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ACOUSTIC EMISSION GENERATED IN THE PROCESS OF RESIDUAL GROWTH STRAIN REDISTRIBUTION UPON GREEN BEECH WOOD HEATING IN WATER[1]

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The paper reports results of measurements of acoustic emission generated upon heating of green beech wood in water of different temperature and on cyclic heating to 85^{0}C and cooling to 20^{0}C. During the process the longitudinal dimension of the samples was measured.

Key words: beech wood, heating in water, acoustic emission, residual growth strain

INTRODUCTION

All materials are characterised by a certain uneven distribution of elastic energy either original or acquired in the process of production or exploitation. If there appears any factor able to alter the state of internal equilibrium (mechanical, thermal, chemical or wetting stimuli), then at one or many sites of the material a certain portion of energy is released and the majority of this portion is spread in the form of an elastic wave. A source of the waves can be movements of dislocations phase transitions, related to changes in the microstructure of the material, formation and spreading of cracks, deformations and internal friction accompanying these processes. The method of acous-

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tic emission (AE) based on measurements of the parameters of the elastic waves generated allows non-destructive observation of changes taking place during the activity of the factor causing the energy release. One of the factors causing a release of the elastic energy accumulated in wood is the liberation of growth strains, which exist in each green wood. Their distribution over the cross-section is uneven and changes with increasing thickness of the wood (Hejnowicz 1973, Saurat and Guneau 1976, Yamamoto *et al.* 1992, Tejada *et al.* 1997). The strength of the strains depends on the kind of wood, anatomical direction, distance from the core, the natural habitat of the tree, its social position in the forest stand and the fact whether the reaction wood has developed in the wood tissue (Saurat and Guneau 1976). The strongest growth stresses are measured in the longitudinal direction and in the tension wood. According to Caster *et al.* (1992) the growth stress in tension wood of poplar tree is about 3.7 times greater than in the normal wood. In the reaction wood of Black Locust (*Robinia pseudoacacia* L.) the growth strain can reach 70 MPa (Okuyama *et al.* 1992).

Partial release of the growth strain occurs already during tree cutting and division into boards. It causes cracks and longitudinal bending of sawn assortment. These faults significantly limit the efficiency and quality of the elements. Further release of the growth strain can be achieved by a long-term storage of wet wood (e.g. Nichlson 1973), heating of logs in hot air (e.g. Tejada *et al.* 1997), steaming of wood (e.g. Okuyama *et al.* 1987, 1988, 1990) and its cyclic wetting and drying (e.g. Perkitny and Helińska 1966, Čunderlik 1997).

This paper reports results of the study verifying the usefulness of the AE method for detection of changes in the residual growth strain in green wood subjected to heating in water of different temperature. Despite a widespread use of the AE method in the study of wood and control of certain technological processes, the AE detection has not been used for monitoring of relaxation of growth stress.

MATERIAL AND METHODS

Experiments were performed on samples of beech wood (*Fagus sylvatica* L.) of the size 150(L)x10(T)x10(R) mm. The samples were cut out from the circumferential part of the butt end log with the centrally located core of the moisture content about 80%. To evacuate air from inside of the samples they were saturated with distilled water of 20^0C in the reduced pressure. This procedure should eliminate the movement of air bubbles during their later heating in hot water. An AE transducer of the specific resonance frequency of 200 kHz was attached to one of the head surfaces of the sample, which was then placed in an isolated glass cylinder in the way shown in Fig. 1. Exactly in the axis of the sample a sensor of movements was mounted with its foot adjacent to the AE transducer. The sensitivity of the sensor was 0.005 mm. The case of the transducer was made of invar steel which ensured that it would not change its size. The sample was then submersion with water heated to a given temperature of 37, 45, 53, 60, 67, 77 and 85^0C. At the moment of submersing, the AE analyser was actuated whose total amplification was 85 dB and the level of noise discrimination –0.5 V. The results were recorded on a PC com-

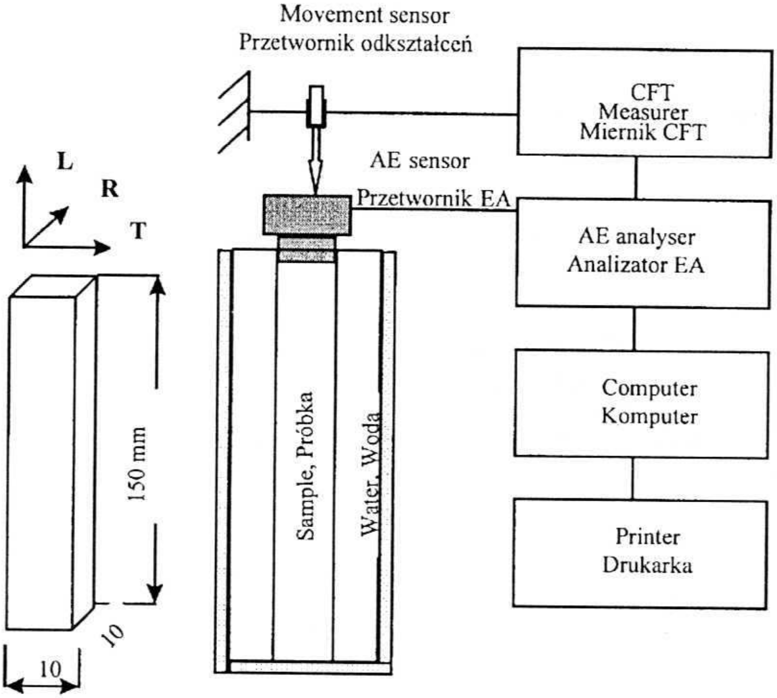

Fig. 1. Illustration of the measurement of AE and longitudinal residual growth strain in green beech wood during its heating in water

Rys. 1. Sposób pomiaru EA i podłużnych resztkowych odkształceń wzrostowych w świeżym drewnie buka podczas ogrzewania próbek w wodzie

puter using a program called DEMA. AE signals were recorded each time for 10 minutes as after this time the signals were not recorded.

In the second series of measurements the analogous measurements were conducted for one sample, which was cyclically heated to 85^{0}C, after cooling it to 20^{0}C. In this series 10 complete cycles were performed.

RESULTS

A typical spectrum of AE signals generated during heating of green beech wood in water is shown in Fig. 2, which presents a typical time dependence of the AE counts rate generated during heating the sample in water of 85^{0}C. As follows from this figure, acoustic emission signals were recorded immediately after submersing the sample with hot water. The AE counts rate quickly increased reaching a maximum in a relatively short time, and then it gradually decreased. Although AE ceased practically after

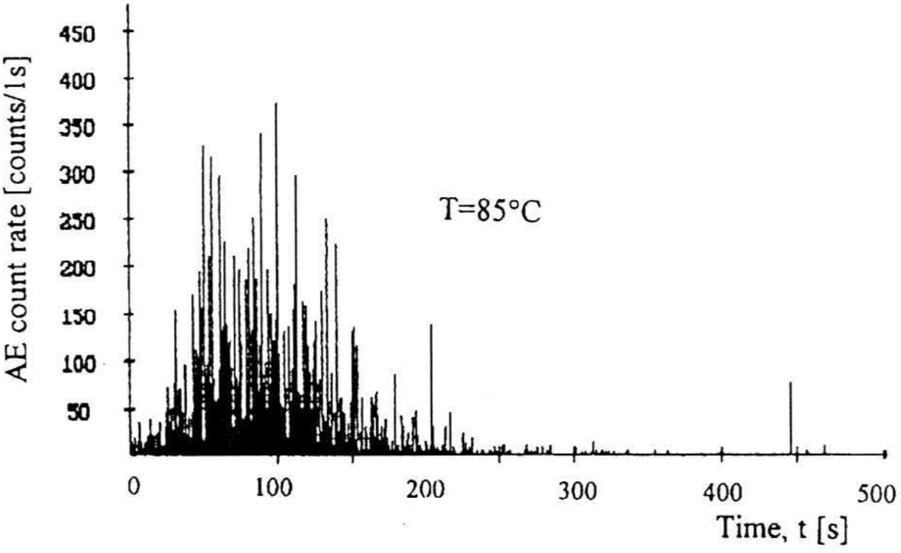

Fig. 2. An exemplary time dependence of the counts rate of AE signals generated in beech wood heated in water at 85°C

Rys. 2. Przykładowy przebieg tempa zliczeń sygnałów EA generowanych w czasie ogrzewania próbek drewna buka w wodzie o temperaturze 85°C

10 minutes of heating, small release deformations were recorded for the next 10 minutes. This fact can be explained by increasing plasticity of the wood and an increase in damping of the generated AE signals. When the sample was submersed with water of a lower temperature, the number and rate of AE signals were lower.

Fig. 3 illustrates the influence of water temperature on the AE cumulative counts and events recorded 10 minutes after the flooding. According to the results the relationship between the temperature of the water bath and the logarithm of AE cumulative counts and events is linear. Also linear is the dependence between the AE cumulative counts and the degree of shortening of the longitudinal size of the samples, Fig. 4. These linear dependencies indicate that the source of AE generated in wood is the deformation processes following from the release of residual growth strain. In other words they imply that the degree of release of the growth strain is proportional to the AE cumulative counts.

The appearance of AE signals immediately after the submersing can be assigned to the effects of friction as a result of the movement of the cellulose skeleton in the matrix undergoing plastification. It is little probable that in the conditions of the experiments (wet wood susceptible to deformation) the source of the acoustic effects were microcracks. Moreover, the stress waves recorded on the heating of wet wood in water (Fig. 5) are characterised by relatively long duration, low amplitude and low frequency, whereas the waves recorded on wood cracking are characterised by high amplitude and short duration (Moliński 1998).

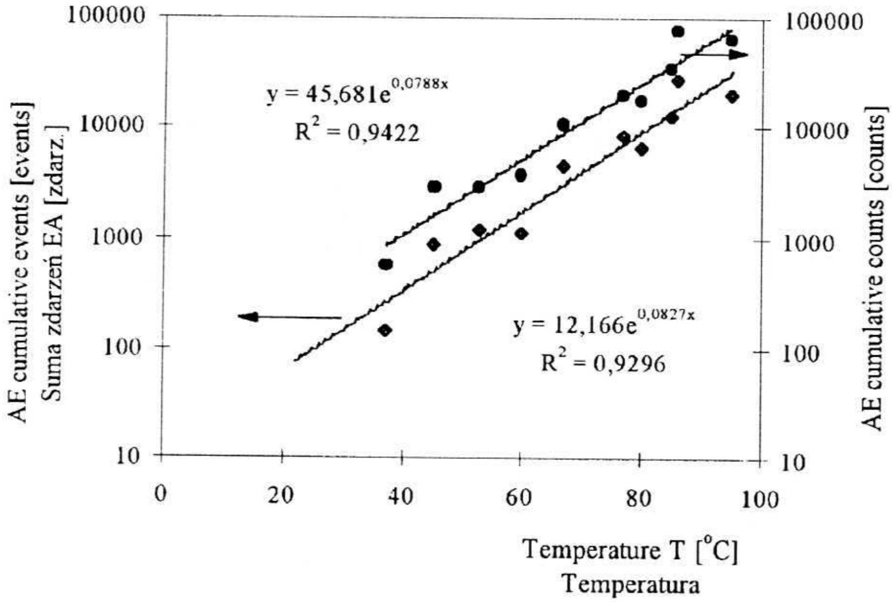

Fig. 3. The AE cumulative counts and events recorded 10 minutes after the wood submersing with hot water versus the water temperature

Rys. 3. Zależność sumy zliczeń i sumy zdarzeń EA zarejestrowanych po 10 min ogrzewania próbek drewna buka od temperatury wody

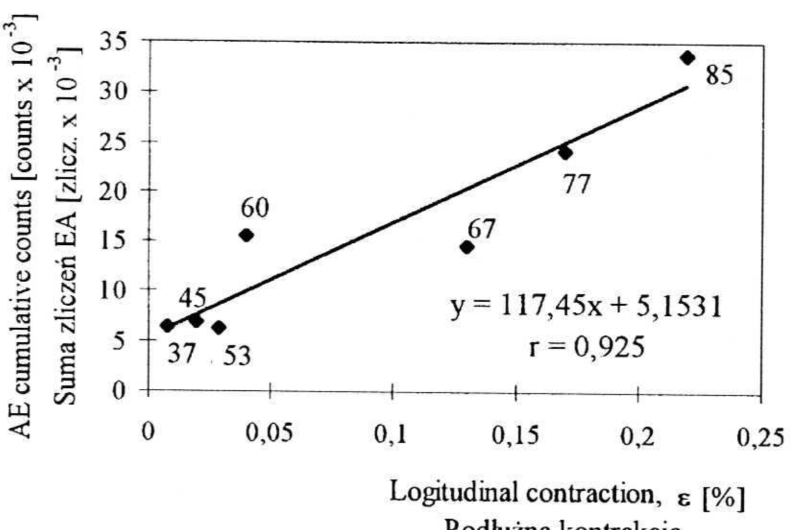

Fig. 4. The AE cumulative counts versus the shortening of the sample length

Rys. 4. Zależność pomiędzy sumą zliczeń sygnałów EA a stopniem skrócenia podłużnego wymiaru próbek

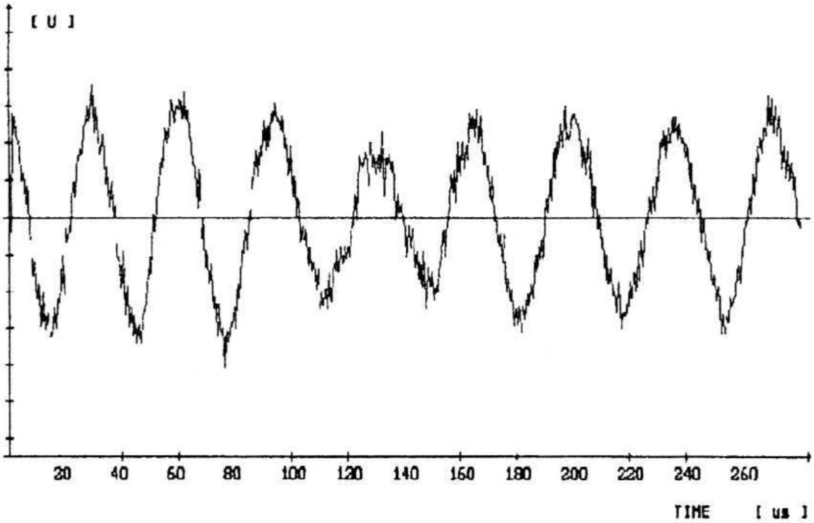

Fig. 5. A typical time dependence of the elastic waves generated in the process of green beech wood heating in water

Rys. 5. Typowy przebieg czasowy fal naprężeniowych generowanych w procesie ogrzewania mokrych próbek drewna buka w wodzie

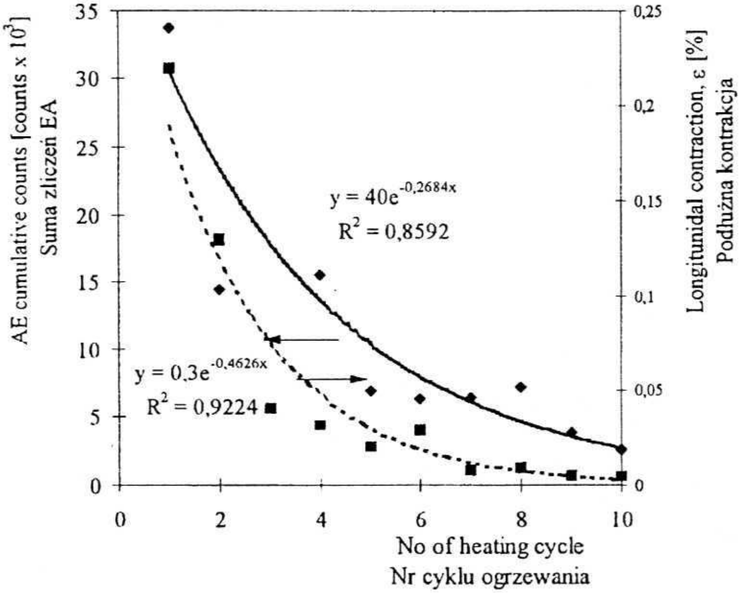

Fig. 6. The number of cycles of wood heating in water of the temperature 85°C versus the AE cumulative counts and shortening of sample length

Rys. 6. Wpływ liczby cykli ogrzewania drewna w wodzie o temperaturze 85°C na sumę zliczeń EA i skrócenie podłużnego wymiaru próbek

The results of the study of AE generated upon cyclic heating of green wood in water of a temperature of 85^{0}C are displayed in Fig. 6. As follows from the figure, the intensity of AE signals as well as longitudinal release deformations caused by a release of residual growth strain decrease relatively fast up to the 5th cycle of wood heating. In the subsequent cycles the release deformations are insignificant and AE signals are low. The fact that even in the 10th cycle of heating AE signals and small shortening of the sample length were still recorded, means that the growth stresses has not been fully relaxed.

CONCLUSIONS

The results of the study provide sufficient evidence to conclude that the method based on measurement of AE signals is suitable for monitoring of the release of residual growth strain in the green wood heated in hot water.

The AE cumulative counts are directly proportional to the deformation of wood caused by the release of residual growth strain.

In the conditions of cyclic heating of green wood in hot water, the number of AE signals fast decreases up to the 5th cycle, whereas in the subsequent cycles this decrease becomes insignificant.

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EMISJA AKUSTYCZNA GENEROWANA W PROCESIE ROZŁADOWANIA RESZTKOWYCH ODKSZTAŁCEŃ WZROSTOWYCH PODCZAS OGRZEWANIA ŚWIEŻEGO DREWNA BUKA W WODZIE

Streszczenie

W pracy przedstawiono wyniki pomiarów EA wzbudzanej podczas ogrzewania próbek świeżego drewna buka w wodzie o zróżnicowanej temperaturze oraz w warunkach cyklicznie powtarzanego ogrzewania w temperaturze 85°C i schładzania do 20°C. W trakcie tego procesu mierzono zmianę podłużnego wymiaru badanych próbek.

Stwierdzono liniową zależność pomiędzy logarytmem sumy zliczeń sygnałów EA i temperaturą ogrzewania. W warunkach cyklicznego wygrzewania liczba zliczeń sygnałów EA gwałtownie maleje do 5 cyklu. W następnych cyklach ogrzewania drewna w wodzie EA obniża się już tylko nieznacznie. Stosownie do obniżającej się w kolejnych cyklach ogrzewania próbek aktywności akustycznej zmniejsza się zmiana podłużnych odkształceń wzrostowych. Pomiędzy sumą zliczeń sygnałów EA a wartością rejestrowanych odkształceń wzrostowych stwierdzono proporcjonalną zależność o stosunkowo wysokim współczynniku korelacji (r=0,925). Przyczyną więc EA wzbudzanej podczas ogrzewania świeżego drewna w wodzie są procesy odkształceniowe wynikające z rozładowania resztkowych naprężeń wzrostowych.

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