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PRESSURE AGGLOMERATION OF MATERIALS OF PLANT ORIGIN – PELLETIZING AND BRIQUETTING (PART ONE)

Summary

This paper presents tests of the process of pressure agglomeration of plant materials (pelletizing and briquetting) performed on a prototype pelletizing and briquetting device with the use of a pelletizing and briquetting matrix. In the course of the tests, the influence of potato pulp content (15%, 20% and 25%) in a mixture with buckwheat hulls and the mass flow rate of the raw material (100 kg/h, 150 kg/h and 200 kg/h) on the kinetic durability of the obtained pellets and briquettes were determined. The tests demonstrated the usefulness of a pelletizing and briquetting matrix. The obtained briquettes and pellets were characterized by high kinetic durability.
***Key words**: pressure agglomeration, pelletizing, briquetting, buckwheat hulls, potato pulp*

CIŚNIENIOWA AGLOMERACJA MATERIAŁÓW POCHODZENIA ROŚLINNEGO – GRANULOWANIE, BRYKIETOWANIE (CZĘŚĆ I)

Streszczenie

W pracy przedstawiono badania procesu ciśnieniowej aglomeracji materiałów roślinnych (granulowania i brykietowania), które przeprowadzono na prototypowym urządzeniu granulująco-brykietującym z wykorzystaniem specjalnej matrycy granulująco-(peletująco)-brykietującej. W trakcie badań określano wpływ zawartości wycierki ziemniaczanej (15, 20 i 25%) w mieszaninie z łuską gryki oraz masowego natężenia przepływu surowca (100, 150 i 200 kg/h) na wytrzymałość kinetyczną otrzymanego granulatu i brykietu. Badania wykazały przydatność matrycy granulująco-brykietującej. Otrzymane brykiety i granulat charakteryzowały się wysoką wytrzymałością kinetyczną (trwałością).
***Słowa kluczowe**: ciśnieniowa aglomeracja, granulowanie, brykietowanie, łuska gryki, wycierka ziemniaczana*

1. Introduction

Pelletizing and briquetting are similar processes. The difference lies mainly in the size of the obtained product (pellets are small rolls with a diameter of approx. 2mm to 10-15mm, while briquettes are usually cylinders or prisms with a cross-section area of 3 cm^2 to about 50 cm^2) [4]. The length of the product depends on its purpose and is up to twenty times greater than its lateral dimensions. Grochowicz [1] claims that for each mixture (depending on its content), there exists an optimum relation between the diameter and the length of matrix openings, at which the required density and durability of pellets are obtained. This is confirmed by numerous studies by other authors [5, 6, 7] as well as the authors' own studies [10, 12, 13].

Pellets and briquettes obtained in a working system with a flat immovable matrix are presented in fig. 1.

Fig. 2 shows a scheme of pellets formation in an open chamber (matrix opening).

The process consists in densifying and feeding subsequent portions of material *3*, which make it harder for next portions to go through. Densification resistance emerges as a result of friction between the material and the chamber (opening) walls. Each subsequent cycle causes movement of the whole densified material from position *1'* to *2'*. Between the cycles of densifying and feeding, the densified material expands (from position 2' to 3').

The agglomerate (pellets) reaches the required density when when a certain resistance stemming from friction forces between the fed portions of densified material and the internal walls of the working chamber (opening) appears at section L [3].

Fig. 1. Example: pellets (4, 5, 6 – a diameter of 4; 6,5; 8,5 mm; briquettes (1, 2, 3 – a diameter of 28 mm, 50 mm) from biomass [2, 3]
Rys. 1. Przykłady: granulat (4, 5, 6 – średnica 4; 6,5; 8,5 mm; brykiety (1, 2, 3 – średnica 28 mm, 50 mm) z biomasy [2, 3]

The mechanism of pellet formation presented in fig. 2 (from individual portions of material) is used in working systems of industrial pellet mills. It should be noted that the number of openings in the pelletizing matrix (flat or ring) is (depending on its geometrical properties) several hundred to several thousand, while their lengths and geometries vary [1, 2, 3, 5, 6, 7, 8, 9, 14].

2. Purpose of the research

The purpose of the research was to assess the use of pelletizing and briquetting matrix in the process of pressure agglomeration.

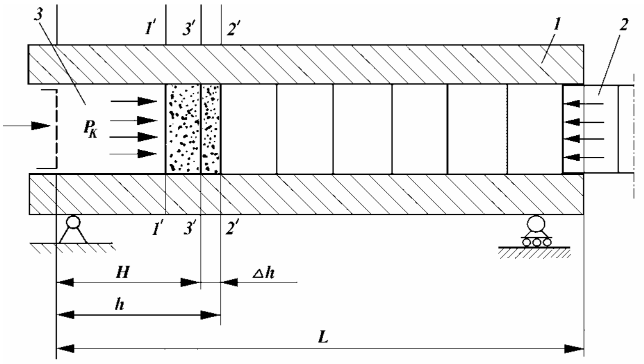


Fig. 2. Scheme of pellets formation in an open chamber [2, 3]
Rys. 2. Scheme of pellets formation in an open chamber [2, 3]

3. Research methods

The research material subjected to the process of pelletizing in the working system of a new prototype pelletizing and briquetting device was a mixture of buckwheat hulls (obtained as waste material in the process of buckwheat groats production in Podlaskie Zakłady Zbożowe S.A. in Białystok) and potato pulp (post-production waste obtained in the process of potato starch production in Zakład PEPEES S.A in Łomża).

The tests of pressure agglomeration (pelletizing and briquetting) were performed on a prototype pelletizing and briquetting device with a flat immovable matrix. A view of the prototype pelletizing and briquetting device is presented in fig. 3.

Source: Own study / Źródło: opracowanie własne

Fig. 3. Prototype pelletizing and briquetting device: 1 - the mixing-pelletizing-feeding system, 2 - drive of the mixing-pelletizing-feeding device, MS7124 electric motor with PM50 reducer, 0.37 kW, 1370 rpm, 3 - charge, 4 - fixing support, 5 - charge, 6 - working system, 7 - outlet, 8 - YX3-180L-4B3IE2 electric motor, 22 kW, 1470 rpm, 9 - built-in Mi20 torque meter by PIMR, 10 - control cabinet, 11 - gear ratios 1:6,8, 12 - base
Rys. 3. Prototypowe urządzenie granulująco-brykietujące: 1 - układ mieszająco-granulująco-dozujący, 2 - napęd urządzenia mieszająco-granulująco-dozującego, silnik elektryczny MS7124 z reduktorem PM50, 0,37 kW, 1370 obr/min, 3 - zasyp, 4 - podpora mocująca, 5 - zasyp, 6 - układ roboczy, 7 - wysyp, 8 - silnik elektrycznyYX3-180L-4B3IE2, 22 kW, 1470 obr·min^{-1}, 9 - wbudowany momentomierz Mi20 (PIMR), 10 - szafka sterownicza, 11 - przekładnia zębata przełożenie 1:6,8, 12 - podstawa

The material subjected to pelletizing is fed through charge 3 to the mixing-pelletizing-feeding system. Drive 2 of the mixing-pelletizing-feeding system is realized by means of an electric motor with a reducer and a chain gear. Support 4 enables regulation of position of the mixing-pelletizing-feeding system. When the material leaves the mixing-pelletizing-feeding system, it is delivered through charge 5 to working system 6, consisting of a dispenser of material and a working system with a flat immovable matrix and pelletizing rolls. The produced pellets are received through outlet 7. The drive of the set of pelletizing rolls is realized from an electric motor through torque meter 9 and reducer 11.

The tests of the process of pressure agglomeration (pelletizing and briquetting) were performed using a special pelletizing and briquetting matrix shown in fig. 4, the object of the authors' patent application [4, 11].

a)

b)

Fig. 4. View of the special pelletizing and briquetting matrix: a) top view, b) bottom view [4, 11]
Rys. 4. Widok specjalnej matrycy granulująco (peletująco)-brykietującej: a) z góry, b) z dołu [4, 11]

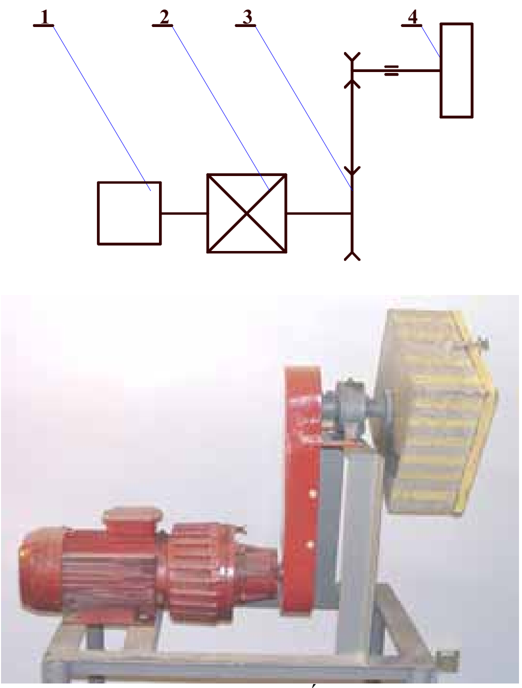
In the course of the tests the influence of potato pulp content (15%, 20% and 25%) in a mixture with buckwheat hulls and mass flow rate of the material (100 kg·h^{-1}, 150 kg·h^{-1} and 200 kg·h^{-1}) on kinetic durability of the briquettes and pellets obtained in the process of densification of these materials with the use of a pelletizing and briquetting matrix were determined.

The assessment of the quality of the product (pellets) obtained with the use of a special pelletizing and briquetting matrix was performed 24 hours after the pellets had left the working system, determined pursuant to PN-R-64834:1998 and the recommendations presented in the papers [15, 16, 17], with the use of a stand for testing the kinetic durability of pellets using Pfost's method, presented in fig. 5.

Rotating tester 4 has a 285x285x120 mm chamber, in which a 230x50x2 mm is placed. The drive of tester 4 is realized by means of electric motor 2 and belt transmission 3. Electric motor 2 is connected with frequency converter 1, owing to which it is possible to achieve the required rotational speed of the tester. During the test, the tester rotates with a rotational speed of 50rpm. The duration of the test is 10 min.

a)

b)



Source: Own study / Źródło: opracowanie własne

Fig. 5. Stand for the measurement of coefficient of kinetic durability P_{dx} of pellets using Prost's method: a) scheme of the stand: 1 - frequency converter, 2 - electric motor, 3 - belt transmission, 4 - tester chamber, b) stand view

Rys. 5. Stanowisko do pomiaru współczynnika wytrzymałości kinetycznej P_{dx} granulatu metodą Prosta: a) schemat stanowiska: 1 - przemiennik częstotliwości, 2 - silnik elektryczny, 3 - przekładnia pasowa, 4 - komora testera, b) widok stanowiska

The quality of briquettes obtained with the use of a special pelletizing and briquetting matrix was assessed on a stand for the measurement of coefficient of kinetic durability of briquettes presented in fig. 6. The rotating tester (pursuant to GOST-18691-73, ASAE S.269-1A recommendations) for 300x300x450 briquettes, was made out of angle bars and covered with a 12.5x12.5 mm mesh net. During the test, feed 10 randomly chosen briquettes with a similar mass (±10%) into the chamber.

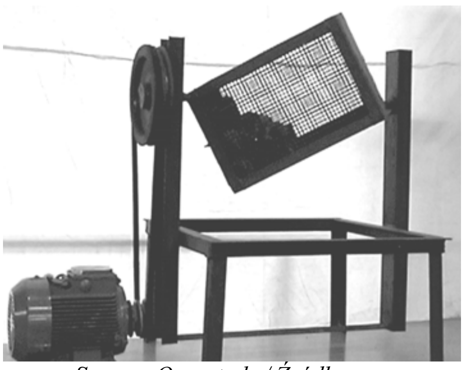


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Fig. 6. View of the stand for the measurement of kinetic durability of briquettes

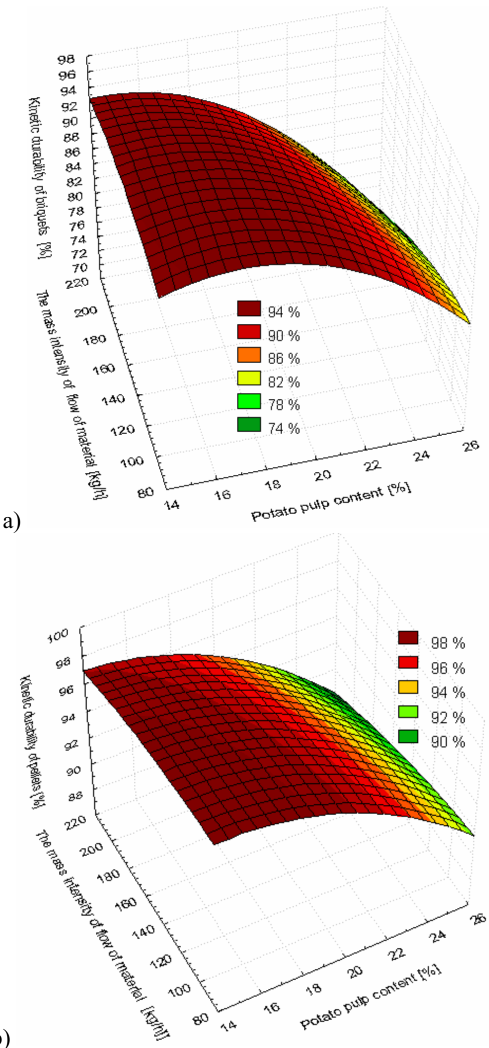
Rys. 6. Widok stanowiska do pomiaru wytrzymałości kinetycznej brykietów

The test is performed within 3 minutes with a speed of 13 rpm. The ratio of briquette mass after the test and the mass of briquettes before the test (expressed in %) is the kinetic durability of the briquettes.

Moisture contents of mixture ingredients and mixtures of the tested waste materials were determined pursuant to PN-76/R-64752 by means of a WPE 300S moisture balance, each time determining the moisture content of five samples with a mass of 5 g, dried in a temperature of 105°C until a constant mass was reached. The end result for the moisture content was the mean value from the obtained determinations.

4. Results of the tests

Fig. 7 shows a graphic representation of the obtained results of the tests of the influence of potato pulp content in a mixture with buckwheat hulls and mass flow rate of the raw material on the kinetic durability of briquettes and pellets obtained during the densification of a mixture of buckwheat hulls and potato pulp with the use of a pelletizing and briquetting matrix.



Source: Own study / Źródło: opracowanie własne

Fig. 7. The influence of potato pulp content in a mixture with buckwheat hulls and mass flow rate of the raw material on the kinetic durability of briquettes and pellets obtained during the densification of a mixture of buckwheat hulls and potato pulp with the use of a pelletizing and briquetting matrix: a) briquette, b) pellets

Rys. 7. Wpływ zawartości wycierki ziemniaczanej w mieszaninie z łuską gryki oraz masowego natężenia przepływu surowca na wytrzymałość kinetyczną aglomeratu otrzymanego podczas zagęszczania mieszaniny łuski gryki i wycierki ziemniaczanej z wykorzystaniem matrycy granulująco-brykietującej: a) brykietu, b) granulatu

The results of the performed tests make it possible to conclude that increasing mass flow rate of the raw material $\dot{Q}_s$ from 100 to 200 kg·h^{-1} causes a slight reduction of the kinetic durability of briquettes and pellets obtained during the densification of a mixture of buckwheat hulls and potato pulp with the use of a pelletizing and briquetting matrix. Increasing potato pulp content from 15 to 25% in a mixture with buckwheat hulls also causes a reduction of the kinetic durability of both pellets and briquettes (fig. 8).

Source: Own study / Źródło: opracowanie własne

Fig. 8. Briquettes (diameter - 28 mm) and pellets (diameter – 8 mm) from a mixture of buckwheat hulls and potato pulp obtained with the use of a pelletizing and briquetting matrix
Rys. 8. Brykiety (średnica - 28 mm) i granulat (średnica – 8 mm) z mieszaniny łuski gryki i wycierki ziemniaczanej otrzymane z wykorzystaniem matrycy granulująco-brykietującej

In the course of the tests average unit energy consumption was respectively:
- 56.2 kWh/ton with potato pulp content of 15%,
- 44.6 kWh/ton with potato pulp content of 20%,
- 30.4 kWh/ton with potato pulp content of 25%.

Average kinetic durability of briquettes:
- 94.8% with potato pulp content of 15%,
- 92% with potato pulp content of 20%,
- 80.9% with potato pulp content of 25%.

Average kinetic durability of pellets:
- 98.2% with potato pulp content of 15%,
- 96.2% with potato pulp content of 20%,
- 91.4% with potato pulp content of 25%.

5. Conclusions

The tests showed the usefulness of a pelletizing and briquetting matrix.

The obtained briquettes and pellets were characterized by high kinetic durability. Further research conducted by the authors will allow to compare the energy consumption of the process when pelletizing, briquetting, and pelletizing and briquetting matrices are used.

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