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INNOVATIONS IN THE STRUCTURE OF PLANT MATERIAL PELLETIZERS[1]

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ABSTRACT

The article presents an innovative mixing-densifying-dosing system of a pelletizer, which feeds plant material to the densifying system. The structure of the system allows simultaneous realization of the mixing operation as well as non-pressure compression of powdery fractions of the processed material. The paper also sets forth results of the presented system. The tests included determination of the rotational speed of the internal cylinder of the system (25, 40, 55 rot·min^{-1}) and mass intensification of the densified raw material flow (4, 8 and 12 kg·h^{-1}) on the amount of the pelletized fraction. Fine-grained waste of nettle from Herbapol plants in Białystok was used as a research material. The tests which were carried out allowed determination of the mixing-densifying -dosing system for initial densification of the fine-grained plant material (nettle waste) before feeding it to the working system of the pelletizer and allowing elimination of the finest fractions of the crumbled plant material by its non-pressure compression during mixing.

Introduction

The process of pressure agglomeration of plant materials (pelletizing, briquetting) is commonly used both in production of fodder and solid organic fuels (often from waste) (Szpryngiel et al., 2011; Skonecki and Laskowski, 2006). In the process, loose plant material (including various compositions of mixtures) acquires a solid form, which brings numerous utility advantages. Variability of plant materials, including physical, chemical, biological properties, which change also during the process (Kaliyan and Morey, 2009; Shaw, 2008), high condensing pressures (60-150 MPa), high temperature in the working system (80-90ºC) causes that this field of science and technique constantly requires many significant innovative supplements (Chłopek et al., 2012; Hejft and Obidziński, 2012; Hejft and Obidziński, 2013).

Pelletizing, briquetting are twin processes. The difference consists mainly in the size of the obtained product (pellet is in the form of rolls with diameter from approx. 2 mm to 10-15 mm, whereas a briquette is often a roll, a cylinder or a prism with the cross-sectional

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area from 3 cm^2 to approx. 50 cm^2). The length of products depends on designation and is from several to dozen or so times bigger than its diagonal dimensions (Hejft, 2002).

Figure 1 presents a prototype pelletizing and briquetting system made as a part of realization of the research paper Ministry of Science and Higher Educatio No. N N504 488239 titled "Testing the working system of the plant materials pelletizer" funded from the budget funds for 2010-2013 (Hejft and Obidziński, 2013a).

Figure 1. A prototype pelletizing system (Hejft and Obidziński, 2013a): 1 – mixing- densifying-dosing system, 2 – drive of the mixing-densifying-dosing device, electric engine MS7124 with a reducer PM50, 0.37 kW, 1370 rot·min^{-1}, 3 – raw material feeding hopper, 4 – mounting support, 5 – feeding hopper for raw material which was initially condensed, 6 – working system, 7 – discharge, 8 – electric engine YX3-180L-4B3IE2, 22kW, 1470 rot·min^{-1}, 9 – embodied torque measuring device Mi20, 10 – control box, 11 – toothed gear ratio 1:6,8, 12 – base

Material subjected to pelleting is fed by the feeding hopper 3 to the mixing-densifying-dosing system 1. Drive 2 of the mixing-densifying-dosing system is carried out through an electric engine with a reducer and a chain transmission. The support 4 allows regulation of the level of location of the mixing-denisfying-dosing system. After the material leaves the mixing-densifying-dosing system it is fed through the feeding hopper 5 to the working system 6 which consists of the material separator, a working system with a flat immovable matrix and pelleting shafts. Produced pellets (briquettes) are taken by the discharge 7. Drive of the pelleting shafts system is carried out from the electric engine through the measuring torque 9 and the reducer 11.

The mixing and densifying system of the pelletizer

Figure 2 presents an innovative mixing-densifying-dosing system before feeding it to the dosing system. The structure of the system allows simultaneous realization of the mixing operation as well as a non-pressure compression of powdery fractions of the processed material (Hejft and Obidziński, 2012a; Hejft, 2013).

The mixing-densifying-dosing system for the working system of the pelletizer may co-operate with both the working system "flat matrix – densifying rolls", as well as "ring matrix- densifying rolls".

Two units have been known so far in the structural solutions of granulating devices (pelleting): mixing and dosing (with a possibility of conditioning material through providing steam). Most frequently these are structures which consist of an immovable cylinder (pipe), inside of which a shaft is turning with a helix reeled on or blades mounted on the helix and of a drive (with an electric engine) (Hejft and Obidziński, 2012a).

The mixing-densifying-dosing system was presented in figure 2, equipped with a rotational cylinder 5, which has openings 5a in the front part, supplying material to the inside. Inside the cylinder there are exchangeable plates 4 mounted with screws to the cylinder (arranged in a helix on its length) with a possibility of regulation of the angle of their arrangement. Drive from the engine 1 is conveyed through a transmission e.g. a belt one onto a movable shield 3, which is mounted on a driven, curved shaft 4. The shield 3 has a cylinder 5 mounted on it, which plays a role of the working mixing-densifying-dosing system and blades 6, which provide raw material inside the cylinder 5.

Making shaft 4 as a curved shaft allows supply of liquid (which may serve as a binder) or another liquid additive or water steam (in relation to demand) through an opening to the cylinder 5.

The rotating cylinder 5 is shielded by the immovable cylinder 8 mounted to the immovable shield 9 through the shield 10 to the casing 11, bearings 12 and is closed with a demountable cover 13. The feeding hopper for raw material 14 and on its end the discharge 15 are mounted to the immovable cylinder 8 over the openings 5a of the cylinder 5. Material fractions introduced to the rotating cylinder 5 through openings 5a and the steering wheel 6 move on the surface of the rotating cylinder 5 which causes partial pelletization (non-pressure) of powdery fraction particles included in material. The structure of the system allows regulation of the tilt angle of the device in relation to the working system of the pelletizer through loosening the screw cap 16 and the change of the arm arrangement 17.

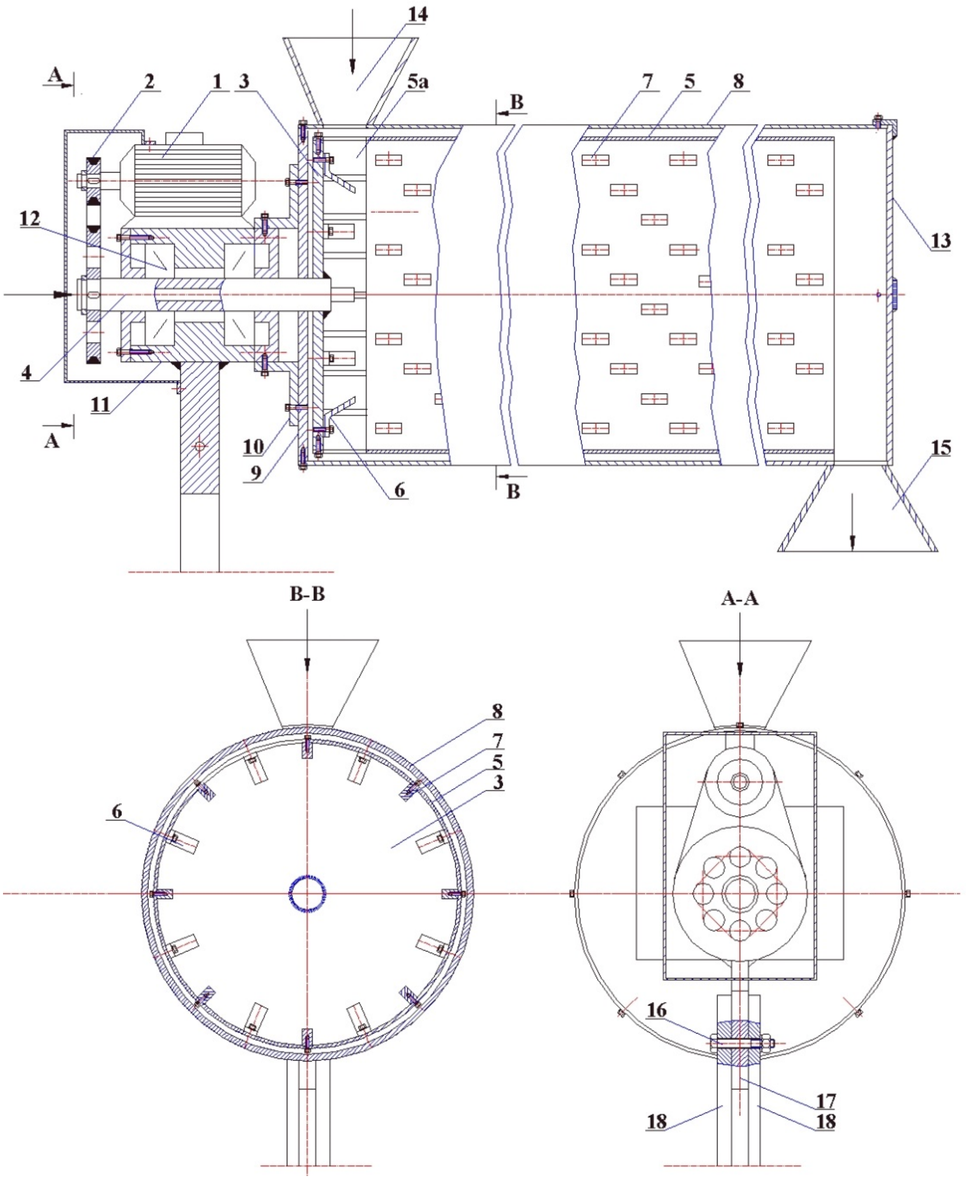

Figure 2. Schematic representation of the mixing-densifying-dosing system (Hejft and Obidziński, 2012a; Hejft and Obidziński, 2013): 1 – electric engine, 2 – belt transmission, 3 – moving shield, 4 – curved shaft, 5 – rotating cylinder, 5a – supplying openings, 6 – blades, 7 – tiles, 8 – immovable cylinder, 9 – immovable shield, 10 – shield, 11 – bearings casing 12 – bearings, 13 – cover, 14 – raw material feeding hopper, 16 – screw cap, 17 – arm, 18 – arms

Figure 3 presents the mixing-densifying-dosing system.

a) b) c)

Figure 3. View of the units of the mixing-densifying – dosing system: a) from the feeding hooper, b) from the discharge, c) from the inside

The objective of the paper

The objective of the paper is to present a structural solution for the mixing-densifying-dosing prototype pelletizing device with a working system "flat immovable matrix- densifying rolls", which allow initial compression of the powdery and fine-grained fraction of material which is pelletized, its mixing and dosing to the working system of the pelletizer and presentation of the initial research of this system.

Methodology of research

The paper includes tests of the non-pressure agglomeration process with the use of the mixing, densifying and dosing system presented in figures 2 and 3.

Fine-grained waste from nettle which came from plants of Herbapol in Białystok and which constituted remaining after processing of these plants during refining and final sorting before drying and during sorting and packing dried herbs were used as the research material.

The initial tests included the rotational speed of the internal cylinder of the mixing-desnifying-dosing system (25, 40, 55 rot·min^{-1}) and mass intensification of the compressed raw material flow (4, 8 and 12 kg·h^{-1}) as variable parameters.

Determination of the impact of the rotational speed of the internal cylinder of the mixing-densifying-dosing system was made at the mass intensification of the compressed raw material flow which is 8 kg·h^{-1}, and the impact of the mass intensity of the compressed material flow was determined at the rotational speed of the internal cylinder of the mixing-densifying-dosing system equal to 40 rot·min^{-1}. These tests were carried out at the 20% participation of binder referred to the amount of the agglomerated material. The content of starch in water solution was 10%.

During the process of agglomeration, binder was supplied into the cylinder through a sprayer nozzle. After the agglomeration process, the obtained product was placed in a separate vessel and dried in the room temperature (approx. 23ºC) for 48 hours and afterwards a screen analysis of each sample was carried out in order to determine the mass participation and the granulometric distribution of the pelletized fraction. Particles which exceed 0.5 mm in size have been assumed as a pelletized fraction.

Determination of the granulometric composition of the fine-grained nettle waste and the pelletized fraction division from the non-pelletized one was made with a shaker LPz-2e by Multiverw Morek company pursuant to the standard PN-EN 932-1. During determination, a previously weighed 50 g -sample of nettle waste was poured onto the upper screen of the screen analysis set. The set of 5 screens with the following dimensions of the square mesh side was applied: 0.5 mm; 0.25 mm; 0.125 mm; 0.063 mm; 0.040 mm. The time of operation of the shaker was 5 minutes at the assumed vibrations amplitude of 80%. After the process of screening, each fraction on the screen was weighed and the obtained result of weighing constitutes a percentage content of a given fraction.

For division of the pelletized and dried fraction the set of 6 screens of the following dimensions of the square mesh side was applied: 0.5 mm; 1.0 mm; 2.0 mm; 4.0 mm; 6.0 mm and 8.0 mm. Division of particular fractions was made by means of its screening within 30 seconds. Results of the obtained measurements were developed in Microsoft Excel.

Results of the research

The screen analysis allowed a statement that in the investigated nettle waste the lowest percentage participation consists of the fraction of 0.5 mm size, the participation of which is 0.13%. The highest percentage participation is in case of a fraction with the size of 0.125 mm, the percentage participation of which is 44.4%, fraction with the size of 0.25 mm amounts to 28.2%. However, waste includes a big amount of fraction with the size of 0.063 mm (19.83%) and fraction with the particle size of 0.040 mm (6.26%). From the point of view of usefulness for pressure compression, this type of granulometric distribution i.e. a considerable participation in powdery fraction waste causes great problems and increases the demand for the power of pelletizing devices. Thus, this type of waste should be mixed before condensation with waste of bigger size of particles or subjected to non-pressure agglomeration before the process of pressure agglomeration.

Based on the obtained research results (fig. 4) a significant impact of the rotational speed of the internal cylinder of the mixing-densifying-dosing pelletizer on the amount of the pelletized fraction of the nettle waste condensed without pressure was determined. Along with the increase of the rotational speed of the cylinder from 20 to 55 rot·min^{-1} a decrease of the amount of the pelletized fraction from 19.29 to 17.48% took place.

The decrease of the mass participation of the pelletized fraction along with the increase of the rotational speed of the cylinder is considerably related to the reduction of time in which the nettle waste stay in a compression drum, which reduces possibility of formation of new agglomerates from the compressed waste, and the time of the increase of the previously formed agglomerates shortens and as a result participation of the pelletized fraction gets lower.

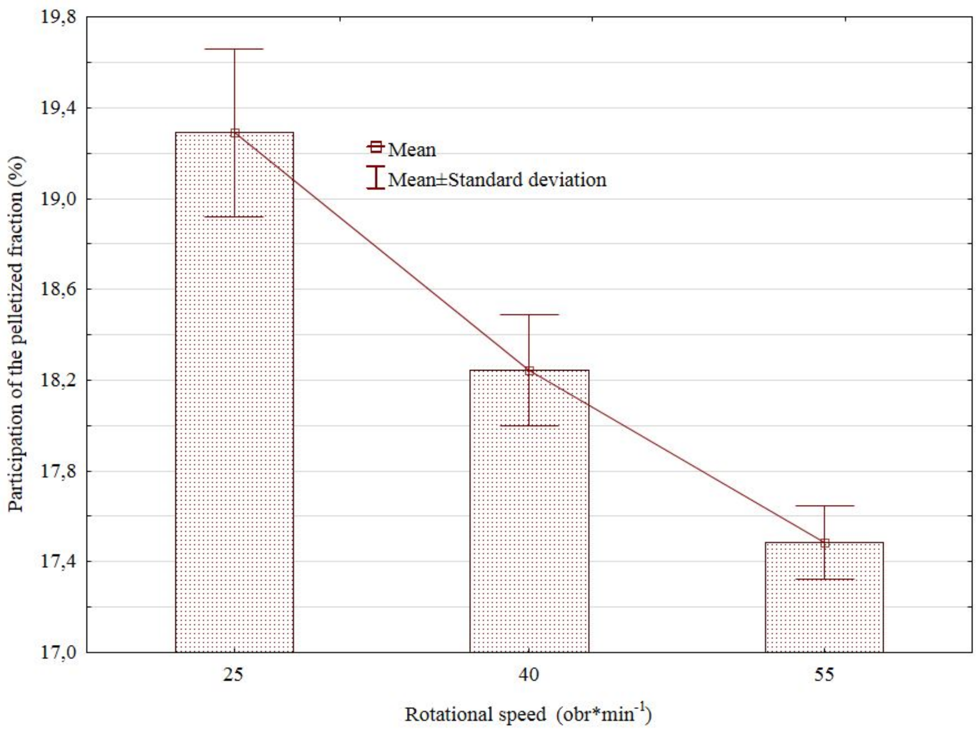

Figure 4. Impact of the rotational speed of the cylinder on the amount of pelletized fraction of the nettle waste

A one-factor analysis of variance (one-dimensional test of significance by Kołmogorow-Smirnow) at the level of significance p=0.05, allowed determination of significant differences between values of the compressed fraction participation, obtained at the increasing rotational speed of the cylinder of the pelletizer.

Figure 5 presents the relation of the amount of the pelletized fraction of nettle waste compressed without pressure to the mass intensification of flow of fine-grained nettle waste.

Increase of the mass intensity of flow of nettle waste from 4 to 12 $kg \cdot h^{-1}$ influenced a slight increase of the amount of the pelletized fraction from 17.45 to 21.18%.

The raise of the mass participation of the pelletized fraction along with the raise of the mass intensity of flow of the compressed waste through the system cylinder is related to the growth of the amount of raw material (nettle waste) in the compression drum, which may simultaneously create new agglomerates from the compressed waste or increase previously formed agglomerates which as a result increases the pelletized fraction participation.

A one-factor analysis of variance (one-dimensional test of significance by Kołmogorow-Smirnow) at the level of significance p=0.05, allowed determination of significant differences between values of the compressed fraction participation, obtained at the increasing rotational speed of the pelletizer cylinder.

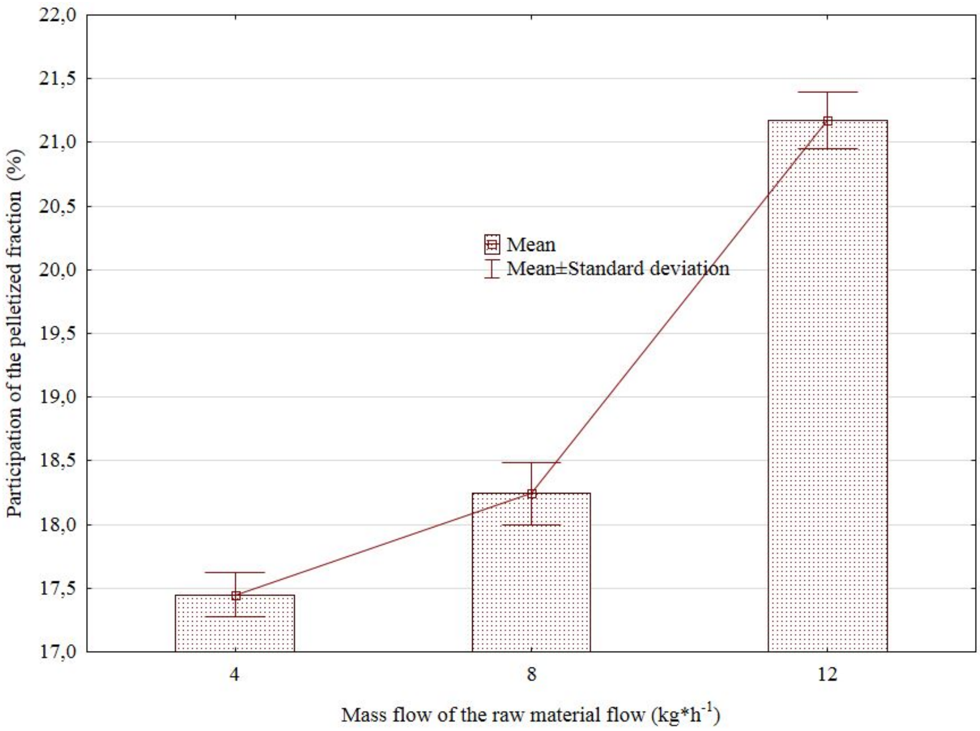

Figure 5. Impact of the mass intensity of flow of raw material on the amount of pelletized fraction of nettle waste

Conclusions

1. The tests which were carried out allowed determination of the usefulness of the mixing-desnifying-dosing system for initial compression of the fine-grained plant material (nettle waste) before feeding it to the working system of the pelletizer and allowing elimination of the finest fractions of the crumbled plant material (pelletized) by its non-pressure compression during mixing.
2. Along with the increase of the rotational speed of the cylinder from 20 to 55 $rot \cdot min^{-1}$ a decrease of the amount of the pelletized fraction from 19.29 to 17.48% took place.
3. The increase of the mass intensity of flow of nettle waste from 4 to 12 $kg \cdot h^{-1}$ influenced the increase of the amount of the pelletized fraction from 17.45 to 21.18%.
4. The one-factor analysis of variance, which was carried out allowed determination of significant differences between the values of the compressed fraction participation, obtained at the growing intensity of flow of the compressed nettle waste and at the growing rotaitonal speed of the pelletizer cylinder.

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INNOWACJE W KONSTRUKCJI GRANULATORÓW DO MATERIAŁÓW ROŚLINNYCH

Streszczenie. W artykule przedstawiono nowatorski układ mieszająco-granulująco-dozujacy granulatora, podający materiał roślinny do układu zagęszczającego. Budowa układu pozwala na jednoczesną realizację zarówno operacji mieszania, jak i bezciśnieniowego granulowania pylistych frakcji przetwarzanego materiału. W pracy przedstawiono także wyniki zaprezentowanego układu. W badaniach określono wpływ prędkości obrotowej cylindra wewnętrznego układu (25, 40, 55 obr$\cdot$min^{-1}) oraz masowe natężenie przepływu zagęszczanego surowca (4, 8 i 12 kg$\cdot$h^{-1}) na ilość frakcji zgranulowanej. Jako materiał badawczy wykorzystano drobnoziarniste odpady z pokrzywy pochodzące z zakładów Herbapol w Białymstoku. Przeprowadzane badania pozwoliły stwierdzić przydatność układu mieszająco-granulująco-dozującego do wstępnego zagęszczania drobno-ziarnistego materiału roślinnego (odpadów pokrzywy) przed podaniem do układu roboczego granulatora i pozwalającego na eliminację najdrobniejszych frakcji rozdrobnionego materiału roślinnego przez jego bezciśnieniowe granulowanie w trakcie mieszania.

Słowa kluczowe: mieszanie, bezciśnieniowe granulowanie, materiał pylisty