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Bogdan KOSTURKIEWICZ, Andrzej JANEWICZ, Marek HRYNIEWICZ
AGH University of Science and Technology, Faculty of Mechanical Engineering and Robotics, Cracow, Poland
kostur@agh.edu.pl; janewicz@agh.edu.pl; mhryniew@agh.edu.pl

SELECTION METHOD FOR THE ROLL PRESS FEEDER

Key words: briquetting, roll presses, screw feeder, tapering-channels feeder.

Abstract: Two types of feeders used for feeding fine-grained materials into the briquetting roll press are presented in this article. Both components enable, to varying degrees, the change of pressure exerted on the material and the briquette compaction degree. It ensures obtaining the proper mechanical strength of the briquettes in the case of unstable feeding material properties and is used to increase the area of application for a given roll press. Based on own experiences of the authors from the experimental research, a simple method of selecting the roll press feeder has been presented. The method was verified in laboratory conditions.

Metoda doboru zasilacza prasy walcowej

Słowa kluczowe: brykietowanie, prasy walcowe, zasilacz ślimakowy, zasilacz zbieżnokanałowy.

Streszczenie: W artykule zwrócono uwagę na 2 rodzaje zasilaczy, które stosuje się w przypadku brykietowania w prasie walcowej materiałów trudnych do scalania. Oba podzespoły umożliwiają zmianę wartości nacisku wywieranego na materiał oraz stopnia zagęszczenia brykietów. Zapewnia to uzyskanie odpowiedniej ich wytrzymałości mechanicznej w przypadku niestabilnych właściwości nadawy oraz służy rozszerzeniu obszaru stosowania określonej prasy walcowej. Na podstawie własnych doświadczeń wynikających z badań eksperymentalnych opracowano metodę doboru zasilacza prasy walcowej, którą przedstawiono w niniejszym artykule. Została ona zweryfikowana w warunkach laboratoryjnych.

Introduction, purpose of the tests

Using roll presses for briquetting fine-grained materials is more and more popular. That is due to the benefits that include continuous work, the possibility of achieving high efficiency, lower power requirements and greater durability of forming element when compared to other briquetting presses. Some materials which are briquetting in roll presses often require a high degree of compaction and a high value of exerted pressure. A solution that enables the change of both these parameters during the press operation can be selected. It has an important meaning in the case of unstable feeding properties or the change of briquetted material. For a specific roll press it can be achieved by using a proper feeder. The type and construction features of the feeder depend on the properties of the compacting fine-grained material, especially its susceptibility to compaction [1]. There are few publications on this subject in the literature. It is due to the competition between companies where research is conducted and roll presses are constructed. Some articles include the results of the studies on screw feeders [2–4] and the model of material flow in such devices [5–8]. The abovementioned arguments caused that the publication authors took proper action. Their purpose was to develop a method of selection of the roll press feeder with given construction and technical characteristics. The results were shown in this article.

1. Gravity and tapering-channel feeder

The most often used method of feeding material into the briquetting zone is gravity feeding. It is conducted by using a gravity hopper with proper geometric construction features. In this case, the wall inclination angle and the outlet size are important factors. Their selection is decided by the following parameters: the density of the fine-grained material for briquetting, the coefficient of side pressure, and the coefficients of static and kinetic external friction. The gravity hopper may be subjected to the vibrating motion. It enables the primary feed venting and enhances the parameters of the flow into the roll press compacting zone.

The Department of Manufacturing Systems AGH UST employees have developed a new type of feeder that combines the features of vibration and gravity feeders [9]. It is called a "tapering-channel feeder." This component is designed to work with a roll press with a horizontal layout of forming rollers. Construction, the kinetic diagram and the operation method of the tapering-channel feeder is shown in Fig. 1.

The use of the elements of compacting aims to initially pack the grained material in forming cavities and extend the time under pressure. It is connected with the increase in its value.

Theoretical considerations related to condensing the fine-grained material in the roll press led to the idealization of the compacting system. Briquetting was replaced with rolling the loose material by using the "replacement roller layout" [10, 11]. After comparing the total volume of the forming cavities in the briquette working roller with the volume of flat rolled band in the replacement layout dependence (1) was achieved that shows the relation between roller radiuses in real and replacement layouts:

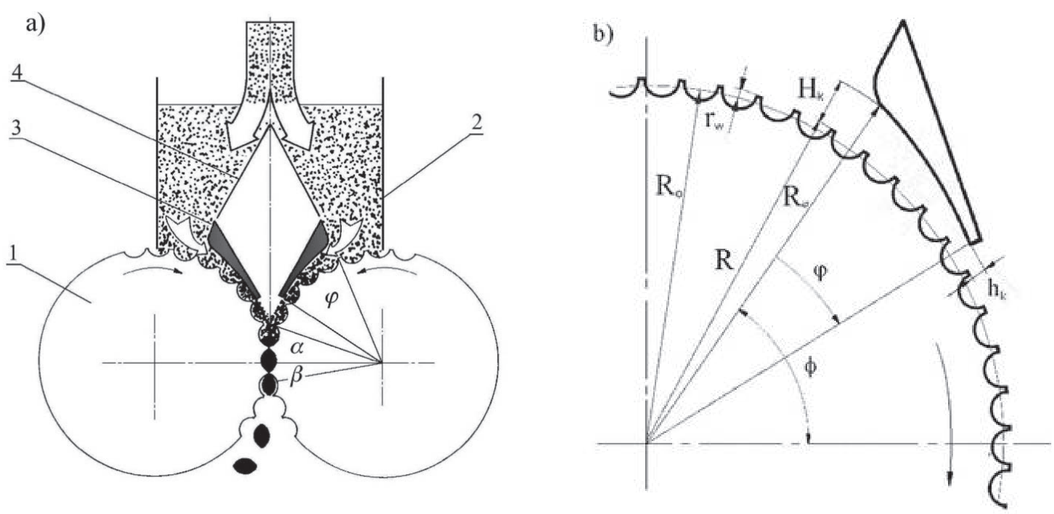

Fig. 1. Tapering-channel feeder: a) diagram: 1 – working rings of the roll press, 2 – feeding container, 3 – elements of preliminary compacting, 4 – elements separating the flowing feed, φ – initial compacting zone in tapering channels of the feeder, α – zone of densification and briquetting of the roll press, β – zone of briquette back-expansion, b) geometry of the thickening channel: R_o – roller radius in the replacement layout, R – real roller radius, $R_φ$ – radius of the channel inlet slot, r_w – thickness of the strip in the replacement layout, H_k – the height of the channel inlet slot, h_k – the height of the channel outlet slot, Φ – total zone of compaction [9]

$$R_o = \sqrt{R^2 - \frac{kV_b}{2\pi B}} \quad (1)$$

where
- R_o – roller radius in the replacement layout [m],
- R – real roller radius [m],
- k – number of roller forming cavities [-],
- V_b – briquette volume [m^3],
- B – roller active width [m].

Compaction degree s achievable in the roll press with the feeder is provided by the dependence (2):

$$s = s_w s_b \quad (2)$$

where
- s_w – initial compaction degree in the feeder [-],
- s_b – the compaction degree achieved in the zone between press rollers [-].

The compaction degree achievable in the tapering-channel feeder is provided by the following formula (3):

$$s_w = \frac{H_k + r_w}{h_k + r_w} \tag{3}$$

where

H_k – the height of the channel inlet slot [m],
h_k – the height of the channel outlet slot [m].

The compaction degree achievable in the zone between the press rollers is [11]:

$$s_b = \frac{h_p}{e} \tag{4}$$

where

h_p – the distance between replacement rollers at the nip angle level that determines the beginning of material compacting [m],
e – slot width between rollers in the replacement layout [m].

After using Formulas (3) and (4) with the Dependence (2) and transforming the expression, Formula (5) was obtained, which enables the calculation of the height of the inlet slot required to achieve the total compaction degree *s* that enables the required mechanical strength of briquette:

$$H_k = \frac{es\left(h_k + r_w\right)}{h_p} - r_w \tag{5}$$

The total compaction degree required is defined in the experimental way by the determination of the material compaction characteristics. In theoretical considerations, the limiting conditions that result from the plastic material flow should be included.

2. Screw feeder

A screw feeder is a component that is often used to feed material into the compacting zone of a roll press. It is a well-known construction solution. Basic functions of this feeder include homogenization and initial material compaction as well as overcoming the resistance of flow caused by damming in the outlet. The screw feeder is used in the case of classic briquetting and compacting, which is based on material compacting in the press with smooth rollers. Figure 2 shows both examples of the screw feeder operation. The use of the screw feeder provides beneficial effects of an increase in material pressure, an increase in the compaction degree, and ensuring the uniformity of the flow. It guarantees stable product quality as well as increased press efficiency. The aforementioned issues were the subject of research that was also presented in other publications [12–16]. However, information on the selection of construction features of the feeder was not provided.

The screw feeder has the functions that make two zones: feeding and homogenization and initial compaction. Material feeding and homogenizing is achieved by using the catcher and first screw coil. The initial compaction zone includes the section from the first to the last screw coil. In this zone, the material is initially vented. It is also affected by the proper screw and cylinder surface shape. The cylinder should be constructed so that resistance caused by friction between moved fine-grained material and its wall was as big as possible. Such situation takes place when cylinder walls are grooved. In that case, the flowing fine-grained material fills the grooves. In consequence, internal friction occurs on the surface where fine-grained material and the cylinder are in contact. In contrast to the cylinder walls, the frictional resistance on the screw surface should be as low as possible. Hence, the surface roughness of the proper feeder working element should be taken into consideration. Cylindrical and tapered screws with fixed or variable stroke are used. Depending on the width of working rollers, the screw feeder is equipped with one or several working elements.

From the point of view of the correctness of material compaction process in the roll press, it is important to select the proper rotational speed of the screw. In order to determine it, a condition of fixed mass flow through the screw feeder and roll press was considered. The condition is as follows:

$$Q_m = W_m \tag{6}$$

where

Q_m – mass flow rate of the screw feeder [kg/h],
W_m – mass flow rate of the roll press [kg/h].

Substituting for Q_m[16]:

$$Q_m = 15z\pi^2\left(D_z^2 - D_w^2\right)D_m n_{sl}\frac{\tan\beta\tan\varphi_m}{\tan\beta + \tan\varphi_m}\rho_w \tag{7}$$

where

z – number of screws [-],
D_z – external screw diameter [m],
D_w – internal screw diameter [m],
$D_m = (D_z + D_w)/2$ [m],
n_{sl} – screw rotary speed [rpm],
β – angle of flow of fine-grained material in the screw feeder [°],
φ_m – average inclination angle of the screw line [°],
ρ_w – density of the material flowing out of the screw feeder [kg/m^3].

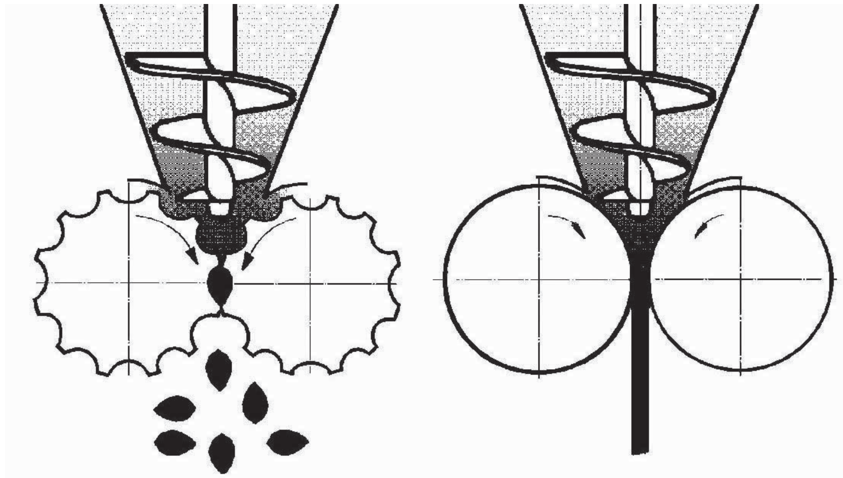

Fig. 2. The examples of the use of screw feeders in roll press assembly to execute the process of a) briquetting, b) compacting [15]

and for W_m [15]:

$$W_m = 60\ V_b i_b n_w \rho_b \tag{8}$$

where

V_b – briquette volume [m^3],
i_b – number of forming cavities [-],
n_w – press roller rotary speed [rpm],
ρ_b – briquette density [kg/m^3].

a dependence was obtained (9) that allows for the calculation of the screw rotary speed as follows:

$$n_{sl} = \frac{60 V_b i_b n_w \rho_b \left(\tan\beta + \tan\phi_m\right)}{15 z\pi^2 \left(D_z^2 - D_w^2\right) D_m \tan\beta \tan\phi_m \rho_w} \tag{9}$$

The quotient of the volume density and the material flowing out of the screw feeder is the degree of compaction achieved in the zone between rollers. Taking this into consideration and using Formula (4), we have a dependence (10) that is used to calculate the density of material flowing out of the screw feeder.

$$\rho_w = \frac{\rho_b e}{h_p} \tag{10}$$

The authors' own observations of the benefits of using the screw feeder in the roll press assembly are presented in Fig. 3. It enables increasing the nip angle α_{sl} from several to tens of percent in comparison to the gravity feed α_g. It causes an increase in the time of pressure on the compacted material and the growth of its maximum value p_{max}. We can assume that the angle of return deformation $\gamma_{sl} = \gamma_g$ under condition that the use of gravity feed enables achieving proper briquettes with satisfactory mechanical strength.

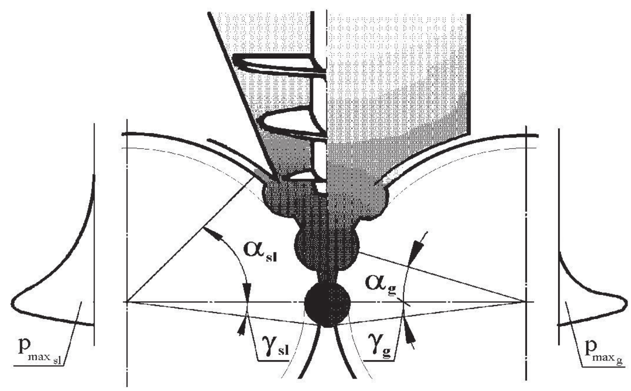

Fig. 3. Diagram showing the influence of the feeder (left side: screw feeder, right side: gravity feeder) on the nip angle value and unit pressure in the roll press forming cavity [16]

The analysis has shown that the feeder affects the material compaction process in roll press and its results. There are different types of this component; however, in practice, three types are commonly used. The method described below can be used during selection. It is related to such a case where the press efficiency and its working roller geometry are known.

3. Characteristics of the selection method for the roll press feeder

The selection procedure for the roll press feeder is presented in Figure 4. There are 5 stages.

The first is related to experimental determination of the material compaction characteristics, its analysis, and the selection of the proper feeder. If the material compaction degree does not exceed 2.0, it

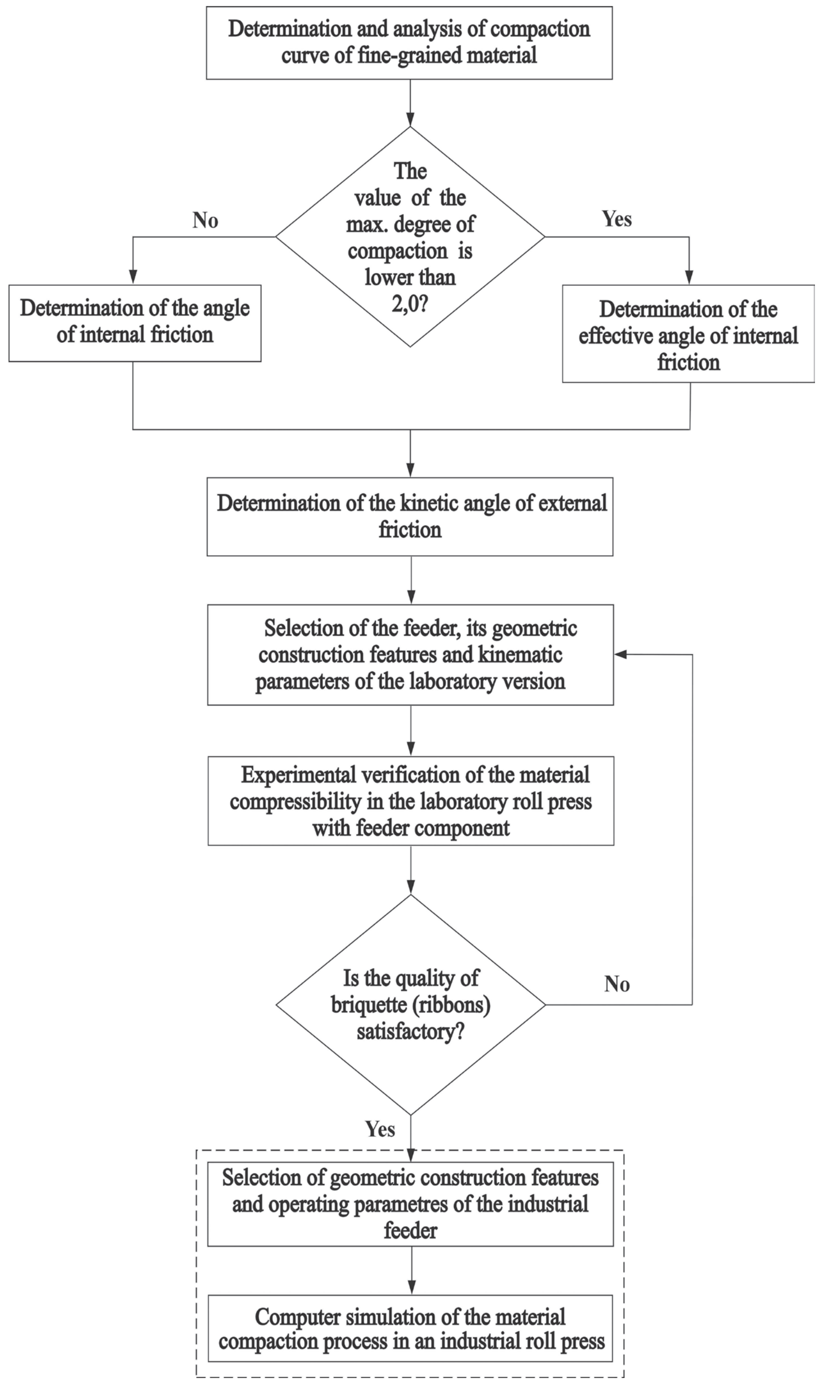

Fig. 4. Selection method for the roll press feeder

is recommended to use the gravity feeder, under the condition that the feed has stable properties. In the opposite case, the press should be equipped with, e.g., a tapering-channel feeder. Achieving the higher material compaction degree requires using a screw feeder. If the degree of compaction does not exceed 2.6, cylindrical screws are used. Higher values can be obtained by the use of tapered screws. These observations were shown in selected examples being the results of the authors' own research (Fig. 5).

During the second stage of experimental research, the angle of internal friction and the angle of kinetic external friction were determined. If the compaction degree required is not lower than 2.0, the effective angle of internal friction is determined instead of the angle of internal friction.

The third stage is related to the selection of the feeder, the determination of its geometric construction features, and the kinematic parameters of the laboratory version.

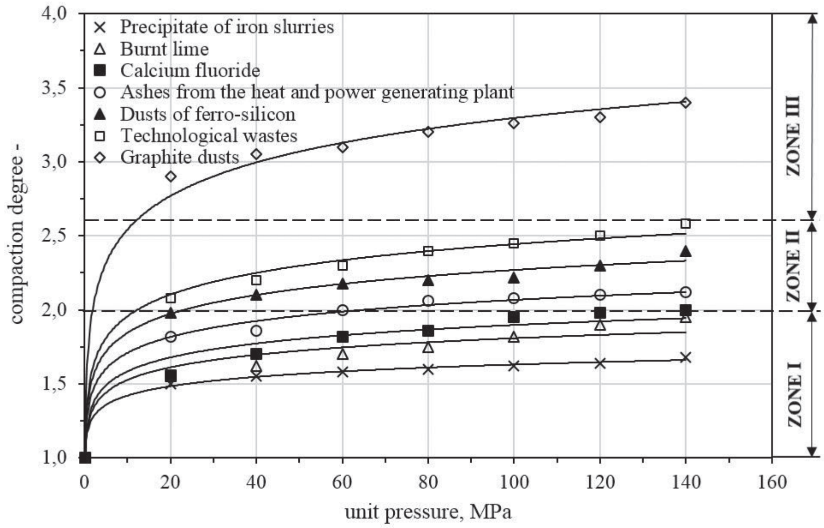

Fig. 5. Examples of the relation between the material compaction curves and the feeding type: Zone I – feeding with the gravity feeder or tapering-channel feeder, Zone II – feeding with cylindrical screws, Zone III – feeding with tapered screws [16]

The fourth stage is the experimental verification of the susceptibility of the fine-grained material on briquetting in the roll press with selected feeder equipped with proper working elements. The execution is possible only if the proper laboratory base is available. Confirmation of the applicability of the given feeder in the roll press laboratory assembly means that the next stage can be commenced.

In the fifth stage, the geometric construction features of an industrial feeder's working elements are selected. Next, the material compaction process in the roll press is simulated to verify the appropriateness of the chosen solution. A necessary condition to execute that task is the familiarity with the construction of the given roll press and its technical characteristics.

Conclusion

The properties of loose material have an important influence on the compaction process in roll presses and the results. Sometimes the properties change for different reasons. There is an increasing need for briquetting with more than just one material in the press. The change of the type or properties may cause worsening in the quality of briquettes. To avoid such a phenomenon, the press should be equipped with a proper feeder. The use of the feeder enables changing the compaction time and unit pressure value at which the material is compacted or briquetted. It affects the maximum degree of briquette compaction.

In this way, one can stabilize its mechanical strength, which decides the quality of the product. The selection of the proper feeder and its construction features and parameters is ensured by the method presented in this article. It was designed on the basis of the authors' own research conducted over many years for cognitive and utilitarian purposes. The method was verified in the laboratory-scale using the following materials: calcium fluoride, copper concentrate, brown coal, bearing chips, dusts of ferro-silicon, graphite dusts, ashes from the heat and power generating plant and post-regenerative iron oxide. It was successfully used during the selection of the feeder for an industrial roll press used for briquetting several types of brown coal of different properties.

Further research is being conducted to improve the roll presses and the process of pressure compaction. It mostly applies to continuous compaction of hard-to-briquette materials. It is anticipated that the results will allow for an improvement of the selection method of roll press feeders.

The problem of selecting the proper screw feeder also applies to fine-grained material compaction [6] and grained material milling [4].

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