AN INFLUENCE OF REPEATED IMPACT LOAD ON BARLEY KERNELS PROPERTIES

PECEN J., HAVRLAND B., KREPL V.

Abstract

The article describes efforts at the detection of some properties of barley kernels by impact analysis. Impact of kernels was realized as uniformly accelerated motion (free fall) of kernels onto a force transducer from height of approximately 21cm. The record of the impact parameters (time and force mainly) was captured and stored by the Digital Storage Oscilloscope (DSO) for subsequent processing. The experimental apparatus is described in detail. The shapes of the impact records of barley kernels were different and depended on the kernel size, its humidity and variety and on the position of acting impact mainly. The repeated impact (with the same kernel onto the same place) brings very similar shapes of impact records in all cases as shown in the captured impact records. The small differeces in these shapes, in the repeated impact, is caused mainly by non central orientation of kernel acting onto the force transducer (at the end of kernel falling).

Key words: repeated impact, impact record, barley kernel, quartz force transducer, oscilloscope

INTRODUCTION

Quality of cereal grain has been and continues to be an increasingly popular subject of research. Very often grain quality depends on the state of endosperm, or rather on the extent is absence of its damage. Non invasive methods for the detection and visualization of damage, determination of its type and its quantification are commonly preferred. Among the modern methods for cereal grain or seed analysis, the X-ray method is very often chosen for its usefulness for the detection of damage to the internal structure of kernels, such as cracks, damage infected by insects, or other types of damage (Pecen, 1994; Pecen, 2006; Pecen, Szwed, Grundas, 2003; Pecen, 2004). The experiments presented here were focused on the application of impact for the characterization of single kernel properties. Kernel impact records were used to extract many different details that characterized the various properties of kernels. On the basis of differences in impact records, the authors considered the applicability of using the method of impact analysis for internal damage detection (Slipek, Zlobecki, 1994) as a substitute for the X-ray method. It was assumed that the time duration and shape of impact record would depend primarily on the orientation of kernels during their fall and on the orientation their acting on the force transducer. It was also expected that differences in the form of the impact record would reflect kernel shapes and their kinds and humidity of kernels and their internal structure and place of impact. One of the goals of the work was to test a simple device for impact record acquisition. Another one was to make a brief analysis of the shapes of impact records from the point of view of reproducing the impact record and determination in what way the shape of the impact record was affected by kernel shape and its orientation at the moment of contact with the force transducer. One example of a good and simple method for recording impacts is described in the reference (Lichtensteiger et al., 1988).

MATERIALS AND METHODS

The experiment was realized as a short study on the possibility and practicability of applying the impact method as a substitute for the X-ray method for the detection of one kind of internal damage to seeds. This was the reason for so much attention being focused on the acquisition of single kernel impact records of good quality and repeated impact records too. The impact was realized by free fall motion of kernel in a pipe of suitable internal diameter. The kernels were falling from heights of 21 cm onto a force sensor (force transducer). The obtained records were compared with respect to their shape and impact duration (the time of impact). All impact records were acquired this way, but no detail analyses of these records were made. Figure 1 shows a typical impact record from the screen of the oscilloscope. Four parameters describe each impact record and they are computed automatically during the record capture in the oscilloscope. Figure 2 explains the geometrical sense of the parameters of impact record. Each impact record is a pulse, and it is analysed from that point of view. Next, processing of these impact records is made on the basis of analysis of the pulses, characterized by mentioned four parameters of the signals which are subjected to simple comparison and statistical processing.

The experimental material used in this case were barley kernels (two Libyan varieties, ALRAIHAN and MAHALI and two Czech varieties, PRESTIGE and

MALZ). Mass of all used kernels covered interval from the lighter to the heavier kernels. Each kernel was used repeatedly, ten times, for acquire of average values of impact record parameters. Fig.1 and 2 explain shortly the meaning of four parameters that characterize each impact record. Next parameters are force, mass and kernel humidity. Acquired parameters were statistically processed. There were two basic groups of experimental kernels in all varieties: damaged and undamaged. The damage of kernels was made artificially by the same way. The impact was realized by free fall motion of kernels in a pipe onto a force transducer from 21 cm height on the germ or the tip (awn) of kernels. A high-speed camera was used for investigation of the kernel trajectory and deformation of the kernel acting part at the moment of its contact with the force transducer.

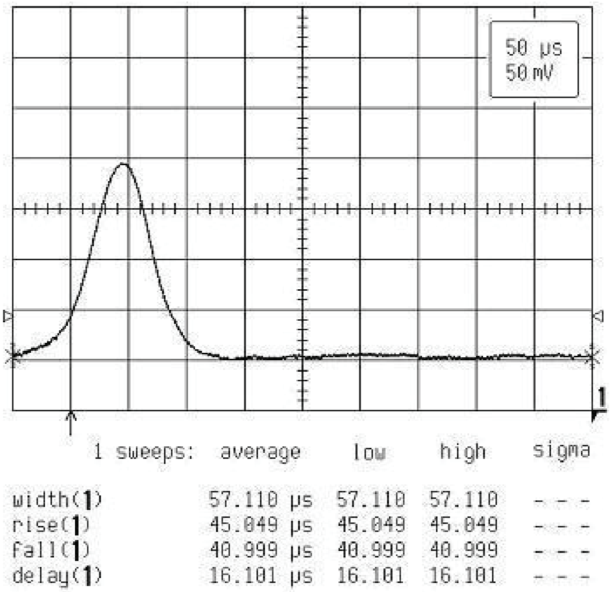


Fig. 1. A typical shape of impact record.

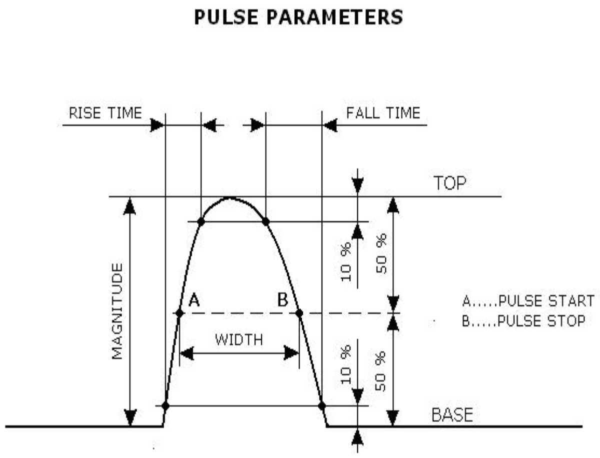


Fig. 2. A graphic presentation of the pulse
The four parameters of the record are defined below.
parameters and their geometric sense

Width (Pulse width) determines the duration between the **Pulse Start** (median point, i.e. the 50% magnitude transition point, on the leading edge) and the **Pulse Stop** (median point on the trailing edge) of a pulse waveform. The pulse stop is a 50% magnitude reference point.

Rise (Risetime) measures the time of a pulse waveform transition with a positive slope.

Fall (Falltime) measures the time of a pulse waveform transition with a negative slope.

Delay is the time from the trigger point to the first 50% transition crossing, i.e. the Pulse Start.
The geometrical meaning of these parameters is presented in Fig.2. The data in the upper right corner this picture (Fig.1) mean:

50 µs is the value of one division of the grid in the horizontal direction

50 mV is the value of force. One division in the vertical direction means 0.05 N (Newton). The data values are valid for all the figures in this paper and reflect the setting of the switch of the charge amplifier. (The setting of the switch depends on expected value of force).

Experimental apparatus
The impact of each kernel was realized by its freely fall from the height of 21 cm onto the force transducer which was connected to the amplifier and the DSO (Digital Storage Oscilloscope) for impact record acquisition and storage. The main components of the apparatus are described below, and the schematic diagram and the overall view of the apparatus are shown in Figures 3 and 4.

Piezoelectric sensor with high output impedance converts a mechanical quantity, such as force or acceleration, directly into an electric charge. The charge produced is proportional to the force acting on the internal (piezoelectric) quartz crystal element of the force transducer. Measurement of the mechanical quantity is thus derived from a force measurement. The sensitivity of the sensor (force transducer) is stated in pC/M.U. (pico Coulomb per Mechanical Unit), e.g. pC/N, pC/Pa, and its measurement range is from 0.01 to 9990 (pC/M.U.). As a sensor, the miniature quartz force transducer was used for measuring dynamic and quasi-static forces from several mN to 2500 N, in two ranges. The threshold of this type of sensor is less than 10 mN. The sensor has very high resolution, high natural frequency, very small dimensions, and welded construction. The sensor used in the study was of the type 9213sp0,1-3 (produced by KISTLER, Switzerland) and was calibrated in the range of 0-250 N. The specification measuring range of the sensor is 0 -

2500 N, with overload at 3000 N and natural frequency of 200 kHz.

The charge signal of the force transducer was transformed into a proportional output voltage in the **charge amplifier,** type 5011B. This microprocessor, controlling a single-channel charge amplifier, converts the electrical charge yielded by piezoelectric sensors into a proportional voltage signal. The amplifier has a built-in IEEE-488 parallel interface as standard, or a serial RS-232C interface is available as an option. Transmission of data measured is not available. The amplifier has a low-pass filter in the range of 0.01-30 kHz (8 stages).

The voltage signal of the charge amplifier, type 5011B, is processed by the **Digital Storage Oscilloscope (DSO),** type LeCroy 9310A. This is a two channel DSO with 400MHz bandwidth, 100MS/s sample rate, and 50 k points acquisition memory capacity (50 k points of measured, captured and stored points. Each point represents 8 bits). Digital Storage Oscilloscopes are essential instruments for capturing, viewing, measuring, analysing and storing electronic signals. Each DSO has a few basic elements and their properties determine the primary applicability of the DSO for practice. The cardinal parameters of the DSO are: **bandwidth, sample rate and acquisition memory length** (record length).

Basic acquisition technique for DSO is **single-shot acquisition** which is very suitable for the study of signal phenomena that have a low repetition rate, or that are not repeated at all – hence *single-shot*. The time base sweeps only once, on receipt of a trigger signal, and the input data signal is captured into acquisition memory for **viewing, measurement and analysis.** All impact records in the experiment were made by this technique.

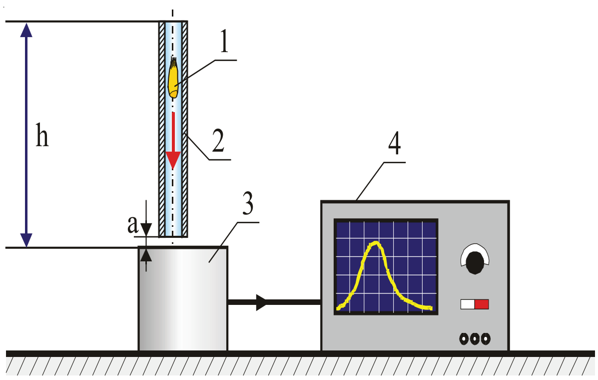


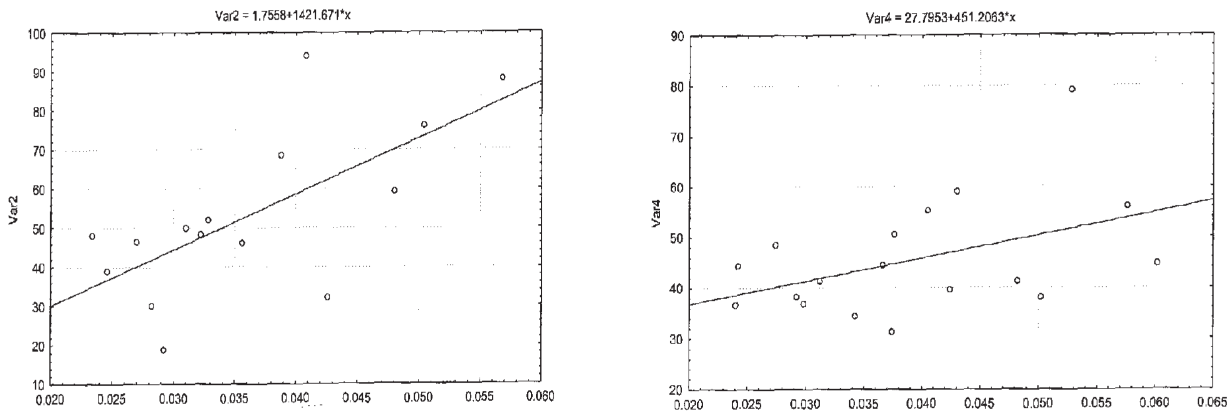
Fig. 3. Scheme of the used apparatus:

1 – barley kernel, 2 – glass tube, 3 – force transducer, 4 – digital oscilloscope (DSO).

Fig. 4. View on the laboratory apparatus set.

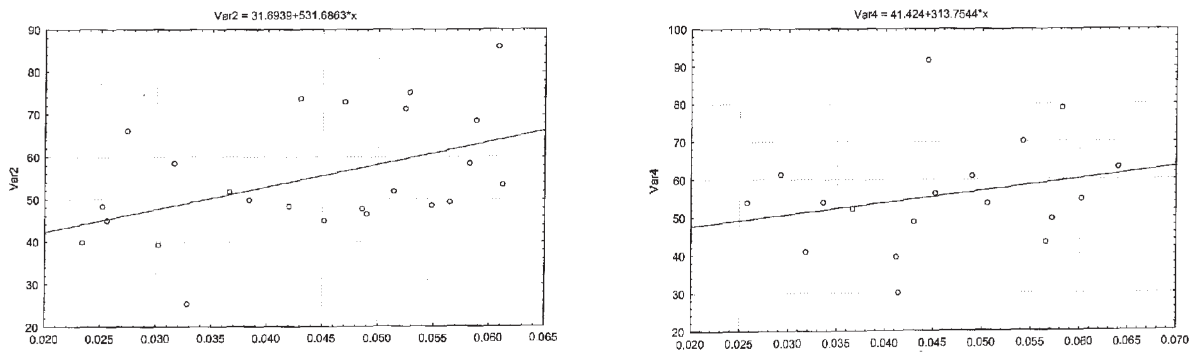
RESULTS

The Czech and Libyan barley varieties show big differeces in their mechanical properties, dimensions and their shape of kernels. The husk on the cover of Libyan varieties is thicker than in Czech varieties and Libyan barley has much longer and lighter kernels. From this reasons the shape of impact record both national varieties of barley is different. A statistical processing of acquired data was made for the relation between **mass** of kernels and **with, rice time, fall time and force** of the impact record for each kernel. The influence of kernel humidity on the above mentioned parameters of impact record was investigated for two varieties till time only. Each point in the graph represents average value from ten or twelve kernels acting singly onto the force transducer. It means that each kernel was used ten (or twelve) times. The kernels were falling onto the force transducer on a germ or the tip (brush) of kernels. All graphs in this article are parameters of impact record of kernels falling on the tip. The figures 5 and 6 show a different **with of impact record** between Czech and Libyan varieties. **Mass** of kernels is an independent variable. For the damaged kernel the with of impact record is smaller (for all varieties and lower relative humidity of kernels). A variance measured parameters of impact record is higher for Libyan varieties than Czech. A smaller difference is between both national varieties in two parameters **rice time** and **fall time** (for lower relative humidity of kernel). The velocity of kernel in the moment of acting kernels onto the force transducer is around one ms^{-1} and it is the same value in all presented cases. Next figures show some properties of mentioned barley kernels.



a) b)

Fig. 5. Barley **ALRAIHAN** with relative humidity 7.3 %.
The vertical axis on both figures (5 and 6) means the with of impact records in μs. The horizontal axis on both figures represents mass of kernels in grams. Letter a) on both figures means undamaged kernels and letter b) marked damaged kernels.



a) b)

Fig. 6. Barley PRESTIGE with relative humidity 7.3 %.

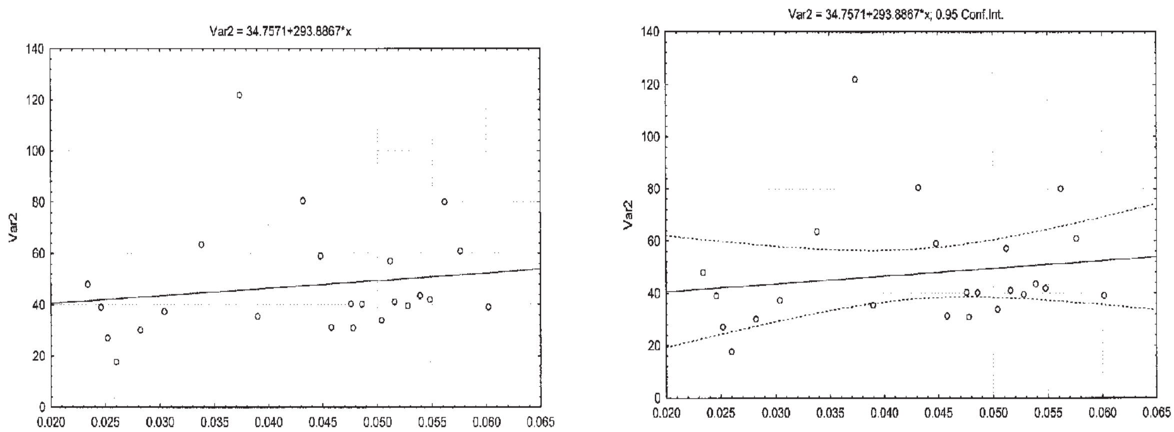


Fig. 7. Barley **ALRAIHAN,** undamaged kernels with relative humidity 0 %. The figure shows the relation between the with of impact records (vertical axis – in μs) and the mass of kernels (horizontal axis - in grams). The graph on the right in Figure 7 and 8 shows the borders for 95 % probability.

The relation between with and force of impact record, for example barley variety ALRAIHAN, presents a strong influence of humidity on properties of kernels. Figure 8. shows the relation between the with (as dependent variable quantity) and the force of impact record for undamaged kernels. As shows the figure 7.

with has very approximately the same value in relation to the value of mass. For the same variety (Alraihan) but non zero humidity of kernel, the regression line in Fig. 7 has another slope as shows the figures 5a. From this point view there is small region humidity of kernels, where many properties have maximum value.

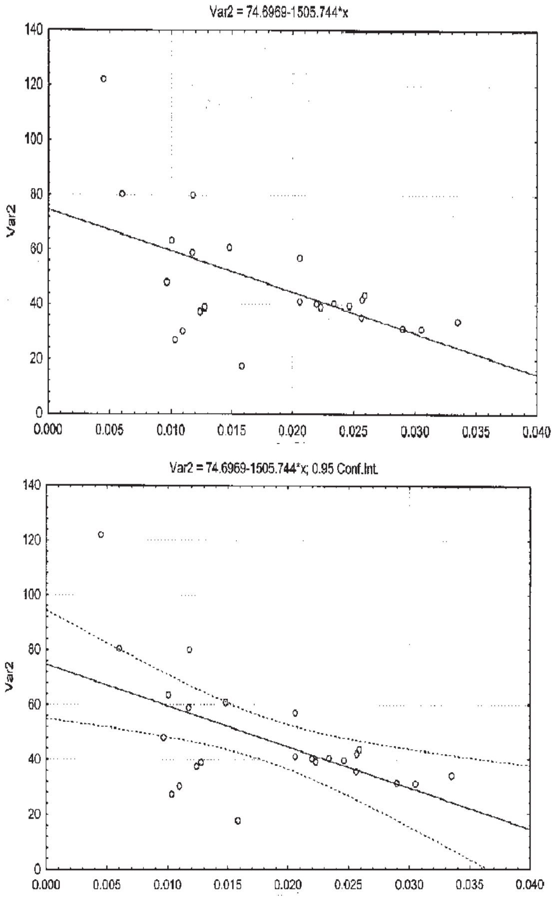


Fig. 8. Barley **ALRAIHAN**, relative humidity 0 %. Vertical axis means with of impact records and horizontal axis means the force of impact.

The high-speed CCD camera was used for short investigation and study the kernels deformation and its trajectory during their contact with the force transducer. The camera frequence that was used for the take off was 5 kHz and 10 kHz respectively. There were two main goals (with the camera operation):

- It made detail visualization of the moment when the kernel (seed) is acting onto the force transducer and recognize the deformation of the kernel.
- It made visualization of the motion and orientation of the kernel in the pipe before its acting on the force transducer and after rebound the kernel from the force transducer.

The seeds of rapeseed and mainly kernels of barley varieties were used for this experiment. For orientation of the kernel motion in the pipe is important its length and rate of diameters (kernel and the pipe).

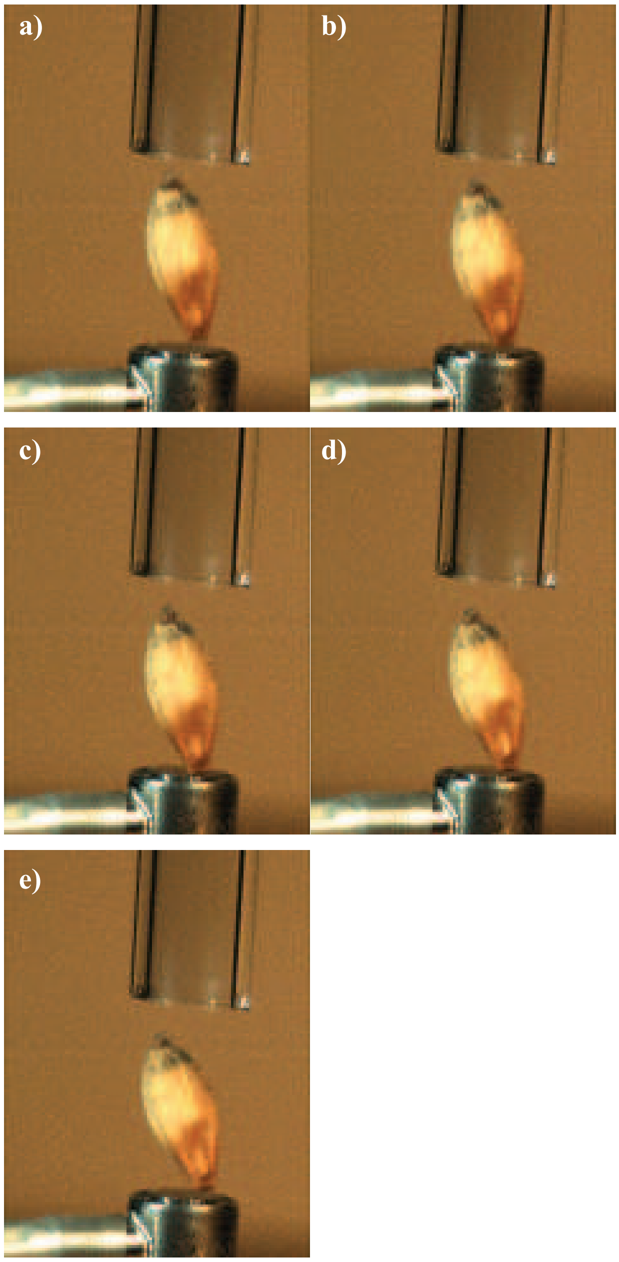


Fig. 9. A visualization of kernel motion and deformation during its acting onto the force transducer is showed. The periodicity of the snaps is 200μs. The kernel of barley, variety PRESTIGE, is falling onto the force transducer (with a diameter 5 mm). The snaps a) and b) are before impact and once d) and e) are after impact of kernel. The impact of kernel (contact the kernel with the force transducer) is showed in the snap c). After rebound the kernel starts its rotation. A incidence of kernel is not on the centre of the force transducer. This fact and the inclination of longitudinal axis of kernel are main reasons of a kernel rotation abound a perpendicular axis.

Fig. 10. The overviews on the laboratory apparatus and CCD camera. The lightening of the scene must be very intensive.

CONCLUSION

- The results showed a significant difference in some parameters Libyan and Czech varieties
- The kernels falling onto the force sensor on the tip achieve smaller variance of parameters
- The parameters of impact record for damaged and undamaged kernels were different and the parameters of damaged kernels had a smaller variance in their values
- The parameters impact record depend on the value of kernel humidity
- The with of impact records depends on humidity of kernels
- Statistics processing of acquired data was needed for a valid results

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