DENSITY OF COMPACTED HERBACEOUS STALK MATERIALS

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Abstract. The 2003 reform of the EU Common agricultural policy introduced a special "energy crop payment" under which a premium of €45 per hectare is available for the production of energy crops. There is possibility in Latvia to provide for the use of approximately 0.36 million ha of the unused now agricultural land for energy crop growing. There are others resources of bioenergy in Latvia as agricultural residues and peat. More than 230 million tones of peat are available for solid biofuel production. Peat can be used as additive for manufacturing of briquettes, because it improves density of herbaceous material briquettes. European countries have standards (ŌNORM 7135, SS 18 71 20 and DIN 51731) concerned with wood pellet and briquette properties. Compacting is necessary operation for solid biofuel production from herbaceous stalk materials because the density of dry herbaceous stalk materials (straw, reeds) is too low (20 – 60 kg m^{-3}) for transportation on long distances. For density determination of compacted biomass different methods were approved and evaluated. Compacting experiments have been carried out in closed die by means of hydraulic press equipment. Maximum pressure 2330 bar was in closed die. Different roughness stalk material particle briquettes had been obtained. Compositions of particles from roughness group 2 – 3 mm and group with size less, than 0.25 mm in different weight proportions let obtain density > 1.0 kg dm^{-3} in briquetting, if content of finest particles is > 30 %. The same density (1.0 kg dm^{-3}) has been obtained in densification of straw stalk particle fraction 2 – 3 mm and peat particle < 3 mm composition, if content of peat is > 20 %. It can be concluded, that fine chopping of stalk materials significantly influence briquetting density.

Key words: herbaceous stalk materials, compacting.

Introduction

According Biomass Action Plan announced by Commission of the European Communities [1], we shall increase reliance on renewable energy sources, given the potential to produce them domestically and their sustainability, diversify energy sources, and enhance international cooperation. These elements can help Europe to reduce dependence on energy imports, increase sustainability and stimulate growth and jobs. The biomass has many advantages over conventional energy sources, as well as over some other renewable energy, in particular, relatively low costs, less dependence on short-term weather changes, promotion of regional economic structures and provision of alternative sources of income for farmers. Biofuel liquid form can be gainfully used in transport, but solid biofuel main application is heating and electricity production. This investigation is devoted to solid biofuel production and particularly to rural activities for this purpose.

The 2003 reform of the EU Common agricultural policy means that income support for farmers is no linked to the crops produced. As a result, farmers can respond freely to increasing demand for energy crops. This reform also introduced a special "energy crop payment" under which a premium of €45 per hectare [1] is available for the production of energy crops. The reform stimulates farmers to grow more energy crops, including short rotation coppice and other perennial crops. Decisions about the appropriate energy crops to grow are best taken at a regional or local level. Energy crop growing have to improve soil stability, fertility and quality of all ecosystem.

The principles of sustainability, implemented for agricultural ecosystem management, can be denominated as an "ecosystem approach to the management". The ecosystem approach means the taking into account the interrelationships among land, air water and all living organisms including humans. The ecosystem approach can be applied to many types of ecosystems, including lake's catchments, watersheds and other agricultural ecosystems. An understanding how the water cycle and the living processes are interrelated in managed ecosystems can be obtained from implementation of ecosystem approach. In the rural area of Latvia open water systems (rivers and lakes) and wetlands play an important role. Soil cultivation in the catchments area of natural open water systems interacts with water flows. The cultivation tends to aerobic decomposition of soil organic carbon compounds to produce CO_2 and water, and to release energy. Organic matter decreasing in soil increases a soil leaching by water flows. Irreversible charge flows (matter loss, mainly alkaline metal cations) from agricultural soils by surface water flows take place. So intense soil cultivation via surface water flows leads to catchments area acidification and desertification. The organic residue removal from the fields must be limited, because it leads to soil impoverishment and erosion. The quantity of herbaceous biomass, which can be removed without significantly affecting the carbon cycle, varies from 20 % to 50 % of the quantity available – it is equal 158 000 tons of straw annually in Latvia. Energy crop growing and biomass energy use improves not only local ecosystem quality, but global also. There is possibility in Latvia to provide for the use of approximately 0.36 million ha of the unused now agricultural land for energy crop growing. There are others resource of bioenergy in Latvia as peat. More than 230 million tones of peat are available for solid biofuel production. Peat can be used as additive for manufacturing of briquettes, because it improves density and quality of herbaceous material briquettes. If only herbaceous biomass is burned for energy production, the sulphur content is low and chlorides are formed [2]. The chlorides are causing the risk of high temperature corrosion. If the sulphur content of the fuel is increased by blending peat with chips or herbaceous biomass, sulphates are formed instead of chlorides and high temperature corrosion is avoided. For these reason herbaceous biomass compositions with peat for solid biofuel production is recommended.

Materials and methods

Growing of herbaceous energy crops for solid biofuel production in rural area is more preferable, because delayed harvesting in winter time let obtain biomass with humidity less than 15 % and content of nutrients (P, K) 50 % less than in autumn [3] 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.

Fig. 1. **Zwick materials testing machine**

Naturally herbaceous biomass is a material of low density (20 – 60 kg m^{-3}) and not favorable for transportation on long distances. Straw baling can increase bulk density to 100 – 200 kg m^{-3}. This practice is usable for energy crop as reed canary grass (Phalaris arundinacea) and other energy crop compacting, which would be source for solid biofuel in future. Different size of bales is used for straw compacting, depending on farm technical provision – small bales 0.36x0.5x0.8 m, round bales ∅ 1.2x1.5 m and Heston bales 1.2 x 1.3 x 2.4 m. Further herbaceous biomass density increasing for solid biofuel production is possible after it shredding and briquetting or pelleting. For necessary shredder and briquetting (pelleting) equipment design mechanical properties of mentioned stalk materials have to be investigated. Common reeds seems the strongest between mentioned before stalk materials, therefore their tensile and shear strength were investigated in order to find methods for cutting (shredding) with minimal energy consumption. Common reed test pieces were produced from flattened stalk slices. To the common reed slice end parts additional slice pieces are fastened with glue. As result we obtain tensile test piece with reinforcements in clamping areas. For tensile strength measurement (Fig. 1.) and cutting experiments the Zwick material testing machine TC-FR2.5TN.D09 was used. Zwick material testing machine has force measurement resolution 0.4 %, displacement measurement resolution 0.1 μm and maximal force value 2.5 kN. Computer controls testing machine using software for force and displacement data collection. Software provides possibility obtain energy consumption data output. Energy consumption for flattened reed stalk cutting had been investigated using the same Zwick materials testing machine equipped with cutting device. Cutting device consists of die with gap and turnable specimen fastening and rectangular prismatic punch with 5 mm thickness. Clearance between punch and gap is 0.02 mm from each side. Cutting device lets to cut specimen at different angle. Flattened reed stalks were used for cutting experiments. Displacement, stress and energy data were collected on computer. Stress and energy diagram can be get by means of Microsoft Office Excel program from the collected data.

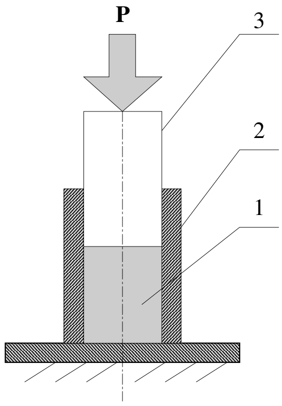

Fig. 2. **Closed die for compacting:** 1 – Biomass composition, 2 – cylinder, 3 – punch

Compacting experiments were carried out in closed die (Fig. 2.) with particles of shredded herbaceous stalk material. Previously shredded biomass had been sieved and separated to different fineness groups. Mixed peat and stalk material particles were used as briquetting compositions. Maximal pressure 230 MPa had been achieved in compacting. The briquettes with different density had been obtained as result. For density calculation the weight of briquette was measured on electronic scales Sartorius GM 312 with division 0.01 g and size of briquettes was measured with sliding calipers (division 0.01 mm). For evaluation of uncertainty of density calculation another method for density determination was used. It was buoyancy method where the apparent weight of the sample during submergence is determined. The buoyancy is the difference between the sample's weight in air and its apparent weight in liquid. The density of the sample is calculated according equation:

$$\rho = \frac{m_u}{m_u - m_s}\rho_w, \tag{1}$$

where m_u – is the weight of the test sample in air;
m_s – is the weight of the test sample in liquid;
ρ_w – is the density of liquid.

Results and discussion

Experimentally stated common reed stalk material ultimate tensile strength is 256 ± 27 N mm^{-2}. This value testifies that common reeds are the strongest material between other stalk materials, mentioned before, because experimentally earlier stated value of wheat stalk (with moisture content ~ 10 %) ultimate tensile strength is 118.7 ± 8.63 N mm$^{-2.}$

Flattened reed stalk cutting experimental investigation results show, that cutting stress reduces at greater cutting angle against cross section of stalk. Cutting stress at cross section cutting is within 52 – 75 N mm^{-2}, but cutting at 60° angles reduces to value 30 N mm^{-2}. Earlier stated value of wheat stalk (with moisture content ~ 10 %) ultimate shear strength is 8.47 ± 0.56 N mm^{-2}. The results demonstrate that from minimum energy consumption aspect flattened stalk cutting at cross section have to be recommended.

Recommended density of straw briquettes >1.0 g cm^{-3} had been obtained in compacting (Fig. 3.) experiments, when peat proportion exceeds 35 %. In praxis when large amounts of particularly difficult biofuels (e.g. logging residues and used wood) are to be combusted, blends with up to 35 % peat are used [4].

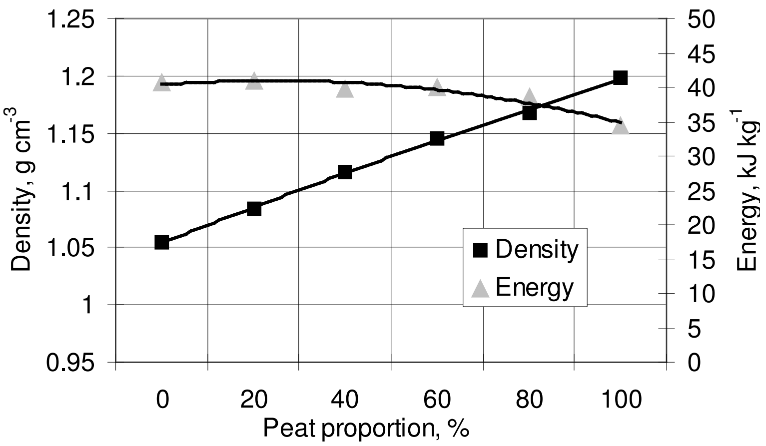

Fig. 3. **Density of stalk material and peat composition briguettes**

Pressing energy consumption for briquetting of chopped common reed stalk material particles with peat showed maximal value ≈ 40 kJ kg^{-1}. The density of reed (1 – 2 mm) briquettes >1.0 g cm^{-3} had been obtained without peat.

Results of density calculation from the weight and size measurements and density determination using buoyancy method for the same briquettes are shown in Fig. 4. It can be seen, that difference in density calculation results is less than 0.008 (0.7 %).

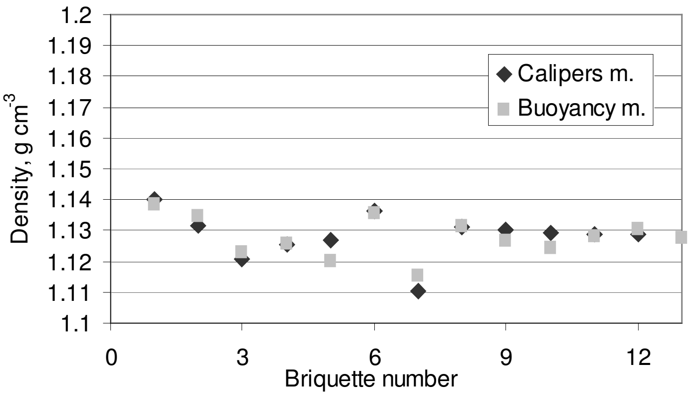

Fig. 4. **Density measurement evaluation**

Experimentally stated values of herbaceous biomass and it composition mechanical properties are recommended for mechanization equipment design for solid biofuel production.

Conclusions

1. Peat can be used as best additive for manufacturing of solid biofuel from herbaceous biomass, because it improves density, durability of stalk material briquettes (pellets) and avoid corrosion of boilers.
2. Experimentally stated common reed stalk material ultimate tensile strength is 256 ± 27 N mm^{-2}. This value testifies that common reeds are the strongest material between other stalk materials as wheat and rape straw and reed canary grass.
3. Specific cutting energy at different angle per area unit for reeds is within 8 – 16 kJ m^{-2}. Calculated specific cutting energy per mass unit on the counter shear for stalk material is within 16 – 32 J m kg^{-1}. For chopped reed stalk material (3 mm) specific cutting energy is within 6 – 10 kJ kg^{-1}.

4. Recommended density of herbaceous stalk material briquettes >1.0 g cm^{-3} is obtained in compaction process if peat proportion exceeds 35 %.
5. Pressing energy consumption for briquetting of chopped common reed and straw stalk material particles with peat showed maximal value ~ 40 kJ kg^{-1}.
6. The difference in density calculation results with two methods for the same briquettes is less than 0.008 (0.7 %).

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