FEATURES OF BIO-BRIQUETTES PRESSING WITH THE PISTON BRIQUETTING PRESS

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Abstract. The paper considers the problem of efficient use of presses with a piston working body for the bio-briquettes production. Structural analysis of the piston briquetting press "BrikStar" model is done and pressing areas are described in detail. The patterns of a material pressing process are analyzed in the working chamber of the matrix with a cut. Interpretation of a character and a behavior of taut portion of the material in the working process allowed proposing a scheme of forces and diagrams of pressures in the pressing chamber pressing matrix with a cut. The expression describing the regularity of axial pressure change along the pressing chamber is presented down as well.

Keywords: plunger, matrix with the cut, lateral pressure, axial pressure, friction, briquette, strain relaxation, matrix compression force.

Introduction

Solving of the problems associated with the production of solid biofuels as an environmentally friendly energy sources depends on the selection of technological equipment. Piston-type briquetting press "BrikStar" seems to be the most effective from the existing types of briquetting presses due to its quality and energy characteristics. The goal is to improve the efficiency of its use by improving the quality of raw materials and selection of appropriate technological regimes. What is why we proposed structural model of a piston briquette press and power analysis of the material pressing process in the working chamber of the matrix with the cut, in accordance to our own researches and the researches of leading scientists in this field. The aim is to establish the optimum regimes of bio-briquettes pressing in this type of press and determine a rational composition of their components that provide a biofuel with high consumer characteristics.

Material and methods

Structural analysis of piston briquetting press model. Briquetting press "BrikStar 50 – 12" allows to obtain briquettes with diameter of 65 mm and a length of 30...50 mm. Material for the briquettes production - biowastes (husks of sunflower seeds, sorghum stalks, wood chips, sawdust, chopped stem mass of cereals, etc.) does not contain any binder, and the effect of hardening is achieved only through the high pressure in a cylindrical matrix, opposition of the material and thanks to gluing adhesive forced out of material sells. Experience of the briquette press operating revealed that the most important element in the briquettes obtaining process is the press device, because a performance, consumption and quality of the briquettes depend on its efficiency. Accordingly the structural analysis of piston briquetting press is conducted and schematically shown in Figure. 1. Pressing device of the press includes (Figure 1): a hydro-drive with the electric drive and adjusting elements 1; the pressing piston of the main hydrocylinder 2 with a punch 3; the feeder of a material from the bunker with screw 4 and valve 5; dosing out chamber 6; a matrix with a cut 7 and the pressing chamber 8; system of a clip of a matrix 9 with a hydraulic drive 10; device for additional compression and relaxations of briquettes 11.

For convenience, the press device (Figure 1) is divided into zones: 0 - metering chamber; I and II working zones of pressing chamber and III – additional compression and strain relaxation. According to it, on the scheme are shown: ρ_0 - initial density of an initial material; - final density a briquette; P_0 – axial pressure created by a punch 3; d-diameter of a punch; $P_г$ -pressure in hydrosystem; D-diameter of the piston of the hydrocylinder; P_{xI}, P_{xII}, P_{xIII} - axial pressure in various zones of pressing; V_0 - volume of an initial portion; V_I, V_{II}, V_{III} - volumes of briquettes portions changing during pressing; $P_{сж}$ – effort of compression of the cut part of a matrix.

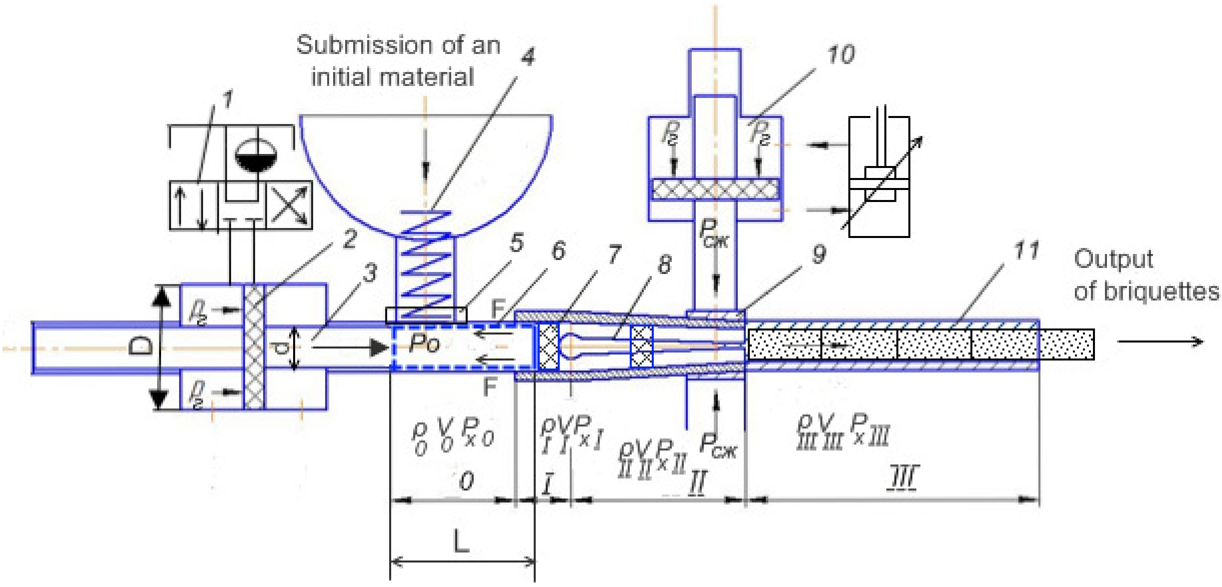

Fig. 1. **The block diagram of experimental installation for the biobriquettes production**

Characterizing stage by stage the working process of pressing, it is possible to conclude that the initial material submitted by the screw has following characteristics ρ_0, V_0, P_{x0} (zone 0). Under action of the axial pressure P_0 created by the hydraulic cylinder 2 with working pressure $P_г$, the portion of weight in the dosing out chamber 6 is compressed by a punch pressed through into working zone I of a matrix 7 and condensed, changing the characteristics up to ρ_I, V_I, P_{xI} (zone I) and further - ρ_{II}, V_{II} и P_{xII} (a zone II). Each new portion of the material forces the way from a working zone of matrix I in a working zone of matrix II, at the subsequent work of a punch 3. Here the matrix 7 is executed with the cut, allowing compressing its end by means of the tightening device 9. Thereof, the working part of the pressing chamber 8 takes the form of a cone. And the conditions of pressing pressure rise up to P_{xII} are provided at punching portions of a briquette through a zone of II pressing chamber. It increases durability as well, and improves quality of briquettes. The essence of processes occurring in the chamber will be considered below. On output of a matrix 7 briquettes pass through the device 11. It leads to their additional compression and a relaxation of pressure (zone III - ρ_{III}, V_{III} *u* P_{xIII}). Use of the device 11 allows increase of briquettes quality as there is a relaxation of internal pressures in briquette, as well as it leads to its durability increase (owing to absence of microcracks).

Results and discussion

Analysis of regularities of the material pressing process in the matrix chamber with a cut. Analysis of the pressing of different materials held by Farbman, Melnikov, Osobov, Nekrashevich, Mazancova, Hutla etc. allowed to obtain the relationship between performance and power density of monoliths. The empirical expressions relating the pressure of pressing with the physical and mechanical properties of the material and the density derived monoliths were proposed.

Accordingly, let's analyze the pressing process of a material in the pressing chamber of a matrix with a cut of the piston press and let's consider the pressing process in the pressing chamber of a matrix as in the open channel in more details. Using substantive provisions of the theory of pressing of biological materials, let's work out the equation of pressing of materials in the channel of a matrix – as at the pressing chamber. The main indicator of the materials pressing process is the ultimate density of the produced briquettes. It depends on the magnitude of the applied pressure to the compressible material. The relationship between these values determines forces acting in the details and arrangements of machines, and energy enough for the compaction.

In justification of pressing pressure R dependency on the density ρ of the material in the pressing chamber, as in the open channel (Figure. 1 (zone I – III) and 9), a number of assumptions that the initial density of a material is identical in whole volume of the pressing chamber has been accepted; initial pressures at absence of external pressure are equal to zero; normal pressures in each point of any section of the pressing chamber are identical; the density of a material during compression increases continuously; efforts of pressing, do not depend on speed of deformation.

These conditions suggest that the derivative of pressure on density is a continuous function of the applied pressure:

$$\frac{dp}{d\rho} = f(P)$$

Then the function $f(R)$ can be considered linear,

$$\frac{dP}{d\rho} = aP + b\ . \qquad (1)$$

Separating the variables and integrating both sides of the equation from ρ_o to ρ and from 0 to ρ we obtain:

$$P = c\left[e^{a(\rho-\rho_0)} - 1\right],\ \text{Pa} \qquad (2)$$

where c – constant parameter for this type of material depends on its structural and mechanical properties – density, strength , humidity, particle size, it is a resistance to compression of the material;
c = a / b, where a and b – coefficients of linear equations of the compaction. They depend on the structural and mechanical properties of the material;
e = 2.718 – base of natural logarithms;
ρ and ρ_0 – the ultimate and initial density of the material.

The resulting equation (2) is the basic equation of pressing. Along with the dependence $P = f(\rho)$ the fundamental law of compaction can be expressed similar dependence between the applied pressure and strain, so $P = f(\varepsilon)$. With regard to the relative linear deformation of compression ε, the basic pressing equation is:

$$P = c\left(\frac{e^{a\rho_0\varepsilon}}{1-\varepsilon} - 1\right),\ \text{Pa.} \qquad (3)$$

Equation 3 shows that the greater the initial density ρ_0, the more pressure must be applied to the material for the strain of the same values.

Patterns of pressures distribution along the pressing chamber. Let's consider the taut portion of the material in different zones of the pressing chamber matrix (Figures 1 and 2) and outside it in accordance to the equation of pressing 3. Figure 2 shows the scheme of forces and diagrams of pressures acting at pressing process, and their distribution along the pressing channel. The characteristic diagrams of pressures arising in the briquettes pressing process are shown in stages in different zones of the working chamber of the matrix with the cut and outside it.

The characteristic of pressing zones. OA (zone 0) - preliminary condensation of portions of the material in the dosing out chamber and its pushing through in zone I, $Px_I = \sum_{-0,5d}^{+0,5d} dP$;

AAI (zone I) - compression of portions of briquettes in a cylindrical part of the matrix – the pressing chamber and its pushing through in a zone II – axial pressure P_{xI}; residual pressure $P_{o.oI}$;

$q_{x.I}$. I - change of lateral pressure; $q_{o.б.I}$ - residual lateral pressure;

The pressing channel is compressed when the new next portion of a material is moved there (curve OA). At achievement of the certain density, the acted portion and the monolith formed earlier force the way in the channel – through zones I-II-III (curve AB). At removal of loading (the piston with a punch makes reverse motion and leaves a zone of an aperture of the channel) there is an elastic expansion of a monolith.

The back-to pushing through of a material in the channel is created by friction forces F of a monolith about walls of a lateral surface of the channel, resulting lateral pressure q_x of the material. Therefore axial pressure P_x on length of the channel rises at the beginning, especially in a zone of a cut of a matrix, and by the end of a matrix decreases (the diagram A, A′, A″). Let's allocate in the received monolith (a portion of the briquette) an elementary layer of a material dx, to explain how there is a change of axial pressure in the channel. The forces (axial pressure P_x at the left and $P_x + dP_x$ at the right) acting on the allocated layer are shown on Figure 2.

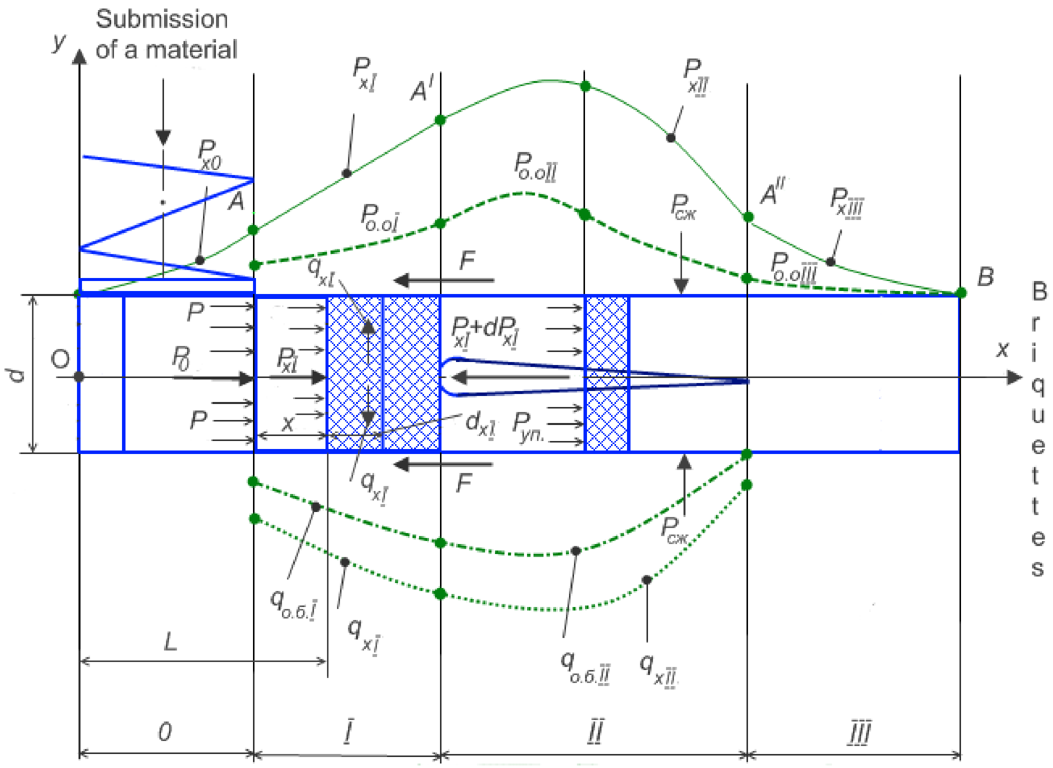

Fig. 2. **The scheme of forces and diagrams of pressure in the pressing chamber of a matrix with a cut:**

P_o – axial plunger pressure, changes by the law (the equations 2 and 3); d_x – an elementary layer (portion) of a material in the pressing chamber of a matrix; x – distance from the end face of a punch up to the elementary layer; and $P_{xI}+dp_{xI}$ – the axial pressure acting on the elementary layer; P_{yn} – pressure upon the emphasis – before the generated parts of a briquette; q_x – lateral pressure; F – force of friction

In the cross section of the perimeter of the element operates lateral pressure q_x and resulting friction force F. This force is directed along the channel of the pressing chamber in the direction opposite the axial pressure. The force F is:

$$F = fq_x \Pi_x dx \text{, N} \tag{4}$$

where f–static factor of material friction about walls of the chamber of pressing, $f = 0.2…0.25$; Π_κ – perimeter of cross-section section of the pressing chamber, m.

The equation of balance of a layer in a projection to an axis of the pressing chamber has a following appearance:

$$p_x S - (p_x + dp_x) S - fq_x \Pi_x dx = 0 \tag{5}$$

from where

$$dp_x = -\frac{fq_x \Pi_\kappa dx}{S}, \tag{6}$$

where S – the area of a lateral surface of the pressing chamber, m^2.

The sign "minus" in the right part of the equation shows, that pressure in a direction of compression decreases. Value of expression $f\Pi_\kappa/S$ is constant. Lateral pressure q_x during compression in the beginning accrues, and then decreases; therefore it is necessary to find out its functional dependence from x or p_x.

For pushing out of a ready monolith from the pressing chamber of a matrix it is necessary to put effort as it is kept in the pressing chamber of a matrix by residual friction force F0 which arises under influence of elastic expansion of a monolith, and also due to presence conical parts of the compressed cut matrix. Hence lateral pressure q_x consists of two components: the first $q_б$ - the lateral pressure arising under action of axial pressure and proportional p_x:

$$q_б = \xi p_x, \tag{7}$$

where ξ – factor lateral spacing [$\xi = \frac{\mu}{1-\mu} = const$, μ – the Paussons factor (0.29…0.31)].

The second $q_{о.б}$ - the residual lateral pressure caused by residual deformations, from axial pressure does not depend.

Thus, full lateral pressure at compression of a material makes:

$$q_x = \xi\, p_x + q_{о.б}. \tag{8}$$

Having substituted in the equation 6 value qx from the equation 8, we shall receive

$$\frac{dp_x}{\xi p_x + q_{об}} = -f dx \frac{\Pi_x}{S}. \tag{9}$$

Integrating the left part of the equation within the limits of from p up to p_x, and right from 0 up to x (l) and solving the equation rather p_x, we shall receive law of change of axial pressure on length of the pressing chamber of a matrix, without taking into account influence a the conical part of the compressed end of the cut matrix.

$$p_x = \left(p + \frac{q_{об}}{\xi}\right) e^{-\frac{f\xi\Pi_{к}X}{S}} - \frac{q_{об}}{\xi}. \tag{10}$$

The law of change of lateral pressure q_x on length of the pressing chamber of a matrix is:

$$q_x = \left(\xi p + q_{об}\right) e^{-\frac{f\xi\Pi_{к}X}{S}}. \tag{11}$$

It is established, that residual lateral pressure almost is much less than the pressure arising from action of axial pressure. In this connection, neglecting residual lateral pressure, the length of the pressing chamber L with sufficient accuracy can be defined from a condition providing reception of monoliths of the set density, i.e.

$$pS \geq f\xi\Pi_к L p, \tag{12}$$

where f – static factor of friction.

According to professor S.V. Melnikov dates for rational feed mixtures f =0.2…0.25 at T = 293 K and p = 21 MPa and f = 0.08…0.1 at T = 373 K and p = 21 MPa. From where

$$L = \frac{S}{f\xi \Pi_к}\text{, m.} \tag{13}$$

For the cylindrical pressing chamber

$$L = \frac{d}{4f\xi}\text{, m} \tag{14}$$

where d – diameter of the pressing chamber channel, m.

The power analysis of pressing process. Accordingly schemes (Figures 2 and 3) the axial pressure (force) P_0 created in this press by the hydraulic piston with diameter of cylinder D and with working pressure $P_г$ it is equal:

$$P_0 = 10^5 \cdot P_г \cdot (\pi \cdot D^2/4)\text{, H} \tag{15}$$

where $P_г$ – working pressure in the hydraulic cylinder, kPa (100 – 130 bars);

D – Diameter of the hydraulic piston, 0.14 m;
P_0 – force of press pressure, N.

Substituting dates we obtain: $P_0 = 10^2 \cdot 120 \cdot (3.14 \cdot 0.14^2/4) = 184.632$ kN.

For working pressure $P_г$ = 100-130 bars, at diameter of hydraulic piston D = 140 mm, operating press force P_0 fluctuates within the limits of from 154 up to 200 kN.

For zone I of a cylindrical matrix (Figure 2 and 3) theoretical value of axial pressure P_{xI} in the pressing chamber 8 can be defined under the formula 10.

Simplistically, pressure P_x in the pressing chamber of briquetting press (Figure 2) is presented by parity:

$$P_x = 4P_0/(10^5 \cdot \pi \cdot d^2) = 4 \times 184.6/(10^5 \cdot 3.14 \cdot 0.065^2) = 556.7 \text{ kPa}, \quad (16)$$

where d =0.065 m – diameter of a punch of the pressing chambers.

It is experimentally received – P_x = 463 up to 603 bar.

Conclusion

The solution for problems connected with increase of efficiency of piston briquetting press "BrikStar" use is provided due to improvement of quality of initial raw material preparation and a choice of corresponding technological regimes of its work. The block diagram of piston briquetting press model and the analysis of laws of the process of material pressing in the working chamber of a matrix with a cut is presented and analyzed in the paper. Results of experimental definition of parameters of pressing process in the chosen type of the pressing device promote optimal regimes for biobriquettes production.

References

1. Биомасса для энергетического использования (Biomass for Energetic Utilisation). Под ред. Проф. Б.Гаврланда. Кишинев-Прага, 2008. (In Russian)
2. Особов В.И. et.al. Машины и оборудование для уплотнения сеносоломистых материалов (Machines and Equipment for Hay and Straw Material Pressing). М. 1974. (In Russian)
3. Скляр П.А., Вранчан В.П., Побединский В.М. Переработка зерна (Grain Processing). Кишинев: Гос. Аграрный университет Молдовы, 2006. (In Russian)