BALE SHREDDER EFFICIENCY DEPENDENCE ON SETTINGS

Andris Kronbergs, Eriks Kronbergs, Edgars Repsa, Mareks Smits
Latvia University of Agriculture
andris.kronbergs@llu.lv, eriks.kronbergs@llu.lv, edgars.repsa@llu.lv, mareks.smits@llu.lv

Abstract. Latvia has a target in 2020 for renewable energy resources to be 40 % in gross final consumption of energy. Herbaceous energy crops would be as the main basis for solid biofuel production in agricultural ecosystem in future. According to it the reed canary grass stalk material properties have to be investigated for solid biofuel production. The main conditioning operation before compaction of herbaceous biomass compositions for solid biofuel production is shredding and milling. Naturally herbaceous biomass is a material of low density ≈ 60 $kg \cdot m^{-3}$ and not favorable for transportation on long distances. Shredding can increase the bulk density to 280 $kg \cdot m^{-3}$. The reed canary grass stalk material shredding properties have to be investigated in order to find minimum of energy consumption for size reduction. The purpose of the work is to investigate the reed canary grass cutting energy consumption dependence on the bale shredder settings. For reed canary grass shredding a bale shredder Tomahawk 404 was used, which was equipped with a 37 kW electrical motor and inverter which changes the frequency in the range from 40 to 60 Hz. According to this frequency range, the velocity of the shredder rotor changes from 430 to 650 min^{-1}. The rotor velocity was changed with a step 110 min^{-1}. The bale shredder was equipped with three different screens with the mesh size 10, 18 and 28 mm. the machine was equipped with an instantaneous power measuring device.

Keywords: shredder efficiency, reed canary grass.

Introduction

Latvia has a target [1] in 2020 for renewable energy resources to be 40 % in gross final consumption of energy. Biomass has relatively low costs, less dependence on short-term weather changes and it is a possible alternative source of income for farmers. Herbaceous energy crops would be as the main basis for solid biofuel production in agricultural ecosystem in future. There is no problem in Latvia that if bioenergy crops are encouraged, then less land will be available for growing food. In 2005 investigation it was stated that 14.6 % of agricultural land of Latvia is unfarmed [2]. Therefore, herbaceous energy crop growing on these lands can provide sustainable farming practice.

Shredding is the main conditioning operation before preparation of herbaceous biomass compositions for solid biofuel production. According to it the cutting properties of reed canary grass bales have to be investigated in order to find the minimum energy consumption for shredding. The purpose of this research work was to determine the energy consumption for reed canary grass bale shredding and the shredder productivity with different screen mesh sizes.

Materials and methods

In the experiments the reed canary grass bales were shredded with a cutting prototype machine (Fig. 1) which consists of a bale shredder and cyclone. In prototype for bale shredding the bale shredder Tomahawk 404 is used.

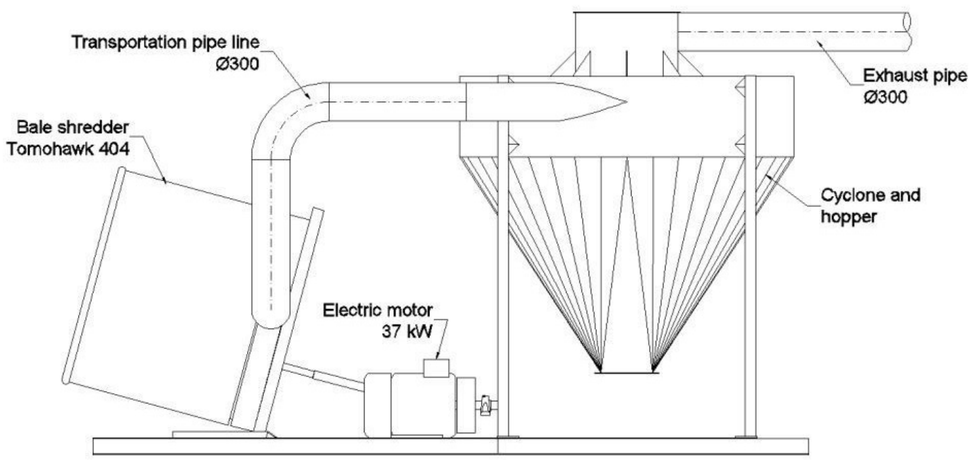

Fig. 1. **Bale shredding prototype machine**

The machine was equipped with a 37 kW electric motor and inverter YASKAWA AC Drive A1000 which changes the frequency in the range from 40 to 60 Hz. According to this frequency range, the velocity of the shredder rotor changes from 430 to 650 min^{-1}. During the experiments the rotor velocity was changed with a step 110 min^{-1}. The bale shredder was equipped with three different screens with the mesh size 10, 18 and 28 mm (Fig. 2, a).

a) b)

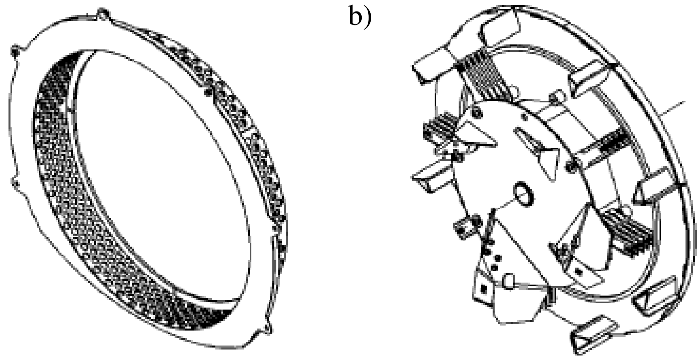

Fig. 2. **Tomahawk 404 cutting implements:** a – screen; b – cutting mechanism with hammers

The cutting mechanism for the bale shredder was equipped with 4 cutting knives and 30 swinging hammers. Each cutting knife was fixed to the rotor. The hammers were connected to the rotor with plugs in 6 rows, where in each row there were 5 hammers.

In the shredding experiments round bales with length – 1.2 m, diameter – 1.2 m were used. Average weight for all bales was 210 kg, average moisture – 21 %. In each experiment one bale with defined shredder parameters was shredded (Table 1).

Table 1

Shredding parameters

Nr.	Screen mesh size, mm	Rotor speed, min^{-1}
1	10	430
2	10	540
3	10	650
4	18	430
5	18	540
6	18	650
7	28	430
8	28	540
9	28	650

For each experiment the instantaneous motor power and bale shredding time were determined. All data were processed with Microsoft Excel software and prepared for further data analyzing.

The shredder productivity was determined for all kinds of screens, when the rotation speed was 540 min^{-1}, what is equal speed as for different agricultural tractor PTO shafts. The productivity of the bale shredder is calculated:

$$Q = \frac{m}{T}, \tag{1}$$

where Q – productivity, t h^{-1};
m – mass of reed canary grass bale, t;
T – bale shredding time, h.

The bale shredder specific cutting energy is calculated:

$$E = \frac{N \cdot T}{m}, \tag{2}$$

where E – specific cutting energy, kWh t^{-1};
N – average instantaneous power, kW.

Results and discussion

During the shredding experiments the screen mesh size and the rotation speed influence on the instantaneous cutting power were determined (Fig. 3). From the determined data it can be concluded that the instantaneous power of shredding is changing in wide range. The reason of power consumption differences are the non-homogenous material structure in the bale and variable material feeding to the hummer mill mechanism.

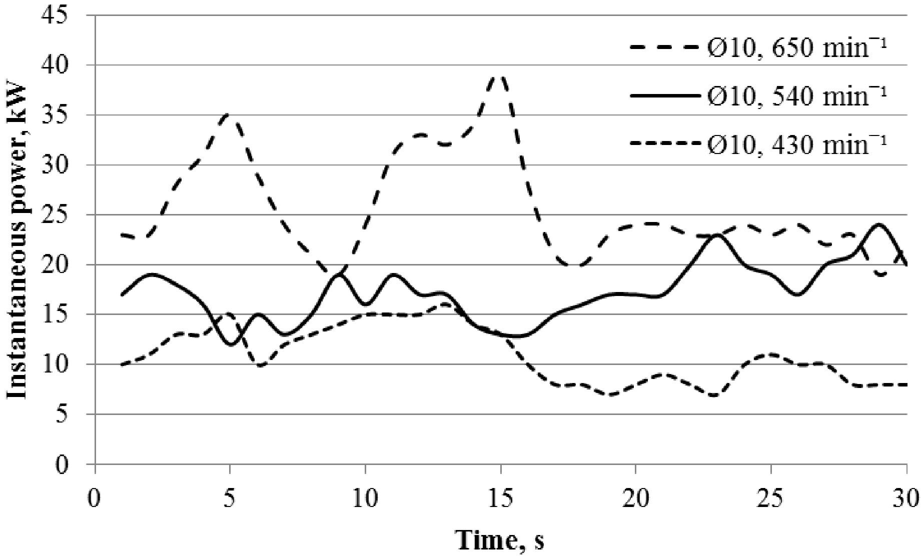

Fig. 3. **Instantaneous power using screen mesh size 10 mm**

The maximal value of the shredding instantaneous power was 68 % more than the average calculated instantaneous shredding power (Table 2).

Table 2

Shredding instantaneous power

Shredding parameters		Shredding power, kW		
Screen mesh size, mm	Rotor speed, min^{-1}	N_{MIN}	$N_{AVERAGE}$	N_{MAX}
10	430	7	11.0	16
10	540	12	17.3	24
10	650	19	25.6	39
18	430	6	11.0	17
18	540	7	12.6	20
18	650	10	18.2	27
28	540	6	9.5	16
28	650	10	11.7	18

The average calculated instentaneous power for all shredding parameters is shown in Fig. 4.

The shredded material had stucked during the experiments, when the rotation speed was 430 min^{-1} and the screen mesh size 28 mm were used. The material stucked in the transportation pipe line and the shredding process was interupted, therefore the data for the mentioned settings were excluded.

The screen mesh size influence on the shredder productivity and specific cutting energy is shown in Fig. 5. From the obtained data it can be concluded that the shredder productivity and specific cutting energy significantly improves if the sreen mesh size is changing from 10 to 18 mm. The shredder productivity in accordance with the mentioned screen mesh size changing increased from 0.53 to 1.63 t h^{-1}, but the specific cutting energy decreased from 32.5 to 7.7 kWh t^{-1}.

The shredded material after all experiments was used for solid fuel briquette production.

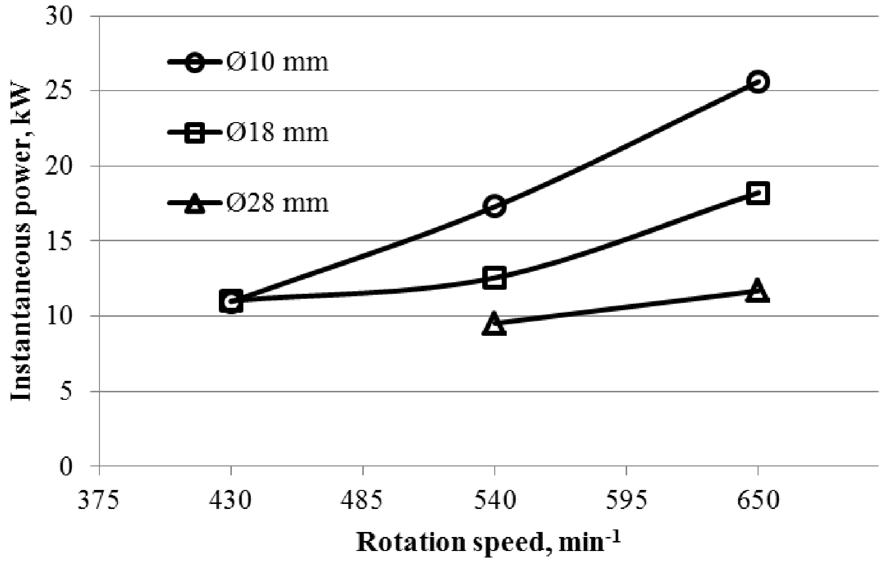

Fig. 4. **Instantaneous power dependence on screen mesh size**

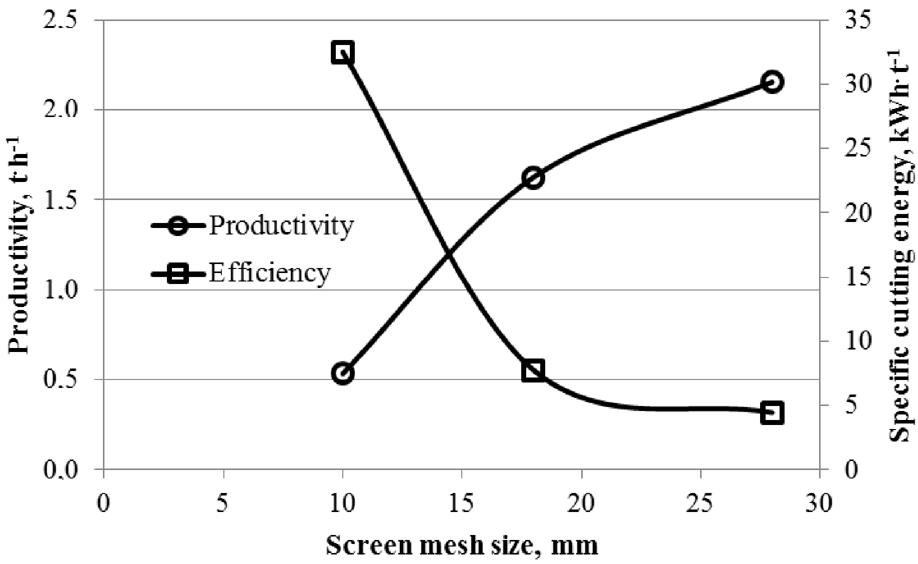

Fig. 5. **Productivity and specific cutting energy dependence on screen mesh size**

Conclusions

1. Instantaneous power of shredding is changing in wide range, as a consequence of non-homogenous material structure in the bale and variable material feeding to the hummer mill mechanism.
2. The maximal value of the shredding instantaneous power was 68 % more than the average calculated instantaneous shredding power 9.5 kW, if the screen mesh size 28 mm and the rotor speed 540 min^{-1} is used.
3. The shredder productivity and specific cutting energy significantly improves if the screen mesh size is changing from 10 to 18 mm. the shredder productivity in accordance with the mentioned screen mesh size changing increased from 0.53 to 1.63 $t \cdot h^{-1}$, but the specific cutting energy decreased from 32.5 to 7.7 $kWh \cdot t^{-1}$.

Acknowledgment

This publication has been prepared within the framework of the ERAF Project „Development of mechanization equipment for energy crops conditioning", contract Nr. 2010/0306/2DP/2.1.1.1.0/10/APIA/VIAA/128.

References

1. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance). http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0028:EN:NOT, (Accessed on 10.02.2013).
2. Land politics statement for years 2008. – 2014. The Order of the Cabinet of Ministers of the Republic of Latvia Nr. 613 (in Latvian), http://www.mk.gov.lv, (Accessed on 10.02.2013).