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PRESSURE AGGLOMERATION OF PLANT MATERIALS – PELLETING AND BRIQUETTING (PART II)

Summary

The aim of this paper was to design and build (construction and instrumentation) a stand for testing the processes of pelleting and briquetting of plant materials of agricultural and food origin. A prototype pelleting and briquetting device was the main element of the stand Its instrumentation in control and measuring equipment allows to densify different mixtures of plant materials, including waste from food and fish processing in order to design new technologies for the production of pelleted and briquetted fodder and ecological solid fuel. This also makes it possible to test innovative constructional and operational solutions for pellet mills with the "flat matrix-densification rolls" system and to determine the influence of technical and technological parameters of the pressure agglomeration process (pelleting, briquetting) of plant materials in order to optimize both the energy consumption and the quality of the obtained product.
***Key words**: pelleting, briquetting, test stand, flat matrix*

CIŚNIENIOWA AGLOMERACJA MATERIAŁÓW ROŚLINNYCH – GRANULOWANIE I BRYKIETOWANIE (CZĘŚĆ II)

Streszczenie

Celem pracy było opracowanie projektu i wykonanie (zestawienie i oprzyrządowanie) stanowiska do badań procesu granulowania i brykietowania materiałów roślinnych pochodzenia rolno-spożywczego. Głównym elementem stanowiska było prototypowe urządzenie granulująco-brykietujące. Oprzyrządowane w aparaturę kontrolno-pomiarową stanowisko pozwala na zagęszczanie różnych kompozycji materiałów roślinnych, w tym odpadowych z przetwórstwa rolno-spożywczego celem opracowania nowych technologii wytwarzania granulowanych i brykietowanych pasz oraz ekologicznego paliwa stałego. Pozwala również na badanie innowacyjnych rozwiązań konstrukcyjno-eksploatacyjnych układów roboczych granulatorów z systemem „płaska matryca - rolki zagęszczające" i określenie wpływu parametrów techniczno - technologicznych procesu ciśnieniowej aglomeracji (granulowania, brykietowania) materiałów roślinnych celem optymalizacji zarówno energochłonności procesu jak i jakości otrzymanego produktu.
***Słowa kluczowe**: granulowanie, brykietowanie, stanowisko badawcze, płaska matryca*

1. Introduction

Each year, the agricultural and food industry in Poland generates over 10,000,000 tonnes of waste, which are utilized [4].

EU's approach to the utilization of waste is based on the following three rules [15]:
- preventing production of waste,
- recycling and reusing of waste,
- facilitation of ultimate waste disposal and monitoring.

The current ecological policy of Poland and the National Waste Management Plan 2014 for the years to come are also compatible with EU guidelines [15].

According to the 2012 GUS, in the years 2010–2011 the proportion of recycled waste decreased by 9.2%, while the proportion of stored waste increased by 21.1% in comparison to the years 2000–2005. These data suggest the necessity to develop technologies for waste processing into useful products [1].

In Poland, the use of post-production waste from the agricultural and food industry as raw material for energy production is legally sanctioned by, for instance, the August 14, 2008 Minister of Economy Ordinance, which poses an obligation to increase the proportion of energy from renewable sources, i.e. the so-called "green energy", in Poland's fuel and energy balance [16].

The type of industrial waste that should be utilized includes post-production waste obtained in the processes of processing of agricultural and food materials, e.g. [10, 13]: buckwheat hulls obtained during the production of groats, rapeseed pellet obtained during the production of rape oil, potato pulp which is a byproduct of starch production [15], corn bran obtained during the production of flour and other corn products, fruit pomace obtained during the production of fruit juice, and many more.

These types of waste can be utilized as potential raw material for reuse as, for instance, fodder material or raw material for the production of alternative fuels.

One of the methods of utilization of plant waste is its pelleting or briquetting (pressure agglomeration) or, in the case of dusty agricultural and food waste, non-pressure agglomeration, or two-stage agglomeration, i.e. non-pressure agglomeration and subsequent pressure agglomeration (pelleting or briquetting).

2. The technological process of solid fuel production (pellets, briquettes) from processing of agricultural and food waste materials

The course of the technological process of solid fuel production (pellets, briquettes) from agricultural and food processing waste materials is presented in fig. 1.

The mechanism of densification (pelleting, briquetting)

The following are the known types of physico-chemical l bindings in the process of pressure agglomeration of plant materials [5, 6]:
- attraction between molecules of solid bodies (van der Waals, electrostatic),
- surface, at the border of the solid and the liquid phase,

- adhesive, occurring in the adsorption layer,
- cohesive, manifesting in the creation of bridges, occurring during sintering, concentration of binder material, fusing, and crystallization of dissolved substances.

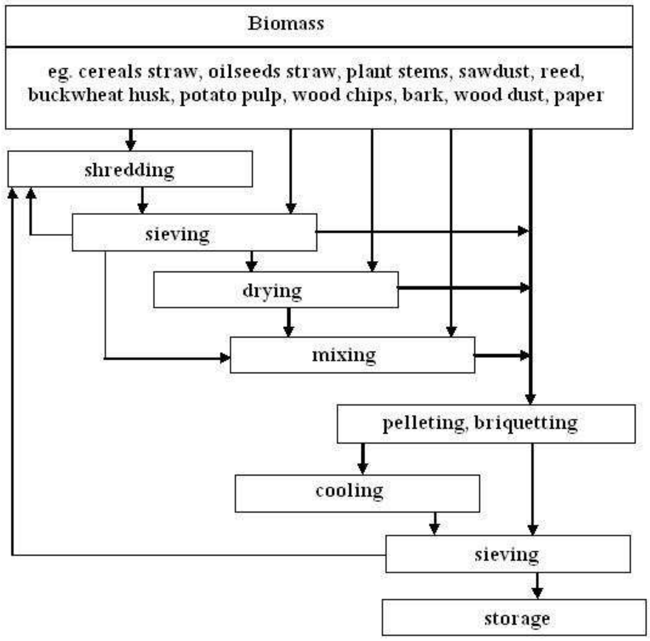

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Fig. 1. Scheme of the technological process of solid fuel production (pellets, briquettes) from processing of agricultural and food waste materials

Rys. 1. Schemat procesu technologicznego wytwarzania paliw stałych (granulatu, brykietów) z surowców z przetwórstwa rolno-spożywczego

The high diversity of plant materials as far as their biological structure, chemical composition, physical properties are concerned, in addition to their tendency to undergo changes during the pelleting and briquetting processes, pose difficulties in determining the dominant types of bindings (this pertains mainly to mixtures of various components). For example, straw is among the materials that are "difficult" both to pelletize and briquette. Hence the numerous attempts to discover methods that would facilitate this process. Among others, destruction of the cellulose-lignin complex of straw may simplify the process considerably. This can be realized by means of chemical methods, e.g. leaching with sodium compounds, treating with lime, ammonia; biological methods, e.g. adding enzymes or microbes to straw; physical methods, e.g. through the action of steam (steaming of straw, gamma ray energy; as well as through mechanical treatment. During pelleting (briquetting) of biomass with a proportion of, for example, shredded cereal grains (a starch content - binder material), the proportion of bindings stemming from cohesive forces is important. When briquetting shredded straw, mechanical bindings occur. Durability of pellets depends on mechanical engaging and wedging of particles, internal friction between particles, binder materials, and capillary forces.

Shredding

The average particle size of pelleted or briquetted material has a significant impact on the course of the processes and the quality of the product. With a certain approximation, it can be initially assumed that the average particle size equals about 0.5 of the diameter of a matrix opening. The granulometric composition of shredded material has an influence on the proportion of internal bindings bonding the particles, thus creating the solid form of the product.

Drying

Drying is optional. It is necessary when moisture content of a pelleted or briquetted material exceeds 18-20%. Biomass can be used as dryer energy, by burning it in the dryer drum, or solar energy from solar thermal collectors.

Mixing

Drying the material to the required moisture content level requires high amounts of energy.

The method of mixing a high-moisture material with a dry material can be a compromise solution. A high moisture content of one of the materials will result in starting the mechanism of particle binding (of the dry material as well) through liquid bridges. Considering the fact that in a dry shredded plant material there is often a large proportion of particles smaller than 1 mm (e.g. straw - an estimated several (up to 20) per cent), then when mixing, this fraction is subjected to non-pressure agglomeration through coating, creating initially densified, many times larger agglomerates. The non-pressure agglomeration mechanism consists in forming a pellet from a dusty material around the pellet nucleus. For example, a ratio of 25% of material with a moisture content of 50% to 75% of material with a moisture content of 10% will produce a mixture with a moisture content of approx. 20%, thus making it fit for further pressure pelleting or briquetting. It should also be added that during the process, a further reduction of moisture content occurs, by several per cent, so the obtained product fulfills quality conditions.

Pressure agglomeration - pelleting, briquetting

The high dynamic loads of pelleting and briquetting systems result in their relatively high energy consumption and quick wear (at simultaneously high production costs).

Research studies, carried out by a team of researchers, make it possible to promote low throughput universal devices for pelleting and briquetting of plant material, capable of producing ecological solid fuel (also from waste) as well as industrial fodder in medium and large homesteads, or in small and medium plant material processing plants [8, 9, 10]. Therefore, special attention should be paid to working systems with a flat immovable matrix (a simple design; for many products, the matrices may be used on both sides; straightforward replacement of the matrix and the densification rolls; a significantly lower price in comparison with other designs, etc.).

The course of the process of pressure agglomeration of plant materials and its energy consumption are influenced by a range of factors, which can be divided into the following groups [2, 3, 6, 7, 11, 12, 14, 17, 18]:

- chemical and biological factors, e.g. chemical composition of the densified material, biological structure of particles,
- material factors - connected with preparation of material for the densification process, e.g. moisture content of the material, its temperature, granulometric composition of the particles of the densified material,
- process factors - connected with the course of the densification process, e.g. densifying pressures, flow rate of the densified material, densification speed, process temperature, conditioning of the densified material,

- construction factors, e.g. matrix diameter; diameter and number of densification rolls; diameter, length, and condition of matrix openings; size of the gap between the matrix and the rolls, etc.

3. The aim of this paper

The aim of this paper was to design and build (construction and instrumentation) a stand for testing pelleting and briquetting of plant materials of agricultural and food origin.

4. Research methodology

Fig. 2 shows the construction of a stand for testing the processes of pelleting and briquetting of plant materials of agricultural and food origin.

a)

b)

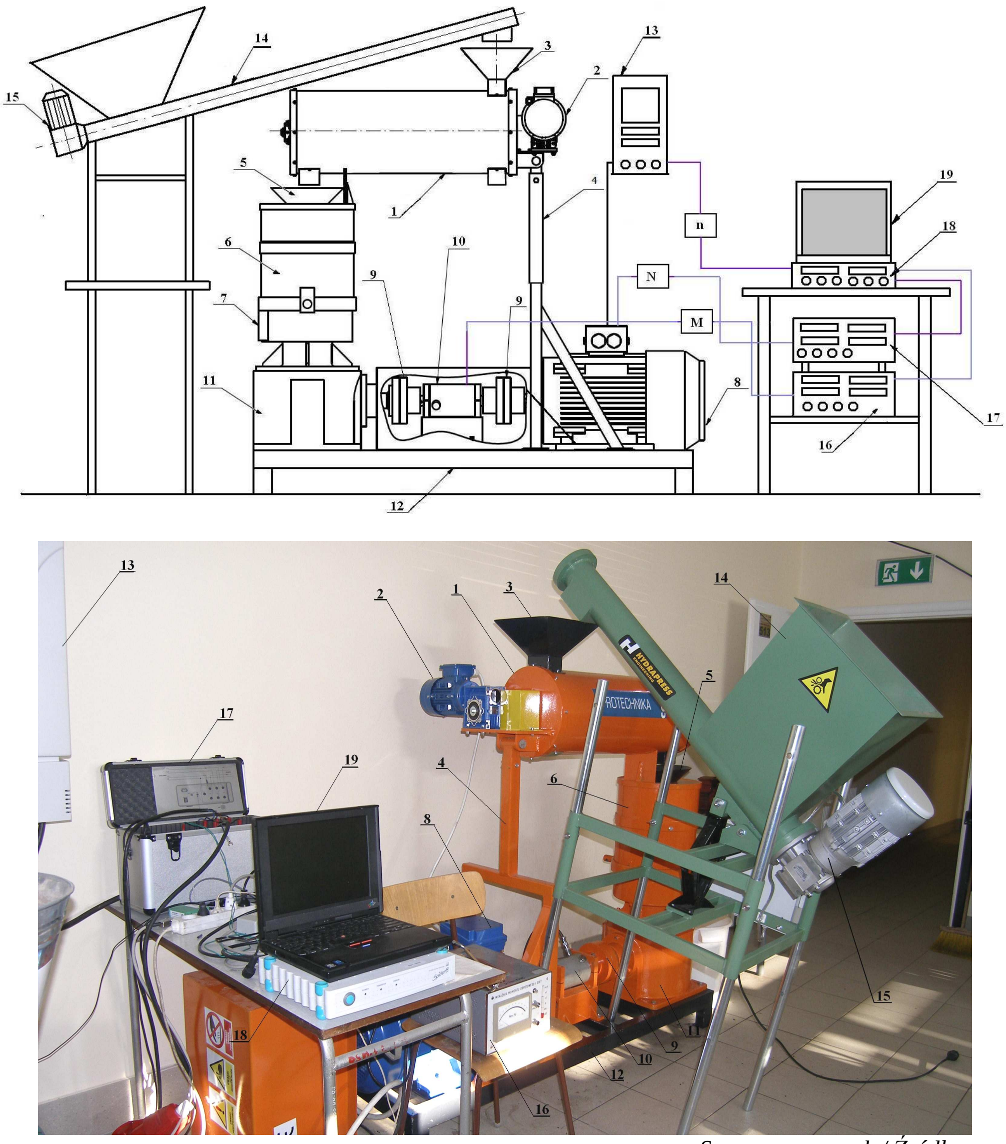

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Fig. 2. Test stand with a new prototype pelleting and briquetting device with a flat immovable matrix [10]: 1 - mixing-pelleting-feeding system, 2 - drive of the mixing-pelleting-feeding system (proMOTOR MS7124 0.37 kW 1370 rpm electric motor coupled with proMOTOR PM 50 1:20 reducer), 3 - material charge to the mixing-pelleting-feeding system, 4 - fixing frame for the mixing-pelleting-feeding system, 5 - material chute for the working system of the pellet mill, 6 - working system of the pellet mill, 7 - outlet for pellets from the working system, 8 - drive of the pellet mill (proMOTOR YX3-180L+B3 IE2 22 kW 1470 rpm electric motor), 9 - clutch, 10 - Mi20 torque meter, 11 - toothed gear with a ratio of 1:6.7, 12 - base, 13 - ABB ACS 800-01-0040-3+E202 variable frequency drive, 14 - feeder, 15 - feeder drive (NORD SK-80LH/4 TF 0.75 kW 1415 rpm electric motor coupled with NORD SK 15/50 1:30 reducer), 16 - WT-1 torque and force indicator, 17 - METROL KWS 1083 device for measuring active power, 18 - Spider 8 (Hottinger Baldwin Messtechnik) recorder, 19 - PC computer

Rys. 2. Stanowisko badawcze z nowym prototypowym urządzeniem granulująco-brykietującym z płaską nieruchomą matrycą: 1 - układ mieszająco-granulująco-dozujący, 2 - napęd układ mieszająco-granulująco-dozującego (silnik elektryczny proMOTOR MS7124 o mocy 0,37 kW i prędkości obrotowej 1370 obr/min połączony z reduktorem proMOTOR PM 50 o przełożeniu 1:20), 3 - zasyp surowca do układ mieszająco-granulująco-dozujący, 4 - rama mocująca układ mieszająco-granulująco-dozujący, 5 - wsyp surowca do układu roboczego granulatora, 6 - układ roboczy granulatora, 7 - wysyp granulatu z układu roboczego, 8 - napęd granulatora (silnik elektryczny proMOTOR YX3-180L+B3 IE2 o mocy 22 kW i prędkości obrotowej 1470 obr/min), 9 - sprzęgło, 10 - momentomierz Mi20, 11 - przekładnia zębata o przełożeniu 1:6,7, 12 - podstawa, 13 - przemiennik częstotliwości ABB ACS 800-01-0040-3+E202, 14 - dozownik, 15 - napęd dozownika (silnik elektryczny NORD SK-80LH/4 TF o mocy 0,75 kW i prędkości obrotowej 1415 obr/min połączony z reduktorem NORD SK 15/50 o przełożeniu 1:30), 16 - wskaźnik momentu obrotowego i siły WT-1, 17 - urządzenie do pomiaru mocy czynnej METROL KWS 1083, 18 - rejestrator Spider 8 (Hottinger Baldwin Messtechnik),19 - komputer PC

The main element of the stand was a prototype pelleting and briquetting device.

The drive of pellet mill 6 consists of electric motor 8 (proMOTOR YX3-180L+B3 IE2, power 22 kW, rotational speed 1470 rpm), whose torque is transferred to the shaft of pellet mill 6, through two-clutch system 9 (between which torque meter 10 is mounted), through conical toothed gear 11, to the shaft of pellet mill 6. Rotational speed of the shaft of pellet mill 6 is controlled by variable frequency drive 13 (ABB ACS 800-01-0040-3+E202 variable frequency drive) coupled with electric motor 8.

Feeding the densified material to the working system of pellet mill 6 was executed by using screw feeder 14, whose drive 15 is a NORD SK-80LH/4 TF electric motor, power 0.75 kW, rotational speed 1415 rpm coupled with the NORD SK 15/50 reducer with a ratio of 1:30). Screw feeder 14 is also equipped with a variable frequency drive, which makes it possible to change the amount of material fed to the working system of pellet mill 6. From screw feeder 14 the material, through charge 3, reaches the inside of mixing-pelleting-feeding system 1. The drive system of mixing-pelleting-feeding system 1 is electric motor 2 (proMOTOR MS7124 electric motor, power 0.37 kW, rotational speed 1370 rpm, coupled with proMOTOR PM 50 reducer with a ratio of 1:20), whose drive is transferred through a chain transmission to the shaft of mixing-pelleting-feeding device 1. From mixing-pelleting-feeding device 1, the material reaches the working system of pellet mill 6 (between the flat immovable matrix, operating with a replaceable rotating system of two (or three) bearing-supported densification rolls, pumped into matrix openings. The pellets leave the working system of the pellet mill through outlet 7.

The stand was instrumented in a universal meter for measuring the energy consumption of pellet mill 17 (METROL KWS 1083, a device for measuring active power), a torque and force indicator 16 (WT-1 type), and recorder 18 (Spider 8 by Hottinger Baldwin Messtechnik) coupled with computer 19. Signals from meter for measuring the energy consumption of pellet mill 17 and from indicator of torque and force indicator 16 are conveyed to recorder 18, in the form of binary files, which are further processed using Microsoft Excel and Statistica 10.0PL software.

5. Conclusions

The presented test stands allows to:

1. Test the process of densification of various mixtures of plant materials in agricultural and food processing, including waste, in order to create new technologies of production of pelleted and briquetted fodders and ecological solid fuel.
2. Study innovative constructional and operational solutions of working systems of pellet mills with the “flat matrix-densification rolls” system.
3. Study the influence of technical and technological parameters of the process of pressure agglomeration (pelleting, briquetting) of plant materials in order to optimize both the energy consumption and the quality of the obtained product.

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This research was financed from funds assigned for statutory activity S/WBiIŚ/5/2014.