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THE CHRONOMECHANICS OF DEFORMATION AND STRENGTH OF NANOMATERIALS

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Abstract. The analysis of phenomenological modeling of elastoviscoplasticity properties of bulk nanostructures is executed. The determining equations of interrelation of deformation and durability properties of initial and nanostructural bulk materials are constructed on the basis of endochronic concepts to the data of diagrams of their stretching, with the use of "vertical" and "horizontal" scales of generalized time depending on parameters of structure and manufacturing techniques. Examples of application of the approach to metals and fulleren-polymeric composites are considered.

1. Introduction

Many works [1, 2, etc.] are devoted to the research of elastoviscoplasticity, durability and other physical characteristics of nanomedia, and also to the establishment and modelling of the dependence of properties on parameters of structure and technology. Research and comparison of structures is often done fragmentary, under separate dot characteristics of conditional or true diagrams of destruction at constant speed of deformation, on the limit of fluidity, size of time resistance, and etc. Dependences of descriptions on the parameters of structure are investigated and formulated. The essential drawback of these works is the absence of the account of time influence on determining properties, that negatively influence scientific and applied problems for these materials. Research and the account of nontrivial spectrum of time properties on the qualities and the processes of manufacturing and operation of nanomaterials and products from them can have a crucial importance.

A modern, endochronic (with own, internal, generalized time) approach [3, 4, etc.] is applied for the most effective account of time properties in the mechanics of deformable media. It is based on experimentally proved physics-mechanics-time correspondence. Such as temperature-, humidity-, radiation-, structure-, stress-, deformation- time and so forth dependences. Various techniques of the approach for the description of the processes of creep, relaxation, plasticity and accumulation of damages in stationary and nonmonotonic processes of deformation of elastoviscoplasticity media are being created. The greatest practical application was received now with the concept of Valanis [3] and other researchers developing it in which a parameter of endocronics close to unit is used. The concept has more limited opportunities in comparison with the techniques of Shapery, Urzhumtsev - Maksimov etc, who use vertical and horizontal scales of time.

In the present work the development of approaches [3, 4] is considered for phenomenological modelling of the connection determining physics-mechanics-time-deformation and strength properties of initial and nanostructural bulk materials depending on parameters of structure and manufacturing technologies. The technique can be applied to all points of the diagrams of destruction or to their parts. It enables us to receive a more effective and flexible approach than the existing ones, a systems estimation of determining properties of nanomaterials.

2. Construction of an endochronic model of interrelation of determining deformation and durability properties of initial and nanostructural bulk media according to the data of diagrams of destruction and to the parameters of structure and manufacturing technologies

Dependences of the value of stress σ on time t of the diagrams of initial (i -initial) and nano- (n -nano) materials at constant speed of deformation ε - look like:

$$\sigma(t) = D_i(t), \quad \sigma(t) = D_n(t). \tag{1}$$

Here D_i and D_n - determining functions of the diagrams of deformation. We shall introduce a determining parameter of structure s with values at different degrees of structurization: $s_0 = s_i$, s_1, s_2, …, $s_k = s_n$. Now it is possible to present (1) in the form of:

$$\sigma(t) = \sigma_k(t) = D_k(t). \tag{2}$$

As a parameter of the structure the size of a grain of metal, the value of the volumetric content of fulleren in a composite on its basis, density of materials etc, and also the technological parameters influencing the change of structure can be used: stress, temperature, time of influence, and many other physical characteristics of structures or methods of their definition. Comparison of the diagrams of initial and nanostructural materials shows, that in many cases the first has essentially lower (higher) ordinates and an extensive (shorter) piece of values of abscissa than the second one. The increase or downturn of the sites of diagrams, which can be connected with the change of the module of elasticity, degree of plasticity, development of a neck in the sample, by hardening or softening of the medium is observed.

For an establishment of the connection between the diagrams or their parts the application of the endochronic concept is offered, generally in a case with "complex" depending on two parameters vertical $g_k^v(s_k, t)$ and horizontal $g_k^h(s_k, t)$ scales or "simple" scales, depending only on the first parameter (see the Example 3.1). We shall enter the following norm of scales: $g^v(s_i, t) = g^h(s_i, t) = 1$ - for the material of initial structure. The scale g_k^v is intended for the reception of values of ordinates of the intermediate fictitious diagram D_{ik} on the ordinates of the initial diagram D_i, by this scale multiplication. The scale g_k^v is defined from the condition that the value of the transformed last ordinate of the diagram D_{ik} was equal to the value of the last ordinate of the diagram D_k. Thus,

$$D_{ik}(t) = g_k^v(s_k, t) \cdot D_i(t). \tag{3}$$

The following step is transformation of argument t of fictitious function D_{ik} by means of its horizontal scaling: - replacement by generalized time of the kind $\xi_k^h(t) = g_k^h(s_k, t) \cdot t$. This, apparently, more often, the "simple" horizontal scale $g_k^h(s_k)$ found from the condition that the fictitious diagrams D_{ik} has been transformed to the diagram D_k:

$$D_{ik}\left[\xi_k^h(t)\right] = D_k(t). \tag{4}$$

Values of scales g_k^v and g_k^h mathematically characterize sizes of excess or reduction of ordinates and abscissa sites of the diagram D_k in comparison with the diagram D_i. Analytical dependence of scales g_k^v and g_k^h on the second argument is defined by the kind of functions

D_i and D_k. A satisfactory approximation can be linear dependence, or independent t (for example, on the site of elasticity).

3. Examples

3.1. About determining mechanics-time properties of metals. One of the typical variants of increasing diagrams of stretching of metals [1, 2] in the initial $\sigma_1(t)$ and nanostructural $\sigma_2(t)$ condition is given schematically on Fig. 1. Points 0, A_k, B_k, and C_k correspond to the beginning of the test, the limit of elasticity and durability (temporary resistance). The possible falling site of the diagrams concerning the neck pulling of the sample and its breakage afterwards is not specified. The scheme of finding and application of scales g_k^v and g_k^h necessary for finding on (3) and (4) of other determining functions is shown. Preliminary testing for an alloy of alluminium has shown satisfactory correspondence of calculation by the offered technique and experimental data. In figure on the right the dependence of scales on time is given. Their dependence on the parameter of structure s is not shown. As the first approximation can by linear.

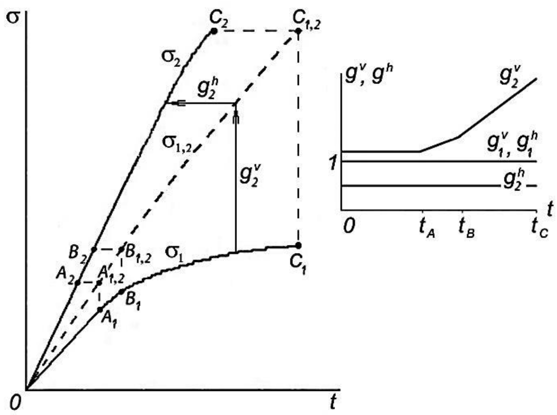

Fig. 1. Diagrams $\sigma_k(t)$ and scales $g_k^v(t)$, $g_k^h(t)$ of metals.

3.2. Mechanics-time properties of fulleren-polymeric composites. On Fig. 2 linear diagrams $\sigma_k(t)$ of nanocomposites are presented: PMMA filled with fullerene C_{60} with various volumetric content φ, received by our processing [5] of the results of tests [6]. The dependence of scales $g_k^v(\varphi)$ and $g_k^h(\varphi)$ of a degree kind is satisfactory.

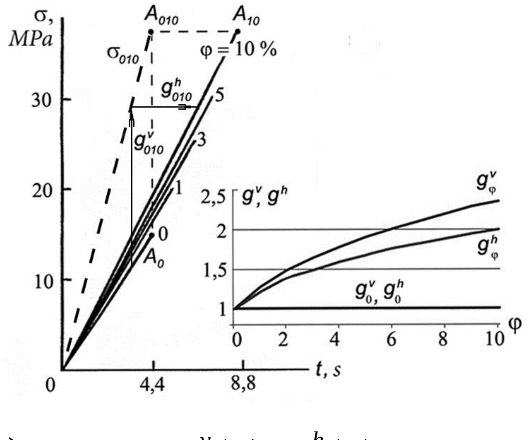

Fig. 2. Diagrams $\sigma_k(t)$ and scales $g_k^v(\varphi)$, $g_k^h(\varphi)$ of fulleren polymeric composites.

4. Conclusion

On the basis of a modern systems phenomenological approach a new effective endochronic technique of analytical modelling of determining viscoalasticity and strength properties of initial and nanostructural bulk materials considering the parameters of structure or parameters of technologies is developed. The technique allows to carry out much fuller, continuous estimation of "vertical" and "horizontal" properties of materials unlike traditionally applied dot vertical estimations. The introduced determining parameters of the approach, vertical and horizontal scales can be considered as physical characteristics of structure.

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