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THE INFLUENCE OF THE PROCESS OF NON-PRESSURE AGGLOMERATION ON THE HYDRAULIC DIAMETER OF PELLETS. PART II

Summary

The paper presents the results of tests of the influence of equipment and process parameters of the plate pellet mill with the a raking blade on the compressive strength and the kinetic durability of pellets. The variable input parameters are: inclination angle of the pelleting plate; inclination angle of the blade in the plate pellet mill; rotational angle of the pelleting plate; mass of water added to the plate during the process and time of the material staying in the pellet mill. In the course of the tests, it was concluded that there is a relationship between the strength of the obtained pellets and the inclination angle of the blade in the pellet mill. Pellets obtained at an inclination angle of the pelleting blade of 60° are characterized by a higher value of the compressive strength and the kinetic durability of pellets than at inclination angles of 90° and 120°.
Key words: *non-pressure agglomeration, pelleting plate, kinetic durability, compressive strength*

WPŁYW PARAMETRÓW PROCESU BEZCIŚNIENIOWEJ AGLOMERACJI NA ŚREDNICĘ ZASTĘPCZĄ GRANULATU. CZĘŚĆ II

Streszczenie

Przedstawiono wyniki badań wpływu parametrów aparaturowo-procesowych granulatora talerzowego z łopatką zgarniającą na wytrzymałość granulatu na ściskanie i wytrzymałość kinetyczną granulatu. Zmiennymi parametrami wejściowymi były: kąt pochylenia talerza granulacyjnego, kąt pochylenia łopatki w granulatorze talerzowym, prędkość obrotowa talerza granulacyjnego, masa dodanej wody do talerza podczas procesu, czas przebywania materiału w granulatorze. W wyniku badań stwierdzono, że istnieje zależność pomiędzy wytrzymałością otrzymanego granulatu a kątem pochylenia łopatki w granulatorze. Granulaty otrzymane przy kącie pochylenia łopatki granulacyjnej 60° cechują wyższe wartości wytrzymałości granulatu na ściskanie i wytrzymałości kinetycznej granulatu niż przy kącie 90 i 120°.
Słowa kluczowe: *bezciśnieniowa aglomeracja, średnica granulatu, talerz granulacyjny*

1. Introduction

The mechanical strength of the obtained pellets depends on many factors connected with properties of the materials taking part in the process (the pelleted raw material and the binding liquid), conditions of lubrication, as well as process and equipment parameters [2, 5, 6, 7, 8].

From the practical point of view, for a given grain for the given pellets, the most important is strength to the particular type of loads that it is subjected to during further operations connected with its processing or use [1; 10, 11, 12, 15, 17].

The final product that is intended for sale is usually devoid of moisture (due to drying), so the assessment of the strength of agglomerates in this form also has an important practical aspect.

2. The aim of the tests

The aim of the tests is to establish the most beneficial equipment and process parameters for the implementation of the process of agglomeration in a plate pellet mill with the use of a raking plate.

3. Research methodology

In the research, pellets created during wet plate pelleting, at various parameters of process implementation, were first subjected to the process of drying and then to strength assessment. The tests were carried out on a test stand, presented in publication [4, 8].

The stand was equipped with devices for the measurement of compressive and kinetic strength.

Compressive strength of pellets R_g is determined with the use of Erwek's TBH 200 D device (fig. 1), which measures the force needed for their crumbling. The tests were performed according to the methodology presented in publication [16].

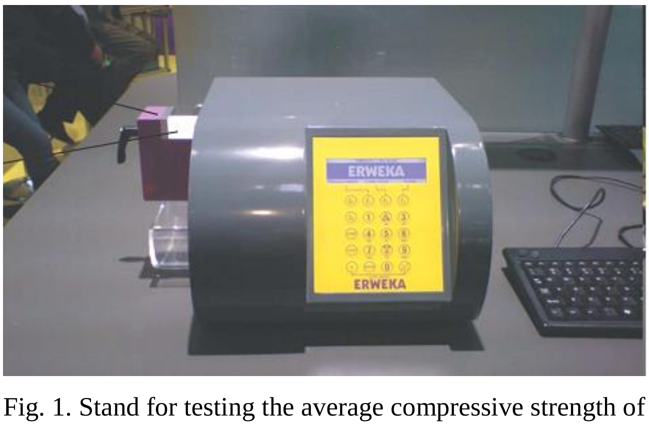

Fig. 1. Stand for testing the average compressive strength of pellets [8]
Rys. 1. Stanowisko do badania średniej wytrzymałości granulatu na ściskanie [8]

The pellets were placed between the working plates of the measuring head, on measuring table. Measurements were carried out until the sample was cracked (or its structure was destroyed). Each time 20-30 single pellets were used for the measurement, with a diameter close to hydraulic diameter d_m, determined by means of the sieve analysis. Determination of the kinetic strength of pellets was performed pursuant to PN-R-64834:1998 [13] and PN-EN 15210-1: 2010 [14].

Pfost's device is a cuboid metal container with strictly determined dimensions with a transversely placed plate inside. The testing device is presented in fig. 2.

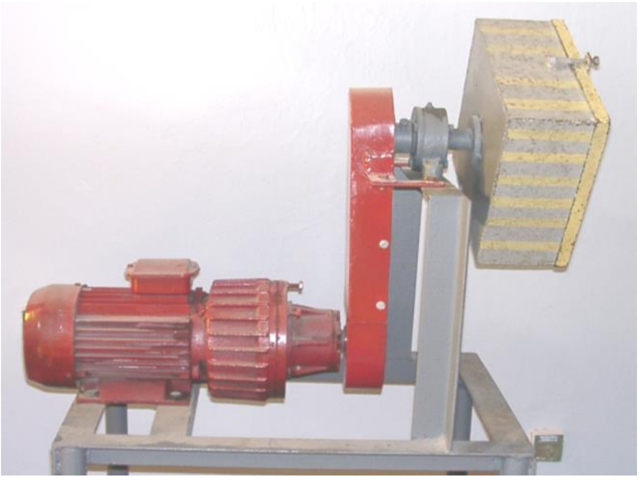

Fig. 2. Device for testing kinetic strength of pellets [3, 9]
Rys. 2. Aparat do badania kinematycznej wytrzymałości granul [3, 9]

The rotating testing machine has a 285x285x120 mm chamber (box), in which a 230x50x2 mm steel plate is placed. The device is driven by means of an electric motor and a belt transmission.

A sample with a mass of 500 g was placed in the box. It rotated for a time of 10 min with a speed of 50 rpm. After the conducted test, on a sieve with an opening diameter of Φ=1 mm, particles that did not undergo crumbling were separated. The kinetic strength of pellets P was determined as the relationship between the mass of the sample after the test m_2 (without a content of the 0-1 mm fraction) to the mass of the sample fed to the tester m_1 [9].

In addition, the test of kinetic strength of pellets P_{dx} was conducted with the use of the device presented in fig. 3, according to the methodology adapted by the staff of the quality department of the plant producing agricultural fertilizers in Susz (Inco S.A. group).

A representative sample with a mass of 50 g was placed on a perforated sieve with an opening diameter of 0.5 mm, with 70 bearing balls with a diameter of 10 mm. The sieve, along with the tested pellets and the balls, was subjected to shaking on a mechanical shaker (Multiserw Morek, LpzE-2e type) for a time of 10 min. After the test was completed, an analysis of changes of proportional mass contents of a size fraction was performed and coefficient P_{dx} was established. For the purpose of the assessment, the ratio between the increment of the proportional content of the size fraction of 0-0.5 mm (pulp) to the initial mass (50 g) was adopted. For the purpose of the tests, a mixture of materials was used, produced and prepared in a production plant of a Polish producer of agrochemicals for agriculture and horticulture, Intermag from Olkusz [4].

Fig. 3. Device for testing kinetic strength of pellets with the use of bearing balls [8]
Rys. 3. Aparat do badania wytrzymałości kinetycznej granul metodą kulek łożyskowych [8]

The variable input parameters in the process of non-pressure agglomeration are: inclination angle of the pelleting plate; inclination angle of the blade in the plate pellet mill; rotational speed of the pelleting plate; mass of the water poured into the plate during the process; time of the material staying in the pellet mill.

4. Research results

The influence of the process parameters: inclination angle of the pelleting plate α inclination angle of the blade in the plate pellet mill χ, rotational speed of the plate n; mass of the added water w_w; time of the material staying in the pellet mill t, is represented by the formulas (1), (2) and (3).

Average compressive strength, R_g [N]:

$$R_g = -407.71 + 0.29\,\alpha + 2.04\,\chi + 9.54\,n + 2414.42\,w_w + +19.64\,t + 0.05\,\alpha^2 + 7.4\,10^{-3}\,\alpha\,\chi - 0.09\,\alpha\,n - 14.06\,\alpha\,w_w - 0.01\,\alpha\,t + 0.01\,\chi^2 + 3.7\,10^{-3}\,\chi\,n - 1.21\,\chi\,w_w - 0.01\chi\,t - 0.39\,n^2 + 16.73\,n\,w_w + 0.12\,n\,t - 2588.44\,w_w^2 - 36.0\,w_w\,t - 0.38\,t^2 \qquad (1)$$

Kinetic strength of pellets, Phost's device, P [%]:

$$P = -631.62 + 10.27\alpha + 1.61\chi + 4.77n + 2562.41w_w + 18.0t - 0.08\,\alpha^2 + 0.01\alpha\,\chi - 0.1\alpha\,n - 13{,}61\alpha\,w_w - 0.04\alpha\,t - 7.1\cdot10^{-3}\,\chi^2 + 2.6\cdot10^{-3}\,\chi\,n - 1.72\,\chi\,w_w - 0.04\chi\,t - 0.4n^2 + 1.78\,n\cdot w_w + 0.13n\,t - 2435.97w_w^2 - 60.96w_w\,t + 0.09\,t^2 \qquad (2)$$

Kinetic strength of pellets, the method of bearing balls, P_{dx} [%]:

$$P_{dx} = -193.26 + 1.74\alpha - 1.87\chi + 2.68n + 1395.77w_w + 20.12t - 0.03\alpha^2 + 4.41\cdot10^{-3}\,\alpha\,\chi + 7.8\,10^{-3}\,\alpha\,n + 2.95\alpha\cdot w_w - 0.12\alpha\,t - 2.1\,10^{-3}\,\chi^2 - 2.9\,10^{-3}\,\chi\,n + 5.96\,\chi\,w_w + 0.02\chi\,t - 0.1\,n^2 - 3.14n\,w_w + 0.16n\,t - 2230.85w_w^2 - 51.25w_w\,t - 0.21t^2 \qquad (3)$$

For example:

For the following process parameters: inclination angle of the pelleting plate:α = 30°; inclination angle of the blade in the plate pellet mill: χ = 90°; rotational speed of the pelleting plate: n = 14.4 rpm; mass of the water added into the plate during pelleting w = 0.288 kg; and time of the material staying in the pellet mill t = 11 min – the average compressive strength R_g = 60.30N, the kinetic strength of pellets, Pfost's device P = 92.0%, the kinetic strength of pellets, the method of ball bearings P_{dx} = 99% (fig. 4).

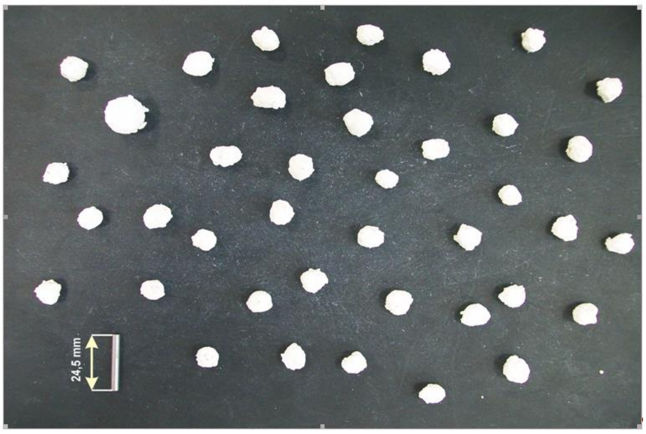

Fig. 4. View of pellets [8]
Rys. 4. Widok granulatu [8]

The view of pellets for the parameters: $\alpha = 30^o$; $\chi = 60°$; n = 21.6 rpm, w = 0.252; t = 8 min: R_g=23.4 N, P = 92.2%, P_{dx} = 94% is shown in fig. 5.

Fig. 5. View of pellets [8]
Rys. 5. Widok granulatu [8]

Analyzing the results of the performed tests as well as the above relationships, it should be concluded that there is a relationship between the strength parameters of the obtained pellets (R_g, P, P_{dx}), and the inclination angle of the blade in the pellet mill. Pellets produced at an inclination angle of the pelleting blade of 60° are characterized by a higher quality than the other pellets, produced at inclination angles of 90° and 120°.

In practice, on the one hand, an important parameter, due to e.g. seed drills, is the diameter of pellets, while on the other hand, e.g. due to pellets transport and their storage, strength is important.

The influence of the hydraulic diameter of pellets d_m on the average compressive strength R_g is represented by formulas (4), (5), (6):

- at an inclination angle of the blade in the plate pellet mill: $\chi = 60°$

$$\boldsymbol{R_g} = -18.5118 + 0.6444 d_m \quad R = 0.7204 \qquad (4)$$

- at an inclination angle of the blade in the plate pellet mill: $\chi = 90°$

$$\boldsymbol{R_g} = -10.1293 + 7.539 d_m \quad R = 0.9506 \qquad (5)$$

- at an inclination angle of the blade in the plate pellet mill: $\chi = 120°$

$$\boldsymbol{R_g} = -10.5772 + 2.47 d_m \quad R = 0.4589 \qquad (6)$$

The above relationships show a significant correlation between the hydraulic diameter of pellets d_m, and an average compressive strength R_g for a blade inclined at an angle $\chi = 90°$, sufficient in the case of $\chi = 60°$, and insufficient for $\chi = 120°$.

The pelleting blade inclined at an angle of 120° (in each of the experiment points) caused the pellets to accumulate in the upper part of the plate, right at its working surface. This resulted in the creation of pellets with reduced strength properties.

Observations of pellets during the strength tests allow to conclude that the character of their destruction is similar to the one occurring in the case of brittle materials. Compressed pellets usually split in two or more parts along the surfaces in line with the direction of their loads.

Owing to the fact that water was the lubricating liquid in the process, and considering the lack of solubility of the material in the binding liquid, in the dry state the grains that compose the pellets are kept whole owing to the existence of direct inter-granary forces. These forces depend on distances between grains, so their values are influenced by densification of particles in pellets, their porousness. A larger degree of packing of grains in pellets results in the increase of the resistance of pellets to external loads, compressive forces.

5. Conclusions

1. There is a relationship between the strength parameters of the obtained pellets (*Rg*, *P*, P_{dx}), and the inclination angle of the blade in the pellet mill.
2. Pellets obtained at an inclination angle of the pelleting blade of 60° are characterized by a higher value than at inclination angles of 90° and 120°.
3. The test results indicate a significant correlation between the hydraulic diameter of pellets d_m, and the average compressive strength R_g for the blade inclined at an angle $\chi = 90°$, satisfactory for $\chi = 60°$, and unsatisfactory for $\chi = 120°$.
4. The pelleting blade inclined at an angle of 120° (in each of the experiment points) caused the pellets to accumulate in the upper part of the plate, right at its working surface. This resulted in the creation of pellets with reduced strength properties.

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