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The characteristics of briquetting process with resistance sensors usage

Abstract: *The analysis of briquetting process assumes the simulation of biomass compaction process in specially prepared compacting tube. During the stress and displacement measures test set has been equipped with resistance sensors for the material compaction characterization. The measured resistance value responds to the assigned values of stress and displacement. Based on the results of the stress and displacement measurements the function of the compaction process was developed and transformed into the equation. The maximum compaction force pressure generated by the strength machine was equal 100 kN.*

Streszczenie. *Analiza przebiegu procesu brykietowania zakładała symulacje zagęszczanej biomasy w specjalnie przygotowanej głowicy zagęszczającej. Zestaw badawczy wyposażony został w czujniki oporowe do pomiaru naprężenia i przesunięcia charakteryzując zagęszczenie materiału badawczego. Zmierzona wartość rezystancji odpowiada przypisanym wartościom naprężenia i przesunięcia. Na podstawie wyników pomiaru wartości naprężenia i przesunięcia opracowano funkcję procesu zagęszczania przekształcając ją do postaci wzoru. Maksymalny nacisk siły zagęszczającej wywołany przez maszynę wytrzymałościową wynosił 100 kN.* (***Charakterystyka procesu zagęszczania z wykorzystaniem czujników oporowych***).

Keywords: Briquetting proces, compaction, resistance sensors, resistance measurement.
Słowakluczowe: Proces brykietowania, zagęszczanie, czujniki oporowe, pomiar rezystancji.

Introduction

Briquetting is the process of the raw material compaction to produce the solid biofuels [4, 9, 16]. According to Heim [2], this process was defined as a phenomenon occurring during contact between primary molecules [1], consisting in a strong relation of forces in molecular assembly bonds [14, 15]. Isotropic material like steel or aluminum according to the Huber-von Mises or Treska criterion, in some way could be predictable in terms of occurring stresses. The biomass [12, 13] is one of anisotropic raw material that physical reactions have not been characterized in details [18]. The briquetting process of plant raw material described in the literature, informs about visco-elastic properties [8] that caused the change of agglomerate volume during the compaction process [3] and the stage of final product as well [17].

An important factor significantly affecting the agglomeration process is the moisture of wood chips. The moisture of freshly chopped biomass from forest residues is between 39.1-47.3% [10]. The moisture content of wood biomass depends by the time that has elapsed since the wood was cut down to it was processed. According to the literature, the most suitable moisture during briquetting of shredded forest residues should be close to 15% [11].

The laboratory equipment used as a diagnostic element of the briquetting process was required to design and develop the prototype compacting tube with adjusted auxiliary devices. The properties of the testing machine were one of the initial parameters during the design of the prototype compacting tube. The maximum stress of the piston was set by the machine manufacturer into level of 100 kN. The compacting prototype compacting tube worked in a non-thru system [5, 6], in which prepared material was compacted in the steel tube ended by the nut in the lower part of the sleeve. The main goal of the measurements was to characterize the anisotropic material during the briquetting process. Setted up laboratory equipment allowed to trace the detailed characteristics during the compaction of the shredded pine forest residues in depends of displacement of the piston.

Methodology

Performed studies were aimed to measure the value of compaction force as a function of piston displacement. The compaction force inside the chamber of prototype compacting tube was registered by a set of tensometers placed on the surface of the working piston. The tensometric bridge according to the material compaction was changing the resistance. The similar pattern of work had a displacement sensor, where the displacement of piston was corresponded to changes in the resistance value. The electrical voltage that was used during the measurement was set on 5V. The resistance value was registered by the DMC Plus digital measuring set.

The fractions of shredded forest residues were compacted at 20 and 80°C. The spot where the tensometers was placed during the measurement of compacting force was chosen in a way to eliminate the influence of temperature. The displacement sensor was mounted on one of the guides pole of the testing machine. The construction allowed to determine the temporary distance of piston on the vertical axis of travel. Measuring equipment integrated with the mounted sensors on the testing machine was recording the values with 1Hz measurement frequency.

Fig. 1. The sensors placement on the testing machine

Before the measurements starts, all elements were calibrated in detail according to the available template. The precision of the measurement was determined by the accuracy of the measuring sensors and the method of calibration of individual components, as well as the characteristics of the stress distribution on the surface of the plane. The measurements of deformations depends of the total surface unit elongation on which the set of tensometers was placed [7], as well as the resistance from the displacement sensor. Designed and applied system allowed to register the pressure value during piston stroke. The view of the sensors placement on the testing machine was presented in Figure 1.

During the briquetting process the compaction forces were recorded as an changes of analog resistance signal. The schematic of the tensometers half-bridge set used in measurements was presented in Figure 2.

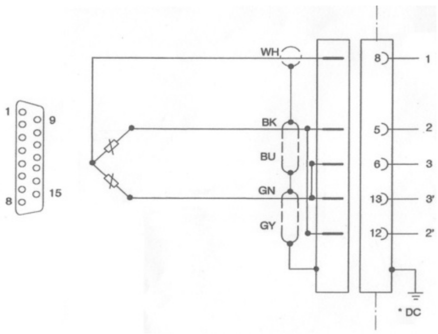

Fig. 2. The schematic of the tensometers half-bridge set used in measurements: 1) Measured signal, 2, 3) Voltage excitation bridge, 2 ', 3') Read

According to the scope of research the displacement sensor required the construction of a measurement setup system recording the piston stroke during the briquetting process. The local position sensor was directly proportional to the position of the sliding spindle. The position of the sliding spindle was recorded by the method of tensometers bridge. The schematic of the tensometers bridge set used in measurements of the displacement was presented in Figure 3.

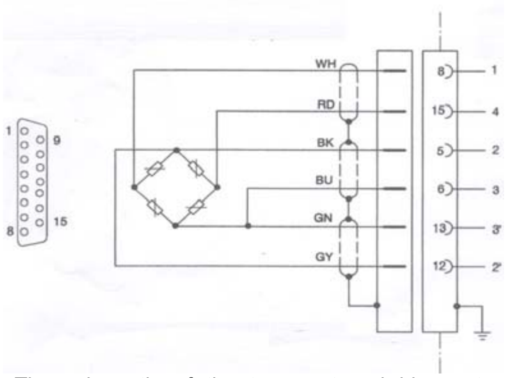

Fig. 3. The schematic of the tensometers bridge set used in measurements: 1) Measured signal, 2, 3) Voltage excitation bridge, 2 ', 3') Read

The displacement value of the piston movement in the the prototype compacting tube was digitally recorded by the synchronized measuring DMC Plus bridge. Shredded pine forest residue with the 15% moisture content, according to the methodology, was impacted at 20 and 80°C. The studies of material moisture content was measured by using the weight difference. The drying process was performed in the laboratory conditions at 105°C, using the MAC 50 Radwag moisture analyzer.

Research results

Before the studies of briquetting process starts, the calibration of all sensors with use of analog standardized measuring templateswas conducted.The measurement of the compaction force inside the chamber of prototype compacting tube was determined by the resistance value (R) that was measured by the set of tensometerscaused by the piston force on the stable plane. Sensorswas calibrated cyclically every 10 kN, for every measuring piston stroke. The mean values of the registered sensor resistancecaused bythe measured forcewas presented in Table 1.

Table 1. The mean values of the registered sensor resistance caused by the measured force

No.	Resistance value [Ohm]	Measuredforce[kN]	force [kN]
1	0.008	0	0.440
2	0.067	10	11.959
3	0.104	20	21.957
4	0.136	30	30.759
5	0.170	40	40.038
6	0.207	50	50.430
7	0.243	60	60.061
8	0.282	70	70.902
9	0.321	80	81.530
10	0.350	90	89.626
11	0.380	100	97.836

The detailed measurements of sensor resistancescaused by the piston force on the stable plane allowed to create the diagram, for which the trend line with a statistical error equal to $R^2 = 0.9967$ was determined. The diagram describing the measured resistances causedby the piston force was presented in Figure 4.

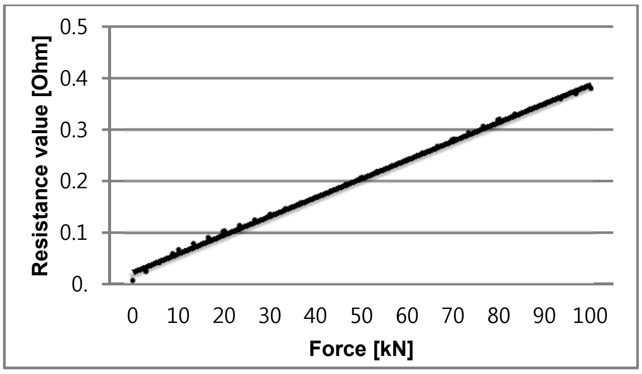

Fig. 4. the measured resistances caused by the piston force

Based on the function of the compaction process was transformed into the equation. Equationallows to specify the instantaneouspiston force (F), that was presented as below formula (1).

(1) $$F = \frac{R+0.012}{0.036}$$

The measurement of the displacement was conducted with the analog rectangular standardized measurement templates use. Used stencils was of the same height. The value of the piston displacement length was determined by the recorded linear resistance of the sensor. In case the sensor pin was placed in a central position inside the measuring tube, the sensor resistance (R) was 0 ohms. The recorded mean values of the linear resistance of displacement sensor was presented in Table 2.

The conducted resistance measurements in depends of the cuboidal template height creates the characteristics of the displacement sensor resistance. The result of the performed scaling was a linear arithmetic function, which the course of mean values determine-nes the trend line. The value of statistical error equal R^2 = 0.9985 and was very accurate. The diagram of function describing the occurring resistances during piston displacement was presented in figure 5.

Table 2. The recorded mean values of the linear resistance of displacement sensor

No.	Resistance value [Ohm]	Measure displacement [mm]	Displacement [mm]
1	5.620	185	183.782
2	4299	235	231.714
3	2.934	285	281.247
4	1.070	335	348.906
5	0.131	385	382.953
6	1.260	435	433.449
7	2.666	485	484.471
8	4.052	535	534.784
9	5.402	585	583.758

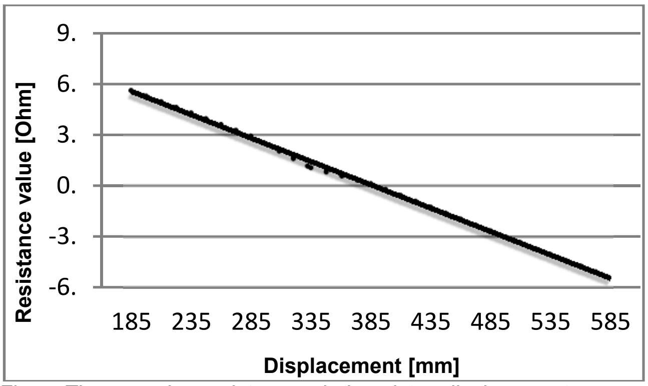

Fig. 5. The occurring resistances during piston displacement

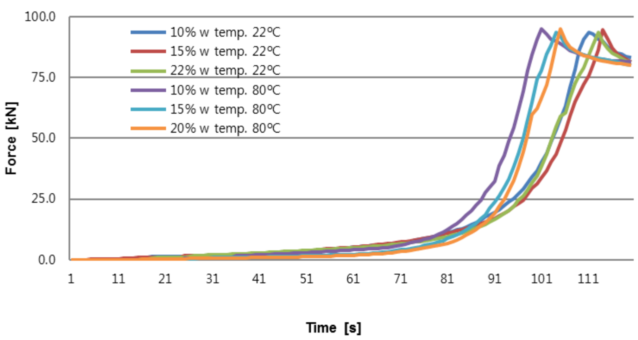

Fig 6. The mean course of the pressure value caused by the piston path during the compaction process of the shredded forest residues

Described function was calculated and converted from its ox value to measure the piston displacement (l) which was presented in the form of formula (2).

(2) $$l = \frac{R-6.964}{1.378}$$

The collected study equipment allows to simulate the briquetting process for the selected raw material parameters. According to the literature recommendations the briquetting process should be performed at the suitably selected pressure [11]. Analized raw material of 10, 15 and 20% moisture was compacted in 20 and 80°C. Records of the created stresses and displacement of the piston allowed to determine the mechanical characteristics of the raw material during the briquetting process. The briquetting press was moving at a constant speed of 2 mm·s-1. The mean course of the pressure value caused by the piston path during the compaction process of the shredded forest residues was presented in Figure 6.

During the studies, the mean values force of piston were recorded in the specification of the existing force levels caused by the piston displacement. It was observed that the determined compaction characteristics for different parameters did not differ significantly from the general scheme.

Summary and Conclusions

Performed laboratory analysis on the testing machine with an integrated prototype compacting tube deliver the capabilities of observation a several results. Created briquette in the temperature of 22°C had length about 10 cm, but the briquette formed at 80°C was shorter by almost 3 cm. That means that the elevated temperature is conducive for compaction of material, and positively affecting at the packing of the raw material during briquetting.

The measuring apparatus integrated with the resistance sensors defining the maximum values of the force and piston displacement, which were mounted on the testing machine, recorded the measured values at a frequency of 1 Hz. During the studies, a trend line was determined based on the measurement of sensor resistances. In the case of piston pressure measurement, the statistical error (R^2) fitted to the trend line was 0.9967, while in the case of the linear sensor resistance displacement was equal to 0.9985, which statistically means very high accuracy. The position in the future can be equipped with more accurate research equipment, for further development of science in this direction.

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