EFFECT OF RHOMBOID PRESSING MECHANISM ON BRIQUETTING ENERGY

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Abstract. The present paper deals with experimental evaluation of rhomboid pressing mechanism effect on briquetting energy. Energy requirement in densification and quality of produced briquettes are used for rhomboid mechanism evaluation. Average value of common reed (*Phragmites australis* L.) briquettes density 889.7 ± 41.3 kg·m^{-3} and specific compacting energy 52.66 ± 3.42 kJ·kg^{-1} has been obtained during briquetting with conventional hydraulic briquetting press. Average value of common reed briquettes density 802.1 ± 29.7 kg·m^{-3} and specific compacting energy 33.55 ± 0.68 kJ·kg^{-1} has been obtained during briquetting with hydraulic briquetting press equipped with rhomboid pressing mechanism. Comparing the obtained results the specific compacting energy difference is 19.11 kJ·kg^{-1}.

Keywords: briquetting, common reeds, rhomboid mechanism.

Introduction

Wood fuels, agricultural straw 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 as the main basis for solid biofuel production in the agricultural ecosystem in future. Herbaceous energy crops reed canary grass (*Phalaris arundinacea* L.) and hemp (*Cannabis sativa* L.) are being grown in recent years. Besides that, there is a possibility to utilize for bioenergy production natural biomass of common reeds overgrowing the shorelines of more than 2000 Latvian lakes.

Naturally biomass is a material of low density (80-150 kg·m^{-3}). The low density of biomass materials makes handling, transportation, storage and combustion processes complicate. Biomass compacting represents technology for the conversation of biomass into a solid biofuel.

Different biomass densification techniques have been developed producing solid fuels that can be classified according to their shape and dimensions. Pelleting, briquetting, and extrusion processing are methods commonly used to achieve densification. Hydraulic piston presses are conventionally used as briquetting machines for densification of biomass. The energy to the piston is transmitted from an electric motor via a high-pressure hydraulic system [1; 2].

Biomass briquetting is a very complicated process because there are many technological parameters (compacting pressure, material moisture, particle size, pressing temperature, pressing time, etc.) and constructional parameters (die design, friction coefficient between die and pressed material, friction between material particles, etc.) that affect this process and quality of briquettes.

The energy consumption during briquetting can be as a criterion for development of briquetting press and biomass densification parameters.

The hypothesis of this investigation is that the energy requirement in the compacting process can be reduced when the pressing mechanism is provided with nonlinear force – displacement characteristic.

The present paper deals with experimental evaluation of the rhomboid pressing mechanism effect on the briquetting energy. Energy requirement in densification and the quality of the produced briquettes are used for rhomboid mechanism evaluation.

The aim of this paper is experimental evaluation of the patented (LV 14201 B) rhomboid pressing mechanism.

Materials and methods

An experimental briquetter with a rhomboid linkage pressing mechanism (Fig. 1) for experimental investigation was used. For experimental investigation a conventional briquetting press with the hydraulic drive cylinder piston diameter 250 mm, pressing piston displacement 300 mm and closed end die cross section dimension 60x150 mm, equipped with a rhomboid pressing mechanism was used.

The rhomboid pressing mechanism was operated with a hydraulic cylinder diameter 100 mm. The hydraulic cylinder was connected between the pressing links with length 500 mm and supporting links with length 1100 mm. The rhomboid pressing mechanism was connected to the pressing piston.

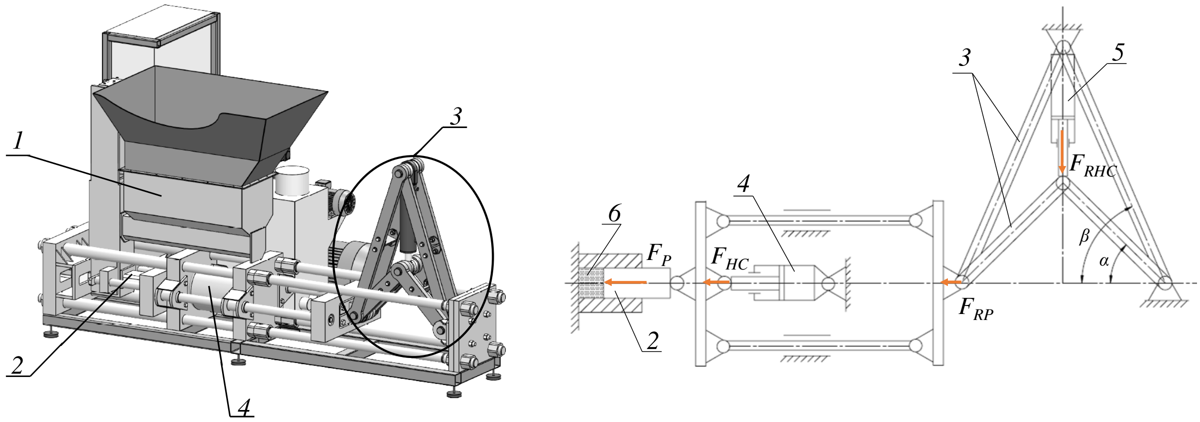

Fig. 1. **Hydraulic press with rhomboid mechanism and kinematic scheme:** 1 – container; 2 – pressing piston; 3 – rhomboid pressing mechanism; 4 – hydraulic press cylinder; 5 – rhomboid pressing mechanism hydraulic cylinder; 6 – pressing material

The experimental investigation was divided in two stages. In the first part of the experiment the briquetting energy was determined using a conventional hydraulic press without the rhomboid mechanism. In the second part of the experiment the briquetting energy of the mechanical system where the rhomboid pressing mechanism was connected to the hydraulic press was determined.

During the briquetting experiments hydraulic pressure was measured with a calibrated pressure sensor and pressing piston displacement with displacement transducer. For data collection Data Logger Pico and a computer were used. The experimental equipment is shown in Fig. 2.

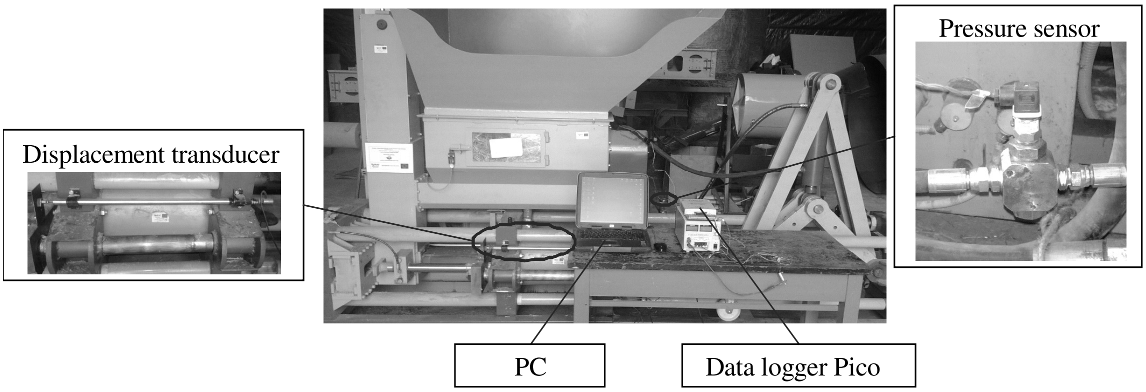

Fig. 2. **Experimental equipment**

Energy requirement for compacting was obtained from force – displacement curves by graphical integration. Energy requirement during briquetting with a hydraulic press equipped with the rhomboid pressing mechanism, force – displacement curves were calculated for the hydraulic press cylinder and rhomboid pressing mechanism cylinder. Total energy consumption for hydraulic press equipped with the rhomboid pressing mechanism was calculated as a sum of both drive hydraulic cylinder energy.

Total specific energy of compacting was calculated by equation:

$$E_{sp} = \frac{W}{m_b}, \tag{1}$$

where E_{sp} – specific compacting energy, kJ·kg^{-1};
W – compacting energy, kJ;
m_b – mass of briquette, kg.

Hydraulic press cylinder force can be calculated by equation:

$$F_{HC} = \left(p_1 \frac{\pi D^2}{4} - p_2 \frac{\pi \left(D^2 - d^2 \right)}{4} \right) \eta , \qquad (2)$$

where F_{HC} – force from hydraulic cylinder, N;
p_1, p_2 – pressure, MPa;
D – piston diameter, mm;
d – rod diameter, mm;
η – mechanical losses.

During the briquetting experiments without the rhomboid pressing mechanism the calculated pressing force is equal to the force from the hydraulic cylinder F_{HC} and the hydraulic cylinder displacement is equal to the displacement of the pressing piston. For the improved system where the rhomboid mechanism was added the pressing force F_P can be calculated as a sum of the hydraulic press and rhomboid pressing mechanism forces:

$$F_P = F_{HC} + F_{RP} , \qquad (3)$$

where F_{RP} – force from rhomboid mechanism, N;

Rhomboid mechanism pressing force can be calculated [4]:

$$F_{RP} = \frac{F_{RHC}}{2 \tan \alpha} - \frac{F_{RHC}}{2 \tan \beta} , \qquad (4)$$

where F_{RHC} – force from rhomboid pressing mechanism drive cylinder, N;
α – angular displacement of pressing links, deg;
β – angular displacement of supporting links, deg.

The rhomboid pressing mechanism drive hydraulic cylinder displacement was calculated from trigonometric relationships and the measured pressing piston displacement.

For the briquetting experiments grinded common reed was used. Grinding of common reed was done with 15 kW hammer mill using a sieve with a round shaped opening size 12 mm.

Moisture of the experimental material was between 11 and 14 %. The moisture content was determined according the standard LVS EN 14774-2:2010 where oven drying of the samples was carried out at 105 ± 2 ºC [3].

The briquettes with different density had been obtained as a result. Briquette density was determined from the ratio of the mass to the volume of the briquette. The weight of the briquette was measured on electronic scales with division 0.1 g and the size of briquettes was measured with sliding calipers (division 0.1 mm).

For evaluation of the produced briquettes the requirements given in the Latvian standard LVS EN 14961-1:2010 were used. The demand of the best biofuel density is >1000 $kg \cdot m^{-3}$ in the standards. For lower quality biomass solid fuel permissible density is >800 $kg \cdot m^{-3}$ [5].

Results and discussion

During the briquetting experiments with the experimental hydraulic press and rhomboid mechanism connected to the hydraulic press (Fig. 1) the hydraulic pressure was measured. An example of the briquetting pressure dependence on time is shown in Fig. 3.

The results of the experiments show that the maximal pressure values do not exceed 24.7 MPa if for briquetting a conventional hydraulic press was used. Maximal pressure values do not exceed 16.3 MPa if for briquetting a hydraulic press equipped with the rhomboid mechanism was used. Reduced maximal pressure values in the hydraulic system equipped with the rhomboid mechanism also reduce the drive power peak value. Therefore, the rhomboid mechanism can be recommended for mobile briquetting machines where the maximal pressure is usually less than 20 MPa. Reduced maximal pressure values are important also for increasing the durability of hydraulic lines in the system. Comparing the briquetting pressure curves the average cycle time difference is two seconds is seen. The reason of this time delay is hydraulic oil supply for two hydraulic cylinders. Briquetting pressure curves show that pressure changes from the minimal to maximal value depending on the resistance in the pressing chamber.

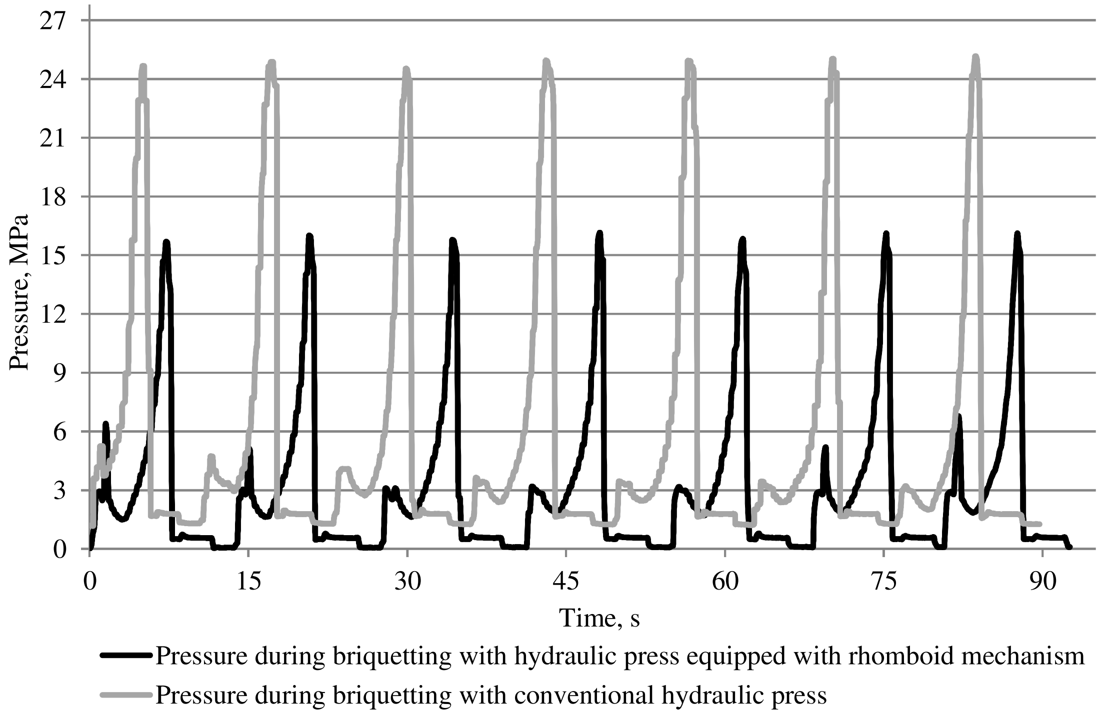

Fig. 3. **Briquetting pressure diagrams**

For typical force-displacement curve force calculation equations (2) and (3) were used and the piston displacement was measured during the experiments. Rhomboid mechanism displacement is the same as the pressing piston and hydraulic cylinder rod. The calculated force-displacement curves are shown in Fig. 4.

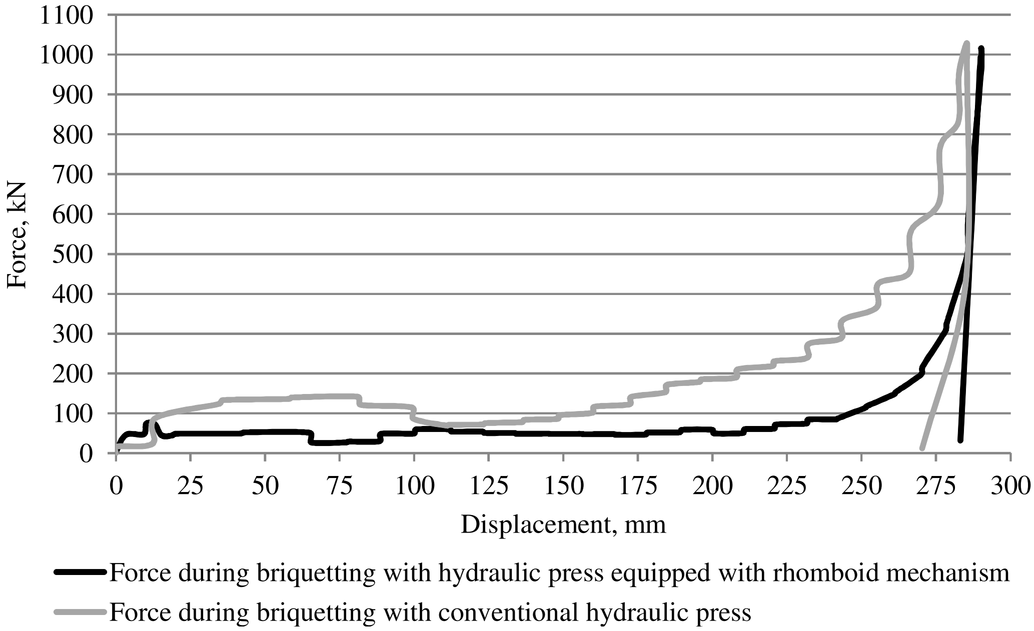

Fig. 4. **Force-displacement curves for one pressing cycle**

Energy requirement for compacting was obtained from the force – displacement curves by graphical integration. Total specific energy of compacting was calculated by equation (1). The obtained results are shown in Table 1 and Table 2. In Table 1 the results of specific compacting energy E_{sp} and density of briquettes ρ_B were for briquetting the hydraulic press was used are shown, but in Table 2 there are the results of the hydraulic press equipped with the rhomboid mechanism. Average value of common reed briquettes density 889.7±41.3 kg·m^{-3} and specific compacting energy 52.66±3.42 kJ·kg^{-1} has been obtained during briquetting with the hydraulic briquetting press. Average value of common reed briquettes density 802.1±29.7 kg·m^{-3} and specific compacting energy 33.55±0.68 kJ·kg^{-1} has been obtained during briquetting with the hydraulic briquetting press equipped with the rhomboid pressing mechanism.

Table 1

Specific compacting energy and density of briquettes (conventional hydraulic press)

No.	1	2	3	4	5	6	7	Average value	Accuracy ±
ρ_B, kg·m^{-3}	918.3	894.9	855.2	995.0	840.0	859.2	865.1	889.7	41.3
E_{sp}, kJ·kg^{-1}	49.88	53.13	52.41	54.95	50.87	51.24	56.12	52.66	3.42

Table 2

Specific compacting energy and density of briquettes (hydraulic press and rhomboid mechanism)

No.	1	2	3	4	5	6	7	Average value	Accuracy ±
ρ_B, kg·m^{-3}	835.6	751.0	766.5	822.4	806.8	802.8	829.9	802.1	29.7
E_{sp}, kJ·kg^{-1}	34.37	32.86	32.30	34.24	32.79	33.82	34.49	33.55	0.68

Comparing the obtained results the specific compacting energy difference is 19.11 kJ·kg^{-1}. The experimental study shows that using a hydraulic press equipped with the rhomboid mechanism it is possible to reduce the specific compacting energy. It can be explained by nonlinear force-displacement characteristics of the rhomboid mechanism. The difference between the density of the produced briquettes is 64.6 kg·m^{-3}. The designed rhomboid pressing mechanism can be recommended for biomass briquetting with drive from the hydraulic system with low maximal pressure.

Conclusions

1. Average value of common reed briquettes density 889.7 ± 41.3 kg·m^{-3} and specific compacting energy 52.66±3.42 kJ·kg^{-1} has been obtained during briquetting with the hydraulic briquetting press.
2. Average value of common reed briquettes density 802.1 ± 29.7 kg·m^{-3} and specific compacting energy 33.55±0.68 kJ·kg^{-1} has been obtained during briquetting with the hydraulic briquetting press equipped with the rhomboid pressing mechanism.
3. The experimental study shows that using a hydraulic press equipped with the rhomboid mechanism it is possible to reduce the specific compacting energy approximately up to 36 %.
4. As the maximal pressure values do not exceed 16.3 MPa if for briquetting the hydraulic press equipped with the rhomboid mechanism is used, it can be recommended for mobile briquetting machines.

References

1. Neethi-Manickama I., Ravindrana D., Subramanianb P. Biomass Densification Methods and Mechanism. In: Distributed Generation & Alternative Energy Journal, Volume 21, No 4, 2006, pp. 33-45.
2. Mazzu A. Study, design and prototyping of an animal traction cam based press for biomass densification. In: Mechanism and Machine Theory, Volume 42, Issue 6, 2007, pp. 652-667.
3. LVS EN 14774-2:2010 standard “Solid biofuels – Determination of moisture content – Oven dry method – Part 2: Total moisture – Simplified method”.
4. Repša E., Kronbergs Ē., Šmits M. Compaction characteristics of common reeds and mechanism for solid biofuel production. In: *From Research to Industry and Market*: Proceedings of the 19th European Biomass Conference and Exhibition, June 6 – 10, 2011, Berlin – Germany. ETA – Florence Renewable Energies, pp. 1866-1870. ISBN978-88-89407-55-7.
5. LVS EN 14961-1:2010 standard “Solid biofuels – Fuel specifications and classes – Part 1: General requirements”.