RHOMBUS BRIQUETTING MECHANISM MODELLING

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Abstract. The purpose of the work is innovative rhombus briquetting mechanism model development. Mechanism model simulation is a tool for the transition from the prototype to the real machine design. For simulation Working Model 2D software was used. The Working Model 2D software is capable of modelling the motion of rigid bodies that may be connected by a variety of joints and constraints. For simulation result evaluation energy consumption for pressing cycles was determined as 2.6 kJ for laboratory experiment and 2.5 kJ for simulation. Difference in the energy consumption results is 4 % for 6.5 grams briquette pressing.

Keywords: hydraulic briquetting mechanism, Working Model 2D.

Introduction

Substitution of fossil feedstock for energy by biomass is an important measure for GHG emission mitigation. For this reason the development of energy crops and agricultural residue utilization for energy are important goals of the rural area. Biomass compacting represents a technology for conversation of biomass into a solid biofuel. Naturally biomass is a material of low 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 material. Biomass briquetting is densification of loose biomass material to produce compact solid composites of different sizes. Briquetting of biomass takes place with the application of pressure, heat and binding agent on the loose materials to produce the briquettes. 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 the quality of briquettes [1; 2]. The energy consumption during briquetting can be as a criterion for development of the briquetting press and biomass densification parameters. The goal of the work is development of a rhomboid linkage briquetting mechanism simulation model with Working Model 2D software. The simulation model will be used for the real machine design on the basis of the laboratory prototype. Obtained simulation results are compared with experimental investigation of the laboratory briquetter prototype.

Materials and methods

Previously the hydraulic cylinder and pressing piston nonlinear force – displacement characteristic curves were determined experimentally for common reed – peat mixture briquetting with rhombus briquetter (patent LV 14604 B) prototype. Experimental briquetter with the rhombus linkage pressing mechanism (Fig. 1) for experimental investigation was used. Rhombus linkage mechanism link size was 200 mm, the drive hydraulic cylinder piston diameter 60 mm and rod diameter 40 mm. Open end tapered pressing die diameter was 25 mm and the pressing piston stroke 175 mm. For briquetting experiments grinded common reed and peat (30 %) mixture was used. Grinding of common reed was realized with the hammer mill using 6 mm sieve screen opening size. Compositions of reed particles with peat allow obtaining briquette density >1000 kg·m^{-3} if the peat proportion in mixture is 30 %.

Hydraulic cylinder piston force – displacement characteristic curves were calculated from the results of pressure measurements. Hydraulic cylinder loading force can be calculated by equation (1).

$$F_L = 0.001\eta\left(p_1\frac{\pi\left(D^2-d^2\right)}{4} - p_2\frac{\pi D^2}{4}\right), \tag{1}$$

where F_L – force, kN;
p_1 – pressure in the rod chamber, MPa;
p_2 – pressure in the piston chamber, MPa;
D – piston diameter, mm;
d – rod diameter, mm;

η – coefficient of mechanical efficiency.

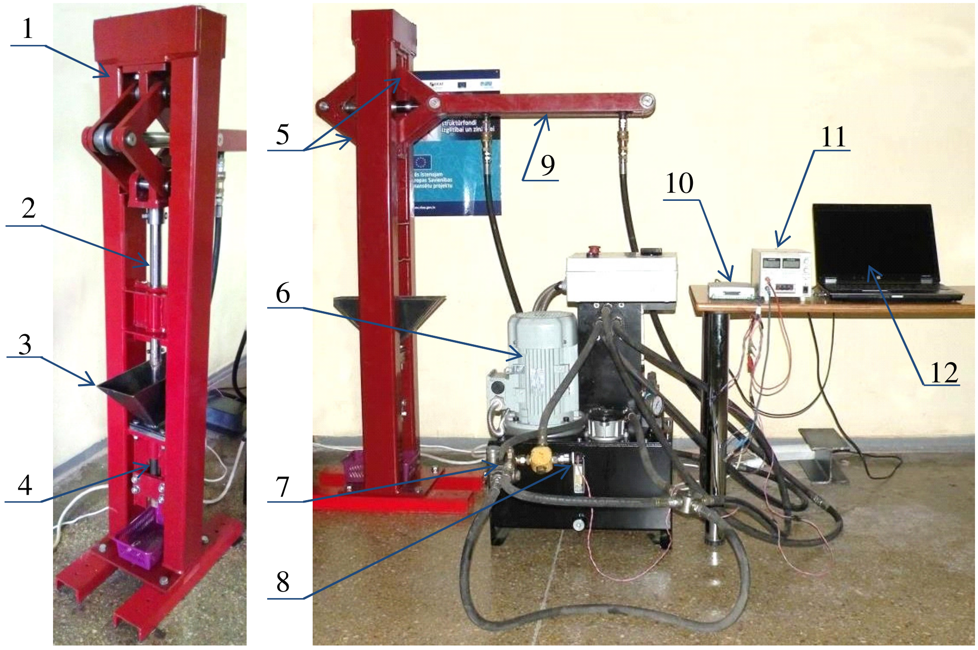

Fig. 1. **Experimental briquetter:** 1 – frame; 2 – pressing piston; 3 – container; 4 – tapered pressing die; 5 – rhombus linkage mechanism; 6 – engine; 7 – flow control valve; 8 – pressure sensor; 9 – drive cylinder; 10 – Data Logger Pico; 11 – power supply; 12 – computer

For experimental laboratory rhombus linkage mechanism pressing force calculation equation (2) is used [3].

$$F_P = \frac{F_L}{\tan \alpha} \eta_f , \tag{2}$$

where F_P – briquetting force, kN;
α – rhombus linkage mechanism linkage position (Fig. 2), deg;
η_f – coefficient of mechanical efficiency in pins.

The calculated force – displacement curve is shown in Fig. 2.

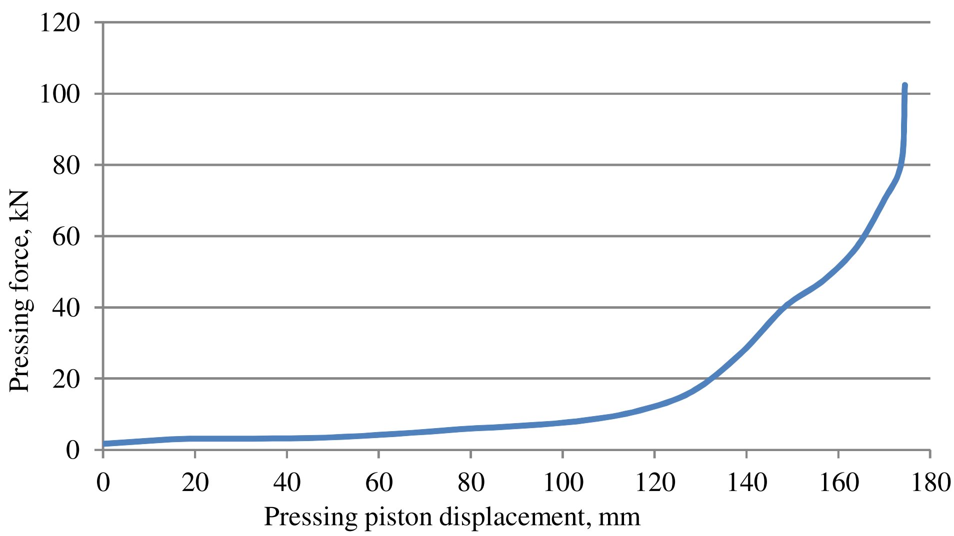

Fig. 2. **Pressing mechanism force – displacement curve**

For simulation Working Model 2D software was used. The rhombus linkage mechanism model is shown in Fig. 3.

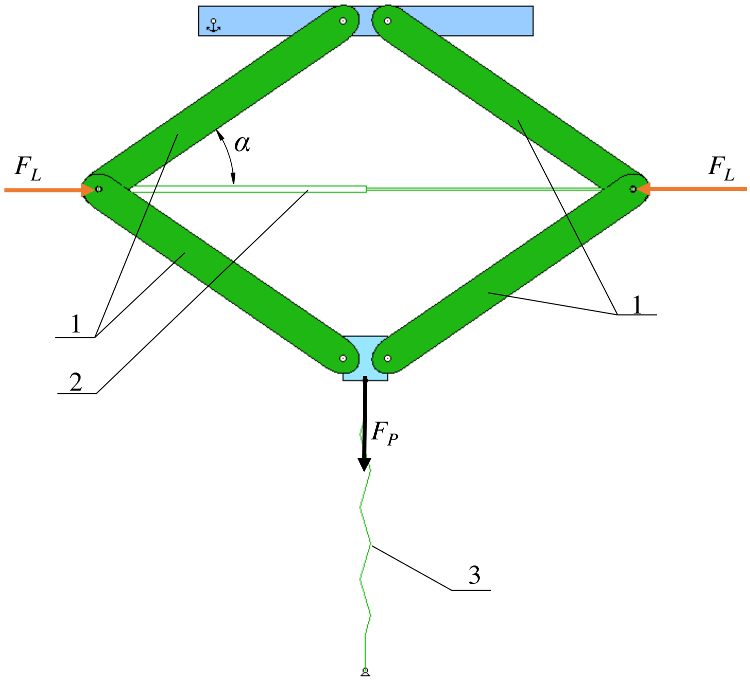

Fig. 3. **Rhombus linkage mechanism in Working Model 2D software:**
1 – links; 2 – hydraulic cylinder element; 3 – spring element

The Working Model 2D software is capable of modelling the motion of rigid bodies that may be connected by a variety of joints and constraints [4]. Rhombus briquetting mechanism in Working Model 2D software had been created by analogy with real briquetting mechanism prototype.

Hydraulic cylinder was replaced by the hydraulic cylinder element 2 with constant drive speed 0.041 $m \cdot s^{-1}$. Resistance F_P in the pressing die was provided with the spring element 3. Spring element compression force has nonlinear characteristic described with equation (3).

$$F_T = \frac{k}{x^2}, \tag{3}$$

where F_T – compression force, kN;
k – spring rate, $kN \cdot m^2$;
x – displacement, m.

Results and discussion

Using the spring rate 0.068 $kN \cdot m^2$ compression force characteristic for pressing load as nonlinear spring element is obtained (Fig. 4). Value 0.068 $kN \cdot m^2$ was found comparing the Working Model 2D spring characteristic with the experimental pressing mechanism force – displacement characteristic.

During simulation the spring element tension and hydraulic cylinder element force were measured. The results of simulation and experiments were compared.

In Fig. 5 the calculated hydraulic cylinder force – displacement curve 1 is shown for the pressing cycle and curve 2 as the result from Working Model 2D simulation. Force curve 1 was calculated from equations (1) according to the experimental results of pressure measurement in laboratory experiments. Force curve 2 was obtained from the hydraulic cylinder actuator tension measurement in Working Model 2D simulation for the pressing cycle.

For simulation result evaluation energy consumption for both pressing cycles was calculated with graphical integration. Area under curve 1 (Fig. 5) represents energy 2.6 kJ and under curve 2-2.5 kJ. Difference in the energy consumption results is 4 % for 6.5 grams briquette pressing.

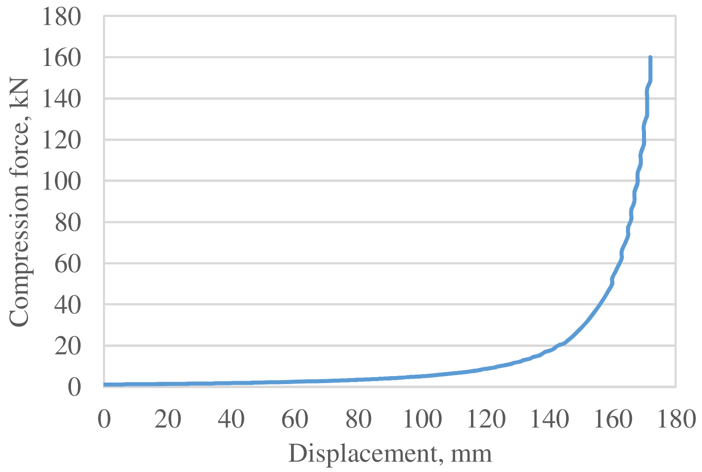

Fig. 4. **Compression force characteristic for spring element**

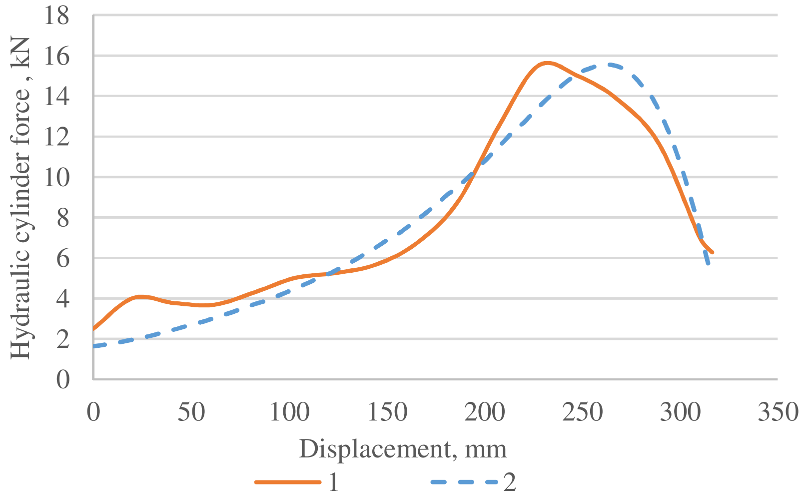

Fig. 5. **Hydraulic cylinder force – displacement characteristic**

Visually, both of the curves 1 and 2 are similar. Working Model 2D software has the advantage of a nonlinear process modelling capabilities, with different load elasticity characteristics. For actuators different force values and kinematic parameters are available.

Further rhombus briquetting machine design can be based on Working Model 2D simulation for real size briquettes production. There is a possibility to include also the viscous damping characteristic of pressing load.

Conclusions

1. Working Model 2D software provides actuators with different forces and kinematic parameters for briquetting mechanism hydraulic cylinder simulation.
2. Resistance in the pressing die in Working Model 2D software is provided with nonlinear stiffness characteristic spring element.
3. Rhombus briquetting mechanism hydraulic cylinder force – displacement curves were obtained on basis of the pressure measurement results in laboratory experiments and as simulation of actuator force in Working Model 2D.
1. For simulation result evaluation energy consumption for both pressing cycles was determined as 2.6 kJ for the laboratory experiment and 2.5 kJ for simulation. Difference in the energy consumption results is 4 % for 6.5 grams briquette pressing.
2. Further rhombus briquetting machine design can be based on Working Model 2D simulation for real size briquettes production.

References

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