STALK MATERIAL BALE SIZE REDUCTION

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Abstract. As agriculture contributes in greenhouse gas (GHG) emissions there are tasks to reduce these emissions. Development of energy crop production and agricultural residue utilisation for energy are important goals of the rural policy in order to reduce GHG emissions. 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 usage of small square bales with size 0.36×0.5×0.8 m is preferable. For solid biofuel pellets and briquettes production size reduction of stalk material is necessary. Patented bale shredder is investigated. The novelty of the invention is location of cutter blades into slots created into hopper surface. The length of the slots complies with displacement during shredding reciprocating movement. The hopper or the cutter mechanism movement during shredding and cutting depth adjustment is provided. Experimentally energy consumption for wheet straw shredding is determined for different feed rate. For this reason parameters of hydraulic drive and movement are measured. Hydraulic drive dynamics during reciprocating movement of hopper is investigated. Theoretically durability of hoses in depending of pressure peak values is analyzed.

Key words: biomass size reduction, shredder investigation.

Introduction

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. Energy crop growing have to improve soil stability, fertility and quality of all ecosystem.

Naturally herbaceous biomass is a material of low density (20 – 60 kg m^{-3}) and not favourable 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 usage of small square bales with size 0.36×0.5×0.8 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.

Biomass properties cause necessity of appropriate mechanization equipment for biomass conditioning for further solid biofuel production. 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 cutterbar have to be designed with friction energy losses decreased to minimum. This aim can to be realized by reducing of area of cutterbar knives moving into stalk biomass and minimizing biomass pressure on cutterbar. 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 usage as additive improves densification properties of such biomass composition and let to increase the size of stalk material particles.

Materials and methods

Former experimentally were stated values for wheat stalks [2] 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 [3] than leaf blades. According this mainly stalk material cutting properties has to be investigated. Therefore straw material is used during experimental investigation of innovative shredder for 0.36×0.5×0.8 m bale size reduction before further solid biofuel production.

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 cutterbar knives moving into stalk biomass and minimizing biomass pressure on cutterbar (Fig. 1).

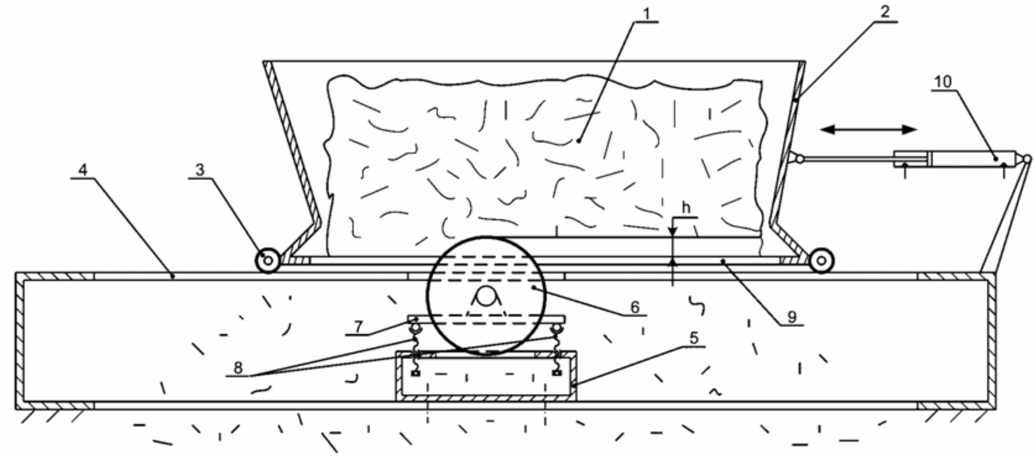

Fig. 1. **Patented shredder design**

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 hydraulically driven 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. 2.

Fig. 2. **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 diplacement transducer and *Picolog* program. Pressure and cutterbar shaft rotation speed was measured using the same *Picolog* program. Hydraulic power *N* for cutterbar rotation and hopper movement was calculated:

$$N = p \cdot Q \,, \tag{1}$$

where p – pressure, Pa;
Q – flow, $m^3\ s^{-1}$.

The shredded biomass was weighed on electronic scales with accuracy 1 g.

Chopped straw and peat additive (30% of composition) with moisture content less than 10% were used for densification. Maximum pressure 1500 bar was in closed die. The density of briguettes was calculated on the basis of dimension measurement and weighing on electronic scales with accuracy 1 g.

Results and discussion

Hydraulic power for straw biomass feeding movement, cutterbar rotation and total for shredding are linear functions (Fig. 3) of hopper feeding speed.

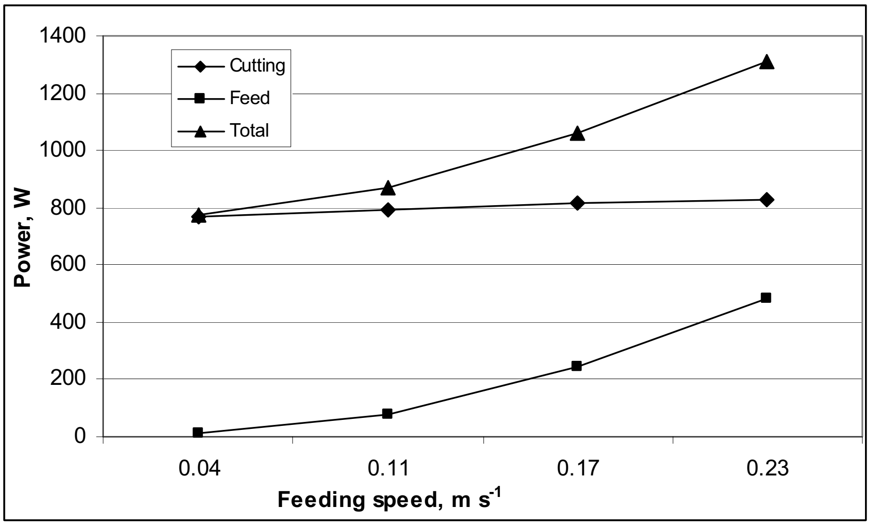

Fig. 3. **Straw size reduction power**

Shredder output in common with total shredding power is linear function (Fig. 4) of hopper feeding speed.

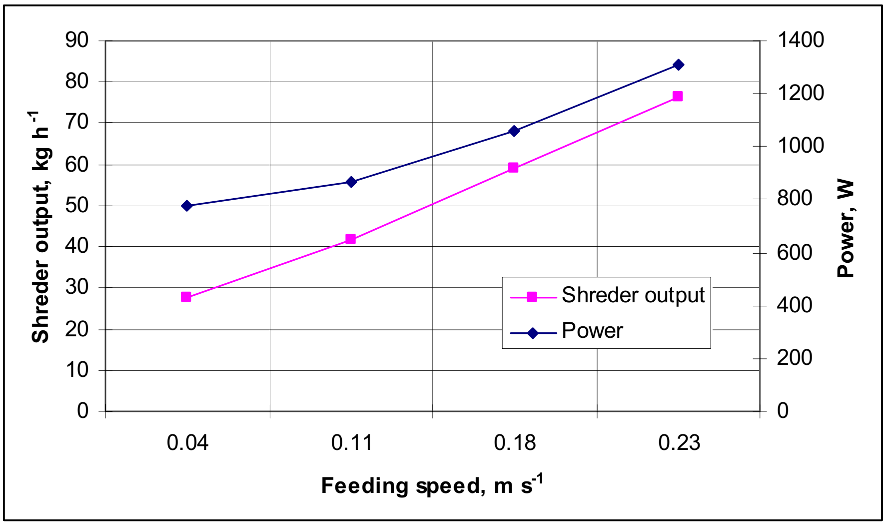

Fig. 4. **Straw shredder output**

Outputs of pressure, displacement and cutterbar rotation transducers recorded with *Picolog* program is shown in Fig. 5. There are fixed pressure peaks A and B in hopper hydraulic cylinder at the moments of movement direction reverse.

These peaks are as necessary pressure diference for direct control valve reverse. From another side it can be noted, that pressure value at diagram point A (60 bar) is less than at point B (80 bar).

Direct control valve adjustment (point B) have to be corrected to value 60 bar, because any needless pressure surges are cause of hydraulic hose service life reduction.

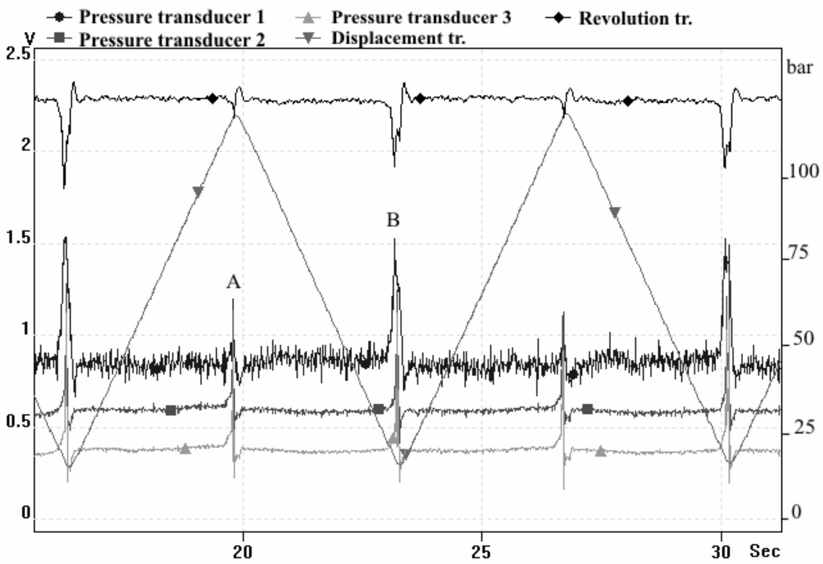

Fig. 5. **Records of transducers outputs**

Standard OCT. 23.1.82 "Hydraulic high pressure hoses" let us calculate hose service life as loading cycles T:

$$T = 43 \cdot \alpha \left(\frac{p_F}{p_B} \right)^{-7.7}, \quad (2)$$

where p_F – pressure de facto;
p_B – burst pressure;
α – hose property coefficient (0.11…1).

If pressure peak value p_F could be reduced, hose service life loading cycles T increase accordingly formula (2). Therefore direct control valve shifting pressure adjusment have to be used minimal possible for hose service life increase. Hydraulic pressure for cutterbar motor idle run has to be decreased in order to improve efficiency of experimental straw shredder.

Conclusions

1. For small scale biofuel production usage of small square bales with size 0.36×0.5×0.8 m is preferable.
2. Reducing of area of cutterbar knives moving into stalk biomass and minimizing biomass pressure on cutterbar friction energy losses is reduced.
3. Hydraulic power for straw biomass feeding movement, cutterbar rotation and total for shredding are linear functions of hopper feeding speed.
4. Shredder output in common with total shredding power is linear function of hopper feeding speed.
5. Hydraulic drive direct control valve shifting pressure adjustment have to be used minimal possible for hose service life increase.
6. Pressure for cutterbar motor idle run has to be decreased in order to improve efficiency of experimental straw shredder.

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