES

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SUMMARY

Investigation of efficiency of the machines for storing grass silage in plastic wrapped round bales was performed on experimental field of Faculty of Agriculture University of Zagreb. On the experimental plot of 7,5 ha was alfalfa and mowing was done first day of experiment, while windrowing, baling and wrapping was done second day. Rotary disc mower with working width of 2,4 m achieved efficieny of 2,0 ha/h, windrower with horizonatal rotor achieved 2,5 ha/h, while round baler with fiwed-geometry chamber achieved efficiency of 2,3 ha or 18,3 bales per hour. Wrapper with rotating table achieved efficiency of 37,5 bales per hour.

Key words: *grass silage, alfalfa, round bales, wrapping, efficiency*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad rad
Expert paper

THE INFLUENCE OF SOIL MULCHING AND GREENHOUSE COVERING MATERIAL ON THE TEMPERATURE DISTRIBUTION IN LETTUCE PRODUCTION

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ABSTRACT

The aim of this research was to investigate the temperature distribution 10 cm above the soil in different conditions of lettuce production system (open filed, mulching, low tunnels, greenhouses). Based on the results, average daily temperatures were calculated. Special attention was given to the morning and temperatures in the afternoon. Results show that there is a significant increase in lettuce yield in the early production phase, for the plants that were covered with agro-textile and PE folia.

Key words: *air temperature, lettuce, mulching, agro-textile, low tunnels, greenhouses.*

INTRODUCTION

Plant production in partially controlled conditions can improve the main climatic conditions that can enable earlier planting and, thus, earlier harvesting. Mulching materials can serve for the frost and wind protection as well as to increase the soil temperature under the mulching material. The production under these conditions is more intensive in sense of yield and production quality if compared to the open filed plant production (Bajkin et al, 2001). However, this production technology is limited by climatic conditions of the region and the quality of mulching and covering materials. The greenhouse (controlled) production is more demanding production system that enables whole-year plant production regardless the climatic conditions (Bajkin et al, 2005). In the greenhouses it is possible to fully control all the production parameters and processes.

Every agricultural production system can be defined by the, so called, three E analysis., which comprise energy, economy and ecology (Ortiz-Cañavate and Hernanz, 1999). This early spring and late autumn production, when analyzed from economical aspect, showed a certain benefit for some vegetables (Đurovka et al, 1996).

The aim of this research was to identify the air temperature in different types of soil mulching and greenhouse lettuce production systems.

MATERIAL AND METHOD

The experiment was carried out in the open filed and in a greenhouse at the testing field of the faculty of Agriculture, Novi Sad. in the 2007/08 autumn and spring production season. For the purpose of research, twelve different treatments were established (Fig. 1).

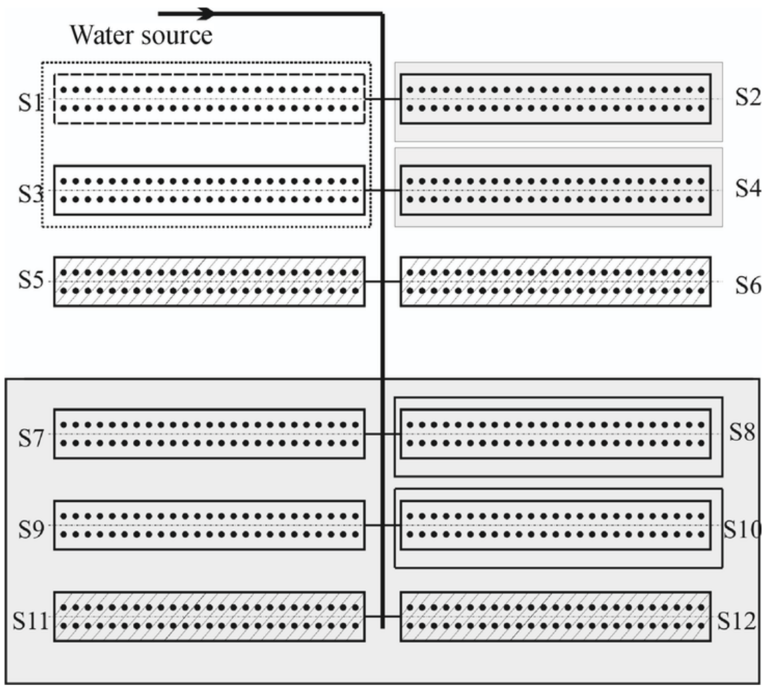

Fig. 1 Organization of the experimental filed

For the soil covering white-black mulch folia was used (treatments S3, S4, S5, S9, S10 and S11). its active width was 80 cm and it was 90 µm thick. In the lots S2, S4, S8 and S10, 2m wide agro-textile was used for covering plants. Transparent folia was used for small (treatments S5, S6, S11 and S12) and walk-in tunnels (S7, S8, S9, S10, S11 and S12). The small tunnels were 0.6 m wide and 5 m long with the 0.4 m central height. The walk-in tunnels were 5 m wide and 11.7 m long with the 2.2 central height. For the walk-in tunnels S1 and S3 a 30% shade net was used for protection against the birds.

The air temperature was measured 10 cm above the ground every 60 s and it was measured simultaneously for the all treatments. Thermocouples, connected to the HP 7500 "PC Data Acquisition System 10" were used for temperature measurements. For the global solar radiation measurement, a CM 11 pyranometer connected to the acquisition system was used. The surrounding air temperature, used as a control treatment, was measured 2 m above the ground. The data base obtained will serve for modeling and predicting the air temperatures within the different lettuce production technologies.

RESULTS AND DISCUSSION

For the twelve given treatments, air temperature and global radiation were measured simultaneously. The influence of different mulching and covering materials was analyzed by comparing the surrounding air temperature and the temperature 10 cm above the soil (Fig. 2).

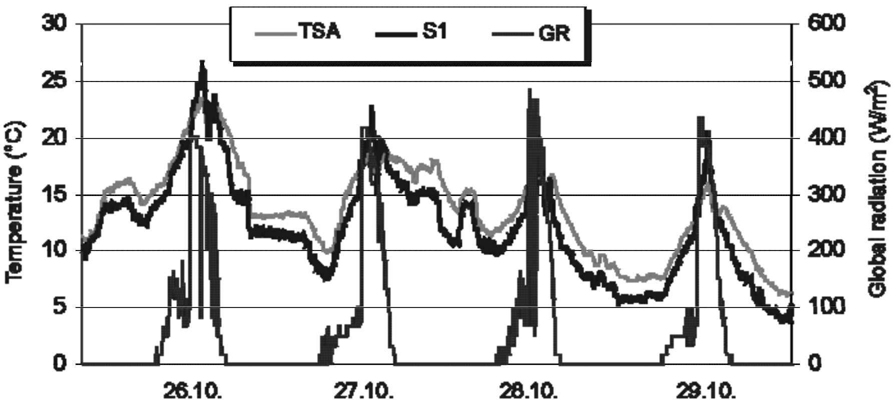

Fig. 2 Global radiation (GR) and air temperature (TSA and S1)

The results show that for the measuring period (6000 minutes) average global radiation was 59.30 W/m^2 while maximal value was 483.33 W/m^2. Global radiation was higher that zero during 2.244 minutes. Radiation sum for the measuring was 2135.10 J/cm^2 while the temperature varied from 6.00° C to 23.57° C, with 13.75° C in average. It can be concluded that the global radiation has the highest value at noon and that air temperature 10 cm above the ground has its maximum in the afternoon. Figure 2 and 3 give the daily temperature variation for the surrounding air (control treatment) and 10 cm above the ground temperatures for the given treatments.

The air temperature measurement was carried out at the beginning, at the middle and at the end of autumn lettuce production cycle, concerning the possibilities of having the lower temperatures at the end of cycle. In the spring lettuce production, temperature was measured at the beginning and at the end of production cycle, when temperature rise was expected. The measurements lasted for 30 days and showed that average global radiation was 81.72 W/m^2 and average surrounding air temperature 15.68° C. Table 1 gives the average daily temperatures 10 cm above the ground for the given treatment.

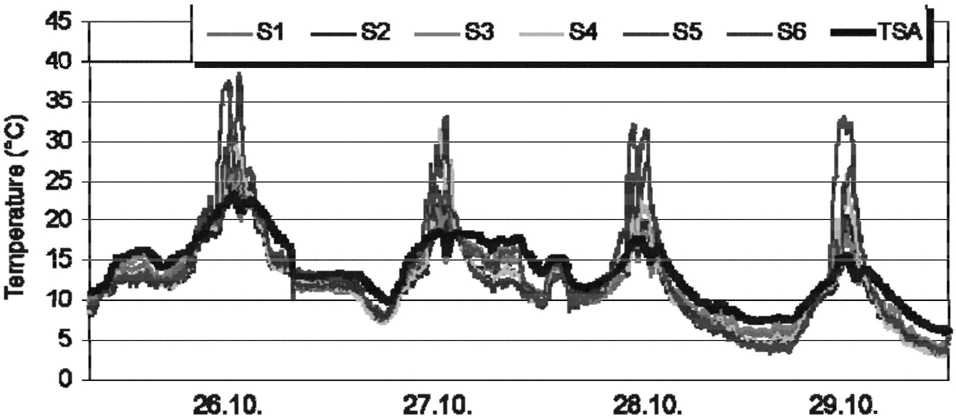

Fig. 3 Air temperatures under different type of covering and mulching materials

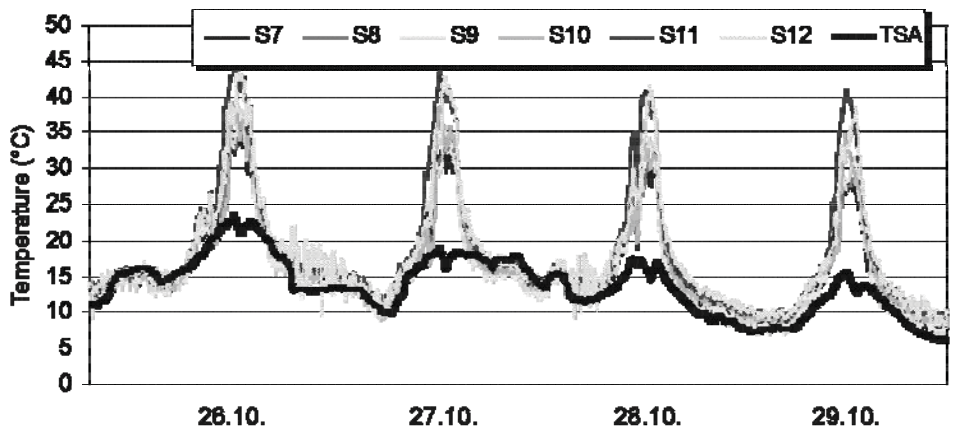

Fig. 4 Air temperatures in the walk-in tunnel

The lowest average daily temperature was measured in the open filed covered with agro-textile (14.63°C) and the highest in the small tunnel where lettuce was covered with agro-textile (16.18°C). Temperatures in the walk-in tunnel were higher that the temperatures in the open filed. The lowest average daily temperature was measured for the treatment without the covering (17.43°C) while the highest was measured for the treatment with small tunnel inside the walk-in tunnel, 19.78°C.

Table 1 Mean temperature values 10 cm above ground

Treatment	Measured value, °C	Deviation from control, (°C)	Deviation from TSA, (°C)
S1	14.87	0	-0.81
S2	14.63	-0.24	-1.05
S3	15.26	0.39	-0.42
S4	15.39	0.52	-0.29
S5	16.18	1.31	0.50
S6	15.70	0.81	0.02
S7	17.43	2.56	1.75
S8	18.95	4.08	3.27
S9	17.83	2.96	2.15
S10	19.45	4.58	3.77
S11	19.33	4.46	3.65
S12	19.78	4.91	4.10
TSA	15.68	0.81	0.00

The real influence of different covering and mulching materials on the air temperature can be seen if the temperatures are compared with control treatment (S1). Relatively high temperature values were measured for the control treatment that were, often, higher than the temperatures under coverings in the open filed. The reason for this is the fact that treatments S1 and S3 had a green anti-hail 30% shade net, placed on a small tunnel construction that was 60 cm high thus giving the additional wind protection.

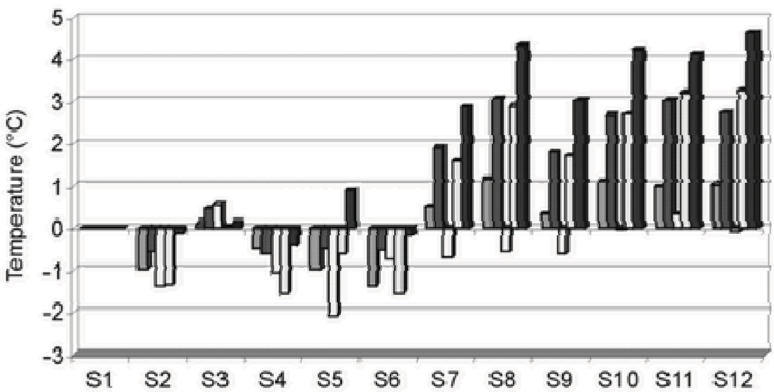

Fig. 5 The differences in air temperatures 10 cm above soil, due to mulching and plant covering from 6 ^{30} to 7 ^{00} hours

A way to determine the quality and the effects of different covering and mulching materials, is to analyze the periods of the highest and the lowest temperatures. The lowest temperatures were measured in the early morning hour s, so the interval from 6 ^{30} up to 7 ^{00} hours was chosen for the analysis (Fig. 5). The results show that lower temperatures were measured in the "partially" controlled conditions compared to the production in the open uncovered filed.

In the walk-in tunnel, temperatures were higher than in the control treatment except in the last weak of measuring period when the days were cloudy with the high air temperatures. By comparing the S7 treatments with the rest of treatments in the tunnel, the effect of different covering and mulching materials was established while the influence of wind and hail net were eliminated. The highest air temperatures were measured in the afternoon. For the purpose of analysis the time interval from 13 ^{30} up to 14 ^{00} hours was used (Fig. 6).

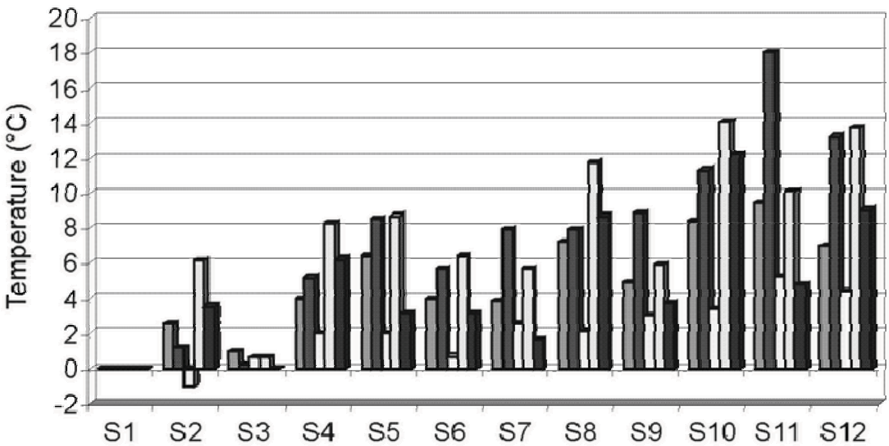

Fig. 6 The differences in air temperatures 10 cm above soil, due to mulching and plant covering from 13 ^{30} to 14 ^{00} hours

The highest temperatures were measured for the treatments with double covering. For example, the temperature for the treatment with white-black mulch folia covered with small tunnel was 5.31 °C higher than the temperature in the control treatment. When only small tunnel was used (S6), temperature was 3.74 °C higher than the control and with using only white-black mulch folia, temperature was only 0.32 °C higher than control.

Air temperatures in the walk-in tunnel were much higher compared to control. Temperatures measured for the S10 treatment showed 12.02 °C higher value that the control treatment.

Statistical analysis (variance, F test and LZD test) showed that the differences between treatments were significant and vary significant. The LZD test showed which treatments showed the most significant differences (Ponjičan, 2004).

The polymer materials have the ability to transfer short infrared radiation and some of the long wave infrared radiation. By transferring this part of spectra the soil, below the covering is heated. When heated, soil acts as a radiant body that gives away its heat, thus heating the surrounding air. The energy that it radiates is with lower energy that can't "escape" through the covering material. This effect is called "greenhouse" effect and as a consequence has higher temperatures below the covering material (Janić et al, 2004).

The results of lettuce mass measuring showed that, on the beginning of the vegetation, the lettuce mass was significantly higher in the treatments were agro-textile and PE folia was used. As the production cycle was coming to the end there was an increase in yield for the treatments where covering of plants and soil was not used. The highest yield was measured for the tunnel structure (S9) with the white-black mulch folia (288.28 g/plant). In the open filed production (Fig. 7), the highest yield was measured for the S5 treatment (202.77 g/plant).

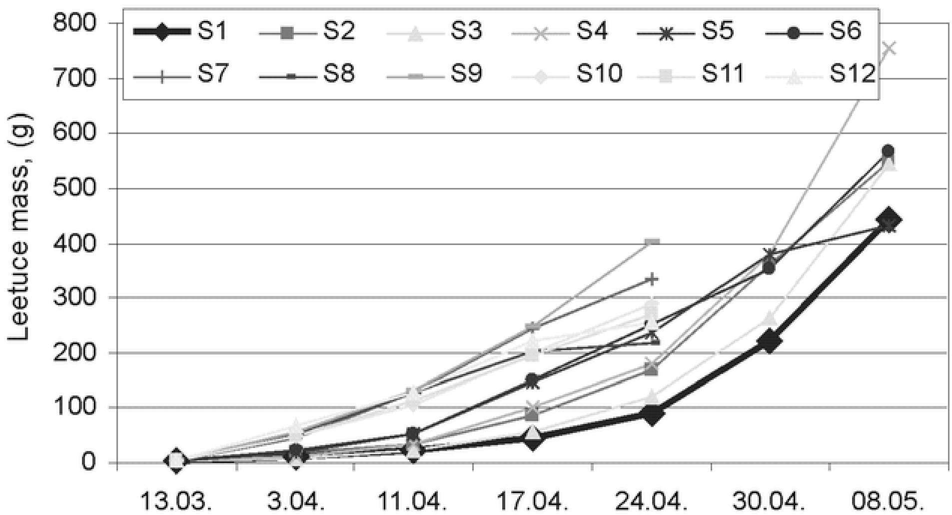

Fig. 7 Dynamics of leaf mass in spring lettuce production

The lettuce in the tunnel structure (S9) was ready for harvesting two weeks before the lettuce in other treatments and its average mass was 402.89 g/plant. In the open filed production the highest yield was measured for the S4 treatment, 756.24 g/plant.

CONCLUSIONS

It can be concluded that on the beginning of the measuring period soil covering has a beneficiary effect concerning the plant growth and development in autumn as well as in spring production. However, at the end of the production cycle, the highest yield was measured for the open filed production. With soil mulching and plant covering higher temperatures were obtained compared to the open filed. The yield increase was, thus, increased due to lower air humidity and lower risk of diseases.

Choosing the plant production system (soil mulching, plant covering and a greenhouse system) influences the time of lettuce harvesting, having a two weeks earlier harvesting in the greenhouses compared to the open filed.

Combination of the greenhouse production systems with the soil mulching, proved to be also beneficiary in the terms of lettuce yield. Further research will be based on more detail temperature studying in the greenhouses, together with the other climatic parameters that affect production processes.

ACKNOWLEDGEMENT

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.563.2:635.62
Prethodno priopćenje
Preliminary communication

ISPITIVANJE SUŠENJA SEMENA ULJANE TIKVE (*Cucurbita Pepo* L) U ŠARŽNIM SUŠARAMA

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SAŽETAK

Sušenje semena uljane tikve najčešće se sprovodi u šaržnim sušarama, a u praksi se primenjuju različiti postupci sušenja. Postavljen je cilj da se istraži mogućnost poboljšanja postupka sušenja sa ciljem da se skrati vreme sušenja, smanji potrošnja goriva, a ostvari dobar kvalitet.

Istraživanje je sprovedeno na šaržnoj sušari, koja korespondira sa onima koje se primenjuju u praksi: rad sa konstantnom temperaturom 50 °C i stalno otvorenim modom, pri kojem agens sušenja jednom prolazi kroz sloj semena i napušta sušaru, što se najčešće koristi u praksi, korišćen je kao kontrolna grupa. Za poređenje je obavljeno fazno sušenje, pri čemu je otvoreni mod korišćen do dostizanja sadržaja vlage oko 32 %, a nadalje su, za dve faze sušenja, primenjene niže temperature i promena moda rada: otvoreni – recirkulacioni. Izračunato je specifično trajanje sušenja, specifična energija sušenja i promena specifične energije sušenja po fazama. Određen je broj mikroorganizama i promena udela slobodnih masnih kiselina u osuše-nom semenu.

Pokazano je da je trajanje sušenja kraće, a specifična energija niža pri primeni viših temperatura agensa sušenja i naizmeničnoj promeni moda rada u drugoj i trećoj fazi. Potrošnja goriva bila je pri faznom sušenju niža za više od 20 %. U svim slučajevima broj mikroorganizama bio je takav da se zrno svrstava u kvalitetnu grupu 3B ili 4B za fazno sušenje, a 4A za kontrolnu grupu. Sadržaj slobodnih masnih kiselina bio je, za sve režime rada, zadovoljavajući.

U budućem radu trebalo bi da se ispita rad sa još višim temperaturama agensa za sušenje u prvoj fazi, a da se nakon dostizanja sadržaja vlage oko 30 % radi sa nižom temperaturom, pri čemu primena treće faze nije neophodna.

Ključne reči: *seme uljane tikve, sušenje, specifična energija sušenja, broj mikroorganizama, kvalitet ulja.*

UVOD

Proizvodnja uljne tikve je lukrativna delatnost, ukoliko se ostvare zadovoljavajući prinosi i kvalitet semena, sa izvesnim plasmanom na domaćem i inostranom tržištu. Seme se koristi za razne namene, a sve više za dobijanje ulja, koje pored nutritivnih ima i lekovito dejstvo.

Postupak proizvodnje je mehanizovan do visokog nivoa. Do žetve se primenjuje uobičajena mehanizacija za ratarsku proizvodnju, a za žetvu specijalne mašine (Wagner 1998; Martinov i sar, 2002). Dorada semena je takođe rešena, pri čemu se koriste uobičajene mašine i oprema za semensku proizvodnju, kao i specijalne mašine za pranje i poliranje (Bojić i sar, 2007).

Sušenje se obavlja u raznim tipovima konvektivnih sušara, kontinualnim–trakastim, semi-kontinualnim – tunelske sa lesama i etažnim, a najčešće u diskontinualnim–šaržnim sa mešanjem sušenog sloja. U literaturi su opisani i drugi postupci sušenja, mikrotalasima i liofilizacija (Martinov i sar, 2007a). Wang et al. (2005) ispitivali su sušenje semena tikve u mikrotalasnoj sušari, a Que et al. (2007) prikazali su rezultate uporednog sušenja u konvektivnoj sušari i primenom liofilizacije. Sacilik (2006) je sproveo ispitivanje sušenja semena u laboratorijskoj konvektivnoj sušari sa temperaturama agensa 40 do 60° C, te sušenje na suncu i tunelskoj solarnoj sušari. U radovima nisu date smernice za, u praksi, uobičajene postupke sušenja.

Praktično orijentisanih istraživanja je malo. Sito i sar. (1998) ispitivali su sušenje semena u šaržnoj laboratoriskoj sušari sa temperaturama agensa 40, 60, 80 i 100 °C. Kvalitet semena ocenjivan je organoleptički, a zaključeno je da je optimalna temperatura 60° C, jer je pri sušenju na temperaturi 80 °C dolazi do „pečenja“ semena. Istu vrednost temperature za sušenje, 60 °C, ali kao maksimalnu, navodi i Wagner (1998). Rossrucker (1992) razmotrio je postupak sušenja sa vrlo praktičnom orijentacijom. Sproveo je laboratorijsko ispitivanje trajanja sušenja pri različitim temperaturama i dobio sledeće podatke: temperature 40, 50, 60 i 70 °C – trajanje sušenja 11,3; 8,8; 7,0 i 5,5 h, respektivno. Za sušenje semenske robe zacrtao je temperaturu od 40° C kao maksimalnu, a za merkantilnu robu 60 °C. Krička i sar. (2005) su takođe sproveli ispitivanje laboratorijskog sušenja, a rad je bez novih i za praksu relevantnih zaključaka.

Kao početni sadržaj vlage semena navodi se najćešće dijapazon 35 do 45 %, a nakon pranja i oceđenja semena 50 do 55 %. Završni, ravnotežni, sadržaj vlage je 8 %.

Neki od istraživačkih napora bili su usmereni ka sušenju mesa tikve (Doymaz, 2007; Nawirska et al, 2009), ali dobijeni rezultati ne mogu da se iskoriste za sušenje semena, jer se radi o značajno različitom materijalu.

Kod nas preovladava sušenje semena tikve u šaržnim sušarama. Proizvođači primenjuju različite temperature agensa, a njihovi stavovi i praksa u pogledu visine temperature i postupka sušenja su različiti. Najčešće primenjuju temperature do 50 °C tokom čitavog procesa sušenja. Kao i u slučaju sušenja lekovitog bilja ponavlja se greška da se temperatura agensa za sušenje poistovećuje sa temperaturom materijala. Poznato je da u početku sušenja isparava fizička vlaga, što je intenzivan proces, te je temperatura semena značajno niža od temperature agensa za sušenje. Ta se faza, prema iskusvu u radu sa lekovitim biljem, završava kada sadržaj vlage padne na 35 do 30 %. Pri kraju sušenja, kada sadržaj vlage padne ispod 20 %, isparavanje vlage je znatno usporeno, a kod lekovitog bilja tada dolazi do opasnosti od ispravanja etarskih ulja, kao i transformacije termonestabilnih jedinjenja. Pretpostavljeno je da bi smanjenjem temperature u višim fazama sušenja, sa primenom promene moda, otvoreni–recirkulacioni, sušenja nakon isparavanja fizički vezane vlage, moglo da se postigne efikasnije sušenje, sa skraćenjem trajanja i smanjenjem specifične energije sušenja, izražene u MJ po kilogramu isparele vode. Takođe je pretpostavljeno da bi primenom recirkulacije agensa u toku druge i treće faze sušenja, kada je isparavanje vlage usporeno, mogla da se smanji potrošnja goriva, uz očuvanje zadovoljavajućeg kvaliteta. Očekuje se da će pri tome, zbog primene viših temperatura, doći i do smanjenja broja mikroorganizma, kao što je to konstatovano pri sušenju lekovitog bilja (Martinov et al, 2008a i 2008b).

Zadatak istraživanja je, takođe, bio i da se utvrdi promena specifične energije sušenja tokom sve tri faze.

Postavljen je zadatak da se istraživanje sprovede na šaržnoj sušari, koja je slična onima koje primenjuju proizvođači, kako bi dobijeni podaci imali primenu u praksi.

MATERIJAL I METODI

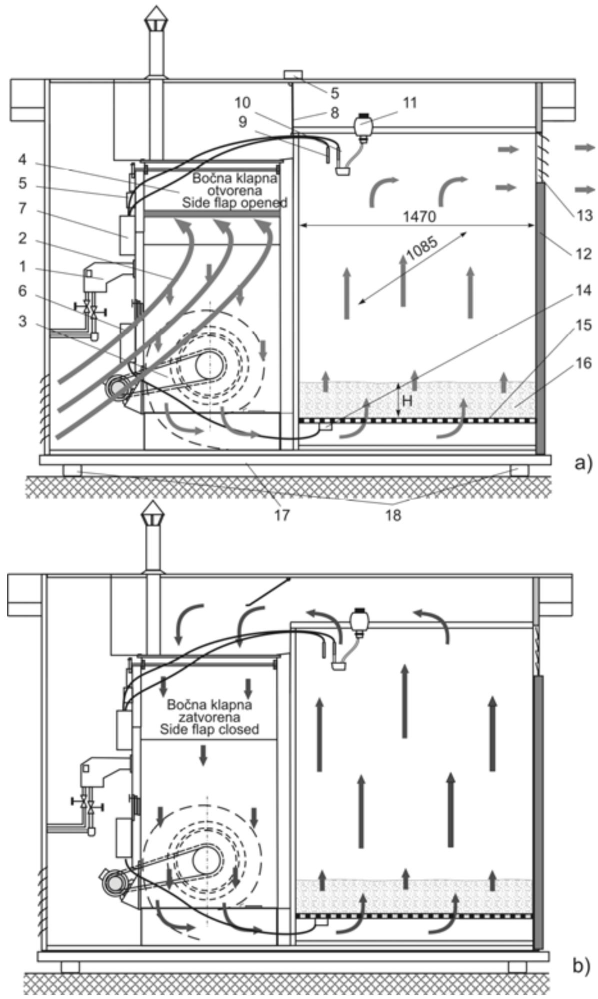
Eksperimentalno sušenje je sprovedeno u Zavodu za hmelj, sirak i lekovito bilje (Insitut za ratarstvo i povrtarstvo) Bački Petrovac u toku 9. i 10. meseca 2009. Korišćeno je seme uljne tikve sorte Olinka. Uzorci su, nakon ubiranja i pranja, donošeni sa raznih lokacija na kojima su gajeni, a vreme od pranja do početka sušenja nije trajalo duže od tri sata. Pre početka sušenja uzimani su uzorci za merenje kvaliteta i broja mikroorganizama svežeg materijala.

Primenjena je šaržna sušara, SD-16 MGA, proizvod *Termoplin* iz Mladenovca, prikazana na sl. 1. Ona je opisana u Martinov et al. (2006a, 2006b), a korišćena je i za eksperimente sa faznim sušenjem nane i kamilice (Martinov et al, 2008a i 2008b).

Senzorima elektronske vage –18 omogućeno je kontinualno merenje težine u toku sušenja biljne sirovine, tačnosti merenja 2 N. Radna površina rešetke sušare je 1,6 m^2. Visina sloja semena bila je 15 do 17 cm, što predstavlja 170 do 180 kg svežeg semena.

Za razliku od spomenutih merenja pri sušenju lekovitog bilja kontinualno je merena i masa rezervoara sa lakim uljem za loženje, koje je korišćeno kao gorivo. Korišćena je elektronska vaga tačnosti očitavanja 1 N. Dobijeni podaci su, kao i u slučaju vage na kojoj je sušara, kontinualno registrovani i potrošnja goriva je preračunavana u kg.

Pre početka svakog eksperimenta vaga sušare je tarirana, te merena količina svežeg semena. Brzim postupkom, pomoću mikrotalasne pećnice, opisanom u Martinov et al. (2007b), utvrđivan je početni sadržaj vlage semena (srednja vrednost tri uzorka). Početni sadržaji vlage opranog i oceđenog semena, bili su u dijapazonu 49 do 55 %. Ove vrednosti poslužile su, pored podatka o početnoj masi sušenog materijala, za izračunavanje trenutnog sadržaja vlage. Tako je određivan trenutak kada se prelazi na narednu fazu sušenja i dostizanja kraja sušenja, kada je sadržaj vlage u semenu 7,5 %. Ovu vrednost je, kao poželjnu, definisao jedan napredni proizvođač.



Sl. 1 Eksperimentalna sušara, a) otvoren mod, b) recirkulacioni mod
1– gorionik, 2– ložište, 3– ventilator, 4– bočne klapne, 5– servo motor, 6– komandni orman, 7– programator, 8– klapna otvora za recirkulaciju, 9– “vlažni” termometar, 10– “suvi” termometar, 11– posuda sa vodom, 12– vrata, 13– natpritisna žaluzina, 14– termometar agensa sušenja, 15– rešetka, 16– biljni materijal koji se suši, 17– ram vage, 18– senzori za merenje težine
Fig. 1 Experimental dryer, a) open mode, b) circulating mode
1– burner, 2– combustion chamber, 3– ventilator, 4– side flaps, 5– servo-motor, 6– electrical cabinet, 7– control unit, 8– circulation opening flap, 9– ”dry” bulb, 10– “wet” bulb, 11– water container, 12– door, 13– overpressure vents, 14– thermometer of drying agent, 15– grate, 16– dried material, 17– balance frame, 18– balance sensors

Temperatura agensa–vazduha za sušenje zadavana je na komandnom ormanu –6, a proveravana termometrom –4. Time je ostvarena tačnost ± 1 °C. Relativna vlažnost agensa u sušari računata je na bazi izmerene temperature „vlažnog“ –9 i „suvog“ –10 termometra, kao i dva dodatna instrumenta, još jednog sa vlažnom i suvom temperaturom i jednog psihrometra, koji su raspoređeni na različitim mestima komore za sušenje. Kao relevantna usvajana je srednja vrednost relativne vlažnosti, koju pokazuju sva tri instrumenta. Tačnost merenja bila je oko ± 3 %.

Rad u otvorenom modu, sl. 1a, podrazumeva da agens prolazi kroz sloj sušenog materijala i napušta sušaru kroz natpritisne žaluzine –13. U tom slučaju su klapne –4 otvorene, a klapna –8 zatvorena. Recirkulacioni mod podrazumeva da agens kruži u sušari, a pri tome su klapne –4 zatvorene, a klapna –8 otvorena. Prvobitno je bilo predviđeno da otvaranjem i zatvaranjem klapni upravlja programator (PLC) –7, ali je u toku sprovođenja eksperimenta konstatovano da veća tačnost može da se ostvari samo ručnom promenom moda, pomeranjem klapni –3 i –8, pri dostizanju odgovarajućih vrednosti relativne vlažnosti agensa za sušenje.

Brzina strujanja agensa za sušenje različito je predstavljena u literaturi. Krička i sar. (2005), navode 0,8 m/s, a Sito i sar. (1998) sproveli su eksperiment sa brzinom 0,8 do 1,6 m/s. Rossrucker (1992) je obrađivao praktičnu primenu sušenja te je došao do preporučenog područja brzina 0,05 do 0,13 m/s. Müller (1992) je detaljno istražio uticaj promene brzine agensa za sušenje na brzinu sušenja lekovitog bilja, uzimajući u obzir i input električne energije.

Zaključeno je da povećanje brzine agensa iznad 0,2 m/s nema opravdanja, jer se intenzitet sušenja neznatno povećava. Zbog toga je za eksperiment odabrana ova vrednost, a tokom procesa sušenja ventilator je podešavan, kako bi ta vrednost bila održana.

Snaga gorionika bila je 15 kW, a motora ventilatora 0,78 kW. Brzina agensa sušenja kontrolisana je merenjem anemometrom pri otvorenoj natpritisnoj žaluzini –13.

Fazno sušenje, slično kao i pri sušenju nane i kamilice, sprovedeno je na sledeći način: postupak je započet sušenjem svežeg semena sa primenom otvorenog moda, pri kojem agens za sušenje, nakon jednog prolaza kroz sloj materijala napušta sušaru. Ova faza se završava kada sadržaj vlage semena dostigne oko W=32 %.

Nakon toga se prelazilo u drugu fazu, pri čemu je primenjena niža temperatura agensa i primena promene moda, otvoreni–recirkulacioni. Prelazak sa recirkulacionog na otvoreni mod sprovodio se kada relativna vlažnost agensa dostigne oko 70 %. To se sprovodi tako da se otvaraju klapne –4, a zatvara klapna –8. Pri radu u otvorenom modu dolazi do snižavanja relativne vlažnosti. Kada bi ona opala na oko 45 % ponovo se prelazilo u recirkulacioni mod. Ova faza se sprovodi do dostizanja sadržaja vlage materijala W=18 %. Treća faza je sprovođena kao i prethodna, ali sa nižom temperaturom, sve do dostizanja krajnjeg, ravnotežnog, sadržaja vlage. U ovoj fazi sušenja prelazak u otvoreni mod sprovodio se pri dostizanju relativne vlažnosti agensa 60 %, a prelazak u recirkulacioni mod kad ona padne na 40 %.

Snižavanje temeprature agensa u drugoj i trećoj fazi preduzeto je iz dva razloga: prvi– seme se zagreva na višu temperaturu, jer je smanjen intenzitet isparavanja vlage; drugi– da ne bi došlo do promene kvaliteta ulja, i presušivanja na kraju procesa.

Sušeno seme je ručno mešano svakih pola sata, da bi se sprečilo lepljenje i stvaranje grudvi, do kojeg dolazi usled prisustva lepljive sluzi. U toku druge i treće faze to je sprovođeno samo onda kada je sušara radila u otvorenom modu, te je na taj način greška pri merenju svedena na mogući minimum.

Eksperiment je sproveden sa tri različite vrednosti početne temperature i temperatura narednih faza, tab. 1.

Tablica 1 Primenjenje temperature po fazama sušenja u °C
Table 1 Applied temperatures for phases of drying in °C

Eksperiment, Trial	1. faza, phase	2. faza, phase	3. faza, phase
A	65	60	55
B	65	55	50
C	60	55	45

Pri istraživanju je primenjena i kontrolna grupa: sušenje u otvorenom modu, u samo jednoj fazi, sa temperaturom agensa 50 °C. To je postupak koji se najčešće primenjuje u praksi.

Za svaku grupu sušenja i kontrolnu grupu sprovedeno je po pet merenja.

Svi podaci o temperaturama, relativnoj vlažnosti, težini–masi materijala i goriva registrovani su posebnim programom na akvizicijskom uređaju proizvođača *AAEON*, model TF-APC-2122HTT-A3, te kasnije obrađeni i predstavljeni tabelarno i grafički u *Microsoft Excell*-u. Rezultati su statistički obrađeni, tako da su izračunate srednje vrednosti i standardna odstupanja.

Nakon dovršetka sušenja svake grupe i kontrolne grupe uzimani su uzorci za utvrđivanje kvaliteta i broja mikroorganizama i čuvani u odgovarajućim uslovima do trenutka obrade.

Kao merilo kvaliteta odabran je sadržaj slobodnih masnih kiselina, koji je meren u skladu sa JUS ISO 729:1992 – Seme uljarica – Određivanje kiselosti.

Broj mikroorganizama meren je prema metodi i u saglasnosti sa nacionalnom regulativom: Pravilnik o mikrobiološkoj ispravnosti namirnica u prometu, Sl. list SRJ, br. 26/93, 53/95 i 46/2002), Sl. list SRJ br. 26, 1993.

REZULTATI I DISKUSIJA

Trajanje sušenja i specifična energija

U tab. 2 prikazani su rezultati trajanja i specifične energije sušenja za tri različita eksperimenta i kontrolnu grupu K, za rad sa 50° C u konstantno otvorenom modu.

Uočava se da je primenom viših temperatura agensa u prvoj fazi i recirkulacije u drugoj i trećoj rezultiralo skraćenjem trajanja sušenja i smanjenjem specifične energije sušenja.

Izražena energija predstavlja primarnu energiju goriva, pri čemu je donja toplotna moć lakog ulja za loženje 41,868 MJ/kg, što je najšire prihvaćena srednja vrednost. Pri preračunavanju u litre usvojena je vrednost gustine 860 kg/m^3.

Tablica 2 Trajanje sušenja i specifična energija
Table 2 Drying duration and specific energy

Eksperiment Trial	Specifično trajanje sušenja po kg suve mase, h/ kg s.m. Specific drying time, h/ kg d.m		Specifična energija sušenja MJ/kg isp. vode Specific drying energy, MJ/kg e.w.	
	SV[1]	SD[1]	SV[1]	SD[1]
K	0,11	0,009	6,4	0,913
A	0,09	0,010	5,3	1,702
B	0,09	0,005	5,5	0,302
C	0,11	0,017	5,6	0,449

[1]SV – srednja vrednost, average value; SD – standardno odstupanje, standard deviation

Specifična energija sušenja po oblastima sadržaja vlage

Postavka eksperimenta i kontinualno registrovanje podataka o masi semena, odnosno izračunatom sadržaju vlage, kao i utrošku goriva, omogućili su da se obračuna specifična energija sušenja po fazama rada. Za kontrolnu grupu, u kojoj je stalno rađeno u otvorenom modu, faze rada definisane su vrednostima sadržaja vlage kao i za fazno sušenje, tab. 3.

Kao što je i očekivano, specifična energija sušenja raste sa smanjenjem sadržaja vlage. Ovde se najjasnije vidi uticaj promene moda sušenja u drugoj i trećoj fazi, na osnovu poređenja vrednosti, koja je dobijena u prvoj fazi sušenja.

Tablica 3 Specifična energija sušenja po fazama
Table 3 Specific drying energy for phases

		Specifična energija sušenjaMJ/ kg isp. vode Specific drying energy, MJ/kg e. w.			
Br, No		A	B	C	K
Faza Phase	I	3,4	3,4	3,9	4,3
	II	5,5	5,8	6,0	8,1
	III	8,1	8,7	10,3	11,7

Tako je za kontrolnu grupu K povećanje specifične energije sušenja u trećoj fazi, u odnosu na prvu, 2,7 puta, a za fazno sušenje A 2,2 puta. Za fazno sušenje C povećanje je 2,6 puta, što je posledica znatnog smanjenja temperature u trećoj fazi.

Kvalitet ulja

Prema Pravilniku o kvalitetu i drugim zahtevima za jestiva biljna ulja i masti, margarin i druge masne namaze, majonez i srodne proizvode, Sl. list SCG, br. 23/2006, granična vrednost sadržaja slobodnih masnih kiselina mora da bude ispod 2 %.

Sadržaj slobodnih masnih kiselina nije se značajno menjao za razne postupke sušenja, mada je viši za eksperimente sa višim temperaturama agensa, tab. 4. Očigledno je da primenjene temperature sušenja, sve do 65 °C u prvoj fazi, ne utiču značajno na promenu kvaliteta semena tikve golice.

Tablica 4 Kiselosti osušenog semena tikve golice
Table 4 Acidity of dried kernels of oil pumpkin

Eksperiment Trial	Sadržaj slobodnih masnih kiselina (% oleinske kiseline) Content of free fatty acids (% of oleic acid)	
	SV[2]	SD[2]
A	0,25	0,01
B	0,30	0,01
C	0,23	0,06
K	0,18	0,03
V[1]	0,24	0,05

[1]V– vlažan uzorak, pre sušenja; fresh sample, before drying
[2]SV – srednja vrednost, average value; SD – standardno odstupanje, standard deviation

Broj mikroorganizama

U skladu sa Evropskom farmakopejom (Anonim, 2005) seme osušeno faznim sušenjem A i B zadovoljava, na osnovu ovog kriterijuma, kvalitetnu grupu 3B. Seme dobijeno faznim sušenjem C i u kontrolnoj grupi zadovoljava grupu, 4B.

Gljive su registrovane samo za fazno sušenje C, kada je temperatura sušenja u trećoj fazi bila 45 °C. Prisustvo *Escherichia coli* konstatovano je za kontrolnu grupu K, i to u granicama koje su dozvoljene za kvalitetnu grupu 4B.

Kako brojnost, tako i njihova metabolička (enzimska) aktivnost svedoče da bakterije prisutne na semenu uljne tikve ne mogu da se uklone primenjenim temperaturama iznad 45 °C. Daljnje smanjenje njihove brojnosti može da se postigne samo tretiranjem parom ili mikrotalasima.

Tablica 5 Mikroorganizmi
Table 5 Microbial count

Uzorak Sample	Broj partikula gljiva Number of fungal particles	Broj bakterija Bacterial count	Enzimska aktivnost (IFA) Enzyme activity(PAI)
	g^{-1}	g^{-1}	$\mu mol\ s^{-1}\ g^{-1}$
A		33600	0,76
B		40700	0,88
C	23	69200	0,93
K		142000	0,94

ZAKLJUČCI

Eksperiment je pokazao da za sušenje semena tikve golice može da se primeni temperatura agensa 60, a za prvu fazu i 65 °C, bez uticaja na smanjenje kvaliteta. Pretpostavlja se da bi za prvu fazu sušenja mogla da se primeni i viša temperatura, na primer 70 ili 80 °C, bez uticaja na promenu kvaliteta, ali bi u narednim fazama morala da se ograniči na 60 °C.

Višefazno sušenje, sa promenom moda, otvoreni i recirkulacioni, za sušenje od sadržaja vlage oko 32 %, pa do kraja sušenja, rezultira smanjenjem utroška goriva za preko 20 %. Na osnovu dobijenih pokazatelja ne bi trebalo da se sprovodi dodatno sniženje temperature za treću fazu, odnosno, očekuju se još bolji rezultati ukoliko se sušenje sprovede u dve faze, sve do dostizanja ravnotežnog sadržaja vlage. To je moguće, jer za razliku od sušenja lekovitog bilja, kod kojeg je termonestabilno etarsko ulje dominantna aktivna materija, ulje tikve je termički znatno stabilnije.

Povišenje temperature sušenja je, kao što je i očekivano, bilo praćeno smanjenjem specifične energije i skraćenjem trajanja sušenja.

Specifična energija sušenja raste od prve ka trećoj fazi, što je i očekivano. Ovaj porast je manji ukoliko se primenjuje promena moda rada sušare, otvoreni – recirkulacioni.

Broj mikroorganizama je niži za rad sa višim temperaturama. Za fazno sušenje sa višim temperaturama u trećoj fazi ostvarena je kvalitetna grupa 3B, a za nižu završnu temperaturu 4B. Pri kontinualnom sušenju na 50 °C konstatovano je i prisustvo bakterija *Escherichia coli*, u granicama koje su dozvoljene za kvalitetnu grupu 4A. Za sušenje postupkom C na semenu je konstatovano i prisustvo gljiva. Očigledno je da za daljnje smanjenje broja mikroorganizma nisu dovoljne visoke temperature sušenja, već je potreban naknadni tretman parom ili mikrotalasima.

U budućim eksperimentima, koji su planirani za sezonu 2010, trebalo bi da se ispitaju sledeće mogućnosti:

1. Ocenjuje se da bi bilo svrsishodno da se ispita sušenje i sa temperaturom vazduha 70, pa i 80 °C, ali samo u prvoj fazi, do smanjenje sadržaja vlage materijala na 32 do 35 %. Primena ovako visoke temperature bila bi moguća u ovoj fazi, jer se, usled intenzivnog isparavanja fizičke vlage, temperatura semena ne povećava iznad granice na kojoj dolazi do stvaranja nepropusnog površinskog sloja, koji bi otežao daljnje sušenje.
2. Konstatovano je da temperatura ne utiče signifikantno na smanjenje sadržaja ulja u semenu tikve, te bi, ukoliko bi temperatura sušenja bila ograničena na oko 60 °C, moglo da se primeni fazno sušenje bez sniženja temperature. Sprovodilo bi se u dve faze: prva kao i do sada, a druga do kraja sušenja sa primenom promene moda sušenja.
3. Bilo bi poželjno da se detaljnije istraže parametri recirkulacionog moda sušenja, tj. da se utvrdi pri kojim vrednostima relativne vlažnosti vazduha treba preći u recirkulaciju, a pri kojim nastaviti sa prisisavanjem vazduha iz okoline. Pretpostavlja se da bi primenom najpovoljnijih vrednosti mogla da se postigne daljnja ušteda goriva, a eventualno i bolji kvalitet osušenog semena.

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DRYING INVESTIGATION OF HULL-LESS PUMPKIN KERNELS (*CUCURBITA PEPO L.*) IN BATCH DRIERS

SUMMARY

The drying of hull-less pumpkin kernels is commonly performed in batch dryers using different procedures and parameters. The objective of this investigation was to improve process with the aim to reduce the drying time and fuel consumption and to obtain safety and quality product.

Three multiphase drying procedures were performed, with different drying agent temperatures. First phase, reduction of moisture content down to 32 %, was performed in open drying mode, whereby drying agent leaves the dryer. The second phase, with lower agent temperature was performed for the reduction of moisture content down to about 18 %, and third one till the end of drying. For the second and third phases open and circulation modes were applied, changed in accordance with achieved relative humidity of drying agent.

As a control group the drying with constant temperature of agent, 50 °C, and open mode for all phases, as usual in practice, was applied.

The specific drying duration was calculated, as well as the specific drying energy, average, and for three phases. The changes of portion of free fatty acids, as well as microbial count in dried kernels, have been analyzed.

It has been shown that the duration of drying was shorter and specific energy lower when higher temperatures, together with mode alternation in second and third phase were applied. The fuel consumption during the multiphase drying was more than 20 % lower. The increase of drying specific energy in second and third phase, compared with the first phase, was lower for multiphase drying.

In all of cases, the quality concerning the content of free fatty acids was found to be satisfactory. The microbial count indicated that the dried kernels belonged to the 3B qualitative group, according to classification in the European pharmacopoeia, for experiments with higher temperatures, and 4B for the trial with lower drying agent temperatures. The control group kernels resulted with lower, 4A, quality group.

The obtained results suggest that in the future should be performed testing with even higher drying agent temperature for the first phase, until moisture content decrease to about 30 %. This should be followed by only one phase, to the final moisture content, whereby the lower drying agent temperature and alternation of drying modes will be applied.

Key words: *oil pumpkin kernels, drying, specific drying energy, microbial count, oil quality.*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC
534.2
Stručni rad
Expert paper

EXPERIMENTAL RESEARCH ON THE CINEMATIC REGIME OF THE OSCILLATING SIEVES BASED ON EFFECTIVE VIBRATION ANALYSIS

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SUMMARY

This paper describes the results of an experimental research on the cinematic regime of the oscillating sieves from the analyze of the signal to a vibration measurement instrument, in order to have a suitable process design, operation and control of separation of cereal seeds from the layer on the sieves, induced by the sieve movement.

Effective vibration analysis begins with acquiring an accurate time-varying signal from an industry standard vibration transducer, an piezoelectric accelerometer produced by PCB Piezotronic, model 353B03, whit sensitivity 9.72 mV/G @ 100 HZ and measurement range ±500 g, mounted to top screen on the device for cleaning and grading by size as means of selecting grain, a Sample Cleaner model SLN 3, manufactured by A/S Rationel Kornservice, Denmark. The material used in this study was wheat, barley, small beans and more difficult products such as sunflower seeds.

The aim of this work was to focus on the internal signal processing path, and how it relates to the ultimate root-cause analysis of the original vibration problem. Based on the obtained result it was shown, that they are characterized by relatively high dynamic factors. The screens are characterized by low frequency of vibrations and small amplitudes. In the screen tested by the authors, the frequency is 10.1 Hz and maximum amplitude of acceleration is 2 g. Velocities of the sieve reaching 0.325 m/s and maximum displacement is 5mm. Within the limitations discussed and further processing, it becomes quite possible to perform extremely accurate diagnoses of equipment condition.

Keywords: *signal analysis; vibration; accelerometer; velocity; cleaning cereals, windowing technique.*

INTRODUCTION

The operation of separation of seeds from the layer on the sieves of cereals harvesting combines takes place due to both the stratification process of the material in its components differentiated according to density and to its sieving state on the separation area induced by the sieve movement (1979).

The material sieving state on the oscillating plane sieve surface depends on the physical and mechanical features of the material to separate, on the ratio between the seed volume and the volume of the other components in the pile, as well as on the constructive and functional parameters of the cleaning system (Ilea, 2001).

Academic studies show that an efficient separation of the seeds in the pile on the sieve takes place when the material has reached a sieving state defined by relative movement, in both directions, on the sieving surface, with a tendency to detachment and a movement resulted from the movement towards the end opposed to the material feeding end. A suitable way to monitor mechanical devices is to observe the vibrations of the components. Accelerometers give the possibility to measure the vibration and convert the effects of mechanical motion into an electrical signal that is proportional to the acceleration value of the motion; there are sensors with a wide range of accuracy (Ellwein, 2000).

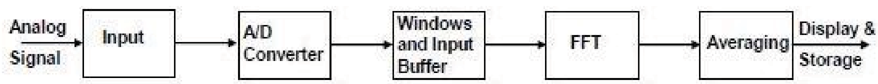

Figure 1 Typical Signal path

The raw analog signal is typically brought into a portable, digital instrument that processes it for a variety of user functions as can show in figure 1 (Prokakis, 1996). The integration of signals producing a velocity or displacement signal, and it can either be processed directly or routed to mathematical integrator for conversion to other units of vibration measurement, but will tend to lose low frequency information and introduce noise. Depending on the frequency of interest, the signal may be conditioned through a series of high-pass and low-pass filters, or band pass filters. By using a windowing technique to shape the time portion of measurement data, to minimize edge effects that result in spectral leakage in the FFT spectrum, the spectral resolution of the frequency-domain result will increase (Harris, 1978).

It is the aim of this paper to present and discuss some significant similarities between these signals which give the ability to develop common approaches for further signal processing tasks with the measured vibration sequences. The signal family is defined in the time-domain and it is highly interpretable in a mechanical sense.

MATERIAL AND METHODS

The experiments have been performed on sieve with rectangular holes using the seeds cleaning and sorting machine of the type Sample Cleaner model SLN3 (Denmark), at laboratory of Depart. of Biotechnical Systems (figure 2). During the experiment, five type of seeds, barley, maize, soy beans and sunflower, from the free market have been used. Two contents, one of “small seeds” and one of “coarse seeds” have been included in the original material, having different impurities contents. The 350 mm long sieve and width of 300 mm with rectangular holes the width of which is of 4.5 mm, with which the machine is equipped has been used. The “small seeds” and “good seeds” passed through the holes of the sieve, while the “coarse seeds” travel on the sieve, have been collected in a box installed under the lower sieve and divided along the length in 3 compartments. The total duration of each experiment was of 70 seconds. Out of the total duration, maximum 10 seconds represent the duration at the beginning and at the end of each experiment, when the separation occurs under transitory regime, and during approximately 60 seconds the separation occurs under stationary regime. This proves that the data obtained through experiments may be considered as resulting from a process of separation occurred under stationary regime.

Vibration measurements

The monitoring system consists of the sensor and a required signal conditioning from plug-in data acquisition (DAQ) devices (a portable data recording module DI-194RS from DATAQ Instruments), notebook Acer AO250 whit processor 1.67GHz, and WINDAQ/Lite waveform recording software. Sensors were chosen, and are strategically mounted on the top screen of the device for cleaning and grading by size (figure 3), to optimize the information that can be obtained about machine condition and operating state. These sensor, a single axis piezoelectric accelerometers type, produced by PCB Piezotronic, model 353B03, whit sensitivity 0.992 mV/m/s^2 @ 100 HZ, resonant frequency 54.2 kHz and measurement range ±500 g, have a single multiconductor cable to carries the signals back to the data acquisition system. The process parameters that are monitored at these installations are detailed below. From the vibration sensors installed on the electric motor are acquired the vibration levels to determine and other process parameters.

Figure 2 Sample Cleaner SLN 3

Figure 3 Sensor

In more limited sense, harmonic vibration of a point or a rigid material is moving in the movement vary continuously in one direction or another, for an unlimited number of times, after the harmonic law:

$$x = x_0 \cdot \sin p \cdot t \tag{1}$$

where *x* represents the position of the mobile at a time, from the origin chosen in the center of oscillation, x_0 amplitude of movement, and p pulsing vibration. The movements in the harmonic regime between displacement x, velocity $\dot{x}$ and acceleration $\ddot{x}$, there are relatively simple relation:

$$|\ddot{x}| = \omega \cdot |\dot{x}| = \omega^2 \cdot |x| \tag{2}$$

where ω is pulsation of harmonic motion. The fast Fourier transform maps time-domain functions into frequency-domain representations. FFT is derived from the Fourier transform equation, which is:

$$X(f) = F\{x(t)\} = \int_{-\infty}^{\infty} x(t) \cdot e^{-j2\pi ft} dt \tag{3}$$

where *x(t)* is the time domain signal, *X(f)* is the FFT, and *ft* is the frequency to analyze. Similarly, the discrete Fourier transform (DFT) maps discrete-time sequences into discrete-frequency representations. DFT is given by the following equation:

$$X_k = \sum_{i=0}^{n-1} x_i \, e^{-j2\pi ik/n} \quad \text{for } k = 0,1, \ldots, n-1 \tag{4}$$

where *x* is the input sequence, *X* is the DFT, and *n* is the number of samples in both the discrete-time and the discrete-frequency domains (Oppenheim,1999).

Direct implementation of the DFT, as shown in equation 4, requires approximately n^2 complex operations. However, computationally efficient algorithms can require as little as $n \log2^{(n)}$ operations. Using the DFT, the Fourier transform of any sequence *x*, whether it is real or complex, always results in a complex output sequence *X* of the following form:

$$F\{x\} = X = X_{Re} + jX_{Im} = Re\{X\} + j \cdot Im\{X\} \tag{5}$$

The power spectrum shows power as the mean squared amplitude at each frequency line but includes no phase information, which is closely related to the FFT, to calculate the harmonic power in a signal. The power spectrum, $S_{xx}(f)$, of a time domain signal, *x(t)*, is defined using the following equation (Prokakis,1996):

$$S_{xx}(f) = X(f)X^*(f) = |X(f)|^2 \tag{6}$$

where $X(f) = F\{x(t)\}$ and $X^*(f)$ is the complex conjugate of $X(f)$.

In practical signal-sampling applications, we obtain only a finite record of the signal. This finite sampling record results in a truncated waveform that has different spectral characteristics from the original continuous-time signal. These discontinuities produce leakage of spectral information, resulting in a discrete-time spectrum that is a smeared version of the original continuous-time spectrum.

The windows used in spectral signal processing to reduce the leakage error of a spectral estimation (Harris, 1978) have some properties which are not suitable for the proposed segmentation task in the time domain. There are many available windowing functions. Rectangular (actually no window), Flat-Top, Hamming, Kaiser-Bessel, and Hanning are among the list available. It is good for analyzing sine waves, as it provides a good compromise on both frequency and amplitude resolution.

The rectangular window has a value of one over its length. The following equation defines the rectangular window.

$$w(n) = 1.0 \; for \; n = 0, 1, 2, \ldots, N-1 \tag{7}$$

where *N* is the length of the window and *w* is the window value. Applying a rectangular window is equivalent to not using any window because the rectangular function just truncates the signal to within a finite time interval. In order tracking, the rectangular window detects the main mode of vibration of the machine and its harmonics.

The Hamming window is a modified version of the Hanning window. The shape of the Hamming window is similar to that of a cosine wave. The following equation defines the Hamming window.

$$w(n) = 0.54 - 0.46 \cdot cos\frac{2\pi n}{N} \; for \; n = 0, 1, 2, \ldots, N-1 \tag{8}$$

where *N* and *w* have the same signification. The Hanning and Hamming windows are similar. However, in the time domain, the Hamming window does not get as close to zero near the edges as does the Hanning window.

The flat top window has the best amplitude accuracy of all the smoothing windows at ±0.02 dB for signals exactly between integral cycles. Because the flat top window has a wide main lobe, it has poor frequency resolution. The following equation defines the flat top window.

$$w(n) = \sum_{k=0}^{4} (-1)^k a_k \cdot \cos(k\omega) \tag{9}$$

where $\omega = \frac{2\pi n}{N}$. The flat top window is most useful in accurately measuring the amplitude of single frequency components with little nearby spectral energy in the signal.

The following equation defines the Exact Blackman window:

$$y_i = x_i[a_0 - a_1 \cos(w) + a_2 \cos(2w)] \; for \; i = 0, 1, 2, \ldots, n-1 \tag{10}$$

where n is the length of the window and $w = \frac{2\pi t}{n}$. The Exact Blackman window has a lower main lobe width and a lower maximum side lobe level than the Blackman window. However, the Blackman window has a higher side lobe roll-off rate than the Exact Blackman window. The computational analyses were done with the mathematical software packages LABVIEW and MATLAB.

RESULTS AND DISCUSSION

In standard Fourier analysis a signal is decomposed into individual frequencies. Unfortunately, there is no way to determine when each of those frequencies has occurred. However, there are signal processing methods that give local information about both time and frequency. These methods localize signal features in both time and frequency; therefore, these methods have the potential to be more sensitive to early changes in the signal due to impending faults.

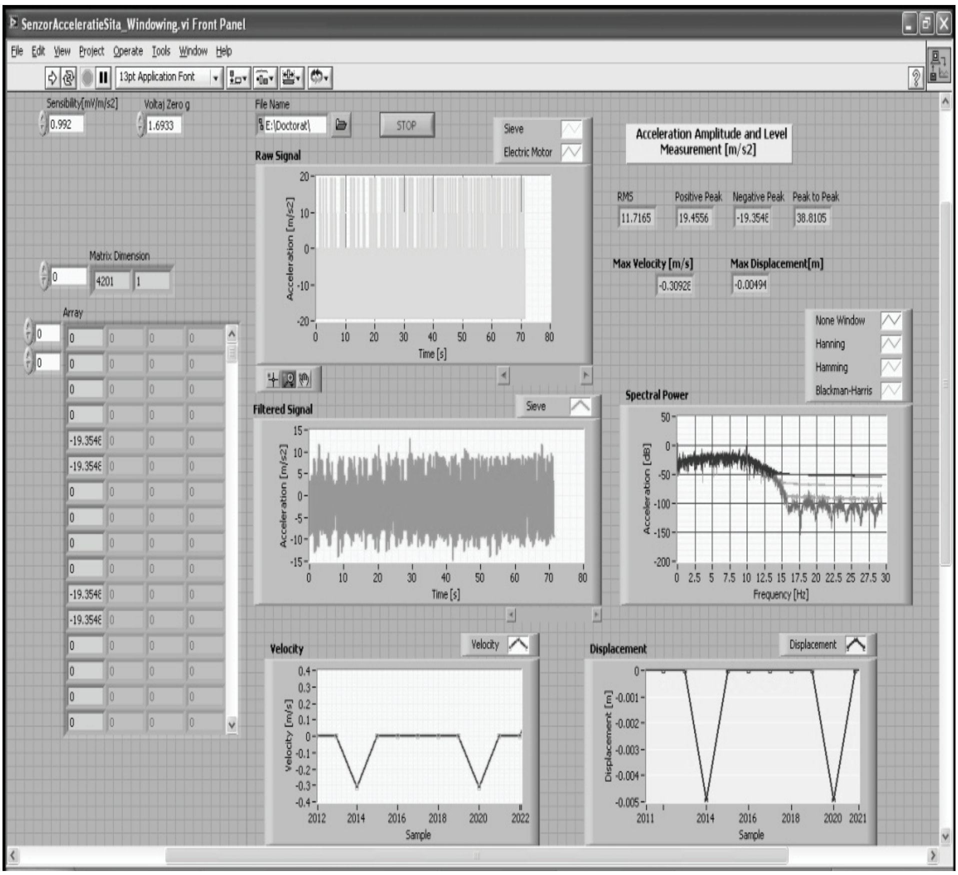

Figure 4 Front panel in LabVIEW program

LabVIEW and its analysis VI (*virtual instruments*) library provide a complete set of tools to perform Fourier and spectral analysis. FFT is a powerful signal analysis tool, applicable to a wide variety of fields including spectral analysis, digital filtering, applied mechanics. To extract useful frequency information, discusses FFT properties, display and manipulate FFT and power spectrum results, we build a LabVIEW library called SieveAccelerometer.VI. The interactive user interface, called the *front panel*, are shown in figure 4. VIs receive instructions from a *block diagram*, which contains the source code for the VI.

The first verification after assembly was completed was of the operating frequency (natural frequency) of the screen with and without seed. It was found that the natural frequency without seed is about 10.02Hz. When incorporating the seed at 0.9-1.0 kg/min, the added weight brings the frequency down to 9.82 Hz. This agrees very well with analytical models of the system, which predicted frequencies between 9 and 10 Hz.

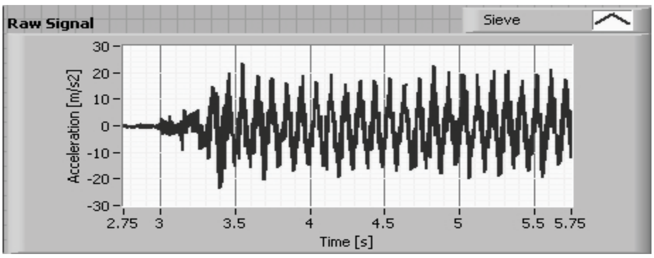

Figure 5 Acceleration signal over time, start, range 0 to 2 seconds

In figure 5 the acceleration signal is shown at startup, the interval 0-2 seconds. It may be noted that immediately after startup (0.2-0.32 seconds) acceleration amplitude peaks around: a_{max} = 20.5 - 21.5 (m/s^2). Acceleration values fall to around 19.41 acceleration (m/s^2) in the next interval 2-4 seconds, then start to rise to steady values, figure 6.

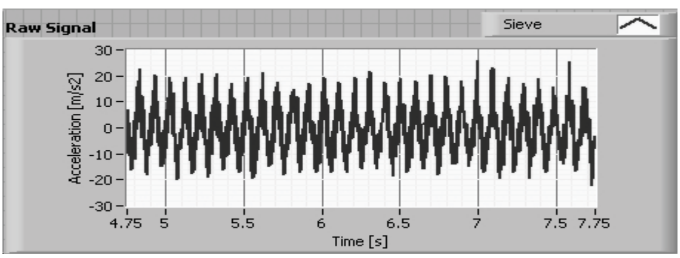

Figure 6 Acceleration signal over time, start, range 2 to 4 seconds

In steady, acceleration amplitude stabilized at values, a ≈ 19.5 to 20 (m/s^2), as can be seen in filtered signal of figure 4 (range 8-70 seconds). To determine the other elements of the movement kinematic the vibration sensors are installed on the electric motor. After the measurements, some aspects may be noted: screen movement is made by a electric motor, in steady, has a frequency (figure 7) f = 20 (Hz), one speed, n = 1200 (rpm);

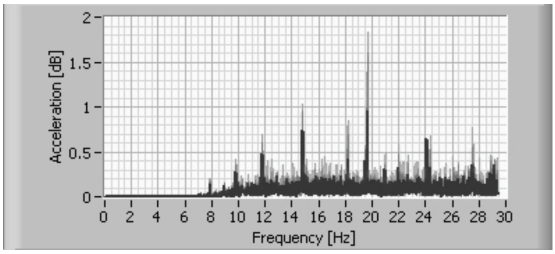

Figure 7 Frequency characteristics of electric motor signal

Thus, for the signal, *x(t)*, represented in figure 6, figure 8 shows the resulting frequency spectrum characteristics of different window, with the correct frequency axis. The resulting frequency interval is 1.44E-02. The application of the above calculation can be seen that the pulsation own grid, f = 10 (Hz), is much smaller than the pulsation disruptive element, which would mean that the filter at startup, will pass through the resonant region and according to the model. As noted above acceleration was reached immediately after the start of a peak, but that goes quickly. This situation is desirable precisely because of the resonance crossing will not affect the functionality of the grid.

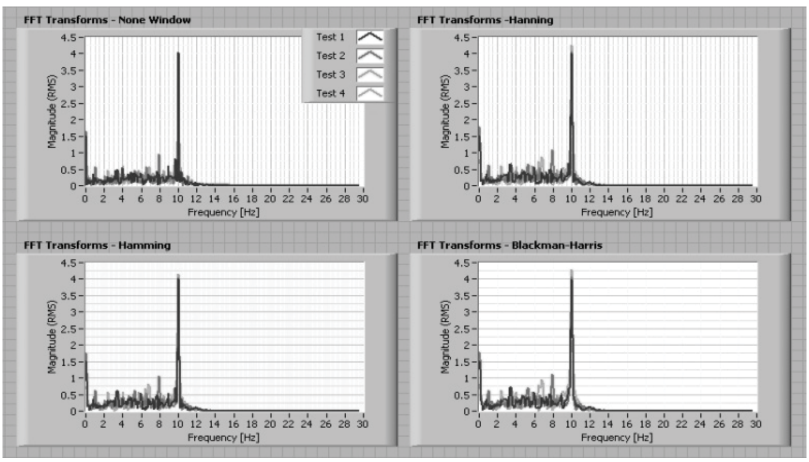

Figure 8 FFT transforms spectrum Frequency

Figures 8 and 9 show power versus frequency for a time-domain signal. The frequency range and resolution on the x-axis of a spectrum plot depend on the sampling rate and the number of points acquired. The number of frequency points or lines in Figure 8 equals N/2, where *N* is the number of points in the acquired time-domain signal. The first frequency line is at 0 Hz, that is, DC. The frequency lines occur at Δf intervals where $\Delta f=1/N\Delta t$ and

Δt=0.0165s is the sampling period. Thus $N\Delta t$ is the length of the time record that contains the acquired time-domain signal. The signal in figures 8 contains 1,024 points sampled at 60 Hz to yield Δf = 1.44E-02 Hz and a frequency range from DC to 5.11 Hz. Figure 8 also shows the maximum values at frequency lines of 9.8 Hz through 10 Hz for each window. The amplitude error at 10 Hz is 4 dB for each window. The graph shows the spectrum values between 0 and 30 Hz.

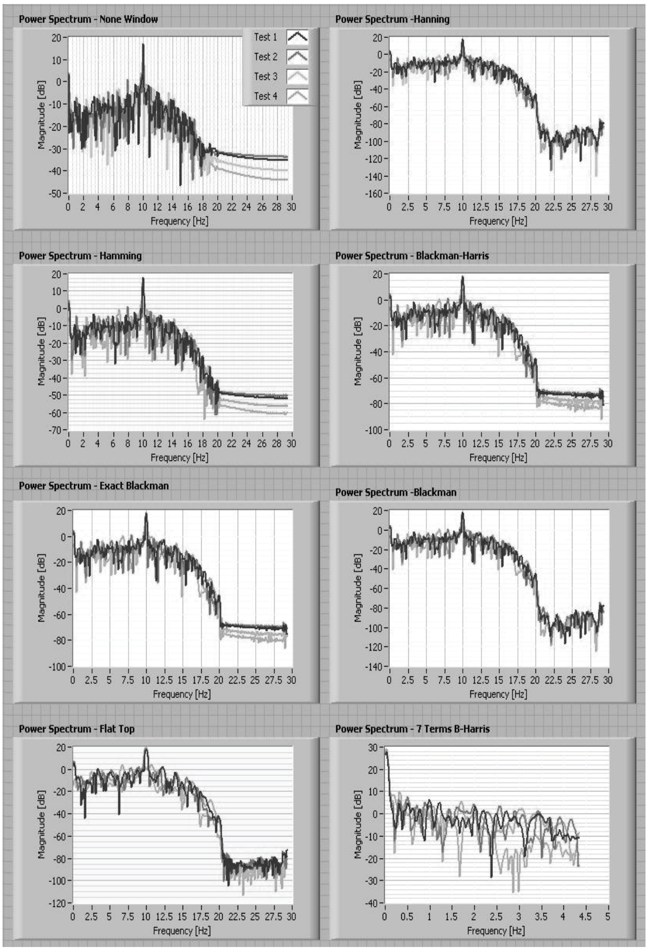

Figure 9 Frequency Response of different Window

Figure 9 shows the single-sided power spectrum characteristics of a different window in more detail. The side lobe characteristics of the window directly affect the extent to which adjacent frequency components bias (leak into) adjacent frequency bins. The side lobe response of a strong sinusoidal signal can overpower the main lobe response of a nearby weak sinusoidal signal. The effects of different windows -- none (Uniform), Hanning (also commonly known as Hann), Hamming, Exact Blackman, Blackman, Blackman-Harris and Flat Top -- when an nonintegral number of cycles have been acquired, in this figure, 102.4 cycles in a 1,024-point record, are shown in figure 9. Notice that the windows have a main lobe around the frequency of interest. This main lobe is a frequency domain characteristic of windows. The leakage factor (ratio of power in the side lobes to the total window power) is in range of 40.24% - 59.81%; relative side lobe attenuation (difference in height from the main lobe peak to the highest side lobe peak) is between -12.4dB and -13.4dB. The Uniform window has the narrowest lobe, and the Hann and Flat Top windows introduce some spreading. The Flat Top window has a broader main lobe than the others. For an nonintegral number of cycles, all windows yield the same peak amplitude reading and have excellent amplitude accuracy. Residuals from models of the different time-frequency analyses have some different characteristics.

Table 1 Data from accelerometer measuring vibration to the top screen

Results analysis							
Test	**Rms**	**Pos. Peak**	**Neg. Peak**	**Vel. [m/s]**	**Displ.[m]**	**Error(%)**	**Abs err.**
Empty Sieve	**12.3211**	**19.4556**	**-19.3548**	**-0.3088**	**0.00495**	**-0.9418**	**-0.00005**
Wheat	**11.8724**	**19.4556**	**-19.3548**	**-0.3086**	**0.00495**	**-1.0748**	**-0.00005**
Sun Flower	**9.8018**	**19.4556**	**-21.9616**	**-0.3090**	**0.00496**	**-0.8424**	**-0.00004**
Barley	**11.8264**	**19.4556**	**-19.3548**	**-0.3085**	**0.00494**	**-1.1204**	**-0.00006**
Soybean	**11.4483**	**19.4556**	**-19.3548**	**-0.3219**	**0.00494**	**-1.1402**	**-0.00006**

If we take into account the steady acceleration amplitude value, we can calculate the range of velocity and screen displacement from equation (2), as can show in table 1.

From figure 10 and 11 we observe the maximum values of screen velocity, v≈3.20m/s, in steady regime, and a value of maximum displacement of 5mm, for signal acquired in experimental test whit empty sieve.

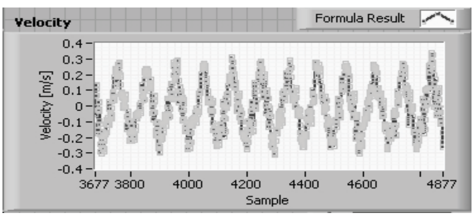

Figure 10. Top screen velocity

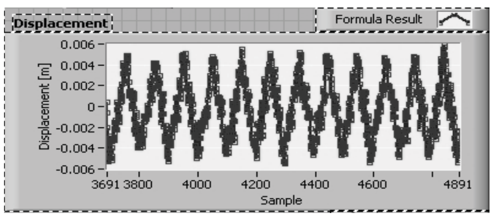

Figure 11. Screen displacement

CONCLUSIONS

There are many prognostic algorithms based on theoretical principals which must be tested and refined using consistent and accurate data acquired from machines as they are subjected to real operating conditions. An understanding of these basic concepts in signal processing and data manipulation will enable one to select instrumentation and to understand its use.

The vibration signal is possibly influenced by the final application of the device. The method of mounting, the resonance frequencies of the whole circuit or machine will affect the vibration signal.

Further case studies will allow us to build a library of normal and improper combinations of seeds separation process parameters and vibration measurements to enable accurate prognosis. Also, the further work remains in order to investigate the relationship between the vibration magnitude of device components and the material motion on the sieve. Moreover, the changes induced by different process parameter on the oscillating sieves application awaken an interest in comparing different operating kinematics.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.363.21:633.11
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Original scientific paper

TESTING CERTAIN DISTRIBUTION LAWS REGARDING SOME PHYSICAL CHARACTERISTICS OF GRINDED WHEAT SEED MIXTURE INSIDE MILLING UNITS AND THE CONNECTION BETWEEN THEM

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ABSTRACT

The paper presents the distribution of dimension class and mass of a mixture of wheat seeds in a mill with Buhler type equipment, from Rosiori-de-Vede, Romania. The regression analysis was realized based on known distribution laws (normal law, gamma laws, gamma generalized, delayed gamma and Weibull law), of measured values for the three dimensions of seeds and their mass and were determined the regression function coefficients, but also the correlation coefficients χ^2 and R^2. Based on measured values of seed dimensions, the volume of each seed that was correlated with its mass was calculated. Based on measured values of seed dimensions, the volume of each seed that was correlated with its mass was calculated. For a regression function, the multiple correlation of seed mass with their three dimensions, was made, by multiple linear regression analysis on the next type of function: $m=a+b\cdot l+c\cdot w+d\cdot t$ (m,l,w,t – mass, length, width, thickness seeds respectively).

Key words*: physical characteristics, wheat kernels, distribution laws, size distribution*

INTRODUCTION AND LITERATURE REVIEW

Researches on the physical characteristics of grains, as well as researches on the relations between grain seeds (wheat, corn) physical characteristics and the grinding process, have been performed and presented in numerous journals and volumes of international conferences, [3,4,5,6,7,8,9,10,11,12].

Seeds dimensions and the mass of each seed and as well as the distribution of seed mixture on size classes is important to be known to determine the efficiency of the grinding machines currently used on the technological flow. However, the volume and the true density of each seed influences the manner the flutes of grinding rollers attack the seed but also the number of shear points during grinding process, [1,2].

The geometrical characteristics of flutes and their mutual position for the two grinding rollers, roller diameter and speed, are influenced by the physical properties of the grinded material and, therefore, and thus, by those of the seeds, [1,2].

The physical characteristics of wheat seeds (volume, shape, and dimension) directly influence the grinding process within the rollers of mill, for their processing into flour, [7]. Shape, volume, dimensions, density, porosity and surface area are important physical characteristics in grains behavior analysis during the grinding process, [13].

The physical characteristics of wheat seeds are influenced by their size and shape, but also by other factors such as level of development, time of harvest, weather conditions, etc. Knowledge of the main dimensions of the seeds, shape and weight of each wheat seed is important in separation process on the sieves, having a special importance in the right choosing of shapes and size of separation equipment holes on the technological flow of seed cleaning department and calculation of grinding power requirements, [4, 10]. Paper [8] shows that wheat seeds of higher size require higher energy consumption than smaller seed size and the lower weight seeds require lower energy consumption than seeds with greater mass. Wheat seeds mass significantly influences the grinding process.

Paper [10] shows that the seed physical properties and the grinding equipment characteristics influence the grinding specific energy and specific surface increase in process, by differential speed of grinding roller, the gap between them and the hardness of seeds.

In paper [10] it is shown that the physical properties of wheat seeds, mainly their sizes, depend on their moisture. For Shiraz wheat variety, mean values of seed length were equal to 6.78 mm, respectively 3.45 mm and 2.84 for width and thickness, for a moisture content of 8%. For the same variety of wheat, the weight of 1000 seeds had values ranging between 20.13 g and 24 g, for moisture contents ranging between 8% and 18%.

Also, moisture content of seeds influences extern seed specific surface and porosity, and bulk density, respectively their true density. Moisture content changes internal and external friction coefficients, [10,14].

Volume, mass and size of wheat seeds for the same moisture content and for the same lot received in a milling unit, are closely correlated.

In general, both sizes and single seed mass are distributed by Gaussian normal law, but they also present deviations from this distribution.

The objective of this study was to test known distribution laws (normal law, gamma laws, gamma generalized, delayed gamma and Weibull law) for physical characteristics of a mixture of wheat seeds in a mill with Buhler type equipment, from Rosiori de Vede, România and the connection between them.

MATERIALS, METHODS AND PROCEDURES

The paper presents the distribution on size and mass classes of a mixture of wheat seeds in a mill with Buhler type equipments, from Rosiori-de-Vede, Romania.

The three samples of 100 wheat seeds were taken, being determined length, width, thickness, respectively the mass of each seed. Seeds come from a grain lot production from 2008 from South-Eastern Romania and were classified by measuring the three dimensions with a calliper with digital display, with accuracy of 0.01 mm, and a analytical Kern balance with 10^{-3}g precision. The mass of 1,000 seeds was within the range 35.3 – 35.8 g. Moisture content of seeds that were analyzed was 9.38 – 10.14%.

It was found that the mean values for seeds length is within the range l = 4.89 – 8.17, for width w = 2.13 – 3.72 mm and for thickness t = 2.13 – 3.22 mm, respectively for single mass m = 0.015 – 0.057 g (mean of three experiments). For the 100 measured values, three seed dimensions and also their single mass were calculated arithmetic mean (m) and dispersion (σ). To calculate the dispersion, the fallowing relation was used:

$$\sigma = \frac{1}{n} \cdot \sum_{i=1}^{n} (x_i - M)^2 \quad (1)$$

where: x_i represent measured values of the three seeds dimensions and their single mass; M represent measured values mean, and n = 100 – number of measured seeds.

Also, fallowing results were obtained: for seed length $M_l = 6.344$, $\sigma_l = 0.326$, for seed width $M_w = 2.988$, $\sigma_w = 0.12$, for seed thickness $M_t = 2.646$, $\sigma_t = 0.266$ and for seed mass $M_m = 0.035$, $\sigma_m = 9.71\times10^{-5}$.

Based on the data obtained, was graphically plotted the variation curve of the seeds distribution by the three dimensions, presented in fig. 1, respectively by the seeds mass presented in fig. 2.

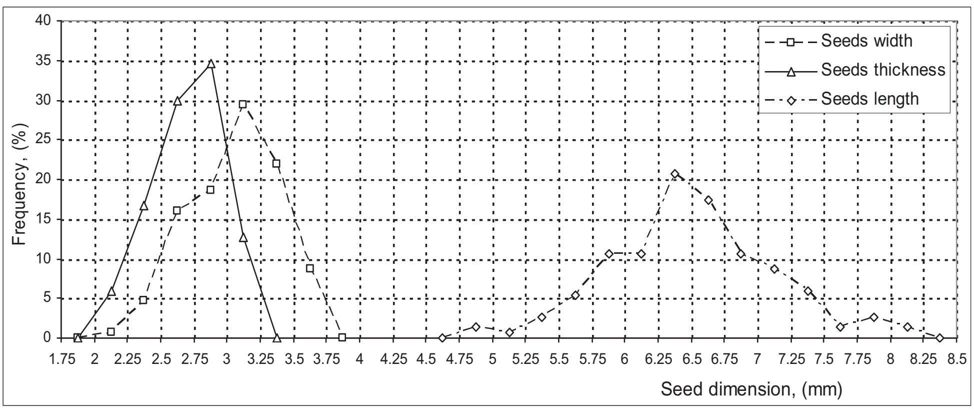

Fig. 1 Wheat seeds distribution on size classes

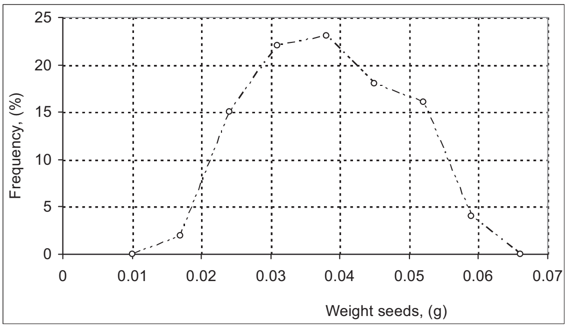

Fig. 2 Wheat seeds distribution depending on their single mass

Profile of the distribution curve, for the three sizes of seeds and also for their mass, can be described using different distribution laws. Following distribution laws were tested :

- normal distribution law:

$$f(x) = a\, e^{-b(x-c)^2} \tag{2}$$

- gamma distribution law with three parameters :

$$f(x) = a\, x^b e^{-c\,x} \tag{3}$$

- gamma generalized distribution law :

$$f(x) = a\, x^b e^{-c\,x^d} \tag{4}$$

- gamma delay distribution law:

$$f(x) = a\, x^b e^{-(c\,x+d)^2} \tag{5}$$

- Weibull distribution law:

$$f(x) = a(x-b)^{c-1} e^{-\frac{(x-b)^c}{d}} \tag{6}$$

both for correlation with the measured three dimensions of seeds, as well for the correlation with the measured values of seeds mass.

The regression analysis was realized by nonlinear regression using the MicroCal Origin program version 6.0. To establish a correlation between the seeds single volume and the mass of each seed, seeds volume was calculated using the fallowing relation:

$$V = \frac{1}{6}\pi\, l\, w\, t \tag{7}$$

where: l, w, t is length, width, thickness measured for each seed, thus assimilating the seeds with ellipsoid geometric bodies. Regression analysis to determine the correlation between volume and single mass of seeds was done in MS Excel program.

To establish a correlation between seed mass and their three dimensions has been done, using MicroCal Origin program, a multiple linear regression analysis on a function like:

$$m = a + b\,l + c\,w + d\,t \tag{8}$$

where: l, w, t have the same meaning as above, and m is seed mass, and a, b, c, d are coefficients of regression functions.

RESULTS AND DISCUSSIONS

After the regression analysis of experimental data with the five distribution laws were determined the coefficients of regression functions, and also the correlation coefficients χ^2 and R^2, of tested functions with the experimental data.

The correlation curves between the regression functions and measured values of three dimensions, respectively seed mass, were mapped graphics, which are shown in fig. 3.

The values of the regression coefficients of the equations and those of correlation coefficients χ^2 and R^2 are presented in table 1.

The regression analysis shows that equation 5 (Weibull law) does not correlate satisfactorily the measured values for seeds mass, which is not shown in the tables.

Analyzing tables and graphs in fig. 3, it was found a good correlation of all five functions with experimental data, the best correlation, however, having the generalized gamma function, for which the correlation coefficient was R^2 = 0.894–0.985 for the three dimensions of seeds, respectively R^2 = 0.984 for seed mass.

For all five regression functions the correlation coefficient R^2 had values above 0.857, for the three dimensions, respectively $R^2 > 0.933$ for seed mass (eq.1 – eq.4).

Using Excel program, was performed a correlation between volume and mass of each seed, the correlation graphic being shown in fig.4, the regression equation with the value of R^2 coefficient being presented on the same graphic. It is found a linear correlation between volume and seed mass, the correlation coefficient having a relatively high value: R^2 = 0.913.

Table 1 Regression coefficients functions a, b, c, d and those of correlation coefficients χ^2 and R^2 for seed sizes and mass

Parametrul	a	b	c	d	χ^2	R^2
	Grosimea semințelor					
Eq.1	35.444	6.032	2.640	-	5.427	0.981
Eq.2	653.479	80.919	30.863	-	8.782	0.970
Eq.3	$5.70 \cdot 10^{-6}$	22.150	0.154	3.750	5.952	0.985
Eq.4	$1.61 \cdot 10^{-7}$	41.288	1.723	0.020	9.201	0.976
Eq.5	$1.87 \cdot 10^{4}$	0.733	– 7.418	0.010	55.168	0.857
	Lățimea semințelor					
Eq.1	26.744	3.467	3.007	-	16.044	0.894
Eq.2	0.104	60.183	20.193	-	17.723	0.883
Eq.3	$3.87 \cdot 10^{-6}$	20.535	0.254	2.995	19.234	0.894
Eq.4	$1.01 \cdot 10^{-6}$	19.883	1.523	– 2.389	19.785	0.891
	Lungimea semințelor					
Eq.1	17.482	1.536	6.346	-	2.8226	0.941
Eq.2	$3.01 \cdot 10^{-27}$	75.712	11.993	-	5.388	0.888
Eq.3	$1.04 \cdot 10^{-29}$	59.665	2.685	1.472	4.392	0.916
Eq.4	$1.30 \cdot 10^{-4}$	6.473	1.210	– 7.258	3.068	0.941
Eq.5	22.960	5.080	2.605	2.784	3.007	0.943
Masa semintelor						
Eq.1	24.280	3476.6	0.038	-	8.022	0.933
Eq.2	$1.85 \cdot 10^{18}$	8.960	252.19	-	6.482	0.947
Eq.3	$1.28 \cdot 10^{12}$	6.157	536.34.19	1.457	7.543	0.948
Eq.4	$3.98 \cdot 10^{12}$	5.974	-33.637	-1.231	7.438	0.949

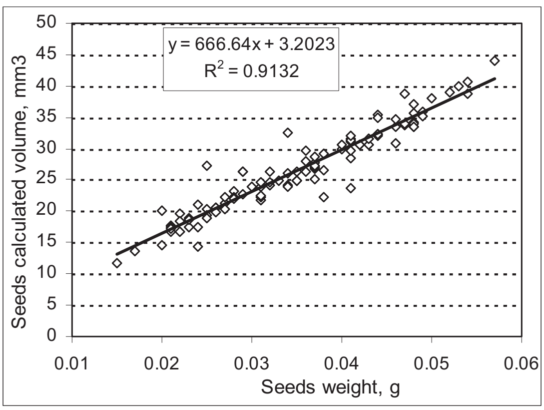

Fig. 4 Correlation between volume and mass of each seed

By multiple linear regression analysis, using the function of eq (7) resulted a satisfactory correlation (R^2=0.906) between seed mass and the three dimensions.

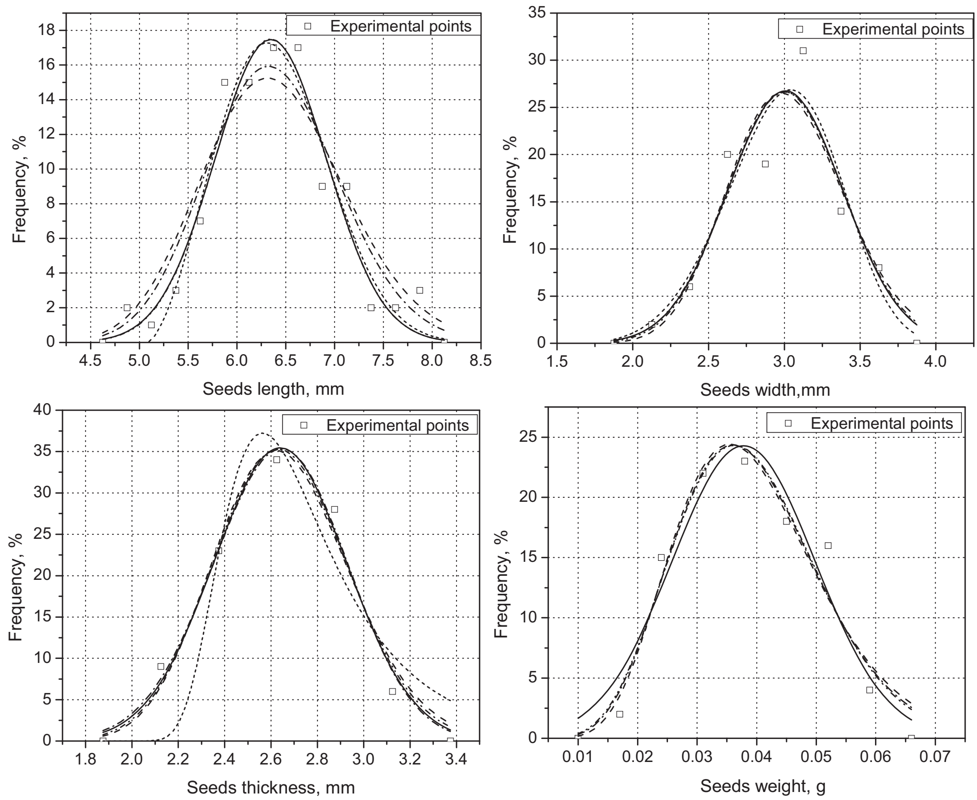

Fig. 3 Correlation curves between regression functions and measured values for the three dimensions and seed mass

——— normal function; - - - - - - gamma function; – · – · – · – generalized gamma function; – · · – · · – delay gamma function; · · · · · · · · Weibull function

CONCLUSIONS

Geometrical dimensions, single seeds mass, volume, in addition to their other physical properties, and mechanical properties, influence structural and functional characteristics of equipment on the processing technological flow, including milling process.

In paper is presented the distribution on sizes and single kernel mass for a lot of seeds of wheat varieties growth in Southern România, which was to be grinding in SC Spicul SA Rosiori de Vede, România, milling unit.

Several distribution laws were tested which correlates experimental data very well. Following the analysis has been found that the best correlation with measured values have normal function and gamma function for which were obtained, in most cases, correlation coefficient values $R^2 \geq 0.916$.

Influence of geometrical dimensions, volume and seeds mass, behaves differently mainly on the working process of grinding rolls and on the grinding degree of seeds, as well as size distribution of fines.

We consider that the results obtained are of real importance to all specialists in the area of milling machines, as well as designers, manufacturers and users.

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THEORETICAL AND EXPERIMENTAL ASPECTS REGARDING THE RHEOLOGICAL CHARACTERIZATION OF BEHAVIOUR OF SOME ROMANIAN WHEAT FLOURS WITH CHOPIN ALVEOGRAPH

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ABSTRACT

In the paper there are presented the results of some experimental research regarding the physical characteristics of some wheat flours of Romanian origin in connection with bread manufacture. There are analyzed four flours types with different ash content (0.48%, 0.55%, 0.65% and 1.25%) and determined their Falling number and gluten content. Then, the rheological behaviour of dough obtained from these flours using the Chopin alveograph is analyzed. There are represented the alveograph curves and determined dough rheological parameters obtained from the above flours. The paper presents the underlying mathematical relationships determining dough rheological characteristics of the four types of flour. Using planimetry technique, it was determined the surface under the alveograph curves and a correlation with the other determined characteristics was established. Test results are appreciated regarding their influence over bakery process.

Key words: *wheat flour dough, rheological characteristics, falling number, alveogram*

INTRODUCTION AND LITERATURE REVIEW

Dough rheological properties present a great importance in the technological process of bread and bakery obtaining. It were developed along time a great number of methods to test dough characteristics which give important informations to the specialists regarding the adequate selection of the working regime parameters for the technological flow machines.

Dough rheological behaviour is non linear [12] and it is mainly influenced by the flour quality used for its preparation, but also by the other ingredients quantity and quality (water, salt, yeast, auxiliary materials). Flour quality used in the technological process of bread obtaining is determined in bakery laboratories by an organoleptic examination and also by physico-chemical and technological examination [1].

Physico-chemical and technological examination consists in determination of flour baking characteristics: gluten content and its quality; gas forming capacity; maltose index, α-amylase content and its activity; bread quality by banking test.

Gluten, a characteristic for wheat flours, contains the majority of flour protein substances, mainly gliadin and glutenin contained in 10-12% proportion in flour, dry mater. This absorb water in kneading process, expanded and form an elastic mass in shape of a three-dimensional net of protein coats and wet gluten (in proportion of 22-30% for commercial wheat flours of Romanian origin, with a minimum protein content between 7-10.5%), [2]. This three-dimensional net constitutes the dough “skeleton” with responsibility in the dough shape maintaining and it has the capacity to retain the fermentation gases which finally gives the crumb porosity.

Protein gluten, which is about 85% of total proteins, is found only in the endosperm and has a better quality as is closer to the endosperm centre, which makes the presence of black flour baking qualities worse than white flour obtained from the same variety of wheat. Proteins quality of a range of flour is determined by the rheological properties of dough or/and gluten, [13,14,15].

The most used method to determine dough rheological properties is the farinograph method (ICC no.115/1; ISO 5530-1; AACC 54-21). In the last decade, more and more, some other methods are developed to determine the rheological characteristics of the dough as the alveograph method (ICC no.121; ISO 5530-4; AACC 54-30, [17]; AFNOR V03-710), the extensograph method (ICC no.114/1; ISO 5530-2; AACC 54-10), a.o. Using the theory of rubber elasticity A.L.Leonard, in [9], tries to characterize the viscoelastic properties of the doughs from wheat flour. For a similar behaviour it is necessary to add in the hard wheat dough a determined quantity of ionic acid to increase the cross-linked density.

In the paper [4], it was represented the pressure – deformation curve in the alveoli filling process for pizza doughs, with a view to the numerical simulation of their rheological behaviour. The studied elasto-plastic parameters, based on Lade theory, depend of the dough physical properties, as moisture content or density. The used dough in study has a moisture content of 35% and an initial bulk density of 917 kg/m^3. The accuracy of theory was tested by the comparison between tension – deformation numerical behaviour results and the measured one, and the tests were favourable.

In several papers were presented and discussed different models for the rheological characterization of wheat flour doughs. So, in [8], the Lathersich rheological model is analysed and justified by experiments. This one is used particularly for the description of shear tension relaxation in the wheat flour dough. It is considered that the developed model can help to the clarification of the relations between baking technological parameters and the dough viscoelastic properties, which are considered to be essential, but which are often unquantifiable.

In the paper [7], the rheological properties of some bread doughs were investigated using a Burgers rheological model with four elements for the determination of dough expansion capability during bread manufacture process. It is shown that the dough with better elastic properties has a better behaviour during growing stage of the bread volume at baking. In the paper [11], oscillatory and relaxation tests of tensions over doughs from four different types of wheat flour, with different absorption water and protein levels were performed. It was demonstrated that for small values of the deformation amplitudes, there are no differences in dough behaviour; otherwise at greater values of this amplitudes the visco-elastic behaviour is different.

Also, tests performed in the paper [10] over tensions relaxation behaviour at dough, gluten and its gluten fractions, show that their relaxation properties depend on proteins and the gel protein is responsible for the net structure of the dough and gluten.

In the present paper the results of some experimental tests – falling number, gluten content, alveograph characteristics – performed over four different types of wheat flour of Romanian origin are presented, together with alveograph curves obtained from testing of samples of flour.

MATERIALS, METHODS AND PROCEDURES

The enzymes activation before the flour introduction in bakery process may degrade the starch particles. This phenomenon determines a poor quality bread obtaining. It was observed an intensive activity of alpha-amylase at the flours obtained from germinated seeds, harvested in conditions of grater humidity than normal (14%). Generally, the enzymatic activity of alpha-amylase is determined by the method of Hagberg falling number, which represents the total time, expressed in seconds, which is necessary as a viscometric stirrer to traverse in free fall a determined distance, in a watery gel of wheat flour or full meal, which is submitted to liquefaction by the introduction of the viscometric tube in a boiling water bath at 100^{o}C. Grains which can form gluten conducting to baking flour have a 40-45% gliadin content and 35-40% glutenin. This is the case of wheat and rye flour. Gluten is determined both in quantity (a great gluten quantity is an indication that the flour has good bakery qualities) and in quality. In a quantity point of view, gluten must be grater than a 25 percent to have bakery flour. A flour is considered to be of a superior quality when it's wet gluten content is in the range 30-35%, [1,13,14].

In this paper, the falling number for the analysed flours was determined with an instrument type Perten-1500, and the wet gluten content with an instrument type Glutomatic-2200, following the procedures specified in their using manuals and procedures SR'ISO-3093/2005 – for falling number, respectively ICC 155-94 – for the wet gluten content. It were analysed four flour varieties, with different ash contents (0.48%, 0,55%, 0,65% and 1,25%), obtained from wheat seeds cultivated in the south of Romania (FA-480, FA-550, FA-650, respectively FN-1250).

The rheological properties of the analysed flours were determined with a Chopin type alveograph, at "Spicul SA" Bucharest.

The principle of the alveograph, manufactured since 1937, is based on the three dimensional deformation of a dough sheet (obtained in specified standard conditions) exposed to air pressure, which is inflates forming a bubble until bursts.

The Chopin alveograph is composed of three main elements: a kneader (mixer) for the dough preparation with a samples extruder, the main unity for the inflation of the dough bubble (proper alveograph) and an alveograph curve recorder, which may be a manometer or an Alveolink computer, [18, 19, 20].

In addition, the alveoghraph is endowed with a laminating unit to obtain the dough sheets, an unit for round cutting of the dough sheets at a diameter of 46±0.5 mm, a thermostatic chamber for the dough sheets preservation until their deformation analyse.

The speed of the mixing arm of the dough mixer is about 60 rpm and is endowed with a calibrated burette for water adding according to the flour humidity. Water is added to flour as a solution of NaCl. The dough is obtained using 250±0.5 g of flour and a NaCl solution 2.5% in distilled water as function of the flour moisture content (ex. for a flour with 12.5% moisture content is used 136.2 ml of NaCl solution) by kneading about 8 min (with one minute brake for dough clear from the mixer walls at one minute from the mixing begin), [16, 17, 18].

After mixing the dough is removed piece by piece from mixer, and it is processed according to the standard method to obtain the test circular sheets, which are lubricated with paraffin oil and allowed to relax in the thermostatic chamber of the alveograph at 25±0.2°C, about 20 min. After relaxation, the swell test of the sheets is performed, placing them, one by one, in proper alveograph. The alveograph curves for all five dough pieces are recorded.

If one curve is total different from the others, it may be discarded, because the device makes the average of the values obtained at all five tests (maximum 2 samples may be discarded).

The obtained curve shows like in fig.1, and it is graphically traced with the recorder of the alveograph.

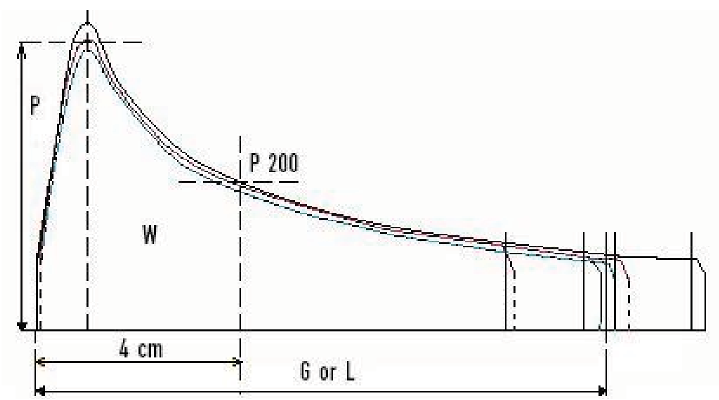

Fig.1 Standard alveogram with the Chopin alveograph experimental measurements indications that appear on these

On this curve, there are recorded:

a) Maximum dough tenacity measure as maximum air pressure P_{max} necessary to extend the dough bubble until burst (measured by mm H_2O):

$$P_{\max} = 1.1 \cdot H_{\max} \tag{1}$$

where: H (mm) is the height average for all five curves;

b) The average length of the alveogram L or the extensibility measured in mm from origin;

c) The swelling index G which takes into account the scaling factor of the device

$$G = 2.226\sqrt{L} \tag{2}$$

which represents the square root of the air volume in cm^3, needed to rupture the bubble:

$$G^2 = V \tag{3}$$

d) The configuration ratio of the alveogram which expresses the relation between the dough tenacity and the dough extensibility showing a balance of these factors. The balance is represented by values of the P/L ratio in the range 0.4–0.7 which are confirmed by practice.

e) The total necessary energy W, to extend the dough bubble until burst, which is given by the area under the alveograph curve:

$$W = 6.54 \cdot S = 1.32\frac{V}{L} \cdot S = 1.32\frac{S}{L} \cdot V = 1.32 \cdot P_{med} \cdot V \tag{4}$$

The coefficient 6.54 is recommended for flours with G in the range 12 – 26 and only in specified conditions précised in the standard method.

f) The elasticity index $I_e = P_{200}/P_{max}$, where P_{200} is the measured pressure in the dough bubble after introduction in its interior a volume of 200 ml of air, which is reached at 4 cm from origin on horizontal axis. Between the volume of air that entered in the dough bubble and the curve length, L is the following relationship:

$$L = \frac{V}{2.226^2} \tag{5}$$

If it is check this relation for the horizontal coordinate of P200 point, results:

$$L_{P_{200}} = \frac{200}{2.226^2} = 40.36 \text{ mm} \tag{6}$$

which represents a different value from 4 cm (40 mm) which is specified in the standard method AACC 54-30A.

It results that a mistake in the estimation of the scaling index appeared, or the method is not enough clearly expressed and concisely (there are no specifications regarding the device to introduce the air the dough bubble, or is very unclear – pump).

If the specified indications to determine the index I_e are considered, then scaling factor is not 2.226 but 2.236 as results from the following relation:

$$I_{\text{scalare}} = \sqrt{\frac{V}{L}} = \sqrt{V_{P_{200}} / \text{L}_{\text{P}_{200}}} = \sqrt{\frac{200}{4}} = 2.236 \tag{7}$$

Also, it is observed the relation:

$$W = 6.54 \cdot S = 1.32\left(I_{\text{scalare}}\right)^2 \cdot S = 1.32\left(2.226\right)^2 \cdot S \tag{8}$$

RESULTS AND DISCUSSIONS

Based on the experimental tests performed at “SC Spicul Bucharest” table 1 was elaborated with the data presented in this paper.

After the tests with Perten-1500 apparatus for the analysed flours, the values of the falling number are in the range 214 – 416 seconds, which shows a very wide range of activity for alpha-amylase and also its influence over the bakery process. The optimal values of the falling number, which indicate a proper enzymatic activity, for harvested at maturity seeds, well grown and which have a moisture content less 14%, are in the range 220-280 seconds with small variations as function of the wheat type. Values over 280 seconds indicate flours with reduced alpha-amylase activity, and values under 220 seconds indicate flours with intensive activity.

It results that almost all kinds of flour (excepted test 22 – FN-1250) are adequate to bakery manufacture, and FA-480 are mainly used in pastry.

It was observed too, that moisture content of the flours was relatively height, over the storing values, because the flours arrive at the bakery or pastry flows, directly from the mill in a short time after seeds were transformed into flour.

Concerning to the wet gluten, this was in the range 26.8-29.6 at flour type 480 and the range 24.8-30.6 at flour type 650 (most used in bakery), which shows that the flours correspond in majority to the technological process for that are destined. It is advisable that the gluten content to be grater at the flours destined to pastry use (type 480), at the produces with grate volume and to puffy ones. For the black flours type 1250, the gluten content in the 26.8-29.2 range is adequate for the bakery process, even that the falling number has values in the 214 – 317 seconds range.

Regarding the dough rheological characteristics of the obtained doughs from the four types of flour, they were determined with the Chopin Alveograph, endowed with alveolink to process and record the data and the alveograph curves. The alveogram shapes, as it was shown, depend of the wet gluten content and quality presenting variation from one flour to another, even for the same gluten content, and more for same ash content (which is grater as the flour is nearer the integral flour, that means that the extraction degree is grater).

Table 1 The main characteristics of Romanian wheat flours and doughs, depending of their ash content

Flour type	Flour hum. %	FN, s	Glúten, %	P, mm H_2O	L, mm	G	V, cm^3	$W.10^{-4}$ J	S, cm^2	Ie	P/L
480	15.40	300	28.8	206	139	26.2	686.4	1129	173.2	81.2	1.48
480	15.30	378	28.6	76	107	23.1	533.6	227	34.5	47.2	0.7
480	14.70	275	29.8	114	116	24.0	576.0	501	76.4	71.8	0.98
480	14.80	335	29.0	58	67	18.2	331.2	128	19.6	46.8	0.87
480	14.70	292	26.8	49	202	31.6	998.5	320	49.0	74.5	0.24
480	14.60	283	29.6	136	126	25.0	625.0	597	91.2	71.3	1.08
550	14.80	334	27.9	63	63	17.7	313.3	130	19.8	44.5	1.00
550	14.70	405	29.4	65	117	24.0	576.0	188	28.9	43.9	0.56
650	15.30	221	26.8	93	147	27.0	729.0	422	64.5	60.6	0.63
650	14.80	267	28.8	105	108	23.1	533.6	409	62.7	66.5	0.97
650	14.80	268	28.0	93	112	23.6	557.0	313	47.8	52.5	0.83
650	15.30	228	26.9	109	130	25.4	645.2	426	65.0	57.6	0.83
650	14.70	338	28.4	86	93	21.5	462.3	302	46.0	63.2	0.92
650	14.80	401	29.8	72	109	23.2	538.2	170	26.1	35.1	0.66
650	15.30	285	24.8	106	100	22.2	492.8	331	50.9	53.9	1.07
650	13.70	380	30.0	75	103	22.6	510.7	230	35.1	49.9	0.73
650	14.30	416	30.6	75	88	20.9	436.8	162	24.7	35.7	0.85
650	12.10	268	29.0	66	141	26.4	696.9	269	41.2	59.4	0.47
650	13.40	231	29.2	77	126	25.0	625.0	307	46.9	58.6	0.61
650	13.60	260	27.4	84	124	24.8	615.0	358	54.7	66.0	0.68
1250	13.70	317	26.8	135	19	9.7	94.1	118	18.1	75.0	7.07
1250	13.20	214	29.2	108	93	21.4	458.0	336	51.7	58.1	1.16
1250	14.30	224	28.2	97	106	23.0	529.0	264	40.1	45.2	0.91

The values of the alveogram parameters are presented in table 1 too, having different variations from one flour to another, that justify the importance of the performed tests for all kinds of flours. So, for the estimation of the dough quality obtained using one flour type, is important the maximum air pressure value necessry to extend the dough bubble until burst, P (in mm H_2O), as well as the air volume introduced in bubble (V in cm^3) corresponding to the alveogram length, L (in cm), and the surface under the alveograph curve to the horizontal axis, S (in cm^2), which specify the consumed energy for the alveolus brake, W (in Joule).

The shape of the alveograph curves vary between the curve types presented in fig.2, corresponding with the indicated flours and the dough characteristics in correlation with the bakery and cooking process, [18].

In the fig.3 it is presented the using mode of the alveograms to improve the quality of the flour assortments, and in fig.4 the alveograms obtained by the test with the alveograph, for the doughs from different kinds of Romanian wheat flour are represented.

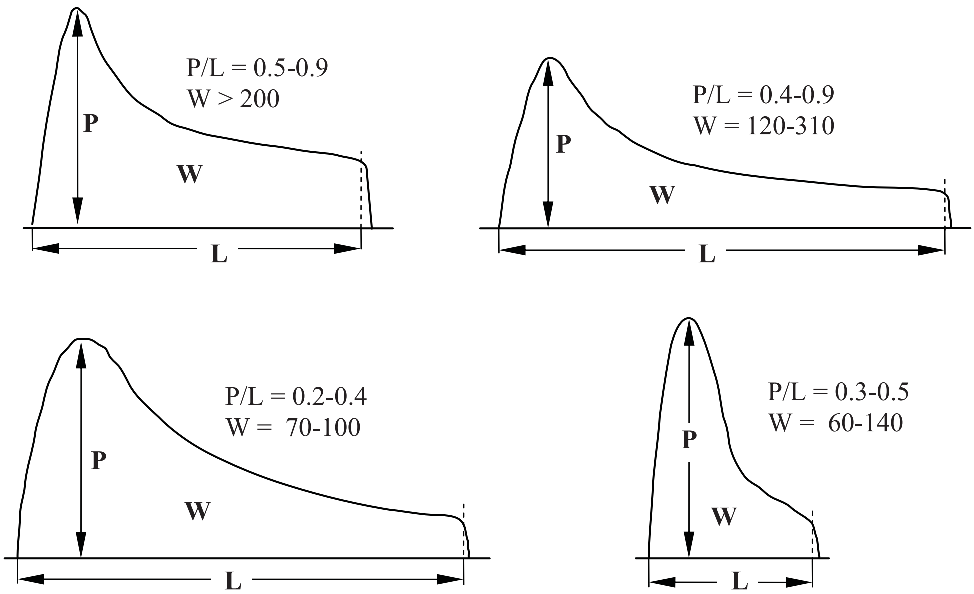

Fig. 2 Specific alveograph curves, for different varieties of flour, [18]
a. very good flour for bakery, strong dough with an excellent bakery potential (high pressure P and long time until burst L); b. good flour for bakery – almost types have an adequate potential for bake (ratio P/L has lower values); c. good flour for biscuits, but for bakery products it must be blended with hard wheat (it result an extensible dough good for biscuits – low pressure P, long time L, low surface W under curve); d. flour not good for bakery, used only for feed (it result a hard dough, without elasticity, high pressures and short time until brake)

A great importance for the dough characterisation and for the type of flour is represented by the alveograph curves ratio P/L. How the values from table 1 and the curve shapes from fig.4 indicate, this ratio has large range values that indicate great variations of the dough rheological characteristics.

So, for the dough obtained from flour type FA-480, the P/L index was in a very wide range of values from 0.24 to 1.48, which specify that the flours, although they are used in pastry, can't be used all of them for every kind of products.

For the flours type FA-550 and FA-650, especially used for bakery (white bread), the values of the P/L index were in the range 0.47–1.07, with large variations which indicate that the bakery products may have different characteristics, if there are not used specific improvers and bakery looses, in the technological process.

Taking into account the gluten content, for the dough from black flour type FN-1250 (ash content 1.25%), the index P/L has high values, which demonstrate a high elasticity for the dough, although, in general, the bread obtained from this kind of flour has a lower volume.

To check relation (8), it was determined by planimetry, with a polar planimeter, the surface under the alveograph curve. The conclusion was that obtained values are in the range of the values indicated in the table 1, with a deviation of ±2.7%.

Knowing the alveogram parameters for different dough obtained from different types of flour, it may be obtained adequate blends so that the flours parameters improve. A model of use for the alveograms is presented in fig.3, in which from 80% flour type A, with the alveogram parameters P=110, G=22.8 and W=400 and 20% flour type B, with the parameters P=55, G=20.2 and W=160, is obtained a flour type C with the alveogram parameters P=66, G=20.7 and, respectively, W=210.

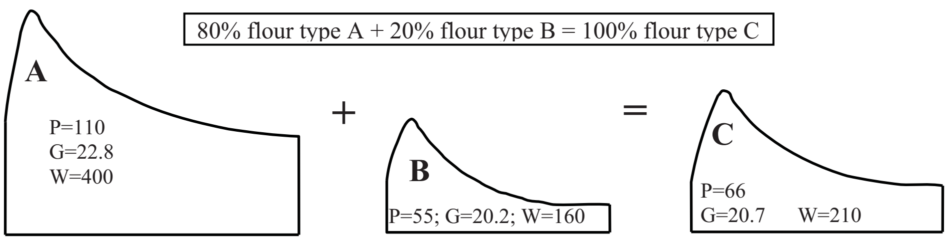

Fig. 3 An using mode of alveograph curves to improve the quality of a flour, [20]

CONCLUSIONS

The physical and rheological characteristics of the wheat flours and the doughs obtained have very large variations, both as function of the mineral content and of the extraction degree, respectively of the gluten content and its quality. Arise from the results of our researches presented in the paper, that the ash content, even if it is mostly placed in the central part of the seed, has not a significantly influence on the gluten content.

The greatest number of flour samples type F-650 (ash content 0.65%) has ratio P/L at the value 1 (over 0.83), but there are samples at which this ratio is lower (under 0.68 – samples 9, 14, 18, 19).

The gluten content do not influence the shape of the alveograph curves, so there are samples with close gluten contents (ex. samples 1, 4, 18, 19, 22), but with index P/L much different. There are samples with the same ash content (F-480 – 0.48%), but with different gluten contents (samples 1, 5), respectively 28.8 and 26.8, at which index P/L varies in large limits (1.48 and 0.24), which presumes a very different gluten quality, although this flours are mainly used for pastry; it will result in this situations products with volumes much different and therefore the flours must be used mainly, for different types of products.

The results and conclusions of this paper have a great importance for the specialists in the field of baking to adopt the best working conditions for the process equipments.

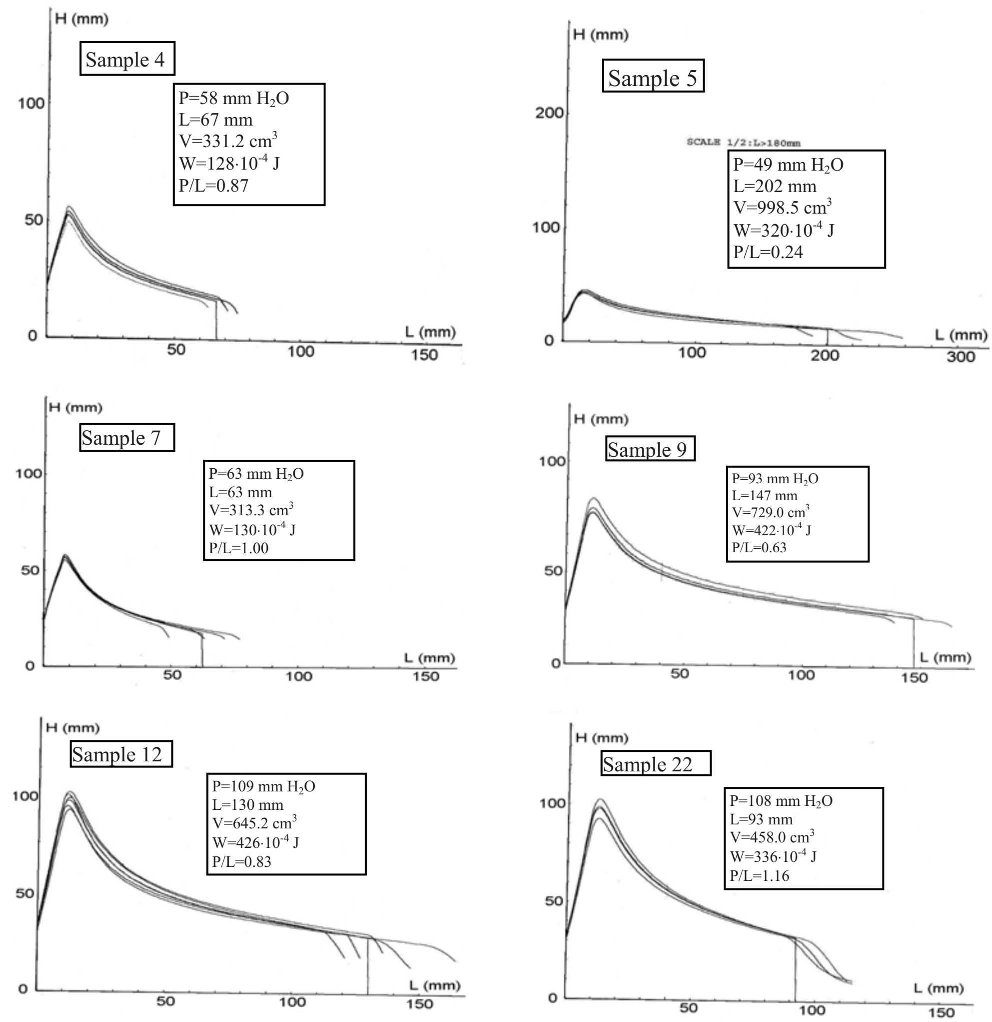

Fig. 4 Alveograph curves obtained for doughs from different kinds of romanian wheat flour and their rheological properties

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39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

OPTIMAL SIZE OF THE AUXILIARY HEATING BOILER IN A TRI-GENERATION SYSTEM

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ABSTRACT

The aim of this paper is to find the optimal size of the auxiliary heating boiler integrated into micro- combined cooling, heating and power system. The mCCHP system supplies for residential homes not connected to grid power, heat and cooling using only biogas, wood pellets and solar energy. The method of thermoeconomic optimisation is used to find the boiler optimal size for a given capital cost and period of operation.

Key words *cost, boiler, exergy, thermodynamic irreversibility, heat transfer area, optimisation*

INTRODUCTION

The components of the micro-combined cooling, heating and power system (mCCHP) developed at ‘Dunarea de Jos” University of Galați are: a micro CHP system driven by a Stirling engine; a low-temperature heat-exchanger with heat accumulation; an adsorption-chiller which produces cold water; solar collectors which produces hot water; two cooling towers; a tank for cool water storage and a wood pellet boiler which produces additional heat to cover the peak demand. The energy demand consists of: heating and hot water (40.5 kW); cold water (38.7 kW) and electricity (3 kW).

The best sizing of boiler is necessary to optimise the system efficiency. The heat demand could be covered by a larger boiler in a shorter period working at the nominal capacity or in a larger period working at reduced load, and as well as by a smaller boiler in a longer period. The thermodynamic performance of a boiler depends on load. It is highest at a certain partial load, depending on the boiler construction. For this it is necessary to know the efficiency versus load characteristics for each boiler and to select the boiler that is best suited to operate at a given load. Boiler that is sized beyond the optimal output capacity, (oversized boiler), will have lower efficiency.

Properly sized boilers will also reduce maintenance costs by starting and stopping less frequently. Oversized boiler wastes fuel and, because of short cycling, ultimately shorten the life of the system. Optimally sized equipment operates more efficiently by cycling properly, thus saving fuel [4].

The total heat transfer area affects most directly both the efficiency and the capital cost of boiler. In fact, increasing the heat transfer area, the boiler cost increases, but the efficiency increases too, which means fuel savings. Using the thermoeconomic optimisation we may determine for boiler the optimal heat transfer area for a given number of operating hours and capital cost [3].

PROBLEM FORMULATION

By thermoeconomic optimisation of a system we achieve for a given system structure, a balance between expenditure on capital costs and exergy costs which will give a minimum cost of the plant product [3]. The thermoeconomy is useful in optimisation of geometric parameters of the elements of a system to maximise component efficiency for a given capital cost.

For optimization of boiler heat transfer area the actual cost of boiler operation during a year was considered as objective function, which can be expressed as:

$$C_t(A) = \tau_o \cdot \dot{C}^O(A) + \tau_o \cdot \dot{Z}_b^{CI}(A) + C_b \tag{1}$$

where:

τ_o - annual operation period (h);

$\dot{C}^O(A)$ -cost rate associated with boiler operating and maintenance that depend on heating surface (€). It consists in exergy cost rate spent by boiler operation (exergy cost rate of fuel and cost rate of electricity consumed by auxiliary installations of the boiler: circulation pump, air fan, etc.). As the coat rate of electricity is much smaller than the exergy cost rate of fuel, we may write:

$$\dot{C}^O(A) = c_{in} \cdot \dot{E}_{in}(A) \tag{2}$$

where:

c_{in} - unit cost of input exergy (€/kWh);

$\dot{E}_{in}(A)$ - boiler input exergy rate dependent on boiler heating surface (kW);

C_b – the part of annual cost which is independent of the boiler heating surface (€);

$\dot{Z}_b^{CI}(A)$ -cost rate associated with boiler capital investment (€/h):

$$\dot{Z}_b^{CI}(A) = \frac{C\dot{A} \cdot \varphi}{3600 \cdot \tau_o} \tag{3}$$

φ =1.06 is maintenance factor

Annual capital cost:

$$C\dot{A}_m = PW \cdot CRF(i,n) \text{ [€/an]} \tag{4}$$

The present worth of boiler:

$$PW = C_k - S \cdot PWF(i,n) \text{ [€]} \tag{5}$$

i =10% is annual rate of return;

n =25 years is boiler life period;

$C_k(A)$ – boiler capitalized cost (€);

Salvage venue:

$$S = C_k \cdot j \tag{6}$$

j =12% is effective rate of return

Present value:

$$PWF = \frac{1}{(1+i)^n} \tag{7}$$

Capital recovery factor:

$$CRF = \frac{i(i+1)^n}{(i+1)^n - 1} \tag{8}$$

Substituting equations (2) to (8) in equation (1), the total annual cost of boiler operation becomes:

$$C_t(A) = \tau_o \cdot c_{in} \cdot \dot{E}_{in}(A) + C_b + C_k(A) \cdot i \cdot \frac{(1+i)^n - j}{(1+i)^n - 1} \ [€] \tag{9}$$

Writing the derivative of the objective function with respect to heating area we get:

$$\frac{dC_t}{dA} = \tau_0 \cdot c_{in} \frac{d\dot{E}_{in}}{dA} + i \cdot \frac{(1+i)^n - j}{(1+i)^n - 1} \frac{dC_k}{dA} \tag{10}$$

As the boiler heating area (A) affects the boiler performance, any variation in size of heating area will cause changes in the irreversibility rate of the boiler ($\dot{I}_t$).

The exergy balance for boiler is:

$$\dot{I}_t(A) = \dot{E}_{in}(A) - \dot{E}_{out} \ [\text{kW}] \tag{11}$$

where the output exergy rate of the boiler ($\dot{E}_{out}$) is independent of *A*.

The derivative with respect to heating area of equation (11) is:

$$\frac{d\dot{I}_t}{dA} = \frac{d\dot{E}_{in}}{dA} \tag{12}$$

Introducing equation (12) in equation (10) we obtain:

$$\frac{dC_t}{dA} = \tau_0 \cdot c_{in} \frac{d\dot{I}_t}{dA} + i \cdot \frac{(1+i)^n - j}{(1+i)^n - 1} \frac{dC_k}{dA} \tag{13}$$

To optimise, we make equation (13) zero and obtain:

$$\frac{d\dot{I}_t}{dA} = -\frac{i}{\tau_0 \cdot c_{in}} \frac{(1+i)^n - j}{(1+i)^n - 1} \frac{dC_k}{dA} \tag{14}$$

Considering that the main thermodynamic irreversibility form in boiler is that due to heat transfer over a finite temperature difference and considering the heat exchange at constant temperature, the irreversibility rate of boiler is:

$$\dot{I}_t = \dot{Q}_u T_0 \left(\frac{1}{T_w} - \frac{1}{T_g} \right) \text{ [kW]} \tag{15}$$

$$\dot{Q}_u = U \cdot A \cdot \left(T_g - T_w \right) \text{[kW]} \tag{16}$$

where:

U - the overall heat transfer coefficient (kW/(m^2·grad));

T_w, T_g – average temperature of heated water and flue gas, respectively, (K).

The capital cost of the boiler can be expressed as a linear function of its heat transfer area:

$$C_k = C_{kf} + C_{ks} \cdot A \tag{17}$$

With equations (15), (16) and (17) the equation (14) becomes:

$$\frac{\dot{Q}_u^2 \cdot T_0}{U \cdot T_w \cdot T_g \cdot A^2} = \frac{i}{\tau_0 \cdot c_{in}} \frac{(1+i)^n - j}{(1+i)^n - 1} C_{ks} \tag{18}$$

From this equation we obtain the optimal heating area:

$$A_{opt} = \sqrt{\frac{\tau_o \cdot \dot{Q}_u^2 \cdot T_0 \cdot c_{in} \cdot \left[(1+i)^n - 1 \right]}{i \cdot \left[(1+i)^n - j \right] \cdot U \cdot T_g \cdot T_w \cdot C_{ks}}} \text{ [m}^2\text{]} \tag{19}$$

The unit cost of input exergy is:

$$c_{in} = 3600 \frac{c_f}{E_f} \text{ [€/kWh]} \tag{20}$$

in which:

c_f – fuel cost, €/kg;

E_f – fuel exergy. For biomass it is given by equation [3]:

$$E_f = \beta \cdot \left(LHV + 2442 \frac{W^i}{100} \right) + 9417 \frac{S^i}{100} \text{ [kJ/kg]} \tag{21}$$

where β is given by the following equations:

- for fuels with the mass ratio $\frac{O^i}{C^i} < 0.667$:

$$\beta = 1.0438 + \frac{0.1882 \cdot H^i + 0.0610 \cdot O^i + 0.0404 \cdot N^i}{C^i} \tag{22}$$

- for fuels with the mass ratio $2.67 > \frac{O^i}{C^i} > 0.667$:

$$\beta = \frac{1.0438 + 0.1882 \frac{H^i}{C^i} - 0.2509 \left(1 + 0.7256 \frac{H^i}{C^i} \right)}{1 - 0.3035 \frac{O^i}{C^i}} + \frac{0.0383 \frac{N^i}{C^i}}{1 - 0.3035 \frac{O^i}{C^i}} \tag{23}$$

H^i, C^i, O^i, N^i, S^i, W^i, – mass fractions of H, C, O, N, S and water respectively in fuel.

RESULTS AND DISCUSSION

We consider a heating boiler with wood pellets having the following constructive and operational characteristics:

- average cost of wood pellets: c_f= 0.1 €/kg;
- thermal boiler power: $\dot{Q}_u$ = 42 kW;
- average temperature of flue gas inside the boiler: T_g = 900 K;
- average temperature of water inside the boiler: T_w = 360 K;
- overall heat transfer coefficient: U = 0.4 kW/(m^2·K).

In figure 1 is shown the variation of optimal heat transfer area as function of investment cost and yearly operating period. It can be noticed the surface decreases with the increase of investment cost and the decrease of average operating period. For an investment cost of 300 €/m^2 and an average yearly operating period of 1000 hours corresponds the boiler surface of 1.5 m^2.

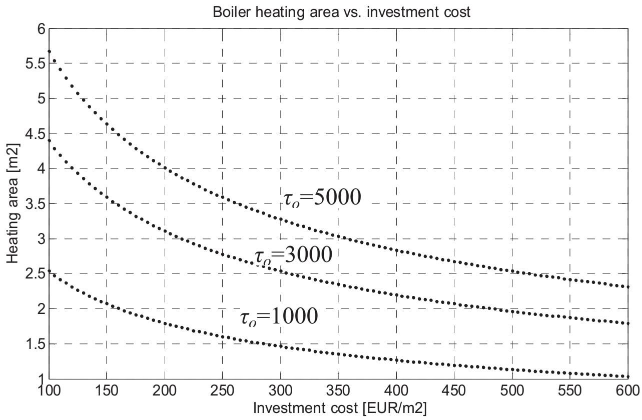

Fig. 1 Variation of optimal heat exchange surface with the average investment cost and operating period in a year

CONCLUSIONS

By thermoeconomic optimisation of the heating boiler was found the optimal size that corresponds to the minimum annual total cost of boiler operation. The optimal size (determined by the heating transfer area) decreases with the increase of investment cost and the decrease of average annual operating period.

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39.
SIMPOZIJ
AKTUALNI
ZADACI
MEHANIZACIJE
POLJOPRIVREDE

UDK
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Stručni rad
Expert paper

UTJECAJ STROJNE MUŽNJE NA STANJE SISA MUZNIH KRAVA

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SAŽETAK

U radu se prate promjene nekih parametara sisa muznih krava kao posljedica strojne mužnje. Za snimanje je korišten ultrazvučni uređaj GE Medical Systems LOGIQ 100 PRO s linearnom sondom VE 5 – 5 MHz. Istraživanje je provedeno na farmi Srednje gospodarske škole u Križevcima na 27 krava, od čega je 19 krava Holstein frizijske pasmine, 2 krave Simentalske pasmine, 4 krave su križanci Simentalske i Holstein frizijske pasmine, a 2 Simentalske pasmine i Crvenog Holsteina. Farma je sa slobodnim načinom držanja s mužnjom u izmuzištu „riblja kost“ 2x3 opremljenom Alfa-Lavalovom opremom za mužnju s Duovac sustavom. Snimanje je provođeno prije jutarnje mužnje i neposredno nakon mužnje na prednjoj i stražnjoj desnoj sisi vimena, a snimani su slijedeći parametri: dužina sisnog kanala (DSK), širina vrha sise (ŠVS), širina cisterne sise (ŠCS) i debljina stijenke sise (DSS). Kao peti i šesti parametar izračunavan je omjer dužine sisnog kanala i širine vrha sise (DSK/ŠVS) i širine cisterne sise i debljine stijenke sise (ŠCS/DSS). Dužina sisnog kanala prednje desne sise bila je nakon mužnje u prosjeku za 1,7 mm (15,4 %) veća nego prije mužnje, odnosno za 2,6 mm (24,3%) kod stražnje desne sise. Širina vrha sise bila je u prosjeku 0,8 mm (3,7%) veća nakon mužnje kod prednje desne sise, tj. 0,7 mm (3,3%) kod stražnje desne sise. Širina cisterne sise smanjila se je u prosjeku za 2,7 mm (24,4%) na prednjoj desnoj sisi, a na stražnjoj za 2,9 mm (25,8%). Debljina stijenke prednje desne sise povećala se je nakon mužnje za 0,5 mm (7,86%), a stražnje za 1,1 mm (15,8%). Omjer dužine sisnog kanala i širine vrha sise (DSK/ŠVS) za prednju desnu sisu iznosio je prije mužnje u prosjeku 0,525, a nakon mužnje 0,584, dok je kod zadnje desne sise taj omjer bio prije mužnje 0,501, a nakon mužnje 0,603. Omjer širine cisterne sise i debljine stijenke sise (ŠCS/DSS) bio je prije mužnje u prosjeku 1,544, a nakon mužnje 1,082 za prednju desnu sisu, odnosno 1,541 i 0,987 za stražnju desnu sisu.

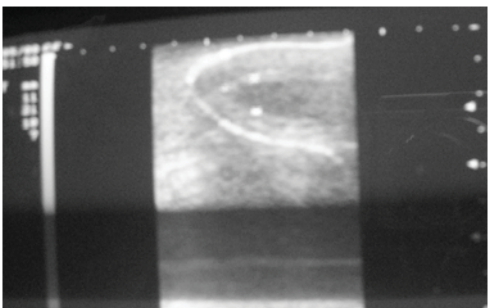
Ključne riječi: *strojna mužnja, muzne krave, sisa, stanje sisa, ultrazvučno snimanje*

UVOD

Strojna mužnja je svakodnevni rutinski postupak na farmama mliječnih krava koji se provodi najčešće dva puta dnevno tijekom laktacije. Kao posljedica djelovanja podtlaka i pulsacija tijekom strojne mužnje javljaju se određene promjene stanja tkiva sisa kao što su naticanje sisa tj. promjena širine vrha sise, promjene dimenzija cisterne sise i sisnog kanala, promjene debljine stijenke sise, boje sise, formiranje prstenastog kalusa na vrhu sise i sl. Neke od tih promjena su kratkoročne i u pravilu se sisa oporavlja u periodu između dvije mužnje, a neke mogu biti dugoročne te dovesti i do kroničnih promjena koje rezultiraju većom pojavnošću mastitisa. Naime, sise predstavljaju prvu liniju obrane od mastitisa (Neijenhuis, 2001). Povećanje debljine vrha sise nakon strojne mužnje za više od 5 % povećava kolonizaciju sisnog kanala mikroorganizmima (Zecconi i sur., 1992). S ciljem utvrđivanja utjecaja strojne mužnje na stanje sisa muznih krava, provedeno je istraživanje na mliječnoj farmi Srednje gospodarske škole u Križevcima.

MATERIJAL I METODE

Istraživanje je provedeno na farmi muznih krava Srednje gospodarske škole u Križevcima na 27 krava, od kojih je 19 Holstein frizijske pasmine, 2 Simentalske pasmine, 4 križanke Simentalske i Holstein frizijske pasmine i 2 križanke Simentalske pasmine i Crvenog Holsteina. Šest krava bilo je u prvoj laktaciji, osam u drugoj, sedam u trećoj, dvije u četvrtoj i četiri u petoj laktaciji. Farma je sa slobodnim načinom držanja krava, a mužnja se provodi dvaput dnevno u izmuzištu riblja kost 2x3 s Alfa-Lavalovom opremom za mužnju s Duovac muznim jedinicama.



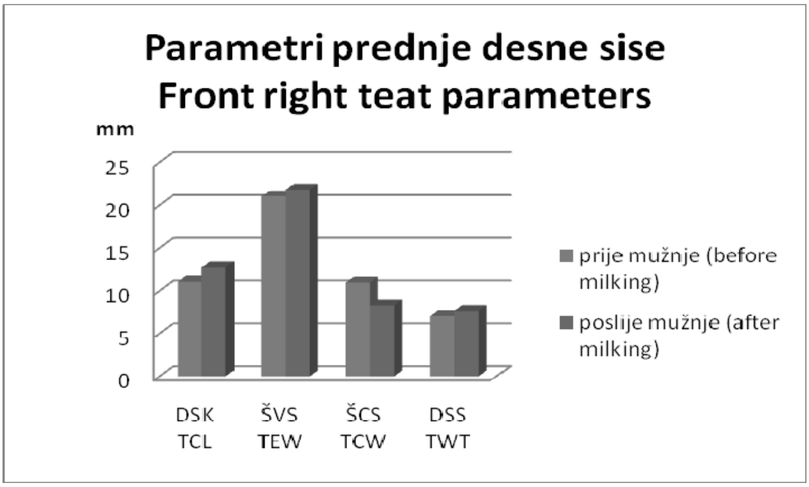
Slika 1 Ultrazvučno skeniranje sise vimena (foto: M. Stojnović)
Fig. 1 Ultrasonographic scanning of teat (photo: M. Stojnović)

Za snimanje promjena parametara sisa korišten je ultrazvučni uređaj GE Medical Systems LOGIQ 100 PRO s linearnom sondom VE 5 – 5 MHz. Snimanje je provođeno prije jutarnje mužnje i neposredno nakon mužnje na prednjoj i stražnjoj desnoj sisi vimena, a snimani su slijedeći parametri: dužina sisnog kanala (DSK), širina vrha sise (ŠVS) na početku sisnog kanala, širina cisterne sise (ŠCS) i debljina stijenke sise (DSS) 1 cm od završetka cisterne sise. Kao peti i šesti parametar izračunavan je omjer dužine sisnog kanala i širine vrha sise (DSK/ŠVS) i širine cisterne sise i debljine stijenke sise (ŠCS/DSS). Sama tehnika snimanja sastojala se je od uranjanja sise u mlaku vodu u plastičnoj vrećici i indirektnog snimanja sise pomoću sonde s vanjske bočne strane, uz korištenje kontakt gela radi dobivanja jasne slike. Određivanjem referentnih točaka na "zamrznutoj" slici dobivene su vrijednosti snimanih parametara (slika 1).

Statističkom obradom prikupljenih podataka dobivene su srednje vrijednosti mjerenih parametara i razlike u parametrima kao posljedica strojne mužnje.

REZULTATI I DISKUSIJA

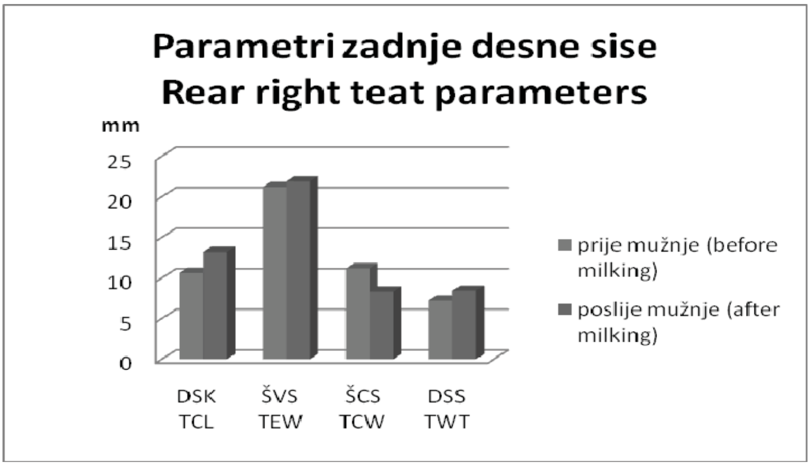
Rezultati ultrazvučnog snimanja parametara sisa prije i poslije mužnje prikazani su u grafikonima kao prosječne vrijednosti u mm za prednju i stražnju desnu sisu.



Grafikon 1 Srednje vrijednosti parametara prednje desne sise prije i poslije mužnje
Graph 1 Mean values of front teat parameters before and after milking

U grafikonu 1 prikazane su prosječne vrijednosti parametara za prednju desnu sisu. Dužina sisnog kanala prednje desne sise nakon mužnje bila je prosječno veća za 1,7 mm ili 15,4%. Širina vrha sise nakon mužnje prosječno je povećana za 0,8 mm ili 3,7%, dok je širina cisterne sise smanjena prosječno za 2,7 mm ili 24,4%. Debljina stijenke sise u prosjeku je povećana za 0,5 mm ili 7,86%.

U grafikonu 2 prikazane su promjene parametara stražnje desne sise nakon mužnje. Dužina sisnog kanala bila je u prosjeku veća za 2,6 mm ili 26,3%, širina vrha sise bila je prosječno veća za 0,7 mm ili 3,3%, širina cisterne sise smanjila se za 2,9 mm ili 25,8%, a debljina stijenke sise prosječno je povećana za 1,1 mm ili 15,8%. Izračunavanjem omjera dužine sisnog kanala i širine vrha sise (DSK/ŠVS) prije i poslije mužnje dobivena je prosječna promjena s 0,525 na 0,584 za prednju desnu sisu, odnosno s 0,501 na 0,603 za stražnju desnu sisu. Isto tako, promijenjen je i prosječan omjer između širine cisterne sise i debljine stijenke sise (ŠCS/DSS) s 1,544 na 1,082 za prednju desnu sisu, odnosno s 1,540 na 0,987 za stražnju desnu sisu.



Grafikon 2 Srednje vrijednosti parametara stražnje desne sise prije i poslije mužnje
Graph 2 Mean values of rear teat parameters before and after milking

ZAKLJUČAK

Rezultati dobiveni ultrazvučnim snimanjem parametara sisa muznih krava prije i poslije strojne mužnje ukazuju na slijedeće:

1. Strojna mužnja uzrokuje svakodnevne promjene stanja sisa muznih krava.
2. Dužina sisnog kanala (DSK) u prosjeku se povećala nakon mužnje za 15,4 % kod prednje desne sise, odnosno za 26,3 % kod stražnje desne sise.
3. Širina vrha sise (ŠVS) u prosjeku se povećala nakon mužnje za 3,7% kod prednje desne sise, odnosno za 3,3% kod stražnje desne sise.
4. Širina cisterne sise (ŠCS) smanjila se nakon mužnje prosječno za 24,4% za prednju desnu sisu, odnosno za 25,8% za stražnju desnu sisu.
5. Debljina stijenke sise (DSS) povećana je nakon mužnje prosječno za 7,86% za prednju desnu sisu, odnosno za 15,8% za stražnju desnu sisu.
6. Promjena širine vrha sise nakon strojne mužnje manja je od 5%, što, prema Zecconiju, ne ukazuje na povećanu vjerojatnost od kolonizacije sisnog kanala patogenim mikroorganizmima.

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INFLUENCE OF MACHINE MILKING ON TEAT CONDITION OF DAIRY COWS

SUMMARY

The paper deals with changes of some teat parameters of dairy cows caused by machine milking. Ultrasonographic scanner GE Medical Systems LOGIQ 100 PRO with linear array VE 5 – 5 MHz probe was used for scanning the teats. Scanning was conducted on a dairy farm at the Agricultural High School in Križevci on 27 cows, nineteen of them of Holstein Friesian breed, 2 Simmental breed, 4 SimmentalxHolstein crossbred and 2 SimmentalxRed Holstein crossbred. The cows were housed in a free stall barn and milked in a herringbone 2x3 milking parlour with Alfa-Laval milking system with Duovac milking units. Teat scanning was done just before morning milking and immediately after milking on the right side of the udders for front and rear teats. The following parameters were measured: teat canal length (TCL), teat end width (TEW), teat cistern width (TCW) and teat wall thickness (TWT). As fifth and sixth parameter ratio between teat canal length and teat end width (TCL/TEW), and teat cistern width and teat wall thickness (TCW/TWT) was calculated. Length of teat canal for the front right teat increased in average for 1.7 mm (15.4%) after milking, and 2.6 mm (26.3%) for the rear right teat. Teat end width of the front and rear right teat increased after milking for 0.8 mm (3.7%) and 0.7 mm (3.3%), respectively. Mean teat cistern width of the front right teat decreased after milking for 2.7 mm (24.4%) while for the rear right teat mean decrease was 2.9 mm (25.8%). Teat wall thickness of the front and rear right teat increased after milking for 0.5 mm (7.86%) and 1.1 mm (15.8%) respectively. The ratio between teat canal length and teat end width changed for the right front teat from 0.525 before milking to 0.584 after milking, while for the right rear teat it changed from 0.501 to 0.603. The ratio between teat cistern width and teat wall thickness changed for the right front teat from 1.544 before milking to 1.082 after milking, and for the right rear teat from 1.54 to 0.987.

Key words: *machine milking, dairy cows, teat, teat condition, ultrasonographic scanning*

39. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.544.7:635.5
Prethodno priopćenje
Preliminary communication

ENERGY EFFICIENCY OF THE LETTUCE GREENHOUSE PRODUCTION

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ABSTRACT

In this paper the influence of greenhouse construction on energy efficiency in winter lettuce production was estimated for different double plastic covered greenhouses in Serbia region. In order to see whether the greenhouse structure influences energy consumption, energy inputs were estimated for lettuce production in four different greenhouse structures (a tunnel and gutter connected structure and three multi-span greenhouses). On the basis of lettuce production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated. Results show that the lowest energy consumption was obtained for gutter connected greenhouse with two bays, 3.11 MJ/m^2. The highest energy consumption was multi-span greenhouse with thirteen bays, 3.30 MJ/m^2. The highest value for output-input ratio was calculated for the multi-span greenhouse with thirteen bays, 0.85 and the lowest for the tunnel structure, 0.47. Regression equations show the nature of the greenhouse structure influence on these parameters.

Key words: *Plastic covered greenhouses, lettuce, tunnel, gutter connected structures, multi-span structures, energy, productivity.*

INTRODUCTION

Greenhouse plant production is one of the most intensive parts of the agricultural production. It is intensive in the sense of yield (production) and in whole year production, but also in sense of the energy consumption, investments and costs (Canakci and Akinci, 2006, Sethi and Sharma, 2007, Singh et al., 2007). In order to reduce the costs and save the energy, various greenhouse constructions and different coverings are offered to the farmers (Nelson, 2003, Hanan, 1998). One of the biggest problems is in winter production when additional heating and light are needed (Damjanovic et al., 2005, Enoch, 1978, Momirovic, 2003, Sethi and Sharma, 2007). During that period construction and coverings fully show their qualities. One of the most common vegetables in Serbia is lettuce. It is grown in greenhouses as well as in open field, and it can be found on the market during whole year. The most important growth factors for the lettuce production are temperature and light (Momirovic, 2003). Concerning the temperature during germination optimal temperature should be 12 - 15° C. The same temperatures should be maintained during the vegetation so that the lettuce head is formed nice and solid. In the winter production these conditions cannot be achieved without additional heating. The most common greenhouse structures in Serbia are tunnels covered with the double PE UV AD folia. However, lately there is a tendency of introducing gutter connected and multi-span greenhouses. This tendency is motivated by the fact that crop rotation is more viable in these structures (Stevens, 1994).

The aim of this paper was to estimate greenhouse energy consumption and the energy efficiency for the winter lettuce production in order to see if and how the different types of greenhouse construction influence energy consumption for a given plant production.

MATERIAL AND METHOD

Influence of greenhouse construction on energy consumption was estimated for four different double plastic covered greenhouses. For the research a tunnel type, 5.5 x 24 m covered with 180 µm PE UV IR outside folia (Figure 1), a gutter connected plastic covered greenhouse 21 x 250 m and with 50 µm inner folia and 180 µm outside folia (Figure 2), a multi-span greenhouse 4 x 8 m wide and 51 m long with 50 µm inner folia and 180 µm outside folia (Figure 3a) and a multi-span greenhouse 13 x 12 m wide and 67.5 m long, with 50 µm inner folia and 180 µm outside folia (Figure 3b) were used.

The experiment was carried out at a private property near Novi Sad (Serbia) on 19°51E altitude and 45°20N latitude and at a private property near Jagodina (Serbia) on 21°16E altitude and 44°1N latitude.

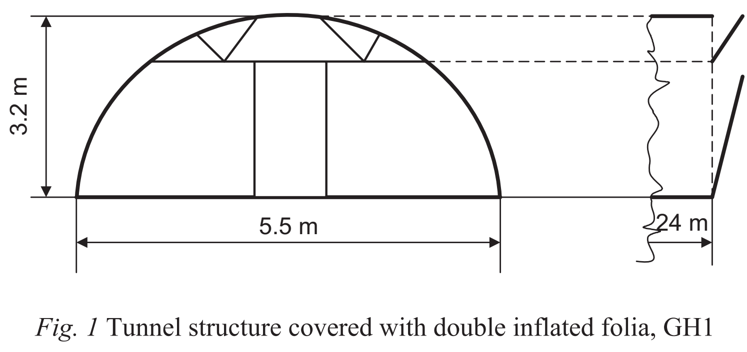

Fig. 1 Tunnel structure covered with double inflated folia, GH1

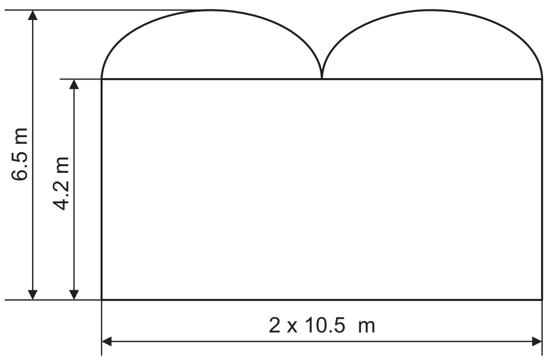

Fig. 2 Gutter-connected greenhouse covered with double inflated folia, GH2

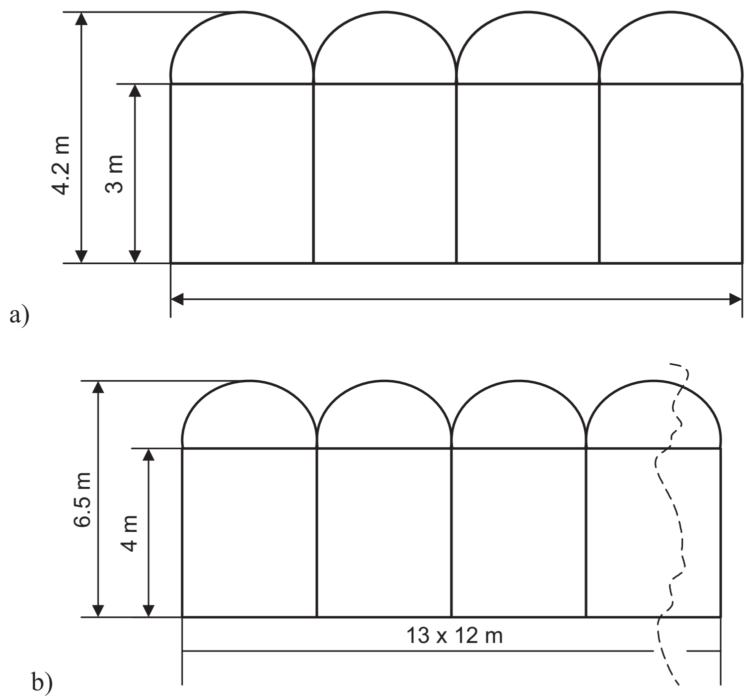

Fig. 3 Multi-span greenhouses covered with double inflated folia, GH3 and GH4

The method used for the energy efficiency analysis (Ortiz-Cañavate, 1999, Djevic and Dimitrijevic, 2004, Hatirli et al., 2006, Ozkan et al., 2007, Mani et al., 2007, Khan and Singh, 1996, Canakci and Akinci 2006) is based on the energy input analysis (definition of direct and indirect energy inputs), calculation of the energy consumption for a given plant production and the energy efficiency. On the basis of lettuce production output and the energy input, specific energy input, energy output-input ratio and energy productivity were estimated as follows:

$$\text{Energy input/kg of product (EI)} = \frac{\text{energy input for production [MJ/m}^2\text{]}}{\text{output [kg/m}^2\text{]}} \qquad (1)$$

$$\text{Energy out/in ratio (ER)} = \frac{\text{energy value of production [MJ/m}^2\text{]}}{\text{energy input for the production [MJ/m}^2\text{]}} \qquad (2)$$

$$\text{Energy productivity (EP)} = \frac{\text{production [kg/m}^2\text{]}}{\text{energy input for the production [MJ/m}^2\text{]}} \qquad (3)$$

The energy inputs were calculated by multiplying the material input with the referent energy equivalent. Energy equivalents for different material inputs as well as for the lettuce output were obtained from different sources (Enoch, 1978, Ortiz-Canavate and Hernanz, 1999, Badger, 1999).

Information on energy input and energy output was entered into Excel spreadsheets and the energy parameters were calculated according to equations 1 - 3.

Lettuce was planted in all greenhouses in November 2008 and harvested in February 2009. In all greenhouses 20 plants per m^2 were planted on the 2 m wide white/black mulch folia 25µm thick. Quantities of the used material were measured using common weighing instruments.

Statistical analysis included the linear regression model. The parameter that was used to describe differences in constructions was the greenhouse covering / production surface ratio. The obtained data and the calculated values were imported in Microsoft Excel 2000 for the statistical analysis.

RESULTS AND DISCUSSION

Energy inputs in plant production can be classified as direct and indirect energy inputs (Ortiz-Cañavate, 1999, Agarwal, 1995, Canakci and Akinci, 2006, Ozkan et al., 2007). Energy of fuel for technical systems and electricity were classified as direct energy inputs and fertilizers, plant protection chemicals, water for irrigation, human labor, technical systems and boxes for lettuce packaging were classified as indirect energy inputs. The obtained values are shown in table 1.

A parameter that can be used to compare the energy consumption for different greenhouse constructions is the specific energy input, MJ/m^2. This parameter showed different values for different greenhouse constructions (tab. 1). The lowest value was calculated for the gutter-connected greenhouse (3.11 MJ/m^2). The other greenhouses had 1.3 - 6.1% higher energy consumption, compared to the gutter structure.

Table 1 Energy consumption for the winter lettuce production in the greenhouses

	Tunnel structure, GH1		**Gutter connected structure, GH2**		**Multi-span structure, GH3**		**Multi-span structure, GH4**	
Direct energy inputs	Quantity	Energy	Quantity	Energy	Quantity	Energy	Quantity	Energy
Diesel, l	1.40	66.92	70.00	3346.00	10.61	507.16	48.58	2322.12
Electricity, kWh	15.30	55.08	1246.04	4485.74	387.34	1394.42	2499.19	8997.08
Indirect energy inputs								
Nutrients								
Nitrogen, kg	0.13	10.23	12.38	974.31	7.77	611.50	50.53	3976.71
Phosphorus, kg	0.13	2.26	3.75	65.25	15.66	272.48	101.07	1758.62
Potassium, kg	0.26	3.56	24.38	334.01	27.65	378.81	178.63	2447.23
Plant protection chemicals								
Pesticides, kg	0.002	0.39	8.35	1661.65				
Fungicides, kg	1.50	138.00	2.00	184.00	0.24	22.08	1.55	142.60
Insecticides, kg								
Water, m^3	2.01	18.09	90.00	810.00	5.38	48.42	34.71	312.39
Technical systems, h	0.50	6.53	3.87	50.54	3.38	44.14	21.55	281.44
Boxes, pieces	60	18.00	3934.00	1180.20	1402.00	420.60	9755.00	2926.50
Human labor, h	52.17	102.25	1643.87	3221.99	736.00	1442.56	5888.00	11540.48
Total, MJ		299.33		8481.94		3240.59		23385.97
Total, MJ/m^2	**3.19**			**3.11**		**3.15**		**3.30**

The structure of the consumed energy is given in table 2. It can be seen that share of direct energy input in total energy consumption varied from 29% (tunnel structure) to 48.01% (gutter-connected structure). In the gutter-connected and multi-span greenhouses, in direct energy input structure, energy input by electricity had the higher share compared to the fuel share.

The highest share in total energy consumption in tunnel structure had fungicides (32.8%) while in gutter-connected and multi-span structures human labor had the highest share and had varied form 19.75% up to 33.25%.

Table 2 The share of the energy inputs in overall energy consumption for the greenhouses

Energy input	Share of energy the inputs in overall energy consumption, %			
	Tunnel structure, GH1	Gutter-connected structure, GH2	Multi-span structure, GH3	Multi-span structure, GH4
Fuel for technical systems	15.90	20.51	9.86	6.69
Electricity	13.10	27.50	27.10	25.92
Nitrogen	2.43	5.97	11.90	11.46
Phosphorus	0.54	0.40	5.30	5.07
Potassium	0.85	2.04	7.37	7.05
Fungicides	32.80	1.12	0.43	0.41
Pesticides	0.09	10.19	0.00	0.00
Water	4.29	4.97	0.94	0.90
Technical systems	1.55	0.13	0.86	0.81
Boxes	4.27	7.24	8.18	8.43
Human labor	24.30	19.75	28.10	33.25
Total	100	100	100	100

Results in the literature (Hatirli et al., 2006, Ozkan et al., 2007, Enoch, 1978) show that highest share in total energy consumption have diesel fuel, human labor and fertilizers. In this case, the share of fertilizers for the production in the tunnel structure was only 3.82%, while in gutter-connected greenhouse it was 8.41%. In more intensive multi-span greenhouse production, the share of fertilizers was 24.57 - 23.58%. The structure of the energy bottom line can be explained by the higher humidity and lower temperatures in tunnel structure (fungicide share of 32.8 %) as well as with more stable temperature and solar radiation conditions in the case of gutter-connected and multi-span greenhouses.

The energy output was calculated based on the energy value for lettuce and obtained yield (tab.3). The highest yield was calculated for multi-span greenhouse GH4 (6.08 kg/m^2) and the lowest for the tunnel (3.30 kg/m^2). It can be seen that lettuce energy output was 49.34 - 84.2% higher in gutter and multi-span greenhouses compared to the tunnel structure.

Based on the measured energy inputs and the energy output, parameters for energy analysis were calculated (tab. 4). It can be seen that different values were obtained for different greenhouse structures regarding basic energy parameters. The higher values of energy input per kg of product were obtained for the tunnel structure compared to the gutter and multi-span structures. The highest energy input per kg of product was calculated for the tunnel structure, GH1, 0.97 MJ/kg, and the lowest value for this parameter was calculated for the multi-span greenhouse GH4, 0.54 MJ/kg. It can be seen that he specific energy input was 35.05 - 44.33% lower in the gutter-connected and multi-span greenhouses than in the tunnel structure. Energy output-input ratio had also showed different values for different greenhouse structures. Gutter-connected and multi-span greenhouses had 55.32 - 80.85% higher energy ratio compared to tunnel structures. Energy productivity also showed lower values for the tunnel structure. Lowest energy productivity was calculated for the tunnel, 1.03 kg/MJ. The multi-span greenhouse GH4 was calculated to be the structure with highest energy productivity of 1.85 kg/MJ. In average, energy productivity in gutter-connected and multi-span greenhouses was 54.37 - 79.61% higher than in the tunnel. This can lead to conclusion that Serbia region is suitable for the greenhouse production because this value for northern Europe in winter lettuce production (Enoch, 1978) is 0.002. All these parameters show that there should be advantage in energy consumption and energy productivity in using greenhouse structures that have a lower covering material surface / production surface ratio.

Table 3 Lettuce yield and energy output for the greenhouses

	Yield, kg	Specific yield, kg/m^2	Energy output, MJ	Specific energy output, MJ/m^2
Tunnel structure, GH1	435.00	3.30	200.10	1.52
Gutter-connected structure, GH2	25920.00	4.94	11923.20	2.27
Multi-span structure, GH3	8874.00	5.44	4082.00	2.50
Multi-span structure, GH4	64041.83	6.08	29459.24	2.80

In order to see if the previously showed differences in energy parameters are influenced by the greenhouse construction, statistical regression analysis was used. The covering material surface / production surface ratio was used as a parameter for describing the greenhouse construction (tab. 4). After importing these data in Microsoft Excel data analysis tool pack, equations 4, 5 and 6 were obtained. These equations gave relations between the calculated energy parameters and the greenhouse specific greenhouse volume.

Table 4 Parameters for the statistical analysis

Greenhouses	Covering material surface / production surface	Specific energy input, MJ/kg	Energy ratio	Energy productivity, kg/MJ
Tunnel, GH1	1.91	0.97	0.47	1.03
Gutter connected structure, GH2	1.62	0.63	0.73	1.59
Multi-span structure, GH3	1.44	0.58	0.79	1.73
Multi-span structure, GH4	1.30	0.54	0.85	1.85

In the case of energy input per kg of product the applied statistical method of linear regression showed that there is a strong correlation between specific energy input and greenhouse construction (92.4%). Equation obtained (eq. 4) gives relation between these two parameters and shows that the decreasing of energy consumption should be expected with the greenhouses with the lower covering material surface / production surface ratio.

$$y = -0.35 + 0.65\,x \tag{4}$$

If the energy ratio is analyzed it can be concluded that there is a strong correlation dependence between this parameter and greenhouse construction (92.74%). The correlation coefficient was estimated to be significant. Regression equitation shows that energy ratio will be higher in conditions of greenhouse structures that have a lower covering material surface / production surface ratio (eq. 5).

$$y = 1.67 - 0.57\,x \tag{5}$$

Similar results were obtained for the energy productivity. Analysis showed that there is a strong correlation between energy productivity and greenhouse type of construction (97%). Regression equitation shows that energy productivity will be higher in conditions of greenhouse structures that have a lower covering material surface / production surface ratio (eq. 6).

$$y = 3.5 - 1.23x \tag{6}$$

Presented results lead to the conclusion that in the sense of lowering specific energy input and having energy productivity higher, greenhouse structures with lower covering material surface / production surface ration should be used. The reason for this kind of tendencies can be searched in the more uniform microclimatic conditions in the gutter connected and the multi-span greenhouse. Also, the tunnels in this area were more susceptible to wind and there were more damaged lettuce heads in the tunnels near the sidewalls.

The obtained results can be helpful in suggesting producers what kind of greenhouse structures should they use in order to have a better energy efficiency, energy productivity and lower energy input per kg of product.

CONCLUSIONS

In the study, the energy input and output for different greenhouse construction in winter lettuce production was analyzed. The results of investigation indicate that in the total greenhouse energy consumption, direct and indirect energy inputs have approximately the same share. The specific energy consumption showed different values for different greenhouse constructions. Lowest value was obtained for the gutter-connected greenhouse and the highest for the multi-span greenhouse with the thirteen bays. Higher yield were obtained in the gutter and multi-span greenhouses compared to tunnel structures, due to better climatic conditions and better utilization of the fertilizer. The multi-span greenhouses also showed lower energy input per kg of product compared to the tunnel structure. The linear regression models were estimated as significant and had shown that the greenhouse structure has a significant influence on energy input, energy efficiency and productivity. The results show that lower covering material surface / production surface ratio can influence a lower energy input per kg of product, higher energy ratio and better energy productivity. Additionally, it can be concluded that the energy efficiency can also be higher with gutter-connected and multi-span greenhouses.

Further research will include more detailed investigations on characteristics of plastic covers and their influence on energy consumption. In order to investigate different growing mediums and their influence on energy consumption different plant species and production technologies will also be included. The results will be used for creating a model for optimal choice of greenhouse construction and covering material regarding energy consumption and energy efficiency.

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