MECHANICAL BEHAVIOUR OF OIL RAPE SEEDS DURING RELAXATION AND CREEP

P. Hrabě, A. Sedláček

Czech University of Life Sciences Prague, Czech Republic

Abstract

This article is focused on determination of the relaxation and creep behaviours of bulk rapeseeds under compressive loading. First part of the measurement examines the relaxation of seeds. In this case, the pressing vessel was filled with a certain amount of seeds and they were loaded compressively. Upon reaching a selected amount of force the decrease of the function of interest in time was observed and recorded. The second part of the measurement was focused on creep. During creep measurements a certain amount of rape seeds was loaded compressively; after attainment, the test load was maintained for a predetermined time. Recorded characteristics during both measurements and their mathematical descriptions are included in this article.

Key words: mathematical model; compression; force; deformation; oil.

INTRODUCTION

Rapeseed (*Brassica napus* L.) is grown on a number of Czech fields and is the oldest and most widespread economic crop in the country. It is widely used in the production of oils for food and cosmetic products. Rapeseed oil is used for the production of lubricating and hydraulic oils, varnishes, soaps, detergents and massage oils. The cakes from the seeds can be used as feed for livestock or as a fuel in the form of densified biomass pellets or briquettes (IZLI ET AL., 2009; SIRISOMBOON ET AL., 2007).

Mechanical behaviour of rapeseeds has been described by several authors (IZLI ET AL., 2009; RUSINEK ET AL., 2007; UNAL ET AL., 2009), but the course of creep and relaxation of rapes is seldom reported in literature. HERAK ET AL., (2011b) established the tangent curve function to describe the deformation characteristics of bulk rapeseeds under compression loading and few studies have been focused on rupture force and deformation characteristics (FOMIN ET AL., 1978; HERAK ET AL., 2011a; KABUTEY ET AL., 2011; HERAK ET AL., 2015; MREMA AND MC NLUTY, 1985) as well as on the mathematical description of the deformation characteristics, limit deformation ratio, maximal deformation ratio, energy ratio and oil point deformation ratio.

The optimal design and control of many primary production and postharvest operations requires an understanding to the dynamic behaviour of agricultural particulates. Agricultural and food materials tend to behave as viscoelastic materials when they are subjected to various conditions of stress and strain (RONG ET AL., 1995; RAJI AND FAVIER, 2003). Furthermore, most agricultural materials exhibit elastic behaviour during initial loading and viscoelastic behaviour with increased loading (ZOERB, 1967). It is clear that mechanical properties are time-dependent and the effect of deformation rate becomes more noticeable over time. Design of pressing devices with minimum energy requirements with respect to maximum oil output requires detailed understanding of the mechanical behaviour of pressed seeds as well as to their relaxation and creep responses under load (BLAHOVEC AND REZNICEK, 1980; FOMIN, 1978). Thus the aim of this study was to describe relaxation and creep behaviour of bulk rapeseeds under compression loading.

MATERIALS AND METHODS

For this experiment the purified rapeseeds from Czech Republic were used. Initial moisture content of seeds was 8.6 ± 0.3% DB. Pressing container with a diameter of 60 mm was filled with rape seeds to a height of 100 mm (Fig. 1). For measurement of relaxation the bulk seeds were compressed about Δl = 10mm, Δl = 20mm, Δl = 30 mm. The dependency between compressive force and time was recorded for 6 minutes on the device (Labortech, MPTest 5.050, Czech Republic).

For measurement of creep the bulk seeds were loaded by constant compressive force F = 4000 N, F = 10000 N and F =19000 N. The dependency between deformation and time was recorded for 6 minutes on the device (Labortech, MPTest 5.050, Czech Republic).

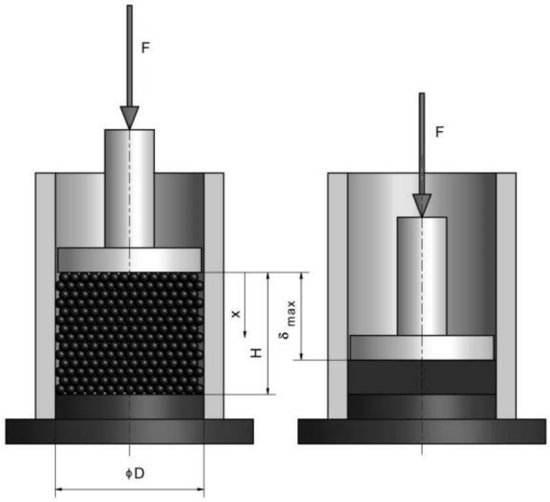

Fig. 1. – Scheme of pressing equipment (HERAK, 2015)

The measured values were evaluated in Mathcad 14. Schematic models of relaxation and creep according to which the functions of the mechanical behavior of viscoelastic materials were determined are shown in Fig. 2. The equations for relaxation and creep are described by following formulas:

Equation for relaxation:

$$R = a + b \cdot e^{c \cdot t} + d \cdot e^{f \cdot t} \qquad (1)$$

Equation for creep:

$$C = a + b \cdot (1 - e^{c \cdot t}) + d \cdot (1 - e^{f \cdot t}) \qquad (2)$$

Creep Relaxation

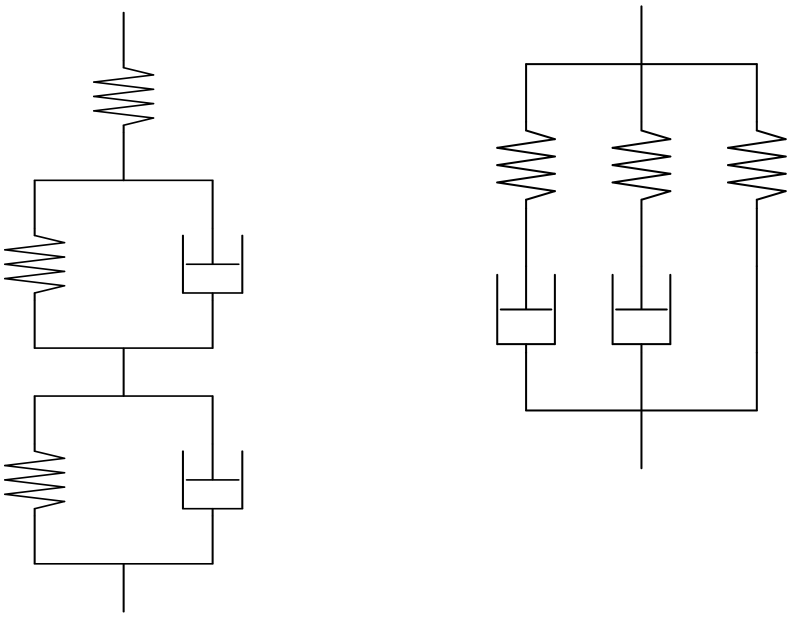

Fig. 2. – Schematic model of relaxation and creep

RESULTS AND DISCUSSION

The measured data of the individual curves of creep and relaxation are shown in Fig. 3 and 4.

The coefficients of the equations for description of relaxation and creep were determined using measured data as shown in Tab. 1 and Tab. 2.

Tab. 1. – Coefficients of relaxation

	Deformation [mm]		
	10	20	30
a [N]	2.187*10^3	4.444*10^3	5.891*10^3
b [N]	955.027	2.976*10^3	8.743*10^3
c [s^{-1}]	-0.148	-0.135	-0.104
d [N]	843.247	2.375*10^3	4.298*10^3
f [s^{-1}]	-0.013	-0.013	-0.0098

Tab. 2. – Coefficients of creep

	Force [N]		
	4000	10000	19000
a [mm]	11.33	23.458	29.891
b [mm]	1.548	3.875	4.549
c [s^{-1}]	-0.004754	-0.005435	-0.005271
d [mm]	0.285	2.628	1.713
f [s^{-1}]	-0.029	-0.057	-0.046

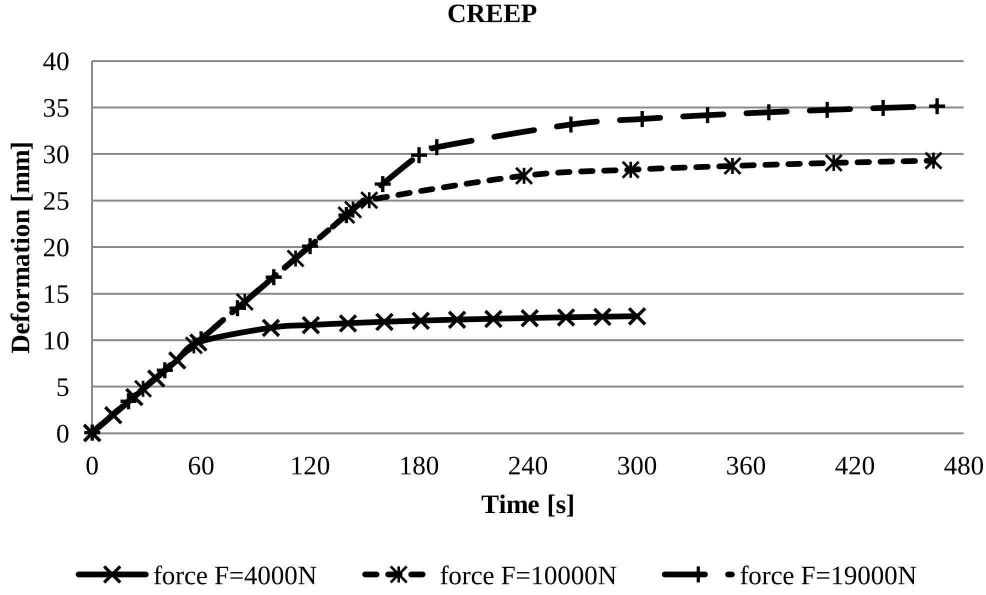

Fig. 3. – Measured values of creep

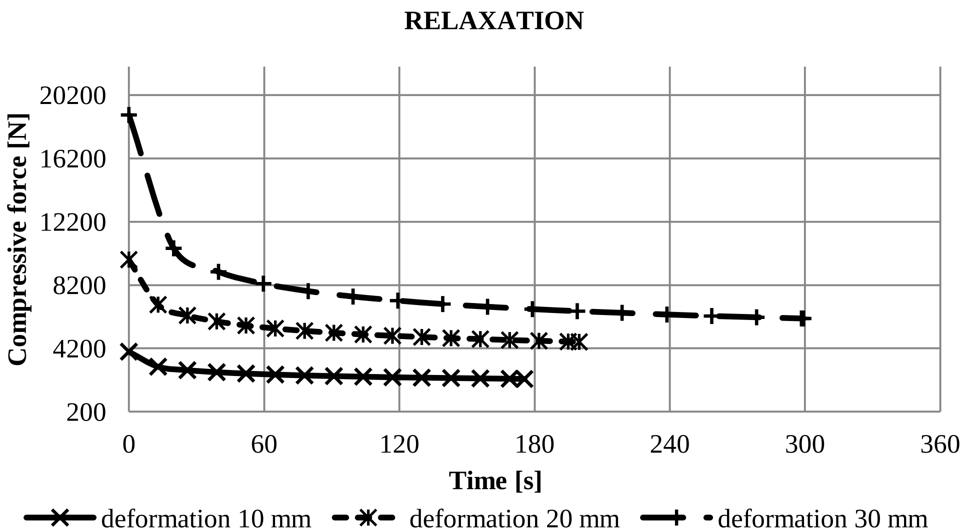

Fig. 4. – Measured values of relaxation

Individual coefficients for relaxation and creep are presented in Tab. 1 and 2.

The coefficient of variation for compressive force and deformation was determined from measured amounts as CV = (7.3 ± 1) % and is in agreement with earlier findings (HERÁK ET AL., 2011; IZLI ET AL., 2009). The largest decrease in compressive force was elicitted by the maximum applied load of 19000 N (Fig. 4). This was significantly larger than those resulting at the smaller imposed loads. Minimal decrease in compressive load with time at 4000 and 10000 N is as a result of the re-arrangement of bulk seeds within the pressing vessel, with minimal resultant deformations (BLAHOVEC ET AL., 1980).

Mathematical models which are based on experimental measurements aid the determination of optimal parameters in the design of processing technologies. However, knowledge of various material parameters such as water content, composition of oilseeds, pretreatment and mechanical pressure is requisite for optimisation.

Earlier studies have focused mainly on on response of bulk rapeseeds under compressive loads (HERÁK ET AL., 2011). However, the response of unloading bulk rape columns subjected to known compressive preloads were observed to be decreasing functions of time (relaxation), the rate of which was amplified by the magnitude of the deformation rate; the rate of deformation with time (creep) varied, and considerable with different loads being less severe at the lower loads.

The loss of energy is caused by internal changes in the seeds, which causes the release of oil; part of the energy is however converted into heat (PETRŮ ET AL., 2012).

Obtained mathematical equations would be useful in modeling extruder systems based on maximum oil yield and optimum energy requirements.

CONCLUSIONS

This study was focused on the determination of relaxation and creep behaviours of bulk rape seeds under compressive loads. Relaxation behaviour was studied at three deformations of 10, 20 and 30 mm. Creep in the bulk seed sections was studied at three compressive loads of 4000, 10000 and 19000 N.

1. The equations of creep and relaxation were determined.
2. The largest decline of relaxation force was observed under loading of 19000N.
3. The results obtained in this study may be used in the further research related to the modeling of extruding systems.

REFERENCES

1. BLAHOVEC, J., REZNICEK, R.: Frakcionace pice (Fractionation of the forage). Prague, VSZ v Praze, 1980: 370 p.
2. FOMIN, V., I.: Wet fractionation of green forage. Rostov on Don, Izdatelstvo Rostovskovo universiteta, 1978: 160 p.
3. HERAK, D., KABUTEY, A., SEDLACEK, A., GURDIL, G.: Tangent curve utilization for description of mechanical behaviour of pressed mixture. Res in Agric Eng 57, 2011b: 13-18.
4. HERAK, D., KABUTEY, A., SEDLACEK, A.: Mathematical description of rape seeds' (Brassica napus L.) mixture mechanical behavior under compression loading. Sci Agr Bohemica 42, 2011a: 31-36.
5. HERAK, D., KABUTEY, A., SEDLACEK, A.: 2011 Mathematical description of rape seeds` (Brassica napus L.) mixture mechanical behavior under compression loading. Scientia Agriculturae Bohemica, 42, 2011: 31-36.
6. HERAK, D., SLEGER, V., MIZERA, C., SEDLACEK, A.: Mechanical behaviour of bulk rapeseeds under quasi dynamic compression loading. Engineering for rural development, Jelgava, 2015: 28–32.
7. IZLI, N., UNAL, H., SINCIK, M.: Physical and mechanical properties of rapeseed at different moisture content. Int Agrophys 23, 2009: 137-145.
8. KABUTEY, A., HERAK, D., SEDLACEK, A.: Behaviour of different moisture contents of Jatropha curcas L. seeds under compression loading. Res in Agric Eng 57, 2011: 72-77.
9. MREMA, G., C., MC NULTY, P., B.: Mathematical model of mechanical oil expression from oilseeds. J Agric Eng Res 31, 1985: 361-370.
10. PETRŮ, M., NOVÁK, O., HERÁK, D., SIMANJUNTAK, S.: Finite element method model of the mechanical behaviour of Jatropha curcas L. seed under compression loading. Biosystems Engineering, 111, 2012: 412–421.
11. RAJI, A., O., FAVIER, J., F.: Discrete element modelling of the impact parameters of a selected fruit: application. Journal of Applied Science and Technology, 21, 2002: 7–12.
12. RONG, G., NEGI, S., C., JOFRIET, J., C.: Simulation of the flow behaviour of bulk solids in bins. Part 2: Shear bands, flow, corrective inserts and velocity profile. Journal of Agricultural Engineering Research, 62, 1995: 257–269.
13. RUSINEK, R., MOLENDA, M., SYKUT, J., PITS, N., TYS, J.: Uniaxial compression of rapeseed using apparatus with cuboid chamber. Acta Agrophysica 10, 2007: 677-685.
14. SIRISOMBOON, P., KITCHAIYA, P., PHOLPHO, T., MAHUTTANYAVANITCH, W.: Physical and mechanical properties of Jatropha curcas L. fruits, nuts and kernels. Biosyst Eng 97, 2007: 201-207.
15. UNAL, H., SINCIK, M., IZLI, N.: Comparison of some engineering properties of rapeseed cultivars. Ind Crop Prod 30, 2009: 131-136.
16. ZOERB, G., C.: Instrumentation and measurement techniques for determining physical properties of farm products. Transactions of the ASAE, 10, 1967: 100–113.

Corresponding author:

Ing. Petr Hrabě. Ph.D., Department of Material Science and Manufacturing Technology, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, phone: +420 22438 3274, e-mail: hrabe@tf.czu.cz