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DEFINITION OF INTERACTION AT THE SAME TIME ATTENDED TRACKS ON THE MODULE OF THE VECTOR OF THE TRANSITION.

І.Є. Андрущак, Ю.Я. Матвіїв, В.А. Кошелюк, О.М. Сіваковська, В.П. Марценюк. **Визначення взаємовпливу одночасно утворених тріщин на модуль вектора переміщень.** У статті розглянуто особливості розв'язання актуальної науково-технічної задачі, а саме – розробки методів оцінки докритичного розтріскування скловолоконних композитних матеріалів за параметрами сигналів акустичної емісії та показані основні переваги і недоліки їх впровадження.

Ключові слова: скловолоконні композити; акустична емісія; докритичне розтріскування; дефект; силовий критерій.

И.Е. Андрущак, Ю.Я. Матвеев, В. А. Кошелюк, А.Н. Сиваковська, В.П. Марценюк. **Определение взаимовлияния одновременно образованных трещин на модуль вектора перемещений.** В статье рассмотрены особенности решения актуальной научно-технической задачи, а именно - разработки методов оценки критическому растрескиванию стекловолоконных композитных материалов по параметрам сигналов акустической эмиссии и показаны основные преимущества и недостатки их применения.

Ключевые слова: стекловолоконные композиты; акустическая эмиссия; критическому розстріскування; дефект; силовой условий.

I.Ye.Andrushchak, Yu.Ya. Mathew, V.A. Koshelyuk, O.M. Sivakovskaya, V.P. Martsenyuk. **Definition of interaction at the same time attended tracks on the module of the vector of the transition.** The article considers the peculiarities of the solution of the actual scientific and technical problem, namely the development of methods for evaluating subcritical cracking of fiberglass composite materials according to the parameters of acoustic emission signals, and shows the main advantages and disadvantages of their implementation.

Key words: fiberglass composites; acoustic emission; subcritical stripping; defect; power criterion.

Formulation of the problem. The need for mankind in new constructional materials grows so fast that the pace of studying the properties of new materials practically does not have time to create them. This is especially true for composite materials (CM), which due to the appearance of new high-strength fibers with low specific gravity and high specific strength, which is significantly higher than that of aluminum alloys and steels, corrosion, chemical, heat, fire and moisture resistance; good thermal and electrical properties are widely used in all spheres of human activity. The development of world-wide production of CM has led to the fact that there is currently no area of technology or the fields of science and management, wherever they would use these materials. CM is particularly widely used in shipbuilding, machine building, aerospace engineering, chemical industry, residential and industrial construction, military industry.

Setting up tasks. In the world practice in the fields of fiber-optic composite materials, there are currently no generally accepted methods for determining the characteristics of their static crack resistance. This is due to the problems of determining the stages of macro-destruction of such composites, which may be due to various factors: the filtration of fibers from the matrix, the destruction of the matrix and the fibers itself, the extraction of the latter, and others like that. To study these processes and in order to effectively detect them, lately, the phenomenon of acoustic emission is increasingly being used. For this purpose, a number of parameters of the acoustic emission signals are used to obtain the necessary information and interpretation of the results of scientific research.

As the world practice shows, the definition of the stages of cracking of composites, and especially the dynamics of its development, is at the stage of formation. That is why the research carried out in this paper is aimed at solving a scientific and technical problem relevant for a number of industries in Ukraine - the development of effective applied methods of quantitative evaluation of the parameters of the pre-crystalline cracking of fiberglass composite materials, which are most prevalent in various spheres of industrialization in Ukraine.

The ability to choose the orientation of fibers and combine their various types in conjunction with the selection of matrix material allows you to create a CM with all the best strength and elastic properties. It should be noted that the most widespread among them is glass fiber, since their cost is the lowest. This led to the greatest use of glass fiber CM in the above technical areas. However, regarding the strength characteristics of fiberglass composites, it should be emphasized that they are essentially different for

different types of reinforcing component and matrix. Therefore, the relevance of the problem of studying the strength properties and crack resistance of such CM can not be overestimated today, as they have not yet been studied in detail.

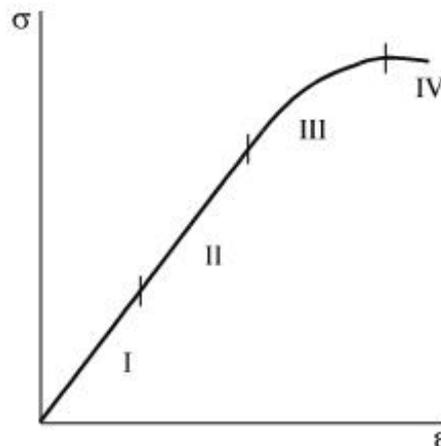
Analysis of recent researches and publications. Often during the operation of products or individual elements of constructions there are situations in which the formation of microcracks occurs in the localized volume of structural material. Such processes are discrete with little time duration and intervals between cracks formation events. For their diagnosis, for example, the AE method, it is necessary to be able to distinguish between sequential events, since this depends on the assessment of the destruction of the CM. In this aspect, the essential role played by the location of cracks in relation to their characteristic dimensions. Of course, non-destructive control and technical diagnostics of CM on the basis of AE phenomena require the establishment of appropriate correlation relations between the AE signals and the processes of formation and growth of various defects that arise under the influence of static and statically-variable charges in the material. They lead to the destruction of the matrix, fibers, filler, as well as the boundaries of the section between them. Therefore, it is especially important to insert the resolution of new techniques, taking into account the threshold of sensitivity of hardware, the specifics of the structure and mechanical characteristics of the CM.

In this article, an analysis of displacements is presented on the basis of a known solution of the dynamic problem of the theory of cracks on the formation of a internal insulated crack of normal separation and a static approach to the interaction of two arbitrarily oriented cracks. The results of the research are published in the works [1-3].

Basic material presentation. The analysis of the deformability of fibrous composites in the longitudinal direction uses mainly the classical theory of mixtures, direct numerical methods for analyzing the stress-strain state near the inclusions of a cylindrical shape, and so on.

The theoretical basis for the deformation of such composites in the cross-section is based on solutions of the flat theory of elasticity and plasticity for plates with single or interacting massive (most often circular and elliptical forms) inclusions in isotropic or anisotropic media for an ideal or partial contact between them. Handling of regularly reinforced fibrous composites according to this approach best describes two-period solutions [4].

In the case of applying forces in parallel to the one-leg direction of stacking fibers in a metal matrix in papers [5, 6], there are four stages of deformation of the CM (dr. 1.1).



Dr. 1. Schematic curve of deformation of composite material with a metal matrix:

I - elastic fiber, elastic matrix; II - elastic fiber, plastic matrix;

III - plastic fibers and matrix; IV - destroyed fiber.

At the first stage there is elastic deformation at the same time both the matrix and the fibers. The experimentally obtained modulus of elasticity in this case is very consistent with the prediction of the theory of mixtures:

$$E_C = E_R f_R + E_R f_R, \quad (1)$$

where E_R , E_M і E_C – modulus of elasticity of the strengthening component (filler), matrix and composite material, respectively; f_R і f_M - bulk particles of fiber and matrix. If the porosity or the third phase is absent, then $f_F + f_M = 1$.

It is established in [7] that equation (1) corresponds theoretically to the lower boundary of the module, when the Poisson coefficients of two phases are very close to each other. The same equation holds for the case of elastic compression of a composite. Higher than calculated values of the elastic modulus can be obtained in the case of nonconformity of the Poisson coefficients. Thus, the simple additivity rule of the properties of mixtures, applied in the field of elastic deformation, proved to be very successful for predicting elastic deformation of the composite material. The second stage of deformation of a unidirectional fibrous metallic composite concerns an area in which the fiber deforms elastically, and the matrix is plastic. Since the volumetric fraction of the fiber is usually high and it has a modulus of elasticity much higher than the matrix, then the elastic modulus E_2 at this stage, almost coincides with the module E_1 the first stage of deformation (1). More precise dependence on the elastic modulus of the composite material along the reinforcement direction (E_{11}) can be obtained on the basis of the similar (1) assumption that this modulus of elasticity is equal to the sum of effective strain curves of the two phases, taking into account their volumetric particles:

$$E_{11} = E_F f_F + (d\sigma_M / d\varepsilon_M)_G f_M, \quad (2)$$

where $d\sigma_M / d\varepsilon_M$ – effective coefficient of deformation strengthening of the matrix.

This coefficient is usually much smaller than the fiber elastic modulus. Therefore, it can be neglected and in this connection, an effective modulus of elasticity on the second (elastic-plastic) part of the deformation curve in most cases can be represented by an expression:

$$E_{11} = E_F f_F. \quad (3)$$

It is necessary to pay attention to the fact that though E_{11} almost equal to the value E_M (85 % E_M for 50% volumetric boron content in the aluminum-boron composition), it is not a real (real) modulus of elasticity. The deformation of the composite material in the elastic-plastic region causes some steel elongation, and the relaxation of the applied stress causes the fiber to be elastically stretched. The matrix thus has residual compressive stresses. The cyclic deformation of the composite in this (second) region of deformation causes the effect of the hysteresis effect, which can significantly change the effect of the previous thermomechanical treatment of the material.

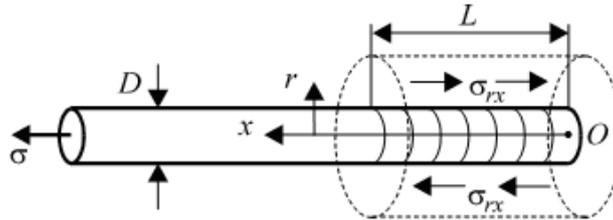
The third stage of deformation occurs when both components (fiber and matrix) undergo plastic deformation and are the usual flat stretch of two phases. In this case, the deformation process of the components in the composition material can fundamentally differ from the deformation of the separately loaded components, as far as neck formation or other type of non-homogeneous plasticity is concerned. For some plastic fibers, the beginning of neck formation is significantly delayed due to the sub-actuation of the matrix. For example, in the composite system, silver-steel fixed [8] increase the strength of the composition above the level of the combined strength of composite materials.

The fourth stage corresponds to a period of gradual destruction of high-strength fibers. At this stage, the matrix transfers the load from the ends of the destroyed fiber to the undiluted parts and there is a flowing flow around the open pores or cracks. Usually this stage ends with the global destruction of composite material. Due to the ductile plasticity of the matrix and the dynamic loads that cause the multiple division of the fiber into a part which does not yet lead to catastrophic destruction, the composite material may remain generally intact if the volume fraction of the fibers is less than a certain critical the size of This stage corresponds to the deformation stage of the composite material containing inside the torn fibers. In the presence of short fibers, the matrix transfers the load as a result of the appearance of tangent stresses on the surface of the fibers near the ends of the broken fiber. These shear stresses are caused by a gradient of normal stresses when moved to the fiber in the radial direction, since the fibers have a higher effective deformation slope than the matrix, which is also apparent from the balance of forces in the direction of the axis x (dr. 2):

$$dP / dx = 2\pi r \sigma_{rx}, \quad (4)$$

where P – the tension of the fiber in the direction x ; $\sigma_{rx} \sim \tau$ – displacement stress on the fiber-matrix separation surface; r - the radial distance from the axis of the fiber.

An approximate solution of the problem of transmission of tangents in an elastic state has the form:



Dr. 2. The forces affecting the reinforcing fiber: σ – tensile stress acting on a cross-section $\pi D^2 / 4$;

τ – tensile shear stress acting on the surface area $\pi D l$

$$P = \varepsilon_F A_F \left(1 - \frac{(\cosh \beta)(l/2 - 1)}{(\cosh \beta)l/2} \right) \quad (0 < x < l/2). \quad (5)$$

There P , l i ε_F - load, length and strain of fiber tension, respectively; A_F – cross-sectional area of the fiber; β – the ratio of length to fiber diameter (the influence of the geometry of the ends of the fibers on the intensity of the transfer of load to the fibers was not taken into account).

When loading composite materials with a metal matrix, when the fiber is deformed elastically, and the matrix is plastic, then in this case the elastic deformation of the matrix is limited to the values of the normal σ_y or shifted τ_y matrix strain stresses. If the deformation strengthening effect is small, then one can predict that σ_{rx} does not depend on x , and therefore, after integrating equation (4), taking into account that the newly formed end of the fiber after its rupture becomes unloaded, will give an expression for the longitudinal force:

$$P = P(0) + 2\pi r_0 \int_0^x \sigma_{rx} dx = 2\pi r_0 x \sigma_{rx}, \quad (6)$$

and then normal tension will be:

$$\sigma_{xx} = P / (\pi r_0^2) = 2\sigma_{rx} x / r_0. \quad (7)$$

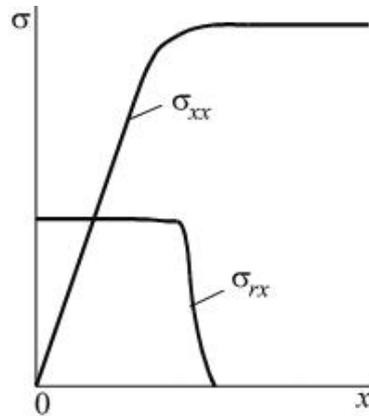
As can be seen from equation (7), the normal tensile stress increases linearly with the distance from the ends of the fiber, provided that the tensile shear stress is steady, as shown in Fig. 3. In the case of composite material with fibers of finite length (short), the minimum critical length of the reinforcing phase may be determined, in which the stresses may increase to the magnitude of the destructive stress. If ticked through σ_F the tensile strength of the fiber, then the critical length of the reinforcing phase L_c can be determined using the value of yield strength τ_y for the displacement of the matrix by tangential stresses. From equation (7), which describes the range of tangential stresses applied at each end of the fiber and which shows that in the middle of the finite fiber of length l tangential stresses σ_{rx} on its surface and normal tensile stresses associated with each other expression $\sigma_{xx} = \sigma_{rx} l / r_0$, we will determine for the boundary state ($\sigma_{xx} \sim \sigma_F$) an expression:

$$L_c = r_0 \sigma_F / \tau_y. \quad (8)$$

Just tension stretch σ_{xx} in the shattered fibers the magnitude corresponding to the stresses for the undiluted fibers will reach, the tensile stresses on the boundary of the separation in the matrix will again be equal to zero (dr. 3), as in the case of a composite material in which there is no damaged fibers.

The destruction of weak fibers in the composite leads to the following results:

1. The overall strength of the composite material in the cross-section in the place of the destruction of the fiber decreases;
2. Effective strength decreases due to the concentration of the static stress field near the crack caused by the broken fiber;
3. There is a certain shock load of the composite material and, accordingly, its retaining ability is reduced due to the generation of waves of dynamic stress during the discharge of the destroyed



Dr. 3. Distribution of normal σ_{xx} and tangent $\sigma_{rx} = \tau$ tension at the ends of the fiber

fiber.

The ability of the composition in the presence of shattered fibers is also related to the critical length of the load transfer on the fiber in the matrix according to equation (8).

In the zone of direct localization of the destruction of the fiber, the strength decreases by the value of the holding capacity of the destroyed element. At distances up to the critical loading load, the material's retaining capacity as a result of the destruction of the fiber decreases.

Conclusion. The processes of deformation of materials are accompanied by the formation of microproblems in zones where a sufficiently high concentration of disulocytic aggregates is achieved. The formation of such microdefects, accompanied by the emission of elastic waves. The registration of elastic waves AE makes it possible to study the kinetics of the processes of accumulation of defects, especially in areas of high concentration of stresses. To construct the calculation model of the emission of elastic waves during the formation of a crack in the zone of intense deformations for loading of the composite material, suppose that such a nubally-formed crack is of a form close to the circular one. To simplify the calculations, replace it with a disc-like split equilibrium crack. We also assume that due to the formation of this discoid crack, the breaking of the solidity of the material is accompanied by the unloading of free surfaces, formed from the initial level σ_0 (in a defect-free material) to zero, which occurs for some characteristic time τ_r . The unloading of the shores of the newly created crack causes fluctuations in its shores and, accordingly, the emission of elastic waves.

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