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FATIGUE STRENGTH OF WHEAT GRAINS. PART 1. THE ANALYSIS OF GRAIN DEFORMATION AT MULTIPLE LOADS*

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A b s t r a c t. In the majority of studies concerning the evaluation of grain resistance, the authors usually make use of the method of visual evaluation of grain condition - with respect both to external and internal damage (X-ray radiographical method). However, it is a subjective method and its application excludes the possibility of comparing the results acquired by different people. Therefore, in the research carried out an analysis was conducted on the process of deformation of single wheat grains of different moisture content, subject to multiple loads of percussive, in order to determine an objective resistance index.

Wheat grain husked manually from ears was used in the research. A sample of selected grain was loaded on a special percussive stand. During impact (deformation) was registered as well as the corresponding input (reaction) value.

K e y w o r d s: multiple loads, grain deformation

INTRODUCTION

Many methods have already been applied to evaluate and study the sensitivity of cereals grains to mechanic impacts. One of the more precise methods - used for the assessment of the effects of various strains of this type - consists in the sample analysis of sprout rises, which allows direct measurement in the decline of energy and germination capacity. It allows assessment of the damage suffered by sawing material. However, this method is labour- and time-intensive. In the case of a large number of measurements (necessary to obtain statistically meaningful results), the applicability of this method is severely limited. That is why most of the authors have applied indirect methods for grain resistance measurement. The most common method consists in the visual assessment of grain - both from the viewpoint of external and internal damage [3]. By nature, this method is very subjective and practically excludes the possibility of comparing the results obtained by different analysts. Therefore, a universal and objective measure for grain resistance has been sought. In the case of grain mass, the colorimetric method [2,4,5] is often applied. In the case of fatigue measurements of single grains, the methods proposed for analysing grain sensitivity to mechanic impacts are unsatisfactory.

Therefore, the present research was conducted to obtain an objective measure of wheat grain resistance, using analysis of the deformation process of individual wheat grains at various moisture levels with multiple strains subjected to dynamic impacts.

MATERIALS AND METHODS

Research was conducted on the Almari variety of wheat grains, manually shelled from the ears. The gathered material was segregated and periodically humidified artificially or dried, in order to obtain the desired moisture levels.

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A laboratory - type sample was obtained by passing the material through laboratory sieves. Wheat grains processed as above were strained at the special mechanic impact post (Fig. 1 - according to the method proposed by Frączek [1]). After the release of the detent pawl (7), the spring is extended and causes the movement of the mandrel (12) directly hitting the grains lying on the measurement bench. The

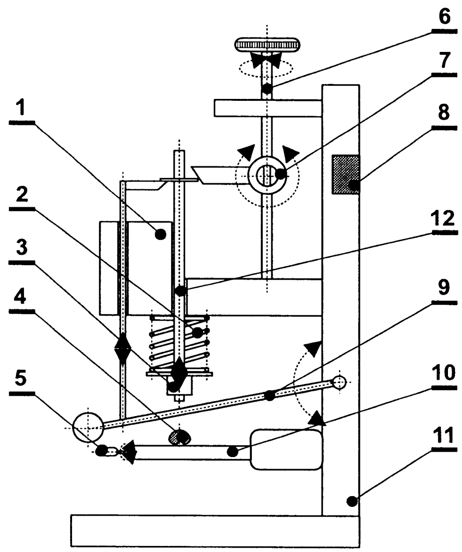

Fig. 1. Diagram of the impact apparatus: 1 - optical sensor, 2 - spring, 3 - tensometric head, 4 - grain, 5 - regulating screw, 6 - regulating screw, 7 - detent pawl, 8 - electronic amplifier, 9 - lever, 10 - table, 11 - body, 12 - mandrel.

tensometric head is installed in the lower part of the mobile mandrel. The entire measurement system is connected to a computer which allows easy recording of the obtained data. In the course of impact, the movement distance (deformation) of the mobile mandrel was registered, as well as the corresponding force value. The main factors influencing the extent of deformation were identified as the moisture level of the wheat grain and number of impacts. Thirty grains were strained for each combination of experiment characteristics.

RESULTS AND DISCUSSION

The analysis was conducted on the reaction force and grain deformation in the course of mechanic impacts. The strain system, together with the grain, must be considered as isolated from the environment. Thus, the rule of energy conservation applies to the entire set. We can accept then that the impact energy E_u is entirely used (neglecting the material deformation of the bench and hitting mandrel) in the plastic deformation E_{pl} and the upward rebound of the mandrel E_{od}:

$$E_u=E_{pl}+E_{od}\,. \tag{1}$$

Assuming the ideal elasticity, the entire impact energy would result in mandrel impact. In reality, however, plastic deformations occur, and - additionally - lagged elasticity when the material returns to its previous shape with much lower velocity than had been the case in the original impact deformation. The latter phenomenon is very difficult to observe, since the grain is subject to many processes related, among others, to the exchange of mass (e.g., the breathing of the grain). For the sake of simplicity, the lagged resilience was neglected in our analysis. On the grounds of the above findings, it must be stated that the lower the amount of energy absorbed in plastic deformation, the higher the material resilience. The work involved in the permanent deformation of grain is measu-red by the difference of kinetic energy levels before and after the impact (correspondingly E_1 and E_2), i.e.:

$$E_{pl}=E_2-E_1=\int_0^{s_1}F_u(s)ds-\int_{s_1}^{spl}F_{od}(s)ds \tag{2}$$

where s_1 - limit value of deformation, s_{pl} - plastic deformation, $F_u(s)$ - the impact force, $F_{od}(s)$ - rebound force.

An example of discussed conditions is shown in Figs 2 and 3, drawn for the first impact at grain moisture levels of 15% and 20%. The graphic representation of kinetic energy changes is offered by the area contained between the curves F_u (s) and F_{od} (s). Parallel to the growth of grain moisture, this area grows and consequently the material becomes less and less resilient. This is related to the increase in permanent linear deformation (the interval s_{pl}).

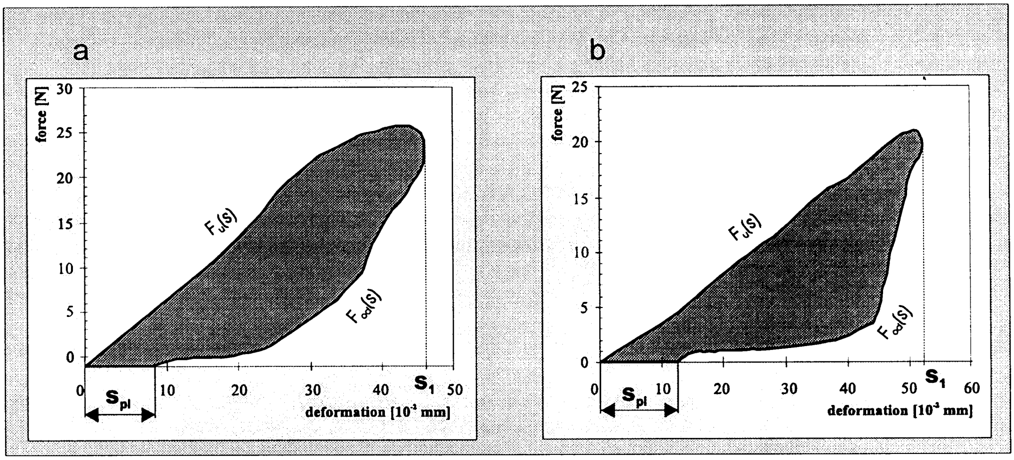

Fig. 2. Example of changes in the course of applied force in the deformation of grain. The first impact, moisture content 15% (a), and 20% (b).

The changes in the value of applied force and deformation in the entire research cycle (i.e., starting at 0 up to the 30th impact) for the randomly selected grain, at the moisture level of 20%, are shown in Figs 4 and 5. With respect to the value of force, it is possible to observe clearly the declining tendency of maximum reaction force, parallel to the increased number of impacts, with simultaneous shortening of application time. In the course of impacts, an increase in the number of linear plastic deformations occurs. This process seems to be most dynamic up to the 15th impact.

In order to compare the reaction force and deformation in the course of impact at various moisture levels of strained material, the diagrams of discussed values were effected for the first and the twentieth impact (Figs 5 and 6). The obtained curves confirm the previous analysis and clearly indicate the declining resilience of the material parallel to to the increasing moisture.

In consequence of the above findings, the chosen material resilience measure is the coefficient W, defined as the ratio of maximum reaction force in the course of single impact:

$$W = P_{i_{\max}} / S_i \tag{3}$$

where $P_{i_{\max}}$ - the maximum reaction force of

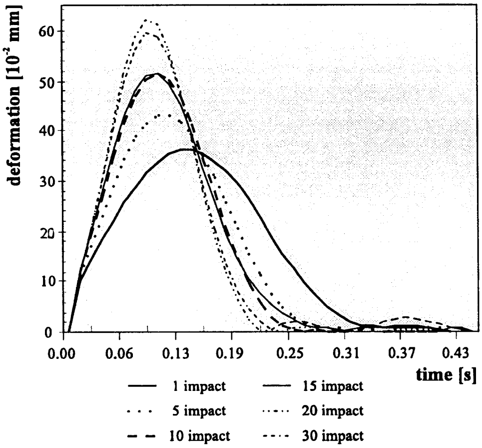

Fig. 3. Deformation change in the course of impact. Moisture content 20%.

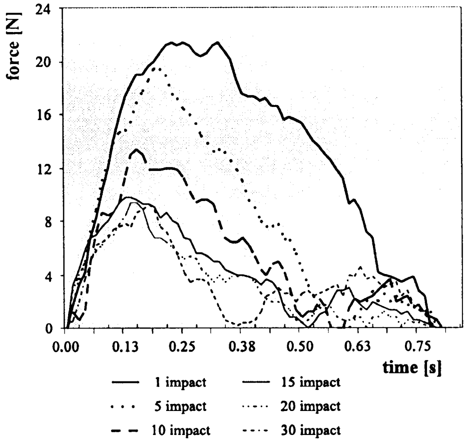

Fig. 4. Changes in reaction force during the impact. Moisture content 20%.

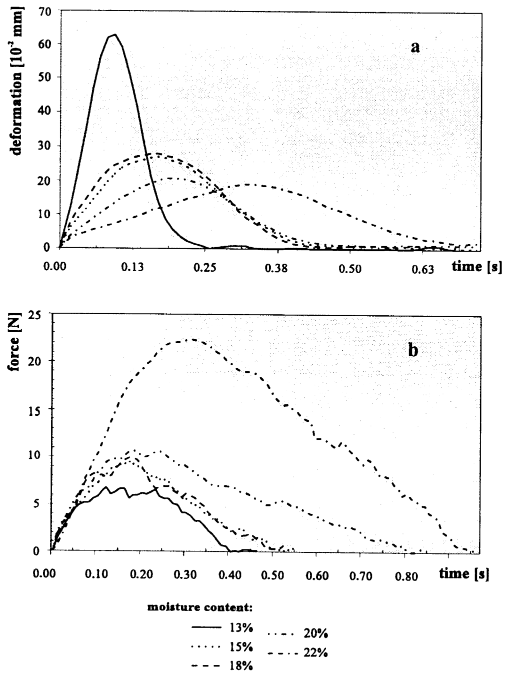

Fig. 5. The changes in deformation value and reaction force in the course of first impact at various moisture levels: a - deformation, b - force.

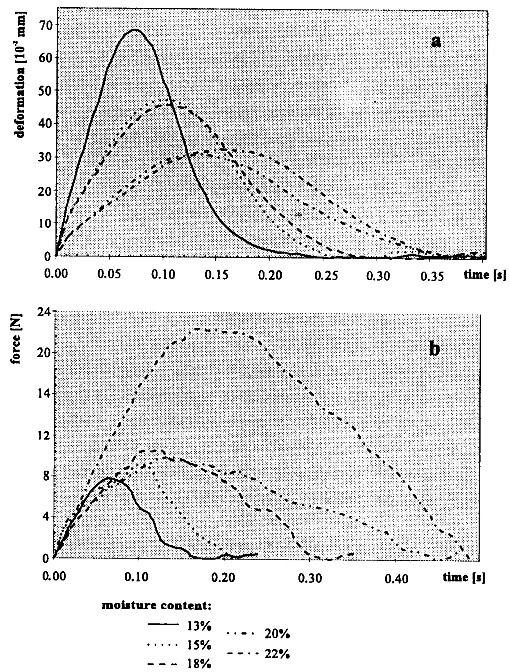

Fig. 6. The changes in deformation value and reaction force in the course of 20th impact at various moisture levels: a - deformation, b - force.

single grain at the i-th impact, S_i - the value of deformation corresponding to $P_{i_{max}}$.

Analysis of the resulting diagrams shows that the growth of moisture is accompanied by increasing diversification of the grain resilience coefficient. At the 13% moisture level of grain, over the entire analysis period, there occurs a proportional decline in grain resistance. In the case of moisture levels 13-18%, the initial insignificant decline in W coefficient evolves to stabilize after approx. 20 impacts. At the moisture levels of 20 and 22%, there occurs the maximum resilience point in the interval of 10 to 20 impacts. This observation leads to the conclusion about the fatigue strengthening of the material. It can be assumed that the high content of water results in the change of material properties (from the qualification of elastic-brittle to viscoelastic). In consequence, every impact leads to permanent plastic deformations in the surface layer, thus promoting the formation of high resistance layer (similarly to the forging process).

CONCLUSIONS

1. The analysis of obtained results allowed us to find that the increasing number of impacts leads to increased plastic deformations.

2. The highest changes in grain elasticity occur in the interval between the first and the fifth impact, and next between the twenty fifth and thirtieth impact.

3. The effect of so called fatigue material strengthening was observed. This effect was particularly pronounced at higher moisture levels.

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