On the basis of the conducted experimental studies and relying on the previously conducted works, the main shortcomings of the pneumatic-type collection devices for pest control were determined. Since most designs of such devices have suction slits, the uneven distribution of air flow in them leads to inefficient collection of pests of agricultural crops from the surface of plants. Another and the main disadvantage of such devices is the formation of several streams that interact to form the following technological process - when pests are blown away by the injection stream, they move to the surface of the soil and do not have time to fall into the suction streams, and younger individuals that can hold on to the surface of the leaves are not blown away at all and remain in place, and this leads to the need for repeated passes of the unit and a decrease in the quality of processing.

For this purpose, a new device for collecting insect pests was proposed, designed for effective collection of pests of nightshade crops using a mechanical-pneumatic method. The design of the upper working element of the device for collecting pest insects was theoretically substantiated and it was established that the angle of attack of the working surface of the device lies in the range from 10 to 60°. The effectiveness of the proposed design of the new device is ensured by the increased effect of mechanical action on the plant of nightshade crops without its damage and the exclusion of pest retention at all levels along the height of the plant, the maximum collection of pests in one pass of the device.

**insect pests of agricultural crops, pest collection, collection device, exterminator, plant protection**

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**Elchyn Aliiev**, Prof. of the Department of Technical Systems Engineering, DSc., Senior Researcher, **Oleksandr Kobets**, Assos. Prof. of the Department of Tractors and Agricultural Machinery, PhD tech. sci., **Mykola Linko**, Holder of the third (educational and scientific) level of higher education
*Dnipro State Agrarian and Economic University, Dnipro, Ukraine*
*e-mail: aliev@meta.ua*

# Physico-mathematical model of the process of compression of compound feed components into expanders

The purpose of the experimental study is to verify the accuracy of conclusions drawn from theoretical research by substantiating experimentally the main parameters and operating modes of the feed compaction process. To compare the results of numerical modeling and laboratory experiments, a program was developed in the Wolfram programming language, which allows linking the technological parameters of the expansion process (W, T) with the physical and mechanical properties of the compound feeds mixture ($E_p$, $\mu_p$, $W_p$). For rational technological parameters ($D_\mu$ = 0.5 mm, W = 20.7 %, T = 137.0 °C), we have the following physical and mechanical properties: $E_p$ = 22.3 MPa, $\mu_p$ = 0.31, $W_p$ = 0.49 N/m. In this case, $S_{\Delta P}$ = 0.772 MPa, Ψ = 1.519, ha = 13.2 mm. Comparisons of dependencies $S_{\Delta P}^E(D_\mu)$ and $S_{\Delta P}^T(D_\mu)$, $\Psi^E(D_\mu)$ and $\Psi^T(D\mu)$, $h_a^E(D_\mu)$ and $h_a^T(D_\mu)$ will be conducted under the condition of rational technological parameters, and a sufficiently high Pearson correlation coefficient (0.94–0.99) has been established.

**feed, pressing, compression, numerical modeling, laboratory research, mixing, pressure, parameters, physical and mechanical properties, efficiency**

**Problem setting.** One of the problems encountered during the transportation of bulk feeds is the loss of uniformity due to component segregation. This issue has been addressed in Europe since the early 1980s through pelletizing or extrusion, where the homogeneity of the mixture is fixed in compressed agglomerations – pellets (extrudates). However, another concern arose for manufacturers – the strength of pellets and their resistance to impact during transportation. Hence, another quality indicator emerged – the pellet durability index (PDI) [1–2].

In an effort to improve PDI, the expansion technology was developed in Europe in the late 1980s. Feed manufacturers in Denmark, Germany, and the United Kingdom were among the first to adopt this technology.

In the early 1990s, new government regulatory requirements mandated that Scandinavian feed manufacturers in Denmark meet specific heat treatment requirements to eliminate Salmonella in animal feed [3]. While extrusion could be used for this purpose, the high capital and operational costs, along with relatively low process productivity, made extruder utilization economically impractical. Conversely, expansion garnered significant attention in Northern Europe as it could be used for economically viable production of feeds meeting rigorous physical and microbiological standards set by consumers and government regulators.

Considering that extrusion and expansion technologies are closely related, let's examine them in more detail and outline the requirements for the characteristics of the resulting product.

**Analysis of the latest studies and publications.** Extrusion and expansion are increasingly popular in the global agro-food industry, particularly in the food and feed sectors. These technologies are utilized for the production of so-called engineered food products and specialized feeds [4]. Summarizing the research [5–6], we have found that extrusion and expansion of plant raw materials involve the formation of pulverized material under barothermic conditions. Using the shear energy provided by a rotating screw and additional heating, the food material is heated to the melting or plasticization temperature [7]. In this altered rheological state, the food material is transported under high pressure through a die or series of dies, and the product expands to its final form. This results in distinct physical and chemical properties of the extrudates different from the properties of the raw materials used [8].

In general, extrusion is a short-term heat treatment of the product at temperatures up to 170 °C and pressures up to 50 atm., resulting in structurally complex mechanical and physical changes. The extrusion process involves forcing plasticized material through openings of constant cross-section (filaments). Let's consider the operation principle of a feed extruder [9].

Pre-moistened or steam-treated raw material (grain, compound feed) is dosed into the working chamber of the extruder, where it is compacted under the action of the screw. As the working chamber is traversed, the raw material heats up and becomes plasticized due to pressure and friction (melting phase). The maximum pressure in the working chamber is reached before the raw material enters the die, at the exit of which it sharply decreases, causing the processed material to foam, increasing in volume by 3–4 times. The extrudate exits the die in a continuous flow, so a rotating knife with adjustable rotation frequency is installed at the exit point for its size reduction, the change of which alters the length of individual product particles. The residence time of the raw material in the extruder's working chamber is up to 20 seconds.

The expansion process is essentially identical to the extrusion process, with differences in less stringent processing conditions for raw materials – temperatures up to 130 °C, pressures up to 30 atm. The expander differs from the extruder in the design of the press matrix – in the expander, the pressing process of the processed raw material occurs through a dense ring-type matrix.

**Setting objectives.** The purpose of the experimental study is to verify the accuracy of conclusions drawn from theoretical research by substantiating experimentally the main parameters and operating modes of the feed compaction process.

**Presentation of the main material.** At the first stage of the research, we will conduct numerical modeling of the process of compressing feed mixture components in a vessel under the action of a piston using the CAE system STAR-CCM+ (fig. 1). The vessel shape is chosen to be ring-like, as the material forms into a ring shape during its movement in the screw expander region. The geometric dimensions of the region are provided in fig. 1.

For modeling, the following continuum models are adopted: the meshless discrete element model (DEM), Lagrangian multiphase, DEM boundary forces, non-stationary implicit solver, solution interpolation model, and gravitational force. The components of the feed mixture are represented as solid spherical DEM particles with constant density. Particle interactions among themselves and with the wall are governed by Hertz-Mindlin models with rolling resistance and linear coupling [10].

According to previous laboratory studies and literature sources [11–13], the physico-mechanical properties of the feed mixture components are assumed as follows: static friction coefficient – 0.62, density – 710 kg/m³, tangential restitution coefficient – 0.6, normal restitution coefficient – 0.6. Time step – 0.01 s. Number of iterations per time step – 5. Exposure time – 4 s. Piston displacement speed – 0.01 m/s.

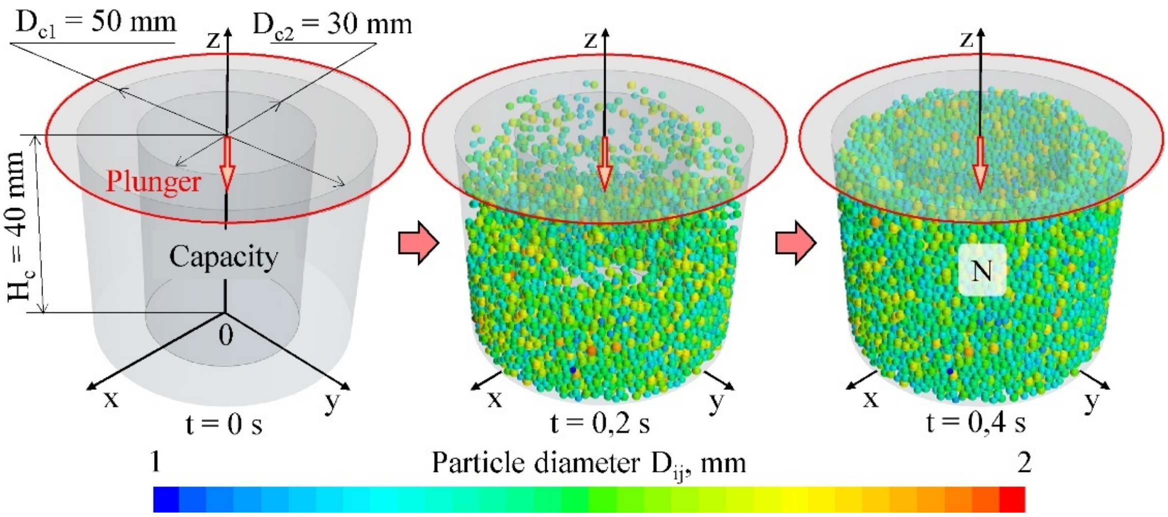



Figure 1 – The computational scheme for numerical modeling of the process of compressing feed mixture components in a cylindrical vessel under the action of a piston

*Source: developed by the authors*

The investigation of the process of compressing feed mixture components was conducted for various physical and mechanical properties, namely the average particle diameter of the mixture $D_\mu$, Young's modulus $E_p$, Poisson's ratio $\mu_p$, and adhesive work per unit area $W_p$. The levels and ranges of variation are presented in table 1. The particles in the mixture are distributed by size (effective diameter) according to a normal distribution. Modeling was performed using a full factorial design with a total of $3^4$ = 81 simulations.

Table 1 – Levels and ranges of variation of factors in the numerical modeling of the process of compressing feed mixture components in a vessel under the action of a piston

| Factor | Effective Particle Diameter | | Young's Modulus | | Poisson's Ratio | | Adhesive Work per Unit Area | |
|---|---|---|---|---|---|---|---|---|
| Designation | $x_1$ | $D_\mu$, mm | $x_1$ | $E_p$, MPa | $x_2$ | $\mu_p$ | $x_3$ | $W_p$, N/m |
| Low | –1 | 0.5 | –1 | 10 | –1 | 0.2 | –1 | 0 |
| Medium | 0 | 1.5 | 0 | 20 | 0 | 0.3 | 0 | 0.25 |
| High | +1 | 2.5 | +1 | 30 | +1 | 0.4 | +1 | 0.50 |
| Interval | 1 | 1.0 | 1 | 10 | 1 | 0.1 | 1 | 0.25 |

*Source: developed by the authors*

Figure 2 represents the graph of elastic hysteresis of feed components depending on their physical and mechanical properties.

The area $S_{\Delta P}$ enclosed within the loop of the elastic hysteresis represents the specific energy (work) converted into thermal energy at each stage of deformation. The deviation of deformations from stress and the elastic hysteresis loop it generates are associated with the so-called internal friction of the material. There are also several characteristics of mechanical losses in dynamic loading regimes.The coefficient of mechanical losses Ψ is defined as the ratio of the hysteresis loop area $S_{\Delta P}$ to the area enclosed between the stress curve and the abscissa axis, where strains $S_{P1}$ are plotted [14]. Therefore, as a criterion for assessing the elastic properties of feed components, it was decided to determine the weighted areas of the elastic hysteresis loop $S_{\Delta P}$ and the coefficient of mechanical losses Ψ based on the average particle diameter of the mixture $D_\mu$, Young's modulus $E_p$, Poisson's ratio $\mu_p$, and the work of adhesion per unit area $W_p$.

The second stage involves laboratory pressing of feed components with subsequent formation of expandates from them under various technological parameters (particle size of components, their moisture content, and temperature).

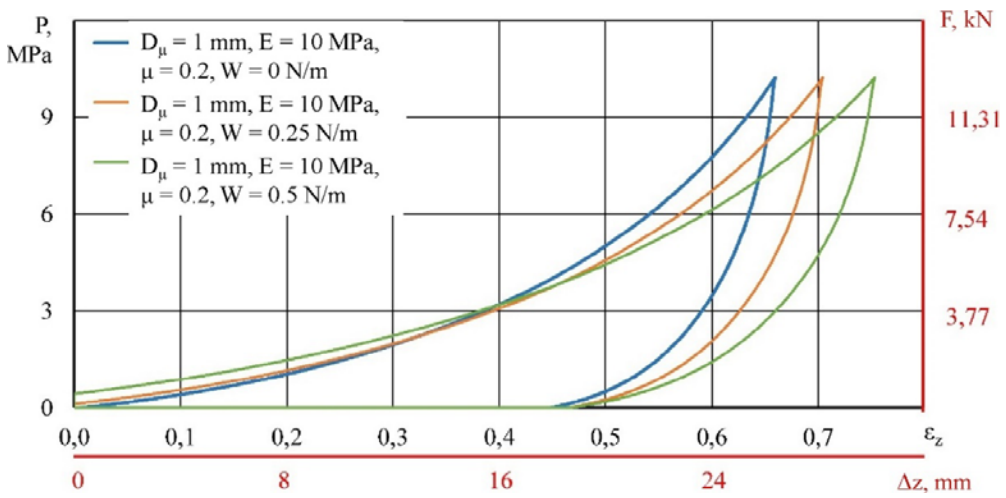



Figure 2 – The dependence of the piston compression force $F_\Sigma$ (pressure $P_\Sigma$) on the absolute (relative) deformation of feed components Δz ($\varepsilon_z$) at different physical and mechanical properties

*Source: developed by the authors*

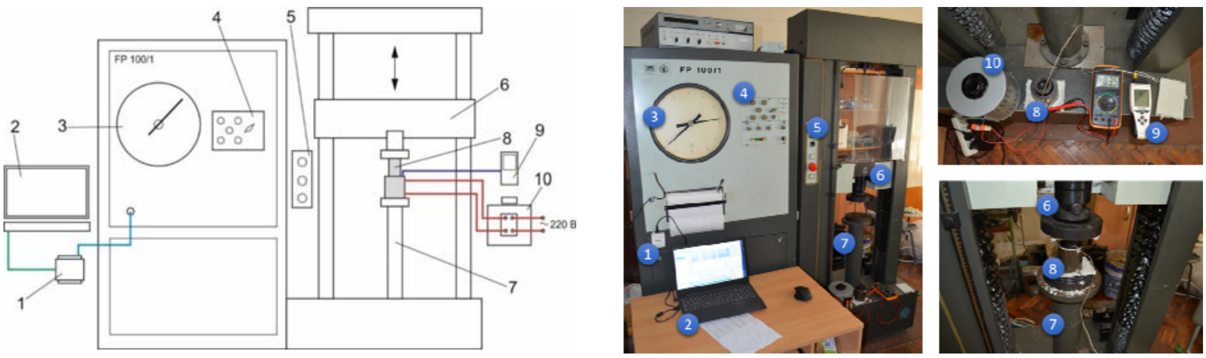
At the beginning of the research, samples of feed with different particle size distributions were prepared. The feed components, in a ratio of 25:25:25:25 %, consisted of wheat, barley, corn, and sunflower meal, ground using a hammer mill with sieve hole diameters of 3.5 mm. Then, using a sieve classifier and a laboratory sieve shaker, the materials obtained after grinding were separated into fractions with particle size ranges of 0–0.99 mm, 1–1.99 mm, and 2–2.99 mm. The preparation of feed was carried out using a laboratory spiral screw mixer for bulk materials, which allows obtaining mixtures with a homogeneity of 94–98 %.

The initial moisture content of the obtained samples was determined by the thermogravimetric method according to DSTU ISO 712:2015 «Cereals and cereal products. Determination of moisture content. Reference method (ISO 712:2009, IDT)» [15] using a SESh-3M drying cabinet. The initial moisture content (10 ± 2 %) of the feed samples was adjusted by adding the corresponding amount of water.

Studies on the effect of the particle size distribution of the feed, its moisture content, and temperature regime on the deformation diagram – the relationship between stress and material deformation – were conducted using the Heckert FP-100/1 testing machine and additional devices and equipment (fig. 3). The principle of operation of the FP-100/1 involves measuring the force when a sample installed on the stationary traverse deforms due to the movement of the movable traverse at a constant preset speed.

The dependence of deformation on loading was recorded using the analog-to-digital converter NI USB-6008, the analog input of which was connected to the measurement unit of the FP-100/1. The results were recorded on a PC using the NI SignalExpress 2015 software.

The research was conducted using a press mold equipped with heating, which consists of a winding of nichrome wire with a diameter of 1.0 mm on the outer surface of the matrix, insulated on both sides with layers of asbestos. Heating of the press mold to the required temperature and its maintenance were carried out by supplying adjustable alternating current to the nichrome winding using a laboratory autotransformer LATR-1M. The dimensions of the forming surfaces of the press mold are as follows: internal diameter of the matrix – 50 mm, diameter of the mark – 30 mm.

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1 – analog-to-digital converter NI USB-6008; 2 – PC; 3 – force gauge; 4 – settings panel FP-100/1; 5 – control panel FP-100/1; 6 – movable traverse; 7 – stationary traverse; 8 – press mold with the test sample; 9 – digital thermometer with thermocouple FLUS ET-960; 10 – laboratory autotransformer LATR-1M

Figure 3 – Scheme (a) and general view (b) of the testing machine Heckert FP-100/1 with additional equipment
*Source: developed by the authors*

The factors under investigation were chosen as the moisture content of the feed W, its temperature T, and the average diameter of the particles of the ground feed components Dμ (Table 2).

Table 2 – Levels of factor variation

| Factor | Lower level (– 1) | Zero level (0) | Upper level (+ 1) | Variation interval, Δ |
|---|---|---|---|---|
| Feed moisture W, % | 10 | 20 | 30 | 10 |
| Temperature T, °C | 80 | 110 | 140 | 30 |
| Average diameter of ground feed component particles $D_\mu$, mm | 0.5 | 1.5 | 2.5 | 1.0 |

*Source: developed by the authors*

The research was carried out using a full factorial experiment with a total of $3^3 = 27$ experiments. The repeatability was threefold.

The visualization of the regularities of the change in compression pressure from the deformation of feed components $\Delta P(\varepsilon_z)$ for individual experiments is shown in fig. 4.

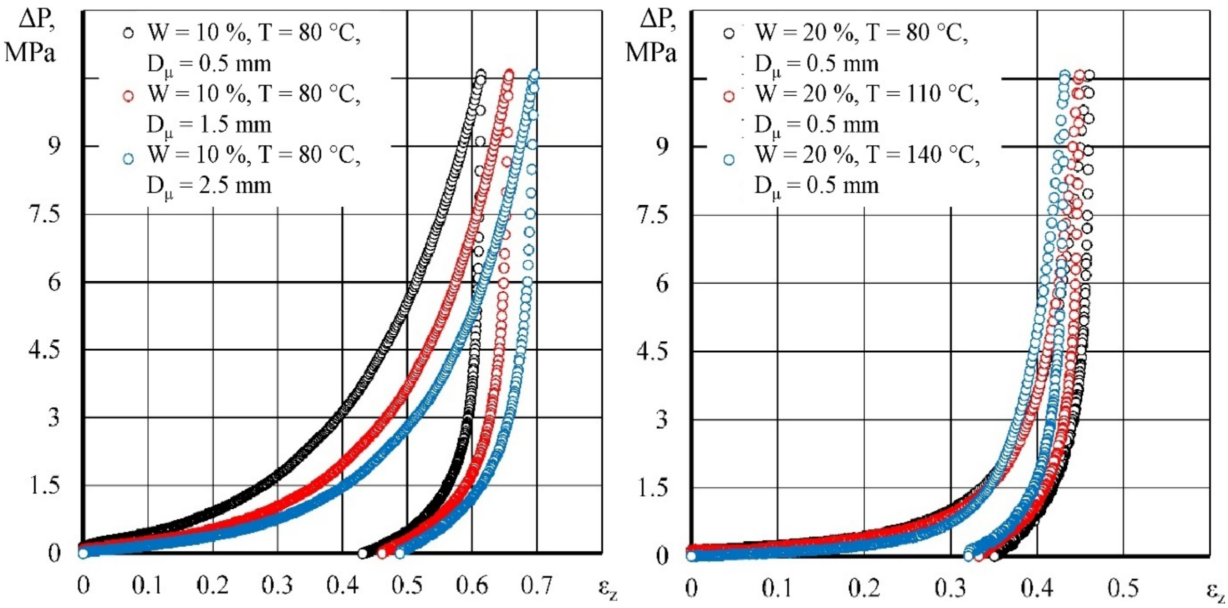


Figure 4 – Patterns of compression pressure change from deformation of feed components $\Delta P(\varepsilon_z)$ for individual experiments

*Source: developed by the authors*

Data processing in Wolfram Cloud resulted in regression equations for the hysteresis loop area SΔP from factors in general form:

– Numerical modeling:

$$S_{\Delta P} = -1{,}91791 - 0{,}0801014\ D_\mu + 0{,}0349022\ E_p + 11{,}7563\ \mu_p - \\ - 0{,}128667\ E_p\ \mu_p + 2{,}02385\ W_p - 0{,}0249772\ E_p\ W_p - \\ - 11{,}6377\ \mu_p\ W_p + 0{,}979359\ W_p^2; \quad (1)$$

– Laboratory research:

$$S_{\Delta P} = 3{,}38929 - 0{,}214174\ D_\mu + 0{,}0425747\ D_\mu^2 - 0{,}00879098\ T - \\ - 0{,}111558\ W + 0{,}000201695\ T\ W + 0{,}00098219\ W^2. \quad (2)$$

Data processing in Wolfram Cloud also resulted in regression equations for the coefficient of mechanical losses Ψ from factors in general form:

– Numerical modeling:

$$\Psi = 1{,}24615 + 0{,}123597\, D_{\mu} - 0{,}0117261\, E_p + 0{,}000293183\, E_p^2 - 1{,}06965\, \mu_p + 1{,}11661\, W_p + 0{,}108226\, D_{\mu} W_p - 0{,}0142308\, E_p W_p + 1{,}56259\, \mu_p W_p; \quad (3)$$

– Laboratory research:

$$\Psi = 0{,}523551 + 0{,}0752476\, D_{\mu} + 0{,}00132849\, T + 0{,}0583049\, W + 0{,}000477652\, D_{\mu} W + 0{,}0000519639\, T W - 0{,}00136235\, W^2. \quad (4)$$

Additionally, regression equations for the height of the expander from factors in general form were obtained:

– Numerical modeling:

$$h_a = 26{,}6886 + 0{,}344829\, D_{\mu} - 0{,}955516\, E_p + 0{,}0151721\, E_p^2 - 5{,}23844\, \mu_p + 0{,}142814\, E_p \mu_p + 0{,}927778\, W_p + 1{,}09198\, W_p^2; \quad (5)$$

– Laboratory research:

$$h_a = 27{,}9931 + 2{,}04722\, D_{\mu} - 0{,}166667\, D_{\mu}^2 - 0{,}0800463\, T - 0{,}00527778\, D_{\mu} T + 0{,}000314815\, T^2 - 0{,}919444\, W + 0{,}0201667\, W^2. \quad (6)$$

During numerical modeling, dependencies of $S_{\Delta P}(T)$ were established from $D_{\mu}$, $E_p$, $\mu_p$, $W_p$ – (1), $\Psi(T)$ – (3), and $h_a(T)$ – (5). In turn, the results of laboratory research allowed determining $S_{\Delta P}(W, T, D_{\mu})$ – (2), $\Psi(W, T, D_{\mu})$ – (3), and ha$(W, T, D_{\mu})$ – (6). By equating these dependencies, we obtain the system of equations:

$$\begin{cases} S_{\Delta P}^{E}\left(W, T, D_{\mu}\right) = S_{\Delta P}^{T}\left(D_{\mu}, E_p, \mu_p, W_p\right); \\ \Psi^{E}\left(W, T, D_{\mu}\right) = \Psi^{T}\left(D_{\mu}, E_p, \mu_p, W_p\right); \\ h_a^{E}\left(W, T, D_{\mu}\right) = h_a^{T}\left(D_{\mu}, E_p, \mu_p, W_p\right); \\ 10 \le W \le 30; \quad 80 \le T \le 140; \quad 0{,}5 \le D_{\mu} \le 1{,}5. \end{cases} \quad (7)$$

The provided system of equations was solved in Wolfram Cloud by composing the corresponding program, the algorithm of which includes the following steps:

– setting regression equations in the form of a function of several variables;

– setting technological parameters W, T, $D_{\mu}$ using the function of dynamic sliders;

– visualization of the intersection function of the system of equations (7) in the form of a three-dimensional graph (fig. 5);

– solving the system of equations (7) using the NSolve numerical calculation function;

– plotting graphs of dependencies $S_{\Delta P}^{E}(D_{\mu})$ i $S_{\Delta P}^{T}(D_{\mu})$, $\Psi^{E}(D_{\mu})$ i $\Psi^{T}(D_{\mu})$, $h_a^{E}(D_{\mu})$ and $h_a^{T}(D_{\mu})$ to compare the results of theoretical and experimental dependencies.

As an example, consider some relationships between technological parameters and the physico-mechanical properties of feed mixtures:

– $D_{\mu}$ = 1.5 mm, W = 20 %, T = 110 °C → $E_p$ = 18.3 MPa, $\mu_p$ = 0.28, $W_p$ = 0.35 N/m → $S_{\Delta P}$ = 0.802 MPa, Ψ = 1.532, $h_a$ = 14.5 mm;

– $D_{\mu}$ = 0.5 mm, W = 10 %, T = 80 °C → $E_p$ = 10.8 MPa, $\mu_p$ = 0.366, $W_p$ = 0.21 N/m → $S_{\Delta P}$ = 1.733 MPa, Ψ = 1.15, $h_a$ = 17.2 mm;

– $D_{\mu}$ = 2.5 mm, W = 30 %, T = 140 °C → $E_p$ = 16.4 MPa, $\mu_p$ = 0.20, $W_p$ = 0.31 N/m → $S_{\Delta P}$ = 0.274 MPa, Ψ = 1.675, $h_a$ = 15.8 mm.

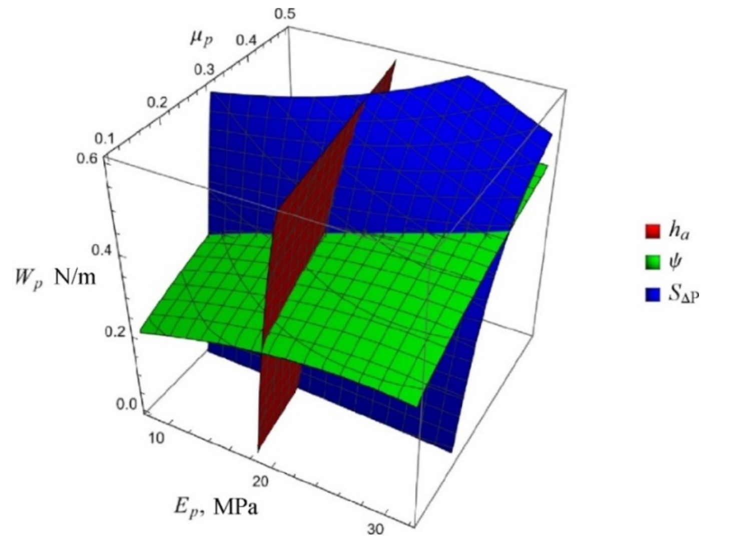


Figure 5 – Visualization of the intersection function of the system of equations at $D_\mu$ = 0.5 mm, W = 20.7 %, T = 137.0 °C

*Source: developed by the authors*

For rational technological parameters, we have: $D_\mu$ = 0.5 mm, W = 20.7 %, T = 137.0 °C → $E_p$ = 22.3 MPa, $\mu_p$ = 0.31, $W_p$ = 0.49 N/m → $S_{\Delta P}$ = 0.772 MPa, Ψ = 1.519, $h_a$ = 13.2 mm. The calculated parameters were used in Section 2 when creating the model of the expander forming process.

Comparison of dependencies $S_{\Delta PE}(D_\mu)$ and $S_{\Delta PT}(D_\mu)$, $\Psi_E(D_\mu)$ and $\Psi_T(D_\mu)$, $h_{aE}(D_\mu)$ and $h_{aT}(D_\mu)$ will be conducted under the condition of rational technological parameters (Fig. 6).

The Pearson correlation coefficient between the modeling data and the laboratory data ranges from 0.94 to 0.99, indicating the adequacy of the conducted research.

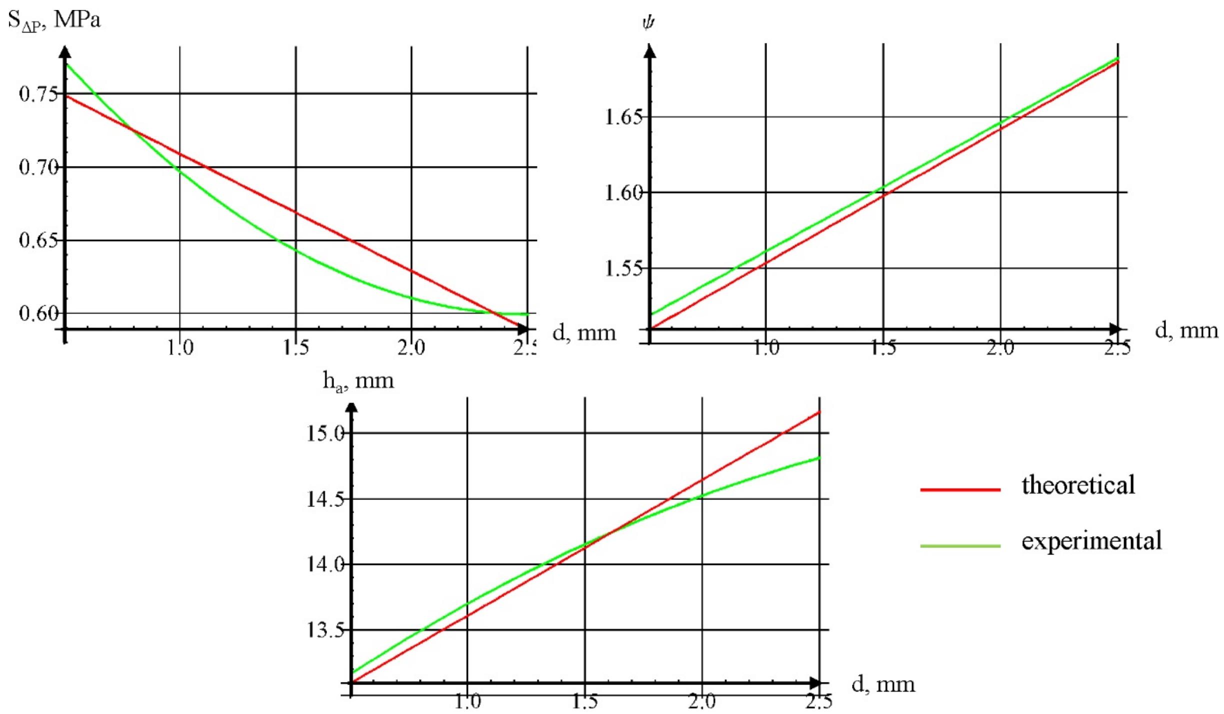


Figure 6 – Comparison of the results of theoretical and experimental dependencies

*Source: developed by the authors*

**Conclusions.** To compare the results of numerical modeling and laboratory experiments, a program was developed in the Wolfram programming language, which allows linking the technological parameters of the expansion process (W, T) with the physical and mechanical properties of the compound feeds mixture ($E_p$, $\mu_p$, $W_p$). For rational technological parameters ($D_\mu$ = 0.5 mm, W = 20.7 %, T = 137.0 °C), we have the following physical and mechanical properties: $E_p$ = 22.3 MPa, $\mu_p$ = 0.31, $W_p$ = 0.49 N/m. In this case, $S_{\Delta P}$ = 0.772 MPa, Ψ = 1.519, $h_a$ = 13.2 mm. Comparisons of dependencies $S_{\Delta P}{}^E(D_\mu)$ and $S_{\Delta P}{}^T(D_\mu)$, $\Psi^E(D_\mu)$ and $\Psi^T(D_\mu)$, $h_a{}^E(D_\mu)$ and $h_a{}^T(D_\mu)$ will be conducted under the condition of rational technological parameters, and a sufficiently high Pearson correlation coefficient (0.94–0.99) has been established.

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**Ельчин Алієв,** проф. кафедри інженерії технічних систем, д-р техн. наук, ст. дослідник
**Олександр Кобець,** доц. кафедри тракторів і сільськогосподарських машин, доц., канд. техн. наук
**Микола Лінко,** здобувач третього (освітньо-наукового) рівня вищої освіти,
*Дніпровський державний аграрно-економічний університет, Дніпро, Україна, aliev@meta.ua*

## Фізико-математична модель процесу стиснення компонентів комбікорму у експандати

Метою дослідження є перевірка правильності висновків, отриманих з теоретичних досліджень, шляхом обґрунтування експериментально основних параметрів та режимів роботи процесу стиснення компонентів комбікорму. Для порівняння результатів чисельного моделювання і лабораторних досліджень складено програму на мові програмування Wolfram, яка дозволяє зв'язати технологічні параметри процесу експандування (W, T) із фізико-механічними властивостями суміші комбікормів ($E_p$, $\mu_p$, $W_p$). Алгоритм якої включає наступні кроки: постановка рівнянь регресії у вигляді функції кількох змінних; встановлення технологічних параметрів W, T, $D_\mu$ за допомогою функції динамічних повзунків; візуалізація функції перетину системи рівнянь вигляді тривимірного графіка; розв'язування системи рівнянь за допомогою функції чисельного обчислення NSolve; побудова графіків залежностей $S_{\Delta P}{}^E(D_\mu)$ і $S_{\Delta P}{}^T(D_\mu)$, $\Psi^E(D_\mu)$ і $\Psi^T(D_\mu)$, $h_a{}^E(D_\mu)$ і $h_a{}^T(D_\mu)$. В якості критерію оцінки пружних властивостей компонентів комбікорму було вирішено визначити зважені площі петлі пружного гістерезису $S_{\Delta P}$ і коефіцієнт механічних втрат Ψ на основі середнього діаметра частинок суміші $D_\mu$, модуля Юнга $E_p$, коефіцієнт Пуассона $\mu_p$ і робота адгезії на одиницю площі $W_p$. Площа $S_{\Delta P}$, укладена в межах петлі пружного гістерезису, являє собою питому енергію (роботу), перетворену в теплову енергію на кожному етапі деформації. Відхилення деформацій від напружень і створювана ними петля пружного гістерезису пов'язані з так званим внутрішнім тертям матеріалу. Коефіцієнт механічних втрат Ψ визначається як відношення площі петлі гістерезису $S_{\Delta P}$ до площі, укладеної між кривою напружень і віссю абсцис, де відкладено деформації $S_{P1}$. Для раціональних технологічних параметрів ($D_\mu$ = 0,5 мм, W = 20,7 %, T =

137,0 °С) маємо наступні фізико-механічні властивості $E_p$ = 22,3 МПа, $\mu_p$ = 0,31, $W_p$ = 0,49 Н/м. При цьому $S_{\Delta P}$ = 0,772 МПа, Ψ = 1,519, $h_a$ = 13,2 мм. Порівняння залежностей $S_{\Delta P}^E(D_\mu)$ і $S_{\Delta P}^T(D_\mu)$, $\Psi^E(D_\mu)$ і $\Psi^T(D_\mu)$, $h_a^E(D_\mu)$ і $h_a^T(D_\mu)$ проведемо при умові раціональних технологічних параметрів і встановлені достатньо високий коефіцієнт кореляції Пірсона (0,94–0,99).
**корм, пресування, стиснення, чисельне моделювання, лабораторні дослідження, змішування, тиск, параметри, фізико-механічні властивості, ефективність**

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**Ю.О. Ковальчук,** доц., канд. техн. наук, **І.О. Лісовий,** доц., канд. техн. наук,
**В.В. Кравченко,** доц., канд. техн. наук
*Уманський національний університет садівництва, м. Умань, Україна*
*e-mail: temp14053@gmail.com*
**А.О. Ковальчук,** доц., канд. техн. наук
*Харківський національний університет повітряних сил імені І. Кожедуба, м. Харків, Україна*

# Лазерне зміцнення інструментів та деталей обладнання ремонтних майстерень автомобільного транспорту в АПК

Досліджено вплив лазерної обробки на приповерхневу мікроструктуру сплавів. Показано, яка сталь матиме максимальну твердість в результаті лазерного зміцнення серед сталей 40Х13, 30Х13 та 20Х13. Визначено оптимальний рівень розчинення в сталях Р6М5, 9ХС і ХВГ вихідних карбідів для отримання максимально можливої твердості при їх лазерній обробці. Досліджено значення мікротвердості та термостійкості бронзи в результаті її лазерного зміцнення. Відмічено значне збільшення терміну експлуатації загартованих лазером виробів в порівнянні зі стандартною термічною обробкою.
**лазерна обробка, лазерне зміцнення, гартування, зносостійкість, мікротвердість**

**Постановка проблеми.** Нині не втрачає своєї актуальності питання збільшення ресурсу виробітку різних інструментів та деталей обладнання ремонтних майстерень автомобільного транспорту в АПК. Забезпечення їх більшої міцності та зносостійкості є однією із першочергових задач, що стоять перед відповідними виробниками.

Багато інструментів та деталей обладнання ремонтних майстерень автомобільного транспорту в АПК, такі як вимірювальні, ріжучі та різьбонарізні інструменти, свердла, мітчики, плашки, фрези, пружини, підшипники, деталі поршневих компресорів, редукторів, різноманітних станків, інструменти, що працюють з ударними навантаженнями та інше технологічне оснащення, які повинні задовольняти відповідні вимоги щодо міцності та зносостійкості, виготовляються з таких сплавів, як, зокрема, сталі 40Х13, 30Х13, 20Х13, Р6М5, 9ХС, ХВГ та з бронзи. Для їх зміцнення може успішно застосовуватися метод лазерної обробки.

Відомо, що під час зміцнення лазером різних інструментів та деталей зі сталі та інших сплавів важливим фактором впливу на їх ресурс виробітку є мікротвердість та