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The use of acoustic emission signal (AE) in mechanical tests

Streszczenie. *W artykule przedstawiono możliwości wykorzystania sygnału emisji akustycznej w badaniach mechanicznych. Przeprowadzono statyczną próbę rozciągania próbek z kompozytu poliestrowo-szklanego z jednoczesną rejestracją sygnału emisji akustycznej generowanego w obciążanym materiale za pomocą podłączonego czujnika piezoelektrycznego (system PAC). Fale akustyczne powstałe we wnętrzu obciążanego materiału zostały przetworzone przez czujnik umieszczony bezpośrednio na próbce i zarejestrowane w formie sygnału cyfrowego w urządzeniu rejestrującym. Sygnał ten poddany został dalszej obróbce i na jego podstawie sporządzono wykresy wartości skutecznej sygnału elektrycznego (RMS) w funkcji czasu, uzyskane wykresy naniesiono na krzywe rozciągania. Porównanie wykresów RMS i rozciągania pozwala na bardzo dokładną identyfikację procesów zachodzących w strukturze badanego materiału poddanego obciążeniu.* ***Możliwości wykorzystania sygnału emisji akustycznej w badaniach mechanicznych***

Abstract*. The article presents the possibilities of using the acoustic emission signal in mechanical tests. A static tensile test of the polyester-glass composite samples was carried out with simultaneous recording of the acoustic emission signal generated in the loaded material by means of a connected piezoelectric sensor (PAC system). The acoustic waves created inside the loaded material were processed by a sensor placed directly on the sample and recorded in the form of a digital signal in the recording device. This signal was subjected to further processing and the RMS values were plotted as a function of time, the obtained graphs were applied to stretching curves. Comparison of RMS and tensile plots allows for very accurate identification of processes occurring in the structure of the tested material subjected to loading.*

Słowa kluczowe: emisja akustyczna, sygnał elektryczny, statyczna próba rozciągania, krzywe rozciągania, proces niszczenia.
Keywords: acoustic emission, electrical signal, static tensile test, stress-time curves, destruction process.

Introduction

The essence of acoustic emission (AE - acoustic emission) is the measurement of elastic wave energy, which arises under the influence of material load [1]. It is a passive non-destructive method. It is associated with the formation and propagation of elastic waves generated in the medium as a result of dynamic processes taking place in it [2]. External loads and internal stresses are the result of their occurrence and can be detected on the surface of the structure using piezoelectric transducers [3, 4]. In the structures of composite materials the wave velocity due to anisotropy / material thickness is variable, depends essentially on the direction of propagation and is much higher towards fibrosis [5]. Measurements of this type of impulses are an excellent method of monitoring the processes of destruction of composites, detecting defects and internal defects and structural changes [6]. In composites the beginning of material destruction is manifested in the form of matrix microcracks, disturbances of fiber and matrix adhesion, fiber breakage, delamination resulting from an internal defect. The signal energy generated on the microcracks is caused by elastic waves of stresses, which are then recorded by the transducer [7, 8]. The resulting noise is removed by medium-pass filters with a frequency of 20 ÷ 300 kHz. Signal monitoring, recording and processing is implemented in the entire volume of the composite material under test [9]. The information contained in the waveforms, such as amplitude, frequency and duration, allow you to fully visualize the changes taking place in composite materials during their operation [10, 11]. Acoustic emission (AE) demonstrates the ability of an effective SHM monitoring system (Structural Health Monitoring) and detection of resulting discontinuities / defects in loaded materials [12, 13]. It is characterized by high sensitivity, the ability to conduct research during their operation, the possibility of uninterrupted tests, the ability to locate the source of AE signals [14 ÷ 17].

The paper presents the possibilities of using the acoustic emission signal for mechanical tests of composite materials. A test stand consisting of a testing machine on which a static tensile test together with a piezoelectric sensor (PAC system - Physical Acoustics Corporation) allowing the recording of acoustic signals was presented. Static tensile tests of samples with simultaneous recording of vibrations of the loaded material using a connected AE sensor were carried out. The signal received from the sensor was subjected to further processing and was used to generate RMS graphs as a function of time. These plots were applied to the corresponding stretching curves.

The main goal of the study was to demonstrate the possibility of using EA to study the mechanical properties of materials on the example of composites [18 ÷ 21]. This is of great importance for this type of research, especially composite materials, because up to now there is no possibility to determine the yield point for composite materials and brittle materials. One of the methods allowing to determine the yield point of composite materials is the metric entropy method presented in the authors' work [22 ÷ 23].

Laboratory station

Samples made of composite materials whose properties are presented in the works were subjected to testing [18 ÷ 21]. The test stand was a universal testing machine Zwick & Roell with hydraulic drive MPMD P10B, with TestXpert II software. In addition, the Epsilon 3542 extensometer and the Physical Acoustics Corporation (PAC) acoustic emission measurement system were installed. The block diagram of the station is shown in Figure 1.

The AE study was performed using a set consisting of: single channel AE node recorder, type 1283 with 20 kHz - 1 MHz bandwidth, preamplifier with bandwidth of 75 kHz - 1.1 MHz, AE-Sensor VS 150M (with range frequency 100 - 450 kHz), computer with AE Win for USB software version E5.30 for recording and analyzing AE data. The AE sensors themselves play an important role in the research. The piezoelectric sensor together with the entire measurement system enables the recording of fast-changing signals, which is an undeniable advantage of the AE method.

The AE sensor - VS150-L (Vallen Systeme GmbH) used in the research is a passive piezoelectric AE sensor. Its frequency response is characterized by a peak at 150 kHz, where it exhibits resonance. It is suitable for almost all AE applications. The VS150-L has a metal casing that makes it particularly suitable for mounting on a test object. It is used on objects that do not have ferromagnetic surfaces, such as composites or aluminum alloys. Figure 2 shows the overall view of the mechanical testing station, with the simultaneous recording of the acoustic signal.

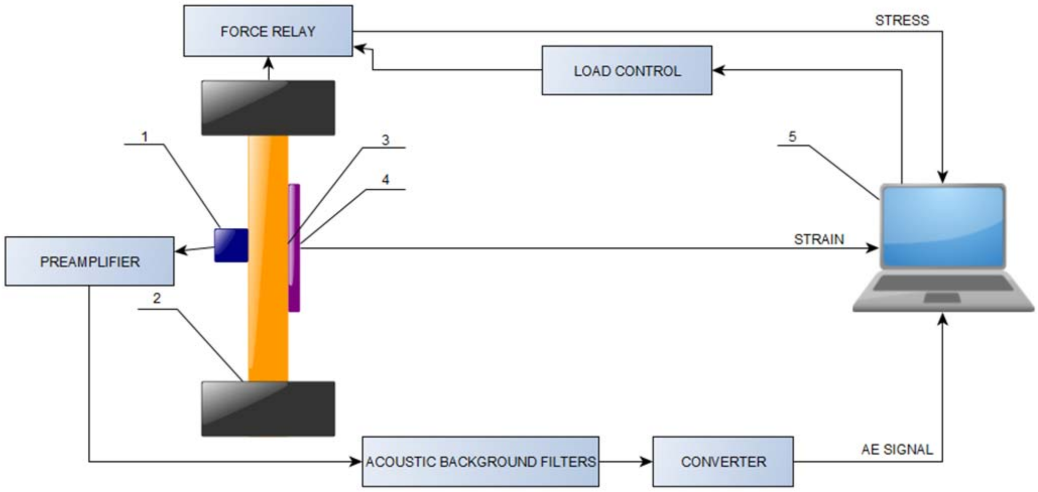

Fig.1. Block diagram of a station for analysis of acoustic emission signal in mechanical tests: 1 – AE sensor, 2 – grip, 3 – sample, 4 – extensometer, 5 – computer PC to analysis

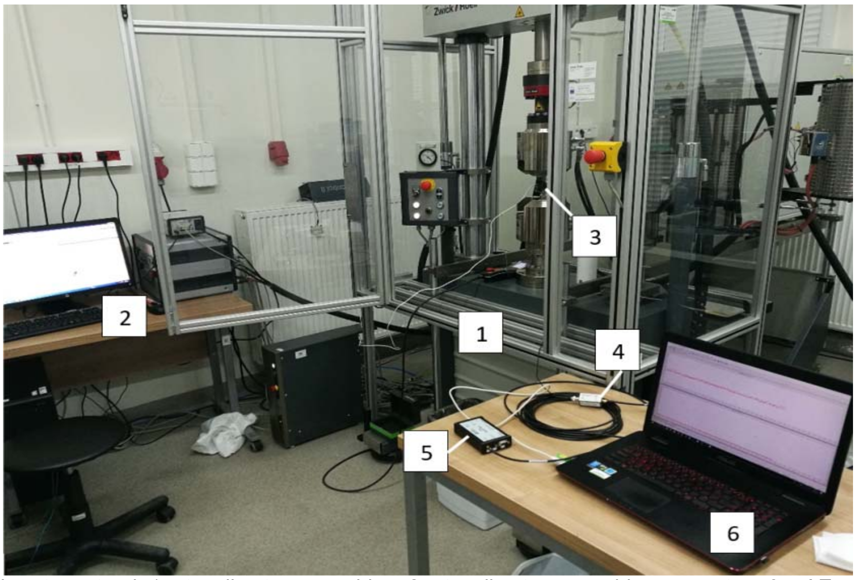

Fig.2. General view of laboratory stand: 1 – tensile stress machine, 2 – tensile stress machine computer, 3 – AE sensor, 4 – preamplifier, 5 – AE recorder, 6 – AE computer

Figure 3 shows a sample mounted in a testing machine, together with an extensometer and an acoustic sensor. A coupling fluid is placed between the sensor and the sample surface. The AE sensor is attached to the sample with a flexible tape.

Fig.3. View of specimen fixed into tensile testing machine grips: 1 – tensile testing machine grips, 2 – specimen, 3 – extensometer, 4 – AE sensor

After assembling and testing the entire system, testing was started by subjecting the sample to a static tensile test. During the static stretching test in time, two parameters were recorded: displacement using an extensometer and AE signal.

Test results

As a result of the static tensile test of samples, the diagrams of the distribution of stress in time were obtained. On the other hand, with the help of the installed equipment, the AE signal generated by internal friction, cracking of the matrix and fibers in the sample, enabled the registration of a number of parameters that were analyzed. The following parameters were analyzed: amplitude, number of events - hits, energy, RMS signal. The analysis of these parameters was made on the basis of the AE Win computer station with the USB Version E5.30 software.

Based on the tests carried out, the Root - Means - Square (RMS) parameter was selected for comparison purposes. In polymeric composites, the acoustic emission signal occurs at a fixed load, and the waveforms correspond to the corresponding microcracks. An example of a graph of a visualized change in signal amplitude versus time recorded during a test is shown in Figure 4.

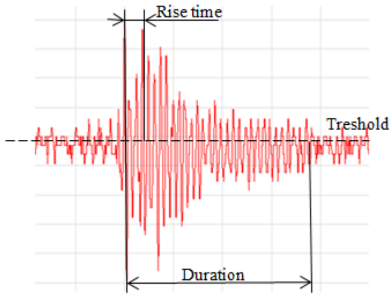

Fig.4. Example of an AE signal recorded during a composite sample - RMS (t)

The threshold separating the actual signal and the continuous signal is usually assumed to be 40 dB and then it is entered into the recording devices. The acoustic event undergoing analysis begins at the first threshold and ends during the event (Fig.4). The obtained results can be graphically represented as a change in the mean amplitude value (Fig.5) or the mean RMS value of the signal in time (Fig.6). In the graphs, a single point corresponds to the average amplitude value or RMS within 50 ms.

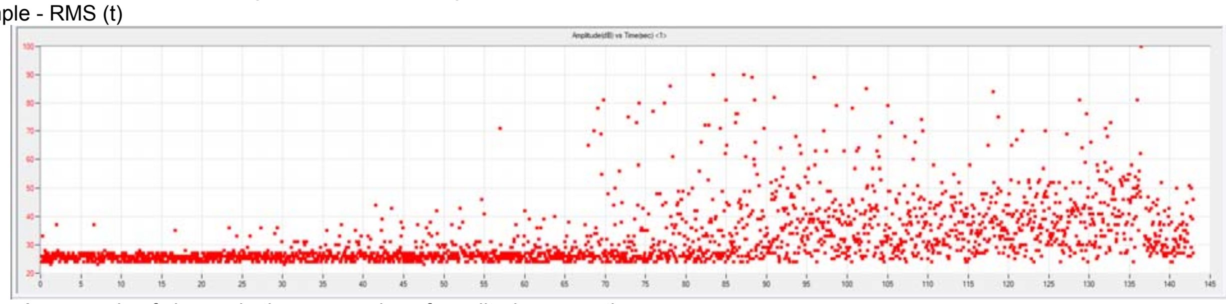

Fig.5. An example of change in the mean value of amplitude versus time

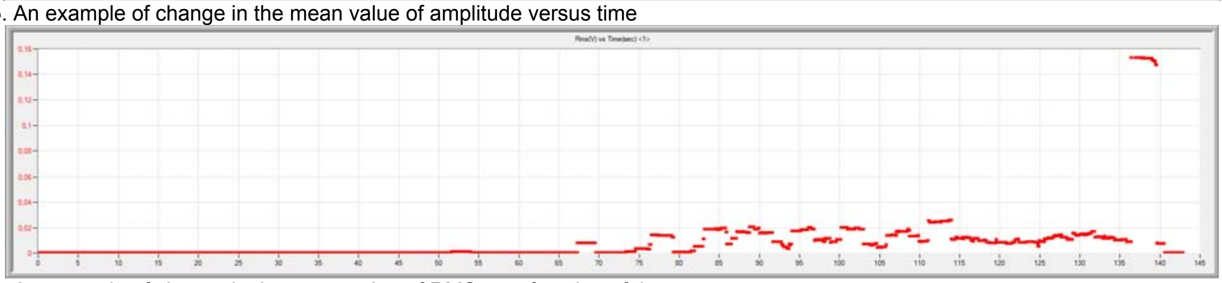

Fig.6. An example of change in the mean value of RMS as a function of time

The values of the effective electrical signal - RMS obtained as a result of AE measurement allowed to obtain stress diagrams as a function of time - as well as (Fig. 7). The application of these graphs allows to analyze the nature of the destruction of composite materials. Detailed analysis of subsequent events may allow the identification of such phenomena as: the nature of matrix cracking, the destruction of adhesion between fibers and the matrix, and the delamination of fibers.

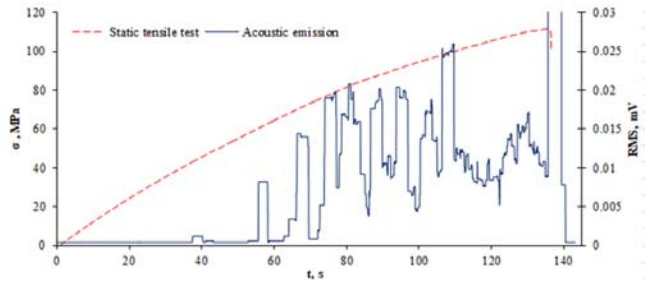

Fig.7. Graph of the value of the effective electrical signal RMS, as a function of time, plotted on the stray plot for the composite material sample

Conclusions

The conducted strength tests on samples made of composite materials using the AE phenomenon showed that the AE method is very useful for testing materials subjected to loads. It was observed that there is a correlation between the continuity of the material structure and the acoustic emission signal. The beginning of material discontinuity due to the load corresponds to the amplitude of the sound-emitting signal. Detailed analysis of the signal distribution allows to determine a number of very important material parameters, such as, for example, the material flow beginning, corresponding to the yield point.

The use of AE method for mechanical testing of materials, allows analysis of changes in materials as a result of load. The obtained values of an effective RMS electrical signal based on graphs inform about the nature of the process of destruction of the tested composites. The obtained results indicate further work on the strength of not only materials but also structures subjected to loads using the AE phenomenon.

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