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MODEL OF ACOUSTIC EMISSION SIGNAL AT THE PREVAILING MECHANISM OF COMPOSITE MATERIAL MECHANICAL DESTRUCTION

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Abstract. A model of acoustic emission signal formation at the prevailing mechanism of the destruction of composite materials is considered. The results of acoustic emission signal modelling are presented, taking into account the variable velocity of loading change. Acoustic emission signal experimental research results corresponding to theoretical research results are considered in this paper. It is shown that irregularity of the trailing edge of the acoustic emission signal is influenced by the change in the rate of the destruction process in composites.

Keywords: acoustic emission, stress, crack growth, loading, signal of acoustic emission, fracture, composite material, fibre bundle model.

1. Introduction

For the description of acoustic emission, which is formed in the process of deformation and destruction of materials, three basic approaches and three types of models are used. Stochastic models of acoustic emission signals (AE) are intended to describe acoustic emission, which is registered on a sensor output in the form of an

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electric time-dependent signal (Иванов *и др.* 1981; D'Attelis *et al.* 1992; Bukhalo *et al.* 2000; Shibata 1984; Маляренко *и др.* 1994; Hall *et al.* 2001; Sheng *et al.* 1999). The pattern of a casual generation of AE signals due to casual physical process is the basis of forming such models. Models give proof of the possibility of applying the individual probabilistic parameters (characteristics) of the AE signals to the item's control. The second type of models is based on the calculation of the stress and deformation fields at the development of structural defects in materials (Аки *и др.* 1983а; Аки *и др.* 1983б; Андрейкив *и др.* 1989; Грешников *и др.* 1976; Hamstad *et al.* 1999; Grosse *et al.* 2008; Miettinen 2000). As a rule, such calculations are carried out as cracks in the material become larger. In this case, the AE signal is considered a response to the change in stress fields and their relaxation at the time of the crack's growth in the material. The third type of AE signal micro-model is used in forming the primary signal of acoustic emission (Иванов 1986; Вайнберг *и др.* 1976; Chandra *et al.* 2004; Бабак *и др.* 2002а*; Бабак и др. 2002б; Бабак и др. 2002в; Babak et al.* 2005a; *Babak et al.* 2005b; Filonenko *et al.* 2008). The physical representation of plastic deformation, ductile and brittle fracture processes, is the basis of such models. In this case, the mechanisms of acoustic emission origin due to the motion of dislocations or brittle fracture of elements at micro and macro levels are taken into account.

One of models used for the description of brittle fracture of composites is the fibre bundle model (Curtin 1991; Newman *et al.* 2001). The material is considered as a bundle consisting of N_0 fibres, and every fibre is deformed elastically till its destruction. The process of such material destruction is considered as a process of successive destruction of fibres with the continuous redistribution of stresses. The analysis of such a destruction process has permitted the expression for the change rate of the remaining fibres to be obtained (Shcherbakov 2002; Turcotte *et al.* 2003):

$$\frac{d}{dt}[N_0 - N_f(t)] = -\nu(\sigma)[N_0 - N_f(t)], \qquad (1)$$

where N_0 is an initial number of fibres; $N_f(t)$ is a time-dependent number of destroyed fibres; $[N_0 - N_f(t)]$ is the number of remaining fibres; $\nu(\sigma)$ is the rate of progress of the destruction process, which depends on the applied stress $\sigma(t)$.

During the process of fibre destruction, stored elastic energy is released in the form of AE energy having a proportionality coefficient that can be regarded as a constant value. The stress is redistributed onto residual fibres, while the rate of fibre destruction is described by this empirical expression: $\nu(t) = \nu_0[\sigma(t)/\sigma_0]^p$, where ν_0 is the initial rate of destruction corresponding to initial stress σ_0; *p* is a power, the value of which lies within the range from 2 to 5. On the basis of it the expressions for the release of energy of AE events rate have been got (Shcherbakov 2002; Turcotte *et al.* 2003). It is shown that as complete destruction approaches, growth in the release rate of AE energy occurs, resulting in an increase in the accumulated energy of the AE event. Such results correlate with experimental results (Guarino *et al.* 1998; Guarino *et al.* 1999). However, at a time corresponding to complete destruction, a discontinuity in the function of the accumulated energy change of AE events is observed (the function tends to ∞), and that is not quite correct. This, in its turn, indicates that the model does not allow the model of the AE signal (event) occurring at the destruction of composite material to be obtained.

A model of the AE signal formed at the destruction of composite material, based on taking into account the kinetic laws of the destruction process, will be considered in this paper. The transformation of the shape and parameters of the AE signal formed will be shown to depend on the rate of loading application to material associated with rate of the progress of the material destruction process and on its physical-mechanical characteristics.

2. Model of destruction of composite material and formation of acoustic emission signal

Let us assume that a specimen of composite material, which has fixed dimensions, consists of N_0 fibres or elements. All elements of the specimen possess the same durability. It can be considered that at the application of stress to such a specimen every element is deformed elastically till its complete destruction. Suppose that the destruction of the specimen is the process of the sequential destruction of its elements. Then, in accordance with R. Shcherbakov and D. L. Turcotte *et al*. the remaining rate of change in the elements (fibres) during the destruction process is described by equation (1) (Shcherbakov 2002; Turcotte *et al.* 2003).

To simplify the description, let us accept denotation for the number of remaining elements $N = [N_0 - N_f(t)]$. Taking into account it, expression (1) can be written as

$$\frac{dN}{dt} = -\upsilon(\sigma)N. \qquad (2)$$

In fact, expression (2) describes the kinetic process of the destruction of the elements According to the kinetic theory of durability, the destruction process develops at a rate that changes on the basis of exponential law (Маламедов 1970; Регель *и др.* 1974):

$$\upsilon(t) = \upsilon_H e^{\beta\ell}, \qquad (3)$$

$$\upsilon_H(t) = \zeta\upsilon_0 e^{r\sigma(t)}, \qquad (4)$$

where β is a coefficient characterising self-acceleration of the destruction process, ℓ is the initial length of the crack, *r* is a constant determined by the physical-mechanical characteristics of the material, υ_0 is the initial rate of crack growth (destruction), ζ is a proportionality coefficient , and $\sigma(t)$ is average stress in the specimen.

Let us consider the destruction of the specimen in the absence of an initial crack. Under such condition, the initial length of this crack is equal to zero, i.e. ℓ=0. It is then possible to write the expression for the rate of the destruction process as

$$\upsilon(t) = \zeta \upsilon_0 e^{r\sigma(t)} . \quad (5)$$

The exponential relationship (5) between the rate and stress determines the avalanche-like character of the destruction process, i.e. increase in the number of destroyed elements, resulting in growth of stress on the remaining elements. In turn, this leads to an increase in the rate of the destruction process.

Taking into account (5), we can write expression (2) in the following way:

$$\frac{dN}{dt} = -\zeta \upsilon_0 e^{r\sigma(t)} N . \quad (6)$$

If the load on the specimen changes according to the linear law $\sigma(t) = \alpha t$, where α is the loading application rate, expression (6) can be thus:

$$\frac{dN}{N} = -\zeta \upsilon_0 e^{r\alpha t} dt . \quad (7)$$

With the integration of (7) and taking into accounts that at the initial time moment t = 0, the value $N_f(t)$ equals zero, i.e. $N_f(0)$ =0, we get expression for the number of non-destroyed elements:

$$\ln \frac{N}{N_0} = -\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha t} - 1) . \quad (8)$$

From expression (8), we receive

$$\frac{N}{N_0} = e^{-\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha t} - 1)} , \quad (9)$$

or

$$N = N_0 e^{-\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha t} - 1)} . \quad (10)$$

Expression (10) describes the number of remaining elements in the process of the destruction of the composite material consisting of N_0 fibres. Now, let us consider the model of the AE signal formed during this process.

Let us assume that the destruction of elements leads to the formation of the AE signal. In this case, the destruction of the single element is accompanied by the excitation of a single pulse, which spreads through material as a displacement pulse. The displacement pulse spreads without damping. The form of a displacement pulse is illustrated in figure 1, where A_0 is the peak value of the displacement single pulse and δ is the width of the displacement pulse. We assume that the width δ of the displacement pulse is many times smaller than the specimen destruction time. Under such conditions, the resulting AE signal formed during the elements destruction process will be proportional to the number of elements destructed per unit time, i.e. $U(t) \sim |dN/dt|$. By differentiating expression (8), we get

$$D = \left|\frac{dN}{dt}\right| = N_0 \zeta \upsilon_0 e^{r\alpha\, t} e^{-\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha\, t} - 1)} . \quad (11)$$

Let us assume that the excitation pulse amplitude $A_0(t)$ is proportional to the stress at which destruction is observed, i.e. $A_0(t) \sim \sigma(t)$, where A_0 is the excitation pulse amplitude. Then, we can write

$$A_0(t) = \psi \alpha t , \quad (12)$$

where ψ is a proportionality coefficient.

Taking into account expression (12), the displacement pulse formed at the destruction of the single element is written as

$$A(t, \tau) = A_0(t) a(\tau) , \quad (13)$$

where $a(\tau)$ is a function determining the form of the displacement pulse which is the same for all destroyed elements and has the unit amplitude.

During the destruction process of the elements within time interval $[\, t - \delta/2, t + \delta/2 \,]$, the resulting displacement $U(t)$ is written as

$$U(t) = \int_{t-\delta/2}^{t+\delta/2} A_0(t) a(\tau) D(t+\tau) d\tau . \quad (14)$$

Under the accepted condition that the duration of excitation δ is many times shorter than the duration of the destruction process, it is possible to consider that within time interval $[\, t - \delta/2, t + \delta/2 \,]$ values $D(t)$ and $A_0(t)$ are constant. Expression (14) is therefore written in the following form:

$$U(t) = A_0(t) D(t) \int_{-\delta/2}^{\delta/2} a(\tau) d\tau . \quad (15)$$

The numerical value of the integral in expression (15) is designated by δ_s, which is determined by the shape of the excitation pulse and has the dimension of time.

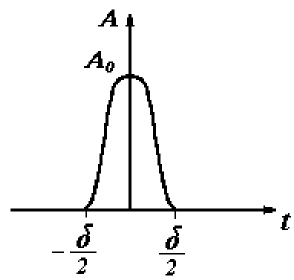

Fig 1. Excitation pulse at destruction of elementary volume

In light of the accepted designation, expression (15) is written as:

$$U(t) = A_0(t) D(t) \delta_s . \quad (16)$$

By using (11) and (12) in (16), we receive the expression for the AE signal:

$$U(t) = N_0 \psi \zeta \alpha t \delta_s \upsilon_0 e^{r\alpha t} e^{-\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha t} - 1)} , \quad (17)$$

or

$$U(t) = u_0 t \alpha \upsilon_0 e^{r\alpha t} e^{-\frac{\zeta \upsilon_0}{r\alpha}(e^{r\alpha t} - 1)} , \quad (18)$$

where $u_0 = N_0 \psi \zeta \delta_s$ is the maximum possible displacement in the event of instantaneous destruction of the specimen with the set of physical-mechanical characteristics.

3. Modelling the acoustic emission signals

Expressions (10) and (18) allow time modelling the destruction processes of the elements and the AE signals formed. The results of such modelling are shown in figure 2. During modelling we used material with the same physical-mechanical characteristics and dimensions. Load was used as a variable parameter.

Figure 2a illustrates the time dependencies of the number of elements remaining during the destruction process upon the loading application rate. Results are given in the form of graphs $\tilde{N}(t) = N(t) / N_o$ and are presented using reduced units. For calculation, the parameters in (10) are expressed as dimensionless reduced values. Time is normalized according to loading application (stress application) time. An increase in value α means an increase of the stress application rate. For graphs the following values of α were used: 1, 2, 3, 4, 5. It is natural to assume that the higher the applied loading the higher the initial rate of crack growth. During calculations, it was therefore assumed that the initial rate υ_0 of the destruction of elements corresponds to the loading application rate, i.e. $\upsilon_0 = \alpha$.

Results of calculations of the time dependence of AE signal amplitude formed during the element destruction process upon the loading application rate are shown in figure 2*b*. Results are given in the form of graphs $\tilde{U}(t) = U(t) / U_o$ and are presented using reduced units of peak values. For calculation, the parameters in (18) are expressed as dimensionless reduced values. Time is normalised according to loading application (stress application) time. An increase in value α means an increase in the stress application rate. For graphs, the following values of α were used: 1, 2, 3, 4, 5. It was assumed that initial rate υ_0 of the destruction of elements corresponds to the loading application rate, i.e. $\upsilon_0 = \alpha$.

The destruction process, in accordance with the model presented, is considered the process that occurs with self-development. It takes place because the destruction of every element is accompanied by redistribution and growth of stresses on the remaining elements. Such a destruction process takes place continuously over time.

Figure 2*a* demonstrates that the time curves of the remaining (non-destroyed) elements have a continuous sloping-down character without a jump, as was the case for the model considered (Shcherbakov 2002; Turcotte *et al.* 2003). With the growth in the loading application rate (growth of the value α) and, respectively, growth in the initial rate of destruction υ_0, the increase in the slope of the change curves of the remaining elements and their shift along the time axis towards smaller values can be observed (respectively, 1, 2, 3, 4 in figure 2*a).* This means that the greater the rate of loading and the greater the initial rate of the destruction of elements, the shorter the time interval required for complete destruction of the specimen is:

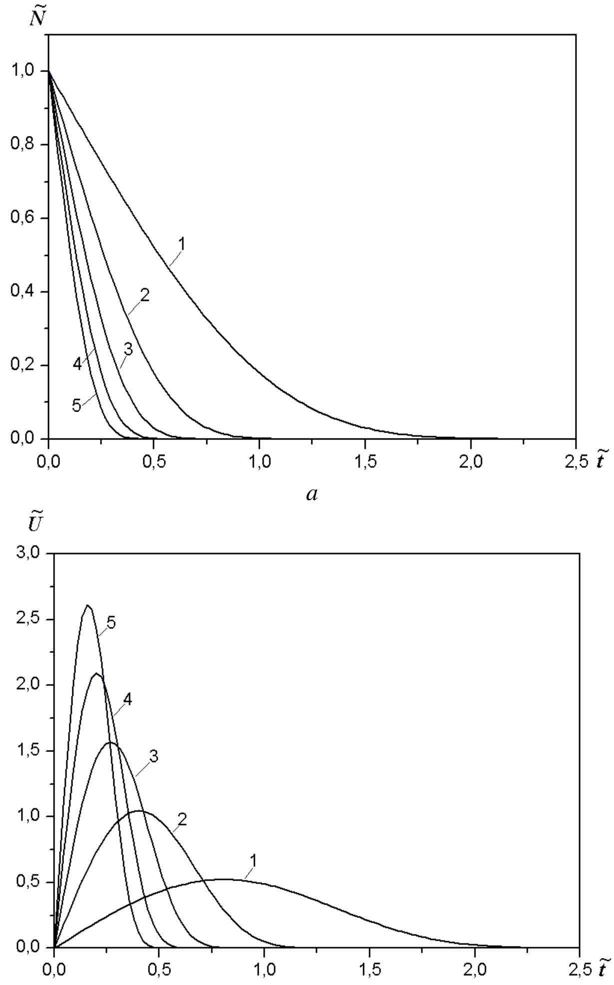

Fig 2. Time versus the number of remaining elements (*a*) according to (10) and AE signals (*b*) according to (18) during the destruction of elements. Values of parameter α : 1 - α =1; 2 - α =2; 3 - α =3; 4 - α =4; 5 - α =5. Values of the initial rate of the destruction of elements υ_0 : 1 - υ_0 =1; 2 - υ_0 =2; 3 - υ_0 =3; 4 - υ_0 =4; 5 - υ_0 =5

Figure 2*b* clearly shows that the continuity of the destruction process of the elements is accompanied by the formation of a continuous AE signal. An increase in the loading rate (growth in value α) and, consequently, the initial rate of the destruction of elements results in growth in the amplitude of AE signals and their compression in time (respectively, 1, 2, 3, 4, 5, figure 2*b).* This change in the parameters of the AE signals is influenced by the acceleration of the destruction process, i.e. the shortening of its time interval.

In case of further growth in the loading application rate and, consequently, the initial rate of destruction, the character of time dependencies of remaining elements and AE signals change remains steady (Fig 3). The curves in figure 3 are reduced like the curves in figure 2. While plotting the graphs in figure 3, we used the following values for the loading application rate α and the initial rate of the destruction of elements υ_0 : 10, 20 and 30. Figure 3a shows that with growth of the loading application rate and initial rate of elements destruction, the shift of remaining elements of curves towards lower values of time and an increase in the slope of curves is observed. This aspect of the destruction process is accompanied by a decrease in the duration of AE signals and an increase in their amplitude (Fig 3*b*). The results obtained also show that the sharper growth in AE signal amplitude and degree of its compression in time is more when the loading rate and, consequently, the initial rate of destruction is more. In this case, the gradual transformation of the AE signal shape into a triangular one is observed (Fig 3*b)*.

During the simulation the time dependencies of the number of remaining elements and appropriate AE signals (Figs 2 and 3) change, and it was assumed that the initial rate of the destruction of elements corresponds to the loading application rate, i.e. $\upsilon_0 = \alpha$.

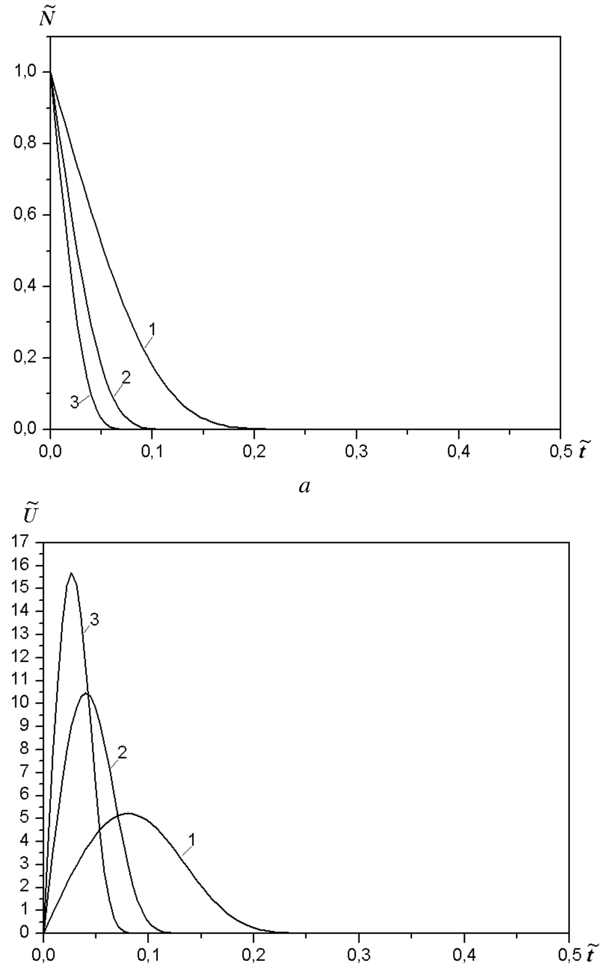

Fig 3. Time versus the number of remaining elements (*a*) according to (10) and AE signals (*b*) according to (18) during the process of the destruction of elements. Values of parameter α : 1 - α =10; 2 - α =30; 3 - α =30. Values of the initial rate of the destruction of elements υ_0 : 1 - υ_0 =10; 2 - υ_0 =20; 3 - υ_0 =30

According to the kinetic theory of strength however, destruction can begin at rather small initial rates (Маламедов 1970; Регель *и др*. 1974). It depends on the physical-mechanical characteristics of materials (plastic or brittle material). Results of modelling the number of remaining elements and AE signals for the destruction process over time for the constant value of initial rate υ_0 and different values of α are shown in figure 4. The graphs in figure 4 are reduced as the graphs shown in figures 2 and 3.

Figure 4 shows that at a constant initial rate of the destruction of elements and an increasing load the change over time the laws of the number of remaining elements and the change over time of AE signals are similar to the dependencies shown in figures 2 and 3. A shift in the curves of the remaining elements towards lower values along the time axis and increase in the slope of curves are observed (Fig 4*a)*.

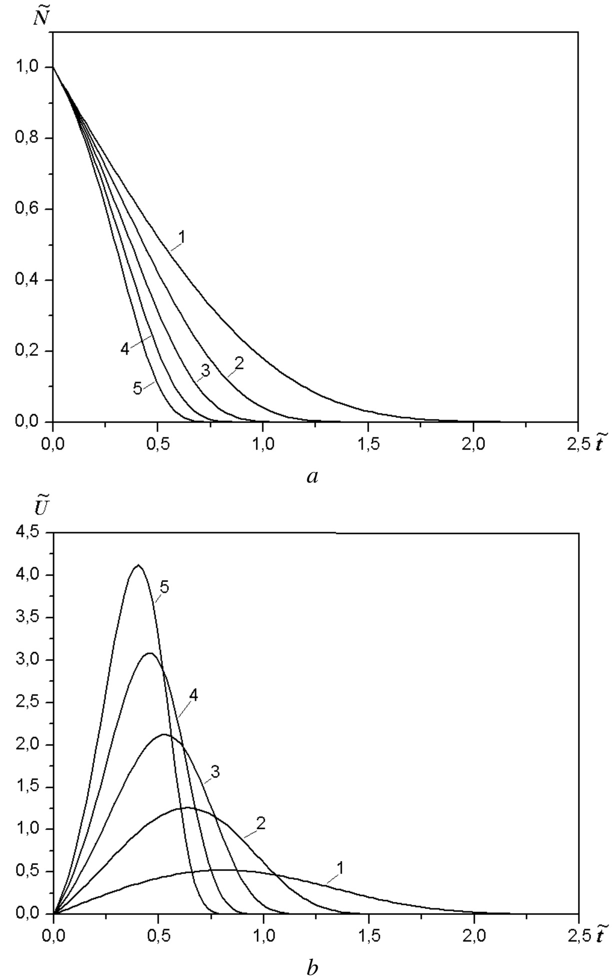

Fig 4. Time versus the number of remaining elements (*a*) according to (10) and AE signals (*b*) according to (18) during the process of destruction of elements. Values of parameter α : 1 - α =1; 2 - α =2; 3 - α =3; 4 - α =4; 5 - α =5. Values of the initial rate of the destruction of elements: υ_0 =const: υ_0 =1

Additionally, a decrease in the duration of AE signals and increase in their amplitude take place (Fig 4*b)*. However, an increase in the loading application rate and a constant initial rate of the destruction of elements cause greater growth in the amplitude of AE signals when υ_0 = α. At the same time, less compression of AE signals over time (Fig 4*b)* is observed. Furthermore, the front edge of the signals experiences accelerated growth.

We do not consider the results of modelling the laws of the number of remaining elements and AE signals over time at a constant loading rate α and increasing the initial rate of destruction υ_0. This is explained by the fact that, as was mention before, the initial rate of destruction depends on the physical-mechanical characteristics of the material. Therefore, analysis of its effect is the subject of individual research.

4. Experimental research of AE signals

Composites consist of matrices and reinforcing components (fillers) (Композиционные... 1978; Новиков *и др*. 1993; Фудзин *и др*. 1982). In the production of composites, metals, ceramics and plastics are used as matrices, and metallic filaments, mono-crystalline 'moustaches', multi-component fibres and dispersible particles of carbides, borides, oxides, diamonds and other materials are used as fillers. One class of composites representing a matrix with a reinforcing component (filler) is materials made on the basis of tungsten-cobalt (Новиков *и др*. 1993; Финкель 1970). This type of product, for example hard-alloy cutters, are widely used for draft and clean treatment of various materials (milling, cutting, drilling), including aviation materials. During work in the area of contact interaction of composite material with a processed surface, there can be considerable stretching stresses (Новиков *и др*. 1993). This leads to the development of micro- and macro-cracks and finally to the destruction of the composite material.

Research was carried out using specimens of VK4 carbolic alloy (Fig 5) with the following dimensions: thickness 4 mm and diameter 8 mm. At a distance of 2 mm from one edge of the specimens, a cut was made. It had the following dimensions: width 0.1 mm and depth 1.5 mm. A cut was made in order to form stretching stress at the mouth of the cut at shear test with a console fixing the specimen (Fig 5). Under such conditions, the tension test mode was realised.

For testing the specimens, a special device was made. A specimen was placed in the device and firmly attached to a fixed support. Loading was applied to the specimen by means of a puncheon that moved in a vertical plane. The load was applied at a distance of 1 mm from the edge of the specimen in front of the cut (Fig 5). The fastenings of the specimen and point of loading were selected in such a manner that maximum stretching stresses were formed for the destruction of the specimen. With the specimen, an adapter was fastened in the clamps of an FP-10 universal testing machine with an electrical drive.

After the adapter was fixed in the clamps of the testing apparatus, the AE sensor was positioned on its lower support (Fig 5). The AE sensor output was connected to the acoustic emission diagnostic complex (AEDK). This complex allowed carrying out signal processing. The complex is constructed on the base of a personal computer. AEDK software allows saving the initial AE signals registered in real-time mode, processing and analysing their basic parameters (amplitude, energy, duration, etc.), and also converting information into mathematical formats for Windows applications. Results of data processing were represented in digital and graphical forms.

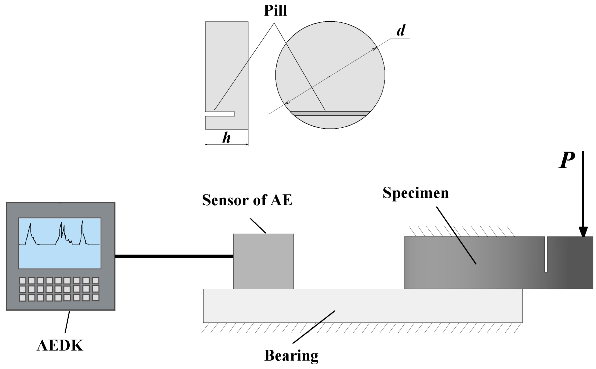

Fig 5. General view of specimens made of VK4 and diagram of their loading: d = 8 mm and h = 4 mm

The specimen destruction tests were carried out at different speeds in a range of 1 mm/min to 10 mm/min. For removal of signals appearing as a result of friction between the mating elements, registration of AE signals was carried out after the preliminary loading of the specimen. The level of preloading of every specimen was equal to 20 kg. The recording of AE signals was interrupted after the destruction of the specimen.

The results of research showed that regardless of the loading rate the acoustic emissions registered during the tests had similar characteristics. AE signals were registered only at the moment the specimen was destroyed and had the similar shapes (Fig 6). With an increase in the loading rate, a change in the parameters of the signals was observed. Time compression of the AE signal and growth in its amplitude are observed too. Such laws of the parameters of AE signal change have a good correlation with the results of theoretical research. They can be explained by the results obtained during modelling (Figs 2 and 3).

During the modelling of AE signals, sharp growth in the front edge of the signals and acceleration of the change in the character of the trailing edge (Figs 2 and 6) are observed. However, at the destruction of the specimens, the trailing edge of the AE signals is cut up. Spikes and falls in amplitude are observed (Fig 6). This characteristic change in the trailing edge of AE signals registered during the specimen test can be explained as follows.

During the modelling of AE signals (Figs 2 and 3), it was assumed that the destruction process occurs without change in its rate. However, under real conditions, the destruction processes of materials occur with a change in their rate. In other words, during crack growth, we can observe breaking at obstacles (grain boundary, inclusions, and other types of defects), acceleration, branching, etc. that is influenced by diverse factors (Финкель 1970). Instability of crack growth during destruction is easily observed on the fractured surface of the tested specimens (Fig 7). In figure 7, the wavy relief of destruction typical for a crack with changing direction of movement and, naturally, changing rate of growth can be seen. Such variation in the rate of the destruction process, of course, leads to change in the shape of AE signals.

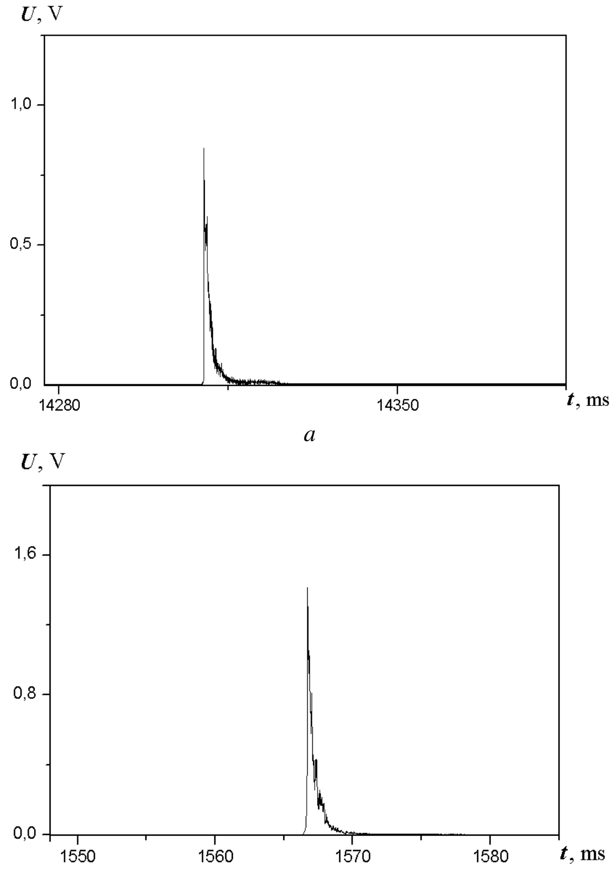

Fig 6. Signals of acoustic emission registered during destruction of specimens made of VK-4 composite with cut: *a* – the specimen loading velocity is 1 mm/min; *b* – the specimen loading velocity is 10 mm/min

The results of modelling AE signals are shown (Fig 8) at values $\upsilon_0 = \alpha$ and also at some constant value of υ_0 and variable rate of destruction process, i.e. when at some time moments $t_1, t_2, t_3, \ldots \in [0, T]$ the destruction rate is equal to $\alpha \pm \alpha_1$, where α_1 is a value of increasing or decreasing the destruction rate; T is time interval till destruction. The graphs in figure 8 are reduced like the graphs shown in figures 2 – 4. The results of modelling (Fig 8) show that if $\upsilon_0 = \alpha$ the amplitude of the changes in AE signals have a smooth character in the given period of time (signal 1, Fig 8*a, b*). If the rate of destruction is changed (increasing or decreasing) at some moment of time during the process, we can see some spires or falls in amplitude (2, Fig 8*a, b*). Analysis of data shown on figures 6 and 8 proves that modelling results have good correction with the results of experimental research.

Thus, the irregular shape of the AE signals registered with amplitude spikes show, that the destruction process takes place with the change in its rate of progress. Destruction means the formation of the main crack and its continuous growth till the complete delamination of the material specimen.

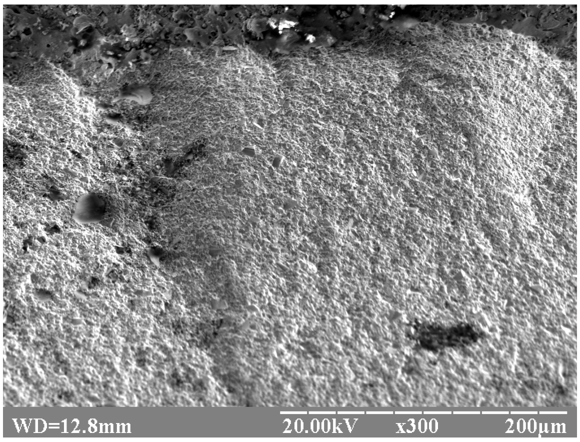

Fig 7. Fractography of fractured surface of specimen made of VK4 alloy

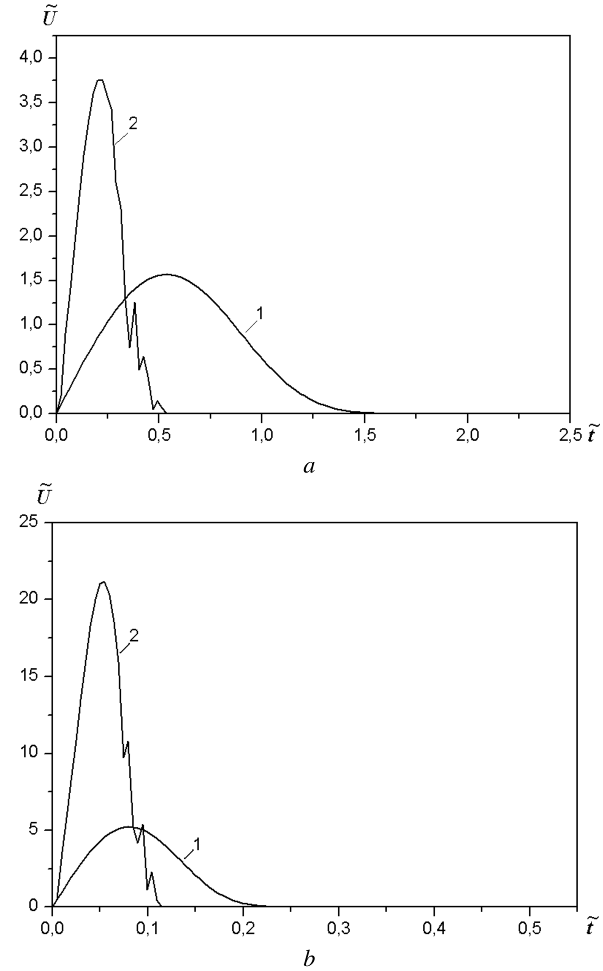

Fig 8. Shapes of AE signals at constant and variable rate of destruction: 1 – *a* is the loading application rate: α =3; 2 – initial rate of destruction υ_0 =const: υ_0=3; final rate of destruction $\alpha \pm \alpha_1$, where α_1 changes in a range from 3 to 5; *b* – is the rate of loading application α =10; initial rate of destruction υ_0 =const: υ_0 = 10; final velocity of the destruction $\alpha \pm \alpha_1$, where α_1 changes in a range from 3 to 5.

5. Conclusions

A model of the destruction of composite material during stress application and a relevant model of the formation of AE signals are developed. The model is developed while assuming the prevailing mechanism of the mechanical destruction of material. It is shown that the time curves of remaining (not destroyed) elements have a continuous sloping-down character with an absence of jumps. The continuity of the destruction process of the elements is accompanied by the formation of a continuous AE signal. Growth in the rate of loading and the initial destruction rate leads to an increase in the slope of curves, representing change in the remaining elements and their shift towards lower values along the time axis. Such a variation in the destruction process is accompanied by the growth in the amplitude of AE signals and their compression in time. The results of experimental research correlate well with the results of modelling. They show that during the destruction of specimens made of VK4 composite material the trailing edge of the registered signals is irregular (amplitude spikes are observed). The results of modelling show that the irregular shape of the registered AE signals with amplitude spikes is caused by the change in the rate of the destruction process.

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AKUSTINĖS EMISIJOS SIGNALO MODELIS SU VYRAUJANČIU KOMPOZITINIŲ MEDŽIAGŲ IRIMO MECHANIZMU

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S a n t r a u k a

Išnagrinėtas akustinės emisijos signalo modelis su vyraujančiu kompozitinių medžiagų irimo mechanizmu. Pateikti akustinės emisijos signalų modeliavimo rezultatai, įvertinant skirtingą apkrovos pasikeitimo greitį. Taip pat pateikti eksperimentinio akustinės emisijos signalų tyrimo rezultatai, kurie sutampa su teoriniais tyrimais. Parodyta, kad akustinės emisijos signalo galinio fronto netolygumas atsiranda tuomet, kai kinta kompozitinės medžiagos irimo greitis.

Reikšminiai žodžiai: akustinės emisija, stresas, plyšys, vystymasis, apkrova, akustinės emisijos signalas, įtrūkimas, kompozitinė medžiaga, pluošto paketo modelis.