DURABILITY OF THE ARRANGED STRUCTURE BIOMASS BRIQUETTES

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Abstract. The main resources for biomass agro-ecotechnologies are cereal straw residues, energy crops and emergent vegetation from wetlands. The herbaceous biomass is a material with low density (20-60 kg·m^{-3}) therefore new mobile equipment and technologies for biomass communition and densification have to be worked out. For the briquettes density standards determined the value $\rho > 1.0$ g·cm^{-3}. To guarantee the quality of biomass briquettes in the handling and usage process, sufficient durability of briquettes should be provided. Density 1.0 g·cm^{-3} has been obtained in densification of straw and reed stalk material particle compositions with peat, if peat proportion exceeds 20 %. Crushing force dependence on particle size for arranged structure briquettes is stated in laboratory experiments. In comparison with unarranged structure briquetting crushing force for arranged structure briquettes increases on average from 3 to 5 times.

Keywords: stalk materials**,** biomass conditioning, biomass briquettes, durability.

Introduction

The reform of the EU Common agricultural policy stimulates farmers to grow more energy crops and utilize crop residues for energy. The main resources for biomass energy production in rural ecosystems are cereal straw residues, energy crops, organic sediments and emergent vegetation from wetlands. In Latvia straw resources what can be used for energy production increased (more than 171 000 t of straw annually), because cattle breading decreased in previous years. As country of Lakes (more than 2000), what have been overgrowing on shorelines with common reed (*Phragmites communis*) it has possibility to utilize this natural biomass. Beside those more than 230 million tonnes of peat is available for biofuel production. Biomass energy production can be realized only in accordance with ecosystem approach and good understanding of agricultural ecosystem function. This approach state that only part of straw residue (20-30 %) can be used for heat production, but another part shall be used as organic fertilizer. Mentioned before peat, reed and straw materials can be denominated as agricultural ecosystem biomass resources only if we have mechanization tools and technologies for collection and utilization processes. In accordance with these possibilities conditioning of herbaceous stalk materials for compositions with peat had been investigated.

The main mechanical properties of the standardized biofuels in form of briquettes are density and mechanical strength. These parameters depend on the used material, its structure, water content, compacting pressure and arrangement of particles in briquetting die. The basic standards for the briquettes are the Austrian ÖNORM M 7135 and German DIN 51731. These documents are valid for wood and bark extrusions. For the briquettes density standards determined the value $\rho > 1.000$ kg·m^{-3}. This value had been used for evaluation of herbaceous material densification results.

As investigation results it is stated, that density 1.0 g·cm^{-3} has been obtained in compaction of wheat straw stalk material particle compositions with peat, if peat proportion exceeds 35 %. Pressing energy consumption for briquetting of chopped common reed and straw stalk material particles (size 1-2 mm) with peat shows maximal value ~40 kJ·kg^{-1}.

To guarantee the quality of biomass briquettes in the handling and usage process, sufficient durability of briquettes will be provided. The mechanical strength of briquettes and its durability can be characterized by different parameters. For industrial durability tests several standardized methods are recommended. International standard ISO 616:1995(E) specifies a method for determining durability of coke by shatter test. Briquettes may be also tested mechanically for abrasion test according to the standard ČSN 441309 (2006).

For laboratory experimental testing of briquettes shear strength and crushing strength should be examined. Shear strength tests were performed for determining ultimate shear tests for briquettes with particles size less than 3 mm. Ultimate shear stress was obtained in direction perpendicular of briquetting direction [1].

Maximal values of ultimate shear stress 1.5 MPa for pure peat (100 %) briquettes had been obtained in durability investigations. Ultimate shear stress ~0.27 MPa was obtained for coarse chopped (particles 2-3 mm) reed briquettes and for rape straw.

Wood chip briquettes with particle size less than 2 mm let obtain ultimate shear stress >0.6 MPa, but the same durability of reed briquettes can be obtained with particle size less than 0.5 mm, ultimate shear stress 0.6 MPa for the straw briquettes can be obtained only by adding ~50 % of peat.

To reduce cutting energy of stalk material it is advisable to use roughly shredded material. Experiments carried out in Laboratory of Mechanics at Latvia University of Agriculture showed decreasing of cutting specific energy from 20 to 40 times for increasing length of particles from 1 mm to 100 mm.

Materials and methods

Roughly shredded straw or reed material does not provide necessary density and durability of briquettes, if material is unarranged in the closed die before cold briquetting.

Wheat straw, reed and reed composition with peat biomass densification experiments had been carried out by means of hydraulic press equipment in closed die (Figure 1). Pressure and piston displacement measurement data were collected on the PC using Picolog software. Chopped to different length stalks with moisture content less than 10 % was used for densification. Maximum pressure 1 780 bar was reached in closed die.

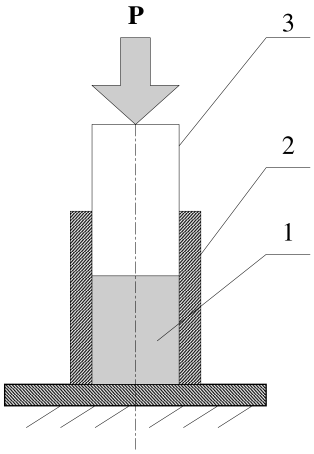

Fig. 1. **Scheme of densification:**
1 – stalk material composition,
2 – closed die, 3 – piston

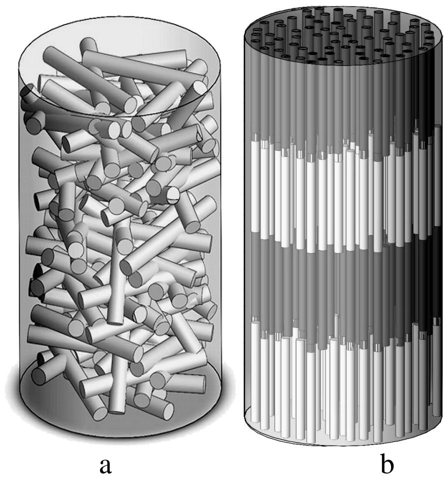

Fig. 2. **Arrangement of stalk material in closed die before briquetting:**
a – unarranged, b – arranged

Length of straw and reed particles was 30, 60 and 100 mm. Experiments was carried out with unarranged straw and reed particles and with arranged straw and reed particles.

Stalk material particles with certain length was arranged in closed die as it is presented in Figure 2b. Arranged particles were located in direction of longitudinal axe of die. Displacement between ends of particles in different layers was approximately from 5 to 15 mm. Particles was slightly compacted in arranging process to obtain the same mass of material for every rerun.

For comparison 30 mm length straw and reed particles was placed in briquetting die without arranging (Figure 2a) and pressed with maximum pressure. After arranging particles was compacted by pressing with the maximum pressure and length, diameter of briquette and weight was measured. Density of briquettes was calculated on the basis of dimension measurement and weighing.

The briquette mechanical strength is characterized by the force necessary for its destruction [2, 3]. The briquette of circular cross section is exposed to the pressure force as shown in Figure 3, i.e. its direction is perpendicular to its axis of symmetry. Briquette was placed on support plate of ZWICK testing machine and compression force *F* was applied to briquette in the direction perpendicular of briquetting direction. This force is gradually increased until the briquette disintegration and splitting. The destruction force intensity was investigated for 11 samples of each composition.

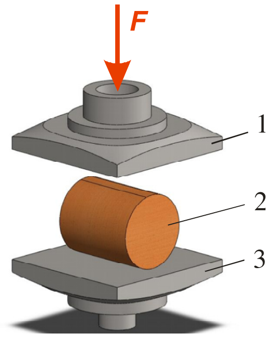

Fig. 3. **Scheme of compression:** 1 – compression plate, 2 – briquette, 3 – support plate

Briquettes diameter produced in experimental pressing device was 62 mm and length 60 mm. For comparison industrially produced wood briquettes and pure peat briquettes was tested in the same way.

Results and discussion

In previous densification experiments of chopped straw, common reed stalk material particles and compositions with additives was stated that compacted with pressure 230 MPa compositions of straw particles from two fineness groups (2-3 mm and < 0.5 mm) have density > 1.0 $g \cdot cm^{-3}$, if fineness proportion (amount of particles < 0.5) exceed 25 %. Density 1.0 $g \cdot cm^{-3}$ has been obtained in densification of straw and reed stalk material particle compositions with peat, if peat proportion exceeds 20 %. Density of briquettes made from coarse chopped material (particle size more than 3mm) were significantly less than 1.0 $g \cdot cm^{-3}$.

Fine communition of stalk material significantly increases energy of grinding. Previously was stated change of specific briquetting energy for different length of particles. Increasing of particle length from 1 to 100 mm decreases specific cutting energy 20 to 40 times.

The scope of investigation was to find method how to increase density and durability of coarse chopped material briquettes. Theoretical analysis of briquetting process was stated before experiments. If particles are inserted in briquetting die without arranging they lay down perpendicularly of pressing direction. Pressing force compact particles, but sharp adhesion between them does not occur because of hard stalk particle surface. The reason is flattening of stalk material particles and decreasing of bonding surface area. To increase density and strength of briquettes necessary to maximize bonding surface area between particles.

Suitable arrangement of straw and reed particles in briquetting die allows changing deformation directions of particles. The stalk material curves and adhesion between particles increases (Figure 4).

Fig. 4. **Straw briquette in the ZWICK testing equipment**

Arranged particles were located in direction of longitudinal axe of die according Figure 2b. Displacement between ends of particles in different layers was approximately from 5 to 15 mm. Particles were slightly compacted in arranging process to obtain the same mass of material for every rerun.

Results of investigation of briquettes density dependence on arranged particle size is presented in Figure 5. Increasing particle length from 30 to 100 mm does not affect significantly density of briquettes. Density of arranged straw briquettes varies between 939 kg·m^{-3} (100mm) and 928 kg·m^{-3} (30 mm). It is less then recommended 1.0 g·cm^{-3} and dependence on the length is less than 1.3 %.

Density of arranged reed briquettes varies between 927 kg·m^{-3} (30 mm) and 947 kg·m^{-3} (60 mm). Density dependence on the particle length for reed briquettes does not exceed 3 %.

The addition of peat to wheat straw and reed particles increases density of briquettes. Figure 6 presents the changes of briquettes density depending on peat content. The addition of 30 % peat increases density of briquettes till ~1.0 g·cm^{-3}. Significant reed+peat briquettes density depending on material length was not stated (Figure 6).

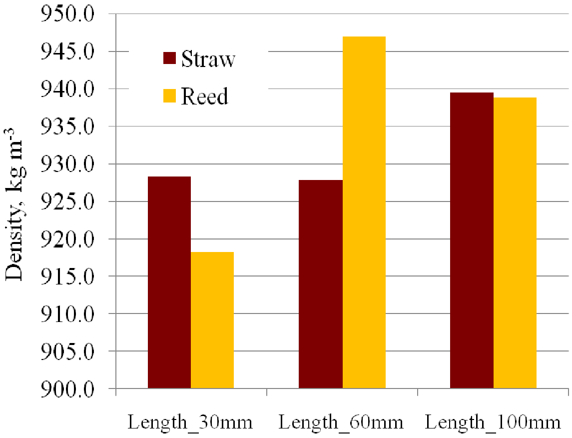

Fig. 5. **Briquettes density dependence on the length of particles**

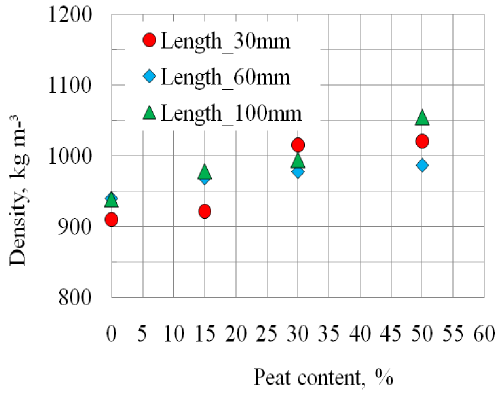

Fig. 6. **Briquette density dependence on the peat content for reed+peat compositions**

The addition of peat to wheat straw and reed particles increases density of briquettes. Figure 6 presents the changes of briquettes density depending on peat content. The addition of 30 % peat increases density of briquettes till ~1.0 g·cm^{-3}. Significant reed+peat briquettes density depending on material length was not stated (Figure 6).

Durability test was carried out using ZWICK and GUNT material testing equipment. As a result of tests briquette splitting force dependence on briquette deformation was stated (Figure 7). Evaluation of average splitting force for all reruns stated dependence of disintegration force on the particle length.

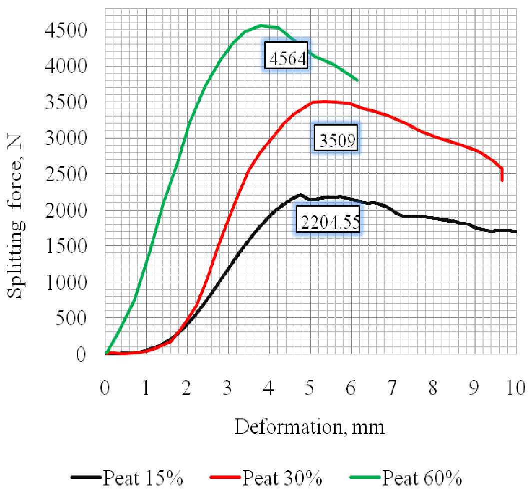

Fig. 7. **Splitting force depending on deformation of briquettes**

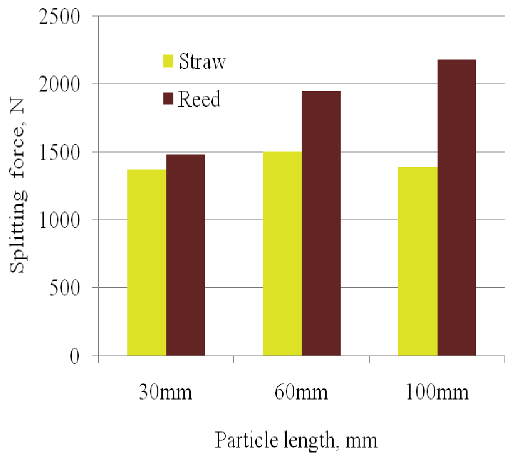

Fig. 8. **Dependence of splitting force on particle length for straw and reed briquettes**

Figure 8 presents dependence of splitting force on the particle length for wheat straw and reed made from arranged structure briquettes. Increasing of durability by increasing of particle length was stated for reed briquettes, but for straw briquettes change of splitting force was not significant.

Peat additives let substantially increase splitting force of reed briquettes (Figure 9). The addition of 15 % peat increases durability of briquettes from 1.2 to 1.3 times for all lengths of particles. Increasing addition of peat till 30 % and more, increases durability of briquettes, but splitting force dependence on particles length is not significant (Figure 9).

For comparison industrially produced wood, unarranged reed and wheat straw and pure peat briquettes was tested using the same method.

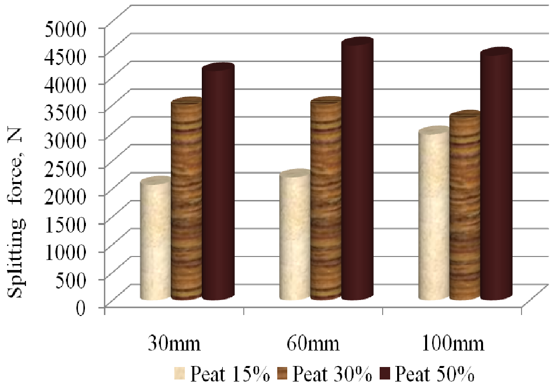

Fig. 9. **Splitting force dependence on peat additive for reed+peat compositions**

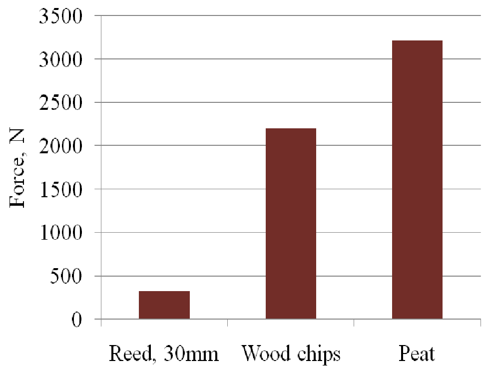

Fig. 10. **Splitting force for unarranged reed, wood and pure peat briquettes**

Unarranged reed particle (length 30 mm) briquettes shows splitting force approximately 300 N (Figure 10). The same value of splitting force was obtained for wheat straw (30mm) unarranged briquettes destroying.

Splitting force for wood briquettes reaches 2200 N and this value can be taken as a base for comparison of experimentally made briquettes. Pure peat briquettes showed splitting force 3200 N.

The addition of 30 % peat to arranged structure reed briquettes gives splitting force value equal to industrially produced wood briquettes (Figure 9).

Arranged structure reed briquettes (particle length 100 mm) reaches the splitting force value equal to wood briquettes (Figure 8).

Conclusions

1. Addition of 30 % peat to coarse chopped straw or reed arranged structure briquettes increases density to recommended value 1.0 $g \cdot cm^{-3}$.
2. Significant dependence of density on length of reed and straw particles was not stated.
3. Destroying force of arranged structure coarse chopped wheat straw and reed briquettes reaches value 2000 N. It is approximately the same as industrially produced wood briquettes.
4. Arranged structure of biomass particles in briquetting die is recommended for significant increasing durability of stalk material briquettes.
5. New briquetting equipment is necessary to design for biomass particle arranging before pressing.

Acknowledgement

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