TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 15(2), Y 2012

METHOD OF DETERMINING THE MINIMUM BREAKING STRENGTH OF THE MUSTARD SEED COAT

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K e y w o r d s: mustard seeds, modeling, susceptibility.

A b s t r a c t

This paper proposes a method for determining the breaking strength and the resulting deformations of the mustard seed coat. A compression test stand for determining breaking strength and seed coat deformations was described. The results of the experiment were processed and analyzed.

Introduction

Mustard is an annual oily plant of the family *Brassicaceae* which produces yellow flowers. Mustard is a well-established crop with numerous applications, and white mustard (*Sinapis Alba*) is the most popular species (WAŁKOWSKI 1997). White mustard grows wild in the Mediterranean region where it is regarded as a weed. Today, it is cultivated in moderate climate zones around the world. White mustard is an annual oily plant which is less susceptible to freezing temperatures than winter rape. The annual yield of white mustard seeds reaches two tons per hectare. It is the basic ingredient in the production of mustard and spices, and it is also grown as a forage plant. In comparison with black mustard, white mustard seeds are characterized by higher fat and protein concentrations and a lower fiber content of the seed coat. White mustard seeds are husked to remove harmful substances, including large quantities of fiber and crude fiber (OCHODZKI, RAKOWSKA 1996).

Stringent requirements set for food products spur a search for raw materials of the highest quality. The microstructure, morphological and anatomical structure of seeds determine the choice of the most effective seed coat removal method in the husking process (MIESZKALSKI 2009).

The size of mustard seeds varies from 1.5 to 3.2 mm, subject to species and variety as well as weather conditions in the year of harvest (PYKAŁO 2002). At the micro and macro level, geometric and mechanical attributes of seeds condition the parameters of a husking device.

The minimal force that causes the seed coat to rupture is one of the key parameters affecting the husking process. A method of determining impact energy has been described by several authors (MIESZKALSKI, SARNIAK 1997). Impact energy values can be used to calculate the breaking strength of the seed coat, but they do not support determinations of minimum breaking strength. The proposed method involves a 5 kg drop-weight which generates impact energy. The determined impact force is a sum of the minimum force required to rupture the seed coat, the seed's deformation strength after coat rupture, the force required to overcome aerodynamic resistance and friction of the drop-weight guide. The force breaking the seed coat causes the seed to become deformed. This is also an important parameter which should be taken into account when setting the parameters of a husking device which removes the seed coat through deformation (SCHNEIDER 1982).

The application of excessive breaking force or deforming force in the husking process lowers the quality of the processed material and increases husking costs. The study set out to investigate the minimum force required to break the seed coat and deform the seed.

Materials and Methods

The objective of this study was to determine the deformation strength of mustard seeds subjected to a load applied perpendicularly to the parting plane of cotyledons.

The adopted model is presented in Figure 1 (NIZIŃSKI 2002, MICHALSKI, SZCZYGLAK 2005).

In the adopted model, the set of constant values *C* contains the following elements:

– c_1 – seed moisture content (7%);
– c_2 – mustard seed variety (Nakielska).

In the adopted model, the set of interfering factors *Z* contains the following elements:

– z_1 – ridged seed surface;
– z_2 – uneven seed diameter;
– z_3 – non-linear measurement path.

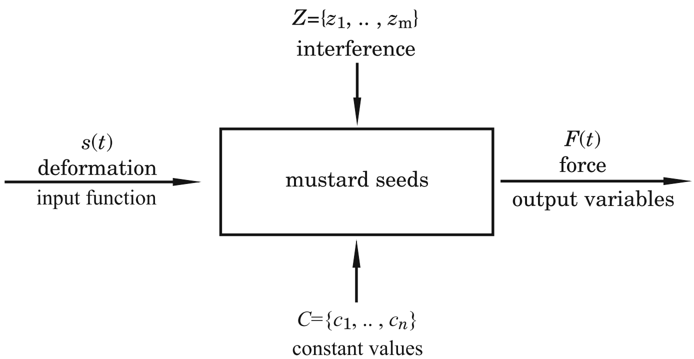

Fig. 1. Analyzed mustard seeds: $s(t)$ – time waveform of mustard seed deformation, $F(t)$ – time waveform of load application, C – set of constant values, Z – set of interfering factors

A seed compression test stand was built for the needs of the experiment (Fig. 2). Seeds were placed on a test platform. The movement of the loading yoke relative to the specimen platform was controlled by a mechanical actuator. The yoke was connected to a power transducer. The position of the yoke relative to the platform was determined with the use of a potentiometric position sensor.

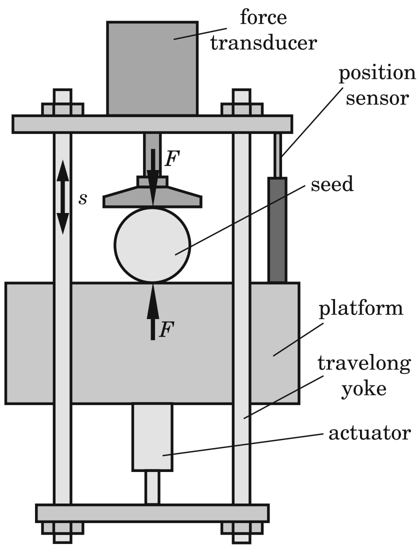

Fig. 2. Seed compression test stand: F – force, s – displacement

The list of measured values and the corresponding measuring transducers are shown in Table 1.

Table 1

List of measured values and the corresponding measuring transducers

Measured value	Symbol	Transducer	Measurement range
Deformation	*s* (*t*)	potentiometric position sensor MM10 10 kΩ	0–11 [mm] (resolution <0.00275 mm)
Load	*F*(*t*)	tensometric power transducer AR 201 50 N	0-50 [N] (resolution 0.0005 N)

A shared sampling time base was used to synchronize the measurements (T_p = 0.01 s). The measured values were registered by a computer connected to an MG-TAE1 logger (Fig. 3).

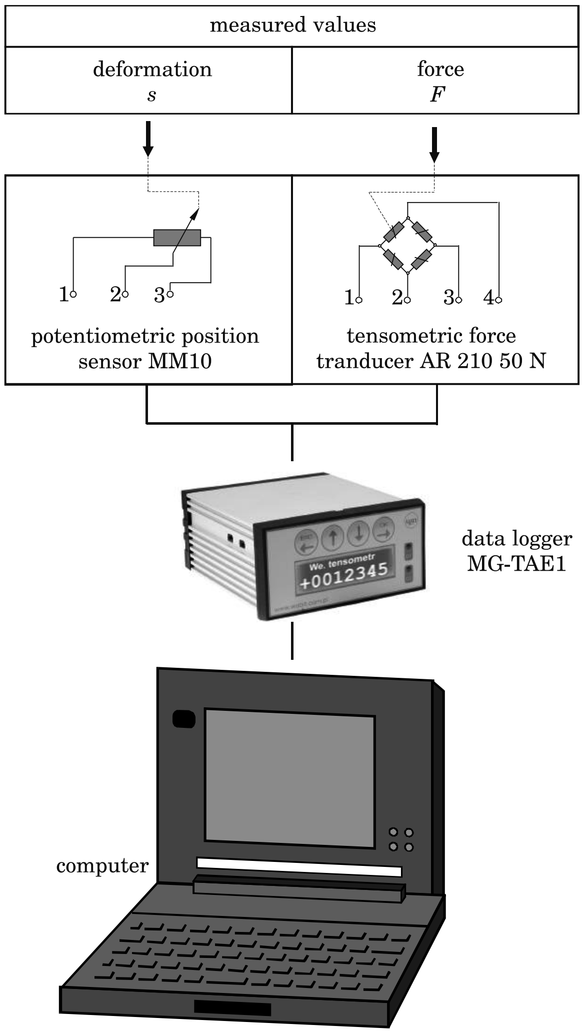

Fig. 3. Measurement path for registering time waveforms of input function and output variables

The resulting time waveforms of deformations and the accompanying loads were subjected to frequency filtration in the MatLab application using the Chebyshev filter (MOLER 2004).

Results

Filtered time waveforms of deformation and load noted in the experiment are exemplified in Figure 4. When breaking strength was exceeded during seed compression, a cracking sound could be heard with an unarmed ear. The above

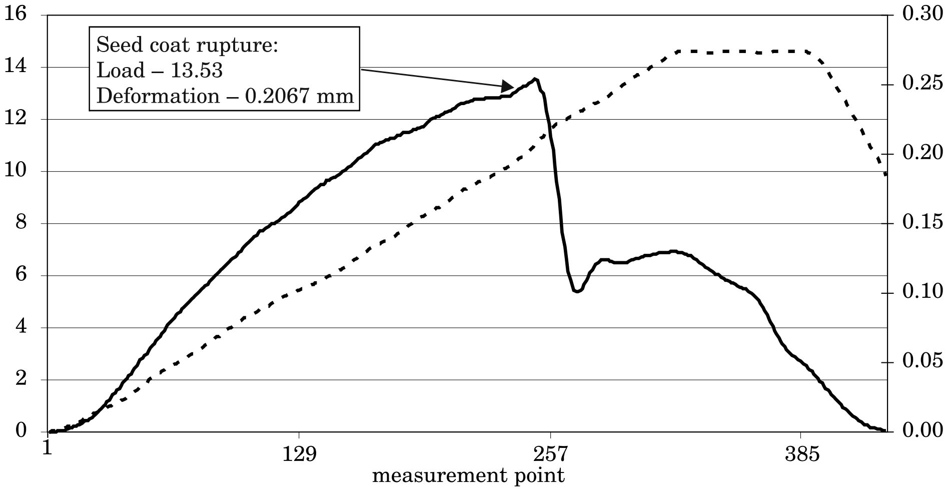

Fig. 4. Time waveforms of mustard seed deformation and the accompanying load

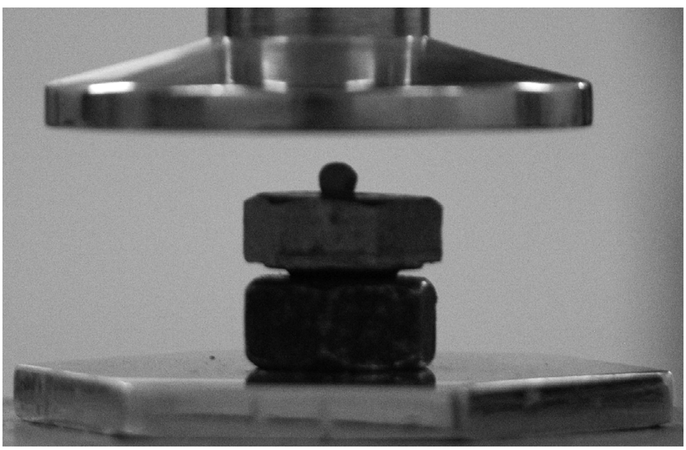

Fig. 5. A compressed seed

was accompanied by a rapid decrease in radial rigidity of the tested seed (Fig. 4). An image of a compressed seed is presented in Figure 5, and the corresponding time waveforms are shown in Figure 4.

The results of the experiment are presented in Table 2.

Table 2

Experimental results

Parameter	Value
Number of samples	30
Average force required to break the seed coat	17.54046 N
Minimum force required to break the seed coat	11.381554 N
Maximum force required to break the seed coat	23.680499 N
Standard deviation (force)	4.941420 N
Median (force)	19.165556 N
Average deformation of the seed coat caused by breaking force	0.213468 mm
Minimum deformation of the seed coat caused by breaking force	0.179499 mm
Maximum deformation of the seed coat caused by breaking force	0.263214 mm
Standard deviation (deformation)	0.026104 mm
Median (deformation)	0.214235 mm

Conclusions

The proposed method supports precise determinations of the minimum force required to break the seed coat. At breaking point, a cracking sound can be heard with an unarmed ear. The above is accompanied by a rapid decrease in the seed's radial rigidity. In the tested samples, the average breaking force was 17.54046 N, and the average deformation was 0.213468 mm. The results were reported for mustard seeds var. Nakielska with a 7% moisture content. We believe that our findings can expand the knowledge base of husking machine designers. Owing to a broad range of mustard seed species, further work is needed to investigate other varieties with different moisture content levels.

Translated by Aleksandra Poprawska

Accepted for print 31.10.2012

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