DENSITY DETERMINATION FOR BIOMASS COMPOSITIONS

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Abstract: Herbaceous biomass compositions with peat for solid biofuel production are recommended. From the previous experiments it is stated that straw (2 – 3 mm particle size) and peat briquette density depends on the compacting pressure (1165 – 2330 bar). The density of compacted straw particles at different pressure is within 0.86 – 0.92 $g \cdot cm^3$ and compacted peat within 1.11 – 1.2 $g \cdot cm^3$. Theoretically the straw and peat composition density at different pressure is calculated. The experimentally stated density of compacted straw and peat compositions at different pressure was compared with the theoretically calculated. The difference between the theoretically and experimentally obtained data is less than 5.8 %.

Keywords: biomass, compositions, density.

Introduction

Development of biomass as a renewable energy resource can help Europe reduce the dependence on energy imports and increase sustainability. Biomass has relatively low costs, less dependence on short-term weather changes; it is a possible alternative source of income for farmers. The main resources of bioenergy in Latvia are cereal crop residues, energy crops, common reeds in wetlands and peat. The quantity of straw biomass, which can be removed without significantly affecting the carbon cycle, varies from 20 % to 50 % of the quantity of the available crop residue. More than 230 million tons of peat are available for biofuel production. Peat can be used as additive to herbaceous biomass for manufacturing of solid biofuel, because it improves the density, durability of herbaceous material briquettes (pellets). Blending peat with herbaceous biomass leads to forming sulphates in boilers, instead of chlorides, and high temperature corrosion is avoided [1]. For these reasons herbaceous biomass compositions with peat for solid biofuel production are recommended.

Materials and methods

Growing of herbaceous energy crops for solid biofuel production in rural areas is more preferable, because delayed harvesting in winter time lets obtain biomass with the humidity less than 15 % and the content of nutrients (P, K) 50 % less than in the autumn [2] season. Such material after shredding can be used for compacting without drying. Therefore, herbaceous biomass as cereal crop straw (mainly wheat straw), common reeds, rape straw and reed canary grass are the most prospective stalk materials for solid biofuel production in Latvia. For production of solid biofuel mainly herbaceous plant stalks are used.

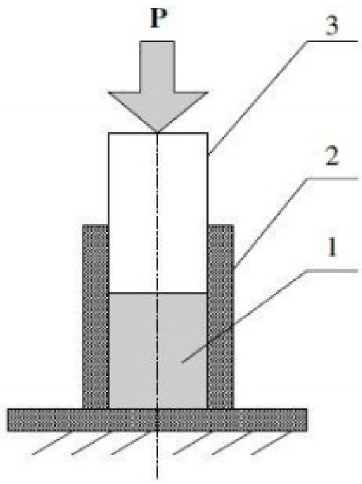

Fig. 1. **Closed die for compacting:** 1 – biomass composition; 2 – cylinder; 3 – punch

Naturally biomass is a material of low density; therefore herbaceous stalk material compacting has to be investigated. The compacting experiments were carried out in a closed die (Fig. 1.) with particles of shredded herbaceous stalk material. Previously shredded straw had been sieved and separated to different fineness groups. 2 – 3 mm fineness group of straw and sieved peat (< 3 mm) was used for experimental compaction. The mixed peat and stalk material particles were used as briquetting compositions with the moisture content 10 %. The pressure amplitude 1165 - 2330 bar had been achieved in compacting. The briquettes with different density had been obtained as a result. The demand for density of solid biofuel briquettes and pellets are > 1.0 $g \cdot cm^{-3}$. For density calculation the weight of the briquette was measured on the electronic scales Sortorius GM 312 with division 0.01 g and the size of briquettes was measured with sliding calipers (division 0.01 mm). At first straw and peat were compacted separately and then different compositions of straw and peat (peat 20 %, 40 %, 60 %) were compacted. Theoretical calculation of straw and peat composition density compacted at different pressure was done.

Any individual substance density may be determined by applying the mass of the substance to its occupied volume, expressed as follows:

$$\rho = \frac{m}{V} \tag{1}$$

where ρ – density, $kg \cdot m^{-3}$;
m – mass, kg;
V – volume, m^3.

To determine the density of the mixture of biomass as a whole, it is necessary to calculate the coefficient of mass:

$$k = \frac{m_1}{m_1 + m_2} \tag{2}$$

where k – coefficient of basic mass;
m_1 – mass of basic component, kg;
m_2 – mass of impurity components, kg.

The density, which is produced by the setting up of a mixture of equal size of the particles, is to be expressed:

$$\rho = \frac{m_1 + m_2}{\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}} \tag{3}$$

where ρ_1 –density of basic components, $kg \cdot m^{-3}$;
ρ_2 –density of impurity components, $kg \cdot m^{-3}$.

In terms of expression (2) the basic stock mass can be determined experimentally by the formula (4) if the impurity component of weight and impurity factor are known:

$$m_1 = \frac{k}{1-k} \cdot m_2 \tag{4}$$

Reunifying equations (3) and (4) it is obtained that:

$$\rho = \frac{\frac{k}{1-k} \cdot m_2 + m_2}{\frac{k}{1-k} \cdot \frac{m_2}{\rho_1} + \frac{m_2}{\rho_2}} \tag{5}$$

Simplifying the expression (5) it is obtained that:

$$\rho = \frac{\rho_1 \cdot \rho_2}{k \cdot \rho_2 + (1-k) \cdot \rho_1} \tag{6}$$

To certain components of the mixture of density relations:

$$C = \frac{\rho_1}{\rho_2} \tag{7}$$

where C – mixture components density relation.

The density of the mixture:

$$\rho = \frac{\rho_2^2 \cdot C}{k \cdot \rho_2 + (1-k) \cdot \rho_2 \cdot C} \tag{8}$$

Simplifying the expression (8) it is obtained that:

$$\rho = \frac{\rho_2 C}{k + (1-k) \cdot C} \tag{9}$$

Results and discussion

European countries have standards (ŌNORM 7135, SS 18 71 20 and DIN 51731) [3; 4] concerned with wood pellet and briquette properties. The demand of the mentioned biofuel density is > 1.0 g·cm^{-3} in the standards. For the compacting process evaluation the density of briquettes has been determined. The aim of the investigation is to find theoretically and experimentally the mixture density if knowing the straw and peat density dependence on different pressure.

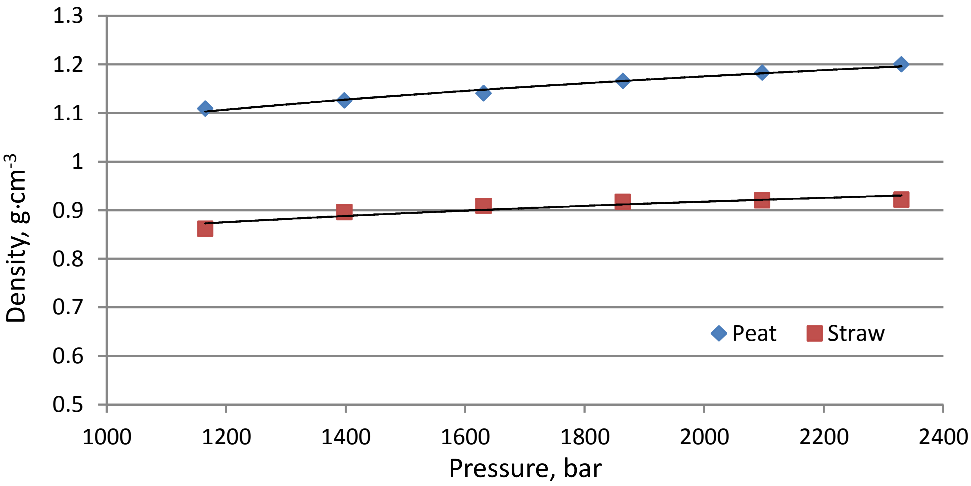

Fig. 2. **Straw and peat density depending on pressure**

Fig. 2 shows the density for briquetting of chopped straw and peat depending on the pressure.

Knowing the straw and peat density data the straw and peat mixture density can be calculated by (9.) formula. The straw and peat mixture theoretical and experimental values are shown in the following illustration (Fig. 3).

The experimentally obtained straw compaction density data vary from 0.87 – 0.93 g·cm^{-3} and the compacted peat experimentally obtained density data vary from 1.1 – 1.2 g·cm^{-3} at different pressure. The experimentally compacted straw and peat mixture density values are between the straw and peat density value data for the same compacting pressure. The compacted straw and peat mixture theoretical values are also shown in Figure 3. The straw and peat mixture theoretical values are higher than the values obtained experimentally. The difference between the experimental and theoretical density values is from 1.8 % to 5.8 %.

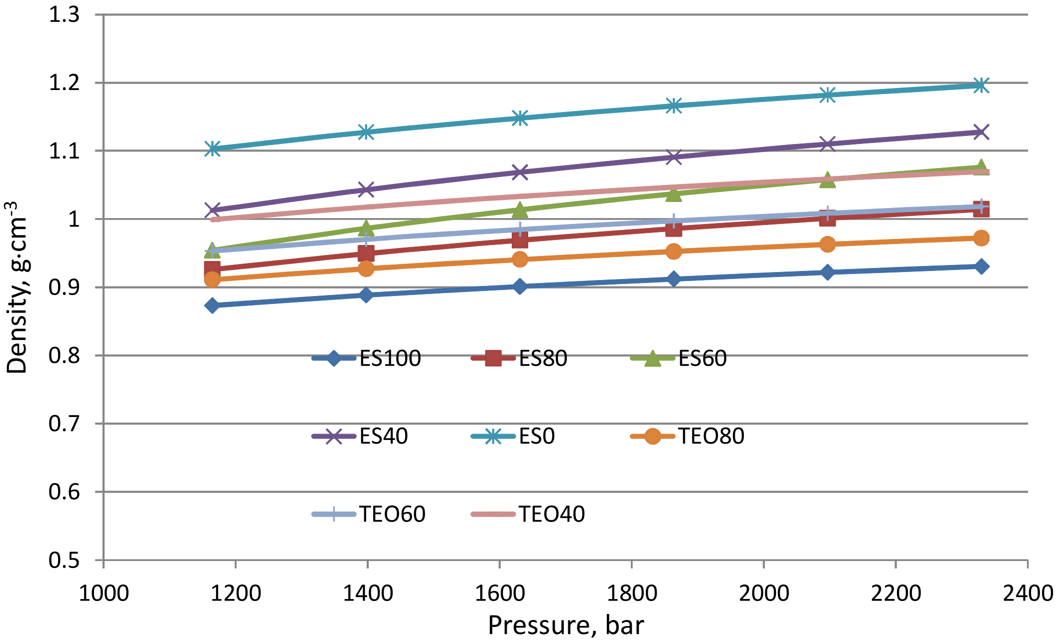

Fig. 3. **Straw and peat mixture density depending on pressure:** ES100 – 100 % straw experimental value; ES80 – 80 % straw exp. value; ES60 – 60 % straw exp. value; ES40 – 40 % straw exp. value; ES0 – 100 % peat exp. value; TEO80 – 80 % straw theoretical value; TEO60 – 60 % theoretical value; TEO40 – 40 % straw theoretical value

Conclusions

1. The straw experimental density data vary from 0.87 – 0.93 $g \cdot cm^{-3}$ and the peat experimental density data vary from 1.1 – 1.2 $g \cdot cm^{-3}$ at different pressure.
2. The experimentally compacted straw and peat mixture density values are between the straw and peat density value data for the same compacting pressure.
3. The difference between the experimental and theoretical density values ranges from 1.8 % to 5.8 %.

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