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Assessment of undulation behaviour of rape and sunflower bulk oilseeds under compression loading

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Abstract. In this present study, a combination of compression forces and speeds were examined for the undulation or serration behaviour of bulk rapeseeds and sunflower seeds using the universal compression device and a pressing vessel of diameter 60 mm with a plunger. For bulk rapeseeds, the forces were from 80, 100 and 120 kN while sunflower seeds, the forces were from 100, 150 and 200 kN. The speed ranged from 5 to50 mm min^{-1}. The study revealed that at force 80 kN in relation to the different speeds, the force and deformation curves of rapeseeds were without the serration effect. This was similar to sunflower seeds at forces 100 and 150 kN. The undulation effect for rapeseed was noticed at forces 100 and 120 kN at speeds between 25 and 50 mm min^{-1}. On the other hand, a smooth curve characteristic was seen for sunflower seeds at force 200 kN and speeds of 5 and 10 mm min^{-1} respectively. At a speed of 15mm min^{-1}, the serration effect was mild. From speeds 20 to 50 mm min^{-1}, the undulation effect was pronounced. In conclusion, increasing the compression force sand speeds demonstrated the undulation behaviour of both sunflower and rape bulk oilseeds. Energy efficiency for maximum oil recovery is realised under the area of the smooth curve behaviour.

1. Introduction

To design new oil processing technology aimed at obtaining maximum oil output with minimum energy input requires detailed research on the mechanical behaviour of bulk oilseeds under compression loading. Our previously published study on rape and sunflower bulk oilseeds in compression test showed that the serration or undulation behaviour was primarily caused by the diameter of the pressing vessel [1, 2, 3]. Based on these studies, it was reported that the pressing vessel diameters of 40 and 60 mm produced the serration effect on the force and deformation curves while that of 80 and 100 mm vessel diameters demonstrated smooth curve characteristics. Furthermore, the authors indicated that only the vessel diameter of 40 mm contributed to the wave effect for sunflower seeds. Here, the force of 100 kN and speed of 60 mm min^{-1}were considered. In a separate study,higher seed moisture content was found to contribute to the serration effect [4]. In order to understand adequately the serration or undulation behaviour on the force and deformation curve of bulk oilseeds under compression loading, different compression forces and speeds for a single vessel diameter were examined.

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2. Materials and Method

Sample

The bulk oilseeds of Rape (*Brassica napus* L.) and Sunflower (*Helianthus annus*L.) of percentage moisture contents of 5.92 and 5.82 on a wet basiswere used. The moisture content of the sample was determined using the standard oven method [5, 6].

Loading test

The bulk oilseeds samples of rape and sunflower were compressed using the universal compression device and a pressing vessel of diameter 60 mm with a plunger. For bulk rapeseeds, the forces were 80, 100 and 120 kN while sunflower seeds, the forces were 100, 150 and 200 kN. The speed ranged from 5 to 50 mm min^{-1}. The initial height of the bulk samples was 60 mm.

Calculation of deformation energy

The area under the force-deformation curve is denoted as the deformation energy, whichwas calculated using Eq. (1) [7, 8, 9, 10].

$$E = \sum_{n=0}^{n=i-1} \left[\left(\frac{F_{n+1} + F_n}{2} \right) \cdot (x_{n+1} - x_n) \right] \tag{1}$$

where E is the deformation energy (J), $F_{n+1} + F_n$ and $x_{n+1} - x_n$ are the compressive force (N) and deformation (mm), n is the number of data points and i is the number of sections in which the axis deformation was divided (step measurement was 0.01).

3. Results and Discussion

The smooth and serration characteristics of the force and deformation curves of bulk sunflower seeds are shown in figures 1 and 2 representing similar information for bulk rapeseeds forall compression forces. At force 80 kN for rapeseeds, and forces of 100 kN and 150 kN for bulk sunflower seeds, at all speeds, a smooth curve behaviour was observed. For rapeseeds at forces of 100 and 120 kN and speeds between 25 and 50 mm min^{-1} was noticed the undulation effect. Again, a smooth curve characteristic was seen for sunflower seeds at force 200 kN for the speeds of 5 and 10 mm min^{-1} respectively. The serration effect was first recognised at a speed of 15 mm min^{-1} but very mild. It was more severe at speeds from 20 to 50 mm min^{-1}. However, at speeds of 40, 45 and 50 mm min^{-1}, the serration effect was extreme causing the ejection of the seedcake through the orifices of the pressing vessel. Furthermore, the increase in compression forces and speeds demonstrated the undulation behaviour of both sunflower and rape bulk oilseeds. Nevertheless, sunflower bulk oilseeds required higher compressive forces than rapeseeds. The maximum oil output and seedcake ejection on the force and deformation curve are described in Figure 3. The 3D scatter plots of deformation energy in relation to the forces and speeds of rape and sunflower bulk oilseeds are also illustrated in figures 4 and 5 respectively. The present study results, among others, are important for designing very efficient mechanical screw presses for processing bulk oilseeds [11, 12].

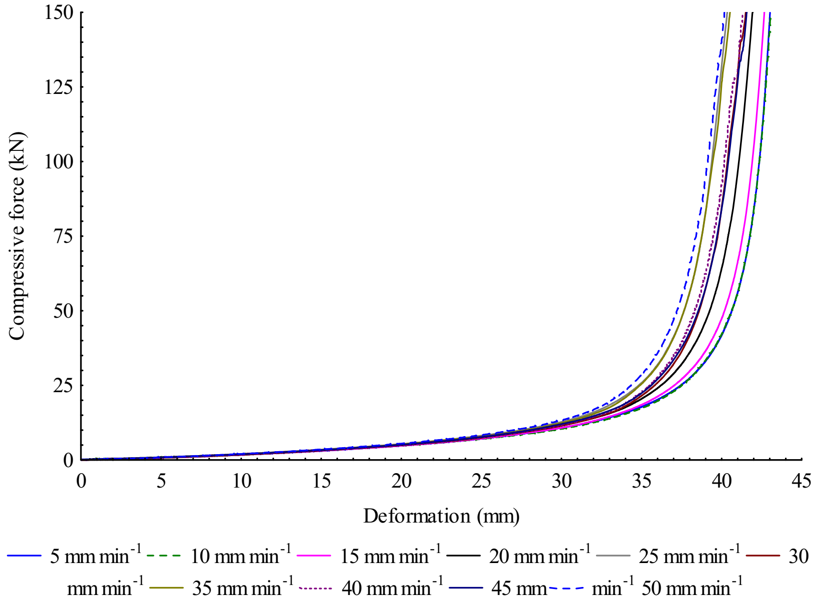

Figure 1. Smooth curve characteristics of sunflower bulk oilseeds at force 150 kN in relation to different speeds similar to rapeseeds at force 80 kN.

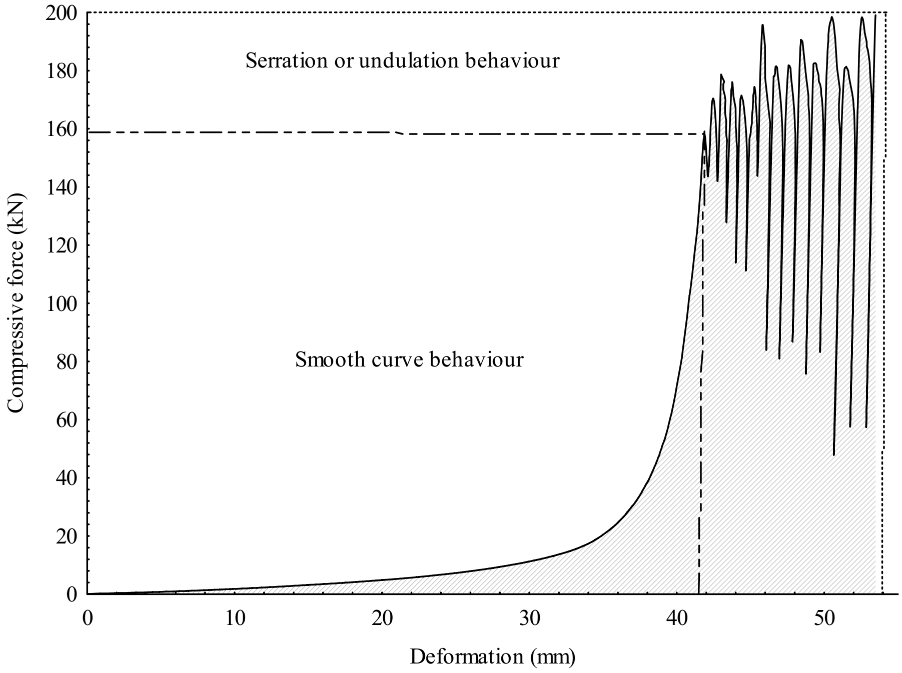

Figure 2. Serration or undulation and smooth curve behaviours at force 200 kN and speed 30 mm min^{-1} of sunflower bulk oilseeds. The area under the curve is the deformation energy [7, 8, 9, 10].

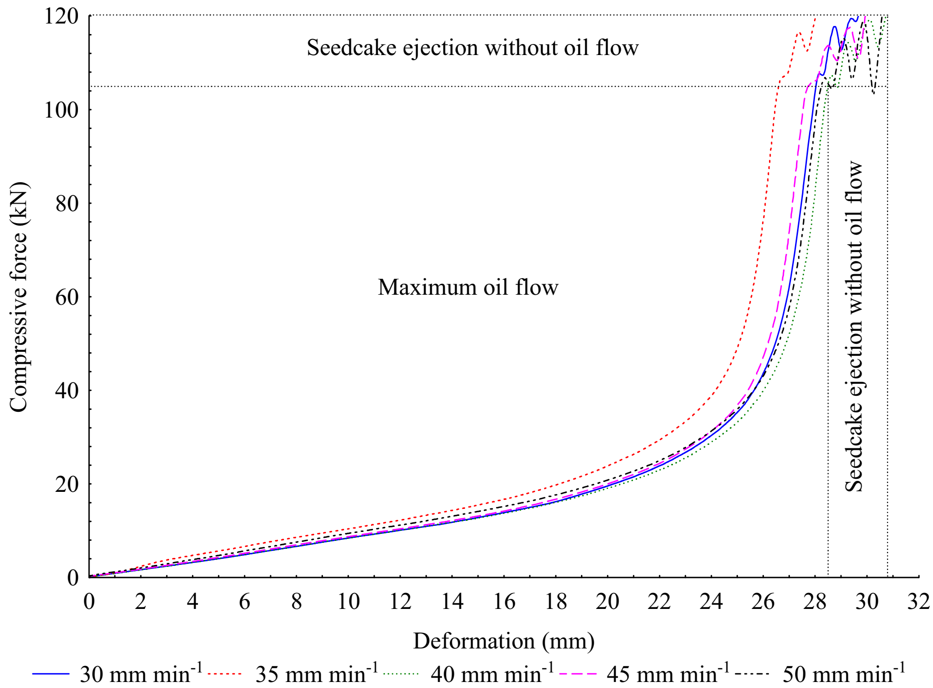

Figure 3. Description of maximum oil flow and seedcake ejection without oil on the force and deformation curves of bulk rapeseeds in relation tospeeds.

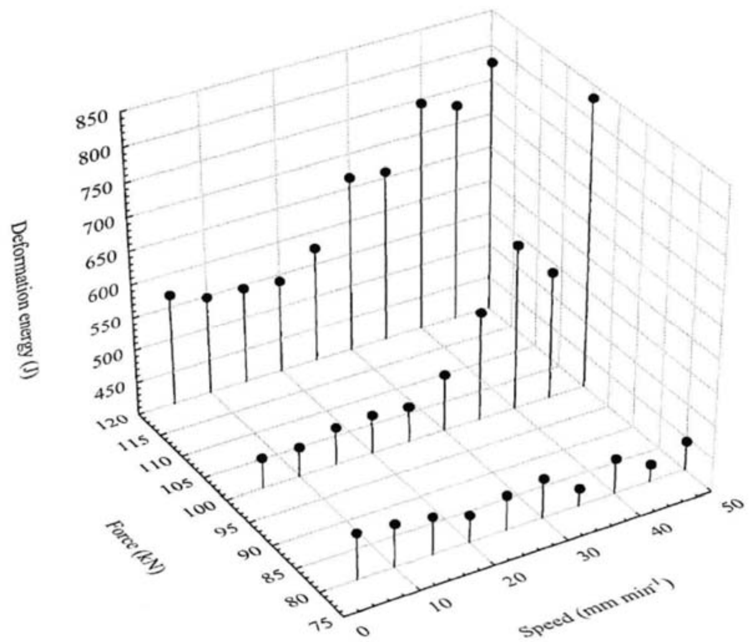

Figure 4. 3D scatterplot of deformation energy against force and speed of bulk rapeseeds

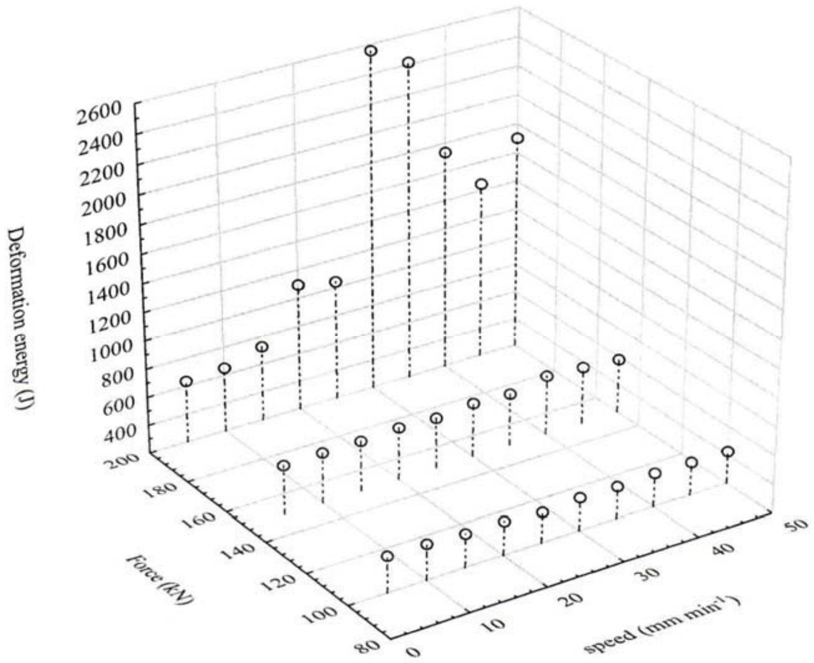

Figure 5. 3D scatter plot of deformation energy against force and speed of bulk sunflower seeds

4. **Conclusion**

Increased compression speeds at a particular force increased the amounts of deformation and deformation energy. The serration effect of rape bulk oilseeds was observed at forces 100 and 120 kN at speeds between 25 and 50 mm min^{-1}. For sunflower bulk oilseeds, the serration effect wassevere at force 200 kN and speeds from 20 to 50 mm min^{-1}.The area under the smooth force-deformation curve behaviour described the optimum energy for maximum oil recovery.The results are valid for vessel diameter of 60 mm. However, compression test of bulk rapeseeds and sunflower seeds using bigger vessel diameters at similar compression forces and speed swould be relevant to advance the present findings established herein.

5. **Acknowledgement**

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References

[1] Divisova M, Herak D, Kabutey A, Sleger V, Sigalingging R and Svatonova T 2014 Deformation curve characteristics of rapeseeds and sunflower seeds under compression loading*Sci. Agric. Bohemica***45**(3):180–186.
[2] Herak D, Kabutey A, Divisova M and Simanjuntak S 2013 Mathematical model of mechanical behaviour of Jatropha curcas L. seeds under compression loading *Bio. Eng.***114**(3):279–288.

IOP Conf. Series: Materials Science and Engineering **420** (2018) 012020 doi:10.1088/1757-899X/420/1/012020

[3] Kabutey A, Herak D, Dajbych O,Boatri W E and Sigalingging R 2014 Deformation energy of Jatropha curcas L. seeds under compression loading*Res. in Agric. Eng.***60**(2): 68–74.
[4] Kabutey A, Herak D and Sedlacek A 2011 Behaviour of different moisture contents of Jatropha curcas L. seeds under compression loading *Res. in Agric. Eng.***57**(2):72–77.
[5] ISI 1996 Indian standard methods for analysis of oilseeds IS:3579 New Delhi Indian Stand. Ins.
[6] Blahovec J 2008 Agromaterials Study Guide. Czech University of Life Sciences Prague.
[7] Chakespari A G, Rajabipour A and Mobli H 2010 Strength Behaviour Study of Apples (cv. *Shaft Abadi & Golab Kohanz*) under compression loading*Mod. Appl. Sci.***4**(7), 173–182.
[8] Grzegorz L 2007 Fracture toughness of pea: Weibull analysis *J. of Food Eng.***83** 436–443.
[9] Demirel C, Kabutey A, Herak D and Gurdil G A K 2017 Numerical estimation of deformation energy of selected bulk oilseeds in compression loading. IOP Conference Series: Materials Science and Engineering, **237**(1), 1–5.
[10] Gupta R K and Das S K 2000 Fracture resistance of sunflower seed and kernel to compressive loading. *J. of Food Eng*. **46**, 1–8.
[11] Karaj S and Muller J 2011 Optimizing mechanical oil extraction of *Jatropha curcas* L. seeds with respect to press capacity, oil recovery and energy efficiency. *Ind. Crops Prod.* **34**, 1010–1016.
[12]. Singh J and Bargale P C 2000 Development of a small capacity double stage compression screw press oil expression. *J. of Food Eng.***43**: 75–82.