Briquetting of dusty rock-salt roll process

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Introduction

Mining plants located in Lubuskie basin have been warning about problems with dusty rock-salt management for a few years now. Simultaneously, and increased demand for salt-licks can be observed. This product enjoys raising popularity among cattle farmers, as well as hunters feeding wild animals in winter. Especially during winter months it is necessary to feed elks, roe deer, fallow deer and stags. The animals replenish sodium deficiencies (which occur due to sweating) in their diet by licking the surface of roads. Such a situation poses risks to road traffic. Additionally, the salt used for dusting roads may be harmful to the animals, as it differs in its composition from rock-salt meant to be used with food. As a result of these issues, an idea was brought up to use dusty rock-salt for production of salt-licks in roll presses.

The process of writing a business plan for the venture requires the determination of certain technical and economic parameters, such as: elementary power demand for the completion of briquetting process. The lack of data in the literature on this topic served as a basis for starting a research programme in the Chair of Manufacturing Systems at AGH University of Science and Technology. During research conducted in the laboratory setting (which consisted, among other things, of a roll press LPW 450, equipped with an asymmetric densification system) rock-salt, mined in "Polkowice-Sieroszowice" mining plant and was being subjected to briquetting process. Fine-grained fraction of the raw material is used nowadays in chemical industry, food industry, heat engineering, dyeing, leather manufacture, food preparation, animal feed production and for road maintenance in winter. However, the problem of dusty rock-salt management exists. As a result of the conducted research it will become possible to use it in food preparation or for industrial purposes after briquetting.

Briquetting of rock-salt

Methodology

Dusty rock-salt was being dispensed into a gravitational charge mounted above the densification zone of the laboratory roll press LPW 450. It had been equipped with forming rings whose purpose was formation of briquettes without parting plane i.e. "saddle" shaped. It is believed that such shape of active surface of rolls enables obtaining high unit pressure in the briquetting process [1]. The research was conducted in an experimental installation, the diagram of which is presented in Figure1.

Amount of the fine-grained material dispensed each time was $5 \div 7$ kg. The mixture was bonded at peripheral speed of the rolls $v_w = 0.05 \div 0.3$ m/s, which is an equivalent of rotational speed $n_w = 2.12 \div 12.72$ rpm. The initial size of the gap between the rolls during the briquetting process was $\delta_{nom} \sim 1.0$ mm. During the experiment, among other things, the following measurements were conducted: density of the briquettes (ρ_b), compression strength of the briquettes after the trial (D_0), unit pressure in the forming wells (p_n), and torque moment on the roll of the press (M_w).
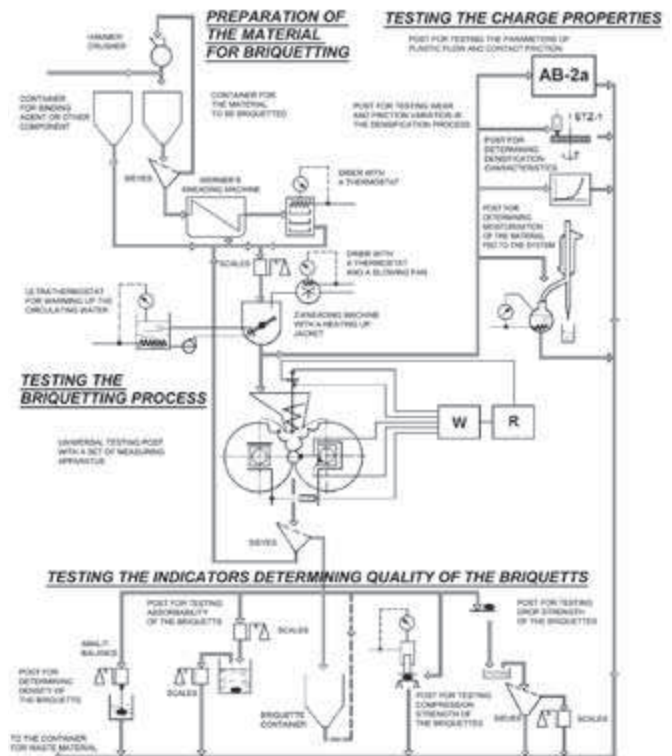

Fig. 1. Diagram of the experimental installation

The material dispensed into the roll press was used to form briquettes shaped accordingly to the shape of the forming wells. Having left the forming wells, the briquettes were moved into a container. Random samples (in series of 10 pieces) were then collected from the container, to be examined with relation to their compression strength. This experiment was conducted at a measuring post equipped with a press ZWICK 1120 with a thrust range of $0 \div 2,000$ N. A briquette was compressed between two parallel planes with the speed of $v = 0.001$ m/s, and the direction of the force was perpendicular to those planes.

After the trial the values for power consumption, weight productivity, and elementary power demand for the completion of the briquetting process were calculated.

The absorbed power in the briquetting process N_b was calculated using the formula:

$$N_b = 2\frac{M_w\, n_w}{9.55} \qquad [kW] \qquad\qquad (1)$$

where:
M_w- torque moment on a roll of a roll press [kNm]
n_w- roll press rotational speed [rpm]

The weight productivity of a roll press, equipped with forming rings with saddle-shaped wells, W_b was calculated using the formula:

$$W_b = 60 V_b\, i_b\, n_w\, \rho_b \qquad [Mg/h] \qquad (2)$$

where:
V_b - briquette volume [m³]
i_b - number of forming wells [-], i=90
n_w - roll press rotational speed [rpm]
ρ_b - briquette density [Mg/m³]

The elementary power demand for the completion of briquetting process Z_e was calculated using the formula:

$$Z_e = \frac{N_b}{W_b} \qquad [kWh/Mg] \qquad (3)$$

where:
Nb   - absorbed power during the briquetting process [kW]
Wb   - weight productivity of the roll press during briquetting process [Mg/h]

Test results

During this study, among other things, time characteristics of unit pressure, and torque moment on a roll of a roll press were registered, and are presented in Figure 2 and 3.
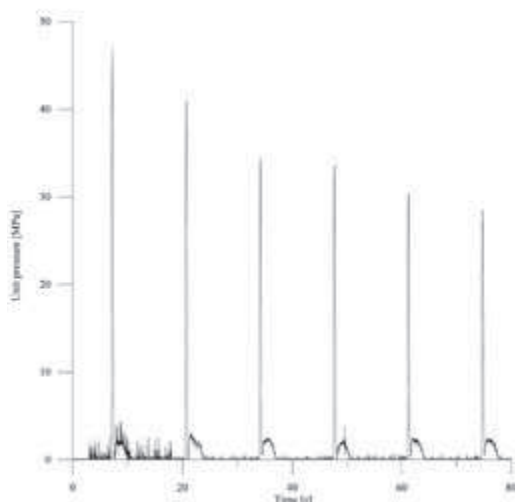
Fig. 2. Time characteristics of unit pressure in a forming well, measured at v = 0.1 m/s

Variation of unit pressure in a forming well was observed during experiments (Fig. 2), and was caused by the lowering of the rock-salt column that was being fed into the densification zone of the device. It is expected that during industrial trials of this type this phenomenon would not take place.

Variation of the values of the torque moment on a roll of the press (Fig. 3) was probably due to a temporary "hang-up" of the rock-salt column in the material dispense zone. This was caused by the strong tendency of dusty rock-salt to form cohesive connections in conditions where increased humidity of the air is present. This problem could be eliminated by using forced feed, instead of gravity feed, e.g. in the form of a worm feeder.

Statistical analysis of the obtained results was conducted in accordance with procedures set for the estimation performed using point assessment. On this basis, the impact of peripheral speed on the unit pressure in the formation wells, power consumption, density, elementary power demand for the completion of briquetting process, and compression strength of the briquettes immediately after the trial, was established. The greatest values of the unit pressure and torque

moment (Fig. 4 and 5) were observed at the peripheral speed of the rolls of the press v = 0.05 m/s, and the smallest at the peripheral speed of the rolls of the press v - 0.3 m/s.
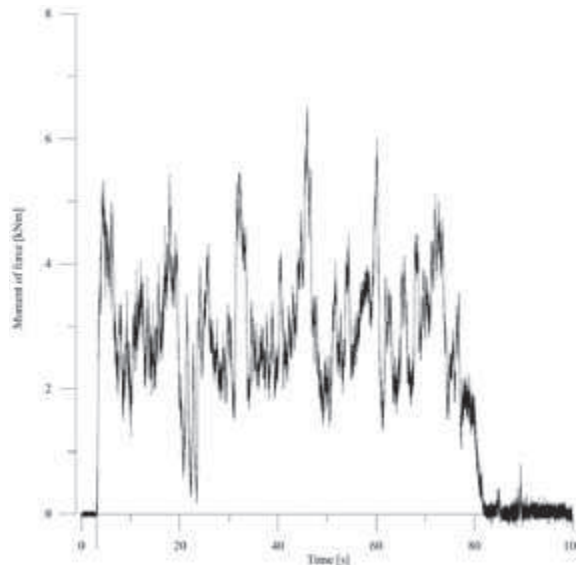
Fig. 3. Time characteristics of the torque moment on a roll of a roll press, measured at v = 0.1 m/s
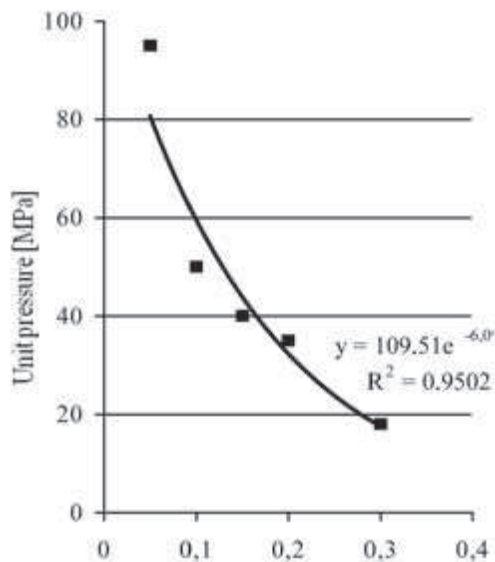
Fig. 4. The relationship between the unit pressure in the formation well and the peripheral speed of the rolls
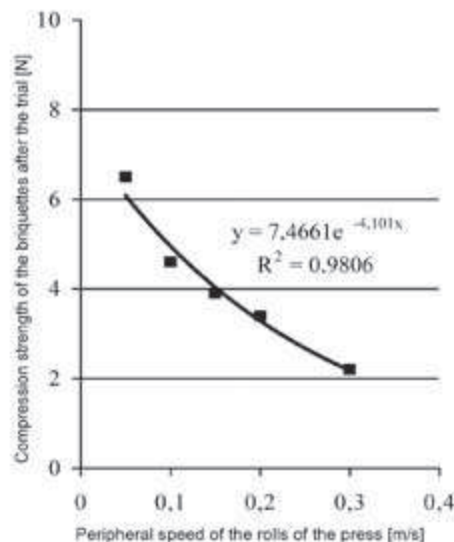
Fig. 5. The relationship between the torque moment and the peripheral speed of the rolls

As can be seen in Figure 6, the compression strength of the briquettes immediately after the trial depended on the values of peripheral speed of the rolls of the press, and amounted to from 205 N – for the peripheral speed of 0.05 m/s - to 356 N– for the peripheral speed of 0.3 m/s. The value of elementary power demand for the completion of the briquetting process was also also linked to the value of peripheral speed of the rolls of the press (Fig. 7).
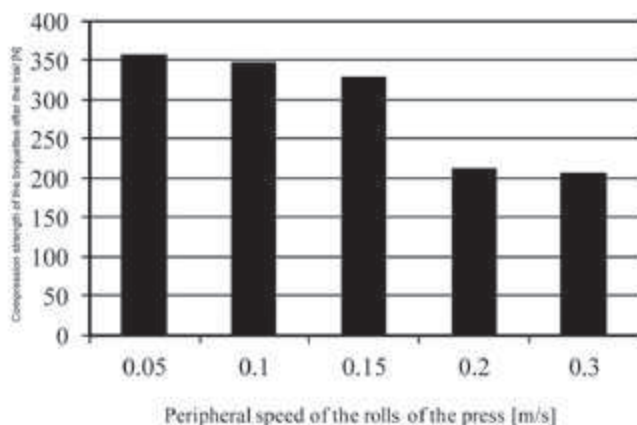
Fig. 6. The relationship between compression strength of the briquettes after the trial and peripheral speed of the rolls
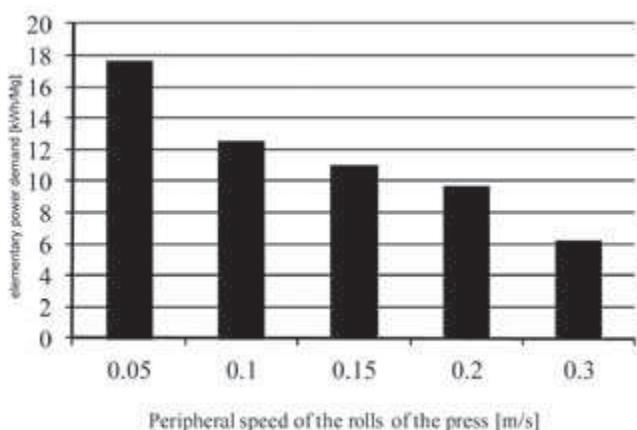
Fig. 7. The relationship between elementary power demand for the completion of the briquetting process and peripheral speed of the rolls
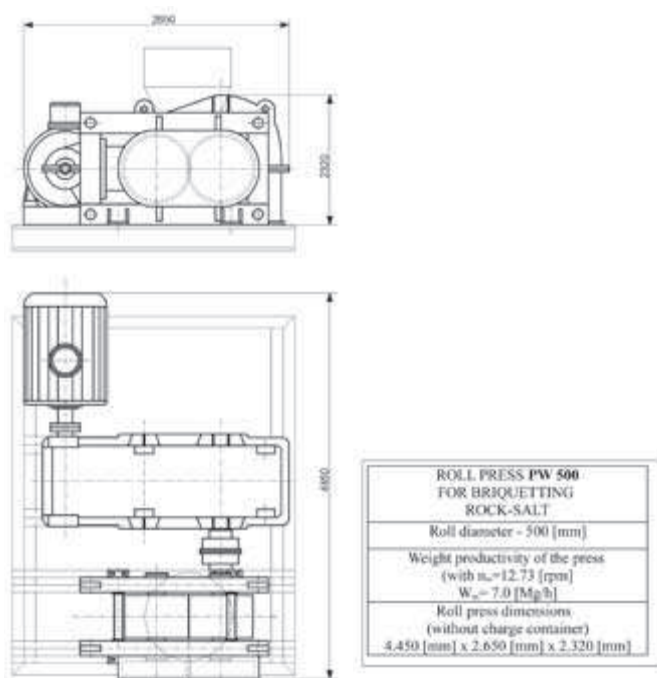
Fig. 8. Diagram of an industrial roll press PW 500 for briquetting rock-salt

The obtained results let us define the guidelines for a plan of an industrialised roll press PW 500 for briquetting dusty rock-salt (Fig. 8). It is expected that the weight productivity of such press at the peripheral speed of $n_w = 12.73$ rpm will amount to approximately 7 Mg/h. The diagram of the industrial roll press PW 500 used for briquetting rock-salt is presented in Figure8.

Summary

Knowledge, experience, laboratory base and access to tested design solutions for roll presses, enable quick planning and subsequent implementation of briquetting technologies for rock-salt. The results obtained from the experiments show that there is a need for additional research aimed at perfecting the feeder systems of roll presses. Previous experience of the authors of this study suggest that the use a worm feeder in the roll press system to ensure a uniform flow of the fine-grained material into the densification zone, and increase the productivity of the process of briquetting of fine-grained material in roll presses, was a legitimate solution. One of the technical and economic indicators determining the appropriateness of use of a technology is the productivity of the device in question. As demonstrated by the results of the experiment [2] it is possible to increase the rotational speed of the rolls of the press, provided that is equipped with a worm feeder, while obtaining similar values of quality indicators for the briquettes, in comparison to using gravitational feed. The choice of configuration for the densification system needs to be preceded by research aimed at determining base material parameters of dusty rock-salt (external kinetic friction coefficient, effective internal friction coefficient, and side thrust coefficient), the results of which will enable determination of geometric design features of the working element of the worm feeder (taper, internal angle of inclination of a screw line).

Literature

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2. Kosturkiewicz B.: *Matematyczny model obciążenia elementu roboczego zasilacza ślimakowego*. Automatyka 2011, **15**, 2, 247-254.

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