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The estimation of the parameters of the stress - strain state of complex technical constructions

A new approach of evaluation is performed on the basis of the function of damage, for its definition, it is necessary to take into account the uncertainties that arise due to the variability of the technological situations in which the diagnoses are presented.

The estimation of the parameters of the stress - strain state of complex technical constructions is a multilevel iterative process of sequential detailing and optimization of diagnostic decisions. Insufficient study of individual phenomena does not allow to have a fully mathematically formalized description of the design. Since evaluation is performed on the basis of the function of damage (refusal), for its definition, it is necessary to take into account the uncertainties that arise due to the variability of the technological situations in which the diagnoses are made.

The simulation of deformation processes and the exhaustion of the equation resource is based on the equation of thermosplasticity, the equation of macrodefect development, the criteria for the stability of resource exhaustion processes and evolution equations [1, 2, 3].

The equations of thermosplasticity contain microparameters that take into account the effect of accumulation of damage on the physical and mechanical properties of the construction material [1, 4, 5].

The criteria for assessing the stability of resource exhaustion processes are based on the control of the magnitude of the derivative damage by the generalized energy parameters, which is the internal time of the data of physical processes [6].

The evolutionary damage equations take into account the physical stages of the process of accumulation of damage, the influence of the parameters of the stress-strain state, temperature, the type of the deformation trajectory, and the effect of deformation on the rate of the process of accumulation of damage, its nonlinear character, nonlinear summing of damage when changing the load regime and from various mechanisms of resource exhaustion [4 , 6].

Existing engineering approaches to resource estimation in multi-cyclic and low cycle fatigue are based on known data on the load on a structure in the form of a certain non-stationary process, set by the values of equivalent stresses or deformations. With the help of known techniques, the real nonstationary deformation process is reduced to a symmetric block process, with the different parts of one cycle may belong to different loads. The rules of linear summing of damages are used. The degree of damage is estimated by the relative number of cycles or relative time. Processes of formation and exhaustion of the resource are modeled separately.

For each stage of the resource exhaustion process, a generalized energy parameter is defined that characterizes the specific conditions of the process for each hazardous zone of construction, which depends on the corresponding fractions of energy dissipation for the creation of microdefects within the framework of the corresponding resource exhaustion mechanism. On the basis of generalized energy parameters formulated the principles of equivalence of processes of exhaustion of the resource among themselves in their equivalence with experimental data. The principle of nonlinear summing of damages is realized. Tasks in the framework of mechanics of damage are formulated as linked to processes of deformation and accumulation of damage. The evolutionary equations of accumulation of damage are formed and the criteria of stability of processes of exhaustion of the resource are determined.

In our case, the evolutionary equation of accumulation of damage will be:

$$w = \sum_z \frac{\alpha_k+1}{l_k+1} f_k(q_k) z_k^{\alpha_p} (1-w)^{-r_k} \langle \dot{z_k} \rangle, 0 \leq w \leq w_f < 1, h = e, p, c \quad (1)$$

where w – normalized function of damage; q_k – parameters of the stress-strain state and the type of trajectory of deformation; z_k –normalized fate of dissipation for the creation of microdefects by mechanisms of many cyclic fatigue z_e, little cyclic fatigue z_p, creep z_c ; α_k, r_k - material parameters - temperature functions; w_f – critical value of microcrack.

The equation (1) integrates together with the equations of thermoplasticity through the parameters q_k, z_k, z_e and temperature T. The material parameters of the thermoplastic equations depend on accumulated damages (failures).

Under the predominant mechanisms of cyclic and cyclic fatigue, the process of accumulation of damage is described by the equation:

$$w = 1 - \left\{1 - \left[(\alpha_p - 1)\int_0^{z_e} f_p(q_k) z_e^{\alpha_p} \langle dz_e \rangle + \right.\right.$$
$$\left.\left. + (\alpha_e + 1)\int_0^{z_k} f_e(q_k) z_k^{\alpha_e} \langle dz_k \rangle \right]^{\frac{1}{r+1}} \right\}, \quad (2)$$

or

$$w = 1 - (1 - \left[y_p^{\alpha_p+1} + y_c^{\alpha_c+1}\right])^{\frac{1}{r+1}}, \quad (3)$$

where y_p and y_e - low cycle and multi-cyclic fatigue as parameters of the internal time of the process:

$$y_p = \left[(\alpha_p + 1)\int_0^{z_p} f_p(q_k) z_p^{\alpha_p} \langle dz_p \rangle\right]^{\frac{1}{\alpha_p+1}}, \quad (4)$$

$$y_e = \left[(\alpha_e + 1)\int_0^{z_e} f_e(q_k) z_e^{\alpha_e} \langle dz_e \rangle\right]^{\frac{1}{\alpha_e+1}}, \quad (5)$$

$$z_p = \frac{W_p - W_a}{(W_f - W_a)_p}, \quad (6)$$

$$z_\varepsilon = \frac{W_\varepsilon - W_y}{W_{f\varepsilon}}, \tag{7}$$

where W_p, W_ε - the fate of energy dissipation, aimed at the formation of microdefects in low-cyclic and multi-cyclic fatigue. The material functions W_a, W_y represent the end of the microdefect generation stage at low cyclic and many cyclic fatigue ($z_k = 0$ for $W_p < W_a$ and $W_\varepsilon < W_y$), and the material functions $W_{f\varepsilon}$ - the critical value of the corresponding energies.

According to equations (2) - (7), for each process characterized by the individual history of the thermo-power load on a certain volume of material, the corresponding curve of accumulation of damage in the plane of variables corresponds to $w \sim W_p$ $(w \sim z_p)$, $w \sim W_\varepsilon$ $(w \sim z_\varepsilon)$, and when the thermoset-load modes change, there is a transition from one curve to another (nonlinear summation). On the phase planes $w \sim y_p$ and $w \sim y_\varepsilon$ each mechanism of exhaustion of the resource, the only generalized damage curves are answered. At the same time, the speed of movement on these curves depends on specific load parameters.

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