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EVALUATION OF CONSTRUCTIONAL CHANGES OF A UNIT FOR COMPACTING BIOMASS BY ROLLING

Summary

The study includes a comparative evaluation of the operation of a unit for briquetting unchopped biomass by rolling for energy purposes. The operation of a unit consisting of four steel rollers was compared with a unit with rollers coated with rubber. Barley straw was subjected to briquetting. The use of rollers coated with rubber resulted in reduction in the average power consumption of approx. 40%. At the same time, regardless of the rollers used, briquettes with the same degree of compaction were obtained.
***Keywords**: briquetting by rolling, straw, briquettes, briquetting rollers, steel rollers, rollers coated with rubber*

OCENA ZMIAN KONSTRUKCYJNYCH ZESPOŁU ZAGĘSZCZAJĄCEGO BIOMASĘ METODĄ ZWIJANIA

Streszczenie

W pracy zawarto ocenę porównawczą pracy zespołu brykietującego niepociętą biomasę metodą zwijania na cele energetyczne. Porównano działanie zespołu złożonego z czterech walców stalowych z zespołem z walcami powlekanymi gumą. Brykietowaniu poddano słomę jęczmienną. Zastosowanie walców powlekanych gumą spowodowało zmniejszenie średniego poboru mocy o ok. 40%. Równocześnie, niezależnie od zastosowanych walców, uzyskiwano brykiety o takim samym stopniu zagęszczenia.
***Słowa kluczowe**: brykietowanie metodą zwijania, słoma, brykiety, walce brykietujące, walce stalowe, walce powlekane gumą*

1. Introduction

Biomass, and in particular cereal straw, can be briquetted in two forms: whole stalks or chaff. In case of briquetting biomass in the form of chaff, several methods of briquetting are known and used in practice [4, 11, 13]. In turn, compaction through briquetting of unchopped agricultural biomass can be carried out by rolling [7, 9, 10, 12, 13].

This method has not been used so far for briquetting cereal straw. Tests of this use are carried out at IIAE in Poznań [1, 2, 3, 4, 5, 6, 8].

Briquetting of unchopped biomass by rolling is carried out in a unit consisting of at least three cylindrical or conical rollers [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13]. Construction of the briquetting unit, developped at IIAE, consists of four conical briquetting rollers. The work includes a comparative analysis of selected operating parameters of steel rollers and rollers coated with rubber.

2. Aim of the study

The conducted study aimed at validating operating parameters of the briquetting unit consisting of grooved steel rollers with a unit of rollers coated with rubber.

3. Material and methodology of the study

Briquetting rollers were made of steel, and their outer surface was specially grooved (Fig. 1).

Preparation of these rollers, and in particular preparation of grooving is costly and time consuming. To reduce costs and facilitate the preparation of the briquetting rollers, they were going to be prepared as steel cones coated with rubber.

These rollers have a core of thick-walled steel pipe the side surface of which was formed by taper turning into a cone of appropriate dimensions: diameter of the base and taper. Then, the core was covered with a rubber layer having a thickness of 8 mm and a hardness of 95°Sh A (Fig. 2).

While conducting the study on briquetting, study methodology of the process of briquetting biomass by rolling, developed at IIAE, was used [1, 2, 3, 5].

Source: own work / Źródło: opracowanie własne

Fig. 1. Steel conical briquetting roller. a) view of the roller, b) cross section of the roller model
Rys. 1. Stalowy stożkowy walec brykietujący. a) widok walca, b) przekrój modelu walca

a) b)

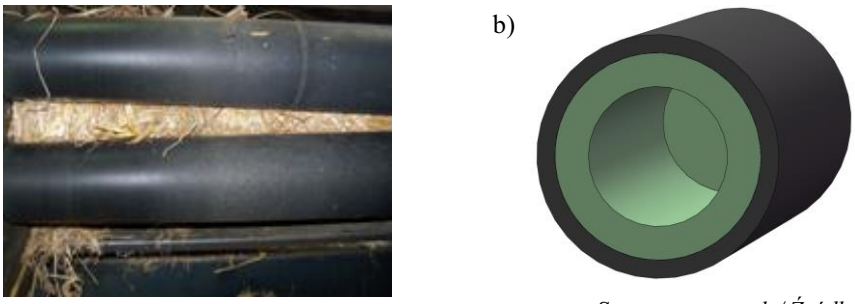

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Fig. 2. Unit of briquetting rollers coated with rubber. a) view of the briquetting unit, b) cross section of the roller model
Rys. 2. Zespół walców brykietujących powlekanych gumą. a) widok zespołu brykietującego, b) przekrój modelu walca

The study was conducted on a prototype stationary machine for briquetting straw by rolling, whose model is shown in Fig. 3.

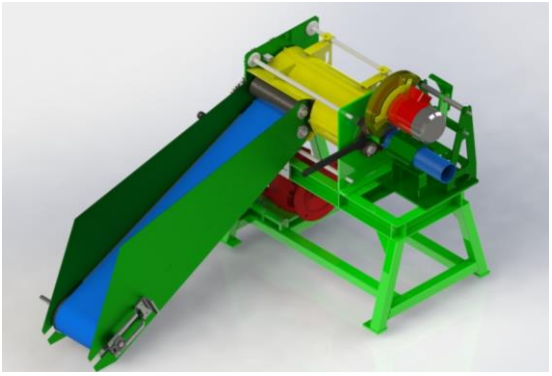

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Fig. 3. Model of the prototype machine for briquetting straw by rolling
Rys. 3. Model prototypowej maszyny brykietującej słomę metodą zwijania

Barley straw with a moisture content of approx. 15%, obtained from a rolled bale was the material used during the study.
The following values of essential operating parameters of the briquetting unit:

- rotational speed of the briquetting rollers n 170 min^{-1};
- twist angle of the turntable plate with pivots of the briquetting rollers β 5;

10 kg of straw was subjected to briquetting for each unit of rollers.

During the study, the power consumed by the drive motor of the briquetting machine and the torque on its shaft were measured. To measure these values, a frequency converter „pDRIVE" of MX type, controlled by a computer equipped with a program MatriX 2.0 was used.

To determine energy unit of briquetting process E_{jo} assigned value of work during each test. This work was calculated by the following formula:

$$W_1 = N_1 \cdot t_{b1} \cdot 3600^{-1} \text{ [kWh]},$$

where:
N_1 – power used for briquetting of each, further portions of straw, in [kW],
t_{b1} – time of briquetting each, further portion of straw, in [s].

The work unit of straw briquetting process was calculated by following relationship [12]:

$$E_{jo} = \frac{W_1}{G_s} \text{ [kWh·kg}^{-1}\text{]},$$

where:
G_s – mass of straw portion for briquetting, in [kg].

Throughput (productivity) of the mechanical power system of test stand, which is also the performance of the test and the compaction process by using straw roll was determined by following equation:

$$Q_{mb} = \frac{G_s}{t_b \cdot 3600} \text{ kg·h}^{-1},$$

where:
G_s – mass of straw portion for briquetting, in [kg],
t_b – time of briquetting one portion of straw, in [s].

4. Study results and its analysis

Briquettes obtained as a result of briquetting unchopped straw by rolling on a prototype stationary machine for briquetting, equipped firstly with steel briquetting rollers, and then briquetting rollers coated with rubber, were subjected to further studies. According to the methodology developed at IIAE [1, 3, 5], values of their volumetric density and degree of compaction were determined. Average values of these parameters are presented in Tab. 1.

Table 1. Average density values of the obtained briquettes
Tab. 1. Średnie wartości zagęszczenia uzyskiwanych brykietów

Type of rollers	Average value	
	volumetric density	degree of compaction
	kg·m^{-3}	
of steel	453	22.7
coated with rubber	447	22.3

Source: own work / Źródło: opracowanie własne

The obtained values did not differ significantly, which leads to the conclusion that the type of material from which side surfaces of the briquetting rollers are made does not have any effect on the density of the formed briquettes.

Power requirement of the briquetting unit is another important parameter which describes the process of briquetting [1, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13]. The conducted study showed that for the briquetting unit equipped with steel rollers, maximum instantaneous values of power con-

sumption reached up to 24 kW (Fig. 4a), and for the unit with rollers covered with rubber, these values were about 10 kW lower, and thus lower by 40% (Fig. 4b). A similar percentage difference was observed in the case of comparing average values of power consumption. The measured values were in the range of 10÷15 kW for steel rollers and 5÷10 kW for rollers covered with rubber.

At the same time, during the study, measurements of the torque on the motor shaft were performed. As in the case of power consumption, significantly higher torque values were recorded for the unit equipped with steel rollers. In the case of instantaneous values, this difference was about 35%. For the unit with steel rollers, these values were 150÷160 Nm, and for the unit equipped with rollers covered with rubber, they were 100÷105 Nm. For normal operation ranges of the unit, i.e. for average values of torque, the difference between the measured values it was 60÷100 Nm for the unit with steel, and for the one with rollers covered with rubber - 20÷60 Nm.

The determined, presented in Table 2 the throughput values of the briquetting system (capacity of briquetting process) support the hypothesis that use of rubber-coated rollers had a positive impact on the parameters and performance briquetting process of uncut straw by rolling method. In the case of throughput achieved up 23% of the average value of this parameter for the rubber-coated rolls. For unit energy consumption recorded an average decline in the value of this parameter approx. 4% for rubber-coated rollers with respect to the rolls of steel.

These data confirm the results presented graphically measuring the power consumption by a briquetting system. The results were obtained in accordance with the assumptions of research, for one, the same speed of roll briquetting for them both types. Different times of the trial are the result of uneven manual feed straw to feed scraper position briquetting stand for accepted test conditions.

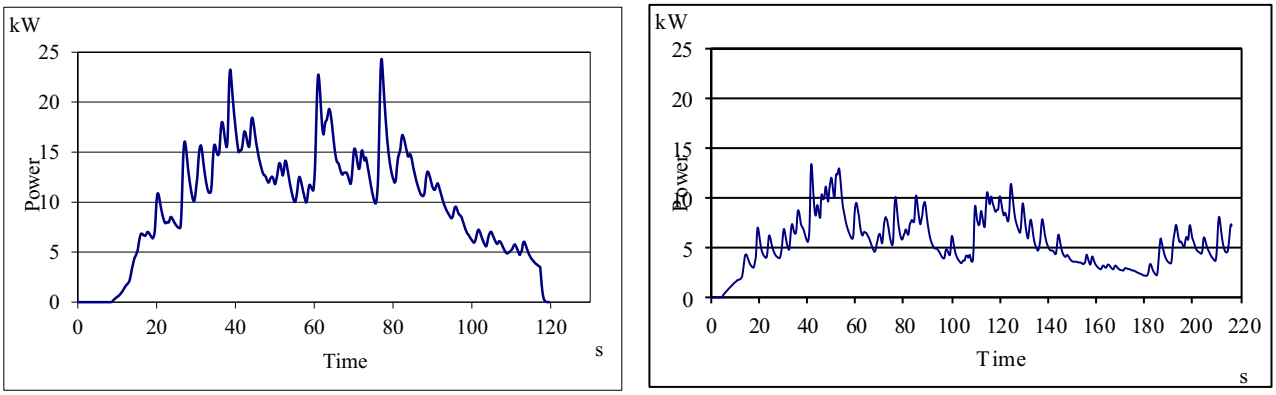
5. Summary

The results of the conducted study lead to the following statements and conclusions:

Comparative study have shown that the use of rollers coated with rubber instead of steel rollers in the biomass briquetting unit is possible and reasoned.

Values of power consumption for conditions used for research for the briquetting unit equipped with steel rollers,, obtained during the study, were about 40% higher, and values of torque were higher by 35% than those for the unit equipped with rollers coated with rubber.

a) b)



Source: own work / Źródło: opracowanie własne

Fig. 4. Courses of variation of power values at the drive shaft of the motor of the briquetting unit equipped with: a) steel rollers, b) rollers covered with rubber

Rys. 4. Przebiegi zmienności wartości mocy na wale napędowym silnika zespołu brykietującego wyposażonego w: a) walce stalowe, b) walce pokryte gumą

Table 2. Throughput and unit energy consumption for briquetting steel rollers and rubber-coated rollers

Tab. 2. *Przebiegi przepustowości i jednostkowego zużycia energii dla walców stalowych i walców pokrytych gumą*

No		Rubber-coated rollers		Steel rollers	
		Throughput **kg·h^{-1}**	Unit Energy consumption **kWh·kg^{-1}**	Throughput **kg·h^{-1}**	Unit Energy consumption **kWh·kg^{-1}**
		Q_{mb}	E_{jo}	Q_{mb}	E_{jo}
1.		224	0,0818	185	0,0848
2.		232	0,0817	180	0,0847
3.		226	0,0819	190	0,0849
4.		227	0,0817	177	0,0847
5.		221	0,0816	186	0,0846
Average value	$\bar{x}$	226	0,0817	183,6	0,0847
Standard deviation	s	4,06	0,0001	4,85	0,0001
Confidence interval	E	(221,3; 230,7)	(0,0816; 0,0818)	(310,4; 321,6)	(0,0846; 0,0848)

Source: own work / Źródło: opracowanie własne

As a result of carrying out the briquetting in the unit equipped with steel rollers, and then rollers coated with rubber, there were not any differences in the size of the obtained degree of compaction of formed briquettes.

Preparation of rollers coated with rubber is technologically simpler, and consequently cheaper.

The use of rubber-coated rollers had a positive impact on the performance and parameters of uncut straw briquetting process by roll method. For throughput achieved an increase of 23% of the average value of this parameter for the rubber-coated rollers, while a decline of approx. 4% of the unit energy consumption of rubber-coated rollers with respect to the rolls of steel

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