Parameters of acoustic emission with variation of composite fracture speed by or and von Mises criterion

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Abstract. Regularities of amplitude and area under envelope of AE signals changes during CM destruction according to the OR and von Mises criteria are considered. It is shown that with ascending of CM deformation speed the ascending of AE signals amplitudes is well described by a linear function. However, when using the OR criterion, the increase of AE signals amplitude advances their ascending when using the von Miees criterion. It is shown that with ascending of CM deformation speed the ascending of area under envelope of AE signals is well described by a exponential function. However, when using the OR criterion, the increase of area under envelope of AE signals advances its ascending when using the von Mises criterion. The obtained regularities of AE signals amplitudes and area under envelope of the AE signals changes can be used in the control, monitoring, and diagnostics of CM state. The obtained results show that at developing methods it is necessary to set the percentage limits of AE signals parameters changes.

1. Introduction

At research of composite materials (CM) destruction processes by a shear load the analysis of acoustic emission (AE) signals is carried out. The researches are directed at finding parameters of registered AE signals for development the methods verification, monitoring and diagnostic of CM condition. This is due to the high sensitivity of AE method to submicro, micro and macro processes in the CM structure under its loading. Thus value has the analytical investigations AE at change of the different factors. The obtained regularities of AE parameters changes are the basis for development the methods verification, monitoring and diagnostic of state. At the same time, in theoretical studies, various criteria of CM destruction are used, which determine regularities of equivalent stresses change at CM loading. Their change can affect the regularities of AE parameters changes and, as a consequence, on the reliability the methods verification, monitoring and diagnostic of CM state.

2. Literature review and problem statement

At research of CM destruction processes by a shear force a fiber bundle-model (FBM) is used [1, 2, 3]. In researches it was assumed that the elements (fiber) of CM can be failed at achievement the critical deformations (stresses) of bending, tension or jointly bending and tension. For the OR criterion and the von Mises criterion a number of analytical and numerical regularities the number of remaining fibers changes during the CM destruction process development under action of the shear force are

obtained. The expression for AE energy liberation speed at CM destruction by a shear force is reviewed in articles [4, 5, 6]. However, the discontinuity of the analyzed functions at the time instant of CM complete destruction did not allow obtaining an expression for describing the generated AE signal.

In activitie [7] at CM destruction by a shear load are considered expressions for the number of remaining elements in time and reshaped AE signal at using the von Mises criterion. Thus was shown that at development of destruction process the dependences of the CM remaining elements in time have a continuous nature decreasing until complete destruction. Thus the continuous pulse AE signals are reshaped. Ascending of CM loading speed results in ascending of reshaped AE signals amplitude and decreasing of their duration. At the same time, there is a transformation of AE signal into a triangular signal. However matching of the obtained legitimacies according to the OR criterion and the von Mises criterion, carried out in article [8], has shown, that with increase coefficient characterizing the ratio of CM elements sizes, there is regularity of equivalent stresses change according to the OR criterion approaching to regularity of equivalent stresses change according to the von Mises criterion. At a certain value of the coefficient according to the OR criterion, the matching of equivalent stresses is achieved with their minimum deviation from each other. However given coordination is limited to a definite time period of change. Deviation of AE signals parameters also is watched at CM destruction according to the OR criterion and the von Mises criterion. It is conditioned by difference in speeds of equivalent stresses change with an approaching to an instant of a beginning of CM destruction. The outcomes of the conducted researches demonstrate, that the difference in AE signals parameters should influence on regularity of their change, that the results in a problem of mining the methods verification, monitoring and diagnostic of CM condition. For solution the indicated problem concern introduces analysis of AE signals parameters legitimacies change with ascending of CM deforming speed in an approaching of composite fracture models according to the OR and von Mises criteria.

3. The aim and objectives of research

The aim of the study is to analysis influencing of deforming criterion on AE signals parameters .

To achieve the goal, the following tasks were set:

- to conduct simulation of AE signals at ascending CM deformation speed in approaching of destruction models according to the OR and von Mises criteria;
- to define regularity maximum amplitude and area under envelope of AE signal change. Carry out a description of the obtained patterns.

4. Researches results.

Simulation of signals AE conducted on expressions
for OR criteria

$$U(t) = U_0 \upsilon_0 [\alpha t(1-\alpha t)(1-g(\alpha t)^{\frac{1}{2}}) - \alpha t_0(1-\alpha t_0)(1-g(\alpha t_0)^{\frac{1}{2}})] \times e^{r[\alpha t(1-\alpha t)(1-g\sqrt{\alpha t})-\alpha t_0(1-\alpha t_0)(1-g\sqrt{\alpha t_0})]} \times e^{-\upsilon_0 \int_{t_0}^{t} r[\alpha t(1-\alpha t)(1-g\sqrt{\alpha t})-\alpha t_0(1-\alpha t_0)(1-g\sqrt{\alpha t_0})]dt}, \quad (1)$$

for von Mises criteria

$$U(t) = U_0 \upsilon_0 [\sigma_m(t) - \sigma(t_0)] \cdot e^{r[\sigma_m(t)-\sigma(t_0)]} \cdot e^{-\upsilon_0 \int_{t_0}^{t} r[\sigma_m(t)-\sigma(t_0)]dt}, \quad (2)$$

where $\sigma_m(t)$, $\sigma(t_0)$ - are, respectively, the change in the equivalent stress on CM elements and the

threshold stress of the onset of CM elements destruction;

$$\sigma_m(t) = \alpha t \cdot 0.5\left[\left(2 - 2\sqrt{\alpha t} + \alpha t^{1.5}\log\left((1+\alpha t)/(1-\alpha t)\right)\right)\right.$$
$$\left. - \alpha t^{1.5}\left(2\sqrt{\left(1-\sqrt{\alpha t}\right)/\alpha t} + \log\left(\left(1+\sqrt{1-\sqrt{\alpha t}}\right)/\left(1-\sqrt{1-\sqrt{\alpha t}}\right)\right)\right)\right], \quad (3)$$

$$\sigma(t_0) = \alpha t_0 \cdot 0.5\left[\left(2 - 2\sqrt{\alpha t_0} + \alpha t_0^{1.5}\log\left((1+\alpha t_0)/(1-\alpha t_0)\right)\right)\right.$$
$$\left. - \alpha t_0^{1.5}\left(2\sqrt{\left(1-\sqrt{\alpha t_0}\right)/\alpha t_0} + \log\left(\left(1+\sqrt{1-\sqrt{\alpha t_0}}\right)/\left(1-\sqrt{1-\sqrt{\alpha t_0}}\right)\right)\right)\right], \quad (4)$$

U_0 - is the maximum possible offset when a CM sample, consisting of N_0 elements, is destroyed instantly; υ_0, r - are the constants, depending on the physical and mechanical characteristics of a CM; α - is the CM deformation speed; g - is a factor that depends on the geometric size of CM elements; t_0 - is the time when the CM elements begin to be destroyed.

Simulation of AE signals in relative units conducted at values of parameters reviewed in article [8]. Thus for the OR and von Mises criteria, the CM deformation speed varied in the range of values from $\tilde{\alpha}$ = 10 to $\tilde{\alpha}$ = 50 with an increment step of 10. For all deformation speed the threshold stress of a beginning destruction was a constant. When simulating AE signals according to the OR criterion, the parameter characterizing the ratio of CM elements dimensions was $\tilde{g}$ = 1.10231.

The constants υ_0 and r, that depend on the CM physical and mechanical characteristics, are accepted equal to $\tilde{\upsilon}_0$ =100000 and $\tilde{r}$ =10000 The U_0 parameter value is accepted equal to $\tilde{U}_0$ =1. The moment of the onset of the destruction of the CM elements based on the Mises criterion t_0 is taken equal to $\tilde{t}_0$ =0.01 A given point of time corresponds to the threshold stress of the onset of the destruction of CM elements equal to $\tilde{\sigma}(\tilde{t}_0)$ =0.05862777965495844.

The outcomes of AE signal simulation at CM destruction on OR criteria and von Mises criteria by the way of AE signals amplitude relations change in time in relative units are shown in Figure 1. The AE signals, that shown in Figure 1, are obtained at CM speed deforming $\tilde{\alpha}$ =10.

From the obtained outcomes it is visible, that at identical parameters of AE signals simulation usage different criteria of CM destruction results in difference in AE signals parameters. The maximum AE signal amplitude for von Mises criteria is less than a maximum AE signal amplitude for OR criteria. Such difference of AE signals parameters is conditioned by difference in speed of equivalent stresses change with an approaching to an instant of a beginning destruction $\tilde{t}_0$ =0.01. The ascending of equivalent stresses speed with an approaching to an instant of a beginning CM destruction by OR criteria are higher, than by von Mises criteria.

It is well visible on the basis of equivalent stresses change by OR criteria and von Mises criteria (Figure 2). The calculations of equivalent stresses by von Mises criteria conducted on expression (3). The calculations of equivalent stress by OR criteria conducted on expression

$$\sigma(t) = \alpha t(1-\alpha t)(1 - g\sqrt{\alpha t}), \quad (5)$$

where α is the CM deformation speed.

By the results of AE signals simulation at composite destruction by OR criteria and von Mises criteria the signal processing with definition of AE signals maximum amplitudes and area under AE signals envelope was conducted. The obtained result in the form of AE signals maximum amplitude relations change and area under AE signals envelope at ascending composite deforming speed are shown in Figure 3.

The outcomes of the conducted researches demonstrate, that to ascending of composite deforming speed there is ascending of AE signals maximum amplitude and area under AE signals envelope both for OR criteria, and for von Mises criteria. Thus the ascending of AE signals amplitudes descends

under the linear law, and area under AE signals envelope on not to the linear law. At the same time the ascending of AE signals parameters by OR criteria advances ascending of AE signals parameters by von Mises criteria. With ascending of deforming speed increase of AE signals parameters deviations is watched at composite destruction by yardstick OR criteria and von Mises criteria. With ascending of deforming speed increase of AE signals parameters deviations is watched at composite destruction by OR criteria and von Mises criteria. Thus the greater difference is watched in the area under AE signals envelope.

The statistical data processing with approximating of AE signals maximum amplitude relations change and area under an AE signals envelope at destruction of composite by OR criteria and von Mises criteria with deformation speed ascending was conducted.

The obtained outcomes have shown, that the relations of AE signals amplitude change with ascending of composite deformation speed (figure 3, a) are well described by expression of kind

$$\tilde{U} = a + b\tilde{\alpha}\,, \tag{6}$$

where $\tilde{\alpha}$ is CM deformation speed; a and b are coefficients of approximating expression.

The approximating expression (6) coefficients a and b values are peer: for a curve 1 - a =-3.71837; b=0.70432; for a curve 2 - a =-3.91795; b=0.74057. At the description of relations on a Figure 1, a the correlation coefficient R is peer: for a curve 1 - R =0.99785; for a curve 2 - R =0.99775.

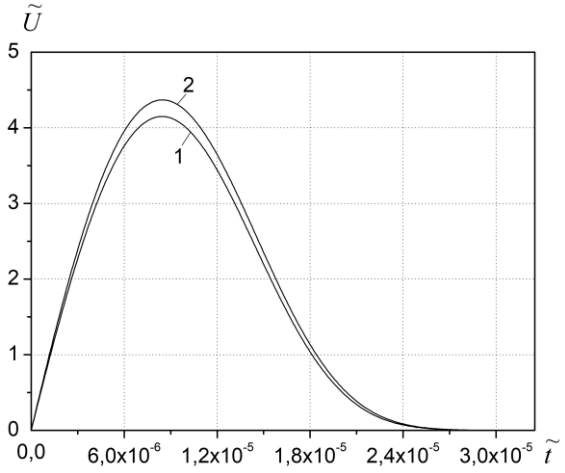

Figure 1. Relations of AE signals amplitudes change in time at CM destruction: 1 - for von Mises criteria; 2 - for OR criteria.

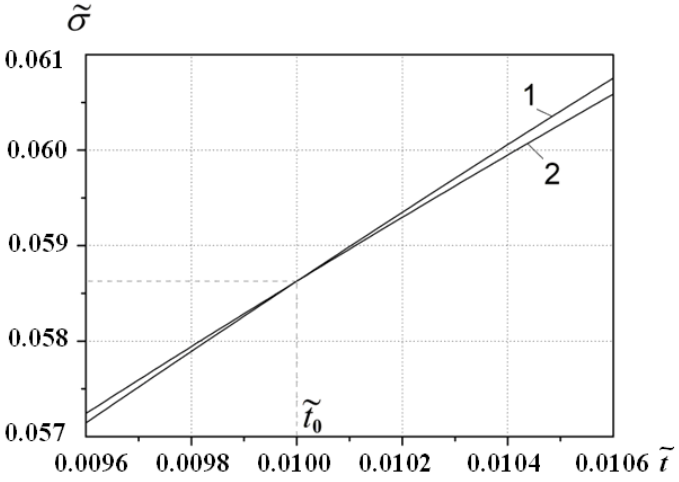

Figure 2. Pieces of equivalent stresses legitimacies change at CM destruction by OR criteria.

(1) and von Mises criteria (2) in the field of value $\tilde{t} = \tilde{t}_0 = 0.1$

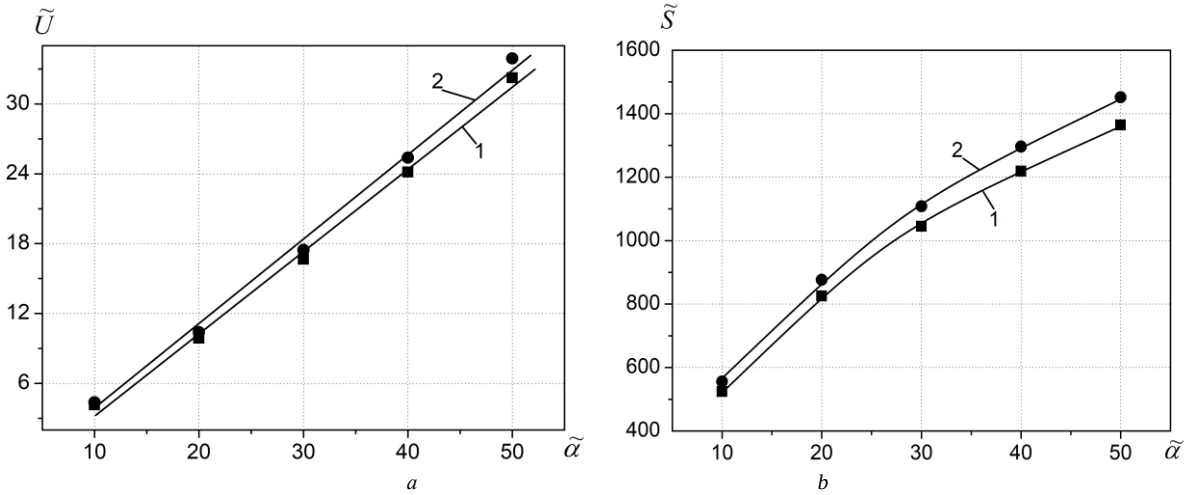

Figure 3. Relations of amplitude (a) and area (b) under envelope of AE signals change from CM deformation speed: 1 - for von Mises criteria; 2 - for OR criteria

At approximating relations shown in Figure 3, *a* criterion of selection approximating expression (6) was the minimum of residual standard deviation.

The obtained outcomes have shown, that the relations of AE signals area under envelope change with ascending of composite deformation speed (fig. 3, *b*) are well described by expression of kind

$$\tilde{S} = c\tilde{\alpha}^d, \quad (7)$$

where $\tilde{\alpha}$ is CM deformation speed; *c* and *d* are coefficients of approximating expression.

The approximating expression (2) coefficients c and d values are peer: for a curve 1 - *c* =144.73; *d*=0.5764; for a curve 2 - *c* =152.59; *d*=0.57865. At the description of relations on a Figure 2, *b* the determination coefficient R^2 is peer: for a curve 1 - 0.99732; for a curve 2 - 0.99754.

At approximating relations shown in Figure 3, *b* criterion of selection approximating expression (7) was the minimum of residual dispersions.

5. Discussion the research results

The outcomes of researches demonstrate that at CM destruction by a shear load with usage an OR criteria and von Mises criterion is watched difference in speed of equivalent stresses change. Thus the best coincidence of equivalent stresses by OR criteria and von Mises criteria are watched provided that parameter describing attitude of CM elements in OR criteria is peer to value 1.10231, and in von Mises criteria is peer to value 1. However and at the data conditions the difference in parameters of reshaped signals AE is watched. The given difference is conditioned, by that that with an approaching to an instant a beginning of CM destruction speed change of equivalent stresses by OR criteria is higher, than by von Mises criteria. Such influencing of equivalent stresses speed change increases with ascending of CM deformation speed. As demonstrate researches, at ascending of CM deformation speed descends ascending rejection of AE signals amplitudes and area under envelope of AE signals at CM destruction by OR criteria and von Mises criterion. The ascending of AE signals amplitudes descends under the linear law, and area under AE signals envelope on not to the linear law. However difference in speeds of equivalent stresses change by OR criteria and von Mises criteria results that the ascending of AE signals maximum amplitude and area under AE signals envelope by OR criteria advances ascending the data parameters by von Mises criteria. As demonstrate the obtained outcomes at deforming speed 10 rejections of AE signals amplitudes make 5 %, and area under envelope of AE

signals - 5.7 %. At ascending deforming speed in 5 times the rejection of AE signals amplitudes makes 7.6 %, and area under envelope of AE signals - 8.1 %.

Conclusions

1. The simulation of AE signals at ascending a CM loading speed by a shear force for cases of destruction by OR criteria and von Mises criteria are conducted. It is shown that the generated AE signals are continuous signals. Simulation conducted in an approaching of models CM destruction by OR criteria and von Mises criteria. It is shown that to ascending of loading speed there is ascending amplitudes and areas under envelope of AE signals. The amplitude of AE signals has linear nature of ascending, and the area under envelope of AE signals has not linear nature of ascending.

2. Are obtained regularity of amplitudes and area under envelope of AE signals change at ascending of CM loading speed for cases of its destruction by OR criteria and von Mises criteria. It is shown that at usage of OR criteria the ascending of AE signals amplitudes advances their ascending at usage of von Mises criteria. At usage of OR criteria the ascending of area under envelope of AE signals advances its ascending at usage of von Mises criteria. As demonstrate the obtained outcomes at deforming speed 10 rejections of AE signals amplitudes make 5 %, and area under envelope of AE signals - 5.7 %. At ascending deforming speed in 5 times the rejection of AE signals amplitudes makes 7.6 %, and area under envelope of AE signals - 8.1 %. The description of the obtained legitimacies is conducted. It is shown that with ascending of CM deformation speed the ascending of AE signals amplitudes is well described by a linear function. It is shown that with ascending of deformation speed the ascending of the area under envelope of AE signals is well described by an exponential function. The obtained regularities of AE signals amplitudes and area under envelope of the AE signals changes can be used in the control, monitoring, and diagnostics of CM state. The obtained results show that at developing methods it is necessary to set the percentage limits of AE signals parameters changes.

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