FRICTION AFFECT ON COMMON REED BRIQUETTING

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Abstract. The paper investigates the briquetting process of common reeds (Phragmites Australis) which are an important natural biomass resource in Latvia. The axial density distribution during compacting of ground common reeds in a closed die and the briquette length influence on the wall friction coefficient were determined. Briquette was separated in three equal parts and the density was measured for every briquette part. Density difference between the upper and lower slice of 52.9 mm briquette is 53 $kg \cdot m^{-3}$. Difference between the upper and lower stress was measured for the wall friction coefficient determination. Lower stress of briquette end linearly decreases up to 1.8 times if the briquette length increases to 57 mm. The calculated wall friction coefficient changes from 0.20 to 0.24 for the briquetting experiment results.

Keywords: compacting, density distribution, wall friction.

Introduction

Biomass briquetting is a very complicated process, because there are many technological parameters (compacting pressure, material moisture, particles size, pressing temperature, pressing time, etc.) and constructional parameters (die design, friction coefficient between die and pressed material, friction between material particles, etc.) that affect this process and the quality of briquettes.

Wood fuels, agricultural straw, and energy crops are the most prominent biomass energy sources. In Latvia approximately 14.6 % of unfarmed agricultural land can be used for herbaceous energy crop growing. Herbaceous energy crops would be as the main basis for solid biofuel production in agricultural ecosystem in future. Herbaceous energy crops reed canary grass (Phalaris arundinacea) and hemp (Cannabis sativa) are grown in recent years. Besides, that there is a possibility to utilize for bioenergy production natural biomass of common reeds overgrowing the shorelines of more than 2000 Latvian lakes.

For briquetting previously comminuted common reeds are used. Friction between the compacting materials – the die wall and piston surface - is important because it can affect the briquette density, durability, etc. Friction forces significantly affect the compacting pressure and cause the die and piston wear. Friction depends on several factors: contact pressure, material density, sliding velocity, sliding distance, temperature, wall roughness, etc. [1].

During the briquetting experiments it was necessary to obtain the relationship between the common reed briquette length, diameter and axial density distribution. It is known that the axial density decreases from the top to the bottom of the briquette. Density at the top and bottom layers can be calculated from the data of common reed briquetting experiments. The relationship between the upper, lower and radial stresses in the compacting die allow to determine the friction coefficient. The radial and axial stress ratio is fixed from literature sources.

The purposes of the presented work are to determine the wall friction coefficient of common reed during compacting in a cylindrical die and evaluate the friction affecting the briquette axial density distribution.

Materials and methods

The compacting experiments had been carried out in a closed die with diameter 35 mm by means of laboratory hydraulic press equipment. Maximum pressure 218 MPa had been achieved in compacting. Force and displacement of the piston had been measured by the force sensor and displacement transducer in the densification process. For data collection Pico Data Logger and computer were used.

Reed stalk material biomass with the moisture content of 8.7 % was ground by a hammer mill with the screen size 3 mm and used for densification.

Three similar dosages of reed particles of the same mass 15 g were separated by steel slices and compacted with the laboratory hydraulic press (Fig. 1). After ejection the slices of briquette were separated and their density was measured. The mass of the briquette slice was measured on electronic scales Sartorius GM312 with division 0.01 g and the size of the slices was measured with sliding calipers (division 0.1 mm).

During compacting of the pressing material in a cylindrical die, the axial force applied on the pressing piston is transmitted as normal force F_{upp} to the pressing material and is transmitted as radial force F_{rad} to the die. Counterforce F_{low} in die closed end is less than F_{upp}. It can be explained by friction between particles and particles and wall friction F_f (Fig. 2). Material compacting in a cylindrical closed die can be explained by mathematical equation [2, 3]:

$$p_h = p_{upp} \exp\left(-\frac{4h\alpha f}{D}\right), \tag{1}$$

where p_h – mean axial pressure at depth h from the top of briquette;
p_{upp} – axial pressure of press, MPa;
h – depth in briquette, mm; if h = H, then $P_h = P_{low}$ (Fig. 2);
α – ratio of the radial to mean axial stress;
f – friction coefficient;
D – die diameter, mm.

The friction coefficient f is defined as:

$$f = \frac{F_f}{F_{rad}} = \frac{\ln\left(\frac{p_{low}}{p_{upp}}\right)}{-\frac{4h\alpha}{D}}, \tag{2}$$

where F_f – friction force, N;
F_{rad} – radial force to the die wall, N;
p_{low} – backpressure in briquette end, MPa;

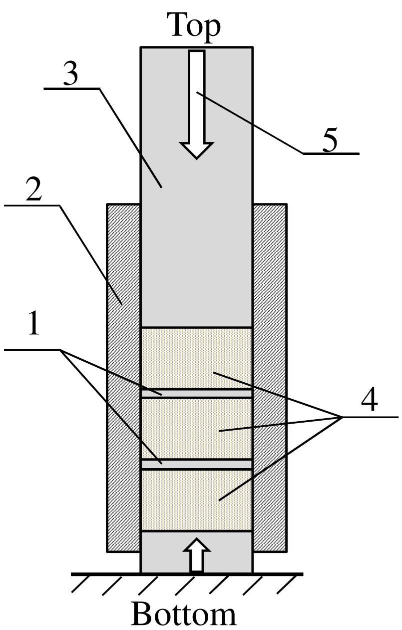

Fig. 1.**Compacting of three slices for axial density determination:** 1 – steel slices; 2 – die; 3 – piston; 4 – briquette slices (15 g); 5 – load from hydraulic press

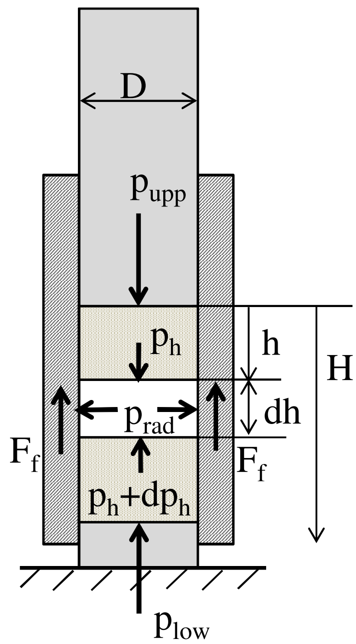

Fig. 2. **Closed die pressing scheme:** D – die diameter; p_{upp} – axial pressure of press; p_h – axial pressure on the briquette; p_{rad} – radial pressure; F_f – friction force; h – depth in briquette; H – length of briquette; p_{low} – backpressure in briquette end

The istance h was measured from the briquette top to the steel slice center. The compacting experiment was repeated 9 times. Equation (1) has shown that the axial pressure exponentially decreases from the briquette top. For experimental investigation lower pressure p_{low} at the briquette end and upper pressure p_{upp} at the briquette top were measured (Fig. 2). The upper pressure for every experiment of briquetting was 218 MPa.

Results and discussion

Axial density distribution during the compacting of ground common reeds in a closed die was investigated with the experiments. The obtained results are shown in Table 1 and Figure 3.

The results had shown that the briquette density decreases from the briquette top to bottom. The difference between the upper and lower briquette slices is 53 kg·m^{-3}.

Table 1

Density evaluation along briquette height

h, mm	Test1, kg·m^{-3}	Test2, kg·m^{-3}	Test3, kg·m^{-3}	Test4, kg·m^{-3}	Test5, kg·m^{-3}	Test6, kg·m^{-3}	Test7, kg·m^{-3}	Test8, kg·m^{-3}	Test9, kg·m^{-3}	Mean, kg·m^{-3}
18.5	1043	1018	1045	1021	1041	1028	1025	1044	1036	1033
36.4	1027	994	1021	1009	1010	991	1022	1011	1026	1013
52.9	1001	936	968	1005	972	966	980	1003	993	980

In Figure 3 the density linear dependence on the ratio of briquette length and diameter is shown. The resulting highest coefficient of determination R^2 for the density dependence on the ratio of briquette height and diameter is determined 0.97.

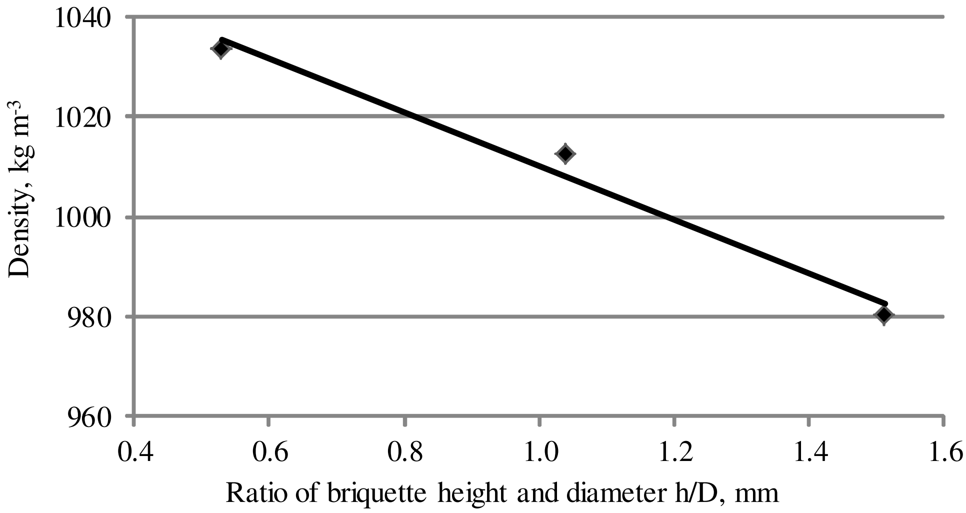

Fig. 3. **Density dependence on ratio of briquette height and diameter**

Density is an important value of solid fuel quality. According to the standards of the European countries the recommended density for biomass solid fuel is 1000 kg m^{-3}. The experimentally obtained results shown that the recommended density for the slice with the ratio of briquette height and diameter is less than 1.2. This ratio provides higher homogeneity of the produced briquettes.

Upper and lower stress dependence on the briquette length is shown in Figure 4.

If the length of the briquette is increased to 57 mm the difference between the upper and lower pressure increases up to 117 MPa. The diameter of the briquette is 35 mm. The results of this investigation shown that the lower layers of the briquette are compacted whit 1.8 times less pressure than the upper layers if the briquette length is 57 mm. The reason is friction between the die and the pressed material. The coefficient of determination R^2 for the results is determined 0.98.

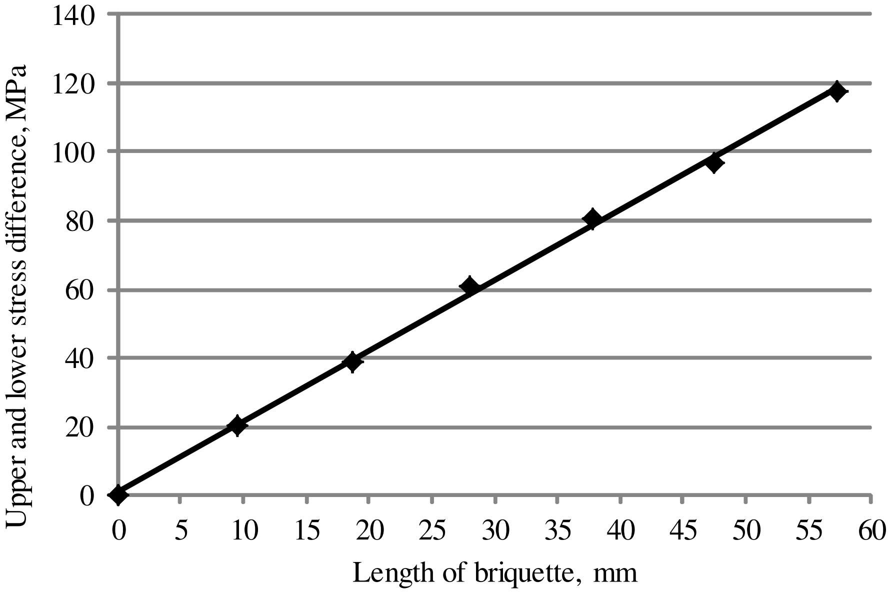

Fig. 4. **Upper and lower stress dependence on briquette length**

The values of upper and lower pressure were used for the friction coefficient calculation by equation (2). During the compacting experiments the ratio p_{low}/p_{upp} and H/D were measured. The value of the ratio $\alpha = p_{rad}/p_{upp}$ was obtained from literature 0.45 for loose materials [2; 4]. The calculated friction coefficient average values are shown in Figure 5.

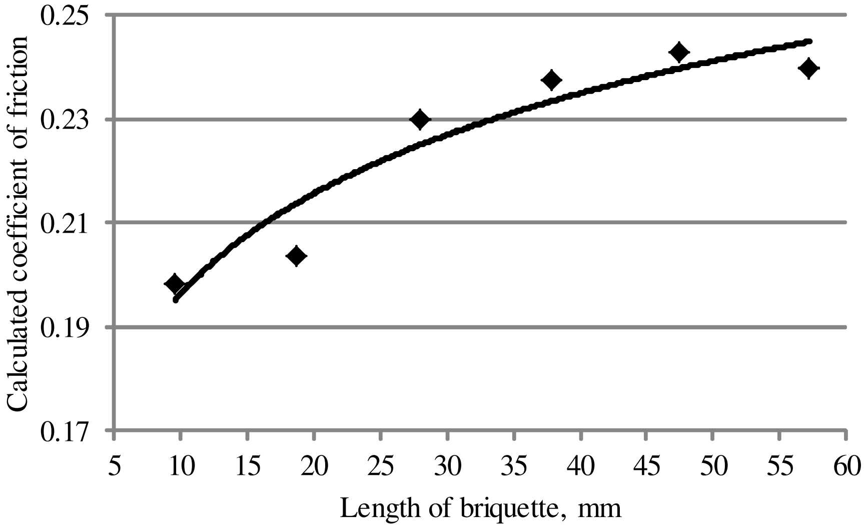

Fig. 5. **Friction coefficient dependence on briquette length**

The values of the friction coefficient change from 0.20 to 0.24 for the briquetting experiments. Average value of the friction coefficient is 0.23. For calculation average values of upper and lower pressure obtained from the compacting experiments were used. The laboratory experiments were repeated 11 times for every length of briquette.

For axial pressure dependence on the briquette length theoretical description during common reed briquetting in a cylindrical die equation (1) was used. The friction coefficient for calculation was 0.23.

The calculated and experimentally obtained results of axial pressure distribution dependence on the briquette length are shown in Figure 6. The difference between the results does not exceed 5 %. This result shows that if the briquette length and diameter ratio H/D do not exceed 1.6 the friction coefficient average value is 0.23.

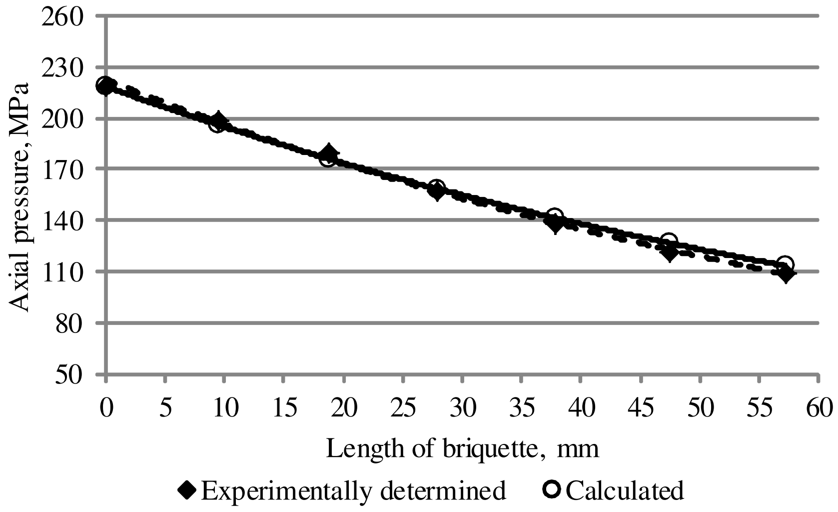

Fig. 6. **Axial pressure dependence on briquette length**

Conclusions

1. The axial density obtained from the compacting experiments decreases from the top to the bottom of the briquette. The density difference between the upper and lower briquette slices is 53 $kg \cdot m^{-3}$.
2. If the ratio of the briquette height and diameter is less than 1.2 then the density 1000 $kg \cdot m^{-3}$ is obtained in briquetting.
3. The lower layers of 35 mm briquette are compacted whit 1.8 times less pressure than the upper layers if the briquette length is 57 mm. The reason is friction between the die and the pressed material.
4. The calculated values of the friction coefficient change from 0.20 to 0.24 for the briquetting experiments. Average value of the friction coefficient is 0.23.
5. The difference of the calculated and experimentally obtained results of axial pressure distribution dependence on the briquette length does not exceed 5 %.

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