MECHANICAL BEHAVIOUR OF BULK RAPESEEDS UNDER QUASI DYNAMIC COMPRESSION LOADING

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Abstract. The article is focused on the description of mechanical behaviour of bulk rapeseeds under compression loading and unloading. Pressing vessel diameter 40 mm was used to compress the bulk rapeseeds which were measured at the pressing height 60 mm. The amount of hysteresis and the amount of deformation ratio were determined in this study. From the study it follows that hysteresis and deformation ratios do not depend on the maximal compressive force and that more than 90 % of the inserted energy is lost in the inner structural changes of the bulk seeds.

Keywords: unloading, energy, lost, hysteresis, deformation, force, ratio, characteristics.

Introduction

The mechanical behavior of bulk rapeseeds under compression loading has already been described in few published studies [1-4] which have been focused on statical loading. However, in true behavior of screw extruders the effect of dynamic loading occurs and consequently it affects the system running as well as the amount of the gained oil and also the efficiency of the pressing technology [5-7]. Therefore detailed description of the shape of the deformation characteristic of rapeseeds under compression loading is necessary for precisely determining the magnitude of the compressive force, strain energy and modulus of elasticity in compression. The shape of these curves and its distribution in the deformation diagram are the most important factors needed for accurate determination of pressing energy performance [4; 8]. The hysteresis curve expressed as dependency between compression loading versus deformation and dependency between compression unloading versus deformation of bulk seed has not been satisfactorily published yet, however, the hysteresis theory of solid compressed materials has been very well known [9]. Nevertheless, the knowledge on the hysteresis mechanical behaviour of oil bulk seeds can contribute to a better understanding of the extrusion process especially at repeated compression loading. Application of this knowledge can minimize arising loss of energy as well as optimize the whole pressing process [5; 6]. The aim of this study is to describe and to compare mechanical behaviour of bulk rapeseeds under compression loading and unloading, (quasi dynamic loading) and to describe hysteresis behaviour of bulk rapeseeds.

Materials and methods

In this experiment, cleaned Rapeseeds (*Brassica napus* L.) obtained from the Czech Republic were used. The general physical properties of the bulk seeds are given in Table 1. The moisture content of the samples was determined using standard moisture measurement equipment (Farm Pro, model G, Czech Republic). The mass of the sample was determined using an electronic balance (Kern 440–35, Kern & Sohn GmbH, Balingen, Germany). The porosity was calculated from the relationship between the bulk and true densities [10]. The bulk density was determined from the mass of the sample divided by initial pressing volume. The true seed density was determined gravimetrically [10]. The results obtained were expressed as mean of three replicates.

Table 1

Physical properties of bulk rapeseeds; data in the table are means ± SD

M_c, %	m, g	V, mm^3	P_f, %	ρ_b, kg·m^{-3}	ρ_t, kg·m^{-3}
8.5 ± 0.2	53.00 ± 1.19	75398 ± 2240	35 ± 1	702 ± 12	1080 ± 12

M_c – moisture content of bulk seeds in dry basis; m – mass of bulk seeds;
V – initial volume of bulk seeds; P_f – porosity of bulk seeds;
ρ_b – bulk density; ρ_t – true density.

A single pressing vessel diameter 40 mm with a plunger (Fig. 1a) and with initial height of pressing H = 60 mm was used. The bulk seeds were compressed up to 5000 N, 8000 N, 11000 N, 14000 N, 17000 N, 30000 N and then loading was gradually reduced to zero. To determine the relationship between the compressive force and deformation characteristic curves, a compression device (Labortech, model 50, Czech Republic) was used to record the course of the deformation function.

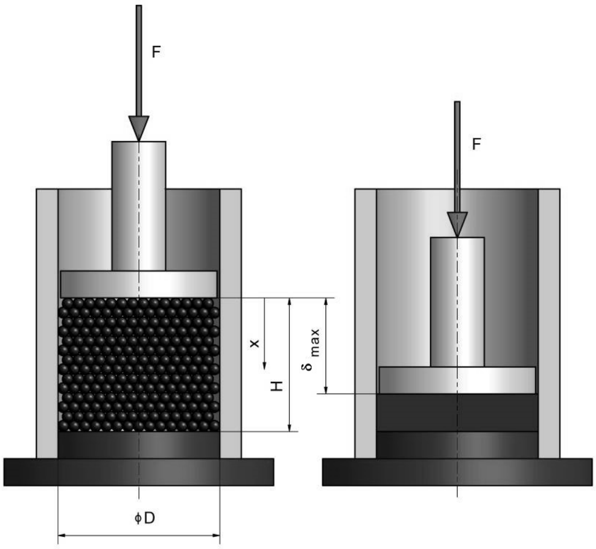

Fig. 1a. **Scheme of pressing equipment**

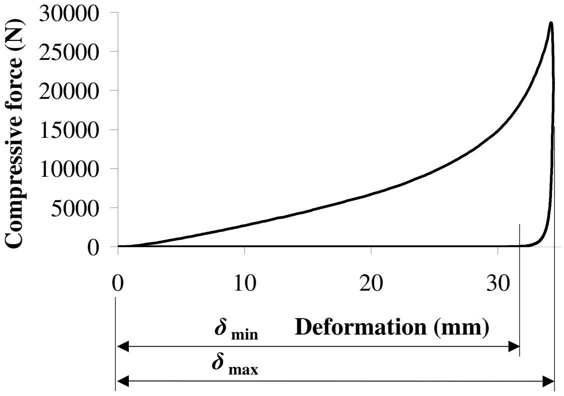

Fig. 1b. **Deformation diagram**

The deformation energy for bulk seeds compression loading E_c (J) was determined as the area under the deformation curve from 0 to the maximal deformation and deformation energy for bulk seeds compression unloading E_r (J) was determined as the area under the deformation curve from maximal deformation to zero (Fig. 1b). Hysteresis λ (%) was calculated by equation (1) and deformation ratio γ(%) by equation (2), where $\delta_{\max}$ (mm) is maximal deformation and $\delta_{\min}$ (mm) is minimal deformation of bulk seeds.

$$\lambda = \frac{E_r}{E_c} \cdot 100 . \quad (1)$$

$$\gamma = \frac{\delta_{\min}}{\delta_{\max}} \cdot 100 . \quad (2)$$

Results and discussion

The measured data of individual pressing curves for different maximal compression forces are shown in Fig. 2 and from Table 1 it explains that the porosity and moisture content are constant for all conducted experiments in this study.

Table 2

Determined amounts of hysteresis characteristics

***F*, N**	***E*$_c$, J**	***E*$_r$, J**	***λ*, %**	***δ*$_{max}$, mm**	***δ*$_{min}$, mm**	***γ*, %**
5000	35.8	1.6	4.47	17.21	13.05	75.83
8000	71.9	2.2	2.99	22.64	18.73	82.73
11000	114.6	2.6	2.31	26.14	21.42	81.94
14000	145.9	3.3	2.28	310	26.46	85.35
17000	172.9	4.2	2.44	33.86	30.82	91.02
30000	247.8	5.8	2.34	34.40	30.80	89.53

F – maximal compression force; E_c – deformation energy for loading;
E_r – deformation energy for unloading; λ – hysteresis;
$\delta_{\max}$ – maximal deformation of bulk seeds; $\delta_{\min}$ – minimal deformation of bulk seeds,
γ – deformation ratio

For each individual experiment, three trials for each compression force, the coefficient of variation of compression force was determined, the means of these amounts are $CV = (7 \pm 1)$ %, which is in accordance with already published studies [2-4; 8]. The amount of the coefficient of variation of compression force was also considered as constant for all results determined in Table 2. From Fig. 2 and Table 2 it is clear that the amount of hysteresis and deformation ratio can be substituted by average amounts $\lambda = (0.028 \pm 0.008)$ and $\gamma = (0.84 \pm 0.05)$. From Fig. 3 it implies that deviation of the amount of hysteresis and amount of deformation ratio for the compression force 5000 N are higher than the other measured values, which is given by reorganisation of compressed bulk seeds during small deformations [10], for other amounts of compression forces the hysteresis and deformation ratio acquire similar values. This could be due to more free spaces occurring between the seeds within the pressing area. Also the size of the seeds and the air gaps inside the bulk seeds could contribute to the deviation. Comparing the results of this study to the results of previous studies focused on rapeseeds [4; 5], it is clear that the shape, dimensions and dimensional similarity of the seeds tend to influence the start of the deformation curve.

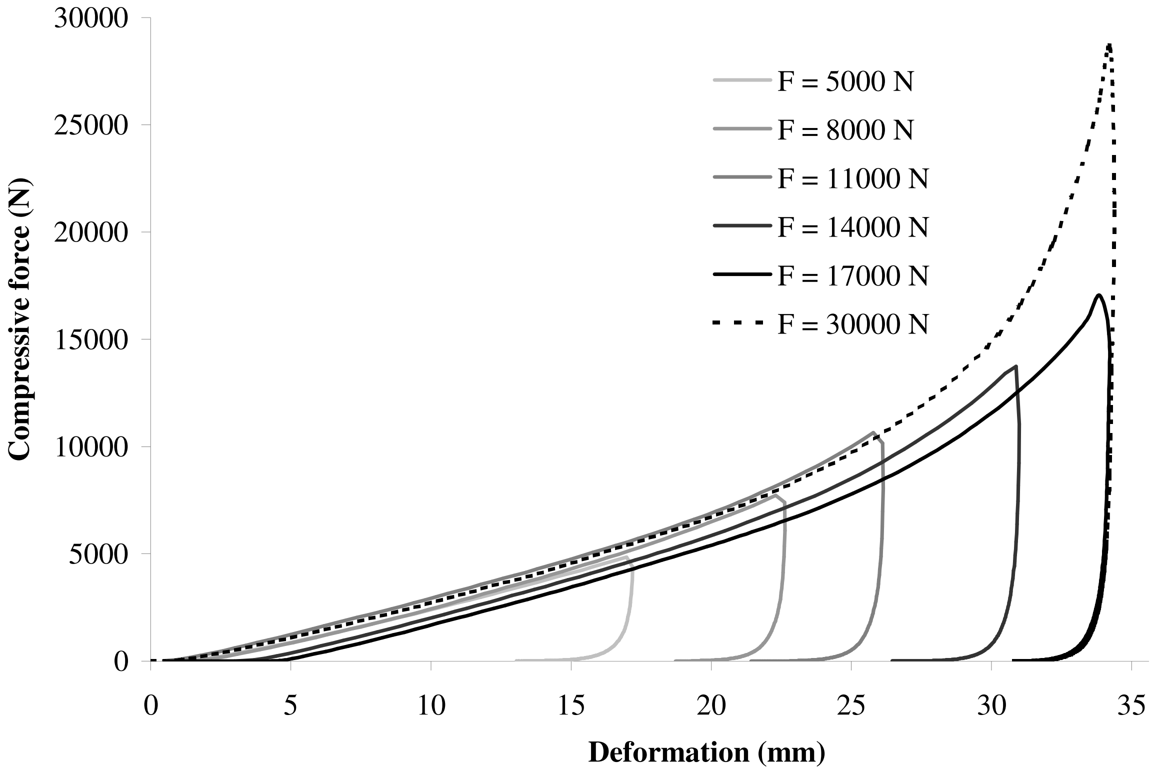

Fig. 2. **Hysteresis curve for different values of maximal compressive force**

It is evident that the results of the present study are similar to the results of the previous studies focused on mechanical behaviour of rapeseeds under compression loading at uniform diameter of the pressing vessel [4; 8].

From the conducted experiment considering the coefficient of variation of compressive force the assumption follows that the amount of hysteresis as well as deformation ratio do not depend on the compressive force. It is also evident that more than 90 % of inserted energy (Table 2) is lost in the internal structural changes of bulk seeds. The part of this lost energy also supports the creation of internal changes which cause oil leakage from bulk seeds and other parts of lost energy are converted into heat [9; 10]. The actual process of hysteresis is also strongly tied to the relaxation behavior and inelasticity as well as internal attenuation [11; 12]. These factors together with the clear description of hysteresis behavior can be transformed into a mathematical model which will describe the mechanical behavior of bulk rapeseeds under compression loading and unloading, it means to create the theoretical background for description of quasi dynamic loading. The gained knowledge can be used as the background for further research and could be transformed into a non-linear pressing system involving mechanical screw presses for the design of an efficient technology for extraction of maximum oil from bulk oilseeds with minimum energy requirement.

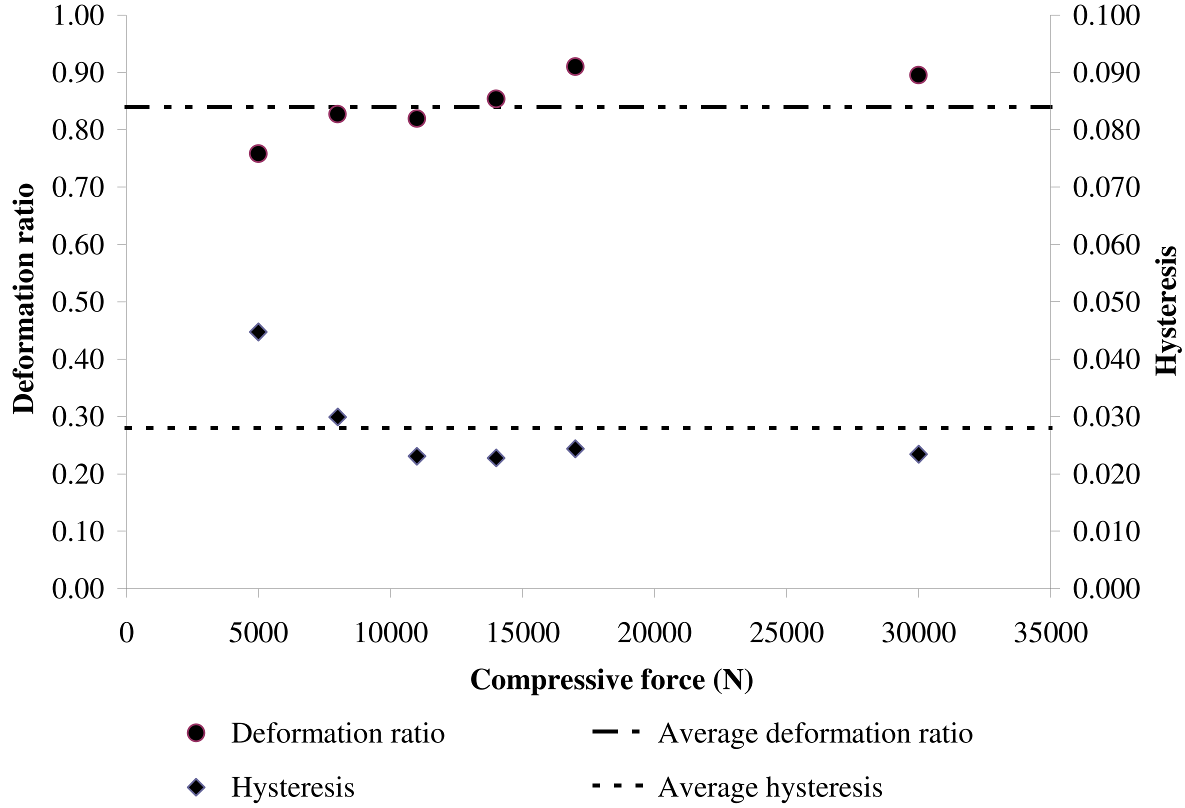

Fig. 3. **Dependency of deformation ratio and hysteresis vesrsus compressive force**

Conclusions

1. The amounts of deformation energy for compression loading and unloading of bulk rapeseeds were determined.
2. The results show that the amount of hysteresis and the amount of deformation ratio do not depend on the amount of maximal compressive force.
3. The results described in this study can be used as the background for further model development which will describe non-linear mechanical behaviour of oilseeds involving the use of screw extruders or presses.

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