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THE ISSUE OF SELECTION: SHAPE AND VOLUME OF BRIQUETTES AGGLOMERATED IN A ROLLER PRESS

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Abstract

A volume and a shape of the briquettes agglomerated in a roller press depend largely on the material properties, the design features of a roller press, and it is a complicated issue. Correctly, selected geometric parameters of the briquettes determine the proper strength of the consolidated product. The paper presents the laboratory and simulation experiments conducted to obtain knowledge about volume and shape of the roller press briquettes.

The main elements of the roller press compacting unit are the forming rollers. They are located horizontally in some roller presses of low efficiency they can be placed vertically. The shape of working surface, the volume of the melding cavities and the characteristics of the briquetted material have an important role in terms of the effects of the briquetting process especially the cost of operating of the roller press. The paper presents the description of the basic shapes of forming surfaces used in the roller presses and it systematises the knowledge of the shape and volume of briquettes produced in the roller presses on the basis of own laboratory and simulation researches.

The information contained in the article can be very useful for designers of roller presses and their users. Further work should be continued to verify the results of tests on other materials and laboratory conditions.

Keywords: *roller press, briquettes, simulation, volume of briquettes*

1. Introduction

The roller presses belong to a group of machines that are designed and manufactured for strictly defined purposes [3, 12, 19]. The basic working part of a roller press is a compacting unit. The correct selection of its configuration and constructional features is a complicated issue and often requires experimental researches [1, 7, 10, 16]. The right configuration of the compaction unit determines an uninterrupted flow of the material in a feeder, obtains a required degree of consolidation and a good product quality [2, 3, 5, 7, 15, 16]. The main elements of the roller press compacting unit are the forming rollers. Usually, they are located horizontally in some roller presses of low efficiency they can be placed vertically. The shape of working surface, the volume of the melding cavities and the characteristics of the briquetted material have an important role in terms of the effects of the briquetting process especially the cost of operating of the roller press. This paper presents the description of the basic shapes of forming surfaces used in the roller presses and it systematises the knowledge of the shape and volume of briquettes produced in the roller presses on the basis of own laboratory and simulation researches.

2. Basic shapes of briquettes

The roller press forming rollers can be made in the form of rings or segments. The rings for briquetting have melded cavities on the sides. The most common shape of the working surface is used to produce briquettes with the dividing plane (Fig. 1a, 2a). It also known its variant, in which (Fig. 1b) the lower zone of the melding cavities is shallower from the middle and upper zones, and the briquettes are in a shape of drop. This profile extends the lifetime of the forming elements and increases the unitary pressure.

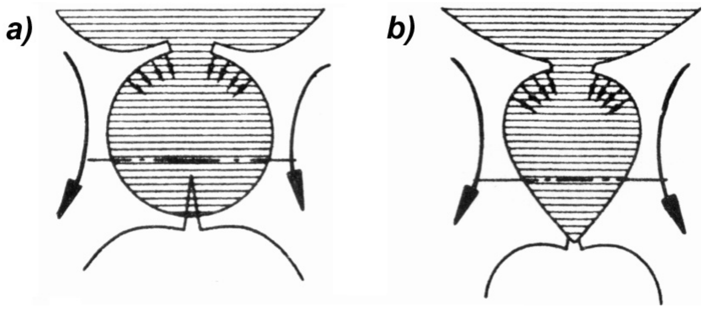

Fig. 1. Two types of forming elements for production the briquettes with a dividing plane (drop shape): a) regular, b) with flattening of the lower part [19]

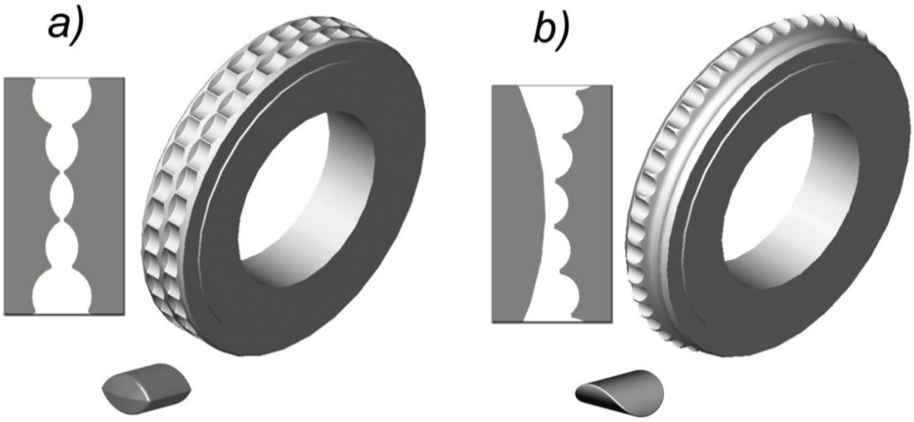

Fig. 2. Examples of roller press forming rollers to produce briquettes: a) in the shape of a drop, b) in the shape of a saddle

It prevents splitting the briquettes in the dividing plane [19, 20]. This disadvantage can be also prevented by using rollers with different working surface geometry, which allows producing saddle-shaped briquettes (Fig. 2b). This shape of the roller-working surface helps to consolidate hard-agglomerated materials in the roller press, and there is a view it allows to obtain a higher unitary pressure values in the briquetting process than the previous solution. This causes also the higher intensity of wear of the forming elements, which are less durable than the classical solution. According to literature, review [4, 6-18] researches using this type of the forming elements are conducted mainly in University of Science and Technology AGH in Krakow, Poland.

Using of a working surface to produce saddle-shaped briquettes is required for plasticity materials or which characterise high elastic deformation more than 10% after a pressure reduction. The first type of the materials has a tendency to remain in agglomerated form in the forming cavities, especially if they have a drop shape. The briquettes made of materials with high elastic deformation tend to brake in the dividing plane. This is mainly due to adverse internal stress distribution. The use of a working surface to produce saddle-shaped briquettes eliminates in the briquettes dividing plane, so prevents from sharing of the briquettes in half.

3. The laboratory and simulation researches about value of unitary pressure during briquetting in a roller press

In the experimental work, attention was focused on performing comparative studies of copper concentrate briquetting in roller press with two different working surfaces of rollers. The first one produces briquettes in the form of drops of volume 13 cm^3, the other in the form of a saddle of volume 6.5 cm^3. They are different volume, which influences of unitary pressure values, especially with gravity feeder. It is a resultant parameter and depends also on the geometrical features of the compaction unit and the properties of the briquetted material. The maximum unitary pressure value significantly influences to the density and mechanical strength of briquettes. It should not be less than the limit value. The time which material is under pressure to extract air from is also important. Values of both parameters are determined by experimental method. Laboratory experiments can also be supplemented by simulation experiments carried out using the existing program for the simulation of fine-grained material briquetting process [12]. It allows determining the course of the unitary pressure value exerted on the briquettes in the central zone of the melding cavity. The computer simulation program was made by the employees of the Department of Manufacturing Systems of University of Science and Technology AGH based on mathematical Hryniewicz model [12]. Performing a simulation of the briquetting process of a material it requires knowledge of the variability of its individual unitary resistant of consolidation (ϑ) and the coefficient of friction (μ_k). Due to the lack of these dependencies for copper concentrate, it was necessary to perform appropriate experimental research. The variability of the copper concentrate compaction resistance was measured using a ZDM-1 press and a cylindrical closed die with an internal diameter of 30 mm. The methodology descripted in [12] was used to test the material mixtures which samples were taken from mixtures prepared for briquetting in a roller press. A moisture content of the compacted material was ranged from 3.74 to 4.59%. The unit pressure value was ranged from 0 to 142 MPa. The stroke feed rate was 6 mm/min. For each moisture of the mixture measure were made three times. Compaction level was calculated by equation (1):

$$s = \frac{H_p}{H_p - x}, \tag{1}$$

where:
s – compaction level,
H_p – initial height of the compacted material,
x – displacement of the stamp.

The results of measurements and calculations are shown in Fig. 3. The regression equation (2) was determined using Statistica 8.0 and the least squares method. Taking into account the values of the coefficients the empirical formula of unitary compaction resistance assumes the following form:

$$\vartheta = 0.13165\, s^{14.68478}\, w^{-1.55615}, \tag{2}$$

where:
ϑ – unitary resistant of consolidation,
s – compaction level,
w – moisture content.

After determining the variability of the unitary resistant of consolidation, the minimum pressure required to briquette the material that was also determined. Observing the briquettes briquetted in the closed die at different unit pressures. It was noted that achieving a solid material structure requires a pressure value, which should not be less than 25 MPa.

Experiments to determine the variability of the external friction coefficient in the briquetting process of copper concentrate were carried out at a laboratory station STZ-1M symbol based on the previously developed methodology [12]. It enables reconstruction of surface phenomena occurring during briquetting at the border: compacted material – roller-working surface. In the case of determining the variation of the external friction coefficient for copper concentrate, the sample was a cylindrical briquette produced in a closed die of ∅20 [mm] diameter and a height around 5 mm. The 18HGT steel of hardness 55 HRC was chosen as a pair sample. The forming rings in the copper industry are made of this kind of steel [11]. The STZ-1M consists of two main components: the disc drive and the punch pressure system. The drive system achieves a rotation speed 10.5 min^{-1}, corresponding to the linear velocity between the briquettes and working rollers $v = 0.0438$ m/s. The pressure of the punch is realized by a hydraulic system in the range of 0-140 MPa. Results of the influence of pressure and moisture content of copper concentrate kinetic coefficient are presented in Fig. 4. It follows that coefficient of external friction pair copper concentrate – 18HGT steel for all tested samples decreases with increasing unit pressure. It was also found that the copper concentrate's moisture content influence to pressure was similar. Its growth reduces the coefficients of external friction.

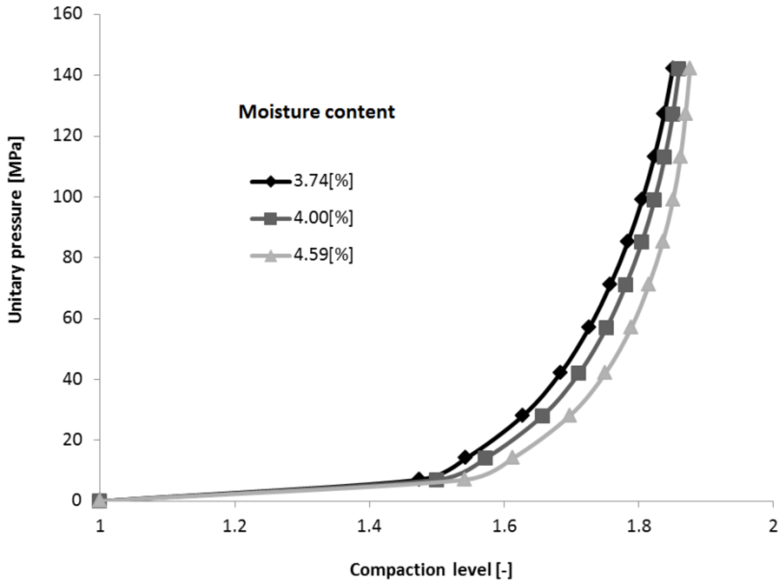

Fig. 3. Compaction level characteristics of copper concentrate for different moisture content

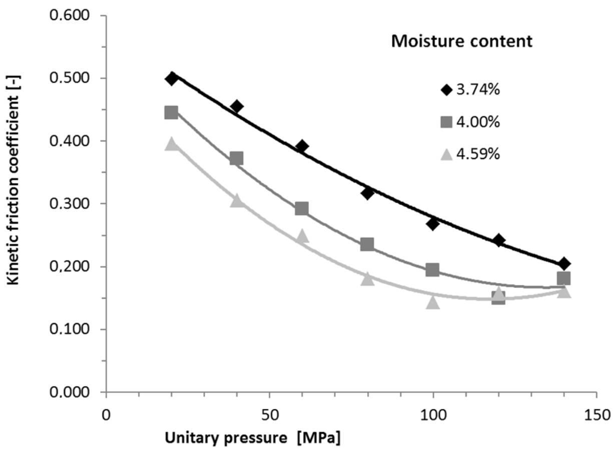

Fig. 4. The dependence of the external friction kinetic coefficient on the value of unit pressure in the process of briquetting the copper concentrate

The results of the tests were used to determine the coefficients of the regression equation, which describes the variability of the external friction kinetic coefficient. The regression equation was determined using Statistica 8.0 and the least squares method. Empirical formula assumes the following equation (3):

$$\mu_k = -1.35629\, s - 0.08215\, w + 3.01968\,, \qquad (3)$$

where:
μ_k – coefficient of kinetic friction,

s – compaction level,
w – moisture content.

Simulation experiments were carried out with the following assumptions:

- roll diameter 450 mm,
- roll width 76 mm,
- height of material in feeder 500 mm,
- the gap between the rolls 1.5 mm,
- angle defining the spring expansion zone of the briquette $\beta = 3.0°$.

The first step in the simulation study was to determine the angle of the grip. Based on the method presented in publication [13], values were determined as follows:

- $\alpha_0 = 8.4°$ for forming rings which produce briquettes in the shape of drop,
- $\alpha_0 = 7.4°$ for forming rings which produce briquettes in the shape of saddle.

The next step was to conduct a simulated study of the copper concentrate briquetting process for two types of roller working surface with a volume used in laboratory tests on used in the experiments. Comparison of the maximum unit pressure values obtained in laboratory tests in the LPW 450 roller press of roller diameter of 450 mm. In the simulation experiments is shown in Tab. 2 and Fig. 5.

Tab. 2. Comparison of maximum unit pressure values obtained during laboratory tests and simulation briquetting of copper concentrate with differentiated moisture content of briquettes

Shape and volume of briquettes	Moisture content [%]	Maximal value of unitary pressure value [MPa]			Average value of unitary pressure value (laboratory tests) [MPa]	Maximal value of unitary pressure value (simulation tests) [MPa]
drop 13.0 cm^3	3.96	28.5	25.3	23.0	25.6	23.0
	4.26	26.1	19.6	21.2	22.3	19.1
	4.43	18.9	18.7	13.4	17.0	17.2
	4.68	12.6	14.4	13.0	13.4	14.8
	5.28	17.3	13.2	—	15.2	10.6
saddle 6.5 cm^3	3.99	80.0	65.5	60.8	68.8	73.3
	4.26	59.7	57.5	35.5	50.9	60.2
	4.48	47.5	44.9	35.4	42.6	51.6
	5.16	59.3	52.2	30.6	47.4	33.0

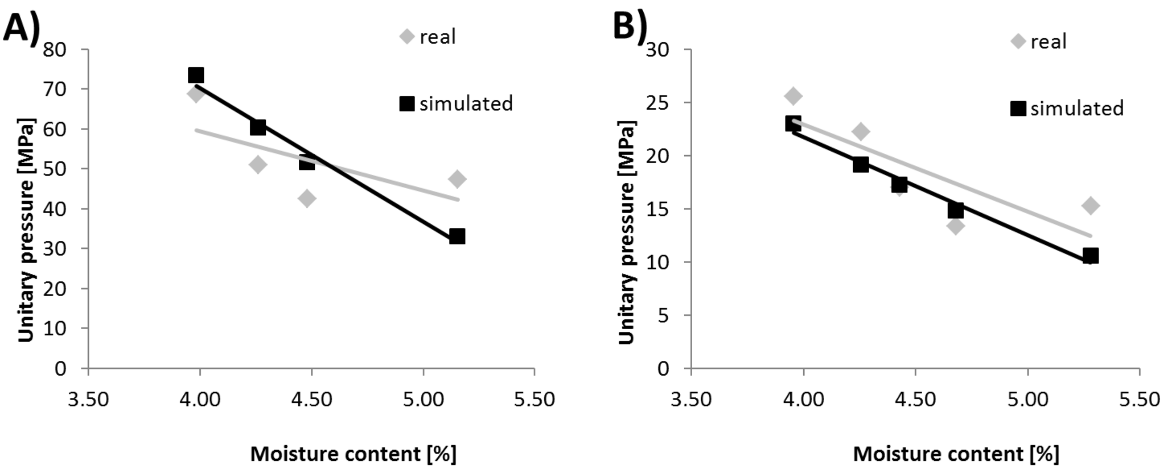

Fig. 5. Comparison of maximum unit pressure values obtained during laboratory tests and simulation of briquetting of copper concentrate with differentiated moisture content for briquettes: A) in the shape of drop of about 13 cm^3, B) in the shape of saddle 6.5 cm^3

The results of laboratory and simulation tests show high compatibility especially in the humidity range between 4.0% and 4.5%. In the case of roller working surface for the production briquettes in shape of drop, the average difference between the maximum unit pressures obtained in laboratory tests and simulation experiments is approximately 9%. For the working surface to produce briquettes in shape of saddle, difference is larger and reaches about 15%. The last step in the simulation study was to determine the course of the unit pressure value for the selected in Tab. 3 geometry of the roller working surface. This table was prepared based on SolidWorks 2006 program in which individual model of the briquettes and their theoretical volume was determined. It was assumed that the simulation experiments would be carried out for the moisture content, which is the mean of the lower and the upper range given above 4.25%. The results of test are illustrated in Fig. 6 and Tab. 3.

Tab. 3. Influence geometry and volume on maximum unitary pressure during simulation of copper concentrate briquetting in LPW 450 roller press

No.	Shape of briquettes	Dimension of cavity [mm]	Volume of briquette [cm^3]	Maximal value of unitary pressure value [MPa]
1.	drop	40x30x10	13.20	19.2
2.		38x30x9.5	11.92	24.5
3.		36x30x9	10.70	27.1
4.		34x30x8.5	9.55	33.6
5.		32x30x8	8.46	39.9
6.		30x30x7.5	7.44	49.3
7.		28x30x7	6.48	63.6
8.	saddle	31x30x13	6.40	60.7
9.		33x30x14	7.52	41.6
10.		35x30x15	8.74	32.1
11.		37x30x16	9.88	25.3
12.		39x30x17	11.10	20.6

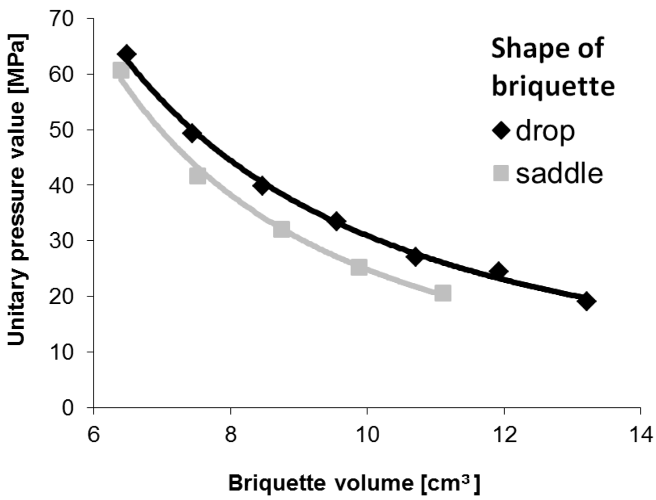

Fig. 6. Influence of the type of roller working surface and briquette volume on maximum unit pressure during briquetting of copper concentrate in the LPW 450 roller press

4. Conclusion

Based on the results of the study, the general opinion that the briquetting of the material in the compacting unit for the production of saddle-shape briquettes is conducive to obtain higher unitary pressures than in the case of a drop-shaped briquette unit system has proved to be false [11]. At the same moisture content of copper concentrate and comparable volume of forming cavities in the range from 6.5 cm^3 to 11.0 cm^3, the maximum unit pressure is approximately 19% higher on the roller-working surface, which allows the production of briquettes in shape of drop. The difference between the maximum values of unit pressure increases with the increase of volume the cavities. On the other hand, the saddle shape of the working surface of the rolls has other advantages. Briquettes are formed in better conditions, do not have a dividing plane and do not tend to split in half for some materials [12]. The information contained in this paper can be very useful for designers of roller presses and their users. Further work should be continued to verify the results of tests on other materials and laboratory conditions.

References

[1] Dec, R., Zavaliangos, A., Cunningham, J., *Comparison of various modeling methods for analysis of powder compaction in roller press*, Powder Technology, Vol. 130, pp. 265-271, 2003.

[2] Dec, R., Zavaliangos, A., Cunningham, J., *Recent developments in FEM modeling of powder processing in the roller press*, Proceedings of Biennial Conference – Institute of Briquetting and Agglomeration, Vol.29, pp. 83-92. Clearwater Beach 2005.

[3] Drzymała, Z., *Industrial Briquetting – Fundamentals and Methods*, Elsevier Science Publishers, Warszawa 1993.

[4] Gara, P., *Research on the fine-grained waste dry granulation process*, Przemysł Chemiczny, Vol. 94, No. 9, pp. 1509-1511, 2015.

[5] Guigon, P., Simon, O., *Roll press design-influence of force feed systems on compaction*, Powder Technology, Vol. 130, pp. 41-48, 2003.

[6] Hryniewicz, M., Bembenek, M., Gara, P., *Possibilities of quicklime and hydrated lime briquetting*, Inżynieria i Aparatura Chemiczna, Y. 45, Vol. 4, pp. 66-67, 2006.

[7] Hryniewicz, M., Bembenek, M., Gara, P., *Problem of roll press compacting unit selection to consolidate material in two-stage granulation process*, Chemik: nauka – technika – rynek, Y. 61, Vol. 9, pp. 425-428, 2008.

[8] Hryniewicz, M., Janewicz, A., Kosturkiewicz, B., *Briquetting of sludge in roll press*, Monografie Wydziału Inżynierii Mechanicznej i Robotyki AGH, Vol. 23, pp. 87-93, 2004.

[9] Hryniewicz, M., Janewicz, A., *Research on possibilities of waste glass wool agglomeration in order to prepare it for utilization*, Odzysk odpadów – technologie i możliwości, Publisher IGSMiE PAN, pp. 201-208, Krakow 2005.

[10] Hryniewicz, M., Kosturkiewicz, B., Janewicz, A., *Selected problems of development of construction and exploitation of roll presses*, Problemy Eksploatacji, Vol. 4, pp. 63-70, 2004.

[11] Hryniewicz, M., *Research on improvement of copper concentrate briquetting technology in roll presses*, Proceedings of Problems in the Construction and Operation of Metallurgical and Ceramic Machinery, pp. 189-195, Krakow 2000.

[12] Hryniewicz, M., *Method of selection of roller presses and assumptions for their modernization or construction*, Rozprawy monografie, Vol. 58, AGH Publisher, Krakow 1997.

[13] Hryniewicz, M., *Problem of nio angle of in modeling the process of briquetting fine-grained materials in roller presses*, Mechanics AGH, Vol. 9, z. 3, pp. 83-89, Krakow 1999.

[14] Janewicz, A., Kosturkiewicz, B., *Compacting of mixed chemical fertilizers*, Monografie Wydziału Inżynierii Mechanicznej i Robotyki AGH, Vol. 32, pp. 261-267, Krakow 2006.

[15] Janewicz, A., *Quality of briquettes and demand for energy in briquetting of waste calcium fluoride*, Monografie Wydziału Inżynierii Mechanicznej i Robotyki AGH, Vol. 32, pp. 231-239, Krakow 2006.

[16] Kosturkiewicz, B., Janewicz, A., *Problem in selection of configuration of compaction arrangemant for roll presses*, Zeszyty Naukowe Politechniki Białostockiej. Budowa i Eksploatacja Maszyn, Vol. 9, pp. 243-252, Białystok 2002.
[17] Kosturkiewicz, B., Janewicz, A., *Briquetting of sewage sludge with burnt lime and coal in a roll press*, Przemysł Chemiczny, Vol. 94, Nr 9, pp. 1524-1526, 2015.
[18] Kosturkiewicz, B., *Issue of the sewage sludge usage as fuel substitute in installations with grate furnaces*, Inżynieria i Aparatura Chemiczna, Y. 45, Vol. 4, pp. 90-91, 2006.
[19] Pietsch, W., *Size Enlargement by Agglomeration*, John Wiley & Sons Inc., New York 1991.
[20] Zavaliangos, A., Dec, R., *Powder processing in the roller press – theory and practice*. Powder Handling & Processing, Vol. 1, pp. 23-28, 2007.