# COMMON REED BRIQUETTING MODELING

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**Abstract.** Removal of common reeds (*Phragmites Australis*) from the lake shorelines is also the lake restoration action and improving the water quality. The use of common reed as biomass for the production of solid fuels can significantly reduce the use of fossil fuels. Common reed is a freely available resource in the overgrown lakes of Latvia. Common reed solid biofuel production technology after grinding provides briquetting to required density. The purpose of the work is theoretically to determine the resistance characteristic for the pressing mechanism modelling. In laboratory experiments briquettes were produced from grinded common reed particles. The main tasks of the laboratory experiments were determination of the compacting force – displacement characteristics for compacting of different size common reed particles. On the basis of the results of the compacting experiments non-linear particle compression resistance characteristic with Mathcad programme was developed. The mechanical model contains a spring incorporated in the rhomboid mechanism. Comparing the results of experiments and modelling the maximal difference 4.96 % (screen size 1.5 mm), 1.98 % (screen size 6 mm), 8.45 % (screen size 12 mm) and 6.94 % (screen size 20 mm) was determined.

**Keywords:** common reed, briquetting, rhomboid mechanism.

## Introduction

Substitution of fossil feedstock for energy by biomass is an important measure for GHG emission mitigation. Renewable energy resources are one of the priority directions in all domains of research of the rural area. There is a possibility to utilize for bioenergy production natural biomass of common reed overgrowing shorelines of Latvian more than 2000 lakes. Removal of common reeds from the lake shorelines is also the lake restoration action and improving the water quality [1; 2]. Therefore, reed use as energy feedstock is also recommended for environment quality improvement.

Biomass compacting represents a technology for convertion of biomass into 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 [3; 4]. Biomass compacting can be realized with different industrial machines. The process of biomass briquetting depends upon the physical properties of the ground particles and the variables: pressure, moisture and temperature. The biomass briquetting process can be better explained, if the compacting mechanism of the material is clear. The compacting mechanism of different biomasses materials will be different from each other. It is also important to investigate the compaction mechanism of biomass particles to design energy efficient compaction equipment and to understand the effect of various process variables on briquette density to enhance the final quality of the produced product. It was stated that compact density of biomass increased with the increase of pressure [5; 6]. In order to be able to design energy efficient briquetting machines, it is necessary to understand the nature of mass pressing. Development of constitutive force – displacement models that can provide adequate physical representation of observed mechanical behaviour for biomass materials, is a challenging problem.

The purpose of the work is theoretically to determine the resistance characteristic for the pressing mechanism modelling.Use of the rhomboid press mechanism for biomass particle compacting was modelled using MathCAD software. Non-linear particle compression resistance curve using the spring incorporated in the rhomboid mechanism has been obtained.

## Materials and methods

Laboratory compaction experiments had been carried out in closed die with diameter 35 mm by means of laboratory hydraulic press equipment. The dosage of 35±0.1 grams of grinded common reed was used for every briquette pressing. During the briquetting experiments the briquetting pressure was measured with a calibrated pressure sensor and pressing piston displacement with displacement transducer. For data collection the Data Logger Pico and computer were used. The experimental equipment is shown in Fig. 2. Collected data were processed by MS Excel.

Grinding of common reed was realised with a hammer mill (15 kW) using four different sieve screen opening sizes 1.5, 6, 12 and 20 mm (Fig. 1). Moisture content of grinded common reeds 8.7 %

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was obtained according to the standard BS EN 14774-2:2009, where oven drying of the samples was carried out at 105±2 ºC [7]. Recommended moisture content is in the range of 8 – 15 % for biomass materials to produce high quality briquettes. At this moisture content, the briquettes are strong and free of cracks and the compacting process is preferential [8; 9]. It is known that briquette densities were of a consistently higher value, when the biomass samples were compressed at a lower moisture level [10], therefore the experiments were carried out on materials with a mean moisture content of 8.7 %.

Screen size1.5 mm | Screen size6 mm | Screen size 12 mm | Screen size 20 mm

Fig. 1. **Grinded common reeds**

The main tasks of the laboratory experiments were determination of the compacting force – displacement characteristics for compacting of different size common reed particles.

For the compacting process modelling of common reed particles a rhomboid resistance mechanism was used. The rhomboid resistance mechanism model is shown in Fig. 3.

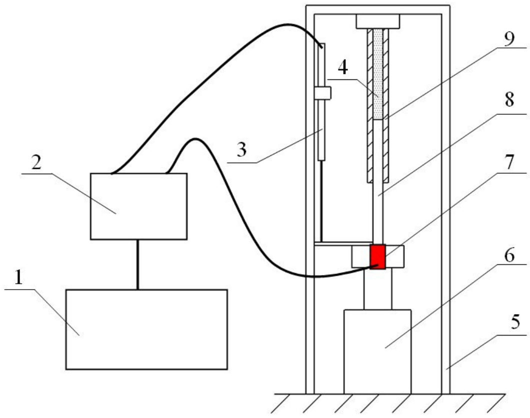


Fig. 2. **Compacting scheme:** 1 – computer; 2 – Pico Data Logger; 3 – displacement transducer; 4 – biomass; 5 – frame; 6 – hydraulic press; 7 – force measurement sensor; 8 – piston; 9 – cylindrical

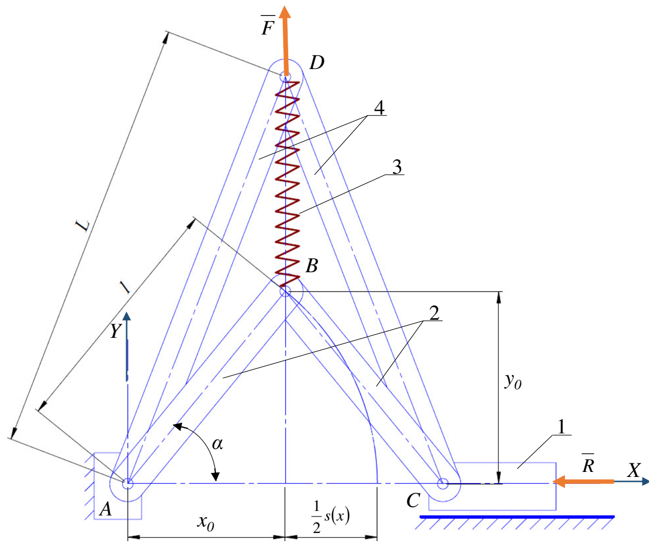


Fig. 3. **Rhomboid resistance mechanism model:** 1 – pressing pisston; 2 – pressing links; 3 – spring element; 4 – suporting links

The rhomboid resistance mechanism for biomass particle compacting was modelled using MathCAD programme. Resistance force in the pressing process and force in the spring can be calculated:

$$R(x)=\frac{x}{2}\left(\frac{1}{\left|\sqrt{l^2-x^2}\right|}-\frac{1}{\left|\sqrt{L^2-x^2}\right|}\right)\left(y-\left|\sqrt{l^2-x^2}\right|\right)k\,, \tag{1}$$

$$F(x) = \left( y - \left| \sqrt{l^2 - x^2} \right| \right) k \,, \tag{2}$$

where $R$ – resistance force during briquetting;
$F$ – force in spring;
$L$, $l$ – length of mechanism members;
$x$, $y$ – point B coordinates;
$k$ – spring stiffness.

Point B coordinates can be calculated:

$$\begin{cases} x = l \cos\alpha, [x_1 .. x_n] \\ y = l \sin\alpha, [y_1 .. y_n] \end{cases} \tag{3}$$

Pressing piston displacement can be calculated:

$$s(x) = 2[x - (l \cos\alpha)] . \tag{4}$$

During modelling it was necessary to change the pressing linkage length depending on the pressing piston displacement and the spring stiffness coefficient. The pressing piston displacement was obtained from briquetting experiments. The spring stiffness coefficient was adapted to the relevant pressing material. The calculated force displacement curves were compared with the results of experiments.

## Results and discussion

During laboratory experiments the compacting force – displacement characteristics for different size common reed particles were determinated. Fig. 4 shows the experimentally obtained pressing force – displacement curves.

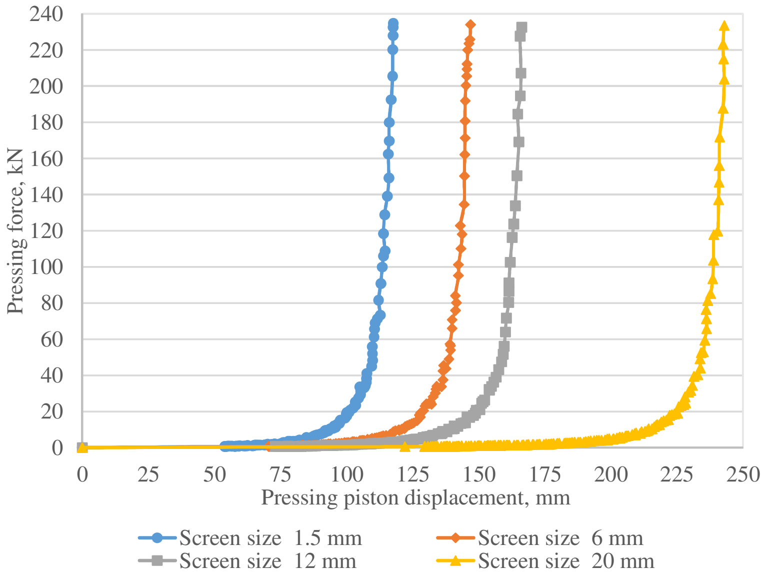


Fig. 4. **Force – displacement characteristics of compacting**

In the laboratory experiments obtained results show that the shapes of the force – displacement characteristics of compacting of different size common reed particles in the laboratory press equipment were similar – nonlinear curves with two quasilinear parts. The maximal piston displacement 243 mm for common reed particles from the sieve screen size 20 mm was obtained and the minimal displacement 188 mm from the sieve screen size 1.5 mm. Maximal pressing force 234 kN. Largest pressing piston displacement is required for initial common reed particle compression to 20 MPa. Material final pressing occurs with more rapid increase of the pressing pressure and at a small piston displacement (average 17 mm). Results of the experiments show that the average pressing piston displacement is 118, 147, 166 and 243 mm accordingly for common reed particles obtained from the sieve screen opening sizes 1.5, 6, 12 and 20 mm.

Modelling the experimentally obtained results they are compared from Fig. 5 to Fig. 8. Using Mathcad software the pressing force and pressing piston displacement for four different pressing materials were calculated. Comparing the results of experiments and modelling the maximal difference 4.96 % (screen size 1.5 mm), 1.98 % (screen size 6 mm), 8.45 % (screen size 12 mm) and 6.94 % (screen size 20 mm) was calculated. The obtained theoretical non-linear particle compression resistance mechanism would be further used to model the pressing process with the Working Model programme.

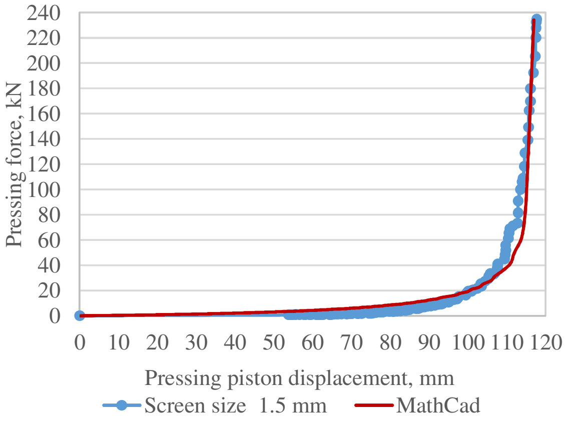


Fig. 5. **Force – displacement (sieve 1.5 mm)**

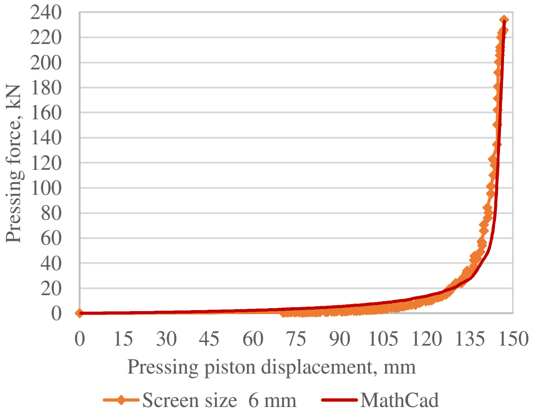


Fig. 6. **Force – displacement (sieve 6 mm)**

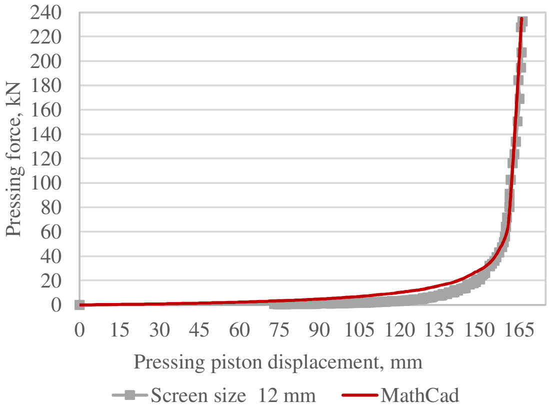


Fig. 7. **Force – displacement (sieve 12 mm)**

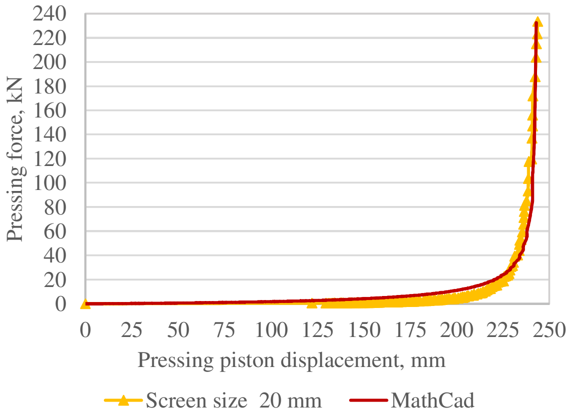


Fig. 8. **Force – displacement (sieve 20 mm)**

The innovative rhomboid pressing mechanism (LV 14201 B), including the actuator and combined with the obtained rhomboid resistance mechanism, will provide modelling of the compacting process for different biomass particles.

## Conclusions

1. The shape of the force – displacement characteristics of compacting of different size reed particles were similar – nonlinear curves with two quasilinear parts.
2. The largest pressing piston displacement is required for initial common reed particle compression to 20 MPa. Material final pressing occurs with more rapid increase of the pressing pressure and at a small piston displacement (average 17 mm).
3. Results of the experiments show that average pressing piston displacement is 118, 147, 166 and 243 mm accordingly for common reed particles obtained from the sieve screen opening sizes 1.5, 6, 12 and 20 mm.

4. Comparing the results of the experiments and modelling the maximal difference 4.96 % (screen size 1.5 mm), 1.98 % (screen size 6 mm), 8.45 % (screen size 12 mm) and 6.94 % (screen size 20 mm) was calculated.
5. The obtained theoretical non-linear particle compression resistance mechanism would be further used to model the pressing process with the Working Model programme.

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