EVALUATION OF BIOMASS COMPACTING MECHANISMS

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Abstract
Biomass compacting represents technology for the conversion of biomass into a solid biomass fuel in shape of briquettes and pellets. Previously chopped stalk biomass is the material of low bulk density (80 – 150 kg m^{-3}), therefore compacting of biomass is one of the important processes for effective handling, transport and storage of this biomass fuel material. This study was conducted to evaluate two biomass compacting mechanisms – hydraulic piston press, and screw press. Technical parameters of these two types of presses were analysed. The energy consumption for solid wood fuel mass unit production in briquetting process is used as the main criterion. The aim of evaluation is to find the most convenient compaction mechanism for energy crop mobile briquetting press design. Density of wood briquettes was determined experimentally and compared with recommendations of the standard LVS EN 14961-3:2011. Experimentally stated compacting density of natural biomass – common reed particles (*Phragmites Australis)* depends on the size of particles. Compositions of reed particles with peat allow obtaining briquettes density of > 1000 kg m^{-3}. Energy consumption for composition compacting is decreasing with increasing of peat proportion.
Key words: briquetting, density, screw press, piston press.

Introduction

After coal and oil, biomass is the third largest energy resource in the world. Until the mid-19th century, biomass dominated global energy consumption. Even though increased fossil – fuel use has prompted a reduction in biomass consumption for energy purposes over the past 50 years, biomass still provides about 1.25 billion tons of oil equivalent (Btoe) or about 14% of the world's annual energy consumption (Parikka M., 2004; Tumuluru J.S., 2010).

Wood fuels, agricultural straws, and energy crops are the most prominent biomass energy sources. In Latvia, approximately 14.6% of unfarmed agricultural land can be used for herbaceous energy crop growing. Herbaceous energy crops would be the main basis for solid biofuel production in agricultural ecosystem in future. Herbaceous energy crops – reed canary grass (*Phalaris arundinacea*) and hemp (*Cannabis sativa*) have been grown in recent years. Beside that there is possibility to utilize for bioenergy production natural biomass of common reeds (*Phragmites Australis*) overgrowing shorelines of Latvian more than 2000 lakes.

Biomass compacting represents technology for the conversion of biomass into a solid biomass fuel in shape of briquettes and pellets. Previously chopped stalk biomass is the material of low bulk density (80 – 150 kg m^{-3}), therefore compacting of biomass is one of the important processes for effective handling, transport and storage of this biomass fuel material.

Pelleting, briquetting, and extrusion processing are methods commonly used to achieve densification. The present paper deals with evaluation of two commonly used biomass densification mechanisms – hydraulic piston press, and screw press with the aim to find the most convenient compaction mechanism for energy crop mobile briquetting press design.

Materials and Methods

The technical data from manufacturers of 15 screw presses and 15 hydraulic piston presses were compared. The specific energy consumption of screw press and hydraulic piston press for biomass unit briquetting was calculated by formula:

$$E_{sc} = \frac{3600P}{Q} , \qquad (1)$$

where

E_{sc} – specific energy of compacting mechanism, kJ kg^{-1};
P – power of compacting mechanism, kW;
Q – capacity of compacting mechanisms, kg h^{-1}.

For density determination, sawdust briquettes were obtained experimentally during compacting (Figure 1) with screw press and hydraulic piston press. Technical parameters of the hydraulic piston press: permissible moisture of input material 8 – 18%; density of produced briquettes 600 – 1100 kg m^{-3}; maximal hydraulic pressure 18 MPa; capacity 30 – 60 kg h^{-1}; power 4 kW. Technical parameters of the screw press: permissible moisture of input material 8 – 10%; density of produced briquettes 900 – 1400 kg m^{-3}; capacity 250 – 300 kg h^{-1}; power 22 kW; power of electric heater 6 kW. The sawdust briquettes made with screw press had a hexagon

Source: Woodworking…, 2011

Figure 1. **Equipment for briquetting experiments**

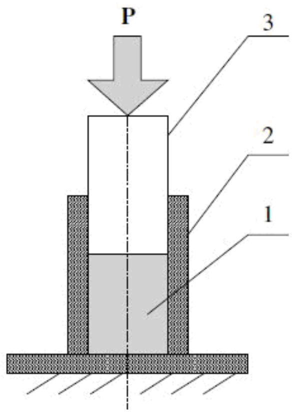

Figure 2. **The closed die for compacting: 1 – biomass, 2 – cylinder, 3 – piston**

cross-section with average edge dimension of 46 mm and with internal hole Ø20 mm. The sawdust briquettes made with hydraulic piston press had a round cross-section with average diameter of 64.5 mm and square form with edges dimension 64 x 150 mm. Briquettes densities were determined from the ratio of the mass to the volume of the briquette. For density calculation the weight of briquette was measured on electronic scales Sartorius GM312 with a division of 0.01 g, and size of briquettes was measured with sliding callipers (division 0.01 mm).

Laboratory compaction experiments were carried out in a closed die with diameter of 35 mm by means of hydraulic press equipment (Figure 2). A chopped common reed and reed-peat mixture material was used for experiments. For reed-peat mixture, peat was added in 15, 30 and 50% proportion. The modified wood shredder Tuenniseen GM-10 was used for reed chopping. The moisture content was determined according to the standard BS EN 14774-2:2009, where oven drying of the samples was carried out at 105 ± 2ºC (BS EN 14774-2, 2009). The dosage of 35 grams of chopped common reed particles and a mixture with peat additive was used for every briquette pressing.

During compacting of individual briquette, the force-displacement data were recorded by Pico Data Logger and computer. Energy requirement for compacting was obtained from force-displacement curves by graphical integration. The average values of measurements were calculated from 11 replicates.

Results and Discussion

The technical data from manufacturers of 15 screw presses and 15 hydraulic piston presses and specific energy consumption calculation for wood biomass unit briquetting are presented in Table 1 and Table 2. From the obtained results, for the screw press the calculated minimal average specific energy is 350 kJ kg^{-1}, maximal – 504 kJ kg^{-1} but for hydraulic piston press

Table 1

Screw press parameters

Screw press (Machine model)	Power, kW	Power of electric heater, kW	Capacity, kg h^{-1} (Min)	Capacity, kg h^{-1} (Max)	Specific energy, kJ kg^{-1} (Max)	Specific energy, kJ kg^{-1} (Min)	Average specific energy, kJ kg^{-1}
BIOMASSER SOLO BS06	4.2	4.5	40	60	783	522	653
SOLO 50	4.2	4.5	40	50	378	302	340
DUO 100	8.75	5	80	100	619	495	557
ZBJI	11	4.5	80	120	698	465	582
ZBJ-I	11	4.5	150	180	372	310	310
BIOMASSER DUO-SET	12.5	6.6	100	140	688	491	590
ZBJ-15	15	4.5	140	200	501	351	426
ПЭ-4	15	4.5	160	300	439	234	337
ZBJ-III	18.5	6.6	230	280	393	323	358
Zhongda	18.5	6.6	250	350	361	258	310
Hongji	18.5	6.6	250	350	361	258	310
ZBJ-ZY	22	9	320	500	349	223	286
Mingyang	22	6.6	240	320	429	322	376
HJJX-11	22	9	250	300	446	372	409
ПТБ	45	6.6	250	650	743	286	515

Source: Internet search results

Table 2

Hydraulic piston press parameters

Hydraulic piston press (Machine model)	Power, kW	Capacity, kg h^{-1} (Min)	Capacity, kg h^{-1} (Max)	Specific energy, kJ kg^{-1} (Max)	Specific energy, kJ kg^{-1} (Min)	Average specific energy, kJ kg^{-1}
BrikStar CS3-12	3	20	40	540	270	405
BrikStar CS4-12	4	30	60	480	240	360
OL.D 52	4	30	50	480	288	384
Weima C140	4	30	40	480	360	420
AECO 30	4.4	20	40	792	396	594
AECO 50	5.4	40	60	486	324	405
Weima C170	5.5	60	80	330	248	289
BP-100	5.6	43	63	469	320	395
Weima TH514	7.5	70	100	386	270	328
OL.D 62	7.5	50	70	540	386	463
BP 2000	18.5	150	225	444	296	370
MAX 350	24	350	500	247	173	210
BP 4000	30	600	750	180	144	162
RUF 600	37	500	600	266	222	244
RUF 1100	55	800	1000	248	198	223

Source: Internet search results

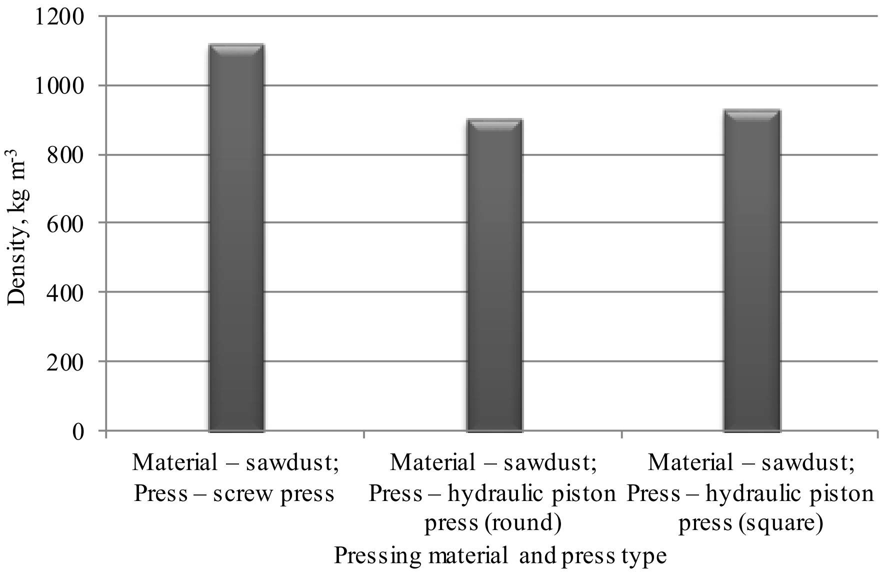

Figure 3**. Density of briquettes**

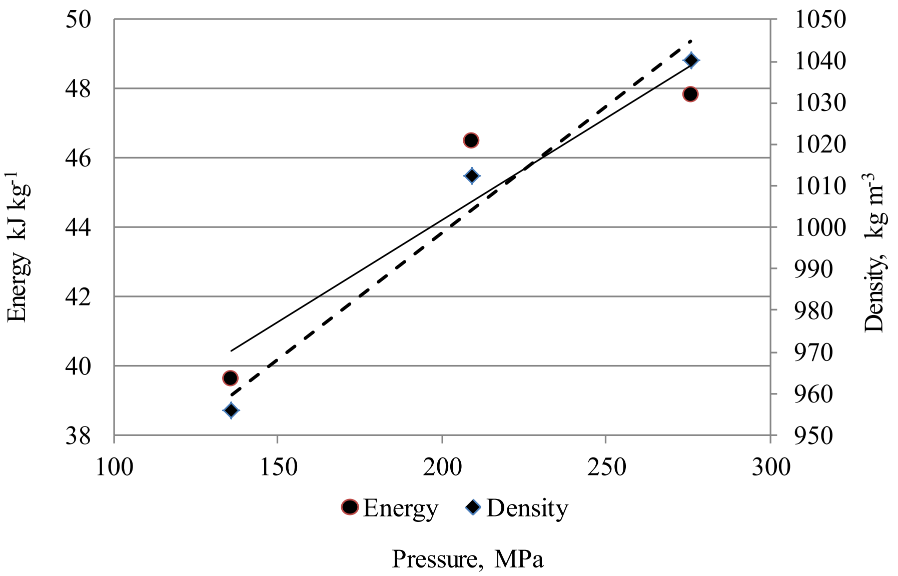

Figure 4**. Briquetting energy and briquettes density depending on pressing pressure**

the minimal average specific energy is 275 kJ kg^{-1}, maximal 424 kJ kg^{-1}. The specific energy differences depend on the minimal and maximal capacities of presses. Average specific compacting energy for the group of 15 screw presses is 407 kJ kg^{-1}, but for the group of 15 hydraulic piston presses – 350 kJ kg^{-1}.

The average specific energy consumption difference of 57 kJ kg^{-1} between the operation of screw press and hydraulic piston press can be explained with by additional energy consumption for biomass heating. Therefore, for mobile briquetting machines the hydraulic piston press mechanism is more preferable.

Density of sawdust briquettes obtained during compacting (Figure 3) with screw press and hydraulic piston press was determined 1122 kg m^{-3} for screw press briquettes, 902 kg m^{-3} for hydraulic piston press briquettes with a round cross-section and 930 kg m^{-3} with a square cross-section.

Density of experimentally produced wood briquettes was compared with recommendations of the standard LVS EN 14961-3:2011. This standard specification of wood briquettes for non-industrial use has two groups, A and B, with recommended densities DE1.0 ≥ 1.0 g cm^3 and DE0.9 ≥ 0.9 g cm^3 accordingly. There are no significant differences between standard LVS EN 14961-3:2011 density recommendations and determined density of wood briquettes produced with the screw press and the hydraulic piston press. The technical properties of the hydraulic piston press let to increase density of briquettes if friction forces in compaction die are enlarged.

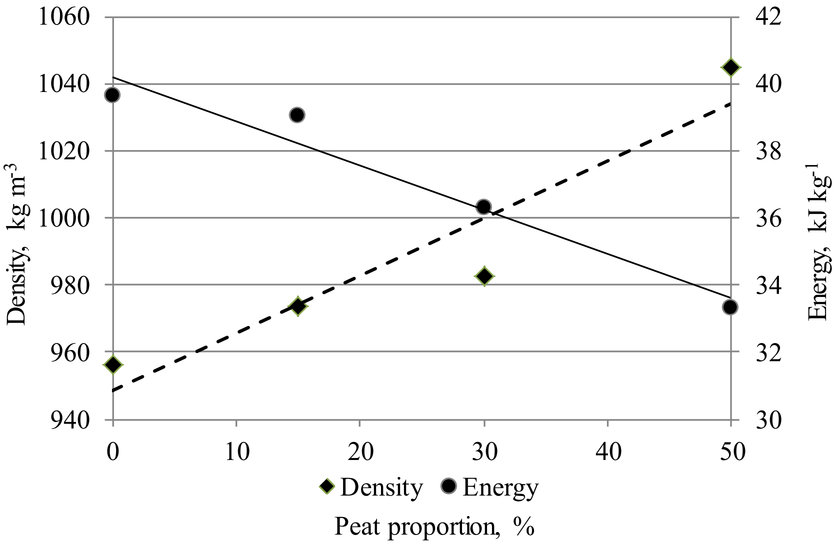

Figure 5. **Briquettes density and briquetting energy depending on peat proportion**

In previous experiments, the stated common reed stalk material ultimate tensile strength was 256 ± 27 N mm^{-2}. This value proved that common reeds are the strongest material among other energy crops, such as wheat and rape straw and reed canary grass, and could be regarded as representative energy crop of this group. Figure 4 shows that increasing compacting pressure from 136 to 276 MPa, the densities of reed briquettes are increasing from 956 to 1040 kg m^{-3}. For compacting experiments were used three pressure levels – 136, 206, and 276 MPa. Specific pressing energy was increasing from 39 to 47 kJ kg^{-1}, but 1000 kg m^{-3} density was achieved only for compacting pressure > 200 MPa. The resulting highest coefficient of determination for compacting data R^2 was determined for density 0.97 and for specific pressing energy 0.88.

Figure 5 shows the pressing energy consumption for briquetting common reeds with peat additive of up to 50%, and the density of produced briquettes. Maximum pressure of 136 MPa was achieved in compacting. Obtained results show that increasing peat additive up to 50%, specific compacting energy reduced from 39 to 33 kJ kg^{-1} and density increased from 956 to 1044 kg m^{-3}.

The resulting highest coefficient of determination R^2 was determined for density 0.95 and for specific energy 0.89. The present results show that peat additive is increasing the density of common reed particle briquettes and is reducing the specific compacting energy.

Conclusions

Average specific compacting energy for the investigated group of 15 screw presses was 407 kJ kg^{-1}, but for the group of 15 hydraulic piston presses – 350 kJ kg^{-1}. The average specific energy consumption difference of 57 kJ kg^{-1} between the operation of screw press and hydraulic piston press can be explained by additional energy consumption for biomass heating. Therefore, for mobile briquetting machines the hydraulic piston press mechanism is more preferable.

There were no significant differences between the standard LVS EN 14961-3:2011 density recommendations (DE1.0 ≥ 1.0 g cm^3 and DE0.9 ≥ 0.9 g cm^3) and the determined density of wood briquettes produced with the screw press and hydraulic piston press. The technical properties of hydraulic piston press allow increasing the density of briquettes if friction forces in compaction die are enlarged. By increasing the compacting pressure of common reed particles from 136 to 276 MPa, the densities of reed briquettes were increasing from 956 to 1040 kg m^{-3}. According to this pressure change, the specific pressing energy was increasing from 39 to 47 kJ kg^{-1}, but 1000 kg m^{-3} density was achieved only for compacting pressure > 200 MPa.

Increasing peat additive up to 50% to common reed particles specific compacting energy reduced from 39 to 33 kJ kg^{-1} and density of briquettes increased from 956 to 1044 kg m^{-3}. Peat additive is increasing the density of common reed particle briquettes and is reducing the specific compacting energy.

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