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PARAMETERS OF IMPACT LOAD ON WHEAT KERNEL*

Josef Pecen

Department of Physics, Technical Faculty, Czech University of Agriculture Prague
ul. Kamýcká 129, CZ 16521 Prague 6 – Suchdol
e-mail: pecen@tf.czu.cz

Abstract. The article describes attempts at the detection of some properties of wheat kernels by impact analysis. Impact of kernels was realized as uniformly accelerated motion (free fall) of kernels onto a force transducer from heights of approximately 83, 21 and 6 cm. The record of the impact parameters (time and force) 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 kernels were different and depended mainly on the size of kernels and on their position on impact. The captured impact records were partly statistically processed.

Keywords: impact record, wheat kernel, quartz force transducer, digital storage oscilloscope

INTRODUCTION

Quality of cereal grain or seeds 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 or 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 inflicted by insects, or other types of damage [2,3,4]. 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 author considered the

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applicability of using the method of impact analysis for internal damage detection [5,7] as a substitute for the X-ray method. It was assumed that the time and shape of impact record would depend primarily on the orientation of kernels during their fall. It was also expected that differences in the form of the impact record would reflect kernel shapes, kinds, and internal structure. One of the main goals of the work was to test a simple device for impact record acquisition. Another was to make a brief analysis of the shapes of impact records from the point of view of reproducing the impact record and determining 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 reference [1].

MATERIAL 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 detection of one kind of internal damage to seeds. This was the reason for so much attention being focused on the acquisition of kernel impact records of good quality.

The experimental material used in the study was wheat kernels of the variety KANCLER, cultivated in Poland, and the variety KROMA, cultivated in the Czech Republic. Wheat kernels have a good lengthwise symmetry, and are very well oriented during their fall through the pipe of the testing apparatus. The impact was realized by free fall motion of kernel in a pipe of suitable internal diameter. Kernels of similar dimensions and mass were selected for the experiment. Kernel impact was realized by free fall, with the kernels falling on the germ or on the brush. The kernels were falling from heights of 6, 21 and 83 cm onto a force sensor (force transducer). The kernels were randomly divided into groups of ten kernels each. Each kernel from each group was tested by falling, from the mentioned three heights, on the germ as well as on the brush. Besides, two kernels from each group were chosen (randomly) and used ten times to acquire impact records (on germ and brush of kernel) to determine the repeatability of the process. The obtained records were compared with respect to their shape and impact duration (the time of impact).

All impact records from each group were acquired this way, but no detail analysis of these records was 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 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 four parameters of the signals which are subjected to simple comparison and statistical processing. Figure 2 illustrates the geometrical sense of the pulse parameters. Their explanation and definitions are presented in the text of Figure 1.

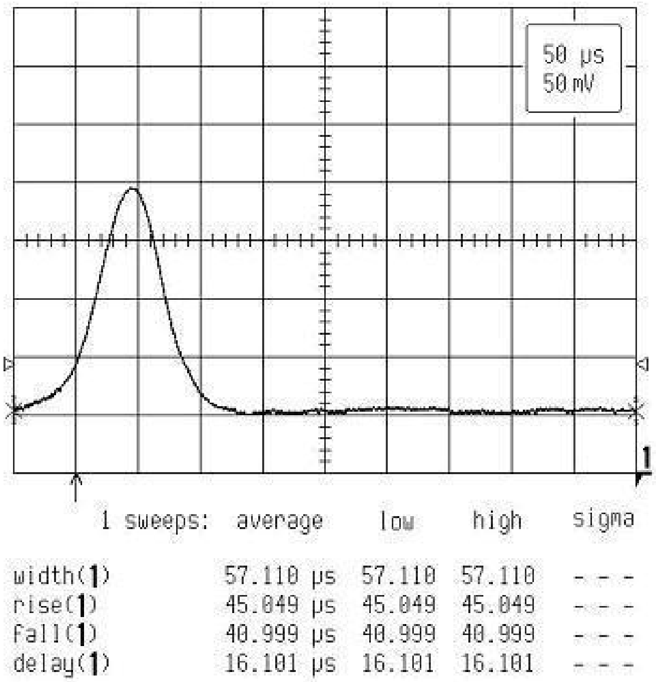

Fig. 1. A typical shape of a wheat kernel impact record (free fall of kernel from the height of 21 cm onto the force transducer). The four parameters of the record are defined below:
Width (Pulse width) determines the duration between the **Pulse Start** (median point, i.e. the 50% magnitude transition 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 Figure2. 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).

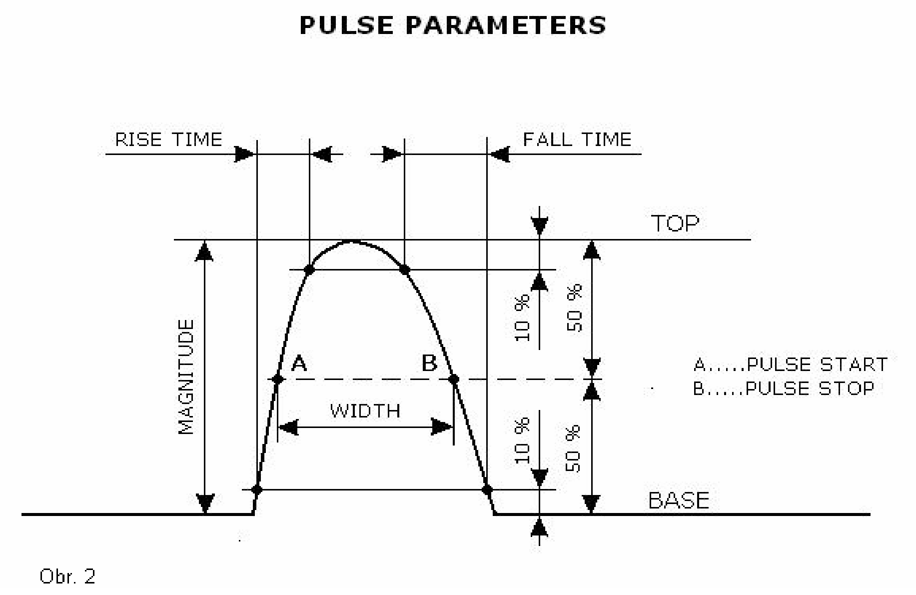

Fig. 2. Graphic presentation of the pulse parameters and their geometric sense wydrapac obe.2

EXPERIMENTAL APPARATUS

The impact of each kernel was realized by letting it fall freely from the height of 83 cm (or 21 and 6 cm, respectively) onto the force transducer which was connected to the amplifier and the DSO (Digital Storage Oscilloscope) for impact record acquisition and storage. The components of the apparatus are described in detail below, and the overall view and a schematic diagram of the apparatus are shown in Figure 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 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.

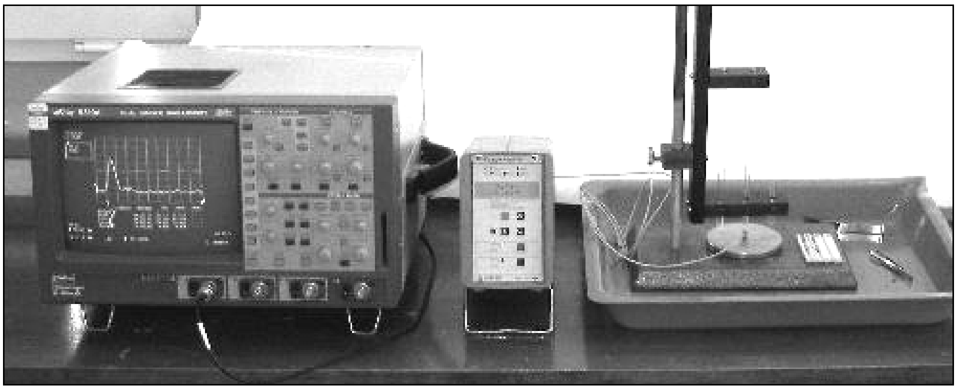

Fig. 3. View on the laboratory apparatus set

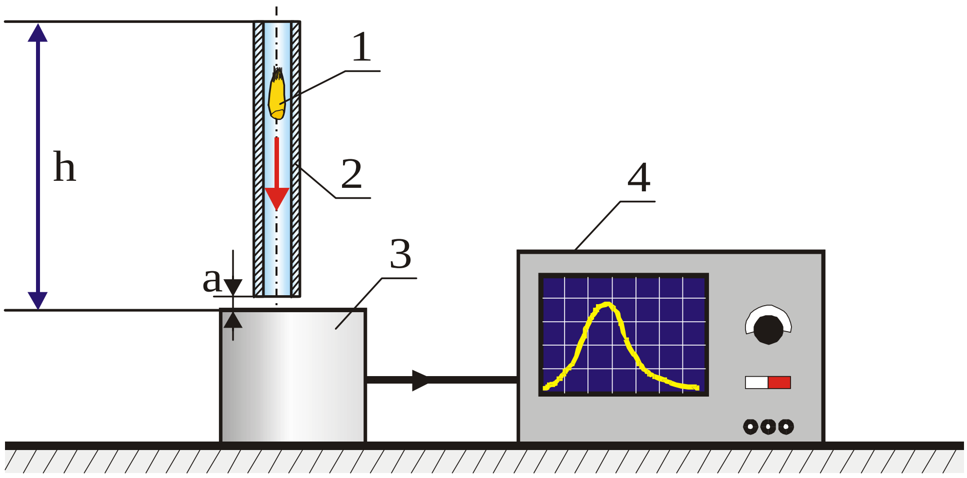

Fig. 4. Schematic diagram of the experimental apparatus: 1 – wheat kernel, 2 – glass tube, 3 – piezo-electric sensor (force transducer), 4 – digital oscilloscope

The charge signal of the force transducer is 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 acquisition memory capacity (50 k 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. An amplifier that amplifies the input signal so that it can be measured by the DSO. An analogue-to-digital converter (ADC) which converts the analogue signal (incoming to DSO) into digital form by translating it into a series of sample points that are then measured and transformed into digital codes representing the signal samples. An acquisition memory system that stores the resulting digital data. System memory of up to 64 MB (maximum for this type of DSO). Processor which controls the entire system and performs special monitoring and measurement functions. Display system that translates the stored data into a graphic display of the original signal shape. The character of measured signals determines the primary specifications of the DSO. 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 short study were made by this technique.

RESULTS

All the main experiments with kernel impact were realized by wheat grains of variety KANCLER. Kernels of the same mass were grouped the thirty groups of ten kernels each. Each impact record was described by four parameters, as shown in Figure 1. At the end of each series of measurements (for one group of ten kernels), simple statistical analysis of the series was made to characterize the group. Table 1 presents results of such analysis for one group. All other groups were characterized in the some way. Figures 5 and 6 show the shapes of the impact records of wheat kernels as characterized by the five parameters given in Table 1. Besides experiments with wheat grains, a few other kinds of kernels were short tested for the impact shape. For that secondary series of tests, kernels of small diameter and spherical shape were preferred. The impact records obtained for those kernels were almost independent of the place of impact effect. Opposite to that, the shape of impact records obtained for wheat kernels were strongly related to kernel orientation at the time of impact, which is exactly why the impact tests for wheat kernels were realized with the kernels falling freely either on the germ or on the brush.

Table 1. Parameters of impact records from Figures 5 and 6 and their processing. Data for wheat kernels of variety KANCLER and free fall height of 21 cm. Force values in the table are maximum values of the force of impact

No	Mass 0.060 g, fall on the germ					Mass 0.060 g, fall on the brush				
	Width (μs)	Rise (μs)	Fall (μs)	Delay (μs)	Force (N)	Width (μs)	Rise (μs)	Fall (μs)	Delay (μs)	Force (N)
1	57.11	45.04	40.99	16.10	0.1830	28.74	18.44	13.85	6.70	0.375
2	65.72	36.43	47.51	7.78	0.1042	32.57	25.70	18.37	8.69	0.235
3	60.13	32.96	42.63	8.04	0.1830	26.95	19.79	15.59	10.29	0.333
4	52.96	31.61	44.70	12.02	0.1892	30.66	16.71	11.08	12.79	0.341
5	48.28	39.66	46.73	12.09	0.1750	26.88	19.32	15.64	8.93	0.283
6	47.98	44.23	61.35	16.54	0.1956	25.96	18.94	14.90	9.59	0.341
7	42.94	37.00	32.56	14.37	0.2331	28.36	24.51	15.58	15.64	0.266
8	40.90	29.09	25.55	13.61	0.2541	24.98	18.25	14.07	9.36	0.347
9	63.40	44.39	57.82	20.02	0.1045	28.92	21.37	13.00	14.79	0.358
10	39.06	27.84	23.84	12.37	0.2452	26.07	19.50	14.68	12.15	0.345
mean	51.81	36.82	42.36	14.75	0.1868	28.00	20.25	14.75	10.89	0.323
σ_n	9.02	6.08	11.72	1.67	0.0491	2.21	2.68	1.67	2.75	0.043
σ_{n-1}	9.50	6.41	12.35	1.76	0.0517	2.32	2.83	1.76	2.85	0.045

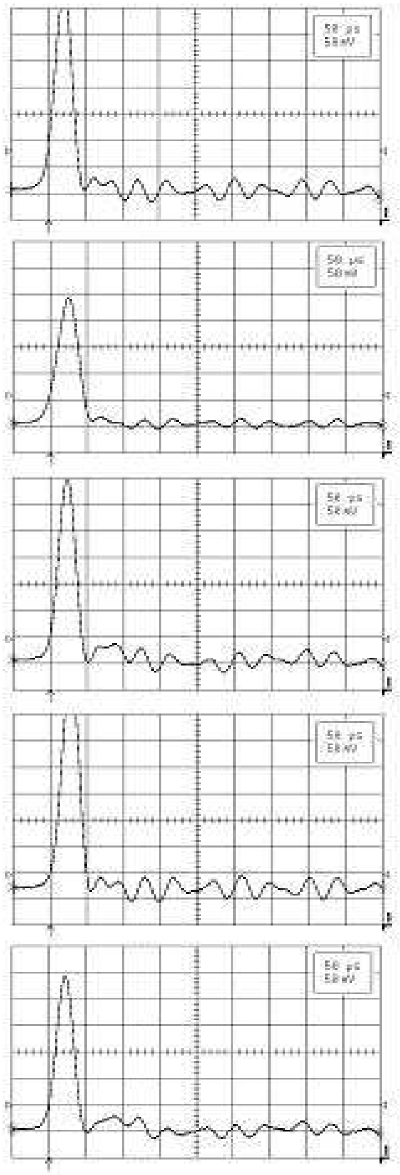

Fig. 5. Impact records for a wheat kernel with a mass of 0.06 g. Height of kernel free fall – 21 cm. The figure shows the first five records out of ten. All the data for this series of measurements are given in Table 1

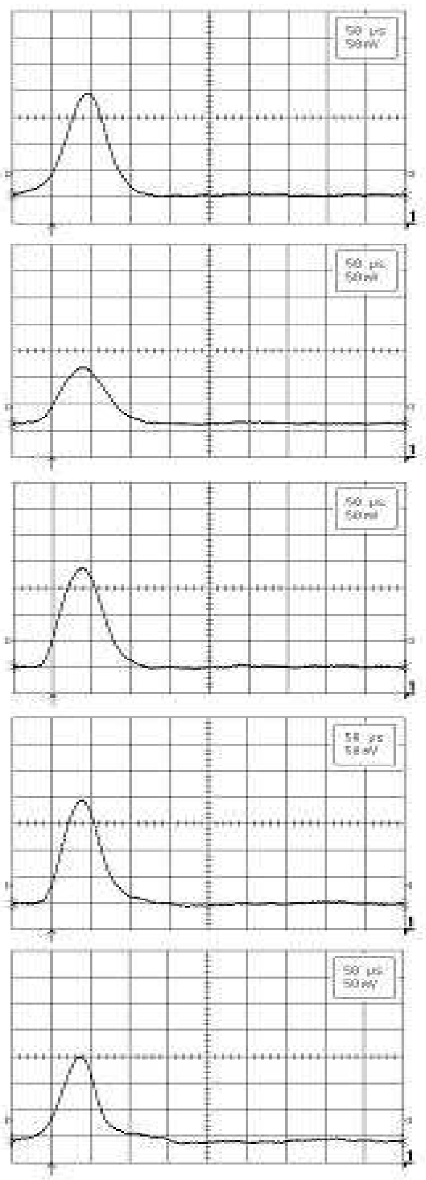

Fig. 6. Impact records for the same kernel as in Figure 5, but with the kernel falling on the germ. Data for this series of measurements are given in the Table 1

Data for wheat kernels with shorter length and the same mass are given in Table 2.

Table 2. Parameters of impact records from Figs. 7 and 8 and their processing. Data for wheat kernels of variety KROMA and free fall height of 21 cm. Force values in the table are maximum values of the force of impact

No	Mass 0.062 g, fall on the germ					Mass 0.062 g, fall on the brush				
	Width (μs)	Rise (μs)	Fall (μs)	Delay (μs)	Force (N)	Width (μs)	Rise (μs)	Fall (μs)	Delay (μs)	Force (N)
1	33.17	19.06	19.73	7.34	0.2331	35.01	34.04	18.16	17.19	0.305
2	32.51	15.27	16.23	7.53	0.3646	34.63	43.37	34.63	14.82	0.212
3	31.17	20.79	20.03	8.62	0.2416	28.92	37.14	28.33	14.22	0.337
4	42.35	29.21	41.98	9.10	0.2081	36.12	32.16	26.72	15.12	0.244
5	31.44	17.84	23.46	9.70	0.3001	32.34	25.45	15.80	10.14	0.296
6	39.12	26.12	36.18	8.92	0.2661	34.83	52.60	67.57	18.10	0.244
mean	35.05	21.38	26.26	8.53	0.2691	34.04	38.52	31.86	14.96	0.273
σ_n	4.24	4.81	9.44	0.84	0.5236	2.85	8.68	17.16	2.42	0.043
σ_{n-1}	4.64	5.27	10.34	0.92	0.0562	3.13	9.51	18.82	2.65	0.047

The impact of wheat kernel on the brush is shorter than the impact of the same kernel on the germ, as shown in both the tables. Figures 7 and 8 illustrate the data from Table 2. The kernel impact record depends also on the place of contact with the force transducer on impact, and on the kernel angle of incidence to the force transducer surface. In the future, this question must be studied in depth, and a solution needs to be found.

Steel ball impact record (hard material with comparison to wheat kernels) is shown in Figure 9. The long tail in the graph presented in the figure is similar to the tails in Figures 5 and 7, only the magnitude is smaller as steel ball is “harder material” than the germ of wheat kernel. The impact record the same kernel hitting the transducer with the brush and not the germ has a smaller tail, as can be seen from Figures 6 and 8.

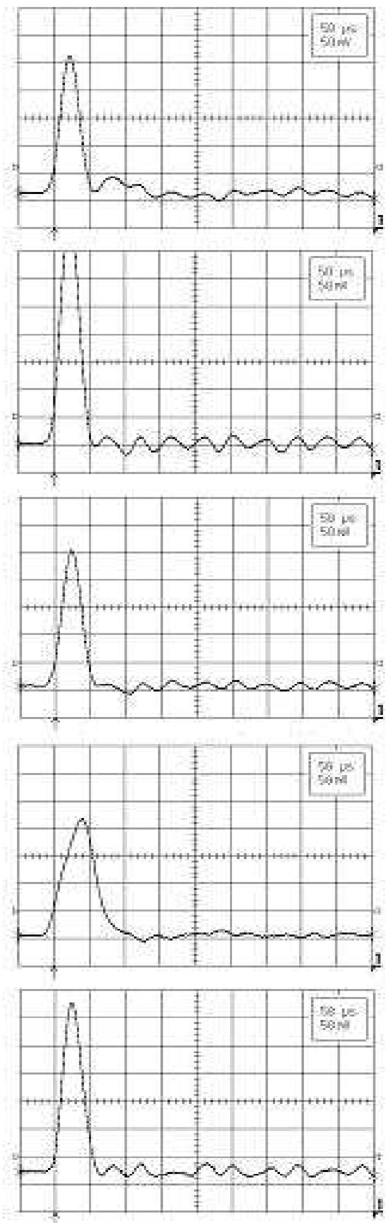

Fig. 7. Impact records for a wheat kernel with a mass of 0.062 g, falling on its germ six times from the height of 21 cm. All data for this series given in Table 2

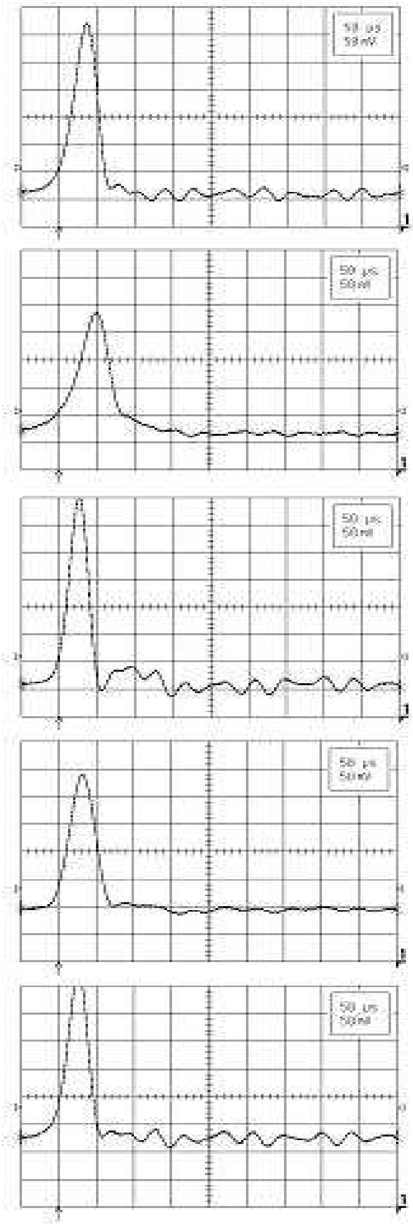

Fig. 8. Impact records for the same kernel as in Figure 7, but with the kernel falling on the brush. See Table 2 for more details

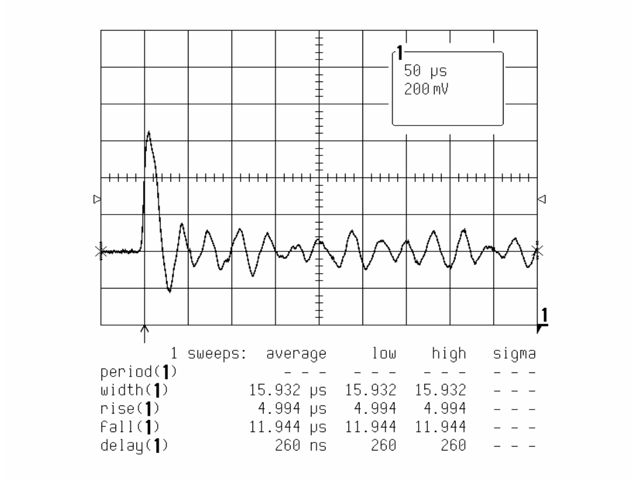

Fig. 9. Impact record for a small steel ball (diameter 2 mm, mass 0.033 g). The long tail in the impact record is caused by the ball skipping on the force transducer. Both bodies (the ball and the force transducer case) are made from metal with high coefficient of restitution. One division in the vertical direction means 0.2 N. The steel ball is an ideal symmetrical body, but its impact record is asymmetrical (after the parameters in Fig. 9)

CONCLUSIONS

On the basis of the experiments, we can formulate some conclusions and recommendations concerning continuation of such experiments in the future. Some of the impact records in Figures 5-8 show small differences in their shapes (differences between the records in each of the figures) that are caused mainly by the differences in the orientation of the kernels during their free fall onto the force transducer. Some comments on this phenomenon are given in the figure captions.

The conclusions formulated on the basis of the study are as follows:

1. Wheat kernel impact on the brush end is shorter and the related impact force is slightly bigger than the corresponding quantities recorded for wheat kernel impact on the germ.
2. The shape of wheat kernel impact record is asymmetrical with respect to kernel impact on the brush or on the germ ends of the kernels.
3. The basic character the kernel impact record is independent of the height of kernel free fall within the range from 10 to 100 cm (the heights of 83, 21 and 6 cm were used).
4. The laboratory apparatus used in the tests accurately detects impact forces from 30 m N and impact time from 0.1 μs.

5. Statistical processing of the parameters of impact records provides a better insight into the differentiation between various properties of individual kernels and of different varieties of grain.

6. The impact records the small and spherical seeds are less dependent on kernel orientation at the moment of impact.

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PARAMETRY OBCIĄŻEŃ UDAROWYCH ZIARNIAKA PSZENICY

Josef Pecen

Wydział Techniczny, Katedra Fizyki, Czeski Uniwersytet Rolniczy w Pradze
ul. Kamýcká 129, CZ 16521 Praga 6 – Suchdol
e-mail: pecen@tf.czu.cz

S t r e s z c z e n i e. W pracy podjęto próbę określenia niektórych parametrów obciążeń udarowych ziarna pszenicy. Próby udarowe ziarna pszenicy realizowano w formie swobodnego spadania ziarniaków na przetwornik siły, z wysokości około 83, 21 oraz 6 cm. Rejestrowano parametry udaru ziarniaków (czas i siłę), a zebrane dane zapisywano w pamięci Cyfrowego Oscyloskopu Rejestrującego (DSO) do późniejszej obróbki. Opisano także szczegółowo zastosowane do badań urządzenie doświadczalne. Kształt wykresów przebiegu prób udarowych jest zróżnicowany i zależy głównie od wielkości ziarniaków i ich położenia w chwili uderzenia. Zarejestrowane przebiegi prób udarowych zostały poddane częściowej obróbce statystycznej.

S ł o w a k l u c z o w e: zapis próby udarowej, ziarno pszenicy, kwarcowy przetwornik siły, cyfrowy oscyloskop rejestrujący