Editorial

The National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry - INMA Bucharest has the oldest and most prestigious research activity in the field of agricultural machinery and mechanizing technologies in Romania.

Short History

- In 1927, the first research Center for Agricultural Machinery in Agricultural Research Institute of Romania - ICAR (Establishing Law was published in O.D. no. 97/05.05.1927) was established;
- In 1930, was founded The Testing Department of Agricultural Machinery and Tools by transforming Agricultural Research Centre of ICAR; that founded the science of methodologies and experimental techniques in the field (Decision no. 2000/1930 of ICAR Manager - GHEORGHE IONESCU ŞIŞESTI);
- In 1952, was established the Research Institute for Mechanization and Electrification of Agriculture - ICMA Băneasa, by transforming the Department of Agricultural Machines and Tools Testing;
- In 1979, the Research Institute of Scientific and Technological Engineering for Agricultural Machinery and Tools - ICSITMUA was founded - subordinated to Ministry of Machine Building Industry - MICM, by unifying ICMA subordinated to MAA with ICPMA subordinated to MICM;
- In 1996 the National Institute of Research-Development for Machines and Installations designed to Agriculture and Food Industry - INMA was founded – according to G.D. no.1308/25.11.1996, by reorganizing ICSITMUA, G.D no. 1308/1996 coordinated by the Ministry of Education and Research G.D. no. 825/2004;
- In 2008 INMA has been accredited to carry out research and developing activities financed from public funds under G.D. no. 551/2007, Decision of the National Authority for Scientific Research - ANCS no. 9634/2008.

As a result of widening the spectrum of communication, dissemination and implementation of scientific research results, in 2000 was founded the institute magazine, issued under the name of SCIENTIFIC PAPERS (INMATEH), ISSN 1583 – 1019.

Starting with volume 30, no. 1/2010, the magazine changed its name to INMATEH - Agricultural Engineering, appearing both in print format (ISSN 2068 - 4215), and online (ISSN online: 2068 - 2239). The magazine is bilingual, being published in Romanian and English, with a rhythm of three issues / year: January-April, May-August, September-December and is recognized by CNCSIS - with B+ category. Published articles are from the field of AGRICULTURAL ENGINEERING: technologies and technical equipment for agriculture and food industry, ecological agriculture, renewable energy, machinery testing, environment, transport in agriculture etc. and are evaluated by specialists inside the country and abroad, in mentioned domains.

Technical level and performance processes, technology and machinery for agriculture and food industry increasing, according to national requirements and European and international regulations, as well as exploitation of renewable resources in terms of efficiency, life, health and environment protection represent essential elements for the magazine INMATEH - Agricultural Engineering.

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MATHEMATICAL MODEL FOR STUDYING THE INFLUENCE OF TILLAGE TOOL GEOMETRY ON ENERGY CONSUMPTION

MODEL MATEMATIC PENTRU STUDIUL INFLUENȚEI GEOMETRIEI SCULELOR DE LUCRAT SOLUL ASUPRA CONSUMULUI DE ENERGIE

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Abstract: In this paper is developed a mathematical model for mechanical energy evaluation in the soil tillage process. A simple tool with plane cylindrical and cylindricaloid surfaces is used in order to describe the mathematical model. The mathematical equations developed include all the influence factors of the working processes: constructive parameters of tools, functional parameters of agricultural machine systems and soil parameters. A PC expert program is elaborated using the mathematical model. A numerical application is presented for validation of the developed mathematical model.

Keywords: mathematical model, soil tillage, energy evaluation

INTRODUCTION

The soil tillage is a process with high – energy consumption. The objective of mechanical manipulation of the soil designed to agricultural production is to create favourable soil conditions and environment to crop growth by changing bulk density, soil granulometry size distribution and other characteristics [5, 7].

The energy required to till the soil depends to a large extent on the physical properties of soil, operating conditions and the design parameters of the tillage tools. Reducing the energy to change the physical properties of the soil is an important consideration, since tillage tools consume a large portion of the energy required to produce the crop. Because of the large amount of energy involved in the process of soil cultivation, even small economy, which might be developed in this process, may have significant value [1, 2].

Tillage tools usually produce several effects simultaneously: movement, stretching, compression, bending, torsion. Tillage tools are used to apply energy to the soil to cause some desired effects such as cutting, breaking, overturning or movement of the soil. Considering the energy consumption diminishing to soil tillage, our goal is to design an optimum tool that will ensure an adequate quality of the soil, efficiency and economy of the tillage process [3].

MATERIAL AND METHOD

Mathematical model

The tillage process consists of three major elements: the soil initial physical properties \( S_i \), the energy \( W \) applied to the soil and the final soil physical properties \( S_f \) [6]. The tillage process, as a system, may be described by the following abstract relation:

\[
S_f = f(S_i, W) .
\]

The energy \( W \) may be expressed depending on soil initial and final state \( S_i, S_f \), the geometry of tool \( G_i \), the manner of soil manipulation and tool movement parameters \( M_i \), respectively:

\[
W = \phi(S_i, G_i, M_i) .
\]

Resumat: În lucrare se dezvoltă un model matematic pentru evaluarea necesarului de energie mecanică la prelucrarea solului. Pentru descrierea modelului matematic s-au utilizat trei scule simple cu suprafața plană, cilindrică și cilindroidală. Ecuțiile matematice dezvoltate include toți factorii de influență ai procesului de lucru: parametrii constructive ai organelor de lucru, parametrii de exploatare ai agregatului și parametrii stării inițiale a solului. Se descrie programul PC elaborat pe baza modelului matematic dezvoltat. Pentru validarea modelului matematic se prezintă o aplicație numerică.

Cuvinte cheie: model matematic, prelucrarea solului, evaluarea necesarului de energie

INTRODUCERE

Prelucrarea mecanică a solului este un proces ce implică un consum ridicat de energie. Obiectivul prelucrării solului constă în crearea condițiilor favorabile și a unui mediu propice dezvoltării plantelor de cultură prin modificarea densității aparente, a compoziției granulometrice a agregatelor și a altor însușiri [5, 7].

Energia necesară prelucrării solului este influențată în mare măsură de proprietățile fizice ale solului, caracteristicile de exploatare ale agregatelor agricole și de parametrii geometrii ai organelor de lucru. Reducerea consumului de energie la prelucrarea solului prezintă o importanță deosebită, având în vedere ponderarea însemnată pe care o are în consumul de energie pentru obținerea recoltelor. Datorită consumului ridicat de energie implicat în procesul de prelucrare a solului, chiar o economie mică reprezintă o valoare semnificativă [1, 2].

Organele de prelucrat solul realizează de obicei, mai multe procese simultan: deplasare, întindere, compresiune, încovoioare, răsucire. Sculele de lucrat solul au rolul de a transfera o cantitate de energie solului, urmărindu-se unele efecte dorite, cum ar fi: tăierea, mărunțirea, răsturnarea și deplasarea solului. Având în vedere reducerea consumului de energie la prelucrarea solului, se urmărește proiectarea unor scule optime din punct de vedere calitativ și economic al lucrării [3].

MATERIAL ŞI METODĂ

Model matematic

Procesul de prelucrare a solului cuprinde trei elemente esențiale: starea inițială a solului caracterizată de însușiri fizice \( S_i \), cantitatea de energie transferată solului \( W \), și starea finală a solului \( S_f \) [6]. Procesul de prelucrare, ca sistem mecanic, este descris de relația abstractă:

\[
S_f = f(S_i, W) .
\]

Energia \( W \) poate fi exprimată în funcție de starea inițială și finală a solului \( S_i, S_f \), de geometria sculei \( G_i \), modul de prelucrare și parametrii de exploatare ai agregatului agricol \( M_i \), respectiv:

\[
W = \phi(S_i, G_i, M_i) .
\]
On the other hand, the total energy required by the process may be expressed as a sum of the elementary energy associated to each phase of working process[3], namely:

\[ W = W_1 + W_2 + W_3 + \ldots + W_n, \]  

where: \( W_1, W_2, W_3, \ldots, W_n \) represent the components of the energy associated to different phenomena being present in the process (e.g., cutting, breaking, moving, friction, adhesion, cohesion etc.). The description of these components of the energy by proper equations is a major task in the soil tillage energy evaluation. One way is to consider that energy is given by the sum of elementary works done by the forces acting on a soil particle during movement over the tool surface. In this case, the following relation may be used:

\[ W = W_T + \sum_1^n (F_{Gx} + F_{Ax} + F_{Cx} + F_{Fx} + F_{fx}) \cdot dx + \sum_1^n (F_{gy} + F_{Ay} + F_{Cy} + F_{fy} + F_{fy}) \cdot dy + \sum_1^n (F_{gz} + F_{Az} + F_{Cz} + F_{fz} + F_{fz}) \cdot dz, \]

where: \( F \) stands for forces; \( F_a \) - for accelerations; \( F_g \) - for gravity; \( F_x \) - for adhesion; \( F_c \) - for cohesion; \( F_f \) - for external and internal friction; \( dx, dy, dz \) - for displacement components; \( W_T \) - for cutting energy. The energy required to the soil cutting \((W_T)\), is expressed by the product of the specific resistance of soil cutting \((k)\), working width \((b)\) and the sum of movements in the direction of motion of the aggregate \((\Sigma dx)\), with the relationship:

\[ W_T = k_v \cdot b \cdot \Sigma dx. \]

To solve the relation (4) a mathematical description of all components of the forces and their trajectories are necessary to be established. In order to calculate these elements we have made the following simplified assumptions:

- The soil furrow is divided in elementary prisms of \( dx \cdot dy \cdot dz = d \) dimensions \((d - \) working depth) by section of furrow with vertical planes \((V_L - \) parallel and \( V_T - \) perpendicular to the direction of machine movement) (Fig. 1);
- The prisms are moving in the reverse direction of forward speed (with the speed \( v_T = v_m \)) and rotate in the transversal plane, being in contact with the tool surface, without breaking;

Pe de altă parte, necesarul de energie pentru prelucrarea solului, se poate exprima ca sumă a energiilor elementare asociate fiecărei faze a procesului de lucru [3], astfel:

\[ W = W_1 + W_2 + W_3 + \ldots + W_n, \]  

unde: \( W_1, W_2, W_3, \ldots, W_n \) reprezintă componentele energiei asociate diferitelor faze ale procesului (de ex: tăiere, măruntire, deplasare, frecare, adeziune, coeziune, etc.). Descrierea acestor componente ale energiei prin ecuații corespunzătoare reprezintă o sarcină dificilă în evaluarea necesarului de energie la prelucrare solului. Pentru simplificarea acestei probleme se consideră că energia este dată de suma lucrurilor mecanice elementare date de forțele ce acționează asupra particulelor de sol în timpul deplasării acestora pe suprafața sculelor. Astfel:

\[ W_T = k_v \cdot b \cdot \Sigma dx. \]

Pentru rezolvarea ecuației (4) se impune descrierea matematică a tuturor componentelor acestor forțe și a traiectoriilor particulelor de sol. Pentru dezvoltarea relațiilor analitice se impun următoarele ipoteze simplificatoare:

- braza de sol se divide în prisme elementare de dimensiuni \( dx, dy, dz = d \) (\( d - \) adâncimea de lucru) prin secționarea brazei cu plane verticale \((V_L - \) paralele și \( V_T - \) perpendicular pe direcția de deplasare a agregatului) (Fig. 1);
- prismele de sol se deplasează în sens invers deplasării agregatului (cu viteză \( v_T = v_m \)) și se rotesc în planul transversal, fiind în contact permanent cu scula, fără a se fragmenta;

Fig. 1 - The idealization of tillage process / Idealizarea procesului de prelucrare a solului
- Based on these considerations, the soil speed \((v)\) is determined by the components \((v_x=ct)\) parallel to the direction of the advancement of aggregate \(Oy\) and transversal \((v_y)\) and vertical \((v_z)\) components - contained in the plan \(xOz\) (Fig. 2);

- prisms of soil are undeformable. Thus, their trajectory can be treated as trajectory of the center of symmetry of the surface \(dx\cdot dy\), that is in contact with the tool surface (point P);
- Also, it is considered that the soil-tool interaction forces have the origin in the P point;
- The system of coordinating axes \(xOyz\) is considered fixed in relation to the tool;
- The tool is composed of many plane surfaces ABC. Each of these planes is tangent in an arbitrary chosen point \(M(x, y, z)\) on tool surface, characterized by the geometrical parameters of the tool \(\alpha, \beta, \gamma\) (Table 1).

\[ \alpha \] is the angle between the straight line AB (the intersection of the tangent plane ABC in the point \(M(x, y, z)\) on the tool surface with the plane \(Oyz\)) and the direction \(Oy\);

\[ \beta \] - angle between the line BC (intersection the surface ABC with plane \(xOy\)) and Ox;

\[ \gamma \] - angle between the line AC (intersection the surface ABC with the horizontal plane \(xOy\)) and Oy;

\[ \theta \] - angle between the plane ABC and horizontal plane \(xOy\).

The functions of variation of the geometrical parameters \(\alpha, \beta, \gamma\) and the surface equations that characterize the three types of tools (plane, cylindrical and cilindroidal) are developed and previously published in the literature [3].

The parametric equations of the soil particle trajectories over the tool surface are obtained by integration of equations of speed. Considering that soil prisms perform a the movement of the furrow in the direction \(Oy\) and the rotation in the \(xOz\) plane, we obtain, respectively:

\[ \text{Fig. 2} - \text{Representation of forces and soil movement path over the tool surface.} \]

\textit{Reprezentarea forțelor și deplasărilor particulelor de sol pe suprafața sculelor.}
**Tool geometry / Geometria sculei, \((G_3)\)**

### Plane tool / Scula plană

![Diagram of Plane tool]

**Surface equation / Ecuată suprafetei:**

\[
x \cdot \tan \beta + y \cdot \tan \alpha + z - h = 0 ,
\]

for \(x \in [0,b]\) and \(z \in [0,h]\).

**Geometrical parameters of the tool / Parametrii geometrici ai sculei:**

\[
\alpha(x,y,z) = \arctan(\sin \gamma \cdot \tan \theta_0) , \quad (18)
\]

\[
\beta(x,y,z) = \arctan(\cos \gamma \cdot \tan \theta_0) , \quad (19)
\]

\[
\gamma(x,y,z) = \gamma_0 = ct . \quad (20)
\]

**Initial dates**

- **Surface height / Înălțimea suprafetei, \(h, [\text{mm}]\):** 100
- **Initial value of the angle \(\gamma\) (for \(z=0\)) / Valoarea inițială a unghiului \(\gamma\) (pentru \(z=0\)), \(\gamma_0^i\):** 45
- **Initial value of the angle \(\theta\) (for \(z=0\)) / Valoarea inițială a unghiului \(\theta\) (pentru \(z=0\)), \(\theta_0^i\):** 45

### Cylindrical tool / Scula cilindrică

![Diagram of Cylindrical tool]

**Surface equation / Ecuată suprafetei:**

\[
(z - h)^2 - 2 \cdot p \left( y - \frac{1}{\tan \gamma_0} \cdot x \right) = 0 ,
\]

for \(x \in [0,b]\) and \(z \in [0,h]\).

**Geometrical parameters of the tool / Parametrii geometrici ai sculei:**

\[
\alpha(x,y,z) = \arctan\left(\frac{p}{z \cdot h}\right) , \quad (21)
\]

\[
\beta(x,y,z) = \arctan\left(\frac{p}{z \cdot h} \cdot \frac{1}{\tan \gamma_0}\right) , \quad (22)
\]

\[
\gamma(x,y,z) = \gamma_0 = ct . \quad (23)
\]

**Initial dates**

- **Surface height / Înălțimea suprafetei, \(h, [\text{mm}]\):** 100
- **Initial value of the angle \(\gamma\) (for \(z=0\)) / Valoarea inițială a unghiului \(\gamma\) (pentru \(z=0\)), \(\gamma_0^i\):** 45
- **Initial value of the angle \(\theta\) (for \(z=0\)) / Valoarea inițială a unghiului \(\theta\) (pentru \(z=0\)), \(\theta_0^i\):** 30

### Cylindroid tool / Scula cilindroidală

![Diagram of Cylindroid tool]

**Surface equation / Ecuată suprafetei:**

\[
tan\gamma \left(\frac{(z-h)^2}{2 \cdot p} - y\right) - x = 0 ,
\]

for \(x \in [0,b]\) and \(z \in [0,h]\).

**Geometrical parameters of the tool / Parametrii geometrici ai sculei:**

\[
\alpha(x,y,z) = \arctan\left(\frac{p}{z \cdot h}\right) , \quad (24)
\]

\[
\beta(x,y,z) = \arctan\left(\frac{p}{z \cdot h} \cdot \frac{1}{\tan \gamma}\right) , \quad (25)
\]

\[
\gamma(x,y,z) = \gamma_0 + \frac{x^2}{2 \cdot r} = ct , \quad \text{for / pentru} \quad r = \frac{h^2}{2 \cdot \Delta y} . \quad (26)
\]

**Initial dates**

- **Surface height / Înălțimea suprafetei, \(h, [\text{mm}]\):** 100
- **Initial value of the angle \(\gamma\) (for \(z=0\)) / Valoarea inițială a unghiului \(\gamma\) (pentru \(z=0\)), \(\gamma_0^i\):** 45
- **Initial value of the angle \(\theta\) (for \(z=0\)) / Valoarea inițială a unghiului \(\theta\) (pentru \(z=0\)), \(\theta_0^i\):** 30
- **Increasing angles / Creșterea unghiurilor, \(\gamma_{\text{max}} - \gamma_0, [\text{°}]\):** 15
RESULTS

The elementary displacement components dx, dy, dz, of the soil particles are calculated by using the equations 6, 7 and 8.

Thus, in the proposed mathematical model the effect of the soil elastic deformation is neglected.

The forces of adhesion \( F_A \) and cohesion \( F_C \) and friction forces act along the direction of tangent to soil particle trajectory (tt).

Based on the above considerations the components of elementary forces of the soil – tool interaction systems are calculated. The particular relations include parameters that characterize the initial soil condition (e.g., \( \mu \) - coefficient of soil – to – metal friction; \( \mu_i \) – coefficient of soil – to - soil friction; \( \rho \) – soil bulk density, and shearing stress). For example, the friction force is expressed by the relation:

\[
F_i = \mu \cdot N_i.
\]

where: the component of normal force \( (N) \) is calculated by using the equilibrium equation of soil – tool interaction forces along the normal direction (nn):

\[
F_{Gn} + N = 0.
\]

Mathematical model for determining of the soil-tool interaction forces \( (F_A) \) - acceleration forces, \( F_G \) - weight, \( F_a \) - adhesion, \( F_C \) - cohesion, and external friction (soil-steel) and internal (soil-soil) - \( F_A, F_S \) is shown in the literature [4].

The projections of the interaction forces upon the axis, of a Cartesian coordinate system xOyz, are calculated by using the directional cosines of the normal and tangent, that are defined according to figure 1.

Considering the normal to the tool surface at the point M as being perpendicular to the ABC plane (tangent to the tool surface), the directional cosines are:

\[
\cos \tau_n = \frac{1}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}},
\]

\[
\cos \tau_n = \frac{\tan \gamma}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}},
\]

\[
\cos \tau_n = \frac{-\tan \gamma \cdot \tan \alpha}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}}.
\]

The directional cosines are expressed as a function of surface geometrical parameters at the arbitrary point M.

The direction of the tangent (tt) to trajectory is defined by derivating the parametric equation of the soil path (eq. 6, 7 and 8), thus:

\[
y = \int \left( \cos^2 \gamma + \sin^3 \gamma \cdot \frac{1}{\sqrt{\sin^2 \gamma + \tan^2 \alpha}} \right) \cdot v \cdot dt = -v_m \cdot dt,
\]

\[
x = \int \sin \gamma \cdot \cos \gamma \left( 1 - \frac{\sin \gamma}{\sqrt{\sin^2 \gamma + \tan^2 \alpha}} \right) \cdot v \cdot dt,
\]

\[
z = \int \sin \gamma \cdot \frac{\sin \gamma \cdot \tan \alpha}{\sqrt{\sin^2 \gamma + \tan^2 \alpha}} \cdot v \cdot dt.
\]

REZULTATE

Ecuățiile 6, 7 și 8 permit determinarea componentelor deplasărilor elementare ale prismeilor de sol pe suprafața sculei.

În modelul matematic propus se neglijiază efectul forțelor de deformare elastică a solului.

Fortele de adheziune \( F_A \), de coeziune \( F_C \) şi forțele de frecare acționează după direcția tangentei la traiectoria prismelor de sol (tt).

Pe baza considerențelor de mai sus, se determină componentele forțelor elementare de interacțiune sol – sculă. Relațiile dezvoltate includ parametrii ce caracterizează starea inițială a solului (de ex: \( \mu \) - coeficientul de frecare sol – oțel; \( \mu_i \) – coeficientul de frecare sol – sol; \( \rho \) - densitatea aparentă a solului, și rezistența la rupere). De exemplu, forța de frecare este descrisă de relația:

\[
F_i = \mu \cdot N.
\]

unde: componenta normală a forțelor \( (N) \), se calculează folosind ecuațiile de echilibrul ale forțelor de interacțiune sol – sculă, după direcția normalii (nn):

\[
F_{Gn} + N = 0.
\]

Modelul matematic pentru determinarea forțelor de interacțiune sol-sculă (forțele de accelerare \( F_a \) de greutate \( F_G \), de adheziune \( F_A \), coeziune \( F_C \), și de frecare externă (sol-oțel) și internă (sol-sol) – \( F_G, F_S \) este prezentat în literatura de specialitate [4].

Proiecțiile forțelor de interacțiune după direcțiile axelor sistemului cartezian de coordonate xOyz, se determină folosind ecuațiile cosinușilor directorii ai normalei și tangentei la traiectorie, descrise în figura 1.

Considerând că normala la suprafața sculei în punctul M este perpendiculare pe suprafața plană ABC (tangentă la suprafața sculei), cosinușii directorii sunt de forma:

\[
\cos \tau_n = \frac{1}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}},
\]

\[
\cos \tau_n = \frac{\tan \gamma}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}},
\]

\[
\cos \tau_n = \frac{-\tan \gamma \cdot \tan \alpha}{\sqrt{1 + (\tan \gamma)^2 + (\tan \gamma \cdot \tan \alpha)^2}}.
\]

Cosinușii directorii sunt exprimați în funcție de parametrii geometrici ai suprafeței în punctul arbitrar M.

Direcția tangentei la traiectorie (tt) este definită prin derivarea ecuațiilor parametrice ale traiectoriei particulelor de sol (ecuațiile 6, 7 și 8), astfel:
Based on the mathematical relation of form (8), we calculate the elementary force components and their projections on axes of Cartesian coordinate system xOyz, by using the relations (11 - 16).

By substituting these values in the relation (4), we obtain the equation that permit to calculate the required mechanical energy for soil cultivation.

The proposed model includes also the equations for the calculation of mechanical energy associated to each phase of the process. For example, the energy required to overcome the friction forces may be calculated by the following relation:

\[ W_f = \sum F_x \cdot dx + \sum F_y \cdot dy + \sum F_z \cdot dz \]  (17)

PC program
A PC program based on the previous mathematical model has been developed for soil tillage energy evaluation. In order to compile the program, the user has to know the following: initial soil parameters, geometrical parameters of tool surface and working parameters. The parameters are listed in tables 1, 2 and 3.

The program structure (Fig. 3) is:
- Equation for the calculation of the (x, y, z) coordinates of a number of (m,n) arbitrary points M, obtained by the intersections of vertical planes, parallel to the direction of travel (m) and transversal planes (n) to the furrow. The variables m and n are imposed by the user;
- Calculation of geometrical parameters \( \alpha, \beta, \) and \( \theta \) in accord with each plane surfaces ABC;
- Calculation of soil travel speed components \( (v_x, v_y, v_z) \) and elementary displacements of soil particles \( (dx, dy, \) and \( dz) \) using the relations (5, 6, and 7);
- Calculation the elementary forces of soil – tool interaction (eq. 8 and 9);
- Calculation of the directional cosines of normal and tangent to soil particle path (eq. 10 – 15) and directional cosine of soil – tool interaction projection of forces upon the axes of xOyz coordinate system;
- Calculation the energy components required for each phase of soil working process by using the relation of form (17);
- Calculation of the specific energy required to a surface unit tillage, in MJ/ha.

Numerical application
In order to validate the method proposed for evaluating the mechanical energy consumption, a numerical application has been developed to determine tillage mechanical energy consumption for two types of soil, characterized by the soil initial parameters (Table 2).

In application are used surfaces tools equations for determining the forces of soil – tool interaction, soil particles displacement on tools surfaces and for soil tillage energetic system components.
The obtained results indicate the total energy consumption $W$ (Table 4) as well as its components (energy losses $W_p$ and useful energy $W_u$).

### Table 2 / Tabelul 2

<table>
<thead>
<tr>
<th>Soil Texture / Textura solului</th>
<th>44.6% Clay / Argilă</th>
<th>19.2% Clay / Argilă</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture / Umiditatea, $w$ [%]</td>
<td>14.67</td>
<td>11.98</td>
</tr>
<tr>
<td>Density / Densitatea, $\rho$ [t/m$^3$]</td>
<td>1.75</td>
<td>1.85</td>
</tr>
<tr>
<td>Friction coefficient / Coeficientul de frecare, $\mu$</td>
<td>0.428</td>
<td>0.372</td>
</tr>
<tr>
<td>Internal friction coefficient / Coeficientul de frecare internă, $\mu_i$</td>
<td>0.418</td>
<td>0.398</td>
</tr>
<tr>
<td>Adhesion coefficient / Coeficientul de adeziune, $\tau_a$ [kN/m$^2$]</td>
<td>3.90</td>
<td>3.04</td>
</tr>
<tr>
<td>Cohesion coefficient / Coeficientul de coeziune, $\tau_c$ [kN/m$^2$]</td>
<td>47.84</td>
<td>39.62</td>
</tr>
</tbody>
</table>

### Table 3 / Tabelul 3

<table>
<thead>
<tr>
<th>Working parameters / Parametrii de exploatare, $(M)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed / Viteza mașinii $v_m$ [m/s]</td>
</tr>
<tr>
<td>Working depth / Adâncimea de lucru $d$, [cm]</td>
</tr>
<tr>
<td>Working width / Lățimea de lucru $b$, [cm]</td>
</tr>
</tbody>
</table>
CONCLUSION

Evaluation of the energy in the tillage process is an important objective that may be solved, in a proper way starting from the mathematical description of the process. In this paper a mathematical model for mechanical energy evaluation is presented. Based on this model a computer program was developed. The program is structured in three subprograms designed to the calculation of displacements \( dx, dy, dz \), the forces and the energy \( W \) within the process.

The results have shown that plane tools involve a minimum energy consumption. Increase the energy requirements by 15-25%, for cylindrical and cilindroid tools is due to increment of soil acceleration forces and trajectory length of soil particles on the tools surface.

Analyzing the results, as compared to the previous research results, it has found that the higher consumption of the mechanical energy for the cylindrical and cilindroid tools, is justified by increasing the soil shredding.

REFERENCES


BIBLIOGRAFIE

DEFINITION OF MOVEMENT TRAJECTORY AND FORCES ACTING ON THE COULTER WITH MECHANISM


Keywords: coulter, motoblock, machine for planting seedlings, slope, force, power

INTRODUCTION

There are many machines for planting seedlings of various constructions, which are intended for planting of seedlings on the ground. Setting a specified row-width spacing (distance between sections for planting seedlings) in these machines is done manually. It took a lot of time and effort.

We developed a mechanism for lateral movement of the sections of machine for planting seedlings. It allows you to change quickly the row-width spacing even during the work [8, 9]. Such immediate and rapid change of the row-width spacing may be necessary by planting of different crops, by the work on the small plots, in various environmental conditions, on the slopes. Developed mechanism is provided mainly for two sections and can move both sections in one way or another to ensure the sustainability movement of the unit on slopes. A lateral movement of the section with the coulter changes the direction of the unit, which moves along the slope and corrects this direction.

In scientific papers [3, 4, 5, 10] and in various constructions of machines for planting seedlings [1, 2] the issues of optimum parameters and operating conditions of apparatus for planting seedlings as well as the coulter are settled. But, there are not discussed the forces acting on the coulter by its lateral movement. There are not taken into account the possibilities of stabilization of the specified direction of movement of the unit on the slopes by the creation of additional reactions to displacement and to turn the unit in required direction.

MATERIAL AND METHOD

In works [6, 7] is described the construction of the mechanism for lateral movement of the section and grounded a perspective of its employment on the small-sized equipment. Theoretical researches of these works allowed to define the value and the point of application of the forces acting on the cheek of the coulter by its lateral movement, but only for some cases of the deformation of the soil along the line of the profile of its surface at the cheek of the coulter (“day-surface”) and at the bottom of the coulter. It is characterizing only a certain condition of the soil at the present moment. As is known, the difficulty of description of "behavior" of the soil at the time of deformation, as well as a large range of variables properties make it difficult to define the dependence, that can characterize the line of the profile of the soil surface. So for the most
complete characteristics of the researched process we must consider the various options of these dependencies. This article continues the researches of this process.

As stated above for high quality work on the slopes (mainly slope up to 15°) we proposed the unit, which consists in motoblock with machine for planting seedlings with movable (in the transverse direction) sections with disk-type apparatus (Fig. 1). A special mechanism, which operator of motoblock engages-disengage by the handle, ensures movement of each section in the necessary direction. This mechanism ensures also a simultaneous rising of the sections [8, 9].

RESULTS

For the performance of this mechanism it is necessary to determine the trajectory of movement of characteristic point of section for planting seedlings during its raising by the unit moving. We take this point \( \mathbf{B}_0 \) in the place of attachment of the lever to the coulter (Fig. 2 and Fig. 3). Lever connects the output shaft (point \( \mathbf{O} \) on Fig. 2) of the mechanism with a point \( \mathbf{B}_0 \), and its length is equal to \( R \). Angle between the lever and the \( x \)-axis is equal to \( \beta_0 \). Point \( \mathbf{B}_0 \) makes a complex movement: transient at the motion speed of the unit \( v \) and relative around the point \( \mathbf{O} \) at the angular speed \( \omega \).

We take the origin of coordinates at the point \( \mathbf{O} \); we direct the \( x \)-axis on a course of movement of the unit and the \( y \)-axis - down (Fig. 2). At the initial moment of time the place of attachment of the lever to the coulter is at a point \( \mathbf{B}_0 \), the coordinates of which are expressed by the equations [7, 8]:

\[
x_0 = - R \cos \beta_0, \\
y_0 = R \sin \beta_0.
\]  

\[\text{(1)}\]

Fig. 1 – Motoblock with machine for planting seedlings with sections that moves in lateral direction / Мотоблок з розсадосадильною машиною з секціями, які переміщуються в боковому напрямку

Fig. 2 – Scheme to defining the trajectory of motion of a point \( \mathbf{B}_0 \) / Схема до визначення траєкторії руху точки \( \mathbf{B}_0 \)

characteristics of the dospіdюваного процесу необхідно розглянути різноманітні варіанти даних залежностей. В даній статті продовжується дослідження даного процесу.

Як було зазначено вище для якісної роботи на схилах (в основному крутістю до 15°) нами запропонований агрегат, який складається з мотоблока з садильною машиною з пересувними (в поперечному напрямку) секціями з апаратом дискового типу (рис.1). Спеціальний механізм, який оператор мотоблока вмикає-викає рукояткою, забезпечує переміщення коміній секції в необхідну сторону. Даний механізм разом з пересуванням забезпечує також одночасне піднімання секцій [8, 9].

РЕЗУЛЬТАТИ

Для характеристики роботи даного механізму необхідно визначити траєкторію переміщення характерної точки садильної секції під час її піднімання при русі агрегату. Приймаєм цю точку \( \mathbf{B}_0 \) в місці кріплення важеля до сошника (рис. 2 та рис. 3). Важіль з'єднує вихідний вал (точка \( \mathbf{O} \) на рис. 2) з механізму з точкою \( \mathbf{B}_0 \), і дозволяє його дійсне в доліне \( R \). Кут між важелем та віссю \( x \) дорівнює \( \beta_0 \). Точка \( \mathbf{B}_0 \) здійснює складний рух: переносний з швидкістю руху агрегату \( v \) і відносний навколо точки \( \mathbf{O} \) з кутовою швидкістю \( \omega \).

Приймаємо початок координат в точці \( \mathbf{O} \); вісь \( x \) направимо по ходу руху агрегату, а вісь \( y \) – вниз (рис. 2). В початковий момент часу місце кріплення важеля до сошника знаходиться в точці \( \mathbf{B}_0 \), координати якої виражаються рівнянням [7, 8]:

\[
x_0 = - R \cos \beta_0, \\
y_0 = R \sin \beta_0.
\]  

\[\text{(1)}\]
After a certain time interval \( t \) the shaft from the point \( O \) will move to the position \( O_1 \) and will make its way \( v_t \). During this same time the lever will turn on the angle \( \omega t \). Point \( B_0 \) go into position \( B \), then the coordinates of this point are expressed by the equations \((\beta_1 = \beta_0 - \omega t)\):

\[
\begin{align*}
x_0 &= vt - R \cos \beta_1 = vt - R \cos(\beta_0 - \omega t), \\
y_0 &= R \sin \beta_1 = R \sin(\beta_0 - \omega t).
\end{align*}
\]

Equation (2) represents the trajectory of the absolute motion of a point \( B \) \((B_0)\).

Thus, if at the initial time the coulter was landed in soil at a depth \( h \), so after a time interval \( t \) it will be already landed in soil at a depth \( h_1 \) (Fig. 3). From Fig. 2 and Fig. 3 we define \( h_1 \):

\[
h_1 = h - (y_0 \cdot y_0) = h - R[\sin \beta_0(1 - \cos \omega t) + \cos \beta_0 \sin \omega t].
\]

Pідінімання секції при їх пересуванні забезпечує зменшення площі бокової поверхні сошника, що знаходиться в ґрунті і, відповідно, зменшення реакції ґрунту на даний сошник, що забезпечує менші затрати енергії на виконання даного процесу.

При переміщення сошника (секції з сошником) в поперечному напрямку утворюється момент сили, який намагається повернути агрегат (мотоблок з розсадосадильною машинкою) в протилежний переміщення сошника бік. Основними точками опори даного агрегату є два колеса мотоблока, що розташовані на одній лінії. Тому сошник, що знаходиться позаду даних коліс (розсадосадильна машина знаходиться позаду мотоблока), при переміщенні в нижній бік схилу розвертає передню частину агрегату в напрямку верхньої частини схилу. Це коректує напрямок руху агрегату у разі його відхилення вниз по схилу чи сповзання і забезпечує стабільність заданого напрямку руху.

Для повної характеристики роботи даного механізму необхідно визначити силу, що діє на занурену в ґрунт частину сошника. Для даних розрахунків приймаємо найпростіші варіанти, тобто початкове положення сошника, коли він занурений в ґрунт максимально і, відповідно, реакція ґрунту на нього є максимальною.

Під час переміщення сошника будуть частинами випадком і лево розраховуватись за прийнятою методикою для початкового положення сошника.

В початковий момент часу сошник \( abcd \) знаходиться в зануреному на глибину \( h \) в ґрунт положенні і площі бокової поверхні, що знаходиться в ґрунті буде площа криволінійної трапеції \( aknd \) (рис. 3). При подальшій роботі механізму сошник буде переміщуватись в бік і одразу піднімається уверх під дузою з центром в точці \( O \). Через певні проміжки часу сошник буде займати різні положення. Одне з таких положень сошника показано пунктиром.

Як було зазначено вище для найбільш повної характеристики досліджуваного процесу необхідно прийняти різноманітні варіанти форм поверхні ґрунту біля ґрунтової поверхні.

Через певний проміжок часу \( t \) вал з точки \( O \) переміститься в положення \( O_1 \) і проїде шлях \( vt \). За цей самий час важливе перетворитися на кут \( \omega t \). Точка \( B_0 \) переїде в положення \( B \), тоді координати даної точки виражаються рівнянням \((\beta_1 = \beta_0 - \omega t)\):

\[
\begin{align*}
x_0 &= vt - R \cos \beta_1 = vt - R \cos(\beta_0 - \omega t), \\
y_0 &= R \sin \beta_1 = R \sin(\beta_0 - \omega t).
\end{align*}
\]

Рівняння (2) виражають траекторію абсолютно глибини точки \( B \).

Таким чином, якщо в початковий момент часу сошник був занурений в ґрунт на глибину \( h \), то через проміжок часу \( t \) він уже буде занурений в ґрунт на глибину \( h_1 \) (рис. 3). З рис. 2 та рис. 3 визначимо \( h_1 \):

\[
h_1 = h - (y_0 \cdot y_0) = h - R[\sin \beta_0(1 - \cos \omega t) + \cos \beta_0 \sin \omega t].
\]
Continuing these researches for our case with certain assumptions and based on our preliminary experimental researches we can take that the curve lines \( kn \) and \( ad \), accordingly, are described by the following functions:

\[
z_2 = A_2 \cos \omega_2 x + \phi_0 + c, \quad z_1 = A_1 \sin \omega_1 x + \phi_0.
\]

The state of the soil near coulters cheek is considered in the broader perspective, namely, when the soil surface is described by a function \( y_2 = A_2 \cos \omega_2 x + \phi_0 + c \), and specifically for the coulter \( z_2 = A_2 \cos \omega_2 x + h \) (line \( kn \)), and at the bottom – by the function \( y_1 = A_1 \sin \omega_1 x + \phi_0 \), and specifically for the coulter \( z_1 = A_1 \sin \omega_1 x + \phi_0 \). Such curve line is formed through the existence of a curved surface directly near the coulters cheek, because of the fact that during the previous tillage deeper than the depth of the coulters motion by planting seedlings, in it are formed the cavities and globs, and therefore the contact with such surface does not occur in a straight line (Fig. 3).

We direct the axes of coordinates as shown in Fig. 3. Z-axis passes through the joining point \( k \) of the front edge of the coulter with the surface of the soil, while the x-axis - along the bottom of the furrow. The length \( l \) of the surface \( aknb \) we take as the average between constructively known sizes \( bc \) and \( ad \) of the coulter. It is known from the theory that for practical calculations the force \( F \) acting on the surface \( S \) is determined by the formula:

\[
F = kS, \quad (4)
\]

where \( k \) – soil resistivity,
\( S \) – surface area.

To simplify we neglect area \( Oka (S_{Oka}) \), because of its value which is much less than the area \( aknd (S_{aknd}) \). Thus, we take that the landed in the soil part of the coulter is the area \( Oknd (S_{Oknd}) \). We will define its value.

If \( S \) is area, which located between the curve lines \( z_1 \) and \( z_2 \), then we have:

\[
\iint_S f(x,z) \, dx \, dz = \int_a^b \int_{z_1(x)}^{z_2(x)} f(x,z) \, dx \, dz
\]

\[
S_{aknd} = \int_{z_1(x)}^{z_2(x)} f(x,z) \, dx \, dz = \int_0^l \int_0^{A_2 \cos \omega_2 x + h} f(x,z) \, dx \, dz = \int_0^l (A_2 \cos \omega_2 x + h - A_1 \sin \omega_1 x) \, dx = A_2 \int_0^l \cos \omega_2 x \, dx + h \int_0^l \, dx - A_1 \int_0^l \sin \omega_1 x \, dx.
\]

We define integral, and have:

\[
S_{aknd} = (A_2 \sin \omega_2 h) \omega_2 + h - A_1 (1 - \cos \omega_1 h) \omega_1.
\]

From the formula (4) we can define the force \( F \) acting on the surface \( S_{aknd} \):

\[
F = k[(A_2 \sin \omega_2 h) \omega_2 + h - A_1 (1 - \cos \omega_1 h) \omega_1].
\]

Fig. 3 – Scheme to determining the value of the force \( F \) and coordinate \( x_c \) of the point \( C \) of its action on the coulter / Схема до визначення величини сили \( F \) і координати \( x_c \) точки \( C \) її дії на сошник

Продовжуючи дані дослідження для нашого випадку з певними припущеннями і спираючись на наші попередні експериментальні дослідження можемо прийняти, що криві \( kn \) і \( ad \) відповідно описуються наступними функціями: \( z_2 = A_2 \cos \omega_2 x + \phi_0 + c, \quad z_1 = A_1 \sin \omega_1 x + \phi_0 \).

Стан ґрунту біля щоки сошника розглядається в більш широкому аспекті, а саме коли на поверхні ґрунту він описується функцією \( y_2 = A_2 \cos \omega_2 x + \phi_0 + c \), і конкретно для сошника \( z_2 = A_2 \cos \omega_2 x + h \) (лінія \( kn \)), а у дна – функцією \( y_1 = A_1 \sin \omega_1 x + \phi_0 \), і конкретно для сошника \( z_1 = A_1 \sin \omega_1 x + \phi_0 \). Така крива лінія утворюється через наявність кривої поверхні безпосередньо у щоки сошника через те, що при попередньому обробітку ґрунту на більшу глибину ніж глибина ходу сошника при садінні россади, в ньому утворюються порожнини і грудки, і таким чином контакт з такою поверхнею не відбувається по прямій лінії (рис. 3).

Направимо осі координат як показано на рис. 3. Вісь \( z \) проходить крізь точку \( k \) стічку передньої кромки сошника з поверхнею ґрунту, а вісь \( x \) – по дну борошни. Довжину \( l \) поверхні \( aknb \) приймаємо як середню між конструктивно відомими розмірами \( bc \) і \( ad \) сошника. З теорії відомо, що для практичних розрахунків сила \( F \), що діє на дану поверхню \( S \) визначається за формулово:

\[
F = kS, \quad (4)
\]

де \( k \) – питомий опір ґрунту,
\( S \) – площа поверхні.

Для спрощення нехтуємо площею \( Oka (S_{Oka}) \), осільки її величина набагато менше площі \( aknd (S_{aknd}) \). Таким чином, приймаємо, що занурено в ґрунт частиною сошника є площа \( Oknd (S_{Oknd}) \). Визначимо її величину.

Якщо \( S \) – область, що знаходиться між кривими \( z_1 \) і \( z_2 \), то маємо:

\[
\iint_S f(x,z) \, dx \, dz = \int_a^b \int_{z_1(x)}^{z_2(x)} f(x,z) \, dx \, dz
\]

\[
S_{aknd} = \int_{z_1(x)}^{z_2(x)} f(x,z) \, dx \, dz = \int_0^l \int_0^{A_2 \cos \omega_2 x + h} f(x,z) \, dx \, dz = \int_0^l (A_2 \cos \omega_2 x + h - A_1 \sin \omega_1 x) \, dx = A_2 \int_0^l \cos \omega_2 x \, dx + h \int_0^l \, dx - A_1 \int_0^l \sin \omega_1 x \, dx.
\]

We define integral, and have:

\[
S_{aknd} = (A_2 \sin \omega_2 h) \omega_2 + h - A_1 (1 - \cos \omega_1 h) \omega_1.
\]

З формулу (4) можемо визначити силу \( F \), що діє на поверхню \( S_{aknd} \):

\[
F = k[(A_2 \sin \omega_2 h) \omega_2 + h - A_1 (1 - \cos \omega_1 h) \omega_1].
\]
It is known from the theory that such force is applied at the point of the center of gravity of this figure. From the known method of definition of coordinates of the center of gravity of planar figure we have: \[ x_C = \frac{\int x f(x)dx}{S} \quad \text{and} \quad z_C = \frac{\int x f(x)dx}{2S} \] where \( S \) is the area of the figure. We define the coordinates for our case, i.e. for the plane Oknd. Using the formula (6) the abscissa of the point C will be:

\[ x_C = \frac{\int x f(x)dx}{S} \quad \text{and} \quad z_C = \frac{\int x f(x)dx}{2S}. \]

The value of 2.8 comes out lengthy and for these researches is not of interest.

We will define the value of the force acting on the coulter cheek. For practical calculations we take: soil resistivity \( k = 30 \text{ kPa} \); amplitudes \( A_1 = 0.02 \text{ m}, A_2 = 0.05 \text{ m}; \) circular frequencies \( \omega_1 = 125.6 \text{ rad/s}, \omega_2 = 94.2 \text{ rad/s}; \) the average length of the coulter \( l = 0.3 \text{ m}; \) maximum depth landing in the soil of the coulter \( h = 0.2 \text{ m}. \)

Substituting these data in the formula (8) we get: \( F_{Oknd} = 1.8 \text{ kN}. \) At a velocity of sections \( v = 0.2 \text{ m/s}, \) we get the value of power for its move \( N = F_{Oknd} \cdot v = 0.36 \text{ kW}. \)

This mechanism is designed for use on small-sized equipment (mobtoblocks) with an average engine capacity 5-6 kW. From this calculation, it is clear that this power satisfies the conditions of work.

From the formula (3) we define the depth landing in the soil of the coulter in a period of time of 1 s. This period of time is sufficient for correction of the direction of movement of the unit, i.e., to turn the front of the unit (mobtoblock) towards the upper side of the slope. We have the constructive values: \( R = 0.5 \text{ m}, \beta_0 = 30^\circ, \omega = 0.4 \text{ rad/s}. \) Substituting these values in the formula (3), we get \( h_1 = 0.12 \text{ m}. \)

From formula (8) we define the value of the force \( F \) (instead of \( h \) we take \( h_1 = 0.12 \text{ m} \)) and we get \( F = 1.08 \text{ kN} \) and, accordingly, \( N = 0.22 \text{ kW}. \) As the calculations indicates, the reaction of the soil on the coulter is reduced by its raising and, accordingly, are reduced the energy consumptions by the execution of this process.

For turning the unit to the upper side of the slope and, accordingly, for correction of its direction of movement, it is necessary that the moment of force \( F \) applied in the centre of loaded in the soil part of the coulter exceed the force \( G \) moment of weight of front of mobtoblock (engine of mobtoblock). Moments are taken relative to a point in the center \( C_0 \) of the line along the axis of the wheels of mobtoblock.

From formula (9) we define the abscissa \( x_C \) of the point \( C \) (instead of \( h \) we take \( h_1 = 0.12 \text{ m} \)) and we get \( x_C = 0.15 \text{ m}. \) Taking into account this value we take the distance from the center \( C_0 \) to point \( x_C, \) i.e. arm \( k = 0.5 \text{ m}. \) The same value, we take for the distance from the center \( C_0 \) to the center \( C \) of front (engine) of mobtoblock, i.e. arm \( k_0 = 0.5 \text{ m}. \) At minimum landing of the coulter in the soil \( (h_1 = 0.12 \text{ m}) \) the force \( F \) moment equals to: \( M = F \cdot k = 1.08 \cdot 0.5 = 0.54 \text{ kN} \cdot \text{m} = 540 \text{ Nm}. \) The force \( G \)
CONCLUSIONS

Resulted higher analysis of work of the mechanism of movement of the sections allows to define the trajectory of the characteristic point of the section for planting seedlings during movement of the unit, the value and the point of application of the force acting on the coulter by its lateral movement at the landing position of the coulter in the soil. Developed mechanism of lateral movement of the sections with the coulter provides its main function, namely, adjustment of the direction of movement of the unit on the slopes. Experiments have shown that the maximum deviation of the unit with this mechanism by the work on slope is up to 15° ± 2 cm, which is within the permissible norms [2].

Resulted higher method of calculation is the main for mechanism of movement of the sections for planting seedlings with movable sections, optimal parameters of the coulter and of all machine for planting seedlings for working in various environmental conditions.

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Scientific Researches on the Qualitative Working Indexes of the Sowing Body of a Modern Technical Hoeing Plants Sowing Equipment

Cercetări experimentale asupra indicilor calitativi de lucru realizate de secția de semănat a unui echipament tehnic modern pentru semănat plante prășitoare

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Abstract: This paper presents the results of experimental researches of sowing body, endowed with a pneumatic distribution apparatus equipped with vertical distributing discs and different sized holes, body which is the main component of a modern technical equipment performed by INMA Bucharest in partnership with S.C. MAT SA Craiova. The output obtained following the experimental researches allows to improve the technology of establishing the hoeing plant crops, so that the agricultural machinery market should benefit of a state-of-the-art technical equipment in compliance with high quality requirements.

Keywords: qualitative working indexes, sowing hoeing plants

Introduction

Within the technological chain of agricultural crops, the sowing operation represents an important link because it assures the density, uniformity and resistance of the respective crop.

The sowing density is a very important technological factor and is established according to the vegetal growing time, soil water stock and nutritive substances supplying degree [1].

Uniformity of sowing (distance between rows, distance of plants in a row and sowing depth) assures big hoeing plants productions and therefore a high profit to the farmer [2].

Having in view the importance of correctly applying the respective technology to hoeing plant crop, the cultivators should take the appropriate measures to achieve the optimum density and uniformity demanded by hybrids [2, 3, 4, 5, 6, 7, 8].

Trying to fulfill the requirements above a new hoeing plant sowing and fertilizing machine SPF8M has been performed, a simplified construction due to new solutions chosen, which give it a good reliability, easy maintenance, simple fittings easily to operate.

Materials and Methods

The laboratory experimental researches were performed with a sowing body belonging to hoeing plants sowing and fertilizing machine SPF8M manufactured at S.C. MAT S.A. Craiova, and the field tests were performed with the sowing body mounted on the sowing machine SPF8M which had worked in aggregate with tractor TD 80D New Holland having the following features: engine power: 58.8 kW (80 HP); engine rotative speed: 2200 rot/min; PTO’s rotative speed: 540 rot/min, working speed: 0.4...2.8 m/s [12].

Sowing machine SPF8M (fig. 1) is designed to perform the sowing of corn and sunflower crops in previously prepared field.

Rezumat: În această lucrare sunt prezentate rezultatele cercetărilor experimentale privind secția de semănăt, prevăzută cu aparat de distribuție pneumatic cu discuri distribuțioare verticale și orificii de dimensiuni diferite, care este componenta principală a unui echipament tehnic modern realizat prin activitatea de cercetare-dezvoltare desfășurată într-un parteneriat format de INMA București și S.C. MAT S.A. Craiova. Rezultatele obținute, în urma cercetărilor experimentale, permit perfeccionarea tehnologiei de înființare a culturilor de plante prășitoare, astfel încât piața mașinilor agricole să beneficieze de un echipament tehnic de înaltă performanță, care să răspundă cerințelor de calitate.

Cuvinte cheie: indici calitativi de lucru, semănat, prășitoare

Introducere

În cadrul lanțului tehnologic al cultivurilor agricole, semănătul reprezintă o verigă deosebit de importantă care asigură densitatea, uniformitatea și vigoarea culturii respective.

Densitatea de semănat este un factor tehnologic foarte important și se stabilește în funcție de durata perioadei de vegetație a populației semănat, de rezerva de apă din sol și de gradul de apropiere a solului cu elemente nutritive [1].

Uniformitatea semănătului (distanța între rânduri, plante pe rând și adâncimea de semănat) asigură producția marți și sigure de plante prășitoare și asfălt un profit deosebit pentru fermier [9,10, 11].

Având în vedere importanța aplicării unei tehnologii corecte în cultura plantelor prășitoare, cultivatorii trebuie să ia măsurile adecvate realizării în câmp atât a densității optime pe care hibrizii o cer, cât și a uniformității acesteia [2, 3, 4, 5, 6, 7, 8].

Căutând să răspundă cerințelor de mai sus a fost realizată o semănătoare nouă pentru semănat și fertilizat plante prășitoare SPF8M, o construcție simplificată datorită soluțiilor noi ale care îi conferă realizarea ușoră, siguranță în exploatare, întreținere, reglaje simple și uşor de exploataat.

Materialele și metoda

Cercetările experimentale în laborator s-au efectuat cu o secție de semănat a semănătorii pentru plante prășitoare cu fertilizator SPF8M executată la S.C. MAT S.A. Craiova, iar cele în câmp s-au efectuat cu secția montată pe semănătoarea SPF8M care a lucrat în agregat cu tractorul TD 80D New Holland cu următoarele caracteristici: puterea motorului: 58.8 kW (80 CP); turata motorului: 2200 rot/min; turația prizei de putere: 540 rot/min, viteza de lucru: 0,4...2,8 m/s [12].

Semănătoarea SPF8M (fig. 1) este destinată să execute semănătul cultivurilor de porumb și floarea soarelui în teren pregătit.
Să menționez doar cele mai semnificative detalii din text, pentru a respecta limita de cuvinte:

- Experiments were performed in testing laboratories and INMA testing field, according to standards ISO 7256:1-1992 and SR 13238-1:1992.
- Tests performed have used the following types of seeds (table 1):

<table>
<thead>
<tr>
<th>Crop / Cultura</th>
<th>Purity / Puritatea [%]</th>
<th>Germination / Germinaţia [%]</th>
<th>1000 seeds mass / Masa a 1000 de boabe [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn, Olt variety /</td>
<td>99.80</td>
<td>95</td>
<td>0.344</td>
</tr>
<tr>
<td>Sunflower, Morena CL</td>
<td>99.70</td>
<td>94</td>
<td>0.067</td>
</tr>
</tbody>
</table>

- The laboratory tests were performed on a stand with fixed sowing body (fig. 2), and the seed distribution disc was driven with rotative speed according to sowing machine displacement working conditions, without skidding. For simulating the sowing machine displacement to soil, under the sowing body was placed a band (fig. 3) which moved with the theoretical forward speed of sowing machine without skidding.

- The laboratory tests were performed on a stand with fixed sowing body (fig. 2), and the seed distribution disc was driven with rotative speed according to sowing machine displacement working conditions, without skidding. For simulating the sowing machine displacement to soil, under the sowing body was placed a band (fig. 3) which moved with the theoretical forward speed of sowing machine without skidding.

- The corn seed of Olt variety (producer INCDA Fundulea), with quality certificate, as production of 2011, has been treated with SEMNAL 500FS, a systemic fungicide produced by Syngenta. In table 2, the grain profile of seeds used is shown.

<table>
<thead>
<tr>
<th>Crop / Cultura</th>
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<th>Germination / Germinaţia [%]</th>
<th>1000 seeds mass / Masa a 1000 de boabe [kg]</th>
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<td>0.067</td>
</tr>
</tbody>
</table>

- Să menționez doar cele mai semnificative detalii din text, pentru a respecta limita de cuvinte:
The tests were performed according to vacuum system depression value, such as:
- for corn: 340 mm H₂O;
- for sunflower: 240 mm H₂O.

The distributing apparata of seeds sowing bodies were endowed with the following sets of sowing discs:
- for corn: disc with 16 holes of Φ 0.0055 m and cutting works (fig. 5);
- for sunflower: disc with 14 holes of Φ 0.003 m and cutting works (fig. 6).

Sowing body adjustment:
- seed level in the box: 50 %
- rotation speed of distributing disc was in accordance with working forward speed of 0.833; 1.388 and 2.5 m/s (table 3):

### Table 3 / Tabelul 3

<table>
<thead>
<tr>
<th>Report of transmission between the distribution disc and driving wheel / Raportul de transmisie între discul de distribuţie şi roata de antrenare</th>
<th>Forward speed in work / Viteza de deplasare în lucru [m/s]</th>
<th>Rotative speed of seed distribution disc, rot/min / Turaţia discului de distribuţie seminţe, rot/min</th>
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</thead>
<tbody>
<tr>
<td>0.833</td>
<td>1.388</td>
<td>2.5</td>
</tr>
<tr>
<td>n₀</td>
<td>n₁</td>
<td>n₂</td>
</tr>
<tr>
<td>0.7150</td>
<td>31.174</td>
<td>43.694</td>
</tr>
<tr>
<td>0.6930</td>
<td>30.215</td>
<td>42.349</td>
</tr>
<tr>
<td>0.6600</td>
<td>28.776</td>
<td>40.333</td>
</tr>
<tr>
<td>0.6000</td>
<td>26.160</td>
<td>36.666</td>
</tr>
<tr>
<td>0.5710</td>
<td>24.896</td>
<td>34.894</td>
</tr>
<tr>
<td>0.5200</td>
<td>22.672</td>
<td>31.777</td>
</tr>
<tr>
<td>0.4510</td>
<td>19.664</td>
<td>27.561</td>
</tr>
<tr>
<td>0.4290</td>
<td>18.704</td>
<td>26.216</td>
</tr>
<tr>
<td>0.3710</td>
<td>16.176</td>
<td>22.672</td>
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<td>1.388</td>
<td>2.5</td>
</tr>
<tr>
<td>n₀</td>
<td>n₁</td>
<td>n₂</td>
</tr>
<tr>
<td>0.7150</td>
<td>31.174</td>
<td>43.694</td>
</tr>
<tr>
<td>0.6930</td>
<td>30.215</td>
<td>42.349</td>
</tr>
<tr>
<td>0.6600</td>
<td>28.776</td>
<td>40.333</td>
</tr>
<tr>
<td>0.6000</td>
<td>26.160</td>
<td>36.666</td>
</tr>
<tr>
<td>0.5710</td>
<td>24.896</td>
<td>34.894</td>
</tr>
<tr>
<td>0.5200</td>
<td>22.672</td>
<td>31.777</td>
</tr>
<tr>
<td>0.4510</td>
<td>19.664</td>
<td>27.561</td>
</tr>
<tr>
<td>0.4290</td>
<td>18.704</td>
<td>26.216</td>
</tr>
<tr>
<td>0.3710</td>
<td>16.176</td>
<td>22.672</td>
</tr>
</tbody>
</table>

Within the experimental laboratory researches, the measurements have been performed for the following parameters:
- variation of seed quantity distributed (sowing norms) [%];

In the experimental laboratory studies, the measurements have been performed for the following parameters:
- variation of seed quantity distributed (sowing norms) [%];
- sowing precision as a distance in a row, in %;
- percentage of pockets with two or more seeds (double) [%];
- percentage of pockets without seeds [gaps] [%].

Variation of seed quantity distributed (sowing norms) for each test was determined as follows:
- the seed quantity distributed \( q \) was weighed [kg];
- three repetitions of 60 s duration were performed;
- the average seed quantity was calculated (1),

\[
q_n = \frac{q}{3}, \text{ in kg}
\]  (1)

- theoretical seed quantity distributed was calculated (2),

\[
q_i = \frac{n \times n_r \times MMB}{1000}, \text{ in kg}
\]  (2)

where:
- \( n \) is the rotate speed of distribution disc, in rot/min;
- \( n_r \) – number of holes of distribution disc;
- \( MMB \) – mass of 1000 grams, in kg.
- the deviation coefficient of sowing rate was calculated by formula (3):

\[
c_i = \frac{q - q_i}{q_i} \times 100, \text{ in } \%
\]  (3)

Conditions of acceptance: according to SR 13238-1:1992, the deviation from the quantity of seeds distributed (sowing rates) (4),

\[
a = 1 - c_i, [\%]
\]  (4)

- max. 3% for less than 70000 plants/ha thickness;
- max. 5% for more than 70000 plants/ha thickness.

Number of plants/ha was calculated by formula (5),

\[
N_pl = 10^3 \times \frac{q_n \times \frac{MMB}{v \times d_r}}{v}, \text{ in plants / hectare}
\]  (5)

where:
- \( v \) is the sowing machine working forward speed [m/s];
- \( d_r \) – distance between the rows sown [m].

Precision of sowing as distance between seeds in a row was determined in laboratory conditions, such as:
- the distances framed between 0.5d-1.5d on band, were measured. \( D \) being the theoretical distance between seeds, namely the percentage of common distances, noted in the subsequent table by \( N \);
- the distances framed between 0-0.5d, were measured on band representing the percentage of pockets with several seeds (double), noted by \( D \) in the subsequent table;
- the distances surpassing 1.5d were measured on band, representing the percentage of pockets without seeds (gaps), noted by \( G \) in the subsequent table.

The experimental researches aimed to determine the field indexes, have been performed on an agricultural field within INMA Bucharest perimeter in the following conditions:
- type of soil: forest reddish-brown soil
- soil category (in terms of specific resistance): medium to heavy;
- previous crop: mustard;
- tractor used: TD 80D New Holland;
- Theoretical forward speed: 1.388 m/s;
- distance between rows: 0.70 m;
- sowing depth fitted: 0.1 m for tests performed before plants sprouting and 0.5...0.6 m for tests after sprouting;
- feeding chamber: supplied along with the sowing machine (without modifications).

In field conditions, was determined the sowing

- precizia de seminat ca distanță între semințe pe rând [%];
- procentul de cuiburi cu două sau mai multe semințe (duble) [%];
- procentul de cuiburi fără semințe (goluri) [%].

Abaterea de la cantitatea de semințe distribuită (norme de seminat) pentru fiecare încercare s-a determinat astfel:
- a fost efectuată trei repetiții cu durata de 60 s;
- a fost calculată cantitatea medie de semințe (1),

\[
q_m = \frac{q}{3}, \text{ in kg}
\]  (1)

- a fost calculată cantitatea teoretică de semințe distribuită (2),

\[
q_i = \frac{n \times n_r \times MMB}{1000}, \text{ in kg}
\]  (2)

unde:
- \( n \) este turarea discului de distribuție, în rot/min;
- \( n_r \) – numărul de orificii al discului de distribuție;
- \( MMB \) – masa a 1000 de boabe, în kg.
- a fost calculat coeficientul de abatere a normei de seminat cu formula (3):

\[
c_i = \frac{q - q_i}{q_i} \times 100, \text{ în } \%
\]  (3)

Condiții de acceptare: conform SR 13238-1:1992, abaterea de la cantitatea de semințe distribuită (norme de seminat) (4),

\[
a = 1 - c_i, [\%]
\]  (4)

- max. 3% pentru desimi mai mici de 70000 plante/ha;
- max. 5% pentru desimi mai mari de 70000 plante/ha.

Numărul de plante/ha s-a calculat cu formula (5),

\[
N_{pl} = 10^3 \times \frac{q_n \times \frac{MMB}{v \times d_r}}{v}, \text{ în plante / hec}
\]  (5)

unde:
- \( v \) este viteză de deplasare în lucru a seminătorii [m/s];
- \( d_r \) – distanța dintre rândurile seminătorului [m].

Precizia de seminat ca distanță între semințe pe rând s-a determinat în condiții de laborator astfel:
- a fost măsurate pe bandă distanțele cuprinse în intervalul 0.5d-1.5d, unde \( D \) este distanță teoretică între semințe, reprezentând procentul de distanțe normale, care în tabelul următor a fost notat cu \( N \);
- a fost măsurate pe bandă distanțele cuprinse în intervalul 0-0.5d, reprezentând procentul de cuiburi cu mai multe semințe (duble), care în tabelul următor a fost notat cu \( D \);
- a fost măsurate pe bandă distanțele mai mari de 1.5d, reprezentând procentul de cuiburi fără nici o sâmânță (goluri), notat în tabelul următor cu \( G \).

Cercetările experimentale, pentru determinarea

indicilor în câmp, s-au efectuat pe un teren agricol aflat în perimetrul INMA București, în următoarele condiții:
- tipul solului: brun roșcat de pâdure;
- categoria solului (din punct de vedere al rezistenței specifice): mijlociu spre greu;
- cultura anterioară: mustar;
- tractorul utilizat: TD 80D New Holland;
- viteză teoretică de deplasare: 1.388 m/s;
- distanța între rânduri: 0.70 m;
- adâncimea de seminat reglată: 0,1 m pentru determinările înainte de răsarire și 0,5...0,6 m pentru determinările după răsarire;
- camera de alimentare: livrată odată cu seminătoarea (fără modificări).

În condiții de câmp s-au efectuat determinări ale
precision as distance between the seeds in row before springing, by digging out the seeds sown (only for corn) and after seeds sprouting ("in green"), uncovering also the non sprung seeds, for eliminating the seed germination as an error source (for corn and sunflower).

Sowing precision before seeds sprouting was determined in the following way:
- sowing machine has moved on a distance of approx. 100 m at 0.1 m depth in the field already prepared for being sown;
- have been uncovered the seeds for 100 spaces starting from min. 20 m in comparison with the beginning of working test;
- have been measured 100 spaces between seeds in 4 sown rows;
- values measured have been grouped in real distances.

The sowing precision after seeds sprouting has been determined in the following way:
- sowing machine has moved on a distance of approx. 100 m at 0.5...0.6 m depth in field prepared to be sown;
- have been measured, starting from min. 20 m comparing with the beginning of the working test, 100 distances between seeds in 4 sown rows;
- values measured have been grouped in real distances.

According to specific testing methodology established previously, during the experimental researches the following measuring devices were used:
- Installation for measuring the depression (tube Pitot-Prandl);
- Mechanical chronometer;
- Electronic precision balance METTLER type;
- Gauge tape of 60 m.

RESULTS
On basis of data obtained and processed during the experimental researches, in laboratory conditions, a synthesis of working qualitative indexes, representing the deviation from the quantity of seeds distributed (rates of sowing), for usual norms of 50000...70000 plants/hectare for corn and sunflower has been drawn up and is shown in table 4.

### Table 4 / Tabelul 4

<table>
<thead>
<tr>
<th>Distributor disk speed /</th>
<th>Sunflower / Floarea soarelui</th>
<th>Corn / Porumb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turatie discului distributor [rot/min]</td>
<td>N_p / plante / ha</td>
<td>q_p [kg]</td>
</tr>
<tr>
<td>30.125</td>
<td>0.0291</td>
<td>95</td>
</tr>
<tr>
<td>28.776</td>
<td>0.0273</td>
<td>99</td>
</tr>
<tr>
<td>26.160</td>
<td>0.0244</td>
<td>99</td>
</tr>
<tr>
<td>24.896</td>
<td>0.0239</td>
<td>98</td>
</tr>
<tr>
<td>22.672</td>
<td>0.0214</td>
<td>99</td>
</tr>
<tr>
<td>19.664</td>
<td>0.1089</td>
<td>99.5</td>
</tr>
<tr>
<td>18.704</td>
<td>0.1045</td>
<td>99.5</td>
</tr>
<tr>
<td>40.333</td>
<td>0.0286</td>
<td>98</td>
</tr>
<tr>
<td>38.666</td>
<td>0.0350</td>
<td>98</td>
</tr>
<tr>
<td>34.894</td>
<td>0.0321</td>
<td>98</td>
</tr>
<tr>
<td>31.777</td>
<td>0.0295</td>
<td>99</td>
</tr>
<tr>
<td>27.561</td>
<td>0.1480</td>
<td>97.4</td>
</tr>
<tr>
<td>26.216</td>
<td>0.1440</td>
<td>99.8</td>
</tr>
</tbody>
</table>

| Forward speed in work of the sowing machine / Viteza de deplasare în lucrul a semânațorii [0.833 m/s] |
|--------------------------|------------------------------|---------------|
| 56.149 | 0.0492 | 93 | 7 | 69396 | | |
| 54.422 | 0.0451 | 88 | 7 | 64108 | | |
| 51.830 | 0.0480 | 99 | 1 | 68230 | | |
| 47.118 | 0.0437 | 98 | 2 | 62118 | | |
| 44.841 | 0.0427 | 98 | 2 | 60697 | | |
| 40.836 | 0.0386 | 99.5 | 0.5 | 54726 | | |
| 35.417 | 0.1939 | 99.5 | 0.5 | 53682 | | |
| 33.690 | 0.1808 | 97.3 | 2.7 | 50055 | | |

In baza datelor obținute și prelucrate pe parcursul cercetărilor experimentale, în condiții de laborator, s-a întocmit o sinteză a indicilor calitativi de lucru, reprezentând abatera de la cantitatea de semințe distribuite (nume de semănă), pentru normele uzuale cuprinse între 50000...70000 plante/hectar la porumb și floarea soarelui, care sunt prezentate în tabelul 4.
Section mounted and tested on a stand has operated for a total of 250 hours, after which the distribution device was subjected to final technical expertise, where it was examined and measured each item subject to wear.

Table 5 presents the qualitative indices values, representing the sown precision as the distance between seeds per row, determined for corn, at each working speed, at usual norms and at 100 measurements for each set distance, in 3 repetitions.

Plants per hectare norm was calculated with the following formula (6):

\[ N_{pl} = \frac{10000}{d_i \times a} \]  

(6)

where:
- \( d_i \) is the distance between sown rows [m];
- \( a \) - theoretical distance between seeds per row [m], was calculated with the formula (7):

\[ a = \frac{2\pi R_d \times i}{n_d} \]  

(7)

unde:
- \( d_i \) este distanța dintre rândurile semănate [m];
- \( a \) - distanța teoretică între semințe pe rând [m], a fost calculată cu formula (7):

\[ a = \frac{2\pi R_d \times i}{n_d} \]  

unde:
- \( R_d \) este raza statică a roții de antrenare, cm (anvelopa 5.00-15 are raza statistică = 0.304 m);
- \( i \) - raportul de transmisie de la roata de antrenare la axul discului distribuitor;
- \( n_d \) – numărul de orificii al discului de distribuție.

Table 6 presents the qualitative indices values representing the sown precision as the distance between seeds per row for sunflower.

<table>
<thead>
<tr>
<th>Working speed / Viteză de lucru \n[ v \text{ [m/s]} ]</th>
<th>Theoretical distance \n[ a \text{ [m]} ]</th>
<th>Plants rate per hectare / N\text{pl} \text{ [plants/ha / plante / ha]}</th>
<th>Work qualitative indices / Indici calitativi de lucru</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gaps / Goluri, G [%]</td>
</tr>
<tr>
<td>0.833</td>
<td>0.0278</td>
<td>51387</td>
<td>1.3 / 1.0</td>
</tr>
<tr>
<td></td>
<td>0.0265</td>
<td>53957</td>
<td>1.3 / 1.0</td>
</tr>
<tr>
<td></td>
<td>0.0229</td>
<td>62258</td>
<td>1.3 / 1.0</td>
</tr>
<tr>
<td></td>
<td>0.0209</td>
<td>68415</td>
<td>2.3 / 2.3</td>
</tr>
<tr>
<td>1.388</td>
<td>0.0278</td>
<td>51387</td>
<td>2.3 / 2.3</td>
</tr>
<tr>
<td></td>
<td>0.0265</td>
<td>53957</td>
<td>3.6 / 3.3</td>
</tr>
<tr>
<td></td>
<td>0.0229</td>
<td>62258</td>
<td>7.3 / 7.3</td>
</tr>
<tr>
<td></td>
<td>0.0209</td>
<td>68415</td>
<td>8.6 / 8.6</td>
</tr>
<tr>
<td>2.5</td>
<td>0.0278</td>
<td>51387</td>
<td>8.3 / 8.3</td>
</tr>
<tr>
<td></td>
<td>0.0265</td>
<td>53957</td>
<td>9.6 / 9.6</td>
</tr>
</tbody>
</table>

In tabelul 5 sunt prezentate valorile indicilor calitativi, reprezentând precizia de semânat ca distanță între semințe pe rând, determinați pentru porumb, la fiecare viteză de lucru, la norme uzuale și la 100 de măsurători pentru fiecare distanță reglată, în 3 repetiții.

Norma de plante la hectar a fost calculată cu următoarea formulă (6):

\[ N_{pl} = \frac{10000}{d_i \times a} \]  

unde:
- \( d_i \) este distanța dintre rândurile semănate [m];
- \( a \) - distanța teoretică între semințe pe rând [m], a fost calculată cu formula (7):

\[ a = \frac{2\pi R_d \times i}{n_d} \]  

unde:
- \( R_d \) este raza statică a roții de antrenare, cm (anvelopa 5.00-15 are raza statistică = 0.304 m);
- \( i \) – raportul de transmisie de la roata de antrenare la axul discului distribuitor;
- \( n_d \) – numărul de orificii al discului de distribuție.

Table 6 presenting the qualitative indices values, representing the sown precision as the distance between seeds per row for sunflower.

<table>
<thead>
<tr>
<th>Working speed / Viteză de lucru \n[ v \text{ [m/s]} ]</th>
<th>Theoretical distance \n[ a \text{ [m]} ]</th>
<th>Plants rate per hectare / N\text{pl} \text{ [plants/ha / plante / ha]}</th>
<th>Work qualitative indices / Indici calitativi de lucru</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gaps / Goluri, G [%]</td>
</tr>
<tr>
<td>0.833</td>
<td>0.02273 / 0.02273</td>
<td>62856</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>0.3386</td>
<td>0.02273 / 0.02273</td>
<td>62856</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>0.3026 / 0.03026</td>
<td>47212</td>
<td>3.3 / 3.3</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.03177 / 0.03177</td>
<td>44964</td>
<td>4.3 / 4.3</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.02273 / 0.02273</td>
<td>62856</td>
<td>3.6 / 3.6</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>1.388</td>
<td>0.02386 / 0.02386</td>
<td>59863</td>
<td>5.3 / 5.3</td>
</tr>
<tr>
<td>0.02262 / 0.02262</td>
<td>54475</td>
<td>3.0 / 3.0</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.03026 / 0.03026</td>
<td>47212</td>
<td>2.0 / 2.0</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.03177 / 0.03177</td>
<td>44964</td>
<td>2.3 / 2.3</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.02262 / 0.02262</td>
<td>54475</td>
<td>9.3 / 9.3</td>
<td>0.6 / 0.6</td>
</tr>
<tr>
<td>0.03026 / 0.03026</td>
<td>47212</td>
<td>3.0 / 3.0</td>
<td>1.6 / 1.6</td>
</tr>
<tr>
<td>0.03177 / 0.03177</td>
<td>44964</td>
<td>3.0 / 3.0</td>
<td>1.6 / 1.6</td>
</tr>
</tbody>
</table>

In tabelul 6 sunt prezentate valorile indicilor calitativi de lucru reprezentând precizia de semânat ca distanță între semințe pe rând pentru floarea soarelui.
Following inspections and measurements was not found abnormal wear of the seed distribution disc or sealing gasket.

Table 7 presents the average values of field measurement results related to sowing precision before seed corn sprouting.

<table>
<thead>
<tr>
<th>Real working speed / Viteza reală de lucru (v) [m/s]</th>
<th>Theoretical distance between seeds / Distanța teoretică între semințe (a) [m]</th>
<th>Plants rate per hectare / Norma de plante la hectar (N_p) [plants/ha / plante / ha]</th>
<th>Section / Secția</th>
<th>Work qualitative indices / Indici calitativi de lucru</th>
<th>Gaps / Goluri, (G) [%]</th>
<th>Double / Duble, (D) [%]</th>
<th>Usual / Normale, (N) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.4</td>
<td>0.0242</td>
<td>59028</td>
<td>1</td>
<td>2</td>
<td>93</td>
<td>96</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>81</td>
<td>81</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>6</td>
<td>4</td>
<td>13</td>
<td>81</td>
<td>81</td>
<td>81</td>
</tr>
</tbody>
</table>

Table 8 presents the average values of field measurement results after seed corn sprouting (seeds germination was of 95%).

<table>
<thead>
<tr>
<th>Real working speed / Viteza reală de lucru (v) [m/s]</th>
<th>Theoretical distance between seeds / Distanța teoretică între semințe (a) [m]</th>
<th>Plants rate per hectare / Norma de plante la hectar (N_p) [plants/ha / plante / ha]</th>
<th>Section / Secția</th>
<th>Work qualitative indices / Indici calitativi de lucru</th>
<th>Gaps / Goluri, (G) [%]</th>
<th>Double / Duble, (D) [%]</th>
<th>Usual / Normale, (N) [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.42</td>
<td>0.0242</td>
<td>59028</td>
<td>1</td>
<td>21</td>
<td>74</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>6</td>
<td>2</td>
<td>19</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>7</td>
<td>3</td>
<td>19</td>
<td>74</td>
<td>74</td>
<td>74</td>
</tr>
<tr>
<td>4</td>
<td>27</td>
<td>9</td>
<td>4</td>
<td>27</td>
<td>64</td>
<td>64</td>
<td>64</td>
</tr>
</tbody>
</table>

One aspect determining the sowing accuracy before sprouting of corn seeds is shown in figure 7.

CONCLUSIONS

The tests carried out showed that work qualitative indices value fall under the work requirements of sowing hoeing plants, so:
- deviation from the quantity of seeds distributed (sowing rates) qualifies SR 13238-1:1992 for working speed 0.833…1.944 m/s and usual rates between 50000...70000 plants/hectare at corn and sunflower;
- sowing precision distance between seeds per row, percentage of pockets with two or more seeds (double) and percentage of pockets with no seeds (gaps) qualifies for ISO 7256:1-1992 for the working speeds 0.833…1.944 m/s and usual rates between 50000…70000 plants/hectare at corn and sunflower;
- sowing precision distance between seeds per row has values less than 90% normal intervals for higher working speeds of 1.94 m/s.

CONCLUZII

În urma verificărilor efectuate a rezultat că valorile indicilor calitativi de lucru se încadrează în cerințele impuse lucrării de semânat plante prăpătoare, astfel:
- abatera de la cantitatea de semințe distribuite (norme de semănat) se încadrează în cerințele SR 13238-1:1992 pentru vitezele de lucru de 0,833…1,944 m/s și normele uzuale cuprinse între 50000…70000 plante/hectar la porumb și floarea soarelui;
- precizia de semânat ca distanță între semințe pe rând, procentul de cuiburi cu două sau mai multe semințe (double) și procentul de cuiburi fără semințe (goluri) se încadrează în cerințele ISO 7256:1-1992 pentru vitezele de lucru de 0,833…1,944 m/s și normele uzuale cuprinse între 50000…70000 plante/hectar la porumb și floarea soarelui;
- precizia de semânat ca distanță între semințe pe rând are valori mai mici de 90% intervale normale pentru vitezele de lucru mai mari de 1,94 m/s.
Experimental results allow development of useful recommendations for farmers who use this technical equipment.

REFERENCES

Rezultatele experimentale permit elaborarea de recomandări utile pentru fermierii care utilizează acest echipament tehnic.

BIBLIOGRAFIE
EXPERIMENTS REGARDING THE INFLUENCE OF WORKING PARAMETERS ON HOEING CROPS SOWING

/ EXPERIMENTĂRI PRIVIND INFLUENȚA PARAMETRILOR DE LUCRU ASUPRA PRECIZIEI DE SEMĂNAT A CULTURILOR DE PLANTE PRĂȘIOTOARE

INMATEH – Agricultural Engineering


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Abstract: Romania’s strategic objective of EU integration imposes, among others, policies that ensure the implementation of community requirements on the free movement of products, which is based on an open market economy, based on competition and economic and social cohesion. Agricultural productivity (main economic branch through its impact on the society and environment) is influenced by technological level of applied work, sowing work occupying a very important place in these technologies. This paper presents a method for testing the hoeing plants sowing machines with the help of a stand equipped with laser sensors that measure the time interval between the fall of two seeds which it transforms in space and which it compares to the reference area calculated by a specialized software after entering the input data (density, distance between rows, number of holes on the disk, speed).

Keywords: sowing machine, precision agriculture, distributing disc

INTRODUCTION
Current studies and researches on sowing methods and equipment, are part of the new trends for precision farming, knowing that sowing uniformity is essential to obtain high crop production and other economic crops productivity, 50% of the crop being determined by the sowing work [2, 3, 7, 8, 10, 11, 12, 13, 14]. Developing a competitive agriculture allowing to obtain increased production, without soil compaction can not be achieved without a proper management of sowing plants work [4].

An important aspect of continuous increasing policy of products quality achieved by each economic agent, is constituted by maintaining compliance of sowing machines and growing prerequisites for achieving these products in terms of repeatability, according to integrated agricultural management [5].

Sowing works qualitative indexes of hoeing plants can be assessed by means of physical measures, measurable, such as the distance between seeds per row, distance between rows, sowing depth, and so on. Any disturbance of the seeding process leads to lower qualitative indexes of the sowing work and finally to decrease production [9]. The main direction of sowing machines improvement, is their constructive improvement (including control and measurement equipment) [15]. Sowing machine performance testing can be performed in the field [1] or in the laboratory [6].

At current sowing machines the centralized driving system of distributing disks is made from a rubber wheel that moves on the soil (with skidding of 10-15%) which transmits the rotation movement through a chain transmission to the distribution discs.

MATERIALS AND METHOD
To highlight the influence of operating parameters on the sowing precision three sowing sections for hoeing plants were mounted on bench SPS-3, (fig.1).

Rezumat: Obiectivul strategic al României de integrare în UE impune, printre altele, politici care să asigure aplicarea exigentelor comunitare privitoare la libera circulație a produselor, care are la bază economia de piață deschisă, bazată pe concurență și coeziune economică și socială. Productivitatea agriculturii (ramură economică de bază prin impactul asupra societății căt și a mediului) este influențată de nivelul tehnologiilor de lucru aplicate, lucrarea de semănat ocupând un loc foarte important în cadrul acestor tehnologii. Lucrarea prezintă o metodă de testare a preciziei semăntătorilor de plante prășitoare cu ajutorul unui stand dotat cu traductoare cu laser care masorează intervalul de timp de cădere între două seminți pe care îl transformă în spațiu și pe care îl compară cu spațiul de referință calculat de un soft specializat, după introducerea datelor de întrare (densitate, distanța între rânduri, număr orificii pe disc, viteza).

Cuvinte cheie: semănător, agricultură de precizie, disc distribuitor

INTRODUCERE
Studiiile și cercetările actuale, privind metodele și echipamentele de semânat, se înscriu în noile tendințe pentru practicarea unei agriculturi de precizie cunoscând că unificarea la semânare este esențială pentru a obține productivități ridicate la pormb, floarea soarelui, și alte culturi prășitoare, 50% din recolta fiind determinată la lucrarea de semănat [2, 3, 7, 8, 10, 11, 12, 13, 14]. Dezvoltarea unei agriculturi performante care să permită obținerea unor producții sporite, fără tasarea solului nu se poate realiza fără un management corespunzător al lucrărilor de semănat a plantelor [4].

Un aspect important al politicii de creștere continuă a calității produselor realizate de fiecare agent economic, îl constituie atât menținerea conformității mașinilor de semănat cât și creșterea premizelor de realizare în condiții de repetabilitate a acestor produse, conform unui management agricol integrat [5].

Indicii calitativi ai lucrării de semănător a semăntătorilor de plante prășitoare pot fi apreciați prin intermediul unor mărimi fizice, măsurabile, cum ar fi distanța între seminți pe rând, distanța între rânduri, adâncimea de semănat, etc. Orice perturbare a procesului de semânat conduce la scăderea indicilor calitativi ai lucrării de semănat și în final la micșorarea producției [9]. Principala direcție de perfecționare a mașinilor de semănat, o constituie îmbunătățirea lor constructivă (incluzând aparatura de control și măsurare) [15]. Testarea performanțelor mașinilor de semănat se poate efectua în câmp [1] sau în laborator [6].

La semanatorile actuale antrenarea centralizată a discurilor distribuitoare se face de la o roată de cauciuc care se deplasează pe sol (cu patinări de 10-15 %) care transmite mișcarea de rotație prin intermediul unei transmiteri cu lanț la discurile distribuitoare.

MATERIALE ȘI METODĂ
Pentru a evidenția influența parametrilor de lucru asupra precizei de semănat s-au montat trei secți de semanat plante prășitoare pe standul SPS-3 (fig.1).
Hoeing plants sowing machines must meet the following requirements:
- Should have high mobility during work and provide greater safety in operation;
- Should dose seeds for achieving the set norm per hectare;
- Should keep during work the setting made on sowers parameters;
- Should be equipped with automation and control apparatus during work;
- Should have multiple, rigorous possibilities of adjustment, and be able to achieve the minimum, usual and maximum norm; provided by agronomic requirements;
- Should be easy, simple to handle and adjust, have a good labor protection;
- Should be standardized and guaranteed for safe use;
- Should achieve high productivity;
- Should have a nice design and facilities at assembling and disassembling;
- Should have low energy consumption and high work efficiency.

SPS-3 bench for sowing stations for precision testing provides testing conditions for all types of sections for sowing hoeing crops, being able to simultaneously test 3 sections for sowing the reference space (d_ref) calculated by the software program after entering input data (density, distance between rows, number of holes on the disc, speed). Distances within the range 0.5-1.5d_ref are considered normal intervals, the lowest 0.5d_ref are considered double, and the biggest 1.5d_ref are considered gaps. Results are displayed on a LCD in a graphical form (fig. 2).

Semănătorile de plante prășitoare trebuie să îndeplinească următoarele cerințe:
- să aibă mobilitate mare în timpul lucrului și să prezinte siguranță mare în exploatare;
- să dozzeze semințele pentru realizarea normei la hectar reglată;
- să păstreze în timpul lucrului regiilele făcute asupra parametrilor semănătorii;
- să fie dotate cu aparatură de control și automatizare în timpul lucrului;
- să aibă posibilități de reglaj multiple, riguroase și să poată realiza norma minimă, uzuială și maximă prevăzute de cerințele agrotehnice;
- să fie ușoare, simplu de manevrat și de reglat, să aibă o bună protecție a muncii;
- să fie standardizate și garantate pentru siguranța folosirii;
- să permită realizarea unor productivityți ridicate;
- să aibă design plăcut și facilități la montare și demontare;
- să aibă consum energetic scăzut și randamente de lucru ridicate.

Standul pentru determinarea preciziei de semănăt SPS-3 asigură condiții de încercare pentru toate tipurile de secții de semănăt culturi prășitoare, putându-se testa simultan 3 secți de semănăt [14].

Viteză de lucru a fost simulată cu un motor electric cu turație variabilă care antrenează transmisia centralizată a discurilor distribuitoare la viteză în intervalul 2-12 km/h. Ați de asemenea aparatelor de distribuție se poate realiza în două variante:
- transmisie individuală – prin sistem cu bandă flexibilă;
- transmisie centralizată – prin transmisie cun lanț.

Standul este echipat cu un generator de vacuum (exhauster-motor asincron-transmisie prin curele), care funcționează la o turație nominală de 4000 rot/min și poate crea o depresiune maximă de 600 mm col.apă (depresiune măsurată prin intermediul unui tub Prandtl-Pitot).

Elementul de referință în acest sistem de prelucrare statistic este intervalul teoretic (reglat) între semințe pe rând. Precizia de semănăt se determină cu ajutorul unor traducere cu aserg care masoară intervalul de timp de cădere între două seminte pe care îl transformă în spațiul și pe care îl compară cu spațiul de referință (d_ref) calculat de softul programului după introducerea datelor de intrare (densiitate, distanța între rânduri, număr orificii pe disc, viteză). Distanțele cuprinse în intervalul 0.5-1.5d_ref sunt considerate intervale normale, cele mai mici de 0.5d_ref sunt considerate duble, iar cele mai mari de 1.5d_ref sunt considerate goluri. Rezultatele sunt afișate pe un LCD sub forma grafică (fig. 2).
Quality indicators calculation:
- $A$ - feeding quality index (1), where:
  - $n_i$ = number of seeds normally sown;
  - $N'$ = number of theoretical intervals.

$$A = \frac{n_i}{N'} \times 100 \, [%]$$ (1)

$D$ - index of doubles (2)
- $n_{s2}$ = number of doubles;
- $N'$ = number of theoretical intervals.

$$D = \frac{n_{s2}}{N'} \times 100 \, [%]$$ (2)

$M$ - gaps index (3)
- $n_{0}$ = number of missed nests;
- $N'$ = number of theoretical interval.

$$M = \frac{n_{0}}{N'} \times 100 \, [%]$$ (3)

Work parameters which were varied:
- working speed;
- level of seed in bunker;
- field slope.

The used seeds were corn and sunflower for which have been determined:
- granulometric profile;
- purity;
- 1000 seed mass.

RESULTS
Influence of speed work on sowing precision
Sowing precision, was determined for corn, under the following conditions:
- mass of 1000 seeds of 344 g;
- distribution disc with 16 orifices;
- depression of 340 mm H2O height;

Fig. 2 - Showing results in graphical form / Afișarea rezultatelor sub formă grafică
- simulated working speed: 5, 7, 9 km/h. Measurements were made in 3 repetitions, for several slope densities per hectare, the results being shown in table 1.

- viteză de lucru simulată: 5, 7, 9 km/h. Determinările s-au făcut în 3 repetiții, la mai multe densități ale plantelor la hectar, rezultatele fiind prezentate în tabelul 1.

Table 1 / Tabelul 1

<table>
<thead>
<tr>
<th>Speed / Viteză [km/h]</th>
<th>Adjustable distance / Distanța reglată [cm]</th>
<th>Norm / Norma [plants/ha / plante/ha]</th>
<th>Corn sowing precision / Precizia de semănat la porumb [M [%]; D [%]; A [%]]</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>27.8</td>
<td>51387</td>
<td>1.3 2.6 96.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.5</td>
<td>1.3 3.3 95.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.9</td>
<td>0.3 5.0 94.7</td>
</tr>
<tr>
<td></td>
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<td>20.9</td>
<td>2.3 3.6 94.1</td>
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<td></td>
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<td>19.9</td>
<td>2.6 3.6 93.8</td>
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<td>7</td>
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<td>22.9</td>
<td>7.3 6.6 86.1</td>
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<td>20.9</td>
<td>8.6 5.0 86.4</td>
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<td></td>
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<td>19.9</td>
<td>6.3 5.0 88.7</td>
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<td>9</td>
<td>27.8</td>
<td>51387</td>
<td>8.3 5.0 85.7</td>
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<td>22.9</td>
<td>10.3 4.9 84.8</td>
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<tr>
<td></td>
<td></td>
<td>20.9</td>
<td>11.6 4.7 83.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19.9</td>
<td>10.5 5.1 84.4</td>
</tr>
</tbody>
</table>

**Sowing precision, was determined for sunflower, under the following conditions:**
- mass of 1000 seeds of 67 g;
- distribution disc with 14 orifices;
- depression of 240 mm H₂O height;
- simulated working speed: 5, 7, 9 km/h.

Measurements were made in 3 repetitions, at more density values of plants per hectare, the results being shown in figure 3.

**Precizia de semănătă, s-a determinat pentru floarea soarelui, în următoarele condiții:**
- masa a 1000 de semințe de 67 g;
- disc distribuitor cu 14 orificii;
- deprezia de 240 mm col H₂O;
- viteză de lucru simulată: 5, 7, 9 km/h.

Determinările s-au făcut în 3 repetiții, la mai multe densități ale plantelor la hectar, rezultatele fiind prezentate în figura 3.

**Hopper seed level influence on sowing precision**

We studied the influence of sowing precision with the hopper loaded at 100%; 50%; 12.5% from the total volume.

Samples were carried out with seeds of corn and sunflower, at a speed of 5 km / h respectively 3 norms of plants per hectare, the results being shown in table 2 and figure 4.

**Influența nivelului de semințe în buncăr asupra preciziei de semănat**

S-a studiat influența preciziei de semănat cu buncărul încărcat 100%; 50%; 12.5% din volumul total.

Probele s-au efectuat cu semințe de porumb și floarea soarelui, la viteză de 5 km/h respectiv la 3 norme de plante la hectar, rezultatele fiind prezentate în tabelul 2 și figura 4.
**Slope influence on sowing precision**

We studied the influence of sowing precision with slope simulation of 11° to the right.

Samples were carried out with seeds of corn and sunflower, at a speed of 5 km/h, respectively 3 norms of plants per hectare, the results being shown in table 3 and figure 5.

**Influența pantei asupra preciziei de semânat**

S-a studiat influența preciziei de semânat cu simularea pantei de 11° dreapta.

Probele s-au efectuat cu semințe de porumb și floarea soarelui, la viteză de 5 km/h respectiv la 3 norme de plante la hectar, rezultatele fiind afișate în tabelul 3 și figura 5.

### Table 3 / Tabelul 3

<table>
<thead>
<tr>
<th>Speed / Viteză [km/h]</th>
<th>Norm / Norma [plants/ha / plante/ha]</th>
<th>Com sowing precision / Precizia de semânat la porumb [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slope / Panta [%] 0 11</td>
</tr>
<tr>
<td>5</td>
<td>53957</td>
<td>95.4 88.9</td>
</tr>
<tr>
<td></td>
<td>62258</td>
<td>94.7 88.4</td>
</tr>
<tr>
<td></td>
<td>68415</td>
<td>94.1 89.3</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

It is noted that at speed variation within the limits of 5-9 km/h, the sowing precision decreases with approximately 5% for each gear speed.

When the hopper is filled up to 100%, 50% and 12.5%, the sowing precision decreases by approximately 3%.

In the case of slope simulation of 11° sowing precision is reduced by approximately 7%.

An optimum seedbed preparation leads to the possibility of achieving a higher speed sowing work thus increasing productivity.

A breakthrough in sowing machines field can be achieved by improving their design by:

- An automatic adjusting of rotation speed of the shaft sections which leads to the distribution of seed disk in conjunction with the speed of the car measured by a sensor;
- Increase the capacity of hopper which would cover a large area of land in which the sowing will be performed without affecting the sowing accuracy.

**CONCLUZII**

Se observă că la variația vitezei în limitele 5-9 km/h precizia de semânat scade cu aproximativ 5% la fiecare treaptă de viteză.

La încârcarea buncărului în proporții de 100%, 50% și 12,5% precizia de semânat scade cu aproximativ 3%.

În cazul simulației pantei de 11° precizia de semânat scade cu aproximativ 7%.

O pregătire optimă a patului germânatic conduce la posibilitatea realizării lucrării de semănat la viteză superioară a ceea ce va determina creșterea productivității.

Perfeclonarea mașinilor de semânat se poate obține prin îmbunătățirea lor constructivă prin:

- reglarea automată a turării axului care antrenează discurile distribuitoare ale secțiilor de semințe în corelație cu viteză de deplasare a mașinii măsurată de un sensor;
- mărirea capacității buncărului de semințe ceea ce ar conduce la acoperirea unei suprafețe mai mari din terenul pe care se va realiza lucrarea de semânat, fără afectarea preciziei de semânat.
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THEORETICAL STUDY ON FEEDING THE TANGENTIAL THRESHING SYSTEM OF CONVENTIONAL COMBINE HARVESTERS

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Abstract: The working capacity of conventional cereal combine harvesters is mainly determined by the working capacity of tangential thresholding system. This depends on the technical and functional characteristics of the threshing system itself, the characteristics of the harvested vegetal matter and the characteristics of the feeding thresholding system with vegetal matter. The feeding thresholding system is made of the feeder house which is composed of a conveyor with chains and slats. The objective of this study is to develop a mathematical model for feeding thresholding system with vegetal matter in order to determine the technical and functional characteristics of the conveyor with chains and slats of the feederhouse. Theoretical research in this area did not fully complete the mathematical model.

Keywords: cereal combine harvester, feederhouse

INTRODUCTION

The tangential threshing system capacity is affected by the uniformity and speed of feeding with vegetal matter of the threshing system, made by the conveyor with chains and slats of feederhouse, by the technical and functional characteristics of the threshing system itself and the characteristics of the harvested vegetal matter.

The feederhouse is positioned in the combine harvester technological flow between the header and the threshing system (Fig.1).

The feederhouse is composed of a housing, a conveyor with chains and slats, a chain stretching system, a system of lifting the fore axle of the conveyor, an assembly of supporting the upper branch of the conveyor, a mechanical transmission for driving conveyor positioned on the drive shaft and an external transmission for driving the header or other equipment (Fig. 2 and Fig. 3).

Elevatorul central este compus dintr-o carcasă, un transportor cu lanți și racete, un sistem de întindere a lanțurilor, un sistem de ridicare a axului anterior al transportorului, un ansamblu de sustinere a ramurii superioare a transportorului, o transmisie mecanică pentru acționarea transportorului poziționată pe axul de antreneu și o transmisie exterioră pentru acționarea hederului sau altui echipament (fig. 2 și fig.3).
Fig. 2 – Systems of chains stretching and lifting the fore axle of conveyor for Laverda combines / Sistemele de întindere a lanturilor și ridicare a axului anterior ale transportorului la combinele Laverda

At some combine harvesters, the feederhouse has a mechanical hydrostatic or electromechanical transmission for reversing the conveyor’s motion, in case of clogging (Fig. 4).

Fig. 3 – Reversor, conveyor with chains and slats, housing and external transmission at New Holland combines / Inversorul, transportorul cu lanturi și raclete, carcasa și transmisia externa la combinele New Holland

La unele combine, elevatorul central are o transmisie mecanohidrostatică sau electromecanică pentru inversarea mișcării transportorului, în caz de înfundare (Fig. 4).

Fig. 4 - Mechanical hydrostatic reverser of the CWS Series combine harvesters (John Deere firm) / Inversor mecanohidrostatic al combinelor din Seria CVS (firma John Deere)

MATERIAL AND METHOD
The harvested vegetal matter from the header of the combine harvester is taken by a conveyor with chains and slats of the feederhouse, ideally oriented with ears farward (Fig. 4).

MATERIAL ŞI METODĂ
Masa vegetală recoltată de hederul combinei este preluată de transportorul cu lanturi și raclete al elevatorului central, ideal cu spiciele orientate înainte (fig. 4).
Each slat is loaded with a quantity of material based on the vegetal mass flow supply of combine harvester, chains speed and the distance between the conveyor chain slats. The vegetal mass transported by one slat is calculated with the relation 1.

$$m_r = \frac{qp}{v_{r1}}$$  \hspace{1cm} (1)

where $m_r$ is the vegetal mass transported by one slat; $q$ – the combine harvested vegetal matter flow; $p$ – the distance between the slats; $v_{r1}$ – the slat speed.

The slat speed can be calculated with the relation 2.

$$v_{r1} = \frac{n_{tr} D_d}{60} \frac{\omega}{2} = \frac{m_n D_d}{2}$$  \hspace{1cm} (2)

where $\omega$ is the angular speed of the conveyor chain sprocket; $n_{tr}$ – conveyor drive speed; $D_d$ – chain sprocket pitch diameter.

The vegetal matter transported by a slat between the two conveyor shafts moves with friction on the slat and feederhouse active surface. In position $A_1$ of the slat the transported material is in contact with the feederhouse active surface and travels relatively to the slat under the forces represented in figure 5.

Transported material moves along the slat active surface from the position $B_1$ to $B_2$. The force acting on a material particle positioned in $B$, along the active part of the slat surface is given by the relation 3.

Materialul transportat se deplasează de-a lungul părții active a raclețelui de la $B_1$ la $B_2$. Forța care acționează asupra particulei materiale aflată în poziția $B$, pe direcția părții active a raclețelui este dată de relația 3.
where $F_1$ is the force acting on a material particle driven by the slat, located in the position $A_1$;
$m_r$ – the material mass transported by one slat;
$g$ – the gravitational acceleration;
$\alpha$ – the conveyor angle measured from the horizontal plane;
$f$ – the coefficient of friction of the material in contact with the components of elevator.

The material particle acceleration is given by the relation 4.

$$a_1 = g(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (3)

where:
$a_1$ is the acceleration of material particle moving along the active surface of the slat, located in the position $A_1$;

The material particle speed along the active surface of the slat is given by the relation 5.

$$v_{m1} = \frac{Lg}{\omega r}(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (4)

where:
$v_{m1}$ is the speed of the material particle moving along the active surface of the slat, located in the position $A_1$;
$L$ – the distance between the two conveyor shafts.

The material particle speed driven by the slat between the two conveyor shafts is given by the relation 6.

$$V = v + v_{m1}$$  \hspace{1cm} (5)

where $V$ is the speed of the material particle driven by the slat between the two conveyor shafts.

The material particle speed angle $\delta_1$ related to the perpendicular to the active surface of the slat is given by the relation 7.

$$\delta_1 = \arctg \frac{4Lg}{\omega^2 D_a}(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (6)

where:
$\delta_1$ is the particle speed angle in relation to the perpendicular of the active surface slat, located in position $A_1$.

The diagram of forces acting on a material particle, on the active surface of the slat, located in the position $A_2$.

FIG. 7 - A diagram of forces acting on a material particle, on the active surface of the slat, located in the position $A_2$.

FIG. 6 - The speed of the material driven by the conveyor slat, located in the position $A_1$.

Viteza materialului transportat de racletele transportorului, aflat în poziția $A_1$.

unde $F_1$ este forța care acționează asupra particulei materiale antrenată de raclete, aflat în poziția $A_1$;
$m_r$ – masa materialului transportat de un raclet;
$g$ – acelașia gravitațională;
$\alpha$ – unghiul de înclinare al transportorului în raport cu orizontală;
$f$ – coeficiențul de frecare al materialului pe componentele elevatorului.

Acelașia punctului material este dată de relația 4.

$$a_1 = g(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (4)

unde:
$a_1$ este accelerația de deplasare a materialului pe partea activă a racletelui, aflat în poziția $A_1$;
Viteza materialului de-a lungul părții active a racletelui este dată de relația 5.

$$v_{m1} = \frac{Lg}{\omega r}(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (5)

unde $v_{m1}$ este viteza de deplasare a materialului pe partea activă a racletelui, aflat în poziția $A_1$;
$L$ – distanța între cei doi arbori ai transportorului.

Viteza materialului antrenat de raclete între cei doi arbori ai transportorului este dată de relația 6.

$$V = v + v_{m1}$$  \hspace{1cm} (6)

unde $V$ este viteza materialului antrenat de raclete între cei doi arbori ai transportorului.

Unghiul vitezii $V_1$ a materialului în raport cu perpendiculara pe partea activă a racletelui este dat de relația 7.

$$\delta_1 = \arctg \frac{4Lg}{\omega^2 D_a}(\cos \alpha \cdot \sin \alpha)$$  \hspace{1cm} (7)

unde $\delta_1$ este unghiul vitezii materialului în raport cu perpendiculara părții active a racletelui, aflat în poziția $A_1$.
The force acting on the material particle along the active surface of the slat, located in position \( A_2 \), is given by the relation 8.

\[
F_2 = m_2 \left[ \omega^2 r_1 + g \left( \cos(\alpha + \beta) - \sin(\alpha + \beta) \right) \right] \tag{8}
\]

Where: \( F_2 \) is the force acting on a material particle on the active surface of the slat, located in the position \( A_2 \); \( r_1 \) - the circle radius of the material particle, located in the position \( B_1 \).

Diagrama forțelor care acționează asupra unei particule materiale, pe partea activă a racletelui, aflată în poziția \( A_3 \).

The force acting on the material particle along the active surface of the slat, located in position \( A_3 \), is given by the relation 9.

\[
F_3 = m_3 \left[ \omega^2 r_2 + g \left( \cos(\alpha + \beta) + \omega^2 r_2 \cdot \sin(\alpha + \beta) \right) \right] \tag{9}
\]

Unde: \( F_3 \) este forța care acționează asupra particulei materiale pe partea activă a racletelui, aflată în poziția \( A_3 \); \( r_2 \) - raza de dispunere a particulei materiale, aflată în poziția \( B_3 \). Accelerația medie de deplasare a materialului este dată de relația 10.

\[
a_m = \frac{1}{2} \left[ \omega^2 (r_2 + r_1) + g \left( \cos(\alpha + \beta) + \cos(\alpha + \beta) \cdot \sin(\alpha + \beta) \cdot \sin(\alpha + \beta) \right) \right] \tag{10}
\]

Unde: \( a_m \) este accelerația medie de deplasare a materialului pe partea activă a racletelui, aflată în mișcare de rotație. Unghiul de descărcare a racletelui poate fi calculat cu relația 11.

\[
\beta = \frac{2 \omega}{\left[ \omega^2 (r_2 + r_1) + g \left( \cos(\alpha + \beta) + \cos(\alpha + \beta) \cdot \sin(\alpha + \beta) \right) \right]} \tag{11}
\]

Unde: \( \beta \) este unghiul de descărcare a racletelui, aflat în mișcare de rotație. Viteza materialului de-a lungul părții active a racletelui este dată de relația 12.

\[
v_{m2} = \sqrt{\omega^2 (r_2^2 + r_1^2) + g(r_2 \cdot r_1) \left[ \cos(\alpha + \beta) + \cos(\alpha + \beta) \cdot \sin(\alpha + \beta) \right]} \tag{12}
\]

Unde: \( v_{m2} \) - viteza de deplasare a materialului pe partea activă a racletelui, aflată în mișcare de rotație. În poziția \( A_3 \), viteza \( V_2 \) de alimentare a aparatului de treier este compusă din viteza \( v_{m2} \) a racletelui și viteza \( v_{m2} \) a materialului imprimată de raclete, aflată în mișcare de rotație, conform figurii 9 și relației 13.
The material speed transported by the conveyor slat, located in position $A_3$ / Viteza materialului transportat de racletele transportorului, aflat în poziția $A_3$

$$V_2 = V_{r2} + V_{n2}$$

where:

$V_2$ - the feeding speed of the threshing system;

$V_{r2}$ – speed of the slat in the position $B_2$.

The material speed angle $\delta_2$ measured from the perpendicular to the slat active surface is given by the relation 14.

$$\delta_2 = \arctg \left[ \frac{\omega r - r_2 + g(r_2 - r_1) \cos(\alpha + \beta) + \cos\alpha \cdot \sin(\alpha + \beta) - \sin\alpha}{\omega r_2} \right]$$

where:

$V_2$ - viteză de alimentare a aparatului de treier;

$V_{r2}$ - viteza racletelui în punctul $B_2$.

Unghiul $\delta_2$ al vitezei materialului în raport cu perpendiculara pe partea activă a racletelui este dat de relația 14.

In the transition zone from the feederhouse to the threshing system, the vegetal mass is moving along an articulated plate to concave, which seals this area. The articulated plate also has the role to reduce the feeding angle with material of the threshing system for its taking over by the bars of threshing cylinder, its configuration being that of the material trajectory discharged by the conveyor slat.

The transition zone, the trajectory and the material speed direction when the material is discharged by the slats are presented in figure 10.

Grosimea materialului la alimentarea aparatului de treier se calculează cu relația 15.

$$h_a = \frac{q}{I_{w2}V_2Y}$$
where:
- \( h_2 \) - the thickness of the crop material feeding the thresher system, in m;
- \( q \) – combine crop material flow, kg/s;
- \( l_{ov} \) – internal width of feeder housing, m;
- \( V_2 \) – the crop material speed entering the thresher system, m/s;
- \( \gamma \) – the crop material bulk density, kg/m³.

For an optimal feeding of threshing system, the material feeding time must be equal to the material takeover time and its passage through the threshing space, according to the relation 16.

\[
t_{\text{aim}} = t_{\text{br}}.
\]

where:
- \( t_{\text{aim}} \) is the material feeding time;
- \( t_{\text{br}} \) - the material takeover time and its passage through the threshing space.

The material feeding time of the threshing system is calculated with the relation 17.

\[
t_{\text{aim}} = \frac{p}{v_i} = \frac{60p}{\frac{m_3}{m_1} D_3}
\]

The material takeover time and its passage through the threshing space is calculated with the relation 18.

\[
t_{\text{br}} = \frac{300}{m_3} n_b
\]

where:
- \( \theta \) - the angle of the bar which takes over the material and the bar which comes out of the threshing space;
- \( n_b \) - the threshing cylinder speed.

Starting from the relation 16, it follows that the conveyor drive speed depends on the threshing cylinder speed corresponding to the harvest vegetal matter and can be calculated with the relation 19.

\[
n_b = \frac{2p}{\theta D_3} n_b
\]

RESULTS

For the calculation of the parameters used in this analysis, the following values characteristic to the combine harvester C110 [4,5] are being used:
- the combine harvester crop material flow: \( q=3.9...6.2 \text{kg/s} \);
- chain sprocket speed for driving the conveyor: \( n_0=518 \text{rot/min} \);
- the chain sprocket pitch diameter: \( D_2=0.142\text{m} \);
- number of slats: \( z_r=14 \);
- the distance between two consecutive slats: \( p=0.16\text{m} \);
- the slat length: \( l_{slat}=1.03\text{m} \);
- the radius to point \( B_1 \): \( r_1=0.096\text{m} \);
- the radius to point \( B_2 \): \( r_2=0.118\text{m} \);
- the feederhouse sloping angle measured from the horizontal plane \( \alpha=32^\circ \);
- the angle of the bar which takes over the material and the bar which comes out of the threshing space \( \theta=2.356\text{rad} \);
- the distance between the feederhouse conveyor shafts: \( L=1.63\text{m} \).

According to the mathematical model presented, the results are:
- the crop material mass transported by one slat: \( m_1=0.162...0.258\text{kg} \);
- the slat speed: \( v_i=3.85\text{m/s} \);
- the speed of the crop material along the active surface of the conveyor slat in position \( A_1 \): \( v_{m1}=2.64\text{m/s} \);
- the speed of the crop material driven by the conveyor slat between the two conveyor shafts: \( V_{l1}=4.67\text{m/s} \);
- the material particle velocity angle measured from the perpendicular on the active surface of the conveyor slat in the position \( A_1 \): \( \delta_1=34.42^\circ \).

REZULTATE

Pentru calculul mărîrilor prezentate în studiu, se folosesc următoarele valori caracteristice comblinei C110 [4,5]:
- debit de alimentare cu masă vegetală al comblinei: \( q=3.9...6.2\text{kg/s} \);
- turaţia roţi de lanţ de antrenare a transportorului: \( n_0=518\text{rot/min} \);
- diametru de divizare al roşii de lanţ: \( D_2=0.142\text{m} \);
- numărul racelilor: \( z_r=14 \);
- pasul recelilor: \( p=0.16\text{m} \);
- lungime racelte: \( l_{alim}=1.03\text{m} \);
- raza punctului \( B_1 \): \( r_1=0.096\text{m} \);
- raza punctului \( B_2 \): \( r_2=0.118\text{m} \);
- unghiul de înclinare al elevatorului central în raport cu orizontală \( \alpha=32^\circ \);
- unghiul făcut de şina bătătorului care preia materialul şi şina care iee din spaţiul de treier: \( \theta=2.36\text{rad} \);
- distanţa între arborii transportorului: \( L=1.63\text{m} \).

Conform modelului matematic prezentat, rezultă:
- masa materialului transportat de un raculet: \( m_1=0.162...0.258\text{kg} \);
- viteza raceltei: \( v_{r1}=3.85\text{m/s} \);
- viteza de deplasare a materialului pe partea activă a raceltei, aflat în poziţia \( A_1 \): \( v_{n1}=2.64\text{m/s} \);
- viteza materialului antrenat de raclete între arborii transportorului: \( V_{l1}=4.67\text{m/s} \);
- unghiul vitezei materialului în raport cu perpendiculara pe partea activă a raceltei, aflat în poziţia \( A_1 \): \( \delta_1=34.42^\circ \).
- the conveyor slat discharge angle when the slat is in a rotation movement: $\beta=16^\circ$;
- the speed of the crop material along the active surface of the conveyor slat in a rotation movement: $v_{\text{ci}}=3.723\text{m/s}$;
- the conveyor slat speed in point $B_2$: $v_{\text{ci}}=6.4\text{m/s}$;
- the speed of the crop material driven by the conveyor slat in a rotation movement: $V_2=7.4\text{m/s}$;
- the material particle velocity angle measured from the perpendicular to the active surface of the conveyor slat: $\delta=30.19^\circ$;
- the height of the crop material entering the threshing system $h=0.064…0.102\text{m}$ (for $y=15\text{kg/m}^3$);
- conveyor drive speed $n_h=918\text{rot/min}$, for the threshing cylinder speed $n_b=960\text{ rot/min}$.

**CONCLUSIONS**

According to mathematical model presented, the drive speed of conveyor with chains and slats must be correlated with the threshing cylinder speed characteristic to vegetal mass harvested. For example, in wheat harvesting, maximum performances of the threshing process conducted by the combine harvester threshing system C110 will get to the conveyor with chains and slats drive speed $n_h=918\text{rot/min}$, which represents a material feeding speed of the threshing system $V_2=13.13\text{m/s}$.

For the current conveyor drive speed $n_h=518\text{rot/min}$, results in an angle of the bar which takes over the material and the bar which comes out of the threshing space of $\theta=239.29^\circ$, the threshing system feeding with material being made with pauses.

**REFERENCES**


- unghii de descărcare a racletelui, aflat în mișcare de rotație: $\beta=16^\circ$;
- viteză de deplasare a materialului pe partea activă a racletelui, aflat în mișcare de rotație: $v_{\text{ci}}=3.723\text{m/s}$;
- viteză racletelui în punctul $B_2$: $v_{\text{ci}}=6.4\text{m/s}$;
- viteză de alimentare a aparatului de treier: $V_2=7.4\text{ m/s}$;
- unghii vitezii materialului în raport cu perpendiculara pe partea activă a racletelui: $\delta=30.19^\circ$;
- grosimea materialului la alimentarea aparatului de treier $h=0,034…0,054\text{m}$ (pentru $y=15\text{kg/m}^3$);
- turația de antrenare transportor $n_h=918\text{rot/min}$, pentru o turație a bătătorului de $n_b=960\text{ rot/min}$.

**CONCLUZII**

Conform modelului matematic prezentat, turația de acționare a transportorului cu lanțuri și raclete trebuie să fie corelată cu turația bătătorului caracteristică masei vegetale recoltate. De exemplu, la recoltarea grâului, performanțe maxime ale procesului de treier realizat de aparatul de treier al combinei C110 se vor obține pentru o turație de antrenare a transportorului cu raclete de $n_h=918\text{rot/min}$, ceea ce reprezintă o viteză de alimentare cu material a aparatului de treier de $V_2=13.13\text{m/s}$.

Pentru actuala turație de acționare a transportorului de $n_h=518\text{rot/min}$, rezultă un unghii făcut de şina bătătorului care preia materialul şi şina care lese din spaţiul de treier de $\theta=239,29^\circ$; alimentarea aparatului de treier cu material a făcându-se cu pauze.

**BIBLIOGRAFIE**

RESEARCHES ON REDUCING OF LOSSES AT FODDER HARVESTING WITH THE WINDROVERS

CERCETARI PRIVIND REDUCEREA PIERDERILOR LA RECOLTAREA FURAJELOR CU VINDROVERELE

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Abstract: The paper presents the theoretical and practical research on the achievement and testing of a trailed windrower for fodder harvesting which carries out the operations of mowing, crushing and placing in continuous and uniform swath of grassy fodder plants on the ground for natural drying, by a single passing. On the windrower were tested two types of conditioning devices for forages aiming the reduction of harvesting losses for different types of crops.

Keywords: windrower, fodder, ensilage, cutting device, rolls forage crusher

INTRODUCTION

Ensuring of a high quality forage throughout the year is one of the main concerns of the animal breeders which monitor the cost reduction by lowering losses at harvest as well as obtaining of some forage with superior nutritional quality and their conservation in advantageous conditions. For this reason the forage harvesting is done at biological maturity when it contains a high amount of nutrients (proteins, phosphorus, potassium) and which does not coincide most times with the maximum vegetative mass. Globally the concerns in the field are particularly complexes and include a wide range of activities. Annual forage losses during harvest, transport, storage and handling up to the animals feeding, are estimated at 28...30% out of annual production, from which about 20% are recorded during the harvest, as well on field drying and 8...10% during storage and distribution operations to animals [8]. The researches conducted abroad and in our country have shown that the harvesting losses do not coincide most times with the maximum vegetative mass. The field losses are estimated at 28...30% out of annual production, from which about 20% are recorded during the harvest, as well on field drying and 8...10% during storage and distribution operations to animals.

Experimental measurements have shown that during the first 4 days of stationing on the field of mowed forage the dry matter losses are 1...1.5% per day and can reach up to 4% daily for longer periods of time. The researches conducted abroad and in our country have shown that it can be reduced to half the forage stationary time in the field by introducing the plant crushing operation, respectively of the stalks along with mowing, process that speeds up the evaporation of water and equalizes leaves and stalks drying [1, 4].

This operation can be performed with crushing devices driven by tractor or, in most cases these are mounted on mowers and the crushing is done simultaneously with plants mowing in the field.

Due to these advantages, the manufacturing companies have developed and diversified a wide range of mowers with crushings called windrovers, which have working widths up to 4.5 m, and in the field carries out in one pass the mowing, crushing and placing the plants in continuous swath on the ground, of various widths, depending on the production requirements.

MATERIAL AND METHOD

INMA has performed and tested an experimental model of towed windrower for harvesting forage called VTR-2.4 (fig. 1) intended for harvesting of grassy fodder plants (alfalfa, clover, grasses, herbs mixed with vegetables) for natural drying. Depending on the adopted working technology, the green crops located in the swath may be

Rezumat: În lucrare sunt prezentate cercetările teoretice și practice privind realizarea și încercarea unui windrower tractat pentru recoltat furaje care efectuează la o singura trecere operatiile de cosire, strivire, și asezare pe sol în braza continua și uniforma a plantelor furajere ieroase în vederea uscării naturale. Pe windrower au fost testate două tipuri de dispozitive pentru conditionat furaje urmându-se reducerea pierderilor la recoltare a diferitelor culturi furajere ieroase destinate pentru obtinerea fânului.

Cuvinte cheie: windrower, plante furajere, insilozare, aparat de taiere, strivitor de furaje cu valuri

INTRODUCERE

Asigurarea de furaje de buna calitate pe tot parcursul anului este una din preocupările de baza ale crescutorilor de animale care urmăresc reducerea costurilor prin micșorarea pierderilor la recoltat care și obtinerea unor furaje cu calități nutritive superioare și conservarea acestora în condiții care nu coincid, doar de câteva ori cu masa vegetală maxima. Pe plan mondial preocupările în domeniu sunt deosebit de complexe și cuprinde o paleta mare de activități.

Anual pierderile de furaje în timpul recoltătului, transportului, depozitării și manipulării pana la administrarea la animale, sunt estimate la 28...30% din producția anuală, din care o parte a pierderilor se regazeste în timpul recoltătului dar și uscarei pe câmp iar 8...10% în timpul operatiunilor de depozitare și distribuire a furajelor [3, 5, 6, 7, 8].

Masuratorii experimentale au aratat ca în primele 4 zile de stationare pe câmp a furajelor cosite pierderile de materie uscata sunt 1...1,5% pe zi putand ajunge pana la 4% pe zi pentru perioade mai mari de timp. Cercetările efectuate în strainatate și în țara au aratat ca poate fi reduz să jumătate timpul de sedere al furajelor pe câmp prin introducerea operatiei de strivire al plantei, respectiv al tulpinilor odate cu cosirea, proces ce evolueaza speed up the evaporation of water and equalizes leaves and stalks drying [1, 4].

Această operatie se poate realiza cu dispozitive de strivire active și asigurarea de bune calități a furajelor este realizată concomitent cu cosirea plantelor din lan.

Datorita acestor avantaje firmele constructoare au realizat și diversificat o gama variată de cositori cu strivire de statii care sunt montate pe mowers si strivitorul se realizeaza concomitent cu cosirea plantelor din lan.

INMA a realizat și încercat un model experimental de windrower tractat pentru recoltat furajelor, denumit VTR-2.4, (fig. 1) destinat recoltarii plantelor furajere ieroase (lucernă, trifoii, ierburi, amestecuri de ierburi cu leguminoase) în vederea uscării naturale. In functie de tehnologia de lucru adoptată, plantele furajere aflate în
collected when they reached the humidity of 50...55% for the ensilage at low humidity, or left to dry until reach 20% humidity, then being collected and stored as hay bulk or bales [2].

The towed windrover VTR-2.4 works in aggregate with 55-80 HP tractors, being coupled to coupling bar and the active elements are powered from the PTO via a cardanic transmission.

The windrover is carried on a frame equipped with two wheels with low pressure tires and a hitch for coupling to the tractor towing bar.

The cutting device is of rotating disc type driven by a transmission with gears mounted in a metal housing. The oval shaped rotating discs are placed above the metal housing on which are positioned two knives articulated by some special screws.

Given the diversity of forage crops from our country (alfalfa, clover, mash, grasses, mixtures of vegetables with herbs) that can be harvested with the forage windrovers, INMA has conducted tests with different forage crushing devices in different culture conditions, in which it was observed the crushing effect on the plants, the losses of material as well as the crushing devices behavior under various adjustments and crop conditions.

There were manufactured and tested the following constructive variants of crushing devices:
• crusher with two metal rollers with continuous helical ribs;
• crusher with two rollers, of which the upper one is rubberized, and the lower is with helical ribs;
• crusher with two rubberized rollers with equal diameters and profiled surface;
• crusher with rotor with elastic metallic claws;
• crusher with rotor with articulated metallic bar and with adjustable comb.

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• crusher with rotor with articulated metallic bar and with adjustable comb.
Disposizivele de strivit cu două valturi (fig. 2) sunt constituite în principal din două valturi de diametre diferite poz. 2 și 3 montate prin intermediul unor lagăre oscilante pe doi pereti din tablă, deflektorul poz. 4 și aparatul de tăiere poz. 1. Valturile au aplicate pe suprafață nervuri drepte sau elicoidale, iar valțul superior are posibilitatea flotării pe verticală în funcție de grosimea stratului de plante care trece prin strivitor.

Procesul de lucru al acestor strivitoare este următorul: plantele furajere cosite din lan sunt preluate de cele două valturi care au sensuri de rotație diferite și datorită forței de apăsare dintre cele două valturi plantele sunt lamine iar nervurile de pe suprafața lor realizează strivirea propriu-zisă. Viteza periferică a celor două valturi poz. 2 și 3 favorizează aruncarea în spate a plantelor strivite în deflektor poz. 4 căzând în brază continuă pe sol.

Disposizivele de strivit cu rotor cu gheare sau bare articulate (fig. 3) sunt de construcție metalică, iar organele de lucru activ îi constituie un rotor cilindric pe care sunt montate gheare metalice sau din alte materiale rigidă, distribuite uniform pe toată lungimea rotorului.

Principiul de lucru al acestor strivitoare este următorul: plantele furajere cosite din lan sunt preluate de ghearele sau barele rotorului și antrenate în sensul de rotație. Strivirea propriu-zisă are loc prin frecarea plantelor (chiar izbirea lor) de un paravan situat în partea superioară a traiectoriei ghearelor, care se poate apropia de rotor, intensificând procesul de frecare și strivire a plantelor (fig 3a).

În cazul strivitorului cu rotor și pieptene (fig. 3b) procesul de strivire este mai intens și cuprinde mai multe faze:
- în prima fază plantele sunt preluate de barele rotorului, și sunt strivite prin lovire;
- în a doua fază, plantele sunt lovită de capotă, lovire care contribuie la accentuarea fisurilor și spargerea peliculei ceroase care acoperă tulpinile;
- în faza a treia plantele sunt trecute printre dinții pieptenii, unde are loc și o defibrare.

Principalele caracteristici ale vindroverului VTR 2.4 sunt următoarele:
- lățimea de lucru, m .............................. 2.4;
- tipul aparatului de tăiere .................................. cu discuri rotative;
- frecvența de rotație a discurilor, min⁻¹ ........ 2700;
- numărul discurilor rotative, buc ...................... 6;
- numărul cutelilor pe disc, buc ......................... 2;
- tipul strivitorului, ........................................ cu două valturi;
- lățimea de lucru a strivitorului, m .................... 1750;
- acționare......................................... tractor de 55...85 CP
- turația prețului de putere, min⁻¹ ...... 540;
- viteza de lucru max., km/h .............................. 10;
- înlățimea de tăiere, mm .................................. 40...60;
- lățimea brazdelui de material, m ..................... 0.8...1.2
- greutatea, daN ........................................ 1840.

Principalele caractere tehnice și funcționale ale strivitoarelor sunt prezentate în tabelul 1 și 2.
Fig. 4 - The windrower VTR -2.4 to harvesting alfalfa / Vindroverul VTR -2,4 la recoltat lucerna

Table 1 / Tabelul 1

<table>
<thead>
<tr>
<th>Specification / Specificație</th>
<th>M.U./U.M.</th>
<th>Type of crusher / Tipul strivitorului</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 rifled metal rollers shaft / 2 valți metalice nervurate</td>
<td>m</td>
<td>2.7</td>
</tr>
<tr>
<td>With a metal roller and a rubberized roller / cu un vaț metalic și un vaț cauciucat</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>2 equal rollers shaft rubberized and profiled / 2 valți egale cauciucate și profilate</td>
<td></td>
<td>2.7</td>
</tr>
</tbody>
</table>

| rollers shaft diameter / Diametrul valțurilor | mm       |
| upper / superior | 168       |
| lower / inferior | 195       |
| rollers shaft speed / Turatia valțurilor | rot/min |
| upper / superior | 741       |
| lower / inferior | 635       |

Constructive working width / Lățimea constructivă de lucru m 2.7 2.7 2.7

- - rotor with elastic claws / rotor cu gheare elasctice
- - rotor with articulated bars and comb / rotor cu bare articulate și pieptene

Active range of claws / Raza activă a ghearelor mm 280 260

Claws pace / Pasul ghearelor mm 85 107

The tests were performed in aggregate with the 65 HP tractor of Romanian manufacturing.

The average values of working qualitative indexes at harvest alfalfa are presented in table 2.

Table 2 / Tabelul 2

<table>
<thead>
<tr>
<th>Index designation / Denumirea indicelui</th>
<th>M.U./U.M.</th>
<th>Determined value / Valoarea determinată</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective working width / Lățimea efectivă de lucru</td>
<td>m</td>
<td>2150</td>
</tr>
<tr>
<td>Cutting height (stubble) / Înăltîmâa de tăiere (mișcătea)</td>
<td>mm</td>
<td>60</td>
</tr>
<tr>
<td>Working speed / Viteza de lucru</td>
<td>km/h</td>
<td>6.2 ... 8.0</td>
</tr>
<tr>
<td>Crushing degree of plants / Gradul de strivire a plantelor</td>
<td>%</td>
<td>85</td>
</tr>
<tr>
<td>Characteristics of swaths / Caracteristicele brazdelor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• width / lățime</td>
<td>mm</td>
<td>0.9 – 1.6</td>
</tr>
<tr>
<td>• height / înăltîmâa</td>
<td>mm</td>
<td>-</td>
</tr>
<tr>
<td>• weight (at harvest) / greutate (în momentul recoltării)</td>
<td>kg/m.l.</td>
<td>approx. 3.2</td>
</tr>
<tr>
<td>Loss of material / Pierderi de material</td>
<td>%</td>
<td>1.5</td>
</tr>
</tbody>
</table>

The cutting height was 60 mm (according to the agrotechnical requirements for harvesting alfalfa) and was uniform throughout the entire working width. It must be noted that the cutting height can be adjusted between 40 and 80 mm depending on requirements of land and culture.

The optimum working speed was 7.5...8.0 km/h, however in the conditions of well leveled land is possible to work with speeds up to 10 km/h at an appropriate cutting height.

Înăltîmâa de tăiere a fost de 60 mm (conform cerințelor agrotehnice pentru recoltat lucernă) și a fost uniformă pe toată lățimea de lucru. De menționat faptul că din reglaje se pot obține înăltîmâi de tăiere cuprinse între 40...80 mm în funcție de cerințele de teren și cultură. Viteza optimă de lucru a fost de 7,5...8,0 km/h, însă în condițiile unui teren bine nivelat se poate lucra cu viteze de până la 10 km/h în condițiile unei înăltîmâi corespunzătoare de tăiere.
RESULTS

The crushing degree was calculated with equation (1):

\[ \lambda = \left(1 - \frac{S_2}{S_1}\right) \times 100\% \]  

(1)

where: \( S_1 \) = sample plant mass remained uncrushed and \( S_2 \) = total sample plants mass passed through crusher [2].

It was considered crushed plant any plant whose stalk was strangled in at least two places.

Material losses were determined by the relation (2):

\[ q = \frac{\delta}{S_2} \times 100\% \]  

(2)

where: \( \delta \) = mass of small leaf and plant fragments collected from the ground by removing the swath immediately after crushing and \( S_2 \) = total mass of plants from the sample surface, [4].

The testings of experimental models of crushers were conducted during the summer (June - August) at SC Agroindustrial Pantelimon, Ilfov County, and ICPCP Magurele Brasov, and the main biological characteristics of forage crops in which took place the testings are presented in table 3. In table 4 are presented the working indices of the crusher with rollers and in table 5 are shown the working indices of the crusher with claws.

Table 3 / Tabelul 3

<table>
<thead>
<tr>
<th>Specification / Specificație</th>
<th>M.U. / U.M.</th>
<th>Alfalfa first mowing / Lucernă coasa I-a</th>
<th>Alfalfa the II-nd mowing / Lucernă coasa a-II-a</th>
<th>Cultivated hayfield / Fâneță cultivată</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green mass production / Producția de masă verde</td>
<td>t/ha</td>
<td>19.5</td>
<td>14.7</td>
<td>23.4</td>
</tr>
<tr>
<td>The average height of the plants / Inălțimea medie a plantelor</td>
<td>mm</td>
<td>600</td>
<td>535</td>
<td>600</td>
</tr>
<tr>
<td>The average length of the plants / Lungimea medie a plantelor</td>
<td>mm</td>
<td>760</td>
<td>600</td>
<td>730</td>
</tr>
<tr>
<td>Vegetation stage / Stâlguirea</td>
<td>-</td>
<td>50% blossomed / inflorescent</td>
<td>70% blossomed / inflorescent</td>
<td>Earing / Înspicire</td>
</tr>
<tr>
<td>Humidity of plants / Umiditatea plantelor</td>
<td>%</td>
<td>78.30</td>
<td>76.20</td>
<td>75.50</td>
</tr>
<tr>
<td>Botanical composition / Compoziția botanică</td>
<td>%</td>
<td>- alfalfa / lucernă: 83</td>
<td>- alfalfa / lucernă =95</td>
<td>- festuca...............35</td>
</tr>
</tbody>
</table>

Table 4 / Tabelul 4

<table>
<thead>
<tr>
<th>Specification / Specificație</th>
<th>M.U. / U.M.</th>
<th>Alfalfa first mowing / Lucernă coasa I-a</th>
<th>Alfalfa the II-nd mowing / Lucernă coasa a-II-a</th>
<th>Cultivated hayfield / Fâneță cultivată</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green mass production / Producția de masă verde</td>
<td>t/ha</td>
<td>19.5</td>
<td>14.7</td>
<td>23.4</td>
</tr>
<tr>
<td>Flow rate of material passing through crusher / Debitul de material ce trece prin strivitor</td>
<td>t/ha</td>
<td>24.3</td>
<td>24.1</td>
<td>24.3</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire</td>
<td>%</td>
<td>82</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire:</td>
<td>%</td>
<td>88</td>
<td>83</td>
<td>-</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire:</td>
<td>%</td>
<td>87</td>
<td>90</td>
<td>20</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire:</td>
<td>%</td>
<td>1.4</td>
<td>1.1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire:</td>
<td>%</td>
<td>1.1</td>
<td>1.0</td>
<td>-</td>
</tr>
<tr>
<td>Material losses caused by crushing / Pierderi de material cauzate de strivire:</td>
<td>%</td>
<td>1.0</td>
<td>&lt;1</td>
<td>-</td>
</tr>
</tbody>
</table>

\[ S_1 \] = total sample plants mass passed through crusher and \( S_2 \) = total sample plants mass passed through crusher [2].

Pie chart:

- It was considered crushed plant any plant whose stalk was strangled in at least two places.

Graph:

- Material losses were determined by the relation (2):

\[ q = \frac{\delta}{S_2} \times 100\% \]  

(2)

where: \( \delta \) = mass of small leaf and plant fragments collected from the ground by removing the swath immediately after crushing and \( S_2 \) = total mass of plants from the sample surface, [4].

The testings of experimental models of crushers were conducted during the summer (June - August) at SC Agroindustrial Pantelimon, Ilfov County, and ICPCP Magurele Brasov, and the main biological characteristics of forage crops in which took place the testings are presented in table 3. In table 4 are presented the working indices of the crusher with rollers and in table 5 are shown the working indices of the crusher with claws.
Table 5 / Tabelul 5

<table>
<thead>
<tr>
<th>Specification / Specificație</th>
<th>M.U./U.M.</th>
<th>Forage crop / Cultura furajer</th>
<th>Cultivated hayfield / Fâneață cultivată</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green mass production / Productia de masă verde</td>
<td>t/ha</td>
<td>Alfalfa the II-nd mowing / Lucernă coasa a-II-a</td>
<td>Cultivated hayfield / Fâneață cultivată</td>
</tr>
<tr>
<td>Flow rate of material passing through the rollers / Debitul de material ce trece printre valturi</td>
<td>t/ha</td>
<td>24.1</td>
<td>24.3</td>
</tr>
<tr>
<td>kg/s</td>
<td>6.88</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Degree of crushing plants for / Gradul de strivire al plantelor pentru:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• crusher with rotor with claws / strivitor cu rotor cu gheare</td>
<td>%</td>
<td>99</td>
<td>73</td>
</tr>
<tr>
<td>• crusher with rotor with bars and comb / strivitor cu rotor cu bare și pieptene</td>
<td>%</td>
<td>99</td>
<td>87</td>
</tr>
<tr>
<td>Material losses, total / Pierderi de material, total</td>
<td>%</td>
<td>5.7,…8.0</td>
<td>1.0…1.3</td>
</tr>
<tr>
<td>• little leaves / frunzule</td>
<td>%</td>
<td>4.5,…6.0</td>
<td>-</td>
</tr>
<tr>
<td>• fragments of stalks / fragmente de tulpini</td>
<td>%</td>
<td>1.2…2.0</td>
<td>-</td>
</tr>
</tbody>
</table>

The field of alfalfa was characterized by an uniform height ground leveled and cleaned of impurities. The field of hayfield was well developed, the land presented small bumps and frequent mole mounds. The results of tests obtained in different culture conditions with the towed windrover VTR 2.4 equipped with crushing devices with rollers, are presented in the table 5, and the results of those with rotor with claws are presented in the table 6. Appropriate to the material flow rate which corresponded to the optimum working regime, the thickness of the material layer was between 10 and 30 mm.
CONCLUSIONS

Analyzing the results from Tables 5 and 6 obtained at tests with experimental models of crushers for forages it has been found the following:

1. The crushers with rollers characterized by a reduced aggressiveness on plants, perform an appropriate degree of crushing of 82 ... 93% at crushing alfalfa and a small crushing degree (not satisfactory) of 20%, at herbs. The losses of material are within 1 ... 1.4% at alfalfa, and at herbs are insignificant having values below 1%. The variant of riffled metal roller crusher realized losses greater than the rubberized variants, but are located below 1.5% according to the agro-technical requirements imposed to these types of machinery.

2. The crushers with rotor which are characterized by a greater aggressiveness on the plants, achieve a high degree of crushing, of 99% at crushing alfalfa, at herbs the degree of crushing being of 73 ... 87%. Due to high mechanical action on the plants, the loss of material at alfalfa crushing is between 5.7 ... 8.0% (well above the limit of 1.5% allowed by the agrotechnical requirements) and consist of little leaves detached from the stalks as well and consist of little leaves detached from the stalks as well of fragments and peaks of stalks. In the case of herbs stalks crushing the losses of material are within the normal range, namely about 1 ... 1.3%.

To highlight the efficiency of crushing of plants was pursued the dynamics of crushed plants drying compared with those non-crushed, both for alfalfa and for herbs. It was used the version of crusher with rollers with one of the rollers rubberized compared with the crusher with rotor with elastic claws, and the results are shown in the graphs in Figure 5. and Fig. 6. It is found that after two days of sun exposure, the crushed plants reach the humidity of 25 ... 30%, and the uncushed plants reach the humidity of about 40% with great unevenness between the side exposed to the sun and the swath bottom. It has also found the insignificant influence of the use of the crusher with rollers on the herbs from the grasslands, because, due to the low level of crushing (20%), the plants dry harder compared to those crushed by the crusher with rotor with elastic claws carrying out an adequate degree of crushing of 87%.

Based on results obtained at tests with experimental models of forages crushing devices can be drawn the following conclusions and recommendations:

- the crushers with rollers are suitable for the crushing of brittle forages (alfalfa, clover) with little leaves that can be easily detached under high mechanical action, producing a corresponding crushing degree under the conditions of low losses (fig. 5). Due to reduced aggressiveness on the plants their use is not recommended for the crushing of herbs from the grasslands because these effects are insignificant and the energy consumption is high.

- the crushers with rotor with elastic claws or with articulated bars (fig. 6), due to high mechanical action on the plants, are recommended for the crushing of herbs from the grasslands, where they provide a suitable crushing and defibring of plants, respectively 73 ... 87%, under the conditions of relatively small losses. Use of these crushers is not recommended for the crushing of alfalfa or clover because of large losses that they produce by splitting of little leaves, the breaking of the peaks or of the stalks.

REFERENCES


CONCLUZII

Analizând rezultatele din tabelele 5 și 6 obținute la încercări cu modelele experimentale de strativitoare pentru furaje se constată următoarele:

1. Strivitoarele cu valuri care se caracterizează printr-o agresivitate redusă asupra plantelor, realizează un grad de strativire corespunzător de 82 ... 93% la strativirea lucernă și un grad de strativire mic (nesatisfăcător) de 20%, la ierburi. Pierderile de material se situează în limitele de 1...1.4% la lucernă, iar la ierburi sunt nesemnificative având valori mai mici de 1%. Varianta de strativitor cu valuri metalice nerezultativo în realizat pierderi mai mari decât variantele cauciucate, dar se situează sub 1.5% conform cerințelor agrotehnice impuse acestor tipuri de mașini.

2. Strivitoarele cu rotor care se caracterizează printr-o agresivitate mai mare asupra plantelor, realizează un grad de strativire mare, de 99% la strativirea lucernă, la ierburi gradul de strativire fiind de 73...87%. Datorită acțiunii mecanice mari asupra plantelor, pierderile de material la strativirea lucernă sunt cuprinse între 5.7...8.0% (cu mult peste limita de 1.5% admisă de cerințele agrotehnice) și sunt constituite din frunzule subpini precum și din fragmente și vârfuri de tulpini. În cazul stratirii tulpinilor de ierburi pierderile de material se situează la limite normale sitându-se în jurul valorii de 1...1.3%.

Pentru a scoate în evidență eficiența strativirii plantelor s-a urmărit dinamica uscării plantelor strativite în comparație cu cele nestrivite, atât pentru lucernă cât și pentru ierburi. S-a folosit variația de strativitor cu valuri cu unul din valurile cauciucat comparativ cu strativitorul cu rotor cu gheare elasitce, iar rezultatele sunt prezentate în graficele din fig.5. și fig. 6. Se constată că după două zile de expunere la soare, plantele strativite ajung la umiditatea de ca. 40% cu neuniformitate mare între partea expusă la soare și fundul brazdelui. Se constată că asemenea influența nesemnificativă a folosirii strativitorului cu valuri asupra ierburilor de pe pajiști, deoarece datorită gradului scăzut de strativire (20%), plantele se usucă mai greu în comparație cu cele estruite de strativitorul cu rotor cu gheare elasitce care realizează un grad de strativire corespunzător de 87%.

Pe baza rezultatelor obținute la încercări cu modele experimentale de dispozitive de strativitate furaje se desprind următoarele concluzii și recomandări:

- strivitoarele cu valuri sunt recomandate pentru strativirea furajelor fragile (lucernă, trifoii) cu frunzule care se pot desprinde ușor sub acțiune mecanice mari, realizând un grad de strativire corespunzător în condițiile unor pierderi reduse (fig. 5). Datorită agresivității reduse asupra plantelor nu se recomandă utilizarea lor pentru strativirea ierburilor de pe pajiști, întrucât efectele sunt nesemnificative iar consumul energetic este mare.

- strivitoarele cu rotor cu gheare elasitce sau cu bare articulate (fig. 6) datorită acțiunii mecanice mari asupra plantelor, sunt recomandate pentru strativirea ierburilor de pe pajiști, unde realizează o strativire și o defibrare corespunzătoare a plantelor, respectiv 73...87%, în condițiile unor pierderi relativ mici. Folosirea acestor strativitoare nu se recomandă pentru strativirea lucernei sau trifoiiului datorită pierderilor mari pe care le produc prin desprinderea frunzelor, roperia vârfurilor sau a tulpinilor.

BIBLIOGRAFIE


REASONING ON PARAMETERS OF ROLLER WITH SPIRAL GROOVE OF FLAX PULLING MECHANISM

INTRODUCTION

Flax harvesting units (flax combines, flax pullers) preferably have the belt pulling mechanisms. Pulling mechanisms in such design cause length of flax band, which is the result of considerable nipping width of the pulling sections. Belt pullers have a complex design and drive, as well as significant dimensions.

Inventors and scientists proposed design of units for the flax pullers [1–5], which work on different principles. However, most design solutions for various reasons have not been achieved. So, now the pressing issue is the development of the design of the unit for the flax puller to eliminate possible shortcomings of existing design, provide high-quality implementation process of flax pulling.

MATERIALS AND METHODS

Theoretical research is carried out using the methods of theoretical mechanics, theory of mechanisms and machines, mathematical modeling. Modeling of roller flax pulling mechanism with spiral groove was performed using software MathCAD.

RESULTS

For pulling of flax it is proposed to install the roller flax pulling mechanisms on harvesting unit (flax combine, flax pullers) (Fig. 1) [2]. Each pulling mechanism contains a pair of rollers with rubberized surface, one of which is made with spiral groove and the other roller being smooth. Rollers have the possibility to rotate towards one another in a direction which is shown in Fig. 1. From the side, the entrance of the stems into the gap between the rollers is equipped with a conical tip. The horizontal axis of roller rotation is parallel to the direction in which the roller unit is moving. Rollers of adjacent sections are located between the stem dividers. From dividers to the cross conveyor over the rollers and along the conveyor, at two levels the guide in the vertical plane is foreseen, which location forms a channel to move stems in the unit.

While driving the puller in the field, the dividers share the stems of flax and send them to the pulling sections of

Abstract: The design of the roller flax pulling mechanism is proposed, in order to eliminate the shortcomings of existing designs, and obtain dependence to justify its basic structural and kinematic parameters. The dependence of the change of stem moving along the working area of the roller flax pulling mechanism is obtained.

Keywords: flax, flax combine, roller flax pulling mechanism, flax band, design, spiral groove, parameters
the roller flax pulling mechanism. In the pulling section, the stems are moved into the gaps between the rollers. Flax stems fall into spiral groove and as result of rotation of the rollers towards each other; they are extracted from the soil. The upper part of the stems moves through the channel formed by guides on two levels in the vertical plane, eliminating the possibility of winding up on the working surface of the machine and damages.

Fig. 1 - Roller flax puller / Вальцьовий витягач стебел
1 – roller with spiral groove / валець з гвинтовим пазом; 2 – smooth roller / гладкий валець; 3 – drive shaft / приводний вал; 4 – casing / кожух; 5 – cone-shaped lugs / конусоподібні наконечники; 6 – dividers / подільники; 7 – brush / щітки; 8 – cross conveyor / перехрестя транспортер; 9 – steering plate / спрямовуюча пластини; 10 – steering path / спрямовуюча доріжка; 11 – guides / спрямовувачі

To take the flax stems with the roller pulling mechanism of the proposed design without the formation of congestion in the working zone of rollers, they need to be moved along the working area of rollers faster than puller moves through the field. The value of the angular speed of rotation of rollers can be determined from the condition:

\[ \omega \geq \frac{2 \pi V}{p}, \]

where: \( V \) – the puller speed in the field, m/s; \( p \) – the step of the spiral groove of rollers, m.

The length of working zone of rollers in the pulling mechanism must be taken with condition that:

\[ l_{\text{min}} \leq l < l_{\text{max}}, \]

where: \( l_{\text{min}} \) – the minimum length of the working area of rollers that is needed to extract the stem root \( l_i \) from the soil (Fig. 2), \( l_{\text{max}} = \frac{p \phi_i}{2 \pi} = \frac{pl_i}{2 \pi} \), m; \( \phi_i \) – the angle of rotation for the roller at which the flax root will be extracted from the soil, rad.; \( r \) – radius of the roller, m;

where: \( \phi \) – the angle of the roller flax pulling mechanism must be taken with condition that: \( \phi \leq \frac{\pi}{2} \).

\( \omega \) – the angular speed of rotation of rollers, rad/s; \( p \) – the step of the spiral groove of rollers, m.

\( l_{\text{min}} \) – the minimum length of the working area of rollers that is needed to extract the flax root from the soil, m; \( l_{\text{max}} \) – the maximum length of the working area of rollers, m.

\( \phi \) – the angle of rotation for the roller, rad.

where: \( l_{\text{min}} \) – the minimum length of the working area of rollers that is needed to extract the flax root from the soil, m; \( l_{\text{max}} \) – the maximum length of the working area of rollers, m; \( \phi_i \) – the angle of rotation for the roller, rad.; \( r \) – radius of the roller, m;
We can conclude that the most favorable case for getting stem groove occurs when \( \varphi = 0 \text{ rad} \) (Fig. 3 a), but in this case the transfer of stems along the roller work area will not happen. Increasing the angle value \( \psi \) creates unfavorable conditions for getting stems into spiral groove of rollers (Fig. 3 b, c), and thus the stems are not nipped and do not move along the work area to the cross conveyor rollers.

Thus, the smaller the angle \( \psi \), the smaller the step \( p \), the more favorable conditions are created for the efficient operation of the roller pulling mechanism. In case of the two rollers with the same step of the spiral groove the angle \( \psi \) is smaller in the roller with the bigger radius.

For an effective process of flax threshing in the flax combine, the flax band needs to be stretched to reduce its thickness. If we denote the thickness of the bands formed after the pulling sections with rollers having the spiral groove with constant step, through \( h \), and the band thickness which enables the efficient threshing is through \( h_{opt} \), than the flax stretching coefficient will be:

\[
k = \frac{h}{h_{opt}}.
\]
If the speed of the flax stem movement along the rollers with steady step of the spiral groove is \( V_s \), and thus the band thickness \( h \) is formed, then to stretch the band, its speed on the following transport mechanisms (cross conveyor, clamping belt) should be increased by \( k \) times:

\[
V_{\text{opt}} = kV_s,
\]

where: \( V_{\text{opt}} \) – the stretching speed of flax band by \( k \) times of the initial value, m/s.

Stretching the band should not be done on the transporting mechanisms but at the stage of pulling of flax stems. This is because stretching of band after pulling of stems from all the sections into a single flow will lead to breakage of the seed capsules because the flax inflorescence of the stems are tightly linked to each other.

The growth of movement speed of the stems in the pulling sections can be achieved either by increasing the value of the angular speed of roller rotation, or by increasing the spiral groove step. Growth of angular speed of rollers can make the pulling of stems from the soil less efficient and damage them. Increasing the step value also affects the nipping of the stems into pulling sections.

The change in stem speed to value \( V_{\text{opt}} \) may be ensured by installation of rollers with variable step of the spiral groove into the pulling sections. Step size should increase from the initial value \( p_0 \), which will provide favorable conditions for entering the stems into the spiral groove and nipping, till the final value \( p_s \), through which the necessary stem speed value is achieved \( V_{\text{opt}} \).

We use the dependence to determine the change of the stem movement speed along the working area of the roller pulling mechanism:

\[
V_s(\varphi) = V_0 + (V_{\text{opt}} - V_s) \frac{\varphi}{\varphi_s},
\]

\[
\frac{dz}{dt} = V_s(t) = V_0 \left(1 + \left(k_{p_{\text{opt}}}-1\right) \frac{\omega \theta}{\varphi_s}\right),
\]

where: \( \varphi \) – the angle of rotation of the roller with spiral groove (where \( \varphi = \omega t \), rad; \( t \) - time, s; \( \varphi_s \) – the angle of rotation of the roller with spiral groove at which the stem reaches the end of the working area of rollers, rad.

The equations of the curve that describes in the system of coordinates \( xyz \) the spiral groove of the roller with variable step (Fig. 4 a, b), have the form:

\[
x(t) = r \cos(\alpha t);
\]

\[
y(t) = r \sin(\alpha t);
\]

\[
z(t) = V_0 \left(1 + \left(k_{p_{\text{opt}}}-1\right) \frac{\omega \theta}{2 \varphi_s}\right),
\]

where: \( 0 \leq t \leq t_{\text{opt}} = \frac{\varphi_s}{\omega} \); \( r \) – the radius of the roller with spiral groove, m.

Якщо швидкість переміщення стебел льону вздовж валців, які мають сталий крок гвинтового паза, складає \( V_s \) і при цьому формується стрічка товщиною \( h \), тоді для розтягування стрічки її швидкість на наступних механізмах (поперечний та затисні транспортери) необхідно збільшити у \( k \) разів, тобто:

\[
V_{\text{opt}} = kV_s,
\]

de: \( V_{\text{opt}} \) – швидкість стрічки за якої відбувається її розтягування у \( k \) разів від початкового значення, м/с.

Розтягування стрічки доцільно проводити не на транспортерах після бранного апарату, а на етапі брання стебел. Це пояснюється тим, що розтягування стрічки після об’єднання потоку стебел з усіх секцій в едну стрічку призводить до обриву насінневих коробочок, оскільки у сформованій стрічці верхівкові частини стебел міцно зчеплені між собою.

Зростання швидкості переміщення стебел у бранних секціях можна досягнути збільшеним кутовою швидкістю валців або збільшенням кроком гвинтового пазу валців. Зростання кутової швидкості може призвести до погіршення умов витягання стебел з ґрунту та їх пошкодження. Збільшення кроку також погіршує умови захоплення стебел валцями, тобто їх попадання у гвинтовий паз валців.

Забезпечити зміну швидкості стебел до значення \( V_{\text{opt}} \) можна за рахунок встановлення валців зі змінним кроком гвинтового паза. Крок гвинтового паза має збільшуватися від початкового значення \( p_0 \), за якого буде забезпечено умови для попадання стебел у гвинтовий паз і їх захоплення, до кінцевого значення \( p_s \), за якого досягатиметься швидкість стебел \( V_{\text{opt}} \).

Використаємо залежність для описаної зміни швидкості стебел вздовж робочої зони валцьового бранного апарату:

\[
V_s(\varphi) = V_0 + (V_{\text{opt}} - V_s) \frac{\varphi}{\varphi_s},
\]

де: \( \varphi = \omega t \) – кут повороту валця з гвинтовим пазом (де \( \varphi = \omega t \), рад.; \( t \) - час, с; \( \varphi_s \) – кут повороту валця з гвинтовим пазом за якого стебло досягне кінця робочої зони валців, рад.

Рівняння кривої, що описує у системі координат \( xyz \) гвинтовий паз валця зі змінним кроком (рис.4 a, b), матимуть вигляд:

\[
x(t) = r \cos(\alpha t);
\]

\[
y(t) = r \sin(\alpha t);
\]

\[
z(t) = V_0 \left(1 + \left(k_{p_{\text{opt}}}-1\right) \frac{\omega \theta}{2 \varphi_s}\right),
\]

де: \( 0 \leq t \leq t_{\text{opt}} = \frac{\varphi_s}{\omega} \); \( r \) – радіус валця з гвинтовим пазом, м.
Speed and cross-clamping transporters of the flax combine should be equal to \( V_m \).

Initial speed of the stems in rollers should be equal to the speed of the flax combine \( V_a = V \), and angular speed of rollers should be calculated as:

\[
\omega = \frac{2\pi V_a}{p_0}.
\]  

Taking into consideration the above, the favorable conditions for pulling of stems and efficiency of the next operations with the band will be ensured.

CONCLUSIONS

The suggested construction of the roller flax pulling mechanism can be installed on flax harvesting machine (flax combine, flax puller). The obtained dependencies can justify the parameters of the roller with the spiral groove of the pulling mechanism in particular (the radius of the roller with spiral groove \( r = 0.05 \) m; the angle of rotation of the roller with spiral groove at which the stem reaches the end of the working area of rollers \( \varphi = \pi \) rad.; the angular speed of rotation of roller \( \omega = 54.5 \text{ rad./s}; \) the flax stretching coefficient \( k = 1.8 \), the equation of the curve that describes the spiral groove of the roller with variable step, and the dependence of the change of stem moving along the working area of the roller flax pulling mechanism.

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ВИСНОВКИ

Запропоновано конструкцію вальцьового браїльного апарату, що може бути встановлений на льонокомбайній агрегаті (льонокомбайній, льонобральні). Отримано залежності, які дозволяють обґрунтувати параметри вальця з гвинтовим пазом браїльного апарату (рабіус вальця з гвинтовим пазом \( r = 0.05 \) м; кут повороту вальця з гвинтовим пазом за якого стебло досягне кінця робочої зони вальців \( \varphi = \pi \) рад.; кутова швидкість вальця \( \omega = 54.5 \text{ рад./с}; \) коефіцієнт розтягування стрічки \( k = 1.8 \) та рівняння кривої, що описує гвинтовий паз вальця зі змінним кроком, а також залежність зміни швидкості стебел вздовж робочої зони вальцьового браїльного апарату.

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THE INVESTIGATION OF THE PROCESS OF A SCREW CONVEYER SAFETY DEVICE ACTUATION / ДОСЛІДЖЕННЯ ПРОЦЕСУ СПРАЦЮВАННЯ ЗАПОБІЖНОГО ПРИСТРОЮ ГВИНТОВОГО КОНВЕЄРА

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Abstract: The article presents the design of a safety device with slipping and axial shifting regimes, which are separated in time and are used in order to recondition the working capacity of a conveyor. Also, power analysis of the operation of a safety mechanism is conducted, which gives the opportunity to estimate the change in the moment of rotation of a driven half-clutch and a screw T depending on the change in the angle of the relative turning of half-clutches ϕ. Based on the results of the static experimental investigation of the safety device, it was determined that the given static analytical dependences can be used in the engineering design of different standard sizes of a safety device.

Key words: screw conveyer, the safety device, half clutch, torque, groove.

INTRODUCTION
Screw conveyers are widely used for moving loose and lump materials in different production processes. However, when transporting some materials, a screw working body may jam, which can be caused by the clearance between the surface of screw rotation and the inner surface of a directing case.

In order to recondition the working capacity of a conveyor it is necessary to shift the jammed edge of a conveyor in the axial direction from the place of contacting with the material and, after the removal of the surcharge, the elements of the drive must provide the initial state of the working body for transporting the materials to the unloading area.

The principle of reversing a jammed body, which is carried out with the help of planetary safety devices, which secure the reverse rotation of a conveyor from a nonessential angle of turn to a couple of complete revolutions with further reconditioning of its initial state, is known. Moreover, it is possible to shift the jammed working body of a screw with the help of ball safety clutches with edgewise making of holes both at clutch release and at clutch engagement [1, 2, 3, 4, 5, 6, 7, 8].

Having analyzed the available investigations, it can be deduced that the main disadvantages of the existing safety devices, which ensure the reversing of overloaded working bodies, are their constructive and technological complexity, material holding capacity and unreliability in use. Also, they have considerable overall size and when working, there can be great dynamical load due to the significant inertia power of the slave holes of a drive and a working body with the automatic reconditioning of its initial state.

MATERIAL AND METHOD
In order to improve the effectiveness of the functioning of conveyers in the extreme conditions of their operation, the circuit of a safety device is propounded (Fig. 1. a), which ensures the axial shift of a screw in the direction opposite to the direction of the screw.

Резюме: В статті представлена конструкція запобіжного пристрою з розділенями в часі режими біккрутування та осьового зміщення шнека для автоматичного відновлення робочого стану конвеєра. Також проведений силовий аналіз роботи захисного механізму, який дає змогу оцінити зміну крутного моменту вedenої півмуфти і шнека T від зміни кута відносного прокруту півмфут T. Виконані експериментальні дослідження запобіжного пристрою, за результатами яких встановлено, що представлені в статті аналітичні залежності можуть бути використані при інженерному проектуванні різних типорозмірів запобіжного пристрою.

Ключові слова: шнековий транспортер, запобіжний пристрій, півмуфта, крутий момент, канавка.

ПЕРЕДУМОВА
Гвинтові транспортери широко використовують під час переміщення сипких і кускових матеріалів в різних виробничих процесах. Однак при транспортуванні матеріалів можливі запобігання гвинтового робочого органу, які виникають внаслідок неправильного використання шнека та внутрішньої поверхні направляючого кожуха.

Для відновлення працевдатності конвеєра необхідно відвести в осьовому напрямку заклінене ребро шнека від контакту з матеріалом, і в подальшому після зняття перевантаження, елементи приводу повинні забезпечити початкове положення робочого органу для транспортування матеріалу в зону вивантаження.

Відомий принцип реверсування закліненого робочого органу, який здійснюється за допомогою планетарних запобіжних пристроїв, що забезпечують зворотне прокрутування шнека від незначного кута повероту до декількох повних обертів з наступним відновленням початкового положення.

Також можливий спосіб осьового відведення закліненого гвинтового робочого органу за допомогою кулькових запобіжних муфт з профільним виконанням лунок, як при виході з заклінення, так і при їх входінні [1, 2, 3, 4, 5, 6, 7, 8].

З аналізу відомих досліджень видно, що основними недоломками існуючих запобіжних пристроїв, які забезпечують реверсування перевантажених робочих органів є їх конструктивна та технологічна складність, велика матеріаломісткість, ненадійність в роботі. Також вони мають значні габаритні розміри, а при їх роботі виникають велики динамічні навантаження, внаслідок значних сил інерції веденого ланцюг приводу та робочого органу з автоматичним відновленням його початкового положення.

МАТЕРІАЛ І МЕТОДИКА
З метою підвищення ефективності функціонування транспортерів у екстремальних умовах експлуатації запропонована схема запобіжного пристрою (рис. 1, a), що дозволяє забезпечити осьове відведення шнека в напрямку протилежному до напряму
material transportation at the automatic reconditioning of its working mode.

When the working body of a screw conveyer is jammed, the driven half-coupling of the device stops and the driving one continues rotation. As a result, the main unlinking of half-clutches takes place, in other words, balls come out of holes with the value of \( \delta_1 \). Then, the balls move along the inclined working grooves with \( \beta \) slope angle on the head plane of a driving half-clutch and thus, smooth and “soft” axial shift of a screw working body with the value of \( \delta_2 \) takes place, which essentially decreases the dynamic overloading of the drive of a screw conveyer. When a similar process occurs in the opposite direction, the balls come back into their holes.

**Fig. 1** – The constructive scheme of the safety device (a) and the scheme of the reamer of the working surface (b) / Конструктивна схема запобіжного пристрою (a) та схема розгортоки робочої поверхні ведучої півмуфти (б)

При виникненні заклинювання робочого органу шнекового транспортера ведена півмуфта запобіжного пристрою зупиняється, а ведуча продовжує обертатись. Внаслідок цього відбувається основне розчеплення півмуфт, тобто здійснюється вихід кульок з лунок на величину \( \delta_1 \). Далі кульки рухаються по похилих робочих канавках з кутом нахилу \( \beta \) на торцевій поверхні ведучої півмуфти, і таким чином здійснюється плавне “м’яке” осьове відведення гвинтового робочого органу на величину зазору \( \delta_2 \), що суттєво зменшує динамічне навантаження.
screw conveyor. Due to the rotation of a driving half-clutch, balls return to their initial state moving along inclined reverse grooves with $\gamma$ slope angle on the head plane of a driving half-clutch, in other words, smooth and "soft" reconditioning of the working capacity of a screw conveyor takes place.

Figure 2 shows the constructive scheme and the general form of the working surface of the driving half-clutch of a safety device [9].

In order to analyze the variations in the value of the moment of rotation from turning the half-clutches of a safety device at different stages of its actuation, power calculation was conducted.

At the first stage, the linkage of the balls and the holes of a driving half-clutch is to be considered (Fig. 1. b).

The initial $T_{1v}$ and the maximum $T_{\text{max}}$ moment of rotation is determined using the following formula (1):

$$T_{1v} = T_{\text{max}} = \frac{Rc\delta_0}{\sqrt{r^2 - (r-h)^2 + (r-h)\tan\varphi}},$$

where $R$ - radius of balls disposition; $c$ - spring stiffness; $\delta_0$ - preliminary spring pull; $r$ - radius of a ball; $h$ - maximum value of the movement of balls on the surface of holes; $\varphi$ - angle of friction.

At the second stage, when balls with a driven half-clutch move along the inclined working groove of a driving half-clutch, which causes the axial shift of an overloaded screw (fig/1,b), the initial $T_{2v}$ and the maximum $T_{\text{max}}$ moment of rotation is determined using the following formula (2):

$$T_{2v} = T_{\text{max}} = \frac{cR(\delta_0 + h + x_1)}{\sqrt{90 - \beta - \varphi}},$$

where $x_1$ is the running value of a ball coming out from a working groove.

At the third stage, when balls with a driven half-clutch move along the inclined flat surfaces of a driving half-clutch on the principal шнекового транспортера. Внаслідок обертання ведучої півмуфти кульки заходять у початкове положення, рухаючись при цьому по похиліх зворотних канавках з кутом нахилу $\gamma$ на торцевій поверхні ведучої півмуфти, тобто відбувається плавне "м'яке" відновлення робочого стану шнекового транспортера.

На рис. 2 зображена конструктивна схема та загальний вигляд робочої поверхні ведучої півмуфти запобіжного пристрою [9].
towards the holes in order to recondition the initial position of the whole system (Fig. 1.b), the initial \( T_0 \) and the maximum \( T_{\text{max}} \) moment of rotation are determined using the following formula (3):

\[
T_{\text{max}} = \frac{c \rho (\delta_i + h - x_2)}{\cos (90° - \gamma + \phi)}
\]

where \( x_2 \) - running value of a ball entering a reverse groove.

Fig. 3 shows the dependency of the change in the moment of rotation of a driven half-clutch and a screw \( T \) on the change of the angle of the relative turning of half-clutches \( \rho \), in static state in different angle positions of half-clutches in one cycle of the actuation of a safety device.

\( T \), Nm / Hz

Fig. 3. – Dependency of the change in the moment of rotation of a driven half-clutch and a screw \( T \) on the change of the angle of the relative turning of half-clutches \( \rho \).

In order to determine the pattern of the change in the maximum moment of rotation at different stages of the actuation of a safety device and, also, in order to determine the adequacy of the theoretical calculations, static experimental investigation was conducted.

For this reason the half-clutches of a safety device were installed in the grips of a pilot machine KM-50-1. The load of the driving half-clutch was performed with the help of rotating the lower grip by an electric motor through a gearing system. The value of the moment of rotation was measured using a circular scale while the relative deviation of the half-clutches was measured using an angular scale. Furthermore, the machine is equipped with a recording device, with the help of which the curve of the dependence of the moment of rotation on the angle of the lower grip turn was traced.

The general view of the test bed, in which a safety device is installed, is shown in fig. 4.

\( T \), Nm / Hz

Zone of the operatin condition of a clutch / Зона робочого режиму муфти

Zone of the full shift of a screw / Зона повного відведення шнека

Zone of the reverse movement of a screw / Зона зворотнього руху шнека

Zone of the smooth shift of half-clutches / Зона плавного віддалення півмуфт

Zone of the maximum shift of a screw / Зона максимального відведення шнека

Zone of the reconditioning of the working capacity of the conveyor / Зона відновлення робочого стану конвейера

Zone of all-clutches coming into their initial state / Зона входження півмуфт в початкове положення

\( \rho \), deg / rad

Zone of half-clutches coming into their initial state / Зона входження півмуфт в початкове положення

In order to determine the pattern of the change in the maximum moment of rotation at different stages of the actuation of a safety device and, also, in order to determine the adequacy of the theoretical calculations, static experimental investigation was conducted.

For this reason the half-clutches of a safety device were installed in the grips of a pilot machine KM-50-1. The load of the driving half-clutch was performed with the help of rotating the lower grip by an electric motor through a gearing system. The value of the moment of rotation was measured using a circular scale while the relative deviation of the half-clutches was measured using an angular scale. Furthermore, the machine is equipped with a recording device, with the help of which the curve of the dependence of the moment of rotation on the angle of the lower grip turn was traced.

The general view of the test bed, in which a safety device is installed, is shown in fig. 4.

\[
T_{\text{max}} = \frac{c \rho (\delta_i + h - x_2)}{\cos (90° - \gamma + \phi)}
\]

\( T_{\text{max}} \) крутий момент визначається за залежністю (3):

де \( x_2 \) - біжуча величина входу кульки у зворотну канавку.

За рис. 3 представлена залежність зміни кругового моменту ведучої півмуфти і шнека \( T \) від кута відносного повернення півмуфт \( \rho \), в станичному стані при різних кутових положеннях півмуфту при одному циклі спрацювання запобіжного пристрою.
In the process of experimentation, the value of the moments of rotation depending on the angle of the turning of a driving half-clutch was measured in a tenfold trial.

RESULTS AND DISCUSSION

Based on the results of the investigation conducted, it was determined that the uncoupling of half-clutches took place at the maximum moment of rotation, which greatly decreased when the balls were coming out of holes onto the inclined working grooves of a driving half-clutch. During the movement of the balls along the working grooves, there is no significant increase in the moment of rotation. In case of the movement of the balls along the inclined reverse grooves the antimoment arises, but its value does not exceed the moment of the actuation of a safety device.

Fig. 5 shows the results of theoretical (solid line) and experimental (dashed line) investigation.

The analysis of the graphical dependence shows that the error between the results of the theoretical investigation and the experimental investigation ranges from 3.5 to 19.1%.

Thus, based on the results of the comparative studies, it was determined that previously deduced analytical dependences (1), (2) and (3) for measuring the moment of rotation, transmitted by a safety device, adequately depict the real processes of the actuation of the designed safety mechanism. That is why the analytical dependences can be used in the engineering design of different standard sizes of a safety device.

При проведенні досліджень фіксували значення крутих моментів в залежності від кута повертання ведучої півмуфти в десятикратній повторюваності.

РЕЗУЛЬТАТИ

За результатами досліджень встановлено, що розчленення півмуфти відбувалось при максимальному крутовому моменті, який значно зменшується при виході кульок на похилі робочі канавки ведучої півмуфти. Під час руху кульок по робочих канавках крутий момент зростає не суттєво. У випадку руху кульок по похилі зворотних канавках виникає протимомент, однак його значення не перевищує момент спрацювання запобіжного пристрою.

На рис. 5 представлені результати теоретичних (суцільна лінія) і експериментальних (штрихова лінія) досліджень.

З аналізу даних графічних залежностей видно, що похибка між результатати теоретичних і експериментальних досліджень знаходиться в межах 3,5…19,1%.

Таким чином, за результатами порівняльних досліджень встановлено, що попередньо виведені аналітичні залежності (1), (2) і (3) для визначення крутового моменту, який передає запобіжний пристрій, адекватно відображають реальні процеси спрацювання розробленого запобіжного механізму. Тому дані аналітичні залежності можуть бути використані при інженерному проєктуванні різних типорозмірів запобіжного пристрою.
CONCLUSIONS

On the basis of the conducted patent survey and having analyzed the existing constructive and technological schemes of the safety devices of screw conveyers, a new construction of a safety device is propounded. The construction allows reducing the dynamic load of the drive, which greatly increases the longevity and improves the operational reliability of screw conveyers. Moreover, power analysis of the operation of a safety mechanism is conducted, which gives the opportunity to estimate the change in the moment of rotation of a driven half-clutch and a screw \( T \) depending on the change in the angle of the relative turning of half-clutches \( \rho \).

Based on the results of the static experimental investigation of the safety device, it was determined that the error between the results of the theoretical investigation and the experimental investigation ranges from 3.5 … 19.1%. That is why the given static analytical dependences can be used in the engineering design of different standard sizes of a safety device.

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ВИСНОВКИ

На основі проведенного патентного огляду, та аналізу існуючих конструктивно-технологічних схем захисних пристроїв гвинтових конвеєрів запропоновано нову конструкцію запобіжного пристрою, яка дозволяє суттєво зменшити динамічні навантаження на привід, що значно підвищує дозволочність та експлуатаційні характеристики шнекових транспортерів. Також проведеній силовий аналіз роботи запобіжного механізму, який дає змогу оцінити зміну крутового моменту веденого півмуфти і шнека \( T \) від зміни кута відносного провіртування півмуфта \( \rho \). Виконані статичні експериментальні дослідження запобіжного пристрою, за результатами яких встановлено, що похибка між результатами теоретичних і експериментальних досліджень знаходиться в межах 3.5…19.1%. Тому представлені в статті аналітичні залежності можуть бути використані при інженерному проектуванні різних типорозмірів запобіжного пристрою.

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RESEARCHES ON AUTOMATION OF WEIGHING AND SACKING PROCESS OF FINISHED AGRICULTURAL PRODUCTS

CERCETĂRI PRIVIND AUTOMATIZAREA PROCESULUI DE CÂNTĂRIRE ŞI AMBALARE ÎN SACI A PRODUSELOR AGRICOLE FINITE

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Abstract: Researches whose results are presented in this paper are on the topic of optimizing the dosing and sacking process in small and medium capacity productive units.

Using automatic weighing and dosing methods and technologies in small and medium capacity productive units brings an increased economic efficiency, leading to increased quantity of bagged products and weighing accuracy. The technological equipment for weighing and automated management EWAM, developed at INMA Bucharest has a direct applicability in small and medium capacity milling units in the technological processes of packaging of finished products (flour and bran) in open bags, performing simultaneously two very important operations: automated bag weighing of the programmed quantity of product with a precision that fits within the prescribed limits and automated management of the quantities of sacked finished products on an indefinite period of time.

In this paper there are presented the experimental investigations for this equipment, work quality indices determined with highlighting the advantages of using the product in the flow of small and medium capacity milling units.

Keywords: weighing, dosing, automated management, dosing auger, PLC

INTRODUCTION

The field of systems and equipment for weighing, dosing and packaging agrifood products is one of the fields with a high economic impact in Romania (especially in the last years), but also in the industrially developed countries [2, 5].

Weighing, dosing and automated management are processes that eliminate, totally or partially, human intervention in the actual operations. Modern weighing, dosing and automated sacking devices represent ingenious technical solutions that comprise fields from both the mechanics and electronics, being characterized by a high precision and sensitivity [3].

Usually, operations involving direct action on the processed material are exclusively done by mechanical mechanisms or components, but also the command and dosage adjustment operations are frequently done by mechanical systems, the electronic systems having a surveillance and fine adjustment role [1].

Technological operations of weighing and dosing are not independent in the manufacturing process of products, but are integrated into various technological processes, so that the result of the operation does not emerge distinctly, but cumulated in the resulted final product, and as a result, the quality of the dosage/weighing directly influencing the quality of the final product [4].

INTRODUCERE

Domeniul sistemelor și echipamentelor de cântărire, dozare și ambalare pentru produsele agroalimentare este unul din domeniile de mare impact economic în România (mai ales în ultimii ani), dar și în ţările dezvoltate din punct de vedere industrial [2, 5].

Cântărirea, dozarea și gestionarea automată sunt procese prin care se elimină total sau parțial intervenția umană din operațiile propriu-zise. Dispozitivele moderne de cântărire, dozare și însăcătuire automată sunt soluții tehnice ingenioase ce cuprind domeniul atât din mecanică cât și din electronică fiind caracterizate printr-o precizie și sensibilitate înaltă [3].

De regulă, operațiile ce presupun acțiunea directă asupra materialului prelucrat sunt efectuate în exclusivitate de mecanisme sau componente mecanice, înșași și operațiile de comandă și reglaj al dozării sunt efectuate de multe ori de sisteme mecanice, cele electronice având rolul de supraveghere și reglaj [1].

Operațiile tehnologice de cântărire și dozare nu sunt independente în procesul de fabricație al produselor, ci se integrează în procese tehnologice diverse, astfel încât rezultatul operației nu apare distinct, ci cumulat în produsul final rezultat, iar ca urmare, calitatea dozării / cântării influențând direct calitatea produsului final [4].
According to the most modern equipment in the field and encompassing innovative constructive solutions, the technological equipment for weighing and automated management EWAM (fig. 1), developed at INMA Bucharest has a direct applicability in small and medium capacity milling units in the technological processes of packaging finished products in open bags, performing two very important operations:
- automated bag weighing of the programmed quantity of product with a precision that fits within the prescribed limits;
- automated management of the quantities of sacked finished products on an indefinite period of time.

The equipment can also be successfully integrated in the technological flows of units producing concentrated fodder or in other specific units that practice packaging granular or powdered product in bags.

Aliniat celor mai moderne utile din domeniu și înglobând soluții constructive inovatoare, echipamentul tehnologic pentru cântărire și gestionare automată ECGA (fig.1) conceput la INMA București, are aplicativitate directă în cadrul unităților de morărit de mică și medie capacitate în cadrul proceselor tehnologice de ambalare în saci deschiși a produselor finite unde realizează două operații foarte importante:
- cântărirea automată în saci a cantității de produs programată cu o precizie care să se încadreze în anumite limite prescrise;
- gestionarea automată a cantităților de produse finite ambalate în saci pe perioade nedeterminate.

Echipamentul se poate integra cu succes și în fluxurile tehnologice din unitățile pentru obținerea nutrețurilor concentrate sau alte unități specifice care practică ambalarea produselor granulare sau pulverule în saci.

Fig. 1. – Equipment for weighing and automated management – EWAM - Overview / Echipament pentru cântărire și gestionare automată ECGA - vedere generală

MATERIAL AND METHOD
In figure 2 is presented the constructive scheme for technological equipment for weighing and automated management EWAM.

MATERIAL ŞI METODĂ
În figura 2 este prezentată schema constructivă a echipamentului tehnologic pentru cântărire și gestionare automată ECGA.
The dosing group (fig. 3) is the subassembly that performs the dosage of products that will be sacked. The augers (pos. 2, 3) are mounted in the framework (pos. 1) through some bearings with oscillating ball bearings that ensure a good sealing against any type of dust.

The command and control of the dosing operations, weighing and recording the work parameters is made by the automation installation. In figure 4, the block scheme for the automation installation is presented.
The software component of EWAM is formed by two independent programs installed on the operating terminal and on the installation’s PLC.

The program loaded on the operating terminal acts as a graphic interface for the user and was developed with the GT Designer 3 graphic programming software. This program has three visualizing windows: Start Page, Parameter Settings and Weighing.

In the Settings Page the work parameters of EWAM are established and management data are visualized: number of bags and the quantity of sacked material on each working station.

In the Settings Page the work parameters of EWAM are established and management data are visualized: number of bags and the quantity of sacked material on each working station.

Componenta software a ECGA este formată din două programe interdependente instalate pe Terminalul de operare și pe PLC-ul instalației.

Programul încărcat pe terminalul de operare are rolul de interfață grafică cu utilizatorul și a fost dezvoltat sub mediul de programare grafică GT Designer 3. Acest program este alcătuit din trei ferestre de vizualizare: Pagina Start, Setare Parametri și Cântărire.

În pagina de Setări se stabilesc parametrii de lucru ai ECGA și se vizualizează datele de gestiune: număr de saci și cantitatea de material însăcuita pe fiecare post de lucru în parte.
The program loaded in the PLC of the automation installation is developed with the GXDEveloper software program, being structured in the form of logic instructions presented as a ladder diagram, and the transmission of signals to and from the PLC is made both analogically and digitally.

The weighing and automated management equipment has the following constructive and functional characteristics:
- overall dimensions, mm:
  - without bunker
    - length 1300 1640
    - width 560 1200
    - height 1739 3000
  - with bunker
    - length
      - dosing auger speed, rot/min 60...560
      - coarse dosing auger gearmotor drive power, kw 0.75
      - fine dosing auger gearmotor drive power, kw 0.37
      - productivity, no. bags /min 3-4
      - weighing precision, % ± 0.1
      - dosed quantity, kg 15-60

The testing of the EWAM equipment was made at INMA, in laboratory and exploiting conditions, using its own experimental methods, carrying out the following activities: preliminary checks, initial technical expertise, experimenting operating without load, calibrating the weighing system, checking the functioning of the automation installation in simulated mode, experimenting operating under load.

For the experiments in working conditions, two types of combined fodder and 650 type flour were used. The active power consumed by every motor was determined using the following relation:

\[ P = \sqrt{3}U^*I\cos \varphi \]  

(1)

where:
- \( P \) - active power consumed;
- \( U \) - tension of electric power;
- \( I \) - intensity of electric power;
- \( \cos \varphi \) – power factor for the electric motor ( can be read on motor label).

The total consumed power will be calculated summing the active electric powers for each motor and the power of the stabilized tension source inside the electric control panel.

The weighing precision was determined with the relation [4]:

\[ P = \left[ (m_c - m_p)/m_p \right] \times 100 \% \]  

(2)

where:
- \( P \) - weighing precision (deviation from the programmed value);
- \( m_c \) – product quantity introduced in the bag determined by weighing;
- \( m_p \) – product quantity programmed and recorded in the system.

RESULTS
The results obtained after testing the equipment in operating conditions are shown in table 1 and 2 and their grafic representation in figures 6 and 7.

Programul încărcat în PLC-ul instalării de automatizare este dezvoltat sub mediul de programare GXDEveloper, fiind structurat sub formă de instrucțiuni logice prezentate ca diagrama ladder, iar transmiterea semnalelor la și de la PLC se face atât analogic cât și digital.

Echipamentul pentru cântărie și gestionare automată are următoarele caracteristici constructive și funcționale:
- dimensiuni de gabarit, mm
  - fără buncăr  cu buncăr
    - lungime 1300 1640
    - lățime 560 1200
    - înălțime 1739 3000
    - turația melcilor de dozare, rot/min 60...560
    - putere motoreductor acționare melc dozare grosieră, kw 0,75
    - putere motoreductor acționare melc dozare fină, kw 0,37
    - productivitatea, nr. saci/min 3-4
    - precizia de cântărire, % ± 0,1
    - cantitatea dozată, kg 15 - 60

Încercarea modelului experimental al echipamentului ECQA s-a realizat în cadrul INMA în condiții de laborator și de exploatare, utilizând o metodică de experimentare proprie fiind efectuate următoarele tipuri de activități: verificări preliminare, expertiza tehnică inițială, experimentări de funcționare în gol; calibrarea sistemului de cântărire, verificarea funcționării instalației de automatizare în regim simulat, experimentări de funcționare în sarcină.

Pentru experimentări în condiții de exploatare s-au folosit ca materie primă două tipuri de nutre combinat și făină de grâu tip 650. Puterea activă consumată de fiecare motor s-a determinat cu relația:

\[ P = \sqrt{3}U^*I\cos \varphi \]  

unde:
- \( P \) - puterea activă consumată
- \( U \) - tensiunea curentului electric
- \( I \) - intensitatea curentului electric
- \( \cos \varphi \) – factorul de putere al motorului electric (se citește de pe eticheta motorului).

Puterea totală activă consumată se va calcula prin însumarea puterilor electrice active calculate pentru fiecare motor în parte și a puterii sursei stabilizate de tensiune din interiorul panoului electric de control.

Precizia de cântărire s-a determinat cu următoarea relație [4]:

\[ P = \left[ (m_c - m_p)/m_p \right] \times 100 \% \]  

(2)

unde:
- \( P \) - precizia de cântărire (abateria față de valoarea programată);
- \( m_c \) – cantitatea de produs introdusă în sac determinată prin cântărire;
- \( m_p \) – cantitatea de produs programată și înregistrată de sistem.

REZULTATE
Rezultatele obținute în urma încercărilor în condiții de exploatare a echipamentului sunt trecute în tabelele 1 și 2, iar reprezentarea lor grafică în figurile 6 și 7.
### Operating Indices / Indici de exploatare

<table>
<thead>
<tr>
<th>Without load / Mers în gol</th>
<th>Motor Loading Frequency / Frecvența alimentare motoare (Hz)</th>
<th>Noise / Zgomot (dB)</th>
<th>Auger speed / Turate melc / (rot/min)</th>
<th>Tension Tensiune I / (V)</th>
<th>Power Current / Curent I / (A)</th>
<th>Power Current / Curent II / (A)</th>
<th>Power output / P output / (W)</th>
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### With load / Mers în sarcină

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<th>With load / Mers în sarcină</th>
<th>Motor Loading Frequency / Frecvența alimentare motoare (Hz)</th>
<th>Noise / Zgomot (dB)</th>
<th>Auger speed / Turate melc / (rot/min)</th>
<th>Tension Tensiune I / (V)</th>
<th>Power Current / Curent I / (A)</th>
<th>Power Current / Curent II / (A)</th>
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Auger – big auger (coarse dosing auger) / Melc – melc mare (melc dozare grosieră) / Melc – small auger (fine dosing auger) / Melc – melc mic (melc dozare fină)

### Functional and Energetic Parameters / Parametri funcționali și energetici

<table>
<thead>
<tr>
<th>With load / Mers în sarcină</th>
<th>Motor Loading Frequency / Frecvența alimentare motoare (Hz)</th>
<th>Filling time / Timp umplere [s]</th>
<th>No. bags/min / Nr. sac/min [pcs/buc]</th>
<th>Weighing precision / Precizia de cântărire [%]</th>
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CONCLUSIONS
Through the constructive and functional solutions adopted after the experimental investigations it was found that the Technological equipment for weighing and automated management– EWAM ensures:
- increased productivity due to reduced service time by overlapping some activities in the packaging process, which is made possible by the fact that the machine is equipped with two workstations served by a single operator;
- easy and fast management of quantities of finished agricultural products resulted from the manufacturing process;
- safe storage in the memory of the equipment for a certain period of time of the data regarding sacked product quantities, data that can be made available to interested parties;
- securing the packaging process by the fact that the programming and work parameter modifications, as well as the system configuration, can only be made by authorized persons based on access passwords only known by those persons;
- increasing operator’s yield due to the reduction of supplementary physical effort.

CONCLUZII
Prin soluțiile constructive și funcționale adoptate în urma investigațiilor experimentale s-a constatat că Echipamentul tehnic pentru cantări și gestionare automată ECGA asigură:
- creșterea productivității muncii ca urmare a reducerii timpului de deservire prin suprapunerea unor activități din procesul de ambalare, lucru posibil prin faptul că echipamentul este prevăzut cu două posturi de lucru deservite de un singur operator;
- gestionarea rapidă și ușoară a cantităților de produse agricole finite rezultate din procesul de fabricație;
- stocarea în siguranță în memoria echipamentului pe o anumită perioadă, a datelor privind cantitățile de produse însăcăute, date ce pot fi puse la dispoziția persoanelor interesate;
- securizarea procesului de ambalare prin faptul că programarea și modificarea parametrilor de lucru precum și configurarea sistemului, se pot face numai de persoane autorizate pe baza unor parole de acces și nu doar de acestea;
- creșterea randamentului operatorului ca urmare a reducerii efortului fizic suplimentar.
Therefore, we can conclude that the usage of methods and technologies for weighing and automated dosage brings a growth in the economic efficiency and has an immediate impact on the evidence of supplied materials, also leading to the growth in the quantity of products packed in bags and in the weighing precision [2].

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THEORETICAL CONTRIBUTIONS TO THE DRIVE OF CEREAL CLEANING TECHNICAL EQUIPMENT ENDED WITH NON BALANCED VIBRATION GENERATING SYSTEMS

CONTRIBUȚII TEORETICE LA AȚIONAREA ECHIPAMENTELOR TEHNICĂ DE CURĂȚIRE A CEREALELOR CU SISTEME GENERATOARE DE VIBRAȚII CU MASE NEECHILIBRATE

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Abstract: The paper presents the scheme of dynamic calculation of vibrating separator endowed with free vibrating plate and the author contributions concerning the determination of the movement of an intensive cleaner separator endowed with non balanced vibration generating systems. Also there are mentioned the advantages of electrical motovibrators utilisation for driving the vibrating sieves of technical equipment used for cereal cleaning in view of their processing.

Keywords: grains, cleaning, vibrating sieves, electrical motovibrator

INTRODUCTION

The primary processing represents an important link of the process of capitalization of vegetal-origin products and, at the same time, an essential operation of the conditioning chain.

The continuous progresses obtained in terms of improving the primary processing methods and techno-material base periodically determine the substantial increase of exigencies related to lack of foreign substances, seeds uniformity, sanitary state, lots' homogeneity in order to achieve a high quality level of agro-food products.

The cereal seeds primary processing before the seeds exploitation represents a complex technological process, including several constructive types of technical equipment for separating and removing the impurities existing in seeds [1, 2, 3, 4].

Therefore, profoundly knowing the technology to be used, the operating method of technical equipment appropriate to relevant technology and technical-functional parameters adjusting represent an important prerequisite to obtain the maximum quality with reduced power and man labour consumption.

Equipping with generating vibrations with non-balanced eccentric masses induced to technical equipment for separation a high yield and high efficiency of separation and theoretical approach of the study of particles motion on the vibrating sieve plan is a current challenge [5, 6].

Intensive Cleaner Separator SAI 800 (Fig. 1) manufactured at INMA Bucharest is a modern technical equipment used at removing the impurities out of cereal matter combining the principle of separation based on size difference (using surfaces put in vibrating movement) with the separation based on aerodynamical characteristics (by using a suction tube).

Rezumat: În lucrare se prezintă schema de calcul dinamic a separatorului vibrator cu un grad de libertate precum şi contribuţiile privind determinarea ecuației de mişcare a unui separator aspirator intensiv acționat cu sisteme generatoare de vibrații cu mase neechilibrate. De asemenea sunt evidențiate avantajele utilizării motovibratoarelor electrice la acționarea sitelor vibratoare ale echipamentelor tehnice de curățire a cerealelor în vederea procesării.

Cuvinte cheie: semințe, curățire, site vibratoare, motovibrator electric

INTRODUCERE

Prelucrarea primară constituie o viteză importantă a procesului de valorificare a produselor de origine vegetală și este o operație primordială a lanțului de condiționare. Progresele continue pe linia îmbunătățirii metodelor de prelucrare primară și a bazei tehno-materiale determină periodic sporirea substanțială a pretențiilor față de lipsa corpurilor străine, uniformitatea semințelor, starea sanitară, omogenitatea loturilor în scopul atingerii unui nivel calitativ ridicat pentru produsele agroalimentare.

Pregătirea semințelor de cereale și plante tehnice înainte de procesare reprezintă un proces tehnicocomplex, care include mai multe tipuri constructive de echipamente tehnice pentru separarea și eliminarea impurităților existente în masa de semințe [1, 2, 3, 4].

Se cere o temeinică cunoașterea a tehnologiei utilizate, a modului de funcționare a echipamentelor tehnice specifice tehnologiei precum și a reglării parametrilor tehno-funcționali ai acestor echipamente în vederea obținerii calității maxime, cu consum minim de energie și forță de muncă.

Echiparea cu generațoare de vibrații cu mase neechilibrate conferă echipamentelor tehnice de separare un randament ridicat și o eficiență sporită a separeării, iar abordarea teoretică a studiului mișcării particulelor pe planul sitei vibratoare fiind o provocare de actualitate [5, 6].

Separatorul aspirator intensiv SAI 800 (fig. 1) conceput la INMA București este un echipament tehnic modern utilizat la separarea impurităților din masa de cereale combinând principiul de separare pe baza diferentei de mărime între acestea (flosind suprafețe aflate în mișcare de vibrație) cu separarea după proprietățile aerodinamice (flosind un canal de aspirație).
MATERIAL AND METHOD

The two electric motovibrators (Figure 1, poz.1) that represented the driven system of separation technical equipment shown in Figure 1 have mounted on their axles two non-balanced eccentric masses \( m = m_0/2 \). These are continuously rotating, in opposite directions developing the centrifugal forces \( F(t)/2 \) whose graphical representation is shown in Figure 2.

The location of the driving system is chosen in equation with the disturbance force trajectory that should cross the mass centre (c.g.) of the whole system, eliminating in this way the additional oscillations of the worked surface which could determine the disturbance, of normal harmonical movement law.

Calculation scheme of conveyor endowed with vibrating free plate, driven by a centrifugal system with non-balanced rotating masses is shown in figure 3. The reduced mass (equivalent) \( m \) of vibrating system oscillates in direction \( S \) under the action of disturbing force \( F(t) \) of driving mechanism with non-balanced masses.

Within the post-resonating operating regime, the rotation frequency of the two masses \( m_0 \) is far smaller than the own frequency of oscillating system.

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Fig. 1 – Experimental Model of Intensive Cleaner Separator SAI 800-overview) / Modelul experimental al Separatorului aspirator intensiv SAI 800-vedere generală

1- electric motovibrators / motovibratoare electrice

Fig. 2 – a) Graphical representation of centrifugal forces / Reprezentarea grafică a forțelor centrifugale [1]

The location of the driving system is chosen in equation with the disturbance force trajectory that should cross the mass centre (c.g.) of the whole system, eliminating in this way the additional oscillations of the worked surface which could determine the disturbance, of normal harmonical movement law.

Locul de plasare al sistemului de acționare se alege în așa fel încât direcția forței perturbațoare să treacă prin centrul de masă (c.g.) al întregului sistem, eliminând prin aceasta posibilitatea oscilațiilor suplimentare ale suprafeței de lucru care ar putea perturba legea armonică normală de mișcare.

Schema de calcul a separatorului vibrator cu un grad de libertate, acționat printr-un sistem centrifugal cu mase rotitoare neechilibrate este prezentată în figura 3. Masa redușă (echivalentă) \( m \) a sistemului vibrant oscilează în direcția \( S \) sub acțiunea forței perturbațoare \( F(t) \) a mecanismului de acționare cu mase neechilibrate.

În regimul de funcționaare postrezonant frecvența de rotație a celor două mase \( m_0 \) este cu mult mai mică decât frecvența proprie a sistemului oscilant.
An external resisting force $F(c, \mu)$ opposes to oscillating mass movement $m$, this force appearing at the level of connecting elastic elements with damping system. Because this force reaches 85...90 % out of the amount of resistance forces, within the dynamic calculations are introduced correction coefficients for external resistance forces of loading movement on the vibrating frame.

The reduced (equivalent) mass $m$ of system elements, which perform the oscillating movement is calculated with the relation (1):

$$m = m_S + k_m m_n$$

where: $m_S$ is the equivalent mass of the vibrating frame and other components connected to it; $k_m = 0.1...0.25$ – reducing factor of loading mass for body frame mass \([5]\); $m_n$ – mass of loading material on the vibrating sieve body.

For the connecting elastic elements with viscous damping, the damping hypothesis through viscous friction is generally used, the external resistance force $F(c, \mu)$ being given by the Eq.(2):

$$F(c, \mu) = cS + c_0 S$$

where $c$ is the elastic elements rigidity with viscous damping and $\mu$ – damping factor by internal friction (for rubber, $\mu = 0.001$ s).

Taking into account the D’Alembert principle applied to the intensive cleaner separator (figure 1), it can be obtained the differential movement equation of reduced mass $m$, namely (3):

$$m \ddot{S} = F(t) - F(c, \mu)$$

Integrating together the Eqs.(2) and (3) we obtain the movement equation allowing to analyze and easily calculate the working parameters of the gravitational separator endowed with non-balanced eccentric masses, considered as vibrating single mass systems, namely (4):

$$m \ddot{S} = F(t)$$

The disturbance centrifugal force $F(t)$, which determines the reduced mass oscillation, taking into consideration the transport movement ($S$) and relative movement ($S_0$) is given by the equation (5):

$$F(t) = m_0 \ddot{S}_0 + \ddot{S}$$

where $\ddot{S}_0$ is the component of the centrifugal acceleration appearing as a result of rotation of each of two masses $0.5 m_0$ of the centrifugal vibrator system.

Having in view the fact that the relative displacement of each mass $0.5 m_0$ towards $S$ is equal to $S_0 = r \cdot \sin \omega t$, unde $S_0$ este componenta accelerăţei centrifuge care apare ca urmare a rotaţiei fiecărei din cele două mase 0,5 $m_0$ ale sistemului vibrator centrifugal. Deoarece deplasarea relativă a fiecărei din mase (0,5 $m_0$) în direcţia $S$ este egală cu $S_0 = r \sin \omega t$, relaţiile pentru
then the equations for speed \( S_0 \) and acceleration \( S_a \) are:

\[
S_0 = r \omega \cos \omega t; \quad S_a = -r \omega^2 \sin \omega t
\]  

(6)

Where: \( r \) is the non-balanced masses eccentricity; \( \omega \) - rotation frequency of non-balanced eccentric masses.

Using the equations (4) and (5), we can obtain the movement equation of separator centrifugally driven by means of non-balanced eccentric masses, namely (7):

\[
(m + m_0) S + c \mu S + c S = m_0 r \omega^2 \sin \omega t
\]

(7)

The particular solution for this differential equation for steady oscillations has the form (8):

\[
S = A \sin(\omega t - \varphi_f)
\]

(8)

Where: \( A \) is the amplitude of system forced oscillations and \( \varphi_f \) - angle of phase difference between the displacement directions \( S \) and \( S_a \).

Differentiating Eq. (8) and replacing the speed \( \dot{S} \) and the acceleration \( \ddot{S} \) of oscillations in Eq. (7), and identifying the factors of functions \( \sin \omega t \) and \( \cos \omega t \) and solving a system of two equations with two unknowns, are obtained the following solutions (9), (10):\[
A = m_0 r \omega^2 / \sqrt{\mu^2 c^2 \omega^2 + (c - m \omega^2 - m_0 \omega^2)^2}
\]

(9)

\[
\varphi_f = \arctg \frac{\mu c \omega}{c - m \omega^2 - m_0 \omega^2}
\]

(10)

The amplitude \( A \) of oscillations of vibrating sieve body depends on the rotation frequency \( \omega \) of non-balanced masses, having the maximum value of \( A_{max} \) for a frequency \( \omega = \omega_1 = \sqrt{c / (m + m_0)} \), when the angle of phase difference \( \varphi_f = \pi/2 \), namely:

\[
A_{max} = m_0 r \omega \sqrt{\mu \cdot c}
\]

(11)

Replacing the particular solution into Eq.(5), we obtain the expression of the system disturbance force:

\[
F(i) = m_0 [r \omega^2 \sin \omega t + A \omega^2 \sin(\omega t - \varphi_f)] = F \sin(\omega t - \varphi_f)
\]

(12)

The amplitude \( F \) of the disturbance force and the angle of the phase difference \( \psi \) between the force and non-balanced masses shifting from equation (12) are unknown.

If Eqs. (9) and (10) are replaced into Eq. (12) and solved through the method above, we found (13), (14) [1]:

\[
F = m_0 r \omega^3 \sqrt{\frac{\mu^2 c^2 \omega^2 + (c - m \omega^2)^2}{\mu^2 c^2 \omega^2 + (c - m \omega^2 - m_0 \omega^2)^2}}
\]

(13)

\[
\psi = \arctg \frac{m_0 \mu c \omega}{\mu^2 c^2 \omega^2 + (c - m \omega^2)(c - m \omega^2 - m_0 \omega^2)}
\]

(14)

The disturbance forces of driving system with non-balanced masses reaches its maximum value at a rotation frequency \( \omega = \omega_1 = \sqrt{c / (m + m_0)} \), and by increasing the rotating speed it decreases and minimizes for a frequency of \( \omega = p = \sqrt{c / m} \).

For a cycle of oscillations the mechanical work of disturbing force is given by the equation (15):

\[
\text{Forța perturbatoare a sistemului de antrenare cu mase neechilibrate are valoarea maximă la frecvența de rotație } \omega = \omega_1 = \sqrt{c / (m + m_0)}, iar prin creșterea turației se micșorează și devine minimă pentru frecvența } \omega = p = \sqrt{c / m}.

Pentru un ciclu al oscilațiilor lucrul mecanic al forței perturbatoare este dat de integrala din relația (15):
unde $T = 2\pi/\omega$ este perioada unei rotații a maselor neechilibrate. Substituind în expresia integralei ecuația (11) și determinând viteza $\dot{s} = dS/dt$ din relația (8) se obține (16):

$$W = FA\omega \int_{0}^{2\pi/\omega} \sin(\alpha - \psi) \cos(\alpha - \phi) \, dt = \pi FA\sin(\phi - \psi)$$  \hspace{1cm} (16)

**RESULTS**

By means of known equations (8), (9), (12) and (13) the expression of the mechanical work is obtained as (17):

$$W = \frac{\pi t_0 c r^2 \omega^3}{\mu c^2 \omega^2 + (c - m \omega^2 - m_0 \omega^2)^2}$$  \hspace{1cm} (17)

Puterea (în kW) necesară pentru asigurarea funcționării separatorului, în cazul unui regim stabilizat, se stabilește cu luarea în considerare a randamentului transmisiei astfel utilizând relația (18):

$$P = \frac{W}{1000T} = \frac{\pi \omega}{2\pi T} [\text{kW}]$$  \hspace{1cm} (18)

unde $T$ este perioada oscilațiilor (în s), dată de relația: $T = 2\pi/\omega$.

În cazul unui reglaj postrezonant, amplitudinea poate fi determinată cu relația aproximativă (19):

$$A = (m_0 / m) r$$  \hspace{1cm} (19)

Determinarea forțelor de rezistență care iau naștere în elementele de legătură elastice cu amortizare este complicată și constituie o problemă de sine stătătoare pentru fiecare tip de separator și sistem de antrenare.

Indicele de izolare a vibrațiilor, asigurat de elementele elastice, este cuprins între $0 < c < 1$ și este dat de relația (20) [5]:

$$I_s = 1 - \frac{1}{f_s \left( \frac{n}{950} \right)^2 - 1}$$  \hspace{1cm} (20)

unde: $f_s$ este sâgeata statică a elementelor elastice sub influența greutății cadrului separatorului și a produsului aflat pe sîta vibratoare la un moment dat, în mm; $n$- pulsăția elementului de antrenare, în s$^{-1}$.

In relațiile de mai sus, se poate constata că:

- pulsăția de antrenare nu influențează într-un mod major amplitudinea rezultantă în cazul acționării cu motovibratoare electrice;
- amplitudinea rezultantă este influențată în mod decisiv de masa excentricului și de rația de amplasare a acestuia;
- generatorul de vibrații împărtășește de faptă un forță perturbatoare direcțional rectiliniu.

**CONCLUSIONS**

Utilizarea motovibratoarelor electrice ca sistem de acționare al echipamentelor tehnice de separare a impurităților din masa de cereale conduce la o serie de avantaje: simplificarea lanțului cinetic, intensificarea procesului de separare, reducerea solicitărilor transmise fundației, montare ușoară a acestora pe organele active ale echipamentului tehnic (datorată volumului mic, astfel încât direcția vibratiei să treacă prin centrul de greutate al întregului sistem), reglarea ușoară a parametrilor tehnico-

\[ W = \frac{1}{\alpha} F(t) \frac{dS}{dt} \]  \hspace{1cm} (15)
functional parameters (amplitude, actuation force) and oscillation’s direction.

Viewing the fact that the state-of-art equipment is aimed at achieving a higher technological effect with specific consumption of reduced materials and energy, the utilization of these systems generating vibrations is fully justified.

REFERENCES
WAYS TO OPTIMIZE THE ELECTROMAGNETIC WAVES APPLICATIONS IN AGRICULTURE AND FOOD INDUSTRY

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ABSTRACT: This paper presents some possibilities to optimize the use of electromagnetic waves, microwaves for the being moment, in agriculture and food industry. Concerns on this issue have arisen from some research topics about heating systems for agricultural products in their manufacturing processes. Obviously, at a later time, other interesting applications were suggested. For the present moment, the applications are limited to the drying process of herbs, fruits and vegetables or materials that must be preheated for processing (sawdust for pellets). For future applications, microwaves and other electromagnetic waves can extend their use in complex treatment for stored fruits and vegetables processing, treatment against pests existing in agricultural fields or in other areas. A mathematical model of a microwave oven from specialized literature is used in this paper in order to obtain a better positioning of organic matter inside the oven or a more favorable thermal field inside the oven.

KEYWORDS: optimization, electromagnetic waves, microwaves

INTRODUCTION

According to [6], microwaves are electromagnetic waves with wavelengths between 1 mm and 1 m, with frequencies between 300 MHz and 300 GHz. Microwaves have multiple applications: communication (telephone, wireless, Bluetooth), radar, radio astronomy, navigation (GPS) spectroscopy, heating, power transmission and application (microwave ovens, semiconductor processing, chemical deposition, TOKAMAK devices, experimental fusion reactors, non-lethal weapons, and so on).

Microwaves can be generated by devices called magnetrons and directed towards target areas using waveguides.

Therefore, the most important applications of microwaves in agriculture and food industry as those from the final category, namely their use for heating, drying or burning of organic tissues or materials in various manufacturing processes [2, 3, 4].

Processes that require thermal heating were studied at INMA in the past several years, this can be achieved by using microwaves [5]:
- biogas plant;
- pellet press when drying sawdust.

Electromagnetic waves or electromagnetic radiation is, according to [8], a natural phenomenon consisting of an electric field and a magnetic field situated in the same space and are mutually generated as they are propagated. Electromagnetic waves satisfy the electromagnetic field Maxwell equations.

RESUMAT: Lucrarea expune unele posibilități de optimizare a utilizării undelor electromagnetice, deocamdată microundelor, în industria alimentară și agricultură. Preocupări legate de această problemă au apărut în legătură cu unele teme de cercetare ce au ca subiect sisteme de încălzire a produselor agricole în procesele de prelucrare ale acestora. Evident că ulterior au fost sugerate și alte aplicații interesante. Pentru moment, aplicațiile se limitează la procesele de uscare a plantețelor medicinale, fructelor și legumelor sau a unor materiale care trebuie preîncălzite în procesul de prelucrare (rumegș pentru peleti). Pentru viitor aplicațiile microundelor, iar apoi a altor undele electromagnetice în general, vor putea fi extinse la procese complexe de tratare a legumelor și fructelor în depozite, la tratamentul împotriva deteriorărilor din plantătiala agricolă sau în alte domenii. În această lucrare se folosește un model matematic al unui cuptor cu microunde, din literatură de specialitate, pentru a obține o cât mai bună poziționare a substanței organice în cuptor sau un câmp termic cât mai favorabil în interiorul cuputorului.

CUVINTE CHEIE: optimizare, unde electromagnetice, microunde

INTRODUCERE

Conform [6], microundele sunt o categorie de unde electromagnetice cu lungimi de undă cuprinse între 1 mm și 1 m, având frecvențe cuprinse între 300 MHz și 300 GHz. Aplicațiile microundelor sunt multiple: comunicări (telefonie, telefonie fără cablu, Bluetooth), radar, radioastronomie, navigare (GPS), spectroscopie, încălzire și transmiterea și aplicarea energiei (cupoare cu microunde, prelucrarea semiconductorilor, realizarea de depuneri chice, instalații TOKAMAK, reactoare de fuziune experimentale, armament neletal, etc.).

Microundele pot fi generate cu ajutorul unor dispozitive numite magnetroane și direcționate în spațiile țintă cu ajutorul unor ghiduri de undă.

Prin urmare, cele mai importante aplicații ale microundelor în agricultură și industria alimentară ar fi cele din ultima categorie, mai precis folosirea acestora la încălzirea, uscarea sau arderea unor țesuturi organice, sau materii prime în diverse procese de prelucrare [2, 3, 4].

Procesele care solicită încălzire termică au fost introduse în studiu la INMA în ultimii ani, aceasta putând fi realizată prin folosirea microundelor [5]:
- instalarea de produs biogaz;
- presa de peleti din rumegș la partea de uscare.

Undele electromagnetice sau radiația electromagnetică, sunt, conform [8], fenomene fizice care constau într-un câmp electric și unul magnetic în același spațiu și care se generează reciproc pe măsură ce se propagă. Undele electromagnetice satisfașc ecuațiile câmpului electromagnetic ale lui Maxwell.
MATERIAL AND METHOD

In order to optimize organic material heating, a mathematical model of the microwave oven whose construction is described in [9] was used:
The list of parameters involved in the computation is given in table 1.

Table 1 / Tabelul 1

<table>
<thead>
<tr>
<th>Nr./No.</th>
<th>Denumire parametru / Parameter name</th>
<th>Notatie / Notation</th>
<th>Unitate de masura / Unit of measure</th>
<th>Valoarea in problema / Problem value</th>
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</thead>
<tbody>
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<td>Intensitatea a campului electric / Electric field intensity</td>
<td>$E$</td>
<td>V·m$^{-1}$</td>
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<tr>
<td>2</td>
<td>Inductia magnetica / Magnetic field</td>
<td>$B$</td>
<td>T</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Inductia electrica / Electric induction</td>
<td>$D$</td>
<td>C·m$^{-2}$</td>
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</tr>
<tr>
<td>4</td>
<td>Intensitatea a campului magnetica / Magnetic field intensity</td>
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<td>A·m$^{-1}$</td>
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</tr>
<tr>
<td>5</td>
<td>Campul de viteza Darcy / Darcy speed field [7]</td>
<td>$u$</td>
<td>m·s$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>Densitate de current / Current density</td>
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</tr>
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<td>Câmpul scalar de temperatura / Temperature scalar field</td>
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<tr>
<td>8</td>
<td>Unitatea complexa / Complex unit</td>
<td>$j$</td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>Conductivitatea mediului / Environmental conductivity</td>
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<td>S·m$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Permitivitatea vidului / Vacuum permittivity</td>
<td>$\varepsilon_0$</td>
<td>F·m$^{-1}$</td>
<td>0</td>
</tr>
<tr>
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<td>Numarul de unda in vid / Vacuum wavenumber</td>
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<td>m$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>14</td>
<td>Conductivitate termic / Thermal conductivity</td>
<td>$k$</td>
<td>W·m$^{-1}$·K$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>Caldura rezistiva (J-E) / Resistive heat (J-E)</td>
<td>$Q$</td>
<td>W·m$^{-3}$</td>
<td>0</td>
</tr>
<tr>
<td>16</td>
<td>Caldura rezultata prin pierderi resistive / Heat generated by resistive loss</td>
<td>$Q_{sl}$</td>
<td>W·m$^{-3}$</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>Caldura rezultata prin pierderi magnetice / Heat generated by magnetic loss</td>
<td>$Q_{sd}$</td>
<td>W·m$^{-3}$</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Capacitatea caloric / Heat capacity</td>
<td>$c_p$</td>
<td>J·kg$^{-1}$·K$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>19</td>
<td>Densitatea de masa / Mass density</td>
<td>$\rho$</td>
<td>kg·m$^{-3}$</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>Freventa de taiere (prag) / Cutoff frequency (threshold)</td>
<td>$\nu_{c,\text{max}}$</td>
<td>Hz</td>
<td>0</td>
</tr>
<tr>
<td>21</td>
<td>Viteza luminii in vid / Speed of light in vacuum</td>
<td>$c$</td>
<td>m·s$^{-1}$</td>
<td>0</td>
</tr>
<tr>
<td>22</td>
<td>frecventa / Frequency</td>
<td>$\nu$</td>
<td>Hz</td>
<td>0</td>
</tr>
<tr>
<td>23</td>
<td>frecventa microundelor / Microwave frequency</td>
<td>$\nu_c$</td>
<td>Hz</td>
<td>0</td>
</tr>
<tr>
<td>24</td>
<td>Numar modal / Modal number</td>
<td>$m$</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>25</td>
<td>Numar modal / Modal number</td>
<td>$n$</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>26</td>
<td>Constanta de propagare / Propagation constant</td>
<td>$\beta$</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>27</td>
<td>Lungimea cuptorului / Oven length</td>
<td>$w_o$</td>
<td>m</td>
<td>0.267</td>
</tr>
<tr>
<td>28</td>
<td>Latimea cuptorului / Oven width</td>
<td>$d_o$</td>
<td>m</td>
<td>0.270</td>
</tr>
<tr>
<td>29</td>
<td>Inaltimea cuptorului / Oven height</td>
<td>$h_o$</td>
<td>m</td>
<td>0.188</td>
</tr>
<tr>
<td>30</td>
<td>Lungimea ghidajului / Waveguide length</td>
<td>$w_g$</td>
<td>m</td>
<td>0.050</td>
</tr>
<tr>
<td>31</td>
<td>Latimea ghidajului / Waveguide width</td>
<td>$d_g$</td>
<td>m</td>
<td>0.078</td>
</tr>
<tr>
<td>32</td>
<td>Inaltimea ghidajului / Waveguide height</td>
<td>$h_g$</td>
<td>m</td>
<td>0.018</td>
</tr>
<tr>
<td>33</td>
<td>Raza placii de sticla / Glass plate radius</td>
<td>$r_p$</td>
<td>m</td>
<td>0.1135</td>
</tr>
<tr>
<td>34</td>
<td>Grosimea placii de sticla / Glass plate thickness</td>
<td>$h_p$</td>
<td>m</td>
<td>0.006</td>
</tr>
<tr>
<td>35</td>
<td>Baza placii de sticla / Glass plate base</td>
<td>$b_p$</td>
<td>m</td>
<td>0.015</td>
</tr>
<tr>
<td>36</td>
<td>Raza cartofului / Potato radius</td>
<td>$r_{pot}$</td>
<td>m</td>
<td>0.0315</td>
</tr>
<tr>
<td>37</td>
<td>Temperatura initiala a cartofului / Initial temperature of the potato</td>
<td>$T_0$</td>
<td>K</td>
<td>281.15</td>
</tr>
</tbody>
</table>
in a stationary electromagnetic analysis in the frequency domain followed by a heat transfer simulation showing how thermal energy is redistributed in the organic material. The geometrical model shown in Fig. 1 is only half of the structure because its symmetry permits a more economical solution. The main components of the model are: the microwave oven, is represented by four copper walls, one waveguide, the side box through which the microwave oven is supplied with microwaves, copper walls, and also a cylindrical glass plate (only half of it because of the model’s symmetry), on which organic material is placed, represented by the fourth component of the model, the potato. The oven is a metal box connected to a 500 W microwave power emitting device with a frequency of 2.45 GHz, which emits through a TE10 waveguide model. The potato is cut on the side that is in contact with the glass plate to make good contact with the flat plate (the top cover support plate from the cylindrical oven) the glass, which on the one hand gives mechanical stability and on the other hand facilitates a fine finite element that is satisfying for the potato-glass plate contact. Although losses have an electrical resistance nature, metal losses are expected to be low, the impedance conditions on these walls ensure that they are taken into account.

The waveguide feeder (oven’s power window) is influenced by a transverse electric wave (TE), which is an electrical wave that has no component on the direction of propagation. According to [6], an excitation frequency of 2.45 GHz, TE10 is the only way to propagate through a rectangular waveguide. Cutting frequencies for different modes are analytically given by:

\[ (\nu_c)_{\text{max}} = \frac{c}{z} \left( \frac{m}{\nu_g} \right)^2 + \left( \frac{n}{d_g} \right)^2 \]  

(1)

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Portul (fereastra de alimentare cu microunde) este excitata de o unda electrica transversala (TE), adica o unda electrica cu nu are componenta pe directia de propagare. Conform [6], o frecventa de excitatie de 2.45 GHz, TE10 este singurul mod de propagare printr-un ghidaj de unde dreptunghiular. Frecventele de taiere pentru diferite moduri sunt date analitic de formula:

\[ (\nu_c)_{\text{max}} = \frac{c}{z} \left( \frac{m}{\nu_g} \right)^2 + \left( \frac{n}{d_g} \right)^2 \]  

(1)

In care m si n sunt numerele modale si c este viteza luminii. Pentru modul TE10, \(n=1\), \(n=0\). Cu dimensiunile sectiunii transversale a ghidajului \(w_p=7.8 \text{ cm} \) si \(d_p=1.8 \text{ cm}\), modul TE10 este singurul mod de propagare pentru frecventa cuprinse intre 1.92 GHz si 3.84 GHz. Conditia necesara pentru propagare prin fereastra necesita o constanta \(\beta\) care la frecventa v data, are expresia:
Model mesh

Meshing complex structural model (due to four types of materials used and the equations to be solved for each air field inside the oven and in the sphere representing the potato) is done automatically by the software, allowing to choose the network refined by the user.

In the space filled with air from inside the oven, thermal electromagnetic field equations emitted by the waveguide are according to [6]:

\[
\rho c_p \frac{\partial T}{\partial t} + \rho c_p u \cdot \nabla T = \nabla \cdot (k \nabla T) + Q
\]

\[
\nabla \times \mu_r^{-1}(\nabla \times E) - k_0^2 \left( \frac{1}{\epsilon_r} - j \frac{\sigma}{\omega \varepsilon_0} \right) E = 0
\]

Discretization of geometries

Discretization of modelului structural complex (datorita celor patru tipuri de materiale folosite si ecuatiiilor de rezolvat in fiecare in domeniul cu aer din interiorul cupruratorului si in domeniul sferei ce reprezinta cartoful) se face automat de program, permitand alegerea unei retele refinate prin alegerea utilizatorului.

In domeniul ocupat de aer din interiorul cupruratorului, ecuatiiile care sunt respectate de campul termo-electromagnetic emis prin ghidaj, sunt, conform [6]:

\[
\rho c_p \frac{\partial T}{\partial t} + \rho c_p u \cdot \nabla T = \nabla \cdot (k \nabla T) + Q
\]

\[
Q = Q_{vis} + Q_{rad}
\]

\[
Q_{vis} = -\frac{1}{2} \mu_r (J \cdot E)
\]

\[
Q_{rad} = \frac{1}{2} \mu_r (J_{tur} \cdot H)
\]

In areas where the potato is placed, equations that describe the termoelectromagnetic field are given by (4):

\[
\nabla \times \mu_r^{-1}(\nabla \times E) - k_0^2 \left( \frac{1}{\epsilon_r} - j \frac{\sigma}{\omega \varepsilon_0} \right) E = 0
\]

The initial conditions for the electric field are given by (5):

\[
\nabla \times \mu_r^{-1}(\nabla \times E) = 0
\]

The pressure for these volumes is considered equal to the atmospheric pressure, 1 atm. Relative permittivity is considered to be 1 for an isotropic material type. The equation describing the magnetic field is:

\[
\nabla \times \mu_r^{-1}(\nabla \times E) - k_0^2 \left( \frac{1}{\epsilon_r} - j \frac{\sigma}{\omega \varepsilon_0} \right) E = 0
\]
The electric field of the source is defined by the equation:

\[ S = \frac{\int_{\Gamma} \left( \mathbf{E} - \mathbf{E}_s \right) \cdot \mathbf{E}_s}{\int_{\Gamma} \mathbf{E}_s \cdot \mathbf{E}_s} \]  

(9)

The microwave source has 500W and the phase is zero. The electric field of the source is defined by the equation:

\[ E_x = 0, E_y = 0, E_z = \cos \left( \frac{\pi y}{M} \right) \]  

(10)

with the propagation constant, \( \beta \) given by equation (2). On the metal boundaries of the subdomains, the following condition exists:

\[ \beta C \mathbf{n} \times \mathbf{H} = (\mathbf{n} \cdot \mathbf{E}) \mathbf{n} = (\mathbf{n} \cdot \mathbf{E}_s) \mathbf{n} - \mathbf{E}_s \]  

(11)

The model proposed in [7, 9], usually gives some results: resistive losses within the model, especially organic material, temperature variation over time in the organic material at various points on its boundary, namely organic material surface temperature (in this particular case a potato) or inside it, and the intensity of the electric field component or its resultant, if needed.

The integrated model, suggested by the one described in [9] using geometric symmetry, gives the results in Fig. 3, 4 and 5, a). Resistive losses in the potato section included in the symmetry plane of the model shown in Fig. 3. Note that the maximum values are localized at the center of the organic material. Temperature growth within the first 5s inside the potato boundary points is shown graphically in Fig. 4. Note that the potato maximum boundary temperature is about 13°C, which is an increase of about 1°C/s for that point. The color map of the thermal field distribution on the potato boundary is given in Fig. 5. It can be observed that the same maximum value specified above, is spread on top of the potato and towards the microwave source.
Additional applications of the model

These results are reached by the application of the examples contained in the library [6]. The reason for the use of this model is that it is worth to be exploited by using it and eventually developing it, important applications can be obtained:

- placement optimization of microwave sources in order to level the temperature in a certain mass of organic matter;
- periodic movement of organic mass in order to standardize the thermal action on it;
- optimization of energy use (single source or multiple sources totaling the same power consumption) with the objective function energy consumption and/or level the thermal field (possibly evaluated by average standard deviation);
- optimization of energy consumption by using a variable power scheme in order to achieve the required temperature at a given time with one or more microwave sources (one can vary the source power or the frequency).

As an application, the mixing method and introduction of organic material can also be considered in order to level the thermal field (either pneumatic or mechanical).

Optimizing the positioning of microwave sources

One of the most interesting applications of this model lies in the ability to move a source in different places within the furnace boundary domain that is located near

Aplicatii suplimentare ale modelului

Pana la aceste rezultate conduce aplicatia continua in exemplele din biblioteca [6]. Motivul pentru care acest model merita exploatare este acela ca folosindu-l si eventual dezvoltandu-l, se pot obtine aplicatii importante:

- optimizarea amplasarii surselor de microunde in vederea uniformizarii temperaturii intr-o masa oreacere de materie organica;
- miscarea periodica a masei organice in vederea uniformizarii actiunii termice asupra acesteia;
- optimizarea consumului energetic (sursa unica sau surse multiple insumat aceeasi putere consumate) folosind ca functie obiectiv energia consumata si/sau uniformitatea campului termic (evaluata eventual pr in abaterea medie standard);
- optimizarea consumului energetic prin folosirea unei regim variabil de alimentare pentru atingerea temperaturii necesare intr-un timp dat cu una sau mai multe surse de microunde (se poate varia puterea sursei sau frecventa).

Tot ca aplicatie se poate considera si introducerea unei metode de agitare a materialului organic tot in vederea uniformizarii campului termic (fie pneumatic, fie mecanic).

Optimizarea amplasarii surselor de microunde

Una dintre aplicatiile cele mai interesante ale acestui model consta in posibilitatea de a muta o sursa indiverse locuri pe frontiera cuptorului pe care este amplasata
the waveguide feeder, so that the most suitable temperature in the organic material is obtained, and the temperature meets the best the energy needed collected by the organic matter. For example, it will considered where the waveguide feeder is placed in the new equidistant points within a network on the $x=w_0$ plane, that is the wall where the waveguide is initially placed. As evaluating temperature will be considered the temperature reached in the specified area with the equation:

$$
T = T(y, z)
$$

(12)

described by points and possibly analytical form by interpolation. Plotting numerical data (the direct results of numerical experiments) and interpolating linearly, we obtain the representation from fig. 6. Note that in order to reach the center block at the maximum possible organic matter after 5s, the waveguide must be placed with its output overlaid on the wall center of the microwave oven.

CONCLUSIONS

In order to optimize the heating process, the following issues should be considered:

- the first important observation is that both targets (organic material) and the source remain fixed, then, appreciable temperature differences exist in the organic material. If you can not auto-mix the organic material (such as liquids do), then, for the homogenization temperature of the organic matter mass a mechanical or pneumatic agitation must be performed.

- it is recommended that the volume of material exposed to microwave heating to be as small as a possible for uniform heating.

Acknowlegment

The results presented in this article were also obtained with the support of COMSOL, Inc. from U.S. which has provided us with an evaluation version of the program COMSOL 4.3 through sales office in Hungary: Hungary Kft Gamax Laboratory Solutions.
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[9]. Software COMSOL Multiphysics, tutorial.

BIBLIOGRAFIE
[8]. http://ro.wikipedia.org/wiki/Radia%C8%9Bie_electromagnetic %C4%83;
[9]. Software COMSOL Multiphysics, tutorial.
Abstract: A SVAT model (CoupModel) was used to simulate water balance from two forest stands and one arable stand throughout growing season (from May to October) in 2008 and 2009. Measurements included soil moisture and the collection of precipitation, canopy throughfall and stem flow. Simulated soil moisture agreed well with daily FDR-measurements and the $R^2$ was 0.73–0.91, namely CoupModel had good validation in this region. Results showed that the total evapotranspiration from May to the end of October was estimated to be 824 mm, 815 mm and 790 mm for oak (Lithocarpus glaber), Chinese fir (Cunninghamia lanceolata) and maize (Zea mays), respectively. Deep percolation (or water recharge) declined from approximately 352 mm in maize arable land to 271 mm for oak and 297 mm for Chinese fir forest, mainly due to differences in the interception loss. Compared with the arable land, simulated interception was increased by 87% for oak and 70% for Chinese fir (88 mm to 114 mm) forest. The simulations indicated that tree species also influenced the magnitude of water balance components in SVAT system, calling for further attention on the selection of tree species in future afforestation, particularly when such projects aiming to keep water infiltrating to the groundwater zone.

Keywords: Afforestation; the Three Gorges Reservoir area (TGRA); oak; Chinese fir; maize; evapotranspiration; deep percolation

INTRODUCTION

The Three Gorges Dam is one of the largest hydroelectric scheme in the world. With the construction of this huge project, human’s interference and destruction inevitably impacted the natural ecosystem of the Three Gorges Reservoir area (TGRA) [1]. Influenced by the climatic change, the expansion of inundated area, as well as the migration project, vegetation degradation and floods and droughts in this region were becoming more and more serious. TGRA was a typical case in terms of the complexity of the natural environment and the fragility of ecosystems in China [1]. Since 1989, the Chinese Central Government enacted a series of policies, such as the Natural Forest Protection Project and the Shelter-Forest Construction Project in the Upstream and Midstream of the Yangtze River, and much effort was made on vegetation restoration to reduce soil and water loss, protect the water source and withstand natural disasters. Benefit from these policies, much of the inefficiently cultivated land (especially slope lands) was converted to forest in this region. By 2000, afforested areas had reached 6.74 million hm$^2$, forest coverage rate had changed to 25% from 19.9%, and the soil erosion area had been reduced by 42% [2]. Most studies are limited to the effect of afforestation on runoff or sediment, nevertheless, quantitative analyses on water balance and water consumption after afforestation also can provide important information on vegetation restoration or forests management in TGRA.
Traditionally, the components of water balance, especially soil evaporation and transpiration, are technically complicated and associated with uncertainty in measurement procedure under field conditions. One way to quantify the constituents of water balance in forest ecosystems is to use water transfer models based on soil, vegetation, and atmospheric characteristics (SVAT models). The CoupModel is a process-based SVAT model for simulating thermal and hydrological processes and the corresponding biological processes that regulate carbon and nitrogen transfer in the soil–plant–atmosphere system [3]. Recently, Ladekarl et al. [4], Christiansen et al. [5], Schmidt–Walter and Lamersdorf [6] all used CoupModel to calculate water balance among different ecosystems. In China, applications of CoupModel have mainly concentrated in the northern area. For example, Zhang et al. [7] used CoupModel to assess the effects of wheat straw mulch and fallow crops on water balance and water use efficiency in the Loess Plateau. Wang et al. [8] investigated two types of planted vegetation (Liaodong oak and black locust forest), modelled water transfer with CoupModel, and studied the importance of vegetation type and slope in relation to water balance in the hill and gully region of the Loess Plateau. Wu et al. [9] and Zhou et al. [10] explored the hydrological processes of frozen soil in the northeastern China and Tibetan Plateau through CoupModel. However, CoupModel has rarely been applied in TGRA.

As a part of vegetation restoration projects, we conducted this research to determine the difference in water balance components among three vegetation patterns, namely, oak (Lithocarpus glaber) forest, Chinese fir (Cunninghamia lanceolata) forest, and maize (Zea mays) farmland, and to assess changes in water balance and water consumption after the afforestation of arable land from May to October in 2008 and 2009.

MATERIAL AND METHOD

Study site

The study site is located in Simian Mountain in southwestern China (N 28°31′–28°46′, E 106°17′–106°30′), upstream of the Yangtze River. This region is also at the upper end of TGRA, a typical case in terms of the complexity of the natural environment and the fragility of ecosystems in China [1]. Simian Mountain is located in a subtropical area and has a continental monsoon climate, with plenty of rainfalls. The elevation ranges from 900 m to 1500 m above sea level. The mean annual air temperature was 18.4 °C, varying seasonally from approximately 5.5 °C in January to more than 37.5 °C in August [2]. The mean annual precipitation was 1096.7 mm (1951–2008) and was concentrated from May to September. The experiment was carried out from May to October in 2008 and 2009.

Two forest plots and one farmland plot were investigated in the Shuangqiaoxi watersheds. The first forest plot comprised oak (Lithocarpus glaber) with an average tree height of 12 m and a mean stem diameter at breast height of 14 cm (in 2008). The second forest plot comprised Chinese fir (Cunninghamia lanceolata), with an average tree height of 14 m and a mean stem diameter at breast height of 10.2 cm (in 2008). The two stands were planted in the 1980s to form shelter woods to control soil and water loss and stand density was approximately 1000 trees/ha. The third plot, located on conventionally managed farmland, was planted with maize (Zea mays) from May to September. The two forest stands were converted from arable land many years before the experiments. During the experimental period, all plots received no fertilization or irrigation, and no natural water balance components were measured.

For water balance of each plot, the two forest stands were planted in the 1980s to form shelter woods to control soil and water loss and stand density was approximately 1000 trees/ha. The third plot, located on conventionally managed farmland, was planted with maize (Zea mays) from May to September. The two forest stands were converted from arable land many years before the experiments. During the experimental period, all plots received no fertilization or irrigation, and no natural water balance components were measured.

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compensation of groundwater resources was observed because of the deep water table. According to the international texture classification system, the three plots displayed similar soil textural characteristics (i.e., sandy loam). Basic information on the experimental plots is presented in Figure 1 and Table 1.

![Fig. 1 - Location of the study site](image)

**Table 1**

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Elevation [m]</th>
<th>Gradient [°]</th>
<th>Aspect</th>
<th>Age of trees</th>
<th>Canopy height [m]</th>
<th>Tree DBH [cm]</th>
<th>Density [Plant·ha⁻¹]</th>
<th>Coverage [%]</th>
<th>Main vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak</td>
<td>1167</td>
<td>5</td>
<td>SW</td>
<td>20</td>
<td>12.0</td>
<td>14</td>
<td>1000</td>
<td>90</td>
<td>Lithocarpus glaber</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Schima superba gardn champ</td>
</tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pteridium aquilinum</td>
</tr>
<tr>
<td>Chinese fir</td>
<td>1178</td>
<td>6</td>
<td>SW</td>
<td>20</td>
<td>14.0</td>
<td>10.2</td>
<td>1000</td>
<td>75</td>
<td>Cunninghamia lanceolata</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pinus massoniana</td>
</tr>
<tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lespedeza bicolor</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Aster ageratoides</td>
</tr>
<tr>
<td>Maize</td>
<td>1165</td>
<td>3</td>
<td>SW</td>
<td>-</td>
<td>1.2</td>
<td></td>
<td></td>
<td>85</td>
<td>Zea mays</td>
</tr>
</tbody>
</table>

Because of the deep water table. According to the international texture classification system, the three plots displayed similar soil textural characteristics (i.e., sandy loam). Basic information on the experimental plots is presented in Figure 1 and Table 1.
Field data

(1) Meteorological variable
Hourly meteorological data, including precipitation, global radiation, air temperature, wind speed, and relative humidity, were recorded by an automatic weather station Vantage PRO2 (Davis Instruments Corp., USA) positioned at a clear-cut area 600 m from the farmland experimental field. Measurements were taken at a height of 2 m. Sensors were factory-calibrated before installation.

(2) Measurement of soil moisture content (SMC)
Soil volumetric water content (θ) was measured by frequency domain reflectometry (FDR; Diviner 2000, Australia). Before the experiment, nine PVC probes (three samples in each plot) were vertically inserted in mineral soil after the removal of the O-horizon (if present). Daily readings of soil moisture content (SMC) were recorded at 20 cm depth intervals from the surface down to 80 cm from May to October in 2008 and 2009. The FDR sensors were calibrated in the field by the comparison of measured soil water gravimetric content in all replicate plots during the experimental period.

(3) Throughtfall and stemflow measurement
Throughfall (TF) was collected in three plastic buckets beneath three standard trees in forest stands with an area of 314 cm² and water was gathered in measuring cylinders after rainfall. Filters were placed on the top of the containers to avoid contamination of the sample by leaves and animals [5]. Stemflow (SF) was collected through a longitudinally split PVC tube around the trunk of three separate trees at a 1.5 m height in each stand and sealed with silicon along the trunk to avoid water running beneath the tube. The tube bottom was connected to a closed bucket on the ground [5,8]. After the rainfall, canopy interception capacity was calculated by precipitation (P) minus TF and SF.

(4) Vegetation properties
Vegetation characteristics, such as leaf area index (LAI), canopy height, and vertical root distributions, were surveyed for use as model input. LAI was measured with a LAI-2000 Plant Canopy Analyzer (LICOR, Lincoln, USA) once a month in growing seasons of 2008 and 2009 with at least 10 adjacent plants on each occasion. In the three plots, 10 plants were chosen as standards, and those heights were surveyed with a measuring rod once a month during growing season. Root depth was investigated by excavating the soil profile, and this procedure was repeated once a month in growing seasons.

(5) Collection of soil samples and laboratory analyses
Volume-intact soil samples were taken through steel cylinders (100 cm³) [5] at 20 cm depth intervals to a depth of 80 cm in May 2008. Within each horizon, three replicates were taken to eliminate soil heterogeneity. The soil samples were kept cold and dark until analyzed. Soil physical characteristics were determined in the laboratory. The particle size of the soil samples was analyzed by the hydrometer method, and saturated hydraulic conductivity (mm/d) was measured by the constant hydraulic head method [8]. In addition, parameters in the Brooks–Corey equation [11] were estimated according to measured points of pF curves by a pressure membrane apparatus (1500F1, Soil Moisture Corp., USA). Soil parameter values in CoupModel were mainly derived from measurements in laboratory, but they also required calibration during simulation.

(6) Surface runoff
Runoff plots were established to measure surface runoff beside every stand. The size of each runoff plot was 5 m x 20 m. At the bottom of the runoff plots, iron runoff buckets were installed to collect runoff. The size of the runoff buckets, 80 cm in diameter and 100 cm in
height, was designed according to the hydrological data derived from the Jiangjin meteorological station. After each runoff event, the water level in the runoff buckets was measured to calculate runoff volume [8]. Since the topography was flat, no surface runoff was found during the experimental period.

Model description
Two coupled differential equations for water and heat flow represent the core of the CoupModel. These equations are solved using an explicit numerical method. The basic assumptions behind these equations are that the law of mass and energy conservation is observed and that flows occur as a result of water potential (Darcy's Law) or temperature gradients (Fourier's Law) [3]. Soil water flow is the sum of matrix, vapor, and bypass flow which is assumed to obey Darcy's law as follows:

\[ q = -k_w \left( \frac{\partial \psi}{\partial z} - D_v \frac{\partial C_v}{\partial z} \right) + q_{bypass} \]

where:
- \( q \) is water flux [mm/
- \( k_w \) is the unsaturated hydraulic conductivity [mm/day],
- \( \psi \) is the water tension [kPa],
- \( z \) is depth [m],
- \( C_v \) is the concentration of vapor in soil air [g·m⁻³],
- \( D_v \) is the diffusion coefficient for vapor in the soil (dimensionless),
- \( q_{bypass} \) is a bypass flux of water in the macro-pores [mm].

(3) Interception
Interception rate (\( I \)) is calculated by a threshold function:

\[ I = \min\left( P \left( 1 - f_{in,d} \right) \frac{S_{\text{max}} - S_i(t-1)}{\Delta t} \right) \]

where:
- \( P \) is precipitation [mm],
- \( f_{in,d} \) is the fraction of precipitation that reaches the soil surface directly without being affected by vegetation (dimensionless),
- \( S_{\text{max}} \) is interception capacity [mm],
- \( S_i(t-1) \) is interception storage remaining from the previous time step [mm].
(4) Soil evaporation

In CoupModel, the actual evapotranspiration can be divided into three parts: evaporation of intercepted water in the canopy, evaporation from the soil surface and transpiration from plants. Soil evaporation (E_s) is based on the Penman combination equation [14]:

\[
L_v E_s = \frac{\Delta(R_{an} - q_v) + \rho_a c_p (e_a - e_v) / r_{as}}{\Delta + \gamma (1 + r_{ss} / r_{as})}
\]

where:
\( L_v E_s \) is latent heat from the soil surface, \( R_{an} \) is net radiation at the soil surface \([\text{J} \cdot \text{m}^{-2} \cdot \text{day}^{-1}] \), \( q_v \) is heat flux to the soil \([\text{J} \cdot \text{m}^{-2} \cdot \text{day}^{-1}] \), \( \rho_a \) is air density \([\text{kg} \cdot \text{m}^{-3}] \), \( c_p \) is heat capacity of air \([\text{J} \cdot \text{kg}^{-1} \cdot \text{°C}^{-1}] \), \( e_v \) is the actual vapor pressure in the air \([\text{Pa}] \), \( e_a \) is the actual vapor pressure at the soil surface \([\text{Pa}] \), \( r_{as} \) is the aerodynamic resistance \([\text{s} \cdot \text{m}^{-1}] \), \( \Delta \) is the slope of the curve of saturated vapor pressure against temperature \([\text{Pa} \cdot \text{°C}^{-1}] \), and \( \gamma \) is the psychrometer constant \([\text{Pa} \cdot \text{°C}^{-2}] \).

(5) Actual transpiration

The potential transpiration, \( E_{tp} \), is also calculated from Penman combination equation [14], and the water uptake is assumed to be equal to transpiration and is partitioned between the soil layers on the basis of root distribution. Actual transpiration, \( E_{wa} \), which accounts for drought, saturation, and temperature effects, is calculated according to:

\[
E_{wa} = E_{wa}^* + f_{umov} (E_{tp}^* - E_{wa}^*)
\]

\[
E_{wa}^* = E_{tp}^* \int_0^\infty \min (f(\Psi(z)), f(\pi(z)) f(T(z)) r(z)) dz
\]

\[
E_{tp}^* = \max (E_{tp}^* - E_{wa}^* / \theta_{rat})
\]

where:
\( E_{wa} \) is actual transpiration \([\text{mm}] \), \( E_{wa}^* \) is transpiration without considering water uptake \([\text{mm}] \), \( f_{umov} \) is the degree of compensatory water uptake (dimensionless), \( E_{tp} \) is potential transpiration minus intercepted evaporation \([\text{mm}] \), \( f(\Psi(z)), f(\pi(z)) \) and \( f(T(z)) \) are functions that reduce the water uptake by roots due to unfavourable soil moisture, salt and soil temperature conditions respectively, \( r(z) \) is the relative root density, \( E_{wa} \) is evaporation of intercepted water \([\text{mm}] \), and \( \theta_{rat} \) is the ratio between potential evaporation rate from interception storage and potential transpiration (dimensionless).

(6) Deep percolation

In this region, the lower boundary of the simulated soil profile is unsaturated since the deep groundwater tables, and the vertical flow \( (D) \) is calculated by function:

\[
D = k_{w,low}
\]

where: \( D \) is deep percolation \([\text{mm}] \) and \( k_{w,low} \) is hydraulic conductivity in the lowest soil layer \([\text{mm}] \).

(7) Runoff

If the precipitation reaching the soil surface exceeds the infiltration capacity, a pool of water is formed on the soil surface. The surface runoff \( (q_{sw}) \) is calculated as:

\[
q_{sw} = \frac{L_v R_{an} - q_v}{\Delta + \gamma (1 + r_{ss} / r_{as})}
\]
\[ q_{\text{surf}} = \alpha_{\text{surf}}(W_{\text{pool}} - W_{\text{pmax}}) \]  

where: 
\[ \alpha_{\text{surf}} \] is an empirical coefficient (0.8, dimensionless), \( W_{\text{pool}} \) is the total amount of water in the surface pool [mm] and \( W_{\text{pmax}} \) is the maximum amount of water that can be stored on the soil surface without any surface runoff occurring [mm].

Model settings and parameters calibration

The simulation ran from May to October in 2008 and 2009. Input variables included precipitation, global radiation, air temperature, wind speed, and relative humidity, with daily outputs of soil moisture and water balance components produced.

In CoupModel, upper and lower boundary conditions were defined as flux boundaries, with the upper boundary accounting for precipitation. As a lower boundary condition, unit gradient gravitational water flow was set up, representing groundwater recharge in this study. Capillary rise and lateral runoff were disregarded. Soil physical and hydraulic properties were measured on the basis of observed values in the laboratory, and air entry tension, saturated water content, wilting point, and residual water content (parameters in the Brooks–Corey equation) were calculated by measurements of pF curves.

In this study, the farmland vegetation canopy was represented by a single leaf concept, whereas for the forest plots, two layers, namely, the tree layer and the understory, were used. Thus, the switch of multiple big leaves was chosen. The most important vegetation characteristics used in the simulations were LAI, tree height, and root distribution, which were measured in the field. Water uptake was defined as a pressure head approach, calculated on the basis of response functions for water content and soil temperature [3].

For forest lands, the start of the growing season (and the corresponding water uptake) was defined by a trigging temperature approach; growing season began when the day length exceeded 10 h and the accumulated temperature was above 9.8 °C, and ended when the day length became less than 10 h according to meteorological observations [5]. However, for farmland, growing season started in May and ended in September.

We used soil moisture (0–80 cm) and throughfall as validation variables in the simulations. Based on field measurements and relevant literature, several parameters were calibrated to achieve satisfactory agreement between the simulated and measured values. All parameter values used to adjust the CoupModel are presented in Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Oak</th>
<th>Chinese fir</th>
<th>Maize</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt met station [m]</td>
<td>( \theta_{\text{met}} )</td>
<td>1165</td>
<td>1165</td>
<td>1165</td>
<td>Measurement</td>
</tr>
<tr>
<td>Alt sim position [m]</td>
<td>( \theta_{\text{sim}} )</td>
<td>1167</td>
<td>1178</td>
<td>1165</td>
<td>Measurement</td>
</tr>
<tr>
<td>Slope E-W [m·m⁻¹]</td>
<td>( \rho_x )</td>
<td>0.59</td>
<td>0.63</td>
<td>0.67</td>
<td>Measurement</td>
</tr>
<tr>
<td>Slope N-S [m·m⁻¹]</td>
<td>( \rho_y )</td>
<td>-0.12</td>
<td>-0.08</td>
<td>-0.11</td>
<td>Measurement</td>
</tr>
<tr>
<td>Air temp mean [°C]</td>
<td>( T_{\text{mean}} )</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>Measurement</td>
</tr>
<tr>
<td>Max LA [m·m⁻¹]</td>
<td>( A_t )</td>
<td>4.5</td>
<td>4.0</td>
<td>4.0</td>
<td>Measurement</td>
</tr>
<tr>
<td>Canopy height [m]</td>
<td>( H_p )</td>
<td>12.0</td>
<td>14.0</td>
<td>1.5</td>
<td>Measurement</td>
</tr>
</tbody>
</table>
### Table

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Oak</th>
<th>Chinese fir</th>
<th>Maize</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root depth [m]</td>
<td>$z_{et}$</td>
<td>1.2</td>
<td>1.3</td>
<td>0.5</td>
<td>Measurement</td>
</tr>
<tr>
<td>Latitude [°]</td>
<td>$e_{ut}$</td>
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<td>28.51</td>
<td>28.51</td>
<td>Measurement</td>
</tr>
<tr>
<td>Albedo wet [%]</td>
<td>$a_{wet}$</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>Reference [7]</td>
</tr>
<tr>
<td>Albedo dry [%]</td>
<td>$a_{dry}$</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>Reference [3]</td>
</tr>
<tr>
<td>Plant albedo [%]</td>
<td>$a_{wet}$</td>
<td>10</td>
<td>13</td>
<td>15</td>
<td>Reference [8]</td>
</tr>
<tr>
<td>Light extinction coefficient</td>
<td>$k_n$</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>Reference [7]</td>
</tr>
<tr>
<td>ThScaleLog $x$</td>
<td>$x_{th}$</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>Reference [7]</td>
</tr>
<tr>
<td>Organic layer thickness [m]</td>
<td>$\Delta z_{humus}$</td>
<td>0.08</td>
<td>0.05</td>
<td>0</td>
<td>Measurement</td>
</tr>
<tr>
<td>Dvap tortuosity</td>
<td>$d_{vap}$</td>
<td>0.66</td>
<td>0.66</td>
<td>0.66</td>
<td>Reference [8]</td>
</tr>
<tr>
<td>Water capacity base [mm]</td>
<td>$S_{max}$</td>
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<td>2.3</td>
<td>0.5</td>
<td>Calibrated Reference [8]</td>
</tr>
<tr>
<td>Water capacity per LA [mm·m$^{-2}$]</td>
<td>$i_{LA}$</td>
<td>0.25</td>
<td>0.25</td>
<td>0.15</td>
<td>Reference [6], Calibrated</td>
</tr>
<tr>
<td>Cond VPD [Pa]</td>
<td>$g_{vap}$</td>
<td>450</td>
<td>450</td>
<td>200</td>
<td>Calibrated</td>
</tr>
<tr>
<td>Cond MAX [m·s$^{-1}$]</td>
<td>$g_{max}$</td>
<td>0.005</td>
<td>0.005</td>
<td>0.020</td>
<td>Reference [16], Calibrated</td>
</tr>
<tr>
<td>Flexibility degree</td>
<td>$f_{umov}$</td>
<td>0.9</td>
<td>0.6</td>
<td>0.6</td>
<td>Reference [8]</td>
</tr>
<tr>
<td>Crit threshold dry [cm]</td>
<td>$\psi_l$</td>
<td>1500</td>
<td>1000</td>
<td>1000</td>
<td>Calibrated</td>
</tr>
<tr>
<td>Root frac exp tail</td>
<td>$r_{frac}$</td>
<td>0.1</td>
<td>0.05</td>
<td>0.02</td>
<td>Calibrated</td>
</tr>
<tr>
<td>Psi Rs-1p</td>
<td>$r_{psi}$</td>
<td>150</td>
<td>150</td>
<td>100</td>
<td>Calibrated</td>
</tr>
<tr>
<td>Ra increase with LA [s·m$^{-1}$]</td>
<td>$r_{ala}$</td>
<td>60</td>
<td>60</td>
<td>50</td>
<td>Calibrated</td>
</tr>
</tbody>
</table>

### Statistical analyses

To evaluate the performance of the model, the indices used in this study were $R^2$, the coefficient of determination of the linear regression between simulated and measured values, the mean error of the model $ME$, and the root mean square error of the model $RMSE$ [5, 7-9]. These indices were calculated according to the following equation:

\[
ME = \frac{1}{n} \sum_{i=1}^{n} (S_i - M_i)
\]

\[
RMSE = \left( \frac{1}{n} \sum_{i=1}^{n} (S_i - M_i)^2 \right)^{1/2}
\]

where: $S_i$ and $M_i$ are the values at the $i$th observation and $n$ is the number of observations.

### RESULTS AND DISCUSSION

#### Model validation

Soil moisture is a prime environment variable related to land surface climatology, hydrology, and ecology [4]. Variations in soil moisture strongly affect surface energy, water dynamics, and vegetation productivity (actual crop yield). In addition, changes in soil moisture are also directly connected to evapotranspiration (ET) because this process is usually related to moisture in the upper 1 m to 2 m of the soil profile, at which depth moisture can easily evaporate or be extracted by plant roots [6]. In short, soil moisture is usually an important validation variable in hydro-ecological simulations.

The time series of measured and simulated soil moisture at depths of 0–20 cm, 20–40 cm, and 40–80 cm for the three plots are shown in Fig. 2. The temporal variation of soil moisture is similar for the three stands.
showing a distinct trend with the highest values during summer (especially from June to August). This trend is consistent with that of precipitation events. Compared with the variability of soil moisture at the 40–80 cm layer, that at the depth of 0–20 cm is significant, with direct and rapid changes as reactions to rainfall. In the entire soil profile (0 cm to 80 cm), the average soil moisture ranged as follows: oak forest (10.22%) < Chinese fir forest (10.88%) < maize farmland (12.36%).

As can be seen from Fig. 2, wider margin of variation between simulated and measured values mainly appeared in the following two circumstances: firstly, a few simulated values were lower than measured values after the rainfall, namely they failed to indicate extreme values. Secondly, a few simulations became higher than measured values in the dry season (e.g. late September). This was probably in relation to soil water movement equation that applied in the model, Darcy’s law and Richards equation, assumed soil as homogeneous medium [4], thus they cannot exactly reflect and explain dynamic change process of water flow in the heterogeneous soil (e.g. the preferential flow).

Validation results showed the desired conformity between the simulated and measured data (Fig. 2 and Table 3). The coefficient of determination for the linear
regression (R²) between the observed and simulated soil moisture in the entire soil profile (0 cm to 80 cm) was 0.83–0.91 (p<0.001) for oak forest but slightly lower for Chinese fir forest (0.8–0.85) and farmland (0.73–0.87). Generally, R² is useful for describing the difference between the simulated and observed dynamics of variables with cyclic fluctuations. In this study, R² is above 0.73 for all plots, indicating that CoupModel well simulates soil moisture. ME and RMSE reflect the deviation between the simulated values and measured values and thus facilitate the depiction of the irregular patterns of variables for soil moisture changes in response to infiltration events and drying processes. For the three plots, ME is -0.83%–1.79%, with RMSE of 0.46%–2.81%. We deduced that the deviation was small between the simulated and measured values, indicating that the model effectively captured the dynamic changes in soil moisture and that the simulation results were reliable. Compared with soil moisture, simulated throughput had disappointing measurements, with R² of only 0.62–0.69, possibly because of the small number of samples.

### Validation of simulated results

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Oak</th>
<th>Chinese fir</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Depth</td>
<td>ME [%]</td>
<td>RMSE [%]</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>0 – 20</td>
<td>0.8</td>
<td>1.52</td>
</tr>
<tr>
<td></td>
<td>20 – 40</td>
<td>0.85</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>40 – 80</td>
<td>0.83</td>
<td>0.26</td>
</tr>
<tr>
<td>Throughtfall</td>
<td>-</td>
<td>0.69</td>
<td>1.92mm</td>
</tr>
</tbody>
</table>

### Simulated water balance components

Simulated monthly outputs of interception (I), transpiration (Eₙ), soil evaporation (Eₛ), and deep percolation (D) were illustrated in Fig. 3 and Fig. 4. Similar to the seasonal variation in the soil moisture, a clear pattern can be seen in the monthly sums of the water balance components of the study plots. For the whole simulation period, evapotranspiration (ET), the sum of I, Eₙ, and Eₛ, gradually increased in May and reach the maximum values (118 mm to 128 mm) in June and August. Afterward, it was reduced due to cold weather with low rainfall. In this study, evapotranspiration was main output of water balance with the percentage up to 91%, and it was ranked as follows: oak forest (824 mm) > Chinese fir forest (815 cm) > farmland (790 mm).

Interception and transpiration generally showed the same temporal variation in the two forest stand and the values in oak stand were higher in most cases. In 2008, interception increased from 34 mm in May, fluctuated between 36 mm and 51 mm through June–September, then declined and reached the minimum (19 mm) in October. For the Chinese fir stand, the maximum and minimum values of interception were 47 mm and 16 mm, which were lower than that from oak. Compared with forest stand, the farmland exhibited the lowest interception loss, accounting for 17% of the precipitation and equalled 121 mm, while it was respectively 232 mm (32%) and 209 mm (29%) for oak and Chinese fir forest. Similar to interception, transpiration from the oak stand was also biggest, equalled 203 mm and constituted 28% of precipitation in 2008. From June to August, the transpiration was at a maximum (36–57 mm per month), then it reduced to the minimum (20 mm) in October. The (R²) of 0.8–0.91 (p<0.001), while the results of farmland were slightly lower for both forests, as shown in Table 3. For the Chinese fir forest, the interception amounted to 209 mm (27%), which was lower than oak. The transpiration was at a maximum (36–57 mm per month), which was 34 mm (36–57 mm per month), then it reduced to the minimum (20 mm) in October. The transpiration exceeded the maximum (36–57 mm per month) in July, then declined and reached the minimum (19 mm) in October. For the Chinese fir stand, the transpiration was at a maximum (36–57 mm per month), which was 34 mm (36–57 mm per month), then it reduced to the minimum (20 mm). The transpiration was at a maximum (36–57 mm per month), which was 34 mm (36–57 mm per month), then it reduced to the minimum (20 mm).
difference was not huge between simulated transpiration in three plots, in Chinese fir forest and farmland, it was 22 mm and 43 mm lower than oak, while this value was 23 mm and 111 mm for interception (Fig. 2 and Table 4). In contrast to the seasonal fluctuations of $I$ and $E_{\text{ta}}$, soil evaporation ($E_s$) remained relatively constant (8 mm to 32 mm every month) throughout the growing season and presented a modest rise in October. For farmland, soil evaporation was 144 mm and constituted 20% of precipitation in 2008, which was significantly higher than that of oak (11% of $P$) and Chinese fir (13% of $P$) stand.

Unlike the gentle fluctuation of evapotranspiration ($ET$), deep percolation ($D$) always abruptly changed (maximum of 200 mm per month) with rainstorm events (mainly in June 2008 and between June and August 2009). In 2009, 438 mm deep percolation /drainage formed in the farmland, more than 45% of the gross precipitation. Corresponding to farmland, the oak and Chinese fir forest plots presented lower deep percolation, accounting for only 36% and 39% of the precipitation. We can deduce that forest significantly reduced the deep percolation.

**Effect of afforestation on water balance**

Table 4 showed simulated water balance among three plots from May to October in 2008 and 2009. It indicated that a shift from cropland to forest would lead to an increase in canopy interception ($I$) while a reduction in deep percolation ($D$) (or groundwater recharge). First, annual interception increased (88 mm to 114 mm, 67%–92% of $P$) after afforestation (Table 4). Compared with crops, trees had a large leaf area in our study sites, implying high canopy capacity for interception storage and a low amount of precipitation directly reaching the ground [6]. Moreover, forests support great biomass with long growing periods as undergrowth, and thus facilitate canopy interception [8]. Second, a 51 mm to 85 mm
(14%–25% of $P$) reduction in annual deep percolation was estimated after afforestation. The probable reason was that most precipitation in forestlands was absorbed by the soil surface and rapidly diffused by evaporation or transpiration after afforestation, thereby decreasing infiltration depth and soil water content below the infiltration depth [5]. Therefore, on sites with low plant available soil water capacity and with roots that have no access to the water table, a change in land use from cropland to forest may negatively affect groundwater recharge. The simulations also indicated that tree species influenced the magnitude of water balance components in SVAT system. Compared with Chinese fir of the same age, oak had the highest interception and lowest deep percolation, that mainly because of the higher water consumption of oak.

**Simulated water balance from May to October**

<table>
<thead>
<tr>
<th>Year</th>
<th>Plot</th>
<th>$P$ [mm]</th>
<th>$ET$ [mm] (% of $P$)</th>
<th>$I$ [mm] (% of $P$)</th>
<th>$E_T$ [mm] (% of $P$)</th>
<th>$E_s$ [mm] (% of $P$)</th>
<th>$D$ [mm] (% of $P$)</th>
<th>$\Delta S$ [mm] (% of $P$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>Oak</td>
<td>729</td>
<td>715 (98%)</td>
<td>232 (32%)</td>
<td>203 (28%)</td>
<td>82 (11%)</td>
<td>188 (26%)</td>
<td>23 (3%)</td>
</tr>
<tr>
<td></td>
<td>Chinese fir</td>
<td>729</td>
<td>702 (96%)</td>
<td>209 (29%)</td>
<td>181 (25%)</td>
<td>98 (13%)</td>
<td>214 (29%)</td>
<td>27 (4%)</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
<td>729</td>
<td>691 (95%)</td>
<td>121 (17%)</td>
<td>160 (22%)</td>
<td>144 (20%)</td>
<td>265 (36%)</td>
<td>38 (5%)</td>
</tr>
<tr>
<td>2009</td>
<td>Oak</td>
<td>978</td>
<td>933 (95%)</td>
<td>253 (26%)</td>
<td>261 (27%)</td>
<td>66 (7%)</td>
<td>353 (36%)</td>
<td>44 (5%)</td>
</tr>
<tr>
<td></td>
<td>Chinese fir</td>
<td>978</td>
<td>928 (95%)</td>
<td>232 (24%)</td>
<td>228 (23%)</td>
<td>89 (9%)</td>
<td>379 (39%)</td>
<td>50 (5%)</td>
</tr>
<tr>
<td></td>
<td>Farmland</td>
<td>978</td>
<td>888 (91%)</td>
<td>139 (14%)</td>
<td>179 (18%)</td>
<td>132 (14%)</td>
<td>438 (45%)</td>
<td>89 (9%)</td>
</tr>
</tbody>
</table>

**CONCLUSIONS**

Based on field measurements from May to October in 2008 and 2009, a physical process-based model (CoupModel) was applied to evaluating the effect of afforestation on water balance in Simian Mountain in the terminal section of the Three Gorges area (TGRA) of China. Afforestation was performed using oak and Chinese fir on former arable land of maize. The simulated values of soil moisture were fairly consistent with the measured ones, with a determination coefficient ($R^2$) of 0.73–0.91. This result indicated that CoupModel can successfully demonstrate the complex interactions between hydrological processes in soil–vegetation–atmosphere (SVAT) system. Evapotranspiration was the main output of water balance from May to the end of October, with a percentage of up to 91%, and it was estimated to be 824 mm, 815 mm and 790 mm for oak, Chinese fir and maize, respectively. Deep percolation (or water recharge) declined from approximately 352 mm in arable land to 271 mm in the oak stand and 297 mm in the Chinese fir stands, mainly due to differences in the interception loss. Compared with the arable land, simulated interception of different tree species was increased by 87% for oak and 70% for Chinese fir (88 mm to 114 mm). The simulations indicated that tree species also influenced the magnitude of water balance components in SVAT system, calling for further attention to the selection of regrown tree species in the planning for afforestation projects, particularly when such projects aim to keep water infiltrating to the groundwater zone.

**Aknowlegement**

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**References**

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RESEARCH ON DEVELOPMENT CHARACTERISTICS AND BRAND SPILOVER EFFECTS OF AGRICULTURAL PRODUCT REGIONAL BRANDS IN CHINA

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Abstract: With the rapid increase in the standard of living and demand for high quality agricultural products in China, the development and protection of agricultural product regional brands (APRB) have begun to receive more and more attention. All developed countries have taken the protection of agricultural product brands in their origins seriously. However, Chinese agricultural brands developed very slowly, and there is little empirical research on APRBs. In this study, an econometric model was established based on data derived from an analysis of 2665 products from 30 provinces of China in order to identify the development characteristics and verify the spill-over effects of Chinese APRBs. The survey results revealed regional imbalances, interregional agglomeration, category diversification of brands, and a shorter industrial chain, with marketing limited to specific seasons, in the development of APRBs. Test results on the empirical models developed for this study show that an APRB is a preferable system design. This can gather small-scale agricultural producers and provide accurate product information to markets at a lower cost within a small region, preventing adverse selections caused by asymmetric information. The added value of agricultural products can be effectively increased by developing APRBs, benefitting the development of Chinese agricultural product brands as well as positively promoting increases in farmers' income and the further development of the Chinese agricultural economy.

Keywords: agricultural product regional brand (APRB); development characteristics; spillover effect; China

INTRODUCTION

With the continuous development of China’s agricultural regional economy, regional image association with unique location and agricultural product regional brands (APRB) are gradually being formed. It is well-known that brands always develop in specific geographic areas within a specific traditional and local situation[1]. Because of the heterogeneous nature of the geographical areas in China however, it is important to identify what the development characteristics of APRB in geographic area are, and what the spillover effects from creating an APRB are. As the Chinese economy has undergone increased development, the demand of citizens for high-end quality agricultural products has increased rapidly. Many internationally famous agricultural product brands have entered China and occupied the high-end market, but the development of Chinese agricultural brands still lags behind. This poses a challenge for agricultural markets and products in China. Previous research shows that using regional branding to develop agricultural product brands has been successful in Europe and United States. Therefore, it is urgent and important to study the formation of APRBs in China. With increasing urbanization and favorable policies concerning agricultural economy and product branding, the objective of this study is to provide theoretical support and recommendations for the further development of these policies.
MATERIALS AND METHODS

Research on Agricultural Product Regional Brands

The ordinary form of APRB is “region name + the category name”. Brand names including a geographical reference can help to better spread and describe the quality characteristics of the agricultural product, such as the flavour, taste and fragrance. For example, branding mutton with the term “New Zealand Mutton” can help consumers more effectively distinguish and selectively purchase mutton from that country[2]. In a generally homogeneous competitive situation this approach can construct customer identity and recognition, and help products sell at high prices by highlighting the differences in their geographical origin [3]. The key point in regional branding is to construct the identity and recognition of such brands[4]. By relating the brand to its geographical origin and using the identity and recognition of regional origin to denote specific qualities, reputation and other characteristics[5], a product can gain a unique local identification[6] that in turn gives consumers a level of quality assurance and wins their trust [7]. For consumers to buy food products such as beef and fresh foods, geographic origin is an important factor in selection[8][9]. More and more agricultural producers have used regional brands to achieve product differentiation to increase profits, and have additionally used regional brands as a marketing tool to build customer loyalty, create product differentiation and provide legal protection [10].

Because agricultural product quality is often concealed until consumption, a kind of signal mechanism must be employed to display quality information. In this way brand and trademark act as signals that transmit agricultural product quality information to consumers. Consumers then assess product quality according to origin and brand information. APRB, as a special identity, has distinct regional characteristics[11]. Its signal display effect and recognition effect are employed to communicate the quality characteristics of particular agricultural products to consumers [12]. An APRB can promote the branding and value of agricultural products, and can gather the intra-area small high-quality agricultural producers to send product quality signals to the market at a lower cost. This helps them avoid the possibility of selection caused by information asymmetry, and is an important and powerful information source for the consumer in making their purchase decision[13].

Above all, agricultural product regional branding has become a hot research topic in high-end agricultural product development throughout the world.

Data Sources for APRB

In this study, sample data sets for 2012 were obtained mainly from China’s Agriculture Ministry, which has assembled information on the most well-known regional agricultural products for thirty provinces (except Tibet). The regional agricultural products selected for this study must have received at least one of the following authentication certifications: Geographical Indications Protection Products, Geographical Indication Proof Trademarks, and/or Agricultural Products Geographical Indications listing. Moreover, the deadline for possession of the above authentication certifications was the end of 2012. Data on a total of 2665 samples of famous regional agricultural products were obtained and divided into seven categories: Fruit, Vegetables, Tea, Grain-Oil, Animal Husbandry, Fish and Other.
**Development Characteristics of APRB in China**

The samples of 2665 regional agricultural brands were unevenly distributed throughout East Region Provinces, Middle Region Provinces and West Region Provinces in China, and the inter-regional differences in brand-development are very obvious. The East Eleven Provinces, including Shandong, Fujian, Zhejiang, Jiangsu, Liaoning, Hebei, Tianjin, Beijing, Guangdong, Shanghai and Hainan, provided 1062 APRB samples and accounted for 39.85% of all samples. The Middle Region Provinces, including Shanxi, Hubei, Anhui, Henan, Heilongjiang, Inner Mongolia, Jilin, Hunan and Jiangxi provinces provided 718 APRB samples and accounted for 26.94% of the samples. The West Region Provinces, including Sichuan, Xinjiang, Shanxi, Gansu, Guizhou, Chongqing, Qinghai, Ningxia, Guangxi and Yunnan, provided 885 APRBs samples and accounted for 33.21% of the total samples. These results showed the imbalances of APRB development scales in Eastern Region Provinces, Middle Region Provinces and West Region Provinces. The East Region Provinces produced the most superior regional brands with Middle Region Provinces following, and the West Region Provinces had the minimum number of agricultural brands.

**Aggregation Characteristic of APRB**

The APRBs had obvious aggregation characteristics, especially in the provinces with rich resources and unique traditions (Table 1). There were five provinces that had more than 100 APRBs in the East Region; Liaoning, Shandong, Fujian, Zhejiang, Guangdong and Shandong, and Shandong province had 298 APRBs by itself. The APRBs of these five provinces accounted for 76.46% of all samples in the East Region, and 30.47% of all samples in China. The two provinces in the Middle Region with more than 100 APRBs were Henan and Hubei. The number of APRBs in these two provinces accounted for 33.29% of all samples in the Middle Region, and 8.97% of all samples in China. The two provinces in the West Region with more than 100 APRBs were Sichuan and Chongqing. There were 228 APRBs in Sichuan. The number of APRBs in these two provinces accounted for 37.74% of all samples in the West Region, and 12.53% of all samples in China.

**Table 1**

<table>
<thead>
<tr>
<th>Region</th>
<th>East Region</th>
<th>Middle Region</th>
<th>West Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brand sum</td>
<td>1062</td>
<td>718</td>
<td>885</td>
</tr>
<tr>
<td>Brand quantity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liaoning</td>
<td>112</td>
<td>101</td>
<td>228</td>
</tr>
<tr>
<td>Shandong</td>
<td>298</td>
<td>115</td>
<td></td>
</tr>
<tr>
<td>Fujian</td>
<td>154</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>Zhejiang</td>
<td>147</td>
<td>128</td>
<td></td>
</tr>
<tr>
<td>Guangdong</td>
<td>9.51</td>
<td>17.27</td>
<td></td>
</tr>
<tr>
<td>Henan</td>
<td>16.02</td>
<td>25.76</td>
<td></td>
</tr>
<tr>
<td>Hebei</td>
<td>33.29</td>
<td>11.98</td>
<td></td>
</tr>
<tr>
<td>Sichuan</td>
<td>76.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>37.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion in intra-region (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30.47</td>
<td>8.97</td>
<td>12.53</td>
</tr>
<tr>
<td>Proportion in China (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Category of Concentration of APRB Products**

In the APRB category, Fruits made up the largest category with 704 APRBs, accounting for 26% of all APRBs. Vegetables contributed 510 APRBs (19%). Tea contributed 209 APRBs (8%). Grains-Oils contributed 373 APRBs (14%). Animal Husbandry contributed 340 APRBs (13%). Fisheries contributed 210 APRBs (8%), and the category contributed 318 APRBs (12%). The above data showed that APRBs have the following characteristics: (1) The product categories are
diversifying and showing an expanding trend; and (2) APRBs are concentrated in several categories including fruits, vegetables and grain-oils. These three APRB categories accounted for 59% of all the APRBs. The industry chain of APRBs was shorter and limited to seasonal marketing. The data show that the industry chains of APRBs are shorter, since the vast majority of APRB products are primary agricultural products. Most regionally branded products were fresh, live, unprocessed or primarily processed foods, and their capacity for development and utilization was seen as being low in the APRB context. It is difficult to store and sell to distant markets and participate in international competition for fresh and live APRB products. In addition, supply is often unstable for APRB products because of seasonal limitations. Therefore, it is important to extend the industry-chain and increase the added value of APRBs to further develop the agricultural sector in China.

APRB Spillover Effect

Theoretical Principles

In information economy theory, the actual quality of goods is often imperceptible, so brands should be used to express product quality characteristics to prevent adverse selection caused by information asymmetry. The system design of APRB, the “public brand”, can help small and decentralized agricultural producers to centralize the transmission of product quality information to market at a low cost, and to eliminate the adverse selection caused by information asymmetry.

Methodology

The development of the agriculture economy not only depends on cultivated area (land), total agricultural machinery power, and the input of technology and manpower, but also relies on the improvement of the conditions for agricultural production, such as farmland consolidation, water conservation facilities and climate. When agricultural land resources remain unchanged, product yields and farmer incomes will increase through improvements in agricultural infrastructure to the point where inputs of agricultural machinery reach saturation point. However, when the agricultural mechanization level can no longer be improved, further investment will have little impact on agricultural output. As the supply of agricultural products increases (without considering the influence of international agricultural product trade), the market will become glutted, which will cause a decline in the prices of agricultural products and a decrease in agricultural income. As a result, it is essential for China to improve the added value in agricultural products and promote the brand management of these products.

Empirical research in many developed countries has verified that the “country of origin effect” promotes agricultural product branding and increases added value. To study the positive spillover effect of APRBs on the development of the Chinese agricultural economy, regional branding was considered to be one of the important input factors in this study. The development effectiveness indexes of the agricultural economy employed were mainly the Gross Agricultural Output Value and Farmer Per Capita Income data supplied by each province, and the other control variables included the number of agriculture workers, the level of agricultural investment, and the area available for Plantation-Breeding.
As noted above, the 2665 APRB samples from 30 provinces in China (except Tibet) used in this study were all obtained from the Chinese Ministry of Agriculture. The agricultural economy development effectiveness indices included Gross Agricultural Output Value (T) and Farmer Per Capita Income (A). The T, A and agricultural investment data were obtained by multiplying the data from 2012 with the average growth rate calculated from 2008 to 2012. Plantation-Breeding Area is the sum of the average agriculture cultivated area, the average aquaculture area, and the average flower planting area between 2008 and 2012. Agriculture Investment is the total amount of agriculture investment that the Central Government directly transferred to all provinces, including investment in fixed assets, agricultural irrigation, water conservation facilities, agricultural machinery and agricultural subsidies. All these data were obtained from the Chinese Statistical Yearbook (Table 2).

### Statistical results

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Unit</th>
<th>Symbol</th>
<th>Sample Size</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Max.</th>
<th>Min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Agricultural Output Value</td>
<td>hundred million Yuan</td>
<td>T</td>
<td>30</td>
<td>2082.23</td>
<td>1482.91</td>
<td>6089.00</td>
<td>170.00</td>
</tr>
<tr>
<td>Farmer Per Capita Income</td>
<td>Yuan</td>
<td>A</td>
<td>30</td>
<td>5711.22</td>
<td>2387.20</td>
<td>12633.73</td>
<td>3042.87</td>
</tr>
<tr>
<td>Agriculture workers</td>
<td>ten thousand</td>
<td>Labor</td>
<td>30</td>
<td>2936.74</td>
<td>2029.75</td>
<td>8330.35</td>
<td>165.47</td>
</tr>
<tr>
<td>Agriculture investment</td>
<td>hundred million Yuan</td>
<td>Invest</td>
<td>30</td>
<td>201.58</td>
<td>83.82</td>
<td>389.53</td>
<td>56.46</td>
</tr>
<tr>
<td>Plantation-Breeding Area</td>
<td>thousand hectare</td>
<td>Land</td>
<td>30</td>
<td>5481.62</td>
<td>3675.32</td>
<td>14480.11</td>
<td>329.32</td>
</tr>
<tr>
<td>Agr-brand quantity</td>
<td>Individual Agr-brand</td>
<td>Agr-brand</td>
<td>30</td>
<td>88.83</td>
<td>57.99</td>
<td>298.00</td>
<td>18.00</td>
</tr>
</tbody>
</table>

### RESULTS AND DISCUSSION

#### Research Model Construction

Two econometric models (1, 2) were established. In the two models, Gross Agricultural Output Value (T) and Farmer Per Capita Income (A) are dependent variables. There are four independent variables, including Agricultural Investment (Invest), Agricultural Workers (Labor), Farming Land (Land) and APRB Quantity (Agr-brand). The following relationships were obtained:

\[
\text{In } T = C + b_1 \text{lnlabor} + b_2 \text{lninvest} + b_3 \text{lnland} + b_4 \text{ln Agr-brand } + \varepsilon
\]  

(1)

\[
\text{In } A = C + b_1 \text{lnlabor} + b_2 \text{lninvest} + b_3 \text{lnland} + b_4 \text{ln Agr-brand } + \varepsilon
\]  

(2)

Where, “C” is a constant, “bi” is regression coefficient, “ε” is the interference and “ln” is the natural logarithm.

### Regression analysis

Reviews 8.0 software was used to carry out regression analysis and estimation. A weighted least square method (WLS) was then employed to adjust the models to eliminate heteroscedasticity. Finally, the stepwise regression method was used to eliminate multicollinearity between the variables. The results of the regression analysis are shown in Tables 3 and 4.
According to the results of the regression analysis of Models 1.1 and 1.2 in Table 3, the $R^2$ for the former was 0.3168, indicating that the goodness-of-fit of this model is low. Therefore, measures of the quantity of APRB and agricultural workers were statistically non-significant, and the model was not precise enough.

Using weighted least squares for regression analysis in the model 1.2, the $R^2$ of the model 1.2 is 0.9815 (t value significantly passed the test), the goodness-of-fit of the model 1.2 is significantly higher, and all variables tested were under the 5% significance level. The estimate effect of the model 1.2 is very good.

The regression analysis results of model 1.2 gave values of 0.3613 and $t$ was 9.6786, indicating that APRBs play a significant and positive role in promoting the development of the agricultural economy. The coefficient for the plantation-breeding area was -0.43, meaning that gross agricultural output value would increase by 0.43% for every 1% decrease in this area. This result further illustrates the point that reducing plantation-breeding area through unit efficiency improvements does not directly reduce gross agricultural output value, since the increasing input from other elements partially offsets the negative impact of reducing plantation-breeding areas. Therefore, it is important to improve the quality of cultivated land, especially to improve the added value of agricultural products, and promote the branding of regional agriculture products.

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>2.1</th>
<th>2.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.9867(2.7143)**</td>
<td>1.0436(51.9432)**</td>
</tr>
<tr>
<td>Agriculture workers</td>
<td>0.0812(0.7312)</td>
<td>0.0132(0.6531)</td>
</tr>
<tr>
<td>Agriculture investment</td>
<td>0.5341(2.4213)**</td>
<td>0.5446(9.1021)**</td>
</tr>
<tr>
<td>Plantation-Breeding Area</td>
<td>0.0542(0.2500)**</td>
<td>0.0812(2.3352)**</td>
</tr>
<tr>
<td>Agr-brand quantity</td>
<td>0.3968(2.3379)**</td>
<td>0.3901(19.7857)**</td>
</tr>
<tr>
<td>Sample Size</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>R2</td>
<td>0.7860</td>
<td>0.9976</td>
</tr>
<tr>
<td>F</td>
<td>24.3986</td>
<td>3925.6351</td>
</tr>
<tr>
<td>Glejser F</td>
<td>2.6956(0.0526)</td>
<td></td>
</tr>
</tbody>
</table>

Note: (1) ***, ** and * indicate 1%, 5% and 10% significance level respectively. (2) The values in brackets are t statistics.
The regression analysis results depicted in Table 4 show that the $R^2$ of model 2.1 is 0.7860 and its Glejser $F$ is 2.6958(0.0526), which indicates that there is heteroscedasticity in the model, with a low degree of fit. Besides, the three contributory variables, agriculture investment, plantation-breeding area and agr-brand quantity, were significant at the 5% level.

The regression results of model 2.2 show an agr-brand quantity regression coefficient of 0.3901 and a $t$ value of 19.7857, which indicates that APRBs play a very significant and positive role in promoting increases in the per capita income of farmers.

CONCLUSIONS

In this study, an econometric model based on selected data from 2665 samples of regional agricultural products from 30 provinces of China was established to empirically identify the development characteristics of Chinese APRBs, and verify their spillover effects. The results revealed regional imbalances, interregional agglomeration, brand category diversification and the shorter industrial chains of APRBs, as well as showing that agricultural regional brand marketing is limited to specific seasons.

Nevertheless, the study shows that APRBs have significant and positive effects on the development of regional agricultural economies, and effectively increases farmers’ incomes. This means that APRB is a preferable system design for regional agricultural products. APRB is also useful for obtaining quality information from small-scale agricultural producers who produce high-quality agricultural products within a specific region, and transmit the information to the market at a low enough cost to prevent adverse selection caused by asymmetric information. Therefore, the added value of agricultural products can be increased by developing APRBs, which will further promote the development of Chinese agricultural product brands.

This research shows that every province in China should make full use of current agricultural policies to favor local, high-quality, brand-name agricultural resources. It is also recommended that small and medium-sized agricultural producers should develop APRBs vigorously to form the scale economy of regional branding. At the same time, registration and development of APRBs can promote the transformation of the development and management modes in the agricultural industry through regional branding and protection of intellectual property rights. Resource aggregation, industrialization and increasing productivity distribution in agriculture will transfer the superiority of regional resources to the superiority of regional brands and market competition, contributing to the rapid development of modern agriculture. Developing APRBs based on specific regional cultures and natural geographic resources can not only reasonably adjust and improve local industrial structures to form a better and special agricultural industry economy, but also promote Chinese regional culture and national soft power by active participation in international competition.

AKNOWLEDGEMENT

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参考文献

Abstract: This study was aimed to identify optimal indicators for microtopography-oriented soil quality assessment. Twenty-two soil physicochemical and biological parameters were investigated at 93 sampling points in five different microtopographic units in semiarid regions of the Loess Plateau, where the principal functions of eroded agriculture soils are related to productivity and anti-erosion ability. The selection of soil quality indicators was accomplished using a combination of sensitivity analysis, principal component analysis, and stepwise regression. The indicators used for microtopography-oriented soil quality assessment were found to be moderately sensitive with no high sensitivity. Moderately sensitive soil quality indicators including the levels of sucrase activity (SA), available phosphorus (AP), total nitrogen (TN), soil organic matter (SOM), and urease (UA) are the major objectives of soil quality restoration and regulation in the study area. The 22 soil physicochemical and biological parameters indicative of soil quality were grouped into seven soil quality factors; SOM, water-holding capacity, total phosphorous (TP), total potassium (TK), soil water content, capillary porosity, and AP. Optimal indicators for microtopography-oriented soil quality assessment in this study area were identified as SOM, TN, SA, UA, AP, CaCO₃, APA, and TK. Among these, the SOM level was the key indicator for characterizing soil quality in relation to microtopography in the semiarid loess region. This study provides reference information for the conservation of agricultural soils and improvement of low-yield farmlands in semiarid regions of the Loess Plateau. This will enable better agricultural decisions by the residents and aid decision making by the government according to local conditions.

Keywords: microtopography; soil quality; assessment indicators; semiarid loess region

INTRODUCTION

The semiarid region of China’s Loess Plateau comprises undulating ridges and hills with crisscrossing ravines and gullies. In this region, soil erosion is one of the primary causes of soil quality degradation[1]. In recent years, ecological restoration measures such as returning farmland to forest or grassland and enclosures for natural vegetation rehabilitation have been implemented, which to some extent have mitigated the exacerbation of water and soil loss[2]. However, the situation of soil erosion remains severe. The action of water erosion not only forms erosion gullies but also fragments slopes into microtopographically diverse landforms such as collapse, gullies, furrows, gently sloped terraces, scarps, and other units[3] (Fig. 1). Soil quality is a comprehensive reflection of soil physicochemical and biological properties, which integrally measures the ability of the soil to supply the nutrients necessary for life and produce biological materials; to accommodate, degrade, and purify pollutants and maintain ecological balance; and to impact and improve the health of plants, animals, and human beings[4]. Despite the widely recognized importance of soil quality for sustainable human development, there is...
presently a lack of consensus on how to assess soil quality[5]. Soil quality assessment aims to comprehensively analyze all aspects of soil functions in a wide scope, including the ability to maintain biological productivity, environmental quality, and plant and animal health[6]. The major goal of assessment lies in the understanding of agricultural soils for effective management and protection. Because soil quality cannot be measured directly, assessment of soil quality becomes necessary. A first step in soil quality assessment is to establish a measurable indicator system that can comprehensively reflect the quality of agricultural soils. Because of the diverse utilization patterns and regional variability of soil resources, different indicators have been used for assessing soil quality but no assessment indicators are commonly accepted [7-9]. The characterization theory and method as well as the assessment indicators for soil quality are currently the main subject of soil quality assessment research internationally and domestically[10-13]. However, few studies have been reported on soil quality indicators oriented to microtopography. Additionally, the existing soil quality assessments have largely used indicators artificially selected rather than statistically screened out from a large number of soil physicochemical and biological indicators [10, 14, 15]. The artificially selected indicators are inevitably subjective and arbitrary to some extent.

In semiarid regions of the Loess Plateau, the unique erosive environment and microtopographical diverse landscapes have caused serious soil degradation and erosion. Therefore, quality restoration, conservation, and direct cultivation of agricultural soils become an important work for agricultural eco-environmental conservation in semiarid loess regions. This present study has the following objectives: (1) to identify microtopography-oriented soil quality factors from 22 soil physicochemical and biological indicators of soil quality in semiarid regions of the Loess Plateau; (2) to analyze the effects of the diverse microtopography on soil quality factors; and (3) to screen out optimal indicators for microtopography-oriented soil quality assessment in the semiarid loess region. The results will provide reference information for agricultural soil quality assessment and its variation patterns and rational sampling, and will aid agricultural soil management.

**MATERIAL AND METHOD**

**Study site**

The study area comprised the Hejiagou catchments of Wuqi County, Yan’an City and the northern Shaanxi Province, China (36°33′33″-37°24′27″N and 107°38′57″-108°32′49″E). The catchments stand at 1233-1890 m above sea level and have a semiarid continental monsoon climate. The area has an average annual temperature of 7.8°C, an accumulative temperature (≥10°C) of 2817.8°C, 2400 average annual sunshine hours, a frost-free period of 96-146 days and an average annual evaporation of 400-450 mm[3]. The topography is gullied and hilly, and the vegetation is a transition from forest steppes to grasslands. Since 1998, the catchments have been closed to facilitate the rehabilitation of vegetation, and the primary vegetation now consists of herbaceous communities accompanied by sparse undershrubs and tree saplings, as well as arbor species on valley bed lands.

**Sample collection and preparation**

The number of soil sampling sites of the different microtopographies of the study area were determined depending on its topographical characters, topographical distribution and the sizes of its microtopographies as follows (Figure 1 and Table 1): 30 sampling sites in the furrows, 12 sampling sites in the gullies, 18 sampling sites in the...
collapses, nine sampling sites on the gently sloped terraces and nine sampling sites on the scarps, making a total of 78 sampling sites. Three sites were chosen as control sampling sites in the undisturbed areas of each microtopography type, making a total of 15 control soil sampling sites. Soil sampling was conducted at 0–20 cm, 20–40 cm, and 40–60 cm. The soils sampled from the three soil layers at three neighboring sampling points were mixed and prepared as one soil sample by quartering, to a total of 93 soil samples.

A 500-g portion of each soil sample was air-dried, pulverized and sieved to 1 mm and 0.25 mm in a campus-based lab for future use.

Fig. 1 - A sketch of the microtopography (QuickBird image) of the study area

Table 1

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Microtopography</th>
<th>Altitude [m]</th>
<th>Degree of slope [°]</th>
<th>Slope position</th>
<th>Slope aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Furrow</td>
<td>1358-1413</td>
<td>12-37</td>
<td>U9, M12, L9</td>
<td>A6, U3, SA18, SU3</td>
</tr>
<tr>
<td>12</td>
<td>Gully</td>
<td>1399-1419</td>
<td>23-27</td>
<td>U3, M9</td>
<td>A6, SA3, SU3</td>
</tr>
<tr>
<td>18</td>
<td>Collapse</td>
<td>1351-1383</td>
<td>12-20</td>
<td>M12, L6</td>
<td>A6, SA12</td>
</tr>
<tr>
<td>9</td>
<td>Gently-sloped terrace</td>
<td>1342-1365</td>
<td>17-27</td>
<td>M9</td>
<td>U3, SU6</td>
</tr>
<tr>
<td>9</td>
<td>Scarp</td>
<td>1396-1416</td>
<td>38-43</td>
<td>M9</td>
<td>A3, U3, SA3</td>
</tr>
<tr>
<td>15</td>
<td>Undisturbed slope</td>
<td>1341-1423</td>
<td>17-36</td>
<td>U3, M9, L3</td>
<td>A3, U3, SA6, SU3</td>
</tr>
</tbody>
</table>

Note: U, M, and L mean upper, middle, and lower positions, respectively; and A, U, SA, and SU mean adret, udadret, semi-adret, and semi-udadret, respectively. The numbers in the description of slope position and slope aspect are the number of samples.

Soil parameter measurements

Eight soil physical parameters [16] were determined where the bulk density (BD), maximum water-holding capacity (MaxWHC), minimum water-holding capacity (MinWHC), and capillary water-holding capacity (CWHC) were measured by ring shear testing, while the soil water content (SWC) was measured by oven drying. The other soil parameters were calculated using the following formulae:

\[
\varphi = \varphi_a + \varphi_b
\]

(1)

\[
\varphi_a = \varepsilon \times \mu
\]

(2)

\[
\varphi_b = (\psi_{max} - \varepsilon) \times \mu
\]

(3)
where, \( \Psi, \Psi^1 \) and \( \Psi^2 \) are the total capillary porosity (TCP, \%), capillary porosity (CP), and non-capillary porosity (NCP), respectively, \( c \) is the CWHC, \( \rho \) is the BD of the soil (g/cm\(^3\)), and \( \rho_{max} \) is the MaxWHC.

Ten soil chemical parameters [17] were analyzed as follows: Total nitrogen (TN) by the semi-trace Kjeldahl method; total phosphorus (TP) by NaOH ligation and molybdenum blue colorimetry; total potassium (TK) by NaOH ligation and flame photometry; available nitrogen (AN) by alkaline hydrolysis and diffusion; available phosphorous (AP) by extraction with 0.5 mol L\(^{-1}\) NaH\(_2\)O\(_4\) and silica-molybdenum blue colorimetry; available potassium (AK) by extraction with NH\(_4\)OAc and flame photometry; soil organic matter (SOM) by heated potassium dichromate oxidation; pH was measured by potentiometry using a pH meter; cation exchange capacity (CEC) was determined by NaOAc flame photometry; and CaCO\(_3\) by NaOH-neutralized titration.

Four soil biological parameters [18] were determined, as follows: the sucrase activity (SA) by 3, 5-dinitrosalicylic acid colorimetry; the alkaline phosphatase activity (APA) by disodium phenyl phosphate colorimetry; the catalase activity (CA) by permanganate titration; and the urease activity (UA) by citric acid colorimetry.

**Assessment indicator selection principles**

(1) Principle of pertinence

Soil quality not only depends on the major functions, type, and region of the soil, but also relies on external factors such as microtopography and soil management measures[19]. Because of different demands for soil functions, clarification of the assessment objectives is necessary (i.e., specific soil functions and problems) when selecting indicators of soil quality. In the erosive environment of microtopographically diverse semiarid loess regions, fertility quality is of greater importance to soil quality than environmental quality and health quality.

This is because fertility quality directly relates to the soil water carrying capacity for vegetation and the restoration capacity of vegetation, thus having implications for eco-environmental restoration and re-construction in the semiarid loess regions. In this region, soil fertility quality is mainly constrained by water and soil loss; thus, vegetation restoration and re-construction (e.g., SOM) is an important aspect of soil quality assessment.

(2) Principle of regionality

Soil quality has regional characteristics under different environmental conditions [20]. The spatial difference in soil quality should be reflected by the assessment indicators selected, and local conditions should be taken into consideration for establishing assessment indicators with regional representativeness. In relation to microtopography, soil quality is determined by the extent of erosion, and soil quality variations are closely related to the erosion process. In the semiarid loess regions, soil quality assessment should highlight the particularity of the erosive environment and reflect the condition and variation patterns of agricultural soil quality under different conditions of microtopography and erosion intensity.

(3) Principle of sensitivity combined with stability

Soil quality indicators are required to sensitively reflect the variations in soil erosion, tillage management, and utilization patterns. However, soil quality indicators should remain relatively stable within a certain period, rather than a higher sensitivity meaning better indicators.

**Statistical analysis**

Descriptive statistics (coefficient of variation and relative range) and principal component analysis were employed in this study to provide a statistical analysis of the soil quality variables in the semiarid loess region. SPSS20.0 software was used for these analyses. SPSS is a statistical analysis software package used for data analysis in various fields, including psychology, sociology, and education. It is widely used in scientific research for its ease of use, powerful functions, and comprehensive analysis results. This software is particularly suitable for the analysis of soil quality data due to its robust statistical functions and user-friendly interface.

The base code for soil quality variables was designed according to the specific requirements of the study, including the selection of appropriate statistical methods and the establishment of an effective data analysis framework. SPSS20.0 was used to perform descriptive statistics and principal component analysis on the soil quality variables, providing a comprehensive and accurate analysis of the soil quality in the semiarid loess region.
Principal component analysis is an important method for multivariate analysis. It essentially involves optimal integration, simplification, and dimensionality reduction of high-dimensional variable systems, and objectively determines the weight of each index to avoid subjective arbitrariness. The focus of comprehensive assessment via principal component analysis is to integrate a multi-objective problem into a single index form both scientifically and objectively point of view. Because soil quality is affected by a variety of factors, principal component analysis provides a practical method for soil quality assessment. Standardization of soil quality assessment indicators is needed to eliminate their effects of inconsistency and being dimensionless on factor loading. In this study, membership functions of soil quality assessment indicators and soil functions were established, and the degree of membership for soil quality assessment was calculated using a single-factor assessment model. In this way, the measured values of soil quality assessment indicators were converted to values between 0 and 1 for normalizing the dimensionless factors of the assessment indicators. Based on a matrix of correlation coefficients, principal component analysis was performed after varimax rotation. The communality of each assessment indicator was derived from the factor loading matrix, which reflects the relative contribution of the indicator to overall variability in soil quality. The weights of individual assessment indicators were converted to values between 0 and 1 by calculating the percentage of individual communality in the sum of communality.

Stepwise regression is an effective method for selection of optimal assessment indicator(s) from a regression equation containing all indicators under the conditions of both-enter-and-exit models and successive elimination of non-significant factors [21]. In the present study, regression analysis (i.e., stepwise regression) was performed with the first, second, third, and fourth principal components (PA1 to PA4, i.e., sample factors with the highest scores in principal component analysis) as the dependent variables, and original variable values of single or multiple indicators that affect each principal component as the independent variables. Stepwise regression was carried out through the $F$-test using the maximum correlation coefficient principle. The principal components selected to characterize soil quality were further analyzed through stepwise regression to choose the one with greatest variability in relation to microtopography. Additionally, the assessment indicators (i.e., soil parameters) that constitute each principal component were subjected to stepwise regression to identify the one with the highest variability in relation to microtopography. Finally, optimal soil quality assessment indicators and the key soil quality characteristic indicator were identified.

RESULTS AND ANALYSES

Sensitivity of soil quality indicators

Soil properties vary with microtopography and the variation rate of soil parameters is relatively high. The assessment of soil quality is not only closely related to soil functions but also sensitive to microtopographic differences. Here CV was used as the criterion to evaluate the sensitivity of soil quality indicators. A greater CV value means that the indicator is more sensitive to the variations in microtopography. Table 2 summarizes the descriptive statistics of the 22 soil physicochemical and biological parameters at 0–60 cm depth.

Principal component analysis is a useful method for soil quality assessment. The sensitivity of soil quality indicators is not only closely related to soil functions but also sensitive to microtopographic differences. Here CV was used as the criterion to evaluate the sensitivity of soil quality indicators. A greater CV value means that the indicator is more sensitive to the variations in microtopography. Table 2 summarizes the descriptive statistics of the 22 soil physicochemical and biological parameters at 0–60 cm depth.

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There are seven principal components with a cumulative eigenvalue (>1) and cumulative contribution (>85%). The principal components were selected by considering the quality assessment. In the principal component analysis, parameters were used as the initial indicators of soil quality. Microtopography-oriented soil quality factors were insensitive indicators. minWHC, MaxWHC, CWC, BD, TCP, and pH levels were moderately sensitive; NCP, APA, AN, SWC, CA, TK, CEC, CaCO₃, MinWHC, and TP levels; pH and CP levels had the smallest relative ranges.

Sensitivity analysis of soil quality indicators (sorted by coefficient of variation, CV)

<table>
<thead>
<tr>
<th>Soil quality indicators</th>
<th>Samples</th>
<th>Range</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>CV [%]</th>
<th>Relative range</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA</td>
<td>31</td>
<td>8.49</td>
<td>1.02</td>
<td>9.51</td>
<td>4.81</td>
<td>2.56</td>
<td>53.22</td>
<td>1.77</td>
</tr>
<tr>
<td>AP</td>
<td>31</td>
<td>5.12</td>
<td>0.93</td>
<td>6.05</td>
<td>2.70</td>
<td>1.14</td>
<td>42.22</td>
<td>1.90</td>
</tr>
<tr>
<td>TN</td>
<td>31</td>
<td>0.62</td>
<td>0.14</td>
<td>0.76</td>
<td>0.36</td>
<td>0.15</td>
<td>41.67</td>
<td>1.72</td>
</tr>
<tr>
<td>SOM</td>
<td>31</td>
<td>8.39</td>
<td>2.91</td>
<td>11.3</td>
<td>5.84</td>
<td>2.42</td>
<td>41.44</td>
<td>1.44</td>
</tr>
<tr>
<td>UA</td>
<td>31</td>
<td>13.31</td>
<td>2.36</td>
<td>15.67</td>
<td>8.45</td>
<td>3.42</td>
<td>40.47</td>
<td>1.58</td>
</tr>
<tr>
<td>NCP</td>
<td>31</td>
<td>6.9</td>
<td>3.50</td>
<td>10.40</td>
<td>5.74</td>
<td>1.76</td>
<td>30.66</td>
<td>1.20</td>
</tr>
<tr>
<td>APA</td>
<td>31</td>
<td>1.38</td>
<td>0.55</td>
<td>1.93</td>
<td>0.90</td>
<td>0.26</td>
<td>28.89</td>
<td>1.53</td>
</tr>
<tr>
<td>AN</td>
<td>31</td>
<td>34.99</td>
<td>16.73</td>
<td>51.72</td>
<td>31.61</td>
<td>8.44</td>
<td>26.70</td>
<td>1.11</td>
</tr>
<tr>
<td>AK</td>
<td>31</td>
<td>74.9</td>
<td>52.87</td>
<td>127.77</td>
<td>84.40</td>
<td>21.25</td>
<td>25.18</td>
<td>0.89</td>
</tr>
<tr>
<td>SWC</td>
<td>31</td>
<td>7.87</td>
<td>4.67</td>
<td>12.54</td>
<td>8.83</td>
<td>2.06</td>
<td>23.33</td>
<td>0.89</td>
</tr>
<tr>
<td>CA</td>
<td>31</td>
<td>0.4</td>
<td>0.36</td>
<td>0.76</td>
<td>0.63</td>
<td>0.10</td>
<td>15.87</td>
<td>0.63</td>
</tr>
<tr>
<td>TP</td>
<td>31</td>
<td>0.17</td>
<td>0.46</td>
<td>0.63</td>
<td>0.54</td>
<td>0.07</td>
<td>12.96</td>
<td>0.31</td>
</tr>
<tr>
<td>TK</td>
<td>31</td>
<td>10.29</td>
<td>13.49</td>
<td>23.78</td>
<td>17.56</td>
<td>2.20</td>
<td>12.53</td>
<td>0.59</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>31</td>
<td>58.59</td>
<td>139.89</td>
<td>198.48</td>
<td>164.97</td>
<td>19.97</td>
<td>12.11</td>
<td>0.36</td>
</tr>
<tr>
<td>CEC</td>
<td>31</td>
<td>4.42</td>
<td>6.48</td>
<td>10.9</td>
<td>8.74</td>
<td>1.05</td>
<td>12.01</td>
<td>0.51</td>
</tr>
<tr>
<td>MinWHC</td>
<td>31</td>
<td>10.71</td>
<td>25.97</td>
<td>36.68</td>
<td>31.93</td>
<td>2.13</td>
<td>6.67</td>
<td>0.34</td>
</tr>
<tr>
<td>MaxWHC</td>
<td>31</td>
<td>10.84</td>
<td>37.22</td>
<td>48.06</td>
<td>41.97</td>
<td>2.66</td>
<td>6.34</td>
<td>0.26</td>
</tr>
<tr>
<td>CWC</td>
<td>31</td>
<td>8.23</td>
<td>33.88</td>
<td>42.11</td>
<td>37.46</td>
<td>1.77</td>
<td>4.73</td>
<td>0.22</td>
</tr>
<tr>
<td>BD</td>
<td>31</td>
<td>0.22</td>
<td>1.15</td>
<td>1.37</td>
<td>1.26</td>
<td>0.05</td>
<td>3.97</td>
<td>0.17</td>
</tr>
<tr>
<td>TCP</td>
<td>31</td>
<td>8</td>
<td>49.73</td>
<td>57.73</td>
<td>52.81</td>
<td>1.86</td>
<td>3.52</td>
<td>0.15</td>
</tr>
<tr>
<td>CP</td>
<td>31</td>
<td>4.66</td>
<td>45.07</td>
<td>49.73</td>
<td>47.18</td>
<td>1.24</td>
<td>2.63</td>
<td>0.10</td>
</tr>
<tr>
<td>pH</td>
<td>31</td>
<td>0.24</td>
<td>8.33</td>
<td>8.57</td>
<td>8.48</td>
<td>0.06</td>
<td>0.71</td>
<td>0.03</td>
</tr>
</tbody>
</table>

To distinguish the differences in their sensitivity, the soil quality indicators were classified into four groups according to their coefficients of variation, i.e., highly sensitive, moderately sensitive, poorly sensitive, and insensitive indicators (Table 3). There are no highly sensitive indicators used for assessing soil quality in the study area; SA AP, TN, SOM, and UA levels were moderately sensitive; NCP, APA, AN, AP, SWC, CA, TP, TK, CaCO₃, and CEC levels were poorly sensitive; and minWHC, MaxWHC, CWHC, BD, TCP, CP, and pH levels were insensitive indicators.

Sensitivity classifications of soil quality indicators

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>CV [%]</th>
<th>Soil quality indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highly sensitive</td>
<td>≥100</td>
<td>None</td>
</tr>
<tr>
<td>Moderately sensitive</td>
<td>40-100</td>
<td>SA, AP, TN, SOM, UA</td>
</tr>
<tr>
<td>Poorly sensitive</td>
<td>10-40</td>
<td>NCP, APA, AN, SWC, CA, TP, TK, CaCO₃, CEC</td>
</tr>
<tr>
<td>Insensitive</td>
<td>≤10</td>
<td>MinWHC, MaxWHC, CWHC, BD, TCP, CP, pH</td>
</tr>
</tbody>
</table>

Microtopography-oriented soil quality factors

In this study, 22 soil physicochemistry and biological parameters were used as the initial indicators of soil quality assessment. In the principal component analysis, the principal components were selected by considering the eigenvalues (>1) and cumulative contribution (>85%). There are seven principal components with a cumulative
contribution close to 86% (Table 4). These seven independent principal components thus can explain nearly 86% of the total variability in soil quality, satisfying the requirement for information extraction. PA1 (35.11%) had factor loadings >0.8 for SOM, AN, SA, pH (negative loading), and UA levels, and >0.7 for TN level; all these indicators were highly significantly correlated with SOM. Thus, PA1 was assigned to a SOM factor. PA2 (12.95%) had factor loadings >0.8 for MaxWHC and BD (negative loading), and >0.7 for CWHC and MinWHC. These indicators all related to soil WHC. Thus, PA2 was defined as a WHC factor. PA3 (12.71%) had greater factor loadings for TP (>0.8) and CaCO\(_3\) levels (>0.7). Because TP and CaCO\(_3\) levels are strongly correlated, PA3 was assigned to a TP factor. PA4 had relatively high factor loadings for strongly correlated TK and APA levels. Thus, PA4 was assigned to a TK factor. PA5 had relatively high factor loading for SWC and thus was defined as an SWC factor. PA6 had relatively high factor loading for CP, thus was defined as a CP factor. PA7 had a relatively high factor loading for AP level, thus was defined as an AP factor.

Table 4

<table>
<thead>
<tr>
<th>Assessment indicator</th>
<th>Principal component</th>
<th>Communality</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOM</td>
<td>1</td>
<td>0.863</td>
<td>0.047</td>
</tr>
<tr>
<td>AN</td>
<td>2</td>
<td>0.859</td>
<td>0.047</td>
</tr>
<tr>
<td>SA</td>
<td>3</td>
<td>0.844</td>
<td>0.045</td>
</tr>
<tr>
<td>pH</td>
<td>4</td>
<td>-0.829</td>
<td>0.041</td>
</tr>
<tr>
<td>UA</td>
<td>5</td>
<td>0.819</td>
<td>0.048</td>
</tr>
<tr>
<td>CP</td>
<td>6</td>
<td>-0.014</td>
<td>0.049</td>
</tr>
<tr>
<td>TCP</td>
<td>7</td>
<td>0.318</td>
<td>0.043</td>
</tr>
<tr>
<td>SWC</td>
<td>3</td>
<td>-0.063</td>
<td>0.048</td>
</tr>
<tr>
<td>MinWHC</td>
<td>4</td>
<td>-0.032</td>
<td>0.050</td>
</tr>
<tr>
<td>AP</td>
<td>5</td>
<td>0.049</td>
<td>0.044</td>
</tr>
<tr>
<td>AK</td>
<td>6</td>
<td>0.150</td>
<td>0.044</td>
</tr>
<tr>
<td>NCP</td>
<td>7</td>
<td>0.326</td>
<td>0.048</td>
</tr>
<tr>
<td>TN</td>
<td>1</td>
<td>0.753</td>
<td>0.046</td>
</tr>
<tr>
<td>TP</td>
<td>2</td>
<td>0.051</td>
<td>0.040</td>
</tr>
<tr>
<td>TK</td>
<td>3</td>
<td>-0.119</td>
<td>0.047</td>
</tr>
<tr>
<td>BD</td>
<td>4</td>
<td>-0.414</td>
<td>0.046</td>
</tr>
<tr>
<td>CEC</td>
<td>5</td>
<td>0.266</td>
<td>0.039</td>
</tr>
<tr>
<td>CaCO(_3)</td>
<td>6</td>
<td>-0.127</td>
<td>0.044</td>
</tr>
<tr>
<td>CWC</td>
<td>7</td>
<td>0.319</td>
<td>0.051</td>
</tr>
<tr>
<td>APA</td>
<td>1</td>
<td>0.369</td>
<td>0.042</td>
</tr>
<tr>
<td>CA</td>
<td>2</td>
<td>0.602</td>
<td>0.051</td>
</tr>
<tr>
<td>MaxWHC</td>
<td>3</td>
<td>0.424</td>
<td>0.052</td>
</tr>
<tr>
<td>Eigenvalue</td>
<td></td>
<td>7.72</td>
<td>1.01</td>
</tr>
<tr>
<td>Variance [%]</td>
<td></td>
<td>35.11</td>
<td>4.61</td>
</tr>
<tr>
<td>Cumulative (%)</td>
<td></td>
<td>35.11</td>
<td>85.88</td>
</tr>
</tbody>
</table>

**Microtopography-oriented soil quality assessment indicators**

Non-significant factors were successively eliminated through stepwise regression as follows:

\[
F = 466.269^* \quad Df = (5, 25) \quad R_s = 0.994 \quad (adjusted \ \text{correlation coefficient})
\]

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F = 466.269^* \quad Df = (5, 25) \quad R_s = 0.994 \quad (adjusted \ \text{correlation coefficient})
\]
The variability of soil quality indicators reflects the environmental sensitivity of these properties. Thus, coefficients of variation can be used for sensitivity classification of APA and TK levels. Of these, SOM is the key indicator for characterizing soil quality in diverse microtopographic units in semiarid regions of the Loess Plateau.

**Discussion**

The major objectives of soil biological quality assessment are to determine the levels of soil biological quality and to establish guidelines for soil biological quality management. For microtopographically oriented agricultural soil quality assessment in northern Shaanxi, it is recommended that macroscopic soil quality assessment and window regression by principal component analysis are selected but insensitive indicators are eliminated. According to this strategy, the following conclusions are obtained:

1. Nine chemical soil quality indicators are selected for soil biological quality assessment: SOM, N, APA, AP, TN, TP, PH, and TK.
2. The partial correlation coefficients of soil biological quality indicators were X1 = APA, X2 = AP, and the partial correlation coefficient of X2 = AP.
3. The partial correlation coefficients of soil biological quality indicators were X1 = APA, X2 = AP, X3 = TP, and the partial correlation coefficient of X3 = TP.

These results show that APA, AP, SOM, and TN are the greatest contributor to the indicators of the TK factor. APA was the major contributor to the indicators of the TP factor.
CONCLUSIONS

This study is the first to investigate microtopography-oriented soil quality assessment indicators in semiarid regions of the Loess Plateau. Results show that the levels of sussure activity, available phosphorus, total nitrogen, soil organic matter, and urease activity were moderately sensitive indicators for microtopography-oriented soil quality assessment. Therefore, potential soil functions can be fully played as long as rational measures are implemented for conservation of agricultural soils, improvement of soil structure, and promotion of soil microbial activities. For the quantitative assessment of soil quality in the study area, it is recommended that moderately sensitive indicators and some poorly sensitive indicators are selected, with insensitive indicators eliminated.

This study identifies optimal indicators (OM, TN, SA, UA, AP, TP, CaCO₃, APA, and TK) for microtopography-oriented soil quality assessment in semiarid regions of the Loess Plateau through stepwise regression and principal component analysis combined with correlation analysis of selected soil parameters and sensitivity analysis of soil quality indicators. The work lays a solid foundation for future microtopography-oriented vegetation allocation and ecological construction and provides a reference for conservation of agricultural soils, improvement of low-yield farmlands, and guidance of agricultural production according to local conditions in semiarid loess regions.

Aknowlegement

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RESEARCH ON POLLUTION CHARACTERISTICS OF RURAL RUNOFF


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Abstract: This paper studied the non-point source pollution type of Meijiadu Village, Gaocheng Town, Yixing City, Taihu Basin, analyzed the process of rainfall-runoff producing- pollution producing of two main runoff pollution sources in the rural area, calculated the mean concentrations of the different rainfall events. Based on local living conditions and poultry farming methods, the runoff pollution characteristics and the influencing factors were analyzed. Besides, a biological detention pond technology suitable for treating runoff pollution under rural conditions was proposed. The results show: The event mean concentrations of these two polluted areas differed significantly; within the same rainfall, the runoff peak occurred 0.6-1.1 h later than rainfall intensity did, and the concentration was also changed along with the runoff process. However, at different rainfall intensities, the loss law of the pollutants was similar. The concentration of runoff pollution reached the peak within the first 10 min, but the water quality became stable after the stabilization of the runoff. Therefore, the concentration of runoff pollution was affected by rainfall intensity, rainfall duration, poultry scale, human activities, surrounding soil properties and many other factors.

Keywords: rural runoff; free-ranging poultry; outdoor septic tank

INTRODUCTION

Water environmental problems of Lake Taihu are mainly endangered by runoff pollution coming from agricultural production, living of residents and poultry farming, etc. [1]. The clumsy life patterns and inadequate understanding of water-use have increasingly overburdened the aquatic system. The obsolete construction of relevant environmental facilities has rapidly degraded the aquatic system in rural areas. Besides, the aquatic system in small towns is prone to eutrophication that is characterized by the increment of organisms, nitrogen and phosphorus [2]. Particularly, runoff pollution is the main factor of rural non-point source pollution [21]. Rainfall runoff pollution refers to the water environment pollution in surface and underground water, which is caused by the diffusible entrance of pollutants in the atmosphere, ground and the soil under the leaching and scouring effect of rainfall runoff. In particular, the chemical fertilizers and pesticides used in agricultural production contribute the most to such pollution [3]. Currently, the urban runoff water quality [4; 5] and rural farmland surface runoff [6] have been studied extensively, while the runoffs of typical residential villages have seldom been referred.

In this study, typical runoff pollution sources in the study area were interviewed and investigated. The runoffs of poultry farming area and outdoor septic tank were determined as two major point source (PS) pollutions of typical rural pollutions. Their pollutants entered the river along with the rainfall runoff and polluted the rural water seriously. Meanwhile, a method for synchronization detection of rainfall-runoff producing- pollution producing was employed to clarify the runoff pollution characteristics and laws. Besides, a biological and ecological treatment technology- biological detention pond technology- suitable for treating runoff pollutions under rural living conditions was proposed [7; 8].
MATERIALS AND METHODS
Area overview and study object
Meijiadu Village, Yixing City is located in the west of Gaoceng Town of the 5 square kilometers area and 580 households in total. There are about 244 scattered small-scale poultry farming households that mainly breed chickens and ducks using free-ranging raising pattern, so the poultry manure cannot be easily collected. The barns are mainly classified into open shed type, simple brick-concrete style and simple wooden assembling type. All of them do not have cushion bedding or manure collection facilities. Hence, the poultry manure pollutants flow to the river directly along with the runoff, thus becoming one of the important pollution sources in rural rivers. In addition, 80% of local farmers have septic tanks, of which 20% are open ones. The manure in open septic tanks flows into ditches and ponds along with the rainfall runoff and eventually into the rivers, thus polluting the water environmental quality seriously and damaging the living environment of villagers.

Based on the local runoff pollution characteristics, poultry farming area and open septic tank as the typical runoff pollution were selected to do the runoff pollution detection, and TN, TP, COD and NH$_4^+$-N are the major indicators.

Sample collection and analysis
Within the catchment area of the study area, there are two sampling sites. Since the areas were not frequently cleaned, the surroundings of the open shed type henry and the septic tank were cleaned to remove the large floating debris and fodders in the early period of rainfall to minimize the effects of the outside factors. During rainfall, synchronous sampling was collected in two sampling sites. To ensure complete detection of rainfall-runoff producing process, the samples were collected at 0-5 min, 5-10 min, 10-15 min, 15-30 min, 30-45 min and 45-60 min respectively within 60 min from runoff formation to stabilization. Since sampling sites had high particle contents at the bottom, the surface runoff samples were obtained by a glass syringe, and then injected into 500 ml polyethylene bottles. Each sample was filled fully in the bottle without air so as not to affect the monitoring. Meanwhile, a measuring cylinder was also placed in the area during sampling, within which the runoff volume was recorded hourly. After sampling, water samples were sent back to the laboratory for analyses. Monitoring indicators included TN, TP, COD, and NH$_4^+$-N.

The fourth edition of the National Standard Sample Monitoring Method was employed for sample analyses [9]. The pollution degree was determined by comparing the concentrations of various pollutants and the ninth category of water standards in GB-3838-2002 Quality Standard of Surface Water Environment.

### Materials and Methods

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**Rainfall characteristics**

There were four rainfalls occurred during this study, mostly in the evening, and lasted 6-14 hours. The rainfall capacity changed significantly from 5.6 mm to 27.3 mm at the 12th hour. In the selected area, the
runoff formation time was postponed by 40-210 min owing to rainfall collection area and rainfall intensity. The characteristic data of the four rainfalls are shown in Table 2.

### Table 2

<table>
<thead>
<tr>
<th>Rainfall session</th>
<th>Rainfall time</th>
<th>Runoff formation time</th>
<th>End time</th>
<th>Accumulated rainfall (unit /:mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013-03-01(3301)</td>
<td>01:30</td>
<td>02:10</td>
<td>07:05</td>
<td>5.6</td>
</tr>
<tr>
<td>2013-03-22(3322)</td>
<td>01:40</td>
<td>03:00</td>
<td>07:15</td>
<td>27.3</td>
</tr>
<tr>
<td>2013-03-23(3323)</td>
<td>16:45</td>
<td>20:15</td>
<td>23:20</td>
<td>8.2</td>
</tr>
<tr>
<td>2013-04-06(3406)</td>
<td>13:10</td>
<td>15:20</td>
<td>05:50</td>
<td>17.6</td>
</tr>
</tbody>
</table>

### Calculation of quantitative index

Since the pollutant concentration changes in a rainfall, when study runoff water quality, the event mean concentration (EMCs) from rainfall runoff [10] is mostly utilized to calculate the pollution degree of a rainfall and to compare horizontally. EMCs, as the ratio of total pollutants amount to that of runoff, can be calculated as equation (1).

\[
PEMCs = \frac{M}{V} = \frac{\int_{t_0}^{T} \rho(t) q(t) dt}{\int_{t_0}^{T} q(t) dt} = \frac{\sum_{i=q(t)}^{T} \rho(t) q(t)}{\sum_{i=q(t)}^{T} q(t)}
\]

Where PEMCs is the rainfall mean concentration (mg/L), M is the total pollutants amount produced in the rainfall events (mg), V is the rainfall runoff amount (L), \( \rho(t) \) is the pollutants mass concentration changed over time (mg/L), \( q(t) \) is the flow changed over time (m³/h), and \( t \) is the runoff duration (h).

As shown in Table 3, the mean concentration of 3323 is higher than that of 3406, while the value of 3301 exceeds that of 3323. Therefore, EMC was related to the rainfall capacity and the number of sunny days in early period, because the accumulated pollutant and stacked poultry excrement were located on the surface in the long-sunny-day areas. In the meantime, the poultry wastewater accumulated on the soil surface of rural area over time. Intense rainfall affected the organic pollutants in soil and the surface particles, leading to more severe pollution of water quality in the initial runoff period. As suggested by the COD values, the two studied regions were subject to severe organic pollution.

### Event mean concentrations (EMCs) of different sampling sites (EMCs)

<table>
<thead>
<tr>
<th>Rainfall session</th>
<th>Rainfall time</th>
<th>Poultry farming area (mg/L)</th>
<th>Surroundings of septic tanks (mg/L)</th>
<th>Number of sunny days</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(3301)</td>
<td>2013-03-01</td>
<td>7.8</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>2(3322)</td>
<td>2013-03-22</td>
<td>12.5</td>
<td>11.6</td>
<td>21</td>
</tr>
<tr>
<td>3(3323)</td>
<td>2013-03-23</td>
<td>9.4</td>
<td>9.1</td>
<td>27</td>
</tr>
<tr>
<td>4(3406)</td>
<td>2013-04-06</td>
<td>10.3</td>
<td>10</td>
<td>14</td>
</tr>
</tbody>
</table>

### RESULTS AND DISCUSSIONS

**Water quality changes of rainfall**

1) Rainfall - runoff changes

Heavy rainfall event on March 22, 2013 and moderate rainfall event on April 06, 2013 were selected to analyze the rainfall change trend. The runoff volume in the rainfall was calculated according to the hourly flow of rainfall into the cylinder. As presented in Figure 1 and Figure 2, the runoff lagged 0.6-1.1 hours behind rainfall. When the rainfall formation time was postponed by 40-210 min owing to rainfall collection area and rainfall intensity. The characteristic data of the four rainfalls are shown in Table 2.

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After the formation of runoff, every runoff in poultry farming area and septic tank behind the house was sampled at different times to get 6 samples. These samples were examined in the laboratory to analyze the runoff water quality changes of TN, TP, COD, and NH$_4^+$-N.

1) Runoff water quality changes of septic tanks

Rural septic tanks are featured with low rate of harmless manure treatment and poor health status. The environment of most toilets is poor. Without harmless treatment, the environment is polluted directly by fecal residues that are accumulated for a long time and discharged arbitrarily. When raining, the pollutants flow into the surrounding rivers along with runoff, and pollute water quality severely [11]. Owing to the difficulty of sampling, the samples were actually collected 20 meters away from the outlet of runoff, and the test data are shown in Figure 3 - Figure 6.

2) Runoff water quality changes of septic tanks

At two different rainfall intensities, each index decreased with extended time (Figure 3 and Figure 4). The water quality changed significantly during the first 20 min and then stabilized. The rainfall of 3322 changed significantly within the first 20 min, indicating that the particles were obviously impacted by the rainfall. Probably, TN concentration decreased before rising while TP concentration dropped steadily owing to the dilution of runoff. COD content decreased over time in the heavy rainfall but fluctuated throughout little rainfall.
3) Runoff water quality changes in poultry farming area

The studied poultry farming area has bred 10 chickens and 4 ducks in the main form of open shed free-ranging, and ducks are placed in the pond next to the henry. The runoff flowed through the henery to the pond, so the runoff at the exit of pond was selected. The surface water was sampled due to considerable impurities at the bottom of the pond.

As exhibited in Figure 5 and 6, all pollution-related indices in poultry farming areas and septic tank areas decrease over rainfall time in the same way. The difference between various rainfalls affected TP more evidently. Phosphorus mostly adhered to small particles. Upon heavy rainfall, the surrounding soils were scoured and the TP contents changed. In the case of little rainfall, TP concentration in the poultry area was higher than that in the septic tank area, probably because the soils surrounding the poultry area were less firm.

TN concentrations in both detection areas changed in the same pattern of “V”-type, being consistent with the results reported by Su et al. [12]. The low ammonia proportion in the process may be attributed to the low contents of DO and oxygen as well as unobvious nitrification in wastewater. Based on the outcomes of the two rainfalls, the number of sunny days in early period and the rainfall intensity exerted significant effects on water quality, especially on TP and COD.

**Effects of runoff water quality features**

(1) Functional areas and rainfall intensity

The rainfall in 3322 was selected for analysis. This rainfall lasted for 12 hours with the capacity of 27.3 mm, accompanied by obvious runoff and serious particle scouring. The runoff water qualities in poultry farming area and open septic tank area were compared as the following figures.
Within the catchment area, runoff water quality in different functional areas was controlled by soil properties. Both catchment areas in poultry area and septic tank area were manure-containing rains, so the water qualities of two functional areas were similar. Figure 7 shows that TN, TP and NH$_4^+$-N concentrations in poultry farming area are all higher than those in septic tank area at the same rainfall intensity, while the COD concentration is lower. The results can mainly be ascribed to the higher organic contents of human feces compared to poultry feces. Phosphorus is produced as a non-point source pollutant by a very complex process, and it is subject to the combined effects of rainfall process (rainfall type, intensity and duration) and the underlying surface factors (topography, landform, chemical and physical conditions of the soil, and agricultural time measures, etc.) [13]. The phosphorus concentration in poultry area was higher because phosphorus compounds were generally adsorbed on particulate matters. However, the loose soils around the poultry area rendered them easily to be washed out by the runoff. As shown in Figure 8, in the same functional area, all pollution indices at heavy rainfall intensity are larger than those at small rainfall intensity, suggesting the impact of rainfall scouring is greater than that of dilution. The influence of rainfall duration remains unclear.

(2) Different times
As evidenced by the detected values, the difference between the pollutant concentrations in initial runoff and later runoff was not significant. The pollution value was high within the first 10 min, but total nitrogen increased slightly in the late period. Overall, each index only decreased a little over time. The highest concentrations all appeared before the runoff peaks.

![Fig. 7 - Water quality comparison of different functional areas](image)

![Fig. 8 - Water quality comparison of different rainfall intensities](image)

![Fig. 9 - Water quality comparison of different times](image)
Rural runoff treatment technology

The traditional rural rainwater drain method of overflowing anywhere has many drawbacks. Rainwater runoff management measure has been widely studied to meet multiple benefits of environment, ecology and economy, which is one of the problems that rural runoff encounters.

Rural surface source pollution has been well treated by constructed wetlands [14-15], with the removal rates of NH$_4^+$-N, TN and TP being higher than 80%. Slope buffer zone can also improve the river water quality in stagnant runoff pollution effectively [16]. Rainwater storage tanks, shallow trench and ponds of vegetation [17], and multiple BMPs ecological processing have been widely used to handle runoff pollution in rural areas, of which biological detention pond is a novel, eligible runoff treatment technology. It has been successfully applied to treat runoff pollutants [19-20]. According to rural land conditions and soil properties, runoff pollution can be feasibly treated by biological and ecological approach. Especially, combined ecological processing technology has been proposed for runoff pollution disposal in poultry farming sites and areas next to the improved septic tank. This technology costs a little for running, but it can significantly improve water quality by partial reuse of treated water and by supplementing the residual into the groundwater.

CONCLUSIONS

1. At different rainfall intensities, runoff formations were delayed by 40-210 min. Runoff formed in the survey area when precipitation exceeded 1 mm; (2) The runoff and precipitation changed similarly; both increased first and then decreased; (3) Water qualities in poultry farming site and septic tank area both changed in the TN's "V"-type pattern, with low ammonia proportions. TP and COD fluctuated less after the stabilization of runoff. At the same rainfall intensity, TP concentration in poultry area was higher than that in septic tank area; (4) The pollution value was highest within the first 10 min before runoff formation and the water quality concentration decreased after stabilization. Both of their values were lower than the initial stabilization.

REFERENCES

INFLUENCE OF BLENDING CONDITIONS ON MORPHOLOGY AND RESISTANCE AT IMPACT OF TERNARY BIOPOLYMERS BLENDS OF PLA/PBAT/PA

INTRODUCTION
Biopolymers represent an area where biodegradability would be a tremendous asset to a variety of casings, insulation and packaging products. Starch, it’s a key component of these renewable raw materials and is becoming an increasingly important input to activities outside the food industry due to the variety of ways in which it can be modified to find applications in industry. Biopolymer blending is a convenient and attractive route for obtaining new biopolymer materials with great properties, adapted to different applications. Making a parallel between the developments of a new biopolymer, making blends of currently available biopolymers offers significant savings in time and cost, and the blend properties may be tuned by changing the composition [4, 7]. Therefore, achieving compatibilization of immiscible polymer blends it was a long-standing academic and technological challenge.

In the last period, despite of the very large number of studies on the compatibilization of binary biopolymer blends, some studies have considered ternary or multi-component biopolymer blends [8,10].

MATERIAL AND METHOD
The material used in this experiment was PLA polymer 3051D (polylactide) produced by Nature Works [2], PBAT (econex F BX 7011) produced by BASF [1] and PA (platamid) produced by ARKEMA. The characteristics of PLA 3051D, supplied by Nature Works are shown in table 1.

PLA (polylactide) polymer 3051D is designed for injection moulding applications where the requirements are clarity...
with heat deflection temperatures lower than 55ºC.

The variety of products made with PLA continues to grow rapidly. Applications include cutlery, cups, plates, saucers and outdoor parts.

The characteristics of PBAT (ecoflex F BX 7011) used, supplied by BASF are shown in table 2.

Table 1 / Tabel 1

<table>
<thead>
<tr>
<th>Property/ Proprietate</th>
<th>Value / Valoare</th>
<th>Test Method / metoda testare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density/ Densitate (g/cc)</td>
<td>1.25</td>
<td>ASTM D792</td>
</tr>
<tr>
<td>Melling Index/ Index topire g/10min (210ºC/2.15Kg)</td>
<td>10 to 25</td>
<td>ASTM D1238</td>
</tr>
<tr>
<td>Melling Point/ Punct de topire, ºC</td>
<td>200 ºC</td>
<td>DSC</td>
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<tr>
<td>Relative Viscosity/ Vascozitate relativa (Pa·s)</td>
<td>3.0-3.5</td>
<td>ASTM D638</td>
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<td>Tensile Strength/ Rezistenta la rupere, (MPa)</td>
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<td>ASTM D638</td>
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<tr>
<td>Elongation/ Intindere %</td>
<td>2.5</td>
<td>ASTM D638</td>
</tr>
<tr>
<td>Notched Impact/ Rezilienta, (J/m)</td>
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<td>ASTM D256</td>
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</table>

Table 2 / Tabel 2

<table>
<thead>
<tr>
<th>Property/ Proprietate</th>
<th>Value / Valoare</th>
<th>Test Method / metoda testare</th>
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<tbody>
<tr>
<td>Density/ Densitate (g/cc)</td>
<td>1.25 to 1.27</td>
<td>ASTM D792</td>
</tr>
<tr>
<td>Melling Index/ Index topire, g/10min (190ºC/2.16Kg)</td>
<td>2.7 to 4.9</td>
<td>ASTM D1238</td>
</tr>
<tr>
<td>Melling Point/ Punct de topire, ºC</td>
<td>110 to 120</td>
<td>DSC</td>
</tr>
<tr>
<td>Tensile Strength/ Rezistenta la rupere, (MPa)</td>
<td>34</td>
<td>ASTM D638</td>
</tr>
<tr>
<td>Elongation/ Intindere %</td>
<td>700</td>
<td>ISO 527</td>
</tr>
<tr>
<td>Water Permeation Rate /Rata permeabilitate la apa, g/(m²*d)</td>
<td>140</td>
<td>DIN 53122</td>
</tr>
</tbody>
</table>

Ecoflex F BX 7011 comes closer than any other biodegradable plastic to the processing properties of a classic polymer. A flexible plastic designed for film extrusion and extrusion coating. Blown film extrusion is a particular area where PBAT shows well-balanced processing properties and the resin can be used in extrusion coating applications.

The density of PA PLATAMID HX 2656 is 1.1 (g/cc), having a melting point around 115-120 ºC.

A laboratory internal mixer type Haake Rheomix R600 (Fig. 1) with mixing chamber volume of 50 cm³ was used to conduct the extrusions. Like we can see in the figure 1, this extruder has two counter-rotates rotors and allows to impose a tangential kneading type at a shear rate given. This device can also measure the temperature of the material and the engine torque exerted by the fluid on the rotor blades.

Fig. 1 - Internal mixer Haake Rheomix 600: (a) mixing chamber, (b) Contra rotates rotors, profiles / Amestecator intern Haake Rheomix 600: (a)camera de amestecare, (b) rotoare contra-rotative, profile
The chamber of extruder was fed at 80 % from full capacity. The experiments characteristics are: 
- **Experiment 1** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 12 min., rotation speed 30 rot/min.;  
- **Experiment 2** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 12 min., rotation speed 50 rot/min.;  
- **Experiment 3** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 12 min., rotation speed 80 rot/min.;  
- **Experiment 4** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 12 min., rotation speed 100 rot/min.;  
- **Experiment 5** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 170 °C, mixing time 12 min., rotation speed 80 rot/min.;  
- **Experiment 6** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 190 °C, mixing time 12 min., rotation speed 80 rot/min.;  
- **Experiment 7** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 20 min., rotation speed 80 rot/min.;  
- **Experiment 8** - 60 % PLA / 20 % PBAT / 20 % PA - temperature 180 °C, mixing time 8 min., rotation speed 80 rot/min.

Before blending all feeding material was dried in the oven at 80 °C, minimum 4 hours. All blends was mixed 12 min. at 180 °C having a rotors speed of 80 rpm. After blending, the material was collected in one use bags, crushed in small pieces and formed in bars by compression moulding. The compression moulding process (Figure 2) was made at 180 °C for all bars.

From each blend were formed 3-4 bars. After that, each bar was tested separately at resistance at impact. The dimensions of the bars were 80 x 10 x 3 mm. The depth under the notch of the specimen is 8 mm.

**RESULTS**

The determined parameter from resistance at impact tests is impact strength according to ISO, expressed in kJ/m². Impact strength (noted R₂) is calculated by dividing impact energy, in J, by the area under the notch. The machine used for determination of impact strength is CESAT 9050 Impact Pendulum (Figure 3). This machine is designed for determining the resilience of thermoplastic materials to impact.

**REZULTATE**

Parametrul determinat pentru testele de rezistență la impact este rezistenta la impact în conformitate cu ISO, exprimată în kJ/m². Rezistența la impact (notată R₂) se calculează prin împărțirea energiei de impact, în J, la suprafața de sub crestătură. Mașina folosită pentru determinarea rezistenței la impact este CESAT 9050 Pendulum impact (figura 3). Acest aparat este destinat determinării capacității de rezistență a materialelor termoplastice la impact.
Tests according to internationally recognized standards belonging to Charpy, Izod, Pipe and tensile impact methods, ranging in energy from 0.5 - 50J.

Testele de rezistență la impact sunt în conformitate cu standardele recunoscute la nivel internațional aparținând lui Charpy, Izod, Pipe, metodele de testare la impact, având un interval de varție între 0,5-50 J.

A graphical interpretation of experimental data is presented in Figure 4, Figure 5, Figure 6.

O interpretare grafica a datelor experimentale este prezentata in figurile 4,5 si 6.

From graphic representation from Figure 4 we can observe that an increasing of rotation speed (up to 100 rpm) during the blending is benefic for obtaining a higher resistance at impact proprieties.

Din reprezentarea grafică din figura 4 se poate observa că o creștere a vitezei de rotație (de până la 100 rpm) în timpul amestecării este benefică pentru a obține proprietăți de rezistență la impact mai mătă.

From graphic representation from Figure 5 we can observe that the optimal temperature during the mixing is at 180°C.

Din reprezentarea grafică din figura 5 se observă că temperatura optimă în timpul amestecării este de la 180°C.

If we decrease the temperature value (170 °C, Experiment 5) during the mixing we obtain smaller values for resistance at impact.

Dacă reducem valoarea temperaturii (170°C, Experiment 5) în timpul amestecării se obțin valori mai mici pentru rezistența la impact.

If we use a higher temperature (190°C, Experiment 6) during the mixing we can observe a decreasing of resistance at impact values.

Dacă folosim o temperatură mai mare (190°C, Experiment 6) în timpul amestecării se poate observa o scădere a valorii rezistenței la impact.
From graphic representation presented in Figure 6 we can observe that the optimal mixing time (using internal mixer Haake Rheomix 600) is at 12 min. If we use a smaller mixing time (8 min., Experiment 8), the results for resistance at impact test are decreasing. Same situation if we use a bigger mixing time (20 min., Experiment 7).

In parallel it was made a morphology study of the mixed blends. The obtained morphology is presented in the Figure 7.

Fig. 5 - Influence of process temperature to the impact strength for studied blends / Influența temperaturii procesului asupra rezistenței la impact a amestecurilor studiate

Fig. 6 - Influence of extrusion time to the impact strength for studied blends / Influența timpului de extrudare asupra rezistenței la impact a amestecurilor studiate

Fig. 7 - Photos with obtained morphology for 60% PLA / 20% PBAT / 20% PA (Experiment 3) / Fotografii cu morfologia obținuta pentru 60% PLA / 20% PBAT / 20% PA
The samples for microscope observations were prepared through cryo fracture by cooling in liquid azote, after that deposit a thin layer of platinum on the studied surface.

For microscope observation it was used ESEM laboratory equipment ZEISS SUPRA 40 with GEMINI column. Another used electronic microscope it was Philips XL30.

After all these experimental studies, we can say that the best volume ratio for obtaining the best resistance at impact, between PLA/PBAT/PA ternary blends is 60/20/20. The best resistance at impact is obtained in case of Experiment 4 with 100 rpm, 180 °C during 12 min.

CONCLUSIONS

By combining three biopolymers, we can obtain a biopolymer blend with new properties. By changing the matrix volume ratio in the blend, we can obtain different materials with different mechanical properties, adapted to each application. In the present study, we used three biodegradable polymers.

If the goal is to design a material with good mechanical properties, an option is to use PLA as the matrix and PBAT and PA as the inclusion. This leads to good impact properties. To use, for example, this polymer blend to make foil would require to increase the volume ratio of the PBAT in the blend.

In general, to increase mechanical properties will require adding compatible agents or a third component, or both.

Acknowledgement

This research was supported by a grant from Q-DOC project of Technical University of Cluj-Napoca, Romania.

REFERENCES


CONCLUSII

Prin combinarea a trei biopolimeri, putem obține un amestec biopolimermeric cu proprietăți noi. Prin schimbarea matricei raportului volumelor în amestec, se pot obține diferite materiale cu proprietăți mecanice diferite, adaptate pentru fiecare aplicație. În studiul de față, am folosit trei polimeri biodegradabili.

Dacă scopul este de a obține un material cu proprietăți mecanice bune, o opțiune este să se folosească PLA ca matrice și PBAT, PA ca și incluziuni. Acest lucru conducă la obținerea unor proprietăți de rezistență la impact bune. Dacă scopul este de a utiliza, acest amestec de polimeri pentru a face folie, este necesară creșterea raportului volumetric al PBAT în amestec.

În general, pentru a crește proprietățile mecanice va fi necesara adăugarea unor agenti de compatibilizare sau a unui al treilea component, sau ambele.

Aknowlegement

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BIBLIOGRAFIE

INTEGRATED TECHNOLOGY FOR OBTAINING AGRIPELLETS

TEHNOLOGIE INTEGRATE  DE OBȚINEREA A AGRIPЕLЕIȚІLОР


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Abstract: In the paper is presented the technology of obtaining pellets and agripellets used by INMA Bucharest, aiming to determine the combustion characteristics of products obtained by technology of creating pellets and agripellets from agricultural and forestry solid biomass and identify the best recipes. Therefore, a number of 13 samples for analyses, as different mixtures (recipes), and biomass sampling have been submitted to laboratory analyses specific to solid fuels, in order to establish the main characteristics, which should allow the best recipes in terms of combustion degree.

Keywords: biomass, agripellets, technology, energy, calorific power, mixture recipes

INTRODUCTION

Biomass represents the whole vegetal agricultural production which can be converted in different forms of energy. The agricultural production comprises the principal production and the secondary production.

Main agricultural vegetal production is converted to bioalimentary energy and secondary agricultural vegetal production represents the principal source of biomass to be transformed in thermal energy [4].

According to European Union regulations, biomass represents the biodegradable share of products and wastes from agriculture, forestry and related industries, as well as biodegradable fraction from municipal and industrial wastes.

Main chemical composition of biomass is:
- lignin (C_{6}H_{10}O_{5}) = 15 – 30 %;
- cellulose (C_{6}H_{10}O_{5}) = 40 – 45 %;
- hemicellulose = 20-35 %.

Variation limits of the main three components are determined by respective species. Cellulose long polymers are used by plants for creating fibers, which offer the plant solidity, and lignin acts as a binder for cellulose fibers [2]. In order to manufacture the pellets the lignin content has to be as high as possible. For a high calorific power it is necessary that ratios O/C and H/C be as small as possible [1].

The main agricultural secondary products to be transformed in thermal energy as agripellets are [10], [11]:
- straw and straw cereals (wheat, rye, barley, two-row barley, rice and oat);
- corn stalks and kernels;
- sunflower and rape stalks;
- soy, green peas and beans stems;
- tendrils of vine;
- fruit trees branches.

Production and distribution flow to consumer, for producing and using pellets or briquettes (future ecological renewable fuel), presented in figure 1 start from vegetal biomass as raw material and comprises 9 phases up to fuel distribution and utilization by final consumer. [8].

For preparing materials involved in technological flux of manufacturing pellets and briquettes, the material used is only as wood chips or agricultural biomass chopped, all types of mobile or stationnary choppers with disc or drum, as well as hammer mills appropriate to grind humid matter being studied. At the

Rezumat: În lucrare se prezintă tehnologia de obținere a peletelor și agripetelor din cadrul INMA București unde s-a urmărit determinarea caracteristicilor combustibilității produselor obținute prin tehnologia de fabricare a peletelor și agripetelor din biomasa solidă agricolă și forestieră. În vederea identificării celor mai bune rețete. Astfel au fost preluate un număr de 13 probe pentru analize, în diferite amestecuri (rețete), iar eșantioanele de probe din biomassă au fost supuse analizelor de laborator specifice combustibilității solzi în vederea stabilirii principalelor caracteristici, care să permită alegerea celor mai bune rețete din punct de vedere al combustibilității.

Cuvinte cheie: biomasa, agripellete, tehnologie, energie, putere calorlică, rețete de amestec

INTRODUCERE

Biomasa exprimă totalitatea producției agricole vegetale care poate fi convertită în diferite forme de energie.Producția agricolă este formată din producția principală și din producția secundară.

Producția agricolă principală este trasformată în energie bioalimentară iar producția agricolă vegetală secundară constituie principala sursă de biomassă care poate fi transformată de regulă în energie termică [4].

Conform legislației Uniunii Europene, biomasa reprezintă fracția biodegradabilă a produselor și deșeurilor din agricultură, domeniul forestier și industriile conexe acestora, precum și fracția biodegradabilă din deșeurile municipale și cele industriale.

Compoziția chimică principală a biomasei este:
- lignină (C_{6}H_{10}O_{5}) = 15 – 30 %;
- celuloză (C_{6}H_{10}O_{5}) = 20-45 %;
- hemi-celuloză = 20-35 %.

Limitele de variație a celor trei componente principale sunt determinate de specie. Polimerii celuliozei lungi sunt folositii de către plante pentru a construi fibrele care conferă plantei soliditate iar lignina acționează ca un liant ce ține fibrele de celuloză legate [2]. Pentru fabricarea peleților conținutul de lignină trebuie să fie cât mai mare.Pentru o putere calorlică ridicată este necesar ca rapoartele O/C și H/C să fie cât mai mici [1].

Principalele produse agricole secundare care pot fi transformate în energie termică sub formă de agripellete sunt [10], [11]:
- pâine și pleva de cereale păioase (grâu, secară, orz, orzocă, orez și ovăz);
- tulpinile și ciocălăii de porumb;
- tulpinile de floarea soarelui și de răpită;
- vreji de soia, mazăre și fasole;
- corzile de vită de vie;
- crengile de pomi fructiferi.

Fluxul de fabricație și distribuție la consumator, pentru producția și utilizarea de peleti sau brichetă (combustibilul ecologic regenerabil al viitorului), prezentat în figura 1 pomeneste de la biomasa vegetală ca materie primă și parcure 9 faze până la distribuirea și utilizarea acestor combustibili de către consumatorul final, [8].

Pentru pregătirea materialelor în fluxul tehnologic de fabricație a peleților sau de brichetelor se utilizează materiul numai sub formă de rumeșug sau tocătură de biomassă agricolă, studiindu-se toate tipurile de tocători cu disc sau cu tambur, mobile sau staționare, precum și morile cu ciclone specifice pentru măcinarea materialelor umede, în vederea obținerii granulației necesare pentru utilizarea materialelor în fluxul de fabricație. De asemenea au fost studiate și
same time, rotative sieves and sorters designed not only to sort but also to remove wastes tree bark, wood and non-wood pieces present in forestry or agricultural biomass, have been studied for obtaining a clean matter chopped without impurities [5].

Fig. 1 – Technological flow for producing and distributing pellets / Fluxul tehnologic de fabricație și distribuție a peleților –

**MATERIAL AND METHOD**

For achieving pellets and agripellets, a technological line designed and performed within INMA Bucharest has been used. It comprises:

- pelleting equipment;
- dimension sorter;
- belt conveyor;
- tilted conveyor with belt and dryer;
- hopper.

By means of pelleting equipment with rotating matrix, pellets/agripellets can be achieved from agricultural and forestry solid biomass, their length being able to be adjusted within 10-30mm by means of adjustable knives.

Pelleting equipment (fig. 2) takes the material from dimensional sorter and produces pellets of 6-8 mm diameter, depending on their composition.

**Dimensional sorter** (fig. 3), is used to sort wood granulous materials and vegetal wastes by two dimensional fractions and to remove the wastes (trees bark, wood and non-wood pieces).

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Fig. 3 – Dimensional sorting equipment / Sortator dimensional SD 2630
1 - frame / cadru; 2 - circular sieve / sită circulară; 3 - feeder hopper / pâlnie alimentare; 4 – evacuating funnel / pâlnie de evacuare; 5 - refusal funnel / pâlnia de evacuare refuzuri; 6 – separating wall / perete despărțitor; 7 – cleaning system / sistem de curățat; 8 – support plate / placă suport; 9 - strainer / întinzător; 10 - wheel / roată I; 11 - wheel / roată II; 12 – evacuating funnel / pâlnie de evacuare; 13 – gearmotor assembly / ansamblu motoreductor; 14 – sorting axle sleeve / manșon ax sortator; 15 – electric installation / instalație electrică

Belt conveyer TB 240 (fig. 4) is an equipment designed to transport of agricultural and forestry biomass chopped and sorted by size (or other similar materials in terms of size, density, specific weight and close friction coefficient), in buffer hoppers (for briquetting or pelleting operation) as well as, directly into feeding hopper of pelleting press or briquettes press.

Technological equipment designed to transport biomass chopped to other technological equipment of technological flow of manufacturing pellets/agripellets and assure biomass drying is represented by tilted conveyor with belt and dryer – TIBU (fig. 5).

Integrated technology of obtaining pellets and agripellets is shown in figure 6.

Fig. 4 – Belt conveyor TB-240 / Transportor cu bandă TB - 240
1 - Transporting assembly / ansamblu transportor; 2 – frame assembly / ansamblu cadru; 3 – feeding hopper / buncărul de alimentare; 4 - control panel / panou de comandă; 5 - frame / cadru; 6, 7 – driving pulley / role de antrenare; 8, 9 - bearings / lagăre; 10 – magnetic separator / separator magnetic; 11 – transport belt / bandă transportoare; 12 - gearmotor / motoreductor; 13 - handles / mantinele; 14 - belt supporting assembly / ansamblu susținere bandă; 15 – hooking element / elementul de prindere; 16 – special screw / șurub special; 17 - antirotation plate / placă antirotire

Fig. 5 - Tilted conveyor with belt and dryer TIBU-0 / Transportor înclinat cu bandă și uscător TIBU-0
1 - Transport assembly TIBU / ansamblu transportor TIBU; 2 – frame assembly / ansamblu cadru; 3 – hopper assembly / ansamblu buncăr; 4 - control panel / panou de comandă
In general, a classical/alternative solid fuel, including biomass is made of:
- organic mass;
- anorganic mass;
- water/humidity (Wt).

Water/humidity (Wt) and anorganic (mineral) mass represent the non-fuel ballast formed by ashes and worsen the energetic quality.

Organic mass (C, H, N, S, O) represents the most important part of a solid fuel, as it has the features and characteristics necessary for being used for energetic valorisation, constituting also the combustion mass.

Chemical characteristics of solid fuels obtained from biomass are the following:
- C content – important characteristic which influences the caloric power must be as high as possible;
- O content – important characteristic which influences the caloric power must be as low as possible;
- H content – important characteristic which influences the caloric power must be as high as possible;
- N content – influences NOx (toxic) emissions and corrosion.

Limit humidity of biomass for combustion should not surpass 60% out of mass.

Total humidity, Wt, is formed of:
- Absorbing humidity - Wf, free or superficial (of surface) from large capillaris, which has a normal vapour pressure and is easily removable by simple storing by air;
- Hygroscopic humidity - Wc, represents water physically bound from pores internal structure, which has smaller vapours pressure than normal one and is released only by drying at over 100°C (respectively 105°C), [6].

Caloric power can be calculated according to chemical composition. Calculation formulae for caloric power, [9]:
1) depending on lignin content, where, (LC) - content of lignin reported to dry state without ashes:
\[ Q = 88,9 \text{ (LC)} + 16821,8 \text{ [kJ/kg]} \]  
(1)
2) depending on fix carbon content, Cf (%) where:
\[ Q = 196 \text{ Cf} + 14119 \text{ [kJ/kg]} \]  
(2)
3) depending on carbon, hydrogen, oxygen and nitrogen content:
\[ Q = 33500 \text{ C} + 14300 \text{ H} - 15400 \text{ O} - 14500 \text{ N} \text{ [kJ/kg]} \]  
(3)

For performing the determinations, was used an equipment "ELEMENTAL ANALYZER Flash EA 1112" which allows to simultaneously determine C, H, S, N, from

In general, a combustible solid classic/alternative, inclusive biomass, is format din:
- masa organică;
- masa anorganică;
- apa/ umiditatea (Wt).

Apa/umiditatea (Wt) and masa anorganică (minerală) reprezintă balastul necombustibil care formează cenușa și care înrăutățește calitatea energetică. Masa organică (C, H, N, S, O) reprezintă parteza cea mai importantă a unui combustibil solid, deoarece este răspunsatoare de proprietățile și caracteristicile ce o recomandă pentru a fi utilizată în scopul valorificării energetice constituiind și masa combustibilă.

Caracteristicile chimice ale combustibilor solizi obținuți din biomasa sunt următoarele:
- conținutul de C – caracteristică importantă care influențează puterea calorifică, trebuie să fie cât mai mare;
- conținutul de O – caracteristică importantă care influențează puterea calorifică, trebuie să fie cât mai mic;
- conținutul de H – caracteristică importantă care influențează puterea calorifică, trebuie să fie cât mai mare;
- conținutul de N – influențează emisiile de NOx (toxice) și corozionarea.

Umiditatea limită a biomasei pentru susținerea arderii nu trebuie să depășească 60% din masa.

Umiditatea totală, Wt, este constituind din:
- umiditatea de îmbibăție - Wf, liberă sau superficială (de suprafață) din capilarele largi, care are presiunea de vapori normală și se îndepărtează destul de ușor prin simpă depozitare în aer;
- umiditatea higroscopică - Wc, reprezintă apa legată fizic din structura internă a porilor, are presiunea de vapori mai mică decât presiunea normală și este cedată numai prin uscare la temperatura de peste 100°C (respectiv 105°C), [6].

Puterea calorifică poate fi calculată în funcție de compoziția chimică.

Formule de calcul pentru puterea calorifică, [9]:
1) în funcție de conținutul de lignină în care, (LC) - conținutul de lignină raportat la starea uscată și lipsită de cenușă:
2) în funcție de conținutul de carbon fix, Cf (%)
3) în funcție de conținutul de carbon, hidrogen, oxigen și azot;

Pentru realizarea determinărilor, a fost utilizat un echipament "ANALIZOR ELEMENTAL Flash EA 1112" care permite determinarea simultană a C, H, S, N, din
solid and liquid tests by sample instantaneously dynamic combustion, followed by reduction, capitation and separation of chromatographic gas and detection by means of thermal conductivity detector (TCD). Analyzer and its characteristics are shown in figure 7.

**RESULTS**

In order to determine the combustibility characteristics of products obtained from manufacturing technology pellets and agripellets from agricultural and forestry solid biomass, were taken for analysis a number of 13 samples in various mixtures / compositions (recipes):

- sample 1: 67% Forestry remnants + 33% Wood chips;
- sample 2: 80% Miscanthus + 20% Wood chips;
- sample 3: /3 Forestry remnants + /3 Stalks + /3 Wood chips;
- sample 4: /3 Forestry remnants + /3 Miscanthus + /3 Wood chips;
- sample 5: /3 Forestry remnants + /3 Straw + /3 Wood chips;
- sample 6: 100% Stalks;
- sample 7: 100% Straw;
- sample 8: 100% Miscanthus;
- sample 9: 100% Fir wood chips;
- sample 10: 100% Forestry remnants;
- sample 11: /3 Miscanthus + /3 Forestry remnants + /3 Wood chips;
- sample 12: 50% Forestry remnants +50% fir;

**REZULTATE**

În scopul determinării caracteristicilor combustibilităţii produselor obţinute prin tehnologia de fabricare a peleţilor şi agripelletelor din biomasa solidă agricolă şi forestieră, au fost preluate pentru analiză un număr de 13 probe în diferite amestecuri/compozitii (rețete):

- proba 1: 67% Resturi forezere + 33% Talas;
- proba 2: 80% Miscanţu + 20% Talas;
- proba 3: /3 Resturi forezere + /3 Cocieni + /3 Talas;
- proba 4: /3 Resturi forezere + /3 Miscanţu + /3 Talas;
- proba 5: /3 Resturi forezere + /3 Paie + /3 Talas;
- proba 6: 100% Cocieni;
- proba 7: 100% Paie;
- proba 8: 100% Miscanţu;
- proba 9: 100% Talas brad;
- proba 10: 100% Resturi forezere;
- proba 11: /3 Miscanţu + /3 Resturi forezere + /3 Talas;
- proba 12: 50% Resturi forezere+50%Talas;
- proba 13: /3 Miscanţu + /3 Resturi forezere + /3 Talas.

Eșantioanele de probe (biomașă) au fost supuse analizelor de laborator specifice combustibililor solizi în vederea stabilirii principalelor caracteristici:

- prin analiza tehnică s-a determinat umiditatea (W₁, W₂, W₃), și cenușa (A₁);
- prin analiza elementară s-a determinat continutul procentual de C, H, S, N cu ajutorul unui analizor elemental FLASH EA 1112 Thermo Fisher Scientific (Model 1112). Oxigen content determination (O) at initial state is calculated using the following relationship:

\[
O = 100 - (W₁ + A₁ + C₁ + H₁ + S₁ + N₁) \text{ [%]} \quad (4)
\]

- determinarea puterii calorice superioare (O₁) s-a realizat prin utilizarea unui sistem calorimetric format din caloriometru Parr Model 6200 cu bomba model 1108;
- puterea calorifică inferioră (O₁) se obține prin calcul function de umiditatea totală (W₁) si continutul de hidrogen din proba supusa determinării, conform formulei:

\[
Q_{\text{inf}} = Q_{\text{sup}} - \gamma(8.94H + W₁) \text{ [kcal/kg; KJ/kg]} \quad (5)
\]

unde:

\[
\gamma = 5.86, \text{ la exprimarea rezultatelor analizei [kcal/kg]};
\gamma = 24.62, \text{la exprimarea rezultatelor analizei [KJ/kg]};
8.94 - cantitatea de apă [g], corespunzătoare la 1 g hidrogen.
\]

Metodele de analiza utilizate în incercările analitice efectuate pentru indicatorii urmăriți (standarde române și metode ISO) sunt prezentate în tabelul 1.
Table 1 / Tabelul 1

Analysis methods / Metode de analiza [3].

<table>
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<tbody>
<tr>
<td>1.</td>
<td>Absorbing humidity / Umiditate de îmbibăție</td>
<td>SR 5264:1995</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Total humidity / Umiditate totală</td>
<td>SR 5264:1995</td>
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Elementary analysis / Analiza elementară

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<tr>
<td>5.</td>
<td>Carbon / Carbon</td>
<td>ASTM D 5373-08</td>
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<tr>
<td>6.</td>
<td>Hydrogen / Hidrogen</td>
<td>ASTM D 5373-08</td>
</tr>
<tr>
<td>7.</td>
<td>Nitrogen / Azot</td>
<td>ASTM D 5373-08</td>
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</tbody>
</table>

Determining superior and inferior calorific power / Determinarea puterii calorifice superioară și inferioară

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<tbody>
<tr>
<td>10.</td>
<td>Inferior calorific power (calculation) / Putere calorifică inferioară (calcul)</td>
<td>ISO 1928:2009</td>
</tr>
<tr>
<td>11.</td>
<td>Processing results (recalculation in different states of analysis: initial) / Prelucrarea rezultatelor (recalcularea rezultatelor la diferite stări de analiză: iniţial)</td>
<td>ISO 1170:2008 STAS 398/82</td>
</tr>
</tbody>
</table>

Analytical test results for samples subjected to analysis and recalculated in accordance with standard STAS 398/82 at initial state of the fuel biomass are shown in Table 2 and figures 8, 9, 10 and 11.

Rezultatele încercarilor analitice pentru probele supuse analizei și recalculate în conformitate cu standardul STAS 398/82 la starea inițială a combustibilului de biomă sunt prezentate în tabelul 2 și figuri 8, 9, 10 și 11.

Table 2 / Tabelul 2

Analytical results for analyzed samples / Rezultatele analitice pentru probele analizate

<table>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>4.55</td>
<td>16.24</td>
<td>20.79</td>
<td>2.33</td>
<td>0.039</td>
<td>42.60</td>
<td>5.54</td>
<td>0.42</td>
<td>28.29</td>
<td>4152</td>
<td>3740</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>6.25</td>
<td>10.79</td>
<td>17.04</td>
<td>1.32</td>
<td>0.049</td>
<td>42.70</td>
<td>5.56</td>
<td>0.57</td>
<td>32.76</td>
<td>4164</td>
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</tr>
<tr>
<td>3.</td>
<td>0.00</td>
<td>11.64</td>
<td>11.64</td>
<td>2.98</td>
<td>0.043</td>
<td>43.88</td>
<td>5.74</td>
<td>0.58</td>
<td>35.14</td>
<td>4395</td>
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<tr>
<td>4.</td>
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<td>11.77</td>
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<td>44.66</td>
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<td>10.72</td>
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<td>42.69</td>
<td>5.56</td>
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<td>10.38</td>
<td>5.76</td>
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<td>40.67</td>
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<tr>
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<td>9.57</td>
<td>7.78</td>
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<td>40.20</td>
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<td>8.</td>
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<td>11.17</td>
<td>6.89</td>
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<td>6.60</td>
<td>1.61</td>
<td>0.039</td>
<td>46.11</td>
<td>6.39</td>
<td>1.10</td>
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<td>3981</td>
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<td>10.</td>
<td>1.95</td>
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<td>6.09</td>
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<td>7.19</td>
<td>7.19</td>
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<td>5.08</td>
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<tr>
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<td>5.26</td>
<td>5.26</td>
<td>3.47</td>
<td>0.043</td>
<td>45.94</td>
<td>5.81</td>
<td>0.38</td>
<td>39.10</td>
<td>4309</td>
<td>3974</td>
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</tr>
</tbody>
</table>

Fig. 8 - Graphical representation of inferior calorific power value for samples 1-8 / Reprezentarea grafică a valorilor puterii calorifice inferioare pentru probele 1-8

Fig. 9 - Graphical representation of total humidity value for samples 1-8 / Reprezentarea grafică a valorilor umidității totale pentru probele 1-8
CONCLUSIONS
Following the laboratory tests it has been found that:
- For agricultural and forestry biomass samples: 1-8:
  - absorbing humidity content (superficial) is very low (for samples 3-8 is zero);
  - total moisture of the analyzed samples is mainly due to hygroscopic humidity;
  - ash content is reduced ranging from 1÷7%;
  - sulfur content is very low (< 0.1%);
  - carbon is situated at values of about 44%;
  - inferior calorific power is situated at a value of 3,600÷4,000 kcal/kg and is inversely proportional with total humidity content (W); for the analyzed samples; as the total humidity is lower, the inferior calorific power is bigger;
  - determinations on inferior calorific power revealed values of about 4,000 kcal/kg for samples 3, 4 and 5 consisting of basis mixture (forestry remnants and wood chips) at which were added various types of vegetable biomass (straw, stalks and miscanthus);
  - from the point of view of superior calorific power it has shown that the values obtained for the analyzed agricultural ground biomass variants (4,004÷4,395 kcal/kg) are bigger than those given in the literature data (ex.: vegetable waste - Table 3: Qs = 3.009.5 kcal/kg).
- For agricultural and forestry biomass samples: 9-13:
  - It has noted that the carbon content is maintained at a value of about 45%);
  - inferior calorific power is situated at a value of about 3,900 kcal/kg, respectively 16.33 MJ/kg;
  - from the point of view of superior calorific power it has found that the values obtained for the variants of analyzed pellets (4.163÷4.354 kcal/kg) are comparable to those presented in the literature data (example: sawdust pellets - Tabel 3: Qs = 4.084.3 kcal/kg).

Acknowledgement
This work was supported by CNCSIS –UEFISCDI, project number PN 09 – 15 01 09.

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CONSIDERATIONS ABOUT DESIGNING OF AN AIR COOLED CYLINDER HEAD FOR A DIRECT INJECTION SMALL DIESEL ENGINE

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INTRODUCTION

The cylinder head is designed for direct injection Diesel engines, which include mono and poly-cylinder engines, we proposed the solution with inlet and outlet channels placed on the same side of the cylinder head. For this reason, the injector should be placed between the rocker arms, which brings the advantage of shortening the injection pipe. Also, this solution provides a large surface design of the cooling air reception, and the thermal regime of the injector is much better controlled than in other types of air-cooled cylinder heads [1, 2, 3, 5, 6]., because the injector is not in contact with a wall of the hot channel. In Table 1 are presented the main features of the engine cylinder head designed.

For the 5.5 bar BMEP value, we got in our combustion code simulations the evolution of pressure, temperature and apparent heat release, as shown in figure 1. In the figure 2 we showed, in the same conditions, the evolution of apparent heat release and cumulative heat release.

Abstract: When designing a cylinder head for two families of stationary Diesel air cooled, engines, with direct injection, we have to consider the BMEP, which is limited to these engines to values of 3.8-5.2 bar. To optimize gases exchange process and obtain a desired swirl number, different solutions are studied: geometry galleries, speed location of valves and gas fields concentrations developed in the combustion process for each proposed solution. The paper presents the optimal solution found in the functional analysis made for a program FLUENT single cylinder engine and one engine family bi-cylinder, looking at for each case of cooling air flow. Another aspect to be taken into account when designing the cylinder heads is to determine the thermal regimes of the cylinder head, piston, cylinder, valves and nozzle, in order to define the development of heat per work engine cycle. From our experience in designing and testing stationary air cooled engines and developing of injectors and new combustion chambers, a combustion code, written in C++, simulates the heat release rate per cycle, also serving to define data used to determine required heat transfer. The objectives of this paper are to define optimum construction solutions for a cylinder head for air-cooled Diesel engine with direct injection, having the stroke of 65 and 82 mm bore.

Keywords: cylinder head, analysis, heat release, direct injection, nozzle

Rezumat: Când se proiectează o chiulă pentru două familii de motoare Diesel, răcite cu aer, cu injecție directă, trebuie luată în considerare problema presiunii medii efective, care este limitată la aceste motoare la valori de 3,8 – 5,2 bar. Pentru optimizarea proceselor de schimb de gaze și obținerea numărului de vârtej dorit au fost studiate soluții diferite pentru: geometria galeriilor, vitezele de ridicare ale supelor și câmpurile concentrațiilor de gaze dezvoltate în procesul de ardere pentru fiecare soluție propusă. Lucrarea prezintă soluția optimă găsită prin analize funcționale, realizate în FLUENT, pentru motorul monocilindric și pentru o familie de motoare cu doi cilindri, verificând în fiecare caz curgerea aerului pentru răcire. Un alt aspect de care trebuie să se țină cont când se proiectează chiuletele este legat de determinarea regimurilor termice ale chiuleșilor, pistoanelor, cilindrilor, supelor și pulverizatorului, pentru a defini dezvoltarea căldurii pe ciclu al motorului.O rutină pentru modelarea procesului de ardere, scrisă în C++, a fost folosită pentru a simulă viteză de degajare a căldurii pe ciclu, servind de asemenea pentru a defini datele necesare evaluării transferului termic, pornind de la experiența noastră în proiectarea și încercările motoarelor răcite cu aer și în dezvoltarea de injectoare și noi camere de ardere. Obiectivele acestei lucrări sunt definirea soluțiilor constructive optime pentru chiulă unui motor răcit cu aer, cu injecție directă, având cursa de 65 mm și aleazul de 82 mm.

Cuvinte cheie: chiulă, analiză, degajarea de căldură, injecție directă, pulverizator

INTRODUCERE

Chiulasa este proiectată pentru motoare Diesel cu injecție directă, care include motoare mono și poli­cilindrice, noi propunem o soluție cu canalele de admisie și evacuare plasate pe aceeași față a chiulasei. Din acest motiv, injectorul trebuie plasat între culbutori, ceea ce aduce avantajul scurtării conductei de in­jecție. De asemenea, această soluție asigură o suprafată mare pentru răcirea cu aer și regimul termic al injectorului este mult mai bine controlat decât la alte tipuri de chiulese răcite cu aer [1, 2, 3, 5, 6], pentru că injectorul nu este în contact cu peretele canali­ului fierbinte. În Tabelul 1 sunt prezentate caracteristicile principale ale chiulasei proiectate.

Pentru o valoare dorită de 5,5 bar a presiunii medii efective, în figura 1 sunt prezentate, folosind rutina proprie de ardere, evoluțiile presiunii, temperaturii și degajării aparente de căldură. În figura 2 sunt arătate, în același condiții, evoluțiile degajării aparente de căldură și degajării de căldură cumulată.

<table>
<thead>
<tr>
<th>Engine specification / Caracteristicile motorului</th>
<th>19,2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore / Aleaj [mm]</td>
<td>82</td>
</tr>
<tr>
<td>Stroke / Cursa [mm]</td>
<td>65</td>
</tr>
<tr>
<td>Compression ratio / Raport de comprimare</td>
<td>343</td>
</tr>
<tr>
<td>Displacement volume / Cilindree [cm³]</td>
<td>3000</td>
</tr>
<tr>
<td>Engine speed / Turatie [min⁻¹]</td>
<td>5,5</td>
</tr>
<tr>
<td>BMEP / Presiune medie efectivă [bar]</td>
<td>5,5</td>
</tr>
</tbody>
</table>

Table 1 / Tabelul 1
The momentary above piston cylinder volume is given by equation (2) where B is bore and \( V_c \) is combustion chamber volume:

To characterize the evolution of volume in cylinder available we established the movement of the piston from top dead center (TDC), as can be seen in equation (1):

Where.

- \( S(\alpha) \) – distance crossed of piston TDC;
- \( r \) – crank radius;
- \( \ell_b = \frac{l_b}{r} \)
- \( l_b \) - connecting rod length;
- \( \alpha \) – crank angle.

In figure 3 is showed the momentary above piston cylinder volume evolution.

\[
S(\alpha) = r \left[ 1 + \ell_b - \cos(\alpha) - \sqrt{\ell_b^2 - \sin^2(\alpha)} \right]
\]

(1)

Volumul instantaneu de deasupra pistonului este dat de ecuația (2) în care \( B \) este alezajul iar \( V_c \) este volumul camerei de ardere:

Pentru a caracteriza evoluția volumului din cilindrul disponibil am stabilit ecuația de mișcare a pistonului pornind din punctul mort superior (PMS), așa cum se poate vedea în ecuația (1):

Unde.

- \( S(\alpha) \) – distanța parcursă de piston pornind din PMS;
- \( r \) – raza manivelei;
- \( \ell_b = \frac{l_b}{r} \)
- \( l_b \) - lungimea bielei;
- \( \alpha \) – unghiul de rotație al arborelui cotit.

\[
V_{\text{cv}}(\alpha) = \frac{\pi B^2}{4} S(\alpha) + V_c
\]

(2)

În figura 3 este prezentată evoluția volumului instantaneu de deasupra capului pistonului.
In order to determine the gases temperature in the compression stage we used equation (3), where:

- \( \mu_r \) - residual gas fraction;
- \( \gamma \) - adiabatic exponent of real gas \( \frac{c_p}{c_v} \);
- \( p_e \) - exhaust absolute pressure;
- \( p_i \) - intake absolute pressure;
- \( T_i \) - intake absolute temperature.

\[
T(\alpha) = \frac{1-\mu_r}{1-\frac{1}{\gamma} p_e + (\gamma - 1)} p_i T_i
\]

Temperature instantanee in timpul fazei de ardere este estimat\'ă cu rela\'ţia (4):

\[
T(\alpha) = \frac{\rho(\alpha) \cdot V(\alpha)}{\frac{8315}{M}(m_{\alpha} + m_{\omega_\alpha} + m_{\omega_\alpha})}
\]

To validate the heat transfer coefficient of the combustion chamber we applied Woschni correlation (4)[4], where:

- B –cylinder bore;
- P – average gases pressure;
- T – gases temperature;
- W- average of gases velocity.

The average heat coefficient is shown in figure 4.

To analyze the gas flow channels and the determination of temperature and thermal stress we used the cylinder head designing in CATIA V5, as shown in figure 5.

RESULTS
Analysis of flow through inlet

To analyze the flow we generated in CATIA V5 the inlet channel, located trough cylinder head, with a length equal of 1.75 out of its diameter, just like at the test bench used to determine the average swirl number. Flow simulation program was done in FLUENT and initial flow conditions are: for input \( P = 101325 \text{ [Pa]} \), \( T = 293 \text{ K} \), for output \( P = 98973.3275 \text{ Pa} \), \( T = 293 \text{ K} \). The results after generating tetrahedral mesh of 1mm side and 563008 elements, can be seen in fig.6. Air intake occurs at the bottom of the cylinder to the depression of 0.025 MPa.
The duct was placed above the cylinder just like in the cylinder head geometry. Inlet valve could be moved like in table 2, where: $H_v$ – lift of valve, $D_v$ – diameter of the intake channel. $D_v=28$ mm.

Canalul a fost plasat deasupra cilindrului chiar în geometria definită a chiulasei. Mișcarea supapei de admisie este corespunzătoare mărimilor din tabelul 2, unde: $H_v$ – ridicarea supapei, $D_v$ – diametrul canalului de admisie, $D_v=28$ mm.
Fig. 6 – Finite element mesh for inlet geometry generated for FLUENT analysis / Rețeaua de elementele finite a geometriei canalului pentru analiza în FLUENT

Table 2 / Tabelul 2

<table>
<thead>
<tr>
<th>No.</th>
<th>$H_v/D_v$</th>
<th>$H_v$ [mm]</th>
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<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.04</td>
<td>1.12</td>
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<td>3</td>
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</tr>
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<td>4</td>
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<td>3.36</td>
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<td>5</td>
<td>0.16</td>
<td>4.48</td>
</tr>
<tr>
<td>6</td>
<td>0.2</td>
<td>5.6</td>
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<td>6.72</td>
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<tr>
<td>8</td>
<td>0.28</td>
<td>7.84</td>
</tr>
</tbody>
</table>

Fig. 7 – Flow simulation for $H_v=1.12$ mm / Simularea curgerii pentru $H_v=1.12$ mm

In the figure 7 is shown the flow for $H_v=1.12$ mm and in the figure 8 is shown the flow for $H_v=4.48$ mm. In figure 9 we can see the pressure field for described flow conditions.
Stress analysis generated by thermo-mechanical fields

The stress type is used by means of thermal analysis DC3D10 coding. This is a typical thermal analysis. They are tetrahedral elements with 2 up to 10 nodes. Thermal analysis was run with the idea of obtaining the temperature field defined by structure analysis. The thermal field was loaded over static analysis. For static analysis we used two-order tetrahedral elements with 10 nodes. Coding element in ABAQUS is C3D10. The analysis of static stress field was obtained on the structure analyzed.

Number of elements in the analysis: 262,509
Number of nodes in the analysis: 451,281

Based on heat transfer coefficient we obtained the plot temperature and stress distribution, which can be seen in figure 10. Plot stress and temperature distribution for inlet can be seen in figure 11, and for exhaust duct is presented in figure 12.

Analisă solicitărilor generate de câmpurile termo-mecanice

Tipurile respective de solicitări sunt folosite utilizând rutine de tipul DC3D10. Este a analiză termică specifică. Sunt elemente tetraedrale cu 2 până la 10 noduri. Analiza termică a fost rulată în ideea de a obține câmpul de temperatură definit din condițiile structurale. Câmpul de temperatură a fost încărcat în condițiile unei analize statice. Pentru analiza statică am utilizat tetraedre de ordinul 2 cu 10 noduri. Codare elementelor în ABAQUS este DC3D10. Analiza solicitării statice a fost obținută pe strucutra analizată.

Numărul de elemente din analiză a fost de 262509
Numărul de noduri a fost 451281

Pe baza coeficientului de transfer termic am obținut distribuția de temperatură și a solicitărilor care se poate vedea în figura 10. Distribuția de temperatură pentru canalul de admisie poate fi observată în figura 10 iar pentru canalul de evacuare este prezentată în figura 12.
CONCLUSIONS
1. Results presented in this work could be used as a preliminary step in a development of two families of Diesel engines, just in terms of the main parameters of the cylinder head and engine performances.
2. Our goal was to create a team to develop this project, about which specific issues such as fuel injection, combustion chamber, types of stress have not been published up to now.
3. Designated cylinder head can be an alternative for the

CONCLUZII
1. Rezultatele prezentate în această lucrare vor putea fi utilizate ca un pas preliminar în dezvoltarea a două familii de motoare Diesel, în ceea ce privește parametrii principali ai chilasei și performanțele motorului.
2. Obiectivul nostru a fost acela de a crea o echipă pentru dezvoltarea acestui proiect despre care nu au fost publicate până acum informații specifice despre in injectia de combustibil, camera de ardere, solicitări particulare.
3. Chiulasa proiectată poate fi o alternativă pentru
development of two families of direct injection Diesel stationary engines air cooled.

REFERENCES
BIO-BUTANOL – ALTERNATIVE FUEL FOR DIESEL ENGINE

BIO-BUTANOLUL – COMBUSTIBIL ALTERNATIV PENTRU MOTORUL DIESEL

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Abstract: The main goals of bio-alcohols use in Diesel engine are the reduction of pollution, greenhouse gas emissions and the replacement of the fossil fuels. The production of the bio-alcohols from plants based on sugar (cane and beet) and starch (cereals, sorghum and maize) will increase their prices, which will affect the living standard of the population, because these are the most commonly used. If bio-alcohol were obtained from waste cellulosic or synthetic waste, its use would represent an alternative solution of fuel for Diesel engine. From the primary alcohols used (bio-methanol, bio-butanol, bio-ethanol) the bio-butanol has the main advantage that it is most appropriate from the point of view of the properties of the Diesel fuel. This paper presents the results of experimental research carried on a Diesel engine with direct injection fuelled with Diesel-bio-butanol mixtures.

Keywords: alternative fuel, bio-alcohols, bio-butanol, Diesel engine, emissions.

INTRODUCTION

Given that the standard of living of the population increases continuously more and more rapidly due to advancement of technology an increase in global energy consumption has been produced. Basically, if the standard of living of the population increases also the consumption of natural resources such as fossil fuels will increase. To meet the growing needs of the population, oil and gas resources will be exhausted.

More rational use of such fossil fuels and alternative fuels are viable solutions for reducing the oil consumption. From alternative fuels, bio-alcohols represent viable solutions, because those can be obtained from biomass. Unlike Diesel fuel, bio-alcohol has a greater support, being a form of renewable energy, that can be produced from biomass; the energy being generated by a natural resource (sunlight), which is unlimited.

Research centres from universities and big companies are involved in serious theoretical and experimental research on bio-alcohol use as fuel for compression ignition engine, being investigated different methods of fuelling. From primary alcohols, bio-butanol has the advantage that shows properties close to those of Diesel fuel compared to others alcohols.

Bio-butanol proprieties comparative to Diesel fuel

Bio-butanol (tert-butyl alcohol) is made up of three methyl groups and one group of oxidril (\(\text{C}_4\text{H}_9\text{OH}\)). Because of its higher self-ignition resistance, the biobutanol (low cetane number, table 1) can’t be used in Diesel engine as single fuel without supplementary measures (the additive use or engine design changes). In order to use bio-butanol in compression ignition engine, this must be enriched with accelerators of organic nitrates type for reducing of the auto-ignition delay, or it can be use in addition with Diesel fuel, solutions that do not involve significant design changes to


Cuvinte cheie: combustibil alternativ, bio-alcool, bio-butanol, motor Diesel, emisii.

INTRODUCERE

Date fiind faptul că standardul de viaţă al populaţiei creşte în mod continuu din cauza avansării tehnologice a societăţii, consumul de energie la nivel global creşte, practic, dacă standardul de viaţă al populaţiei creşte şi consumul resurselor naturale va creşte alături de combustibilii de natură fosilă. Pentru a reduce consumul de energie de la nivel national este necesară o utilizare mai raţională a combustibililor alternativi, bio-alcoolii fiind combustibilele alternativi sau complementare, care nu pot să îmbina în ambianta globală…

Utilizarea mai raţională a combustibililor alternativi pentru reducerea consumului de peelă naturală, este o soluție care să reducă consumul de peelă naturală, fără a afecta performanțele motorului.

BIO-BUTANOLUL – COMBUSTIBIL ALTERNATIV PENTRU MOTORUL DIESEL

Cuvinte cheie: combustibil alternativ, bio-alcool, bio-butanol, motor Diesel, emisii.

INTRODUCERE

Dat fiind faptul că standardul de viaţă al populaţiei creşte în mod continuu din cauza avansării tot mai rapide a tehnicii s-a produs o intensificare a consumului energetic la nivel global. Practic, dacă standardul de viaţă al populaţiei creşte şi consumul resurselor naturale va creşte alături de combustibilii de natură fosilă. Pentru a satisface nevoile tot mai accentuate ale populaţiei, resursele de peelă şi gaze naturale se vor epuiza.

Utilizarea mai raţională a combustibililor alternativi pentru reducerea consumului de peelă naturală, este o soluție cu o mare potențială, care să reducă consumul de peelă naturală, fără a afecta performanțele motorului fiind o soluție cu o mare potențială, care să reducă consumul de peelă naturală, fără a afecta performanțele motorului.

Centre de cercetare din universități și mari companii, sunt implicate în serioase cercetări teoretice și experimentale privind utilizarea bio-alcoolului drept combustibil pentru motorul Diesel, fiind investigate diferite metode de alimentare. Dintre alcoolii primari, bio-butanolul are avantajul că prezintă proprietăți mai apropiate de cele ale motorinei comparativ cu celelalte alcoole.

Proprietățile bio-butanolului comparativ cu motorina

Bio-butanolul (tert-butil alcoolul) este format din trei grupuri de metil și o grupare oxidril (\(\text{C}_4\text{H}_9\text{OH}\)).

Bio-butanolul având întârlire mare la autoapindere (cifră cetanici mai mică, tabelul I) face ca acesta să nu poată fi utilizat drept combustibil unic pentru motorul Diesel fără a se lua măsuri suplimentare, adăvitare sau modificări constructive ale motorului. Pentru ca bio-butanolul să poată fi utilizat la motorul cu aprindere prin comprimare trebuie fie adăvitat cu acceleratori de tipul nitrărilor organici pentru a reduce întârzierea la autoapindere, fie utilizat în amestec cu motorina, soluții ce nu implică
The main properties of bio-butanol compared to the Diesel fuel are shown in Table 1.

<table>
<thead>
<tr>
<th>Nr. crt.</th>
<th>Parameter / Parametru</th>
<th>Unit of measure / Unitatea de măsură</th>
<th>Bio-butanol / Bio-butanol</th>
<th>Diesel fuel / Motorină</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Chemical formula / Formula chimică</td>
<td>[-]</td>
<td>C₆H₁₃OH = C₆H₁₄</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Boiling temperature (1,013 bar) / Temperatura de fierbere (1,013 bar)</td>
<td>[°C]</td>
<td>82.8</td>
<td>180 .360</td>
</tr>
<tr>
<td>3</td>
<td>Auto-ignition temperature / Temperatura de autoaprindeare</td>
<td>[°C]</td>
<td>340</td>
<td>≈ 250</td>
</tr>
<tr>
<td>4</td>
<td>Flame temperature / Temperatura flăcării</td>
<td>[°C]</td>
<td>2220</td>
<td>2054</td>
</tr>
<tr>
<td>5</td>
<td>Evaporation heat / Căldura de vaporizare</td>
<td>[kJ/kg]</td>
<td>595</td>
<td>251 .314</td>
</tr>
<tr>
<td>6</td>
<td>Low calorific power / Puterea calorifică inferioră</td>
<td>[kJ/kg]</td>
<td>32560</td>
<td>41855</td>
</tr>
<tr>
<td>7</td>
<td>Cetane number / Cifra cetanică</td>
<td>[-]</td>
<td>&lt;18</td>
<td>45 .55</td>
</tr>
<tr>
<td>8</td>
<td>Dynamic viscosity at 20 °C (1,013 bar) / Vâscozitatea dinamică la 20 °C (1,013 bar)</td>
<td>[mPa·s]</td>
<td>2.95</td>
<td>1.6 .6.8</td>
</tr>
<tr>
<td>9</td>
<td>Gravimetric composition / Compoziția gravimetrică</td>
<td>C [%]</td>
<td>64.86</td>
<td>≈ 86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>H [%]</td>
<td>13.5</td>
<td>≈ 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O</td>
<td>21.64</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Fuel air ratio / Raportul aer combustibil</td>
<td>[kg air/kg comb.]</td>
<td>11.1</td>
<td>14.5</td>
</tr>
<tr>
<td>11</td>
<td>Flash temperature / Temperatura de inflamabilitate</td>
<td>[°C]</td>
<td>34</td>
<td>50 .140</td>
</tr>
<tr>
<td>12</td>
<td>Density at 20 °C / Densiitate la 20 °C</td>
<td>[kg/m³]</td>
<td>810</td>
<td>820 .860</td>
</tr>
<tr>
<td>13</td>
<td>Specific heat at 20 °C (1,013 bar) / Căldura specifică la 20 °C (1,013 bar)</td>
<td>[kJ/kg·K]</td>
<td>2.3</td>
<td>1.9</td>
</tr>
</tbody>
</table>

An addition of 25% accelerator in alcohol leads to an auto-ignition delay similar to that of Diesel fuel, [3]. Difficult auto-ignition to use bio-butanol is accentuated by decreasing temperature trend due to the heat of higher vaporization higher of alcohols than Diesel fuel (heat of vaporization of bio-butanol being about 2 times higher than the vaporization of Diesel fuel produces an intense cooling effect).

Higher bio-butanol auto-ignition temperature involves measures to decrease the temperature in the cylinder such as increasing the compression ratio.

From primary alcohols, the bio-butanol has the most similar viscosity to that of the Diesel fuel and the higher miscibility, which recommends it as a good alternative fuel. However, the bio-butanol's viscosity is lower than Diesel fuel (this can dilute the oil) producing some of its adverse effects in the lubrication.

Adding bio-butanol in Diesel fuel decreases the mixture viscosity, which influences on angle of jet dispersion in terms of increasing, reduction of droplet diameter and decreasing of jet penetration. Another aspect is the influence of fluidity to low temperature, which can be improved by the addition of bio-butanol.

Also the use of bio-butanol as a fuel must be taken into account that for the same amount of energy stored in the fuel tank for bio-butanol will have a larger volume and weight compared to Diesel fuel due to lower calorific value of bio-butanol comparative to Diesel fuel.

From the special technical literature some results on the use of bio-butanol in Diesel engine using different methods are known.

In the paper [9] are presented some results of the experimental research on an engine with a single four-stroke cylinder of type Lister 1-9, at different loads using the blends method (10% iso-butanol, 20% iso-butanol, 30% iso-butanol, 40% iso-butanol) and finding that the blends are effective in increasing the compression ratio, unloading of the engine, and reducing the fuel consumption. However, the use of bio-butanol will have a larger volume and weight compared to Diesel fuel due to lower calorific value of bio-butanol comparative to Diesel fuel.
Experimental researches on combustion behaviour of biobutanol are presented in paper [15] using as fuelling method the blends method (8% biobutanol and 16% percentage by volume). Experimental tests were performed on a six-cylinder turbocharged engine with direct injection. The engine was subjected to the tests at three different loads while maintaining constant speed (1200 rev/min to 1500 rev/min). The results showed that to the use of biobutanol in blends with Diesel fuel, the fuel injection pressure diagrams are slightly delayed, and the auto-ignition delay increased. Also, a decrease of the maximum cycle pressure and of the in-cylinder gases temperature during the rapid combustion phase was obtained.

The research presented in the paper [14] investigates the mechanisms of formation of nitrogen monoxide, smoke and combustion noise produced during the warm start method using blends method. The results obtained at the use of blends: 30% bio-Diesel and Diesel fuel with 25% n-butanol are comparatively presented. The use of Diesel fuel in blends with n-butanol leads to a significantly reduction of exhaust gases opacity, but to a notably increase of NO emission.

In paper [17] the influence of bio-butanol mixed with Diesel fuel and bio-Diesel is analysed. The results showed that the addition of 20% n-butanol in a mixture of Diesel fuel and 20% bio-Diesel resulted in a slight increase in specific fuel consumption and thermal efficiency compared to Diesel fuel. The CO and HC emissions decreased, while NOx emissions remained almost unchanged at low engine loads and for high engine loads the NOx emission decreased. Also, the smoke opacity was reduced.

MATERIAL AND METHODS

The experimental researches were performed on a Diesel engine KS9 type - 1.5 dCi (maximum power 92 kW and maximum power engine speed 3900 rot/min) mounted on a test bed.

The stand for testing is equipped with Schenck E90 dyno for torque measurement, flowmeters for measurement of the air and fuel consumption, thermometers, for measurement of the supply air temperature, cooling liquid, exhaust gas, cooling system oil, manometer for pressure boost measurement, oil pressure lubrication system. For analyzing the exhaust gas was used an analyzer type AVL Dicom and an opacimeter type AVL Dicom 4000. In the engine’s cylinder was mounted a piezoelectric pressure transducer type AVL for monitoring the pressure. Also the stand includes a data acquisition system type AVL.

Experimental investigations have been carried out using a blend of 10% Diesel and 20% bio-butanol. Experimental investigations have been carried out in the load modes of 100% and 85% at the speed of 2000 rev/min. At the use of bio-butanol, the fuel cycle dose increased (bio-butanol-Diesel blend) in order to restore standard engine power. The injection timing was optimized in terms of NOx emissions and to limit the maximum in-cylinder pressure maintaining the standard engine power.

40% iso-butanol). Rezultatele experimentale au arătat: reducerea temperaturii de evacuare a gazelor, scăderea puterii eficace şi reducerea randamentului termic la utilizarea amestecurilor bio-butanol-motorină în diferite proporţii faţă de funcţionarea motorului doar cu motorina. De asemenea şi coeficientul de exces de aer s-a diminuat [9], iar consumul specific de combustibil efectiv a crescut la utilizarea izo-butanolului. Autorul limitează procentul de bio-butanol la 30%, constatând înrăutăţirea parametrilor energetici ai motorului analizați la procente mai mari, ca de exemplu 40%.


Cercetările prezentate şi în lucrarea [14] investeşte mecanisme de formare a monoxidului de azot, fumului şi zgomotului de ardere produs în timpul pornirii la cald utilizând metode amestecurilor (motorină cu 30% bio-Diesel şi motorină cu 25% n-butanol). La utilizarea n-butanolului în amestec cu motorina a s-redus semnificativ opacitatea gazelor de evacuare, dar a crescut în mod notabil, emisia de NO.

În lucrarea [17] este analizată influența bio-butanolului în amestec cu motorină şi bio-Diesel. Adăugarea de 20% n-butanol în amestecul de motorină şi 20% bio-Diesel a determinat o ușoară creștere a consumului specific de combustibil şi a randamentului termic comparativ cu motorina. Emisiile de CO şi HC a scăzut, iar emisia de NO, a rămas aproape neschimbată la sarcini mici ale motorului, iar la sarcini mari emisia de NO, a scăzut. De asemenea reducându-se şi opacitatea fumului.

MATERIALIȘ METODE

Cercetările experimentale s-au efectuat pe motorul Diesel tip K9K – 1.5 dci (puterea maximă 52 kW la turaţia de 1500 rot/min) montat pe un stand de încercări în laborator.

Standul de încercări este dotat cu frână Schenck E90 pentru măsurarea momentului motor, debitmetre pentru măsurarea consumurilor de aer şi combustibil, termometre, pentru măsurarea temperaturilor aerului de alimentare, lichidului de răcire, gazelor de evacuare, uleiurilor din sistemul de răcire, manometre pentru măsurarea presiunii de supraalimentare, presiunea uleiului din sistemul de ungere. Pentru analiza gazelor de evacuare s-a utilizat analizorul de gaze şi opacimetrul AVL Dicom 4000. În cilindru motorului a fost montat un traductor piezoelectric de presiune AVL pentru monitorizarea presiunii. De asemenea standul conţine şi un sistem de achiziţie de date AVL.

S-au efectuat măsurători, utilizând un amestec de motorină cu 10% respectiv 20% bio-butanol. Investigaţiile experimentale s-au efectuat la regimurile de sarcină 100% şi 85% la turaţia de 2000 rot/min. La utilizarea bio-butanolului s-a mărit doza de combustibil (amestec bio-butanol-motorină) pentru refacerea puterii motorului standard. Avansul la inieţie a fost optimizat din punct de vedere al emisiilor de NOx, şi al limitării presiunii maxime din cilindru menţinând puterea motorului standard.
RESULTS

The figures 3…12 present the results of the experimental investigations carried out.

Energy aspects

Figure 3 shows the pressure variation versus the crankshaft angle at the standard injection timing for engine operation at Diesel fuelling and optimized for Diesel fuel, 10% and 20% bio-butanol fuelling at full load, and in the figure 4 the variation of cycle maximum pressure versus the volume percentage of Diesel fuel replacement ($x_d$) at 100% ($\chi = 1$) load and 85% ($\chi = 0.85$) are shown. We find that the maximum pressure from the cycle decreased about 10% when is using 20% bio-butanol than Diesel fuel at full load with the optimized injection timing. This is due to bio-butanol, which has a cooling effect more intensely than Diesel fuel. Maximum pressure for 10% bio-butanol doesn't change compared to Diesel fuel, because the cooling effect of the bio-butanol is compensated from the better burning speed of the bio-butanol than Diesel fuel (fig. 3).

For the standard injection timing, the maximum pressure has small variations with the percentage of bio-butanol at 100% load because of the combustion improvement (fig. 4). By optimizing of the injection timing for the limitation of the emission of NOx level, the maximum pressure is reduced at the increase of the bio-butanol percentage at 100% load and for 85% load the maximum pressure is maintained constant.

Figure 5 shows the maximum rate pressure rise of variation versus bio-butanol percentage in blends with Diesel at different loads and speed of 2000 rev/min. The maximum rate pressure rise increases at the use of bio-butanol mixed with Diesel fuel than Diesel fuel, because the auto-ignition delay increases both for the full load and for the 85% load (fig. 5).

At the increase of the proportion of bio-butanol, increases the duration of injection because of a much lower calorific power value and lower density of bio-butanol comparative to Diesel fuel and decreases the combustion time duration due to the better bio-butanol's combustion properties (fig. 6). We notice that 20% bio-butanol mixed with Diesel fuel significantly influences the auto-ignition delay (increases compared with Diesel fuel), due to biobutanol's lower cetane number, which moves the combustion toward the detente being necessary the modification of the injection timing for optimizing the performance. The variation of the apparent heat release rate is kept approximately at the same level (fig. 6), but

REZULTATE

 În figurile 3…12 sunt prezentate rezultate ale investigațiilor experimentale efectuate.

Aspecte energetice

În figura 3 se prezintă variația presiunii în funcție de unghiul arborelui cotit pentru avansul la injecție standard la funcționarea motorului alimentat cu motorina și optimizat la funcționarea motorului alimentat cu motorină. 10% și 20% bio-butanol la sarcină totală, iar în figura 4 se prezintă variația presiunii maxime pe ciclu în funcție de procentul de substituție volumetric a motorinei ($x_d$) la sarcinile 100% ($\chi = 1$) și 85% ($\chi = 0.85$). Găsim că presiunea maximă pe ciclu scade cu circa 10% față de motorină, când este utilizat 20% bio-butanol la sarcină totală cu avans la injeție optimizat. Acest lucru se datorează bio-butanolului, care are un efect de răcire mai intens decât motorina. Presiunea maximă pentru 10% bio-butanol nu se modifică comparativ cu motorina, deoarece efectul de răcire al bio-butanolului este compensat de viteză de ardere mai bună a acestuia comparativ cu motorina (fig. 3).

Pentru avansul la injeție standard, presiunea maximă are variații reduse cu procentul de bio-butanol la sarcina de 100% datorită îmbunătățirii arderii (fig. 4). Prin optimizarea avansului la injeție pentru limitarea nivelului emisiilor de NOx, presiunea maximă se reduce cu creșterea procentului de bio-butanol la sarcină totală, iar la sarcina de 85% presiunea maximă se menține constantă.

În figura 5 este prezentată viteză maximă de creștere a presiunii cu procentul de bio-butanol din amestec la diferite sarcini și turatie de 2000 de rot/min. Viteză maximă de creștere a presiunii la utilizarea bio-butanolului în amestec cu motorina crește față de motorină, deoarece se mărește întârzierea la autoapridere atât pentru sarcina totală cât și pentru sarcina de 85% (fig. 5).

Totodată, la creșterea procentului de bio-butanol crește durata injecției datorită puterii calorifice inferioare și a densității mai mici a bio-butanolului comparativ cu motorina și scade durata în timp a arderii datorită proprietăților de ardere mai bune ale acestuia (fig. 6). Observăm că 20% biobutanol în amestec cu motorina influențează semnificativ întârzierea la autoapridere (crește comparativ cu motorina), datorită cifrei cetanice mai scăzute a biobutanolului, ceea ce deplasează arderea în destindere fiind necesară modificarea avansului la injeție pentru optimizarea performanțelor. Viteză maximă de decajare a căldurii se menține aproximativ la aceeași valoare, (fig. 6), dar la utilizarea...
when using bio-butanol, the combustion time being more reduced explains the increase of the maximum pressure and the rate of increment of pressure.

Regarding the cyclic variability (formula 1), coefficient of variation in maximum pressure at full load is 0.92% for the Diesel fuel (standard injection timing) and 0.69%, for 20% bio-butanol (optimized injection timing), while for the 85% load is 0.56 for Diesel fuel (standard injection timing) and 0.61% for 20% of bio-butanol (optimized injection timing), indicating a high stability of the combustion process.

\[ COV = \frac{\sigma}{\bar{x}} \times 100 \]  

where: \( COV \) represents the cyclic variability coefficient of the maximum pressure;  
\( \sigma \) – mean square deviation for max. pressure;  
\( \bar{x} \) – average for maximum pressure.

In figure 7 is presented maximum pressure in cylinder versus angle crankshaft for 150 cycles at the fuelling only with Diesel fuel or with 20% bio-butanol in mixture. 

For 20% bio-butanol in mixture, the cyclic dispersion is lower than the functioning with Diesel fuel. The angle of maximum pressure for 20% bio-butanol has a value between 9÷12 CA after TDC (Fig. 7).

Figure 8 presents the variation of the specific energetic consumption compared with the volumetric percentage of bio-butanol in the blend with Diesel fuel. Generally, the brake specific energetic consumption is reduced by the increasing of the bio-butanol percentage, due to improvement of the combustion (bio-butanol of bio-butanolului, durata arderii fiind mai redusă explică creşterea presiunii maxime și viteza de creştere a presiunii.

În ceea ce privește variabilitatea ciclică (formula 1), coeficientul de variație a presiunii maxime la sarcină totală este 0,92% pentru motorină (avans la injecția standard) și 0,69%, pentru 20% bio-butanol (avans la injecția optimizat), în timp ce pentru 85% sarcină este 0,56 pentru motorină (avans la injecția standard) și 0,61% pentru 20% bio-butanol (avans la injecția optimizat), indicând o stabilitate mare a procesului arderii.

\[ COV = \frac{\sigma}{\bar{x}} \times 100 \]  

unde: \( COV \) reprezintă coeficientul de variabilitate ciclică a presiunii maxime  
\( \sigma \) – abaterea medie pătratică a presiunii maxime;  
\( \bar{x} \) – media aritmetică a presiunii maxime.

In figura 7 este prezentată presiunea maximă din cilindru în funcție de unghiul de rotație al arborelui cotit al motorului.

În figura 8 este prezentată variația consumului specific energetic efectiv în raport cu procentul volumetric de bio-butanol din amestec. Se constată, în general, reducerea consumului specific energetic cu creșterea procentului de bio-butanol datorită îmbunătățirii arderii (vitează de ardere...
higher burning rate and a higher content of oxygen in biobutanol molecule). For the optimized injection timing, reducing the specific energetic consumption is more pronounced: at 20% bio-butanol, the reduction is about 5% at full load and about 6% at 85% load.

Pollution aspects
At 85% load to the optimized timing injection NOx emission level doesn’t change compared to the standard one. Also, at the same load, the emission of NOx level decreases against the full load regime, because of the decrease of the temperature from cylinder (fig. 9).

Figure 9 shows the variation of NOx emissions level by the percentage of biobutanol for the investigated regimes. It was found a reduction of NOx emissions level assured by optimization of the injection timing, which was reduced comparatively to the standard injection timing.

Regarding the emission of HC, it increases with the percentage of biobutanol possible because of the flame extinction at wall and in air-bio-butanol homogeneous mixture, which becomes relatively leaner (fig. 10).

The exhaust gas opacity variation with the biobutanol’s percentage at the investigated regimes is represented in fig. 11. Generally the exhaust gas opacity decreases with the biobutanol percentage increasing. At 85% load, the influence is reduced both for the standard injection timing and for the optimized injection timing, while for the 100% load at optimized injection timing there is a slightly increase than the standard injection timing at the biobutanol’s percentage increase, which can be due to a reduction of air excess coefficient.

It is found that CO2 emission level decreased at the biobutanol use comparing to Diesel fuel for an injection timing optimized at full load, possibly due to higher oxygen content of biobutanol molecule (the combustion has improved due to the higher burning rate of the bio-butanol and a con\n
mai bună și un conținut mai mare de oxigen în molecula de bio-butanol). Pentru avansul la injecție optimizat, reducerea consumului specific energetic este mai pronunțată: 20% bio-butanol, reducerea este de circa 5% la sarcină totală și de circa 6% la sarcina de 85%.

Aspecte de poluare
La sarcina de 85% la avansul optimizat emisia de NOx nu se modifică față de cel standard. De asemenea, la sarcina de 85% emisia de NOx scade față de regimul de sarcină totală, deoarece scade temperatura din cilindru (fig. 9).

În figura 9 este prezentată variația emisiei de NOx cu procentul de bio-butanol la regimurile investigate. Se constată o reducere a emisiilor de NOx prin optimizarea avansului la injecție care a fost redus față de avansul la injecție standard.

În ceea ce privește emisia de HC, aceasta crește cu procentul de bio-butanol, posibil din cauza stingerii flăcării la perete și în amestecul omogen aer-bio-butanol, care devine relativ sărac (fig. 10).

În figura 11 este reprezentată variația opacității fumului din gazele de evacuare cu procentul de bio-butanol la regimurile investigate. În general opacitatea gazelor de evacuare scade cu creșterea procentului de bio-butanol. La sarcina de 85% influența este redusă atât pentru avansul standard cât și pentru cel optimizat, iar pentru sarcina de 100% la avansul optimizat se constată o ușoară creștere față de avansul standard la creșterea procentului de bio-butanol, fapt care poate datora scăderii coeficientului de exces de aer.

Se constată că emisia de CO2 a scăzut la utilizarea bio-butanolului comparativ cu motorina pentru un avans la injecție optimizat la sarcină totală, posibil datorită conținutului mai ridicat de oxigen din moleculea de bio-butanol (arderea s-a îmbunătățit datorită vitezii de
butanol). At a load of 85% at an optimized timing injection, CO₂ emission level doesn’t change from standard injection timing (fig. 12).

CONCLUSIONS
Bio-butanol represents a viable alternative solution for its use as fuel for Diesel engine in order to reduce pollution and increase engine’s economy.

Experimental tests performed on a Diesel engine with direct injection revealed the influence of bio-butanol’s percentage from the mixture with Diesel fuel on the combustion, fuel consumption and pollution emissions. Compared with the results of standard engine at the operation of the engine with Diesel fuel mixture and 20% bio-butanol, the following conclusions can be presented:

• specific energetic consumption of the engine was reduced by about 5%;
• maximum pressure from the cylinder decreases with the increase of the bio-butanol’s percentage from the mixture, while the maximum rate pressure rise registers a slightly increase;
• gas opacity easy increases with biobutanol content in mixture with the Diesel fuel at the full load but slightly decreases at 85% load;
• NO₅ emission was significantly reduced by about 25% for example at full load at the operation with optimized injection timing;
• CO₂ emission was reduced by about 10% for full load;
• CO emission was below measurable limit for both Diesel and bio-butanol using.

The fuelling of the Diesel engine with Diesel fuel-bio-butanol blends represents a relatively easy method to apply without requiring major changes in the construction of the engine. Researches are required to establish the adjusting optimum parameters in order to obtain the best energetic performance and reduced pollution with maintaining or increasing power performance.

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INMATEH – Agricultural Engineering

REARECHES REGARDING THE USE OF LPG AT A DIESEL ENGINE

CERCETARI PRIVIND UTILIZAREA GPL LA MOTORUL CU APRINDERE PRIN COMPRIMARE


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Abstract: The need of fresh air breathing, especially in congested places and fuel price increasing led to new solutions for Diesel engine fuelling. The alternative fuels are a very good choice regarding pollutant emissions and price decreasing. This paper objective is to highlight comparative aspects between results obtained in the case of fuelling a Diesel engine with Diesel fuel and, respectively Diesel fuel and LPG, in order to be also used at agricultural tractors, either experimentally on test bed, or by thermodynamic processes modeling. The computer software used in this work is AVL Boost, a friendly and powerful environment, built by AVL Austria. The created model simulates a dual mode fuelling of a Diesel engine with Diesel fuel and LPG.

Keywords: Diesel, combustion, heat release law, pollutants, injection rate

INTRODUCTION

The reduced LPG price and its good behavior regarding pollutant emission made this fuel to be very attractive for study, either experimentally or by computer modeling. The development of engines in the last period requires interest for what is happening inside the cylinder and especially for the phenomena with the greatest complexity, the combustion. Many researchers applied engine cycle computing models, this models being calibrated with experimental methods. The engine processes computing started in 1950 with simple thermodynamic models [13], afterward appearing multi zone models in 1970 [13]. By using computer modeling precious time can be saved, test bed measurements requiring long time for equipment calibration and preparing and money, because the engine is turned off and the fuel is saved. By modeling can be investigated phenomena like: dual fuelling system influence, injection timing influence, engine speed influence, fuel cycle dose influence, supercharging pressure influence over pollutant emission and engine energetic performance etc. In the case of using LPG, as an alternative fuel which replaces a part of Diesel fuel, like in this work, can be showed its substitute ratio influence. A dual fuel system was studied by J. Barata in the paper [4], the author being interested about pollutant emissions in the case of propane fuelling. Important results were obtained, especially for the nitric oxides emissions level, which was lesser than standard engine emission for all the studied regimes and for unburned hydrocarbons reducing the EGR quantity increasing was necessary. Due to EGR increased quantity, the combustion become faster, because of the presence of radicals [3]. Another very important aspect for a Diesel engine is the combustion noise. This noise was studied first by Ricardo in 1931 [12], and a very tight connection between the combustion noise and the rate of pressure rise was discovered [12]. This fast rate of pressure rise creates a sound wave that

Rezumat: Nevoia de a respira un aer mai curat, mai ales în zonele aglomerate, precum și creșterea prețului combustibilului a condus la găsirea de noi soluții pentru alimentarea motorului Diesel. Combustibilii alternativi sunt o foarte bună alegere în ceea ce privește emisiile poluante și prețul. Obiectivul acestei lucrări este evidențierea unor aspecte comparative între rezultatele obținute în cazul alimentării motorului Diesel cu motorină, respectiv motorina și GPL, în vederea utilizării și la tractoarele agricole, atât experimental pe standul de incercari, cât și prin modelare. Software-ul utilizat în această lucrare este AVL Boost, un mediu prietenoși și foarte performant, realizat de firma AVL Austria. Modelul creat simulează un motor Diesel alimentat în mod dual cu motorină și GPL.

Cuvinte cheie: motorină, ardere, lege de degajare a căldurii, poluante, lege de injecție

INTRODUCERE

Pretul reduz al GPL-ului și nivelul reduz al emisiilor poluante fac acest combustibil foarte atractiv pentru studiu, atât experimental, cât și prin simulare. Dezvoltarea mașinilor din ultima perioadă necesită un interes deosebit asupra a ceea ce se întâmplă în interiorul cilindrului și mai ales asupra a celui mai complex fenomen, și anume arderea. Multi cercetători au aplicat modelele de calcul ale ciclului motor, aceste modele fiind calibrate prin metode experimentale. Modelarea computerizată a proceselor a început în anul 1950 cu modelele termodinamice simple [13], apărând după aceea modelele multizone în 1970 [13]. Utilizând simularea computerizată se poate economisi atât timp prețios, măsurătorile pe stand necesitând un timp îndelungat pentru calibrarea și pregătirea echipamentelor, precum și bani, nemai coincind necesară funcționarea motorului. Prin modelare se pot investiga fenomene ca: influența sistemului dual de alimentare, a dozei de combustibil pe ciclu, a presiunii de supraalimentare asupra emisiilor poluante și performanțelor energetice ale motorului etc. În cazul utilizării GPL-ului ca și combustibil alternativ care înlocuiește o parte din motorină, asa cum se analiceaza în această lucrare, se poate evidenția efectul gradului de substituție al motorinei cu GPL. Un sistem dual de alimentare a fost studiat de J. Barata în lucrarea [4], autorul fiind interesat de nivelul emisiilor poluante în cazul alimentării cu propan. Au fost obținute rezultate importante, în special pentru emisia de oxizi de azot, care a fost mai redusă decat cea a motorului standard pentru toate regimurile studiate, iar pentru reducerea emisiiei de hidrocarburi neare a fost necesară marirea gradului de recirculare a gazelor arse. Odată cu creșterea cantității de EGR, arderea a devenit mai rapidă datorită prezenței radicălor [10]. Un alt important aspect în funcționarea motorului Diesel îl reprezintă zgomotul de ardere. Aceasta a fost studiat prima dată de Ricardo în 1931 [12], el descoperind o stransă legatură între zgomotul de ardere...
which propagates in the engine mass and produces vibrations. The combustion noise can be increased or decreased by many facts: the use of a Diesel fuel – water emulsion [6, 15], steam injected in intake plenum in the case of dual fuel system operation [16, 17], fuelling with gaseous fuels like: LPG, methane or other gases [18, 17]. In the work [14], the author realized a quasi-dimensional model, combined with a kinetic mechanism, to study the combustion process for an engine fuelled in dual system, at part load, with EGR quantity and Diesel fuel pilot increasing. The work achieved result like proper combustion positioning near TDC, EGR quantity optimization for unburned hydrocarbons reducing at the same level with the standard engine. The injection rate modifying was studied by A. Voicu in [20], using a quasi-dimensional model written by AVL from AVL Boost software. Was investigated the influences of modifying the injection rate from a standard one to a fractioned one, with Diesel fuel pilot, over energetic and pollutant performances, for a tractor Diesel engine fuelled in dual system. The study led to the brake thermal efficiency increasing and pollutant emission optimization according with the engine manufacturer limits [19]. In [5], the authors studied the influence of injection timing for a tractor engine fuelled with Diesel fuel and hydrogen enriched gas. The software used was AVL Boost 2009. After injection timing optimization, the following results were obtained: a slight increase of the brake thermal efficiency, a slight increase of the cylinder maximum pressure, a significant reducing for the carbon monoxide emission but an increase of the nitric oxides emission [5]. Abd Alla et al. [1, 2] developed a model used for combustion computing in a Diesel engine with indirect injection and fuelled with a dual system. The model predicted the engine energetic performance and studies the effect of the gaseous fuel mixing kinetic mechanisms and the role of the Diesel fuel pilot injection. Also, the EGR influences were investigated. For the combustion study in this case of dual fuel system, a double Vibe function was used. Karim et al [8, 9], investigated the EGR influence theoretical and experimental. Investigations of the EGR benefits could be deteriorated by the dilution effect. The paper shows the effects of using LPG at a Diesel engine either experimental or by modeling.

MATERIAL AND METHODS

Theoretical and experimental investigations

Both theoretical and experimental analysis were made on a K9K 792 dCi Diesel engine, at the 85% load regimen and 2000 rpm, fuelled with LPG using Diesel-Gas method with different substitute ratios of the Diesel fuel. In the engine cylinder is burnt an air-LPG homogeneous mixture ignited by Diesel fuel pilot prior injected. The engine parameters are presented in table 1 and LPG properties in Table 2.

Table 1 / Tabelul 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore / Aleaj</td>
<td>76 mm</td>
</tr>
<tr>
<td>Stroke / Cursă</td>
<td>80.5 mm</td>
</tr>
<tr>
<td>Compression ratio / Raport de comprimare</td>
<td>18.5</td>
</tr>
<tr>
<td>Total displacement / Cilindree totală</td>
<td>15.5</td>
</tr>
<tr>
<td>Connecting rod length / Lungimea bielei</td>
<td>134 mm</td>
</tr>
<tr>
<td>Maximum power @ speed / Putere maximă @ turatie</td>
<td>52 kW @ 3900 rpm</td>
</tr>
<tr>
<td>Maxim torque @ speed / Moment maxim @ turatie</td>
<td>156N.m @ 2000rpm</td>
</tr>
</tbody>
</table>

şti viteză de creştere a presiunii [12]. Creşterea rapidă a presiunii crează o undă de şoc care se propagă în întreaga masă a motorului şi produce vibrații. Zgomotul de ardere poate fi modificat în sensul creşterii sau descărcării prin mai multe procedee: utilizarea unei emulsii apă-motorină [6, 15], injectia de abur în colectorul de admisie în cazul utilizării unui sistem dual de alimentare [16, 17], alimentarea cu combustibil gazoși cum ar fi: GPL, metan sau alte gaze [18, 17]. În lucrarea [14], autorul a realizat un model cvasidimensional, combinat cu un mecanism cinematic, în scopul studierii procesului de ardere pentru un motor Diesel alimentat în mod dual, la sarcini parțiale și cu creșterea cantității EGR. Lucrarea a avut rezultate ca: poziționarea arderii langă PMI, optimizarea cantității EGR pentru reducerea emisiilor de hidrocarburi nearse până la nivelul motorului standard alimentat cu motorină. Modificarea legii de inecție a fost studiată de A. Voicu în [19], folosind un model cvasidimensional al firmei AVL. Au fost investigate influențele modificării legii de inecție de la cea standard la una cu pilot de motorină, asupra performanțelor energetic et de poluare ale unui motor de tractor alimentat în sistem dual. Studiul a dus la creșterea randamentului efectiv și optimizarea emisiilor poluanțe în limitele impuse de fabricant [20]. În [5], autorii au studiat influența avansului la inecție pentru un motor de tractor alimentat cu motorină și gaz bogat în hidrogen. Programul utilizat a fost AVL Boost 2009. După optimizarea avansului au fost obținute următoarele rezultate: o ușoară creștere a randamentului efectiv, o creștere ușoară a presiunii din cilindru, o reducere semnificativă a emisiiei de monoxid de carbon, dar o creștere a emisiiei de oxizi de azot [5]. Abd Alla et al. [1, 2], au dezvoltat un model de calcul al arderii pentru un motor Diesel cu inecție indirectă și alimentat cu un sistem dual. Modelul a prezis performanțele energeticet și studiază efectele mecanismelor cineticet de amestecare ale combustibilului gasos și rolul inecției pilot de motorină. De asemenea, influențele EGR au fost investigate. Pentru studiul arderii în acest caz al sistemului dual de alimentare a fost utilizată o gea dublă Vibe. Karim și alții [8, 9] au investigat influența EGR prin modelarea analitică a autoaprimerii unor amestecuri de aer-propan, aer-metan. Rezultatele au condus la faptul că efectele benefice ale EGR pot fi diminuate de efectul de diluție. Lucrarea prezintă unele efecte ale utilizării GPL la motorul Diesel atât experimental cât și teoretic.

MATERIAL ŞI METODĂ

Investigații teoretice și experimentale

Atât analiza teoretică, cât și cea experimentală a fost efectuată pe un motor Diesel K9K 792 dCi, la regimul de 85% sarcină și 2000 rpm, alimentat cu GPL prin procedeel Diesel-Gas și cu diferite grade de substituție ale motoriniei. În cilindru este ars un amestec omogen de aer-GPL aprins de pilotul de motorină. Parametrii motorului sunt prezentati în tabelul 1, iar proprietățile GPL în tabelul 2.
### LPG properties, comparing to Diesel fuel [7]

<table>
<thead>
<tr>
<th>Properties / Proprietăți</th>
<th>Diesel fuel / Motorină</th>
<th>Propane / Propan</th>
<th>Butane / Butan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density / Densitate [kg/m³]</td>
<td>800-840</td>
<td>503</td>
<td></td>
</tr>
<tr>
<td>Vaporization heat / Caldură de vaporizare [kJ/kg]</td>
<td>465</td>
<td>420</td>
<td></td>
</tr>
<tr>
<td>Self ignition temperature / Temperatura de autoapriindere [ºC]</td>
<td>225</td>
<td>481</td>
<td>544</td>
</tr>
<tr>
<td>Inflammability limits / Limite de inflamabilitate [%]</td>
<td>0.6-5.5</td>
<td>2.1-9.5</td>
<td></td>
</tr>
<tr>
<td>A/F ratio / Raport aer/ Combustibil [kg/kg]</td>
<td>15</td>
<td>15.71</td>
<td>15.49</td>
</tr>
<tr>
<td>Flame temperature / Temperatura flăcării [ºC]</td>
<td>2054</td>
<td>1990</td>
<td></td>
</tr>
<tr>
<td>Caloric heating value / Putere calorifică inferioară [MJ/m³]</td>
<td>3.6x10⁴</td>
<td>2.3x10⁴</td>
<td></td>
</tr>
<tr>
<td>Caloric heating value / Putere calorifică inferioară [MJ/kg]</td>
<td>42.5</td>
<td>46.34</td>
<td>45.55</td>
</tr>
<tr>
<td>Cetane number / Cifra cetanică [CC]</td>
<td>40-55</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Boiling point / Punct de fierbere [ºC]</td>
<td>71-193</td>
<td>-42.1</td>
<td>-11.7</td>
</tr>
</tbody>
</table>

### IN CYLINDER PROCESSES MODELING

All the engine cylinders are identical; therefore the mathematical model was made only for one cylinder. The software used was AVL Boost, the model being presented in figure 1. The injector presented in figure is used for LPG gaseous injection.

### MODELAREA PROCESELOR DIN CILINDRUL MOTORULUI

Tot cilindrii motorului sunt identici, asadar modelul matematic a fost realizat doar pentru un cilindru. Software-ul utilizat a fost AVL Boost, modelul fiind prezentat in figura 1. Injectorul prezentat in figură este utilizat pentru injectia de GPL in stare gazoasă.

![Fig. 1 - The model created in AVL Boost / Modelul creat in AVL Boost](image-url)
The combustion model chosen is one developed by AVL, named AVL MCC (Mixture Controlled Combustion) [3]. One of the model hypotheses: due to developments in recent years, the ignition delay is shorter than it was in old period, and the time between injection and auto-ignition became very close [3]. So the heat release is considered to be controlled by the fuel quantity available and the turbulent kinetic energy density [3]:

\[
\frac{dQ}{d\phi} = C_{\text{mod}} f_1 (M_f, Q) * f_2 (k, V) \quad [3]
\]

(1)

\[
f_1 (M_f, Q) = M_f - \frac{Q}{LCV} \quad [3]
\]

(2)

\[
f_2 (k, V) = \exp(C_{\text{rate}} \sqrt{\frac{k}{V}}) \quad [3]
\]

(3)

Where:
- \( C_{\text{mod}} \) - model constant \([\text{kJ/kg/deg CRA}]\);
- \( C_{\text{rate}} \) - constant of mixing rate \([\text{s}]\);
- \( k \) - local density of turbulent kinetic energy \([\text{m}^2/\text{s}^2]\);
- \( M_f \) - injected fuel mass \([\text{kg}]\);
- \( LCV \) - the lower heating value \([\text{kJ/kg}]\);
- \( Q \) - cumulative heat release \([\text{kJ}]\);
- \( V \) - instantaneous cylinder volume \([\text{m}^3]\);
- \( \phi \) - crank angle \([\text{deg CRA}]\).

Unde:
- \( C_{\text{mod}} \) – constanta modelului \([\text{kJ/kg/deg RAC}]\);
- \( C_{\text{rate}} \) – constanța ratei de amestecare \([\text{s}]\);
- \( k \) – densitatea locală a energiei cinetice turbulente \([\text{m}^2/\text{s}^2]\);
- \( M_f \) – masa de combustibil injectată \([\text{kg}]\);
- \( LCV \) – puterea calorifică inferioară \([\text{kJ/kg}]\);
- \( Q \) – căldură degajată \([\text{kJ}]\);
- \( V \) – volumul instantaneu al cilindrului \([\text{m}^3]\);
- \( \phi \) – unghi rotație arbore cotit \([\text{deg RAC}]\).
Since the effects of squish and swirl over the kinetic energy are relative small, only the kinetic energy from the fuel spray is taken into account [3]. The amount of kinetic energy introduced into the cylinder charge is determined by the injection rate using the following relation:

\[
\frac{dE_{\text{kin},f}}{d\varphi} = 18 \rho_F \left( \frac{n}{\mu A} \right)^2 \nu^3 \tag{3}
\]

Where:
- \(\mu A\) - effective nozzle hole area \([m^2]\);
- \(\rho_F\) - fuel density \([kg/m^3]\);
- \(\nu\) - injection rate \([m^3/s]\);
- \(n\) - engine speed \([rpm]\).

For the calculation of the instantaneous level of kinetic energy the dissipation should be taken into account also [3]. The dissipation is considered proportional to the kinetic energy.

\[
\frac{dE_{\text{kin},F,\text{dis}}}{d\varphi} = \frac{dE_{\text{kin},F}}{d\varphi} - \frac{C_{\text{Diss}}}{6n} E_{\text{kin},F,\text{dis}} \tag{3}
\]

With oxidation, the kinetic energy of the jet is transferred to the combustion gas [3]. So only the kinetic energy of the unburned fuel can be utilized for mixture preparation [3]. The local turbulent kinetic energy density, \(k\), is given by:

\[
k = C_{\text{turb}} \frac{E_{\text{kin},F,\text{Diss}}}{M_F (1 + \lambda_{\text{Diff}} m_{\text{stoch}})} \tag{3}
\]

The constant \(C_{\text{turb}}\) considers the efficiency of the transformation from kinetic energy to turbulent energy [3].

- \(C_{\text{turb}}\) - constant for turbulence generation \([\cdot]\);
- \(E_{\text{kin},F}\) - jet kinetic energy \([J]\);
- \(E_{\text{kin},F,\text{Diss}}\) - jet kinetic energy considering dissipation \([J]\);
- \(m_{\text{stoch}}\) - stoichiometric mass of fresh charge \([kg/kg]\);
- \(\lambda_{\text{Diff}}\) - air excess ratio for diffusion burning \([\cdot]\).

The combustion model is defined in figure 4, and injection model in figure 5. The rate of injection was modified according to the studied regime.

Cum efectele fenomenelor de squish și swirl asupra energiei cinetice sunt relativ mici, doar energia cinetică a jetului de combustibil este luată în considerare [3]. Cantitatea de energie cinetică este determinată din legea de injecție, utilizând următoarea relație de calcul:

\[
\frac{dE_{\text{kin},f}}{d\varphi} = 18 \rho_F \left( \frac{n}{\mu A} \right)^2 \nu^3 \tag{3}
\]

Unde:
- \(\mu A\) - aria efectivă a orificiului pulverizatorului \([m^2]\);
- \(\rho_F\) - densitatea combustibilului \([kg/m^3]\);
- \(\nu\) - debitul volumic de combustibil \([m^3/s]\);
- \(n\) - turația motorului \([rpm]\).

Pentru calculul nivelului instantaneu al energiei cinetice, disipația trebuie deasemenea luată în considerare [3]. Disipația se considera a fi proporcională cu energia cinetică.

\[
\frac{dE_{\text{kin},F,\text{dis}}}{d\varphi} = \frac{dE_{\text{kin},F}}{d\varphi} - \frac{C_{\text{Diss}}}{6n} E_{\text{kin},F,\text{dis}} \tag{3}
\]

Odată cu oxidarea jetului, energia sa cinetică este transferată gazelor de ardere [3]. Deci doar energia cinetică a combustibilului neașteptat poate fi utilizată pentru pregătirea amestecului [3]. Densitatea locală de energie cinetică turbulentă, \(k\), este dată de:

\[
k = C_{\text{turb}} \frac{E_{\text{kin},F,\text{Diss}}}{M_F (1 + \lambda_{\text{Diff}} m_{\text{stoch}})} \tag{3}
\]

Constanta \(C_{\text{turb}}\) consideră eficiența transformării energiei cinetice în energie turbulentă [3].

- \(C_{\text{turb}}\) - constanta pentru generarea turbulenței \([\cdot]\);
- \(E_{\text{kin},F}\) - energia cinetică a jetului \([J]\);
- \(E_{\text{kin},F,\text{Diss}}\) - energia cinetică a jetului considerând disipația \([J]\);
- \(m_{\text{stoch}}\) - masa incărcătării proaspete la dozaj stoichiometric \([kg/kg]\);
- \(\lambda_{\text{Diff}}\) - coeficientul de exces de aer pentru arderea difuzivă \([\cdot]\).

Lega de ardere este definită în figura 4, iar legea de injecție în figura 5. Lega de injecție a fost modificată în funcție de fiecare regim.

Fig. 4 - The combustion model parameters / Parametrii legii de ardere
The mathematical model takes also into account the wall heat transfer. The heat transfer for high pressure cycle is evaluated by Woschni equation [3].

\[
\alpha_w = 130D^{-0.2} p_c^{0.8} T_c^{-0.53} \left( C_1 c_m + C_2 \frac{V_D T_{c,1}}{p_{c,0} V_c} \right)^{0.8} \]  \hspace{1cm} (7)
\]

\[
C_1 = 2.28 + 0.308 \frac{c_u}{c_m}
\]
\[
C_2 = 0.00324 \text{ for direct injected engines;}
\]
\[
C_2 = 0.00622 \text{ for indirect injected engines;}
\]
\[
D \text{ - cylinder bore;}
\]
\[
c_m \text{ - mean piston speed;}
\]
\[
c_u \text{ - circumferential velocity;}
\]
\[
V_D \text{ - displacement per cylinder;}
\]
\[
P_{c,0} \text{ - cylinder pressure of the motored engine [bar];}
\]
\[
T_{c,1} \text{ - temperature in the cylinder at intake valve closing (IVC);}
\]
\[
P_{c,1} \text{ - pressure in the cylinder at intake valve closing IVC [bar];}
\]

For the gas exchange processes, the heat transfer is evaluated by the following relation:

\[
\alpha_w = 130D^{-0.2} p_c^{0.8} T_c^{-0.53} \left( C_3 c_m \right)^{0.8} \]  \hspace{1cm} (8)
\]

\[
C_3 = 6.18 + 0.417 \frac{c_u}{c_m}
\]

Figure 6 presents the heat transfer input parameters.

For procesele de schimb de gaze transferul de căldură este evaluat de următoarea relație:

\[
\alpha_w = 130D^{-0.2} p_c^{0.8} T_c^{-0.53} \left( C_3 c_m \right)^{0.8} \]  \hspace{1cm} (8)
\]

\[
C_3 = 6.18 + 0.417 \frac{c_u}{c_m}
\]

Figura 6 prezintă parametrii de intrare ai transferului de căldură.
Experimental investigations
Experimental investigations were made on the engine mentioned above, equipped with a LPG fuelling system, at load 85% and 2000 rpm. The test bed equipment used was Schenck E90 eddy current engine dynamometer, load actuator, AVL acquisition system, AVL piezoelectric pressure transducer, AVL DiCom 4000 gas analyzer and opacimeter, Optimass fuel mass flow meters, Khrone volumetric air flow meter, thermocouples and thermoresistences for temperature measuring, gas leak detector. Prior to measurements, equipment was calibrated.

The engine parameters are presented in the table 1 and the test bed diagram in figure 7.

Working procedure
For each energetic substitute ratio of the Diesel fuel with LPG investigated, the Diesel fuel cycle dose is reduced and LPG cycle dose is increased to keep the standard engine power, either for test bed or computer modeling. Energetic substitute ratio $x_c$ is evaluated by relation 9:

$$x_c = \frac{m_{\text{LPG}} H_{\text{LPG}}}{m_{\text{LPG}} H_{\text{LPG}}} + m_{\text{diesel fuel}} H_{\text{diesel fuel}}$$  \[11\]

Procedura de lucru
Pentru fiecare grad de substituție al motorinei cu GPL investigat, doza de motorină este redusă, iar doza de GPL mărită pentru a menține puterea motorului la nivelul celei standard, atât în cazul măsurătorilor pe standul de incercari, cât și în cazul modelării matematice. Gradul de substituție energetic a motorinei cu GPL $x_c$ este evaluat de relația 9:
Where:

- $\text{d}_{\text{LPG}}$ - LPG cyclic dose measured with fuel mass flow meter;
- $\text{d}_{\text{df}}$ - Diesel fuel cyclic dose measured with fuel mass flow meter.
- $H$ - the caloric heating value.

RESULTS

First was determined the reference fueling the engine only with Diesel fuel, than Diesel fuel was partially substituted with LPG. The engine power was conserved. Figures below presents LPG influences over cylinder pressure, temperature and pollutant emissions.

In figure 8 is presented measured and calculated cylinder pressure, for the reference case.

![Fig. 8 - Measured and calculated cylinder pressure for the reference case](image)

According to the working procedure, LPG was introduced in intake collector using Diesel-Gas method.

Three energetic substitute ratios were studied: $x=2.46$, 6.76 and 28.39. For a proper combustion positioning near TDC, the injection timing was modified. Figure 9 presents the cylinder pressure trace either for measurement or modeling for the first substitute ratio studied $x=2.46$. The maximum pressure is maintaining almost the same like in the case of Diesel fuel.

![Fig. 9 - Measured and calculated cylinder pressure for $x=2.46$](image)

In concordanță cu procedura de lucru, GPL-ul a fost introdus în colectorul de admisie folosind metoda Diesel-Gas. Trei grade de substituție au fost studiate: $x=2.46$, 6.76 și 28.39. Pentru o poziționare corectă a arderii față de PMI, avansul la injecția pilotului a fost modificat. Figura 9 prezintă evoluția presiunii pentru gradul de substituție $x=2.46$, atât în cazul măsurătorilor, cât și al modelării. Presiunea maximă se menține aproape la același nivel ca în cazul alimentării cu motorină.
The increase of the LPG quantity led to a higher maximum pressure because of increases of the heat released. This can be observed in figures 10 and 11.

Even if the maximum pressure increases, it doesn’t affect the engine durability.

Regarding the maximum computed cylinder temperature, it increases from T=1985 K (obtained for Diesel fuel) to T=2057 K (obtained for the maximum substitute ratio investigated). The cylinder temperature trace for all the studied cases is presented in figure 12.

Creșterea cantității de GPL a dus la creșterea presiunii maxime datorită cresterii cantității de caldura deținute în timpul fazei arderii rapide. Acest aspect poate fi evidențiat în figurile 10 și 11.

Creșterea moderată a presiunii nu afectează durabilitatea motorului.

În ceea ce privește temperatura calculată maximă, aceasta crește de la T=1985 K (obținută pentru motorina) la T=2057 K (obținută pentru gradul maxim de substituție investigat). Evoluția temperaturii din cilindru este prezentată în figura 12.
Regarding pollutants, two emissions were investigated: nitric oxides emission and smoke emission, represented by soot. For computed model, the emissions are modeled in the following way: for the nitric oxides emission calculation, the extended Zeldovich mechanism is employed [3] and for the soot emission is taken into account the hypothesis that the concentration of soot in the exhaust gases is determined by formation and oxidation laws [3]. The following equations describe soot formation and oxidation laws:

\[
\frac{dm_{sf}}{dt} = A_{sf} m_{fg} p^{0.5} \exp \left( \frac{-E_{sf}}{RT} \right) \quad [3] \tag{9}
\]

\[
\frac{dm_{sc}}{dt} = A_{sc} \frac{m_{sc} p_{O_2}^2}{p} \exp \left( \frac{-E_{sc}}{RT} \right) \quad [3] \tag{10}
\]

Where:
- \(m_{S}\) - soot mass
- \(m_{fg}\) - gaseous fuel mass
- \(m_{sf}\) - soot mass formed
- \(m_{sc}\) - soot mass oxidized
- \(E_{sf}\) - activation energy formation
- \(E_{sc}\) - activation energy oxidation

Din punct de vedere al emisiilor poluante, două emisiile au fost studiate: oxizii de azot și fumul, reprezentat de funingine. Pentru modelul calculat, formarea emisiilor este modelată astfel: pentru emisia de oxizi de azot este folosit mecanismul Zeldovich extins [3], iar pentru emisia de funingine se ia în calcul ipoteza conform căreia concentrația de funingine din gazele de evacuare este determinată de legile de formare și oxidare [3]. Ecuțiile următoare descriu legile de formare și oxidare ale funinginii:

\[
\frac{dm_{sf}}{dt} = A_{sf} m_{fg} p^{0.5} \exp \left( \frac{-E_{sf}}{RT} \right) \quad [3] \tag{9}
\]

\[
\frac{dm_{sc}}{dt} = A_{sc} \frac{m_{sc} p_{O_2}^2}{p} \exp \left( \frac{-E_{sc}}{RT} \right) \quad [3] \tag{10}
\]

Unde:
- \(m_{S}\) - masa funinginii
- \(m_{fg}\) - masa combustibilului gazos
- \(m_{sf}\) - masa de funingine formată
- \(m_{sc}\) - masa de funingine oxidată
- \(E_{sf}\) - energia de activare pentru formare
- \(E_{sc}\) - energia de activare pentru oxidare

The NO\textsubscript{x} emission is lower than in the case of Diesel fuel for all the substitute ratios used, either for measuring or modeling. This is possible because in the case of using LPG, the excess air ratio become lower. In table 3 are presented the nitric oxides emissions levels for all cases, measured and computed with AVL Boost.

![Fig. 13 - The AVL Boost pollutants model / Modelul de calcul al poluantilor în AVL Boost](image)

<table>
<thead>
<tr>
<th>Case / Caz</th>
<th>measured / măsurat NO\textsubscript{x} [ppm]</th>
<th>Computed / Calculat NO\textsubscript{x} [ppm]</th>
<th>Relative error / Eroare relativă [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel fuel / Motorină</td>
<td>758</td>
<td>782</td>
<td>-3.07</td>
</tr>
<tr>
<td>(x=2.46)</td>
<td>562</td>
<td>581</td>
<td>-3.27</td>
</tr>
<tr>
<td>(x=6.76)</td>
<td>443</td>
<td>431</td>
<td>2.78</td>
</tr>
<tr>
<td>(x=28.39)</td>
<td>491</td>
<td>486</td>
<td>1.03</td>
</tr>
</tbody>
</table>

Emisie de NO\textsubscript{x} este mai mică decât în cazul alimentării cu motorină pentru toate gradele de substituție investigate. Acest lucru este posibil deoarece în cazul utilizării GPL coeficientul de exces de aer scade. În tabelul 3 este prezentat nivelul emisiei de oxizi de azot pentru toate cazurile investigate, atât pentru măsuratori, cât și pentru modelare în AVL Boost.

![The nitric oxides emission / Emisia de oxizi de azot](image)
The smoke emission, in the case of LPG fueling is maintaining at the same level like in the case of Diesel fuel for substitute ratios until 6.76. For substitute ratio $x_c=28.39$ the smoke emission increases suddenly because the mixture become rich, LPG being injected in intake manifold and replacing partially the intake air. The smoke emission is presented in table 4, relative to the case of standard engine fueling.

<table>
<thead>
<tr>
<th>Case / Caz</th>
<th>Relative measured smoke Emisia de fum relativă măsurată [%]</th>
<th>Relative computed smoke Emisia relativă calculată de fum [%]</th>
<th>Relative error Eroarea relativă [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel fuel / Motorină</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>$x_c=2.46$</td>
<td>1.043</td>
<td>1.12</td>
<td>-7.33</td>
</tr>
<tr>
<td>$x_c=6.76$</td>
<td>0.863</td>
<td>0.963</td>
<td>-11.58</td>
</tr>
<tr>
<td>$x_c=28.39$</td>
<td>8.93</td>
<td>6.75</td>
<td>24.45</td>
</tr>
</tbody>
</table>

Regarding the combustion noise, evaluated by the maximum rate of pressure rise, the results are presented in figure 14.

Regarding the combustion noise, evaluated by the maximum rate of pressure rise, the results are presented in figure 14.

The rate of pressure rise increases its value for all the investigated substitute ratios. This is explained by higher flame speed in air-LPG homogeneous mixture, flame which appears in pilot Diesel fuel jet envelope.

For the computed model the results are little different. The computed maximum rate of pressure rise is presented in figure 15.

Viteza de creştere a presiunii creşte pentru toate gradele de substituţie investigate. Acest lucru este explicat de o viteză mai mare a flăcării în amestecul omogen de aer-GPL, flacără ce apare în anvelopa jetului pilotului de motorină.

Pentru modelul calculat rezultatele sunt puţin diferite faţă de cele experimentale. Evoluția vitezei maxime de creștere a presiunii calculate este prezentată în figura 15.
The brake specific energetic consumption, in the case of LPG fuelling was maintained approximately constant for all the investigated substitute ratios. The measured energetic break fuel consumption is presented in figure 16.

![Fig. 15 - The computed maximum rate of pressure rise versus the substitute ratio / Viteza maximă de creştere a presiunii calculată.](image)

**CONCLUSIONS**

1. Nitrous oxides emissions level decreases for all the investigated substitute ratios.
2. The smoke emission is maintained approximately at the same level like in the case of using pure Diesel fuel for substitute ratios up to 6.76% and increases for greater substitute ratios, because of cylinder air filling worsening.
3. The software can predict very well engine performance and emissions after calibration.
4. Fuelling with LPG will not affect the engine reliability.
5. The maximum rate of pressure rise increases for all the investigated substitute ratios, because of higher flame speeds in air-LPG homogeneous mixtures.
6. The break specific fuel consumption maintained approximately constant for all the investigated substitute ratios.

**ACKNOWLEDGEMENTS**

The authors would like to thank AVL List GmbH Graz, Austria, for providing the possibility to use AVL Boost software.

Consumul specific energetic în cazul alimentării cu GPL s-a menținut aproximativ constant pentru toate gradele de substituție analizate. Consumul specific energetic măsurat este prezentat în figura 16.

![Fig. 16 - The measured brake energetic consumption versus the substitute ratio / Consumul specific energetic masurat versus gradul de substituție](image)

**CONCLUZII**

1. Nivelul emisiiei de oxizi de azot scade pentru toate gradele de substituție investigate.
2. Emisia de fum se menține aproximativ la același nivel ca în cazul alimentării cu motorină, pentru grade de substituție până la 6.76% și crește pentru grade de substituție mai mari deoarece umplerea cilindrilui se înrăutătește.
3. Programul de calcul poate prezice foarte bine performanțele motorului după calibrare.
4. Alimentarea cu GPL nu afectează fiabilitatea motorului.
5. Viteza maximă de creștere a presiunii crește pentru toate gradele de substituție investigate, din cauza vitezei mai mari a flăcării în amestecul omogen de aer-GPL.
6. Consumul specific energetic se menține aproximativ la același nivel pentru toate gradele de substituție investigate.

**MULTUMIRI**

Autorii doresc să mulțumesc fără firmei AVL List GmbH Graz, Austria, pentru oferirea posibilității de a utiliza programul AVL Boost.
REFERENCES

[3]. AVL Boost UsersGuide.pdf;
[18]. Selim M.Y.E. (2005) - Effects of Engine Parameters and Gaseous Fuel Type on the Cyclic Variability of Dual

BIBLIOGRAFIE

[3]. AVL Boost UsersGuide.pdf;
[18]. Selim M.Y.E. (2005) - Efectul parametrilor motorului si a tipului combustibilului gazos asupra variabilității ciclice în cazul motoarelor alimentate dual, Combustibili, Jurnalul
Three types of manuscripts may be submitted:

1. Regular Articles: These should describe new and carefully confirmed findings, and experimental procedures should be given in sufficient detail for others to verify the work. The length of a full paper should be the minimum required to describe and interpret the work clearly (max. 8 pages);

2. Short Communications: A Short Communication is suitable for recording the results of complete small investigations or giving details of new models or hypotheses, innovative methods, techniques or apparatus. The style of main sections has not necessarily to be in accordance with that of full-length papers (max. 6 pages);

3. Reviews: Submissions of reviews and perspectives covering topics of current interest are welcome and encouraged (max. 8 pages).

All manuscripts are reviewed by the 2 members of the Scientifically Review. Decisions will be made as rapidly as possible, and the journal strives to return reviewers' comments to authors in approx. 3 weeks. The editorial board will re-review manuscripts that are accepted pending revision.

NOTE: Submission of a manuscript implies: that the work described has not been published before (excepting as an abstract or as part of a published lecture, or thesis) that it is not under consideration for publication elsewhere.

1. ARTICLES OBIȘNUITE

All portions of the manuscript must be typed single-spaced, A4, top and bottom: 2 cm; left: 2 cm; right: 2 cm, font: Arial, size 9 pt, except the title which will be 11 pt. and explicit figures, which will be 8 pt.

Text paper will be written in two equal columns of 8.3 cm, 0.4 cm space between them, except the title, authors and their affiliations, tables, figures, graphs and equations to be entered once.

Text will be written in English in the left column, respectively in native language in the right column.

The chapter titles are written Uppercase (eg: INTRODUCTION, MATERIAL AND METHODS), between chapters is left a space for 9 pt. At the beginning of each paragraph to leave a tab of 0.5 cm.

The paper will be written in Word, “Justify” alignment;

The paper should be transmitted by E-mail.

There are allowed 2 papers by each first author.

The Title should be a brief phrase describing the contents of the paper. PAPER'S TITLE will be uppercase, Bold (the title in English language) and Bold italic (the title in native language), center, 11 pt.

Under the paper’s title, after an space (enter) 9 pt., write authors’ names (eg: Vâsilescu G.), (font: 9 pt., bold) and affiliations, the name of the corresponding author (next row), (9 pt., regular). Also be passed: the phone, fax and E-mail information, for the first author of paper’s (font: 8 pt., italic).

Title should be short, specific and informative. Avoid long titles; a running title of no more than 100 characters is encouraged (without spaces).

The Abstract should be informative and completely self-explanatory, briefly present the topic, state the scope of the experiments, indicate significant data, and point out major findings and conclusions. The Abstract should be 100 to 300 words in length. Complete sentences, active verbs, and the third person should be used, and the abstract should be written in the past tense. Standard nomenclature should be used and abbreviations should be

Procesul de evaluare (recenzie)

Toate manuscrisele sunt evaluate de către 2 membri ai Comitetului Științific. Deciziile vor fi luate cât mai rapid posibil și revista va returna comentariile evaluărilor înapoi la autorîi în aproximativ 3 săptămâni. Conducerea editorială va reevalua manuscrisele care sunt acceptate în vederea publicării în revistă.

1. ARTICOLE OBIȘNUITE

Toate capitolele manuscrisului trebuie să fie scrise single-spaced, A4, sus și jos: 2 cm; stânga: 2 cm; freapta: 2 cm, font: Arial, mărime 9 pt, cu excepția titlului care se scrie cu 11 pt. și figurile explicite, care se scriv cu 8 pt.

Textul lucrării va fi scris în două coloane egale de 8.3 cm, 0.4 cm spațiu dintre ele, exceptând titlul, autorii și afilierea acestora; tabelele, figurile și echiuatele care nu se scriu pe coloane ci pe toată pagina (vezi modelul atașat);

Textul se va scrie în limba engleză în coloana din stânga, respectiv în limba maternă - coloana din dreapta;

Titlurile capitolelor sunt scrise cu majuscule (ex: INTRODUCERE, MATERIAL ȘI METODE), între capitole se lasă un spațiu de 9 pt. La începutul fiecărui paragraf se lasă un "tab" de 0.5 cm;

Lucrarea va fi scrisă în Word, alinieră "Justify";

Lucrarea trebuie trimisă prin e-mail.

Sunt permise max. 2 lucrări ca prim autor.


Titlul trebuie să fie scurt, specific și informativ. Evitați titlurile lungi, un titlu de sub 100 caractere este recomandat (fără spații).

Rezumatul trebuie să fie informativ și ușor de înțeles; prezentat pe scurt topica, stadiul experimentelor, date semnificative, și evidenția descoperirilor majore și concluziile. Rezumatul trebuie să cuprindă între 100 și 300 cuvinte. Propozițiile complete, verbele active, și persoana a III-a trebuie folosite (rezumatul să fie scris la timpul trecut). Se va utiliza nomenclatura standard iar abrevierile trebuie evitate. Nu se vor utiliza citări de lucrări în
avoided. No literature should be cited (font: 9 pt., the title - bold italic; the text of abstract: italic). Following the abstract, about 3 to 10 Keywords that will provide indexing references should be listed (font: 9, bold italic - the title and 9 pt., italic - the text).

A list of non-standard Abbreviations should be added. In general, non-standard abbreviations should be used only when the full term is very long and used often. Each abbreviation should be spelled out and introduced in parentheses the first time it is used in the text. Only recommended SI units should be used. Authors should use the Solids presentation (mg/ml). Standard abbreviations (such as ATP and DNA) need not to be defined.

The INTRODUCTION should provide a clear statement of the problem, the relevant literature on the subject, and the proposed approach or solution. It should be understandable to colleagues from a broad range of scientific subjects.

MATERIALS AND METHODS should be complete enough to allow experiments to be reproduced. However, only truly new procedures should be described in detail; previously published procedures should be cited, and important modifications of published procedures should be mentioned briefly. Capitalize trade names and include the manufacturer's name and address. Subheadings should be used. Methods in general use need not be described in detail.

RESULTS should be presented with clarity and precision. The results should be written in the past tense when describing findings in the authors' experiments. Results should be explained, but largely without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the Results but should be put into the Conclusions section. Subheadings should be used.

The CONCLUSIONS should interpret the findings in terms of the results obtained in this and in past studies on this topic. State the conclusions in a few sentences at the end of the paper. The Results and Discussion sections can include subheadings, and when appropriate, both sections can be combined.

The Acknowledgments of people, grants, funds, etc should be brief (if necessarily).

Tables should be kept to a minimum and be designed to be as simple as possible. Tables are to be typed single-spaced throughout, including headings and footnotes. Each table must be written on the entire width of the page, into the text where reference is made, the columns are broken - one column (see attached sample). Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should preferably be described in the legend instead of in the text. The same data should not be presented in both table and graph form or repeated in the text. Table's title will be centered bold (in English) and bold italic native language then separated by a slash. In the table, each row will be written in English (Arial, regular, size: 9 pt.) / native language (Arial, italic, 9 pt.). The table and its number is written right justified, bold - in English and bold italic - native language, separated by a slash (/).

Figure legends should be typed in numerical order. Graphics should be prepared using applications capable of generating high resolution JPEG before to introducing in the Microsoft Word manuscript file (Insert - From File - "rezumat" (font: 9 pt., titlu - bold italic; textul rezumatului - italic). Cuvinte cheie: ca urmare a rezumatului, între 3 şi 10 cuvinte cheie trebuiesc listate, aceste oferind referinţe de indexare (font: 9 pt., bold italic – titlul şi 9 pt., italic – textul).

Trebuie adăugată o listă de abrevieri specifice. În general, aceste abrevieri se folosesc atunci când termenul folosit este foarte lung şi des întâlnit în lucrare. Fiecare abreviere ar trebui introdusă în paranteză pentru prima dată când este folosită în text. Doar unități din SI trebuiesc folosite. Autorii trebuie să folosească prezentarea Solidus (mg/ml). Abrevierile standard (ca ATP sau ADN) nu trebuiesc definite.

INTRODUCEREA trebuie să ofere o expunere clară a problemei, esenţa relevantă a subiectului şi abordarea propusă sau soluţia. Aceasta trebuie să poată fi înțelesă de către colegi din diferite domenii științifice.

MATERIALE şI METODE: trebuie să fie suficient de complete pentru a permite experimentelor să fie reproduse. Totuși, numai metodele cu adevarător ne trebuiesc descrise în detaliu; metodele publicate anterior trebuiesc citate; modificările importante ale metodelor publicate trebuiesc menționate pe scurt. Scrieți cu majuscule denumirile comerciale și includeti numele și adresa producătorilor. Subcapitolele trebuie utilizate. Metodele utilizate în general, nu trebuie descrise în detaliu.

REZULTATELE trebuie prezentate cu claritate și precizie. Acestea trebuie scrisă la timpul trecut, atunci când descriu constatațiile în experimentele autorilor. Rezultatele trebuie să fie explicite, dar în mare măsură, fără a se face referire la literatura de specialitate. Discuțiile, speculațiile și interpretarea detalizată a datelor nu trebuie să fie incluse în rezultate, ci trebuie incluse în capitul Concluzii. Subcapitolele trebuie utilizate.

CONCLUZIILE trebuie să interpreteze constatațiile în ceea ce privește rezultatele obținute în această lucrare și în studiile anterioare pe această temă. Concluziile generale vor fi prezentate în câteva fraze la sfârșitul lucrării. Rezultatele și discuțiile pot include subpoziții, și atunci când este cazul, ambele secțiuni pot fi combinate.

Multumirile către oameni, cei care au acordat burse, fonduri, etc., trebuie să fie scurte (dacă este necesar).

Tabelele trebuiesc menționate la un nivel minim și să fie proiectate pentru a fi cât mai simple posibil. Tabelele vor fi scrisă la un rând, inclusiv titlurile și notele de subcol.

Fiecaredue tabel trebuie scris pe întreaga lătime a paginii, între textul în care se face trimitere; coloanele sunt eliminate - o singură coloană (vezi atașat modelul). Tabelele trebuie să fie auto-explicative, fără referire la text. Detaliile cu privire la metodele utilizate în experimente trebuie să fie, de preferință, scrise în legătura și nu în text. Aceleași date nu trebuie prezentate atât în tabel cât și sub formă grafică (decat dacă este absolut necesar) sau repetate în text. Titlul tabelului va fi scris centrat, bold (în engleză) și bold italic (în limba maternă), separate de un slash (/). În tabel, fiecare rând va fi scris în limba engleză (9 pt., normal) / limba maternă (9 pt., italic). Tabelul și numărul acestuia se scrie aliniat la dreapta, bold - în limba engleză și bold italic în limba maternă, despărțite de un slash (/).

Figurile trebuie scrise în ordine numerică. Grifica trebuie realizată utilizând aplicații capabile să genereze JPEG de înaltă rezoluție. Înainte de a introduce în dosarul manuscris Microsoft Word (Insert - From File - ... JPEG).
Mathematics

Authors must provide instructions on how symbols and equations should be set. Equations should be numbered sequentially in the right-hand side and in parenthesis. They should be referred to in the text as Equation (4) or Eq. (4). Each equation must be written on the entire width of the page, into the text where reference is made, the columns are broken (see attached sample).

REFERENCES: are made in the text; a reference identified by [1], [2], ... [n] is written in the order that was placed at the end of the work - alphabetically.

Example:


REFERENCES should be listed at the end of the paper in alphabetical order. Articles in preparation or articles published in technical journals should not be included in the reference list but should only be mentioned in the article text (e.g., A. Danciu, University of Bucharest, Romania, personal communication). Authors are fully responsible for the accuracy of the references.

REFERENCES: are made in the text; a reference identified by [1], [2], ... [n] is written in the order that was placed at the end of the work - alphabetically.

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Dissertation / Thesis:

Units, Abbreviations, Acronyms
- Units should be metric, generally SI, and expressed in standard abbreviated form.
- Acronyms may be acceptable, but must be defined at first usage.

2. SHORT COMMUNICATIONS
Short Communications are limited to a maximum of two figures and one table. They should present a complete study that is more limited in scope than is found in full-length papers. The items of manuscript preparation listed above apply to Short Communications with the following differences: (1) Abstracts are limited to 100 words; (2) instead of a separate Materials and Methods section, experimental procedures may be incorporated into Figure Legends and Table footnotes; (3) Results and Conclusions should be combined into a single section.

3. REVIEWS
Summaries, reviews and perspectives covering topics of current interest in the field, are encouraged and accepted for publication. Reviews should be concise (max. 8 pages). All the other conditions are similar with regular articles.

Diplomă / Teze de doctorat

Unități, Abrevieri, Acronime
- unitățile metrice trebuie să fie, în general, SI, și exprimate în formă prescurtată standard;
- acronimele pot fi acceptate, dar trebuie să fie definite la prima utilizare.

2. COMUNICĂRI SCURTE
Comunicările scurte sunt limitate la maxim 2 figuri și un tabel. Acestea trebuie să prezinte un studiu complet, care este mai limitat decât în cazul articolelor normale (de dimensiuni mai mari). Elementele de pregătire a articolelor normale (manuscriselor) enumerate mai sus se aplică și la comunicările scurte, cu următoarele diferențe: (1) Rezumatul este limitat la 100 cuvinte; (2) capitoele Materiale și Metode, Procedurile experimentale pot fi scrise împreună, incorporând figurile și tabellele; (3) Rezultatele și Concluziile pot fi combinate într-o singură secțiune.

SINTEZELE
Sienteze, comentariile și perspectivele acoperind subiecte de interes din domeniu sunt încurajate și acceptate spre publicare. Sientezele trebuie să fie concise și nu mai mari 8 pagini. Toate celelalte condiții sunt similare cu cele de la articolele normale (obișnuite), enumerate mai sus.