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ACOUSTIC EMISSION AS A METHOD FOR THE DETECTION OF FRACTURES IN THE PLANT TISSUE CAUSED BY THE EXTERNAL FORCES*

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A b s t r a c t. In order to detect fractures in the plant tissue resulting from deformations, the method of acoustic emission has been applied. Simultaneous measurements of the mechanical parameters and the acoustic emission signal show that the destruction of the cell structure begins at the lower deformation values than the ones at which there is a decrease in the stress level. The results obtained show that the method of measuring the acoustic emission signal allows for an early detection of plant tissue defects arising from the activity of external forces.

K e y w o r d s: acoustic emission, stress, strain, plant tissue

INTRODUCTION

Agricultural media, especially of plant origin, are often subjected to all sorts of outside mechanical loading. In order to lower (often very high) losses in yields it is necessary to learn about relations in the structure: machine - plant medium. Destruction of the studied medium starts with the smallest elements of its structure, and by a series of chemical-biological processes it leads to some irreversible changes lowering the quality of the whole yields. Recognition of this phenomenon at an elemental level can, in practice, limit the losses considerably, and aid research work on the still imperfect theory that would allow for the prediction of the basic stress-strain relations.

In the recent years methods utilising acoustic waves were introduced for the evaluation of quality of plant produce. They are mainly the methods consisting in the analysis of the acoustic waves that go through the sample. The source of the waves is most often some kind of an external factor, e.g., an impact with a small hammer, microphone or piezoelectric transducer emitting elastic waves [1,4]. For that reason the above methods can be regarded as active. They are mainly used for the evaluation of the mechanical parameters of the material artificially not damaged, or after a stimulus creating damage.

In the studies on material the so-called method of acoustic emission AE is often applied [2]. This method is regarded as passive, i.e., the material subjected to the external stimulus generates acoustic signal of its own. Other advantages of the method of acoustic emission are as follows: high sensitivity in detecting the generated defects, obtaining the signal at the moment they are created, as well as the possibility to localise the signal source (when a few sensors of acoustic emission are used) [2,3,5]. In the mechanical studies an external force

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that causes sample deformations is most often used as the external stimulus that generates the acoustic emission signal.

So far the method of acoustic emission has not been used in the studies on damages resulting form the external forces acting on the plant material of agricultural origin. The present work presents an attempt at the application of AE and preliminary results obtained for the soft potato tissue.

STUDY MATERIAL AND METHODS

The term acoustic emission (AE) describes the phenomenon of generation and propagation of elastic waves created as a result of the release of the stored inner energy.

In the heterogeneous cell structures (e.g., such as plant tissue) subjected to the influence of external forces, a certain state of heterogeneous and momentary condition of tension in the cell walls is generated. As a result of trespassing the critical local tension, the process of rupture takes place. The energy released at that time is used for performing local mechanical work, heat and radiation in the form of elastic waves. The resulting elastic waves propagate to the surface where they can be recorded by the suitable reception transducers. The frequency of these waves ranges in a very broad spectrum depending on the material and wave source (from a fraction of a Herz to 1 kHz).

Cylindrical samples of potato tissue var. 'ibis' were used for the present experiment. The samples were 21 mm high and had a diameter of 11 mm.

A block scheme of the apparatus used in the experiment has been presented in Fig. 1. The main elements of the system are as follows: a hydraulic system with a pump, a system of sensors, and a system of data recording. A sample was placed between two plates parallel to each other. The hydraulic system forces uniform motion (with the speed of 13 mm/s) of one of the plates which causes deformation to the sample. The process was carried out till the moment of a distinct decrease in the stress of the sample. The stress was measured by means of a tensiometric sensor with a negligibly low deflection, whereas deformation was measured by means of an induction sensor. The experiment was carried out in ten repetitions.

Measurements of the acoustic emission

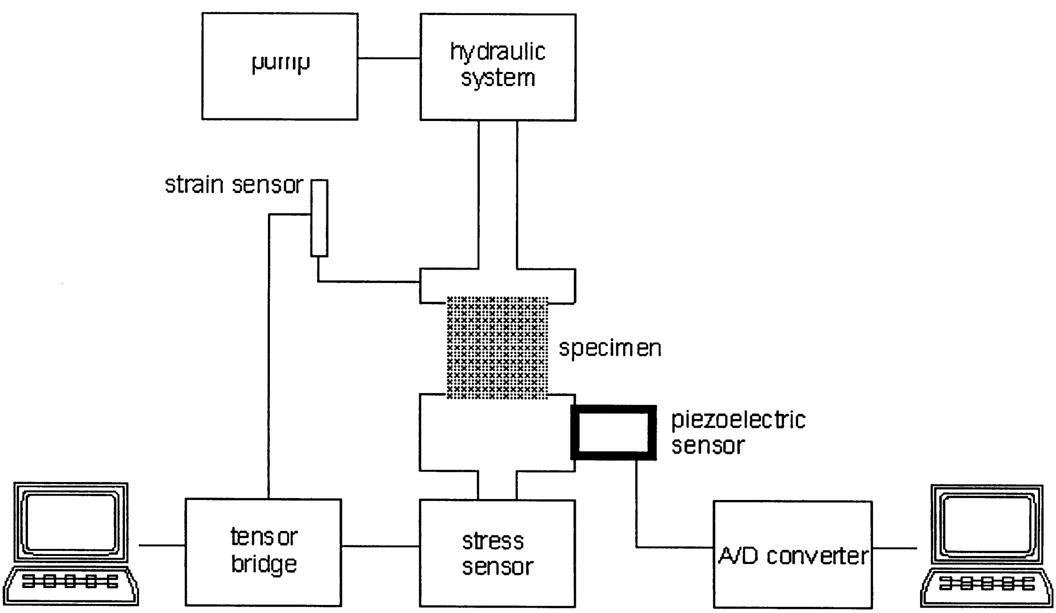

Fig. 1. Block diagram of the measuring apparatus used in the experiment.

signal were conducted by means of a resonance piezoelectric sensor with the resonance frequency of 200 kHz examined in the Institute of Fundamental Technological Research of the Polish Academy of Sciences [3]. The examination proved that the transformer used is characterised by a high sensitivity in a considerably wide range of frequencies: from about 20 kHz to over 200 kHz. The sensor of acoustic emission was directly connected with the analogue-digital board with high amplification that allowed for signal sampling with the frequency of 500 kHz. It allowed for the measurement of the acoustic emission signal with the frequency up to 250 kHz.

Since the friction of the compressed sample against the front part of the transformer disturbs the measurements of the acoustic emission signal, it was indispensable to attach a detector to the lower compressing platform.

RESULTS AND DISCUSSION

Due to a very large number of data obtained during one deformation process, it is possible to present only some of the acoustic emission signals chosen from the time series of the whole loading process. Figures 2a, 3a and 4a present some chosen time intervals during which the most characteristic changes of the amplitude change (voltage) of the signal detected by the AE transducer. The signals presented appeared before the decrease in the stress of the sample that took place at the stain value of =0.33, and the stress of =1250 kPa.

The acoustic emission signal obtained is of a discreet character. Individual AE peaks are of the relaxation character (the time of the amplitude increase in the signal envelope is a lot smaller than the time of falling). At each measurement it is possible to distinguish several individual signals of acoustic emission that take place one after another in irregular time intervals. Before the moment of destruction the frequency of occurrence of the signals of acoustic emission increases. It is also characteristic that the initial signals (i.e., Fig. 2a) have a far smaller amplitude than the signals appearing before the moment of sample destruction (i.e., Figs 3a, 4a).

It follows from the literature on the subject [2,3] that the discreet emission of a relaxation character is accompanied, among others, by the ruptures and their propagation and the appearance of the slip lines. These processes take place also during deformation of the plant tissue. As a result of a certain state of stress created by the external forces in the tissue, two processes resulting in the emission of the acoustic signal are possible: ruptures in the cell wall, and deglutination of cells from one anther. That is why it is possible to ascribe the above mentioned processes to the signals of acoustic emission observed in the present experiment. An additional increase in the amplitude of the signal obtained and an increase in the frequency of the signal occurrence together with an increase in the sample stress proves that sample destruction is of an

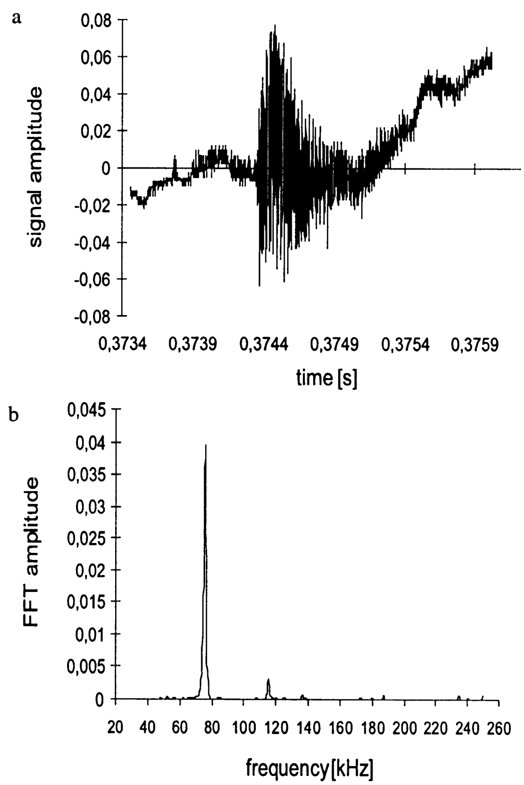

Fig. 2. The characteristics of potato tissue obtained at the strain of ~0.2, and the stress of about 600 kPa. (a) the acoustic emission signal, (b) spectrum analysis of the AE signal by means of FFT.

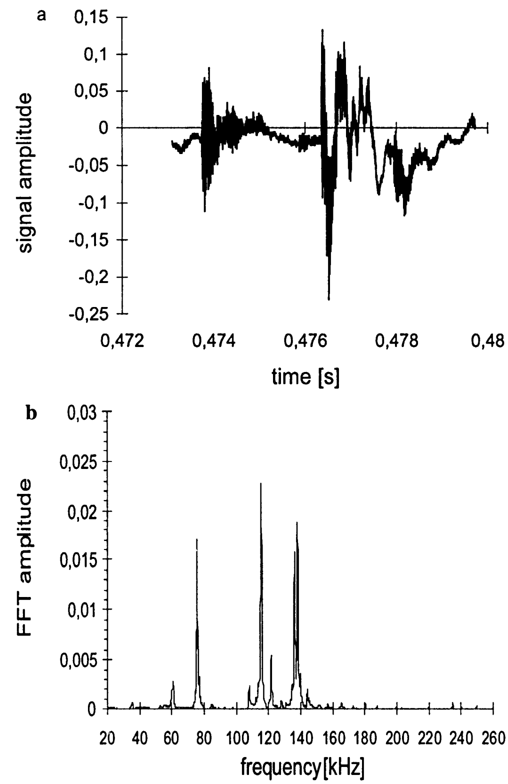

Fig. 3. The characteristics of potato tissue obtained at the strain of ~0.26, and the stress of about 800 kPa. a) the acoustic emission signal, b) spectrum analysis of the AE signal by means of FFT.

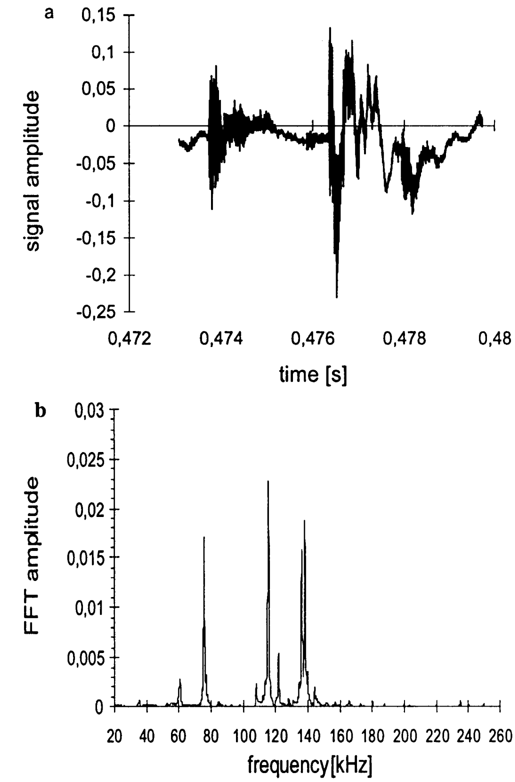

Fig. 4. The characteristic of potato tissue obtained at the strain of ~0.275, and the stress of about 900 kPa. a) the acoustic emission signal, b) spectrum analysis of the AE signal by means of FFT.

'avalanche' character. However, a detailed identification of the individual ways of destruction is not possible at present because of the difficulties in determining the functions of the signal passage from the source to the detector.

Figures 2b, 3b, 4b present frequency spectra for the acoustic emission signals for the respective time intervals. The frequency range that is presented in the graphs has been limited from the bottom by cutting off disturbing frequencies (<5 kHz). Comparison of the spectra shows that it is possible to distinguish some certain characteristic frequencies of the signal that occur during deformation process. These characteristic frequencies are as follows: 60 kHz, 75 kHz, 115 kHz, 135 kHz. It is very interesting that the signals have one or two dominant frequencies, whereas the signals immediately before the moment of a distinct decrease in the stress have five or six components in the spectrum. It may prove an increase in the number of processes causing destruction at certain values of the stress. At the stress values close to sample destruction (Figs 3b and 4b) various processes take place simultaneously which is manifested by the simultaneous appearance of signals with various frequencies.

It follows from the comparison of the mechanical values and the acoustic emission signal that AE peaks occur before the decrease in the stress begins. The first AE signals that we were able to observe, appeared immediately before strain ≈0.21, i.e., 65 % (Fig. 2a) of the value of strain at which there appeared a distinct decrease in the sample stress. It can be stated that the method of acoustic emission is a method of early detection of the cell structure defects that result from the activity of external forces.

CONCLUSIONS

The obtained results show that method of measuring the acoustic emission signal allows for the detection of defects in the plant tissue that result from the activity of external forces. The measuring apparatus used allows for the detection of defects at the deformation values far lower that the ones at which a distinct decrease in the stress value of the stress - strain characteristics. The character of the acoustic emission signal obtained shows that during deformation of the plant tissue we experience an 'avalanche' type of processes of cell wall ruptures or deglutination of the cells from one another.

The frequency analysis of the acoustic emission signal that has been carried out, allows to conclude that some characteristic frequencies can be distinguished in the process of destruction of plant tissue (in the case of potato tissue these signals fall into the range from 60 to 150 kHz). Various processes taking place during the deformation of plant tissue can be assigned to these frequencies.

A series of measurements taking into consideration a wider range of deformation speeds and individual properties of the studied material together with some improvements of the measuring apparatus will make it possible in the future to apply the method of acoustic emission in the studies of the mechanical properties of plant materials.

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