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Статистичне моделювання впливу режимних параметрів процесу термічного модифікування деревини в середовищі вуглекислого газу на динаміку зміни її щільності

Досліджено зміну щільності деревини дуба в процесі термічного модифікування методом високочастотної денситометрії. З використання методу множинної регресії отримано математичні залежності зміни щільності деревини при її термічному обробленні в середовищі CO_2 та графічні залежності поверхні відклику рівнянь регресії.

Ключові слова: щільність деревини, термічне модифікування, статистична обробка, високочастотна денситометрія, множинна регресія.

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IDENTIFYING THE WORKING CONDITIONS OF FLAT DIE PELLET PRESS HOLES WITH PREDETERMINED GEOMETRICAL PARAMETERS

The method for determining the working capacity of flat die pellet press holes with predetermined geometrical parameters has been proposed.

Keywords: pellet press, hardwood pellet, flat die, hole geometry.

Introduction. The characteristics of a flat die in pellet press can determine its performance through the blank and effective thickness, the reliefs and the hole pattern [1]. The most important physical characteristics of a flat die are the blank thickness and the effective thickness. The blank thickness determines the overall strength of the flat die. The thicker the blank, the more it resists deflection caused by the rollers. Blank thickness should be increased instead of ligament thickness, especially in cases of repeated circumferential breakage.

Effective thickness is the length of the pellet chamber that will perform the pelleting. Effective thickness governs the amount of work the flat die will perform on a material, increasing pellet quality. Changes in material necessitate changes in effective thickness due to changes in the materials coefficient of friction [1-7].

Reliefs were developed so that increased blank thickness could be used with applications that needed thinner effective thicknesses. Currently, there are two major types of relief's: straight hole and tapered. Straight holes can be oversized, while tapered holes can be at different angles. Tapered reliefs are extended by adding a straight relief to it. These two reliefs' can be drilled in three methods: variable, non-variable, and special variable.

Standard is the normal pattern and the heavy one is used in high pressure, for hardwood waste. These patterns, when applied to various wood materials, will give different results. Every opportunity should be taken to get maximum hole count in a flat die as it increases the throughput and die life.

Research objectives – determination of movement condition of hardwood wastes, during compaction in a die hole with specific geometry.

For flat die standard hole to formulate efficiency condition by changing its basic geometrical parameters.

Let p_0, p_1, p_2 – pressure at the inlet to the channel, the output from the first and second parts; p – pressure on a layer of material; T – friction; p_b – the pressure on the lateral surface; 2φ – the angle at the top of the cone in the first section; d_1, d_2 – the diameter of the channel on the first and second sections

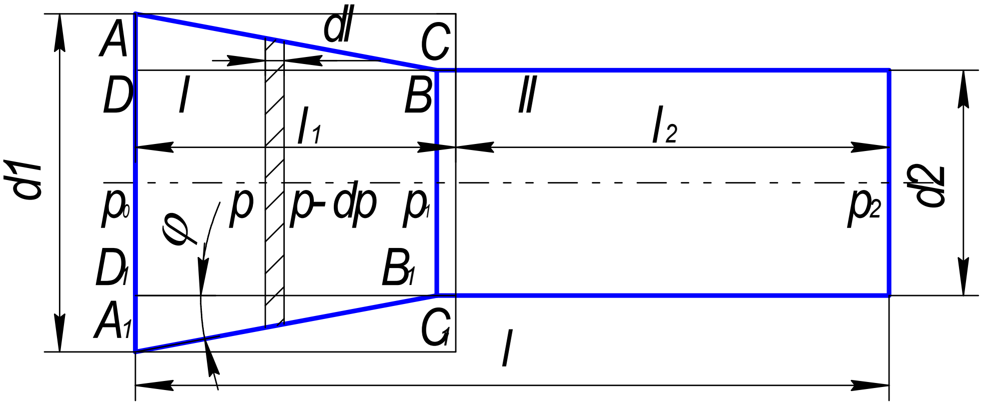


Fig. 1. Geometry of standard hole for pellet press with flat die. Design scheme

Equation for friction and pressure forces on the lateral surface of the layer can be written as: $T = \pi dpf\xi dl$, $p_b = p\xi$ (1)

where: ξ – coefficient of lateral friction; f – coefficient of external friction.

We assume that the product of the lateral pressure on the friction coefficient does not vary along the length of the channel [2]. We write the equation of equilibrium of all forces on the length of the layout of the material length. Taking as a positive trend of specific pressure movement direction of the mass of material, we obtain:

$$-\frac{\pi d_2^2}{4} dp = \pi d_2 pf\xi dl . \quad (2)$$

After transformation: $$-\frac{dp}{p} dp = \frac{4}{d_2} f\xi dl \quad (3)$$

On integrating the left side of the equation from p_1 to p_2, and right from 0 to l_2, we have: $$p_2 = p_1 \exp\left(-\frac{4}{d_2} f\xi l_2\right) \quad (4)$$

Consider the first conical section. The expression (1) shows that the friction force and the pressure are increasing when the diameter and the length of the hole are increased because: $$T_k \le T_{ACC_1A_1} \quad (5)$$

where: T_k – the friction in the conical section ABB_1A_1; $T_{ACC_1A_1}$ – friction in the cylinder with a diameter d_1 and length A_1B_1. On the other side of the equation (4) it is shownshows that for reducing walues in the bursting pressure of the material through the die hole it is necessary to reduce the channel length and increase in diameter, so:

$$P_1 := P_{1,k} \le P_{1,DBB_1D_1} \quad (6)$$

where: P_k – the pressure in the conical section, ABB_1A_1 – pressure in a cylinder with a diameter d_2 and length l_2. Then condition of equilibrium can be written as follows:

$$T_k \le T_{ACC_1A_1} = P_1 \le P_{1,DBB_1D_1} \quad (7)$$

$$-\frac{\pi d_2^2}{4} dp = \pi d_1 pf\xi \frac{dl}{\cos\varphi}, d_1 = d_2 + 2l_1 \tan\varphi \quad (8)$$

After transformation we obtain: $$-\frac{dp}{p}=4\frac{d_2+2l_1\tan\varphi}{d_2^2}f\xi\frac{dl}{\cos\varphi} \tag{9}$$

On integrating the left side of the equation from p_0 to p_1 and the right one – from 0 to l_1, we have:

$$\ln\left|\frac{p_1}{p_0}\right|=-4\frac{d_2+2l_1\tan\varphi}{d_2^2\cos\varphi}. \tag{10}$$

Than: $$p_1=p_0\exp\left(-4f\xi l_1\frac{d_2+2l_1\tan\varphi}{d_2^2\cos\varphi}\right). \tag{11}$$

From formulas (4) and (11), we obtain:

$$p_2=p_0\exp\left(-4f\xi\left(\frac{l_2}{d_2}+l_1\frac{d_2+2l_1\tan\varphi}{d_2^2\cos\varphi}\right)\right) \tag{12}$$

A necessary condition for the movement of material through the hole is the excess pressure forces needed to overcome the material force of friction is:

$$\frac{1}{3}\pi\left(d_1^2+d_1d_2+d_2^2\right)(p_0-p_1)+\pi\frac{d_2^2}{4}(p_1-p_2)>$$
$$>\pi(d_1+d_2)\frac{l_1}{\cos\varphi}f\xi(p_0-p_1)+\pi d_2l_2f\xi(p_1-p_2) \tag{13}$$

And $$\left(\frac{1}{3}\left(d_1^2+d_1d_2+d_2^2\right)-(d_1+d_2)\frac{l_1}{\cos\varphi}f\xi\right)\left(1-\exp\left(-4f\xi l_1\frac{d_2+2l_1\tan\varphi}{d_2^2\cos\varphi}\right)\right)>$$
$$>\left(d_2f\xi l_2-\frac{d_2{}^2}{4}\right)\left(1-\exp\left(-\frac{4}{d_2}f\xi l_2\right)\right) \tag{14}$$

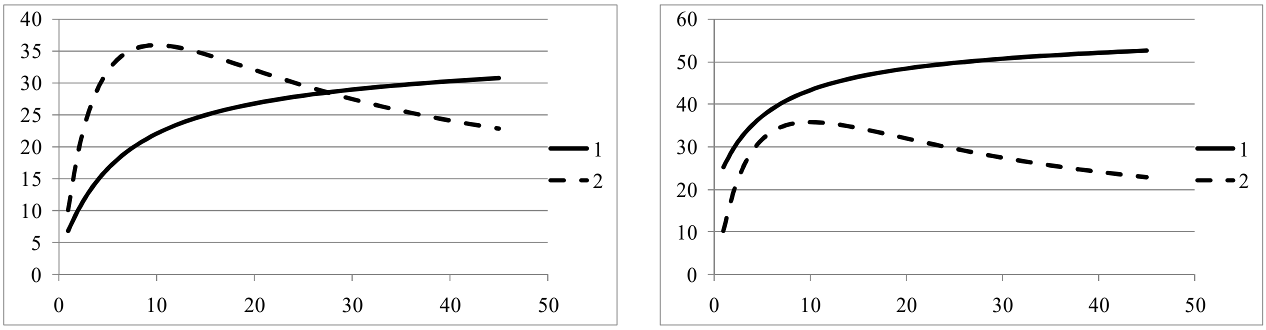
To determine the efficiency of the die hole, we performed a computational experiment. For the basis is taken experimentally obtained parameters of granulation in a single channel pelleter [3].

Initial data for numerical experiment are as follws:

- coefficient of lateral friction, $\xi=0{,}6$;
- coefficient of external friction, $f=0{,}39$;
- diameter of cylindrical areas, d_2 = 6; 7; 8; 9;
- diameter of the cone base areas, $d_1=1{,}0\div1{,}5\cdot d_2$;
- the angle at the top of the cone on the first plot, $\varphi=5^o\div50^o$;
- the recommended [4] length of the hole L, L = 3,25 d_2.

Tu outline limits change of basic geometric parameters of the standard hole geometry (Fig. 1) relation is used (14). Based on initial data four computational experiments for diameters of cylindrical parts were held. Fig. 2, shows the correlation of forces acting on the material in order to push through the channel (number 1) and the forces that resist movement (number 2). The experiment was conducted in relative units. Therefore, the results can only serve to define boundaries of die hole performance with given geometry. After a series of experiments, in which the above mentioned factors were analyzed, the generalization of the limits of performance of the die hole for a given coefficient of lateral friction ξ=0.6 and external friction *f*=0.39. Adequacy of the proposed model illustrated Fig. 2 a, b.

The increase in the total length L, hampers material transfer in the hole, and, at a certain threshold value for the given conditions (L = 38 mm) – Fig.2b, the channel becomes inoperable. For fixed values $d_1=1{,}0\div1{,}5\cdot d_2$ of the diameter of base conic section with step 0.2 hole performance interval is defined in which the left part of the relationship (11) is greater than the right. Family united in set intervals, gives as an idea to build the performance area with preserving mobility criterion of the material in the hole. Figure 3 shows the four zones of performance for die hole with fixed diameter of cylindrical section. Each zone is bounded be above quantity and is equal $t = 1{,}5 \cdot d_2$. This is not expedient to use the base diameter of the cone channel larder than holes in the die step t.



a) b)

Fig. 2. Analysis the performance of die hole by changing its overall length:

a) hole functioning within the angle $\varphi = 5^{i} \div 26^{i}$ at L = 26 mm,

b) hole capacity is completely lost at L = 38 mm

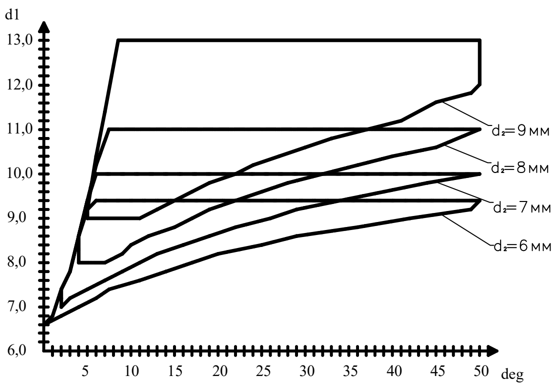


Fig. 3. Working condition for fixed diameter die hole in absolute units.

Conclusions: With prolonged use of die, depth and shape of the original tapered holes become distorted. We can grind flat die to a smaller thickness, but in general, it will reduce the overall length of the channel and change the lengths ratio of conical and cylindrical parts of hole. The above formulas show that even while maintaining the movement conditions in the channel, pressing material particles may not work. So when we may produce flat pellet die with such geometrical parameters of holes to further flatness is recovered. The proposed method can identify the limits of working capacity for known hole geometry. This will ensure the nominal conditions of pressing the mixture and keep the condition of material motion in the die hole during the whole operation.

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Ідентифікація умов працездатності каналів із заданими геометричними параметрами в грануляторі із плоскою матрицею

Запропоновано метод визначення працездатності отворів плоскої матриці гранулятора із заданими геометричними параметрами.

Ключові слова: гранулятор, паливні гранули, плоска матриця, геометрія каналу матриці.

UDC 674.028.9.004.15:519.216.3 ***Assoc. prof. B.Ya. Kshyvetskyy – UNFU; prof. M.G. Chausov – National University of Life and Environmental Sciences of Ukraine***

STRESS MODELLING FOR THERMOPLASTIC ADHESIVE WOOD JOINTS

The paper concerns modelling stresses in thermoplastic adhesive wood joints. As a result of modelling heat-and-mass transfer, the distribution pattern of normal and tangential stresses was revealed and their influence on the durability of thermoplastic adhesive wood joints was shown.

Keywords: adhesive joint, moisture, heat transfer, stress-strain condition, strain and relaxation processes, stress components.

The mathematical calculations for moisture transfer which are presented in the work [1] enabled to mathematically describe the effect of cyclic variation in moisture content on thermoplastic adhesive wood joints. The studies presented in the works [2, 3, 4] show that the cyclic variation in moisture and temperature results in increased stresses in thermoplastic adhesive wood joints, also this causes changes in the stress-strain condition. The amount of stresses that develop in the adhesive joint will depend on many factors of which physical and mechanical properties of the material to be glued, that is wood, and the material that glues, that is an adhesive, are of paramount importance. The effect of cyclic variation in moisture content and temperature on the adhesive wood joints during their service is responsible for changes in the stress-strain condition both of the wood and the glue line.

Thermoplastic adhesive wood joints, as contrasted with thermosetting ones, are able to relax the stress-strain condition to a certain point of time. This is possible due to elasticity of the glue line whose relaxation limits are determined by physical and mechanical properties of the thermoplastic glue film [5].

The stress-strain condition as well as relaxation processes that take place in adhesive wood joints are directly related to the change in wood joints strength and are responsible for their durability. This is supported by the works devoted to the issue of strength and durability of thermoplastic adhesive wood joints [6, 7, 8]. To describe mathematically the deformation and relaxation processes that occur in thermoplastic adhesive wood joints is not an easy task; however, it must be done since this would provide a means of detailed studying and modelling the processes involved.