HERBACEOUS BIOMASS SHREDDING FOR BIOFUEL COMPOSITIONS

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Abstract. *The 2003 reform of the EU Common agricultural policy stimulates farmers to grow more energy crops, including short rotation coppice and other perennial crops. Peat can be used as additive for manufacturing of solid biofuel, because it improves density, durability of stalk material briquettes (pellets) and avoid corrosion of boilers. For these reason herbaceous biomass compositions with peat for solid biofuel production is recommended. The main conditioning operation before biomass compacting is shredding. It was stated that common reed stalk material particle size reduction during cutting (shredding) process increased energy consumption very significantly. The calculation of energy consumption for common reed cutting to sizes 0.6 and 0.5 mm was giving results 31.3 kJ kg^{-1} and 43.5 kJ kg^{-1}. The shredder cutter bar has to be designed with friction energy losses decreased to minimum. This aim can to be realized by reducing of area of cutter bar knives moving into stalk biomass and minimizing biomass pressure (Patent LV13447) on cutter bar.*

Keywords: *biofuel compositions, herbaceous biomass shredding.*

Introduction

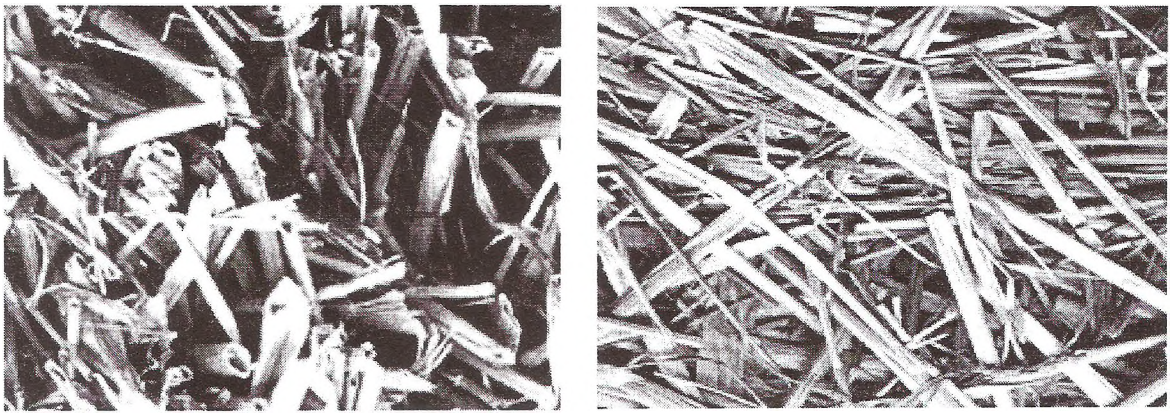
The 2003 reform of the EU Common agricultural policy stimulates farmers to grow more energy crops, including short rotation coppice and other perennial crops. There are others resources of bioenergy as agricultural residues and peat. Peat can be used as additive for manufacturing of solid biofuel, because it improves density, durability of stalk material briquettes (pellets) and avoid corrosion of boilers. The burning performance of stalk material biomass fuel if we use peat additive is improved also. If only wood chips or herbaceous biomass are burned, the sulphur content is low and chlorides are formed. The chlorides then tend to condense on heat transfer surfaces of the steam boiler, slowing down the heat transfer and causing the risk of high temperature corrosion. If the sulphur content of the fuel is increased, e.g. 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.

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*) compacting, which would be source for solid biofuel in future. For small scale biofuel production, as pellets and briquettes, usage of small square bales with size 0.36x0.5x0.8 m is preferable. The acceptance of the small rectangular baler for straw has come about because people like the size, shape and density of the bales. Bales are small enough to be stacked by hand and dense enough for efficient long distance hauling and inside storage.

The main conditioning operation before biomass compacting is shredding. There is necessity to improve mechanization equipment for biomass shredding for solid biofuel production. The shredder cutter bar has to be designed with friction energy losses decreased to minimum. This aim can to be realized by reducing of area of cutter bar knives moving into stalk biomass and minimizing biomass pressure on cutter bar. There is also possibility to cut down energy consumption for stalk material shredding by increasing the size of particles for compacting. Previously for production of straw briquettes it was necessary to reduce size of straw particles less than 3 mm. Peat usages as additive improves densification properties of such biomass composition and let to increase the size of stalk material particles.

Materials and methods

Technology of small square baling causes some orientation of straw stalks. There are stalk crosscuts on bale sides (Fig. 1a) and slightly flattened stalks without strong orientation have been seen on top of bale (Fig. 1b).



a) b)

Fig.1. **Orientation of stalks in a straw bale**

This stalk orientation in bale has to be taken into account designing a shredder cutter bar. Former experimentally were stated values for wheat stalks [1] ultimate tensile (118.7 ± 8.63 N mm^{-2}) and shear (8.47 ± 0.56 N mm^{-2}) strength, modulus of elasticity (13.1 ± 1.34 GPa) and shear modulus (0.643 ± 0.043 GPa) in order to find methods for mechanical conversion with minimal energy consumption. Reed canary grass stalks (stems) are more useful with delayed harvesting for fuel production [2] than leaf blades. According this mainly stalk material cutting properties have to be investigated.

Experimental investigation of common reed stalk conditioning properties as flattening and cutting can characterize maximum of energy consumption in these operations for all group of mentioned stalk materials because reeds have higher tensile strength (~200 N mm^{-2}) and accordingly another strength parameters.

Specific cutting energy per mass unit E_{sc} for stalk material can be calculated using equation:

$$E_{sc} = \frac{E_{scq}}{\rho}, \quad (1)$$

where: E_{sc} - specific cutting energy per mass unit, J m kg^{-1};

ρ - reed stalk material density, kg m^{-3}.

Specific cutting energy per area unit E_{scq} for reed stalk biomass varies in 8-16 kJ m^{-2}, depending of stalk strength.

Reed stalk material density varies from 500-700 kg m^{-3}. According equation (1) for average density 600 kg m^{-3} calculated specific cutting energy per mass unit E_{sc}=13.3-27 J m kg^{-1}. The value of E_{sc}=38 J m kg^{-1} can be found for alfalfa stalk material [3] cutting energy requirement calculations. These specific cutting energy values are the same order and can be used for calculations in cutting equipment design process. The cutting (chopping) energy E_c for stalk biomass unit (kg) is calculated [4] using equation:

$$E_c = \frac{E_{sc}}{L_c}, \quad (2)$$

where: E_{sc} - specific cutting energy per unit mass (J m kg^{-1});

L_c - length of stalk cut (m).

E_c - cutting energy per unit mass (J kg^{-1});

Innovative shredder (patent LV13447) with aim to reduce friction energy losses during shredding operation has been designed. This aim is realized by reducing of area of cutter bar knives moving into stalk biomass and minimizing biomass pressure on cutter bar.

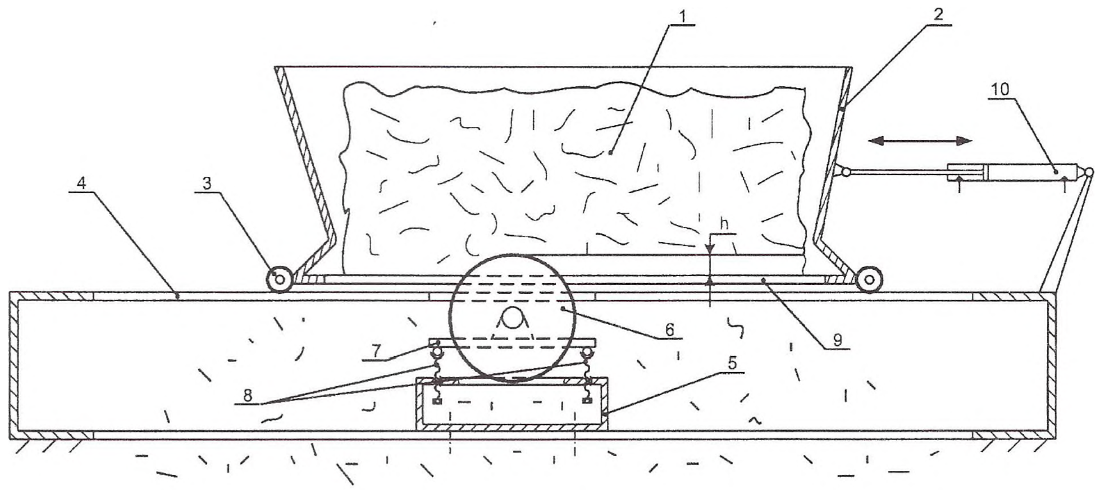


Fig.2. **Patented shredder design**

Biomass bale 1 is placed into hopper 2, which has reciprocating movement during shredding operation by means of rolls 3, connected with frame 4. Cutter frame 5 and cutter bar 6 have height adjustment possibility for bearing base 7 by means of regulate bolts 8. Cutter bar 6 blades is positioned into hopper slots 9. The cutting height h is adjusted with regulate bolts 8. The shredding reciprocating movement for hopper 2 is provided by means of hydraulic drive cylinder 10. Experimental shredder with described patented design is shown in Fig. 3.

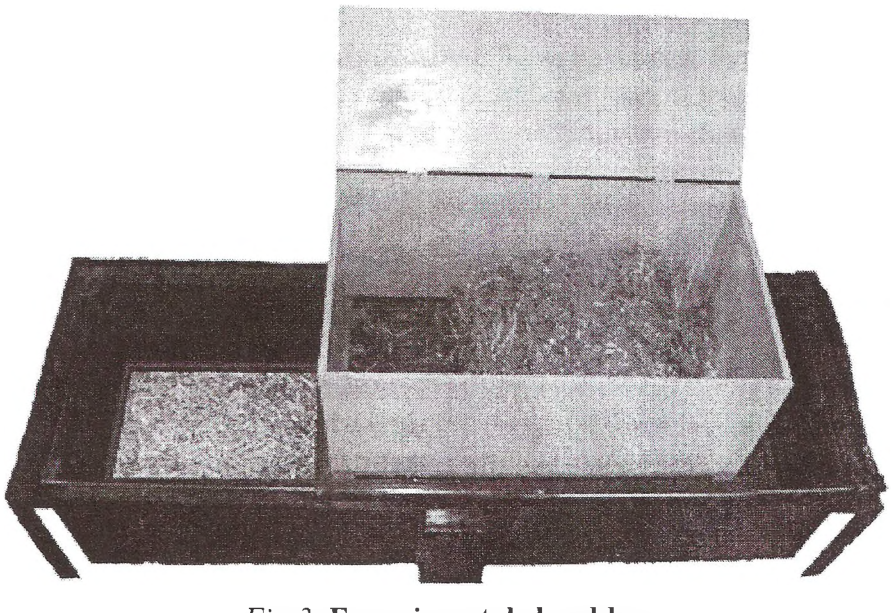


Fig.3. **Experimental shredder**

During laboratory experiments shredder output was determined as function of hopper speed in reciprocating movement. For this purpose hopper displacement was measured using displacement transducer and Picolog program. The shredded biomass was weighed on electronic scales with accuracy 1g.

Results and discussion

Energy consumption for common reed cutting (average specific cutting energy per mass unit E_{sc}=20 J m kg^{-1}) according formula (2) illustrates Fig. 4.

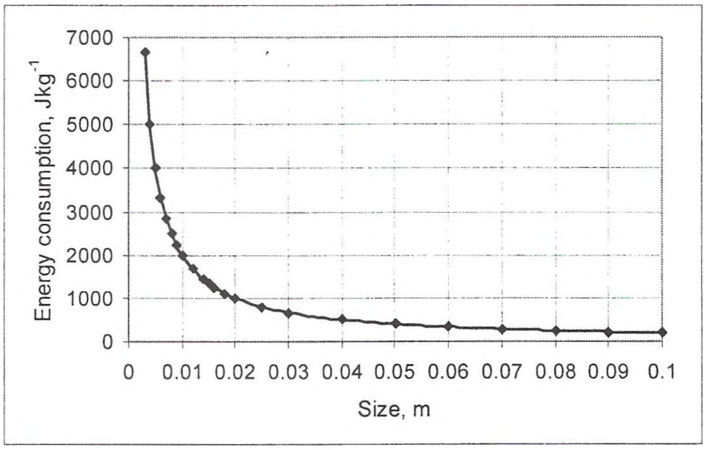


Fig.4. **Energy consumption for common reed cutting**

Reed stalk material particle size reduction during cutting (shredding) process increases energy consumption very significantly. Wheat straw and switchgrass grinding performance investigation [5] shows the same order values of energy consumption per mass unit. The grinds from hammer mill with screen size of 3.2 mm had a large size distribution with a geometric mean particle diameter 0.64 mm for wheat straw and 0.46 mm for switchgrass grinds. Corresponding energy consumption for grinding is 11.36 kW h t^{-1} (40.9 kJ kg^{-1}) for wheat straw and 23.84 kW h t^{-1} (85.8 kJ kg^{-1}) for switchgrass. The calculation of energy consumption for common reed cutting to sizes 0.64 and 0.46 mm is giving results 31.25 kJ kg^{-1} and 43.48 kJ kg^{-1}. Taking into account that common reeds have higher values of ultimate tensile and shear strength, this theoretical calculation, without energy losses from friction during shredding process, is giving feasible results. The shredder cutter bar has to be designed with friction energy losses decreased to minimum. This aim can to be realised by reducing of area of cutter bar knives moving into stalk biomass and minimizing biomass pressure on cutter bar. With these conditions taken into account common reed specific cutting energy per mass unit E_{sc}=13.3 – 27 J m kg^{-1}.

Determined output of experimental shredder as function of hopper average speed in reciprocating movement illustrates Fig. 5.

Shredder output is linear function of hopper speed. Speed more than 0.20 m s^{-1} for hopper is not recommended because then significant dynamic forces result from reciprocating movement.

There is possibility to increase shredder output with increasing of cutting height for blades. In this situation the friction of blades is growing up and more energy is wasted. Optimum of cutting height adjustment has to be determined during shredding in dependence of biomass properties.

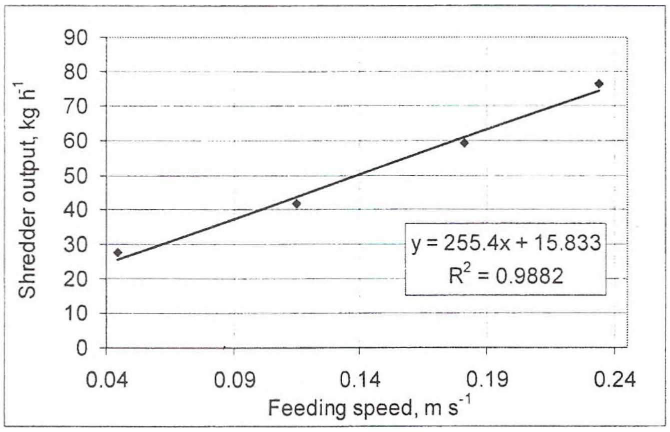


Fig. 5. **Shredder output**

Conclusions

1. The orientation of biomass stalks in bale has to be taken into account designing a shredder cutter bar and hopper size.
2. Reed stalk material particle size reduction during cutting (shredding) process increases energy consumption very significantly then size is less 0.01m.
3. The common reed specific cutting energy per mass unit is E_{sc}=13.3-27 J m kg^{-1}.
4. Shredder output is linear function of hopper speed.
5. Speed more than 0.20 m s^{-1} for hopper is not recommended because then significant dynamic forces result from reciprocating movement.

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