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CREEP FRACTURE OF PLATES IN UNSTEADY COMPLEX STRESS STATE IN THE PRESENCE OF AMBIENT MEDIUM

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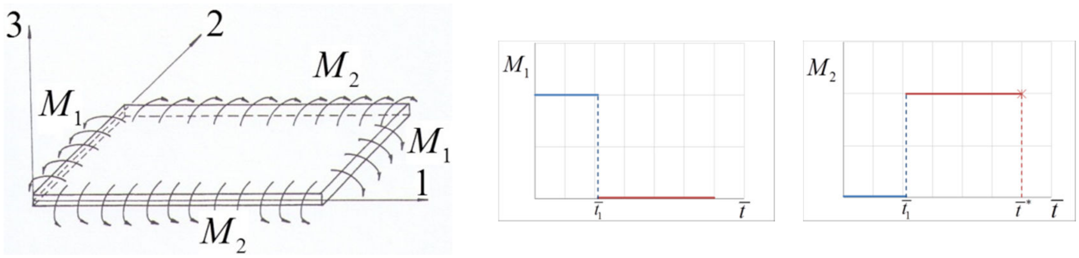
ABSTRACT

Creep fracture of bended rectangular plate is researched in unsteady complex stress state with consideration for the effect of an ambient medium. Using Rabotnov's kinetic theory, time to fracture of such plate was determined during sequential bending in different planes. Piecewise constant dependences of bending moments levels and directions on time are considered. The time to fracture of the plate is determined using a fractional linear creep model. The effect of the ambient medium on the creep and the creep fracture of the plate is attributed to diffusive penetration of ambient medium elements into the material of the plate. Ambient medium effect is taken into consideration by introducing a function of cumulative average concentration into constitutive and kinetic fractional linear equations. The times to fracture while using scalar and vector damage parameters are compared.

Keywords: rectangular plate; bend, creep; diffusion; diffusion front, creep fracture, linear fractional model; scalar damage parameter; vector damage parameter

INTRODUCTION

Forecasting durability of materials and structural elements under long-lasting high temperature loading in the presence of an aggressive ambient medium is an extremely important problem to ensure reliability during the entire operational life. This study is based on Rabotnov's kinetic theory of creep and creep rupture (Rabotnov, 1969). Under research, there is creep fracture of a rectangular plate of thickness H that is exposed to bending moments M_1 and M_2 distributed along its edges as represented in Figure 1.



(a) (b)

Fig. 1 - (a) Loaded plate and (b) plate loading program.

A linear diffusion process along axis 3 (thickness) symmetric with respect to the middle plane of the plate is considered. An approximate method to solve the diffusion equation based on the introduction of a diffusion front is used (Lokoshchenko, 2016).

FRACTIONAL LINEAR CREEP MODEL

The aggressive medium effect is taken into consideration by introducing into fractional linear (Shesterikov, Yumasheva, 1984) constitutive equation of the function of cumulative average concentration of the aggressive medium $f\left(\bar{c}_m\left(\bar{t}\right)\right)$ in the plate

$$\dot{p}_u = A\left(\sigma_u/\left(\sigma_b - \sigma_u\right)\right)\cdot f\left(\bar{c}_m\left(\bar{t}\right)\right),$$

where $\dot{p}_u$ - creep strain rate intensity, σ_u - stress intensity, σ_b - short-time strength limit at given research temperature, $f\left(\bar{c}_m\left(\bar{t}\right)\right)$ - function of cumulative average level of concentration $\bar{c}_m\left(\bar{t}\right)$ of the ambient medium elements in the plate, A - material constant.

The function $f\left(\bar{c}_m\left(\bar{t}\right)\right)$ is introduced into the kinetic equations. The kinetic equation given a scalar damage parameter is assumed to have the following form

$$\dot{\omega} = d\omega/d\bar{t} = C\left(\sigma_u/\left(\sigma_b - \sigma_u\right)\right)\cdot f\left(\bar{c}_m\left(\bar{t}\right)\right), \quad \omega\left(\bar{t}=0\right)=0, \quad \omega^* = \omega\left(\bar{t}=\bar{t}^*\right)=1 .$$

Kinetic equation for vector damage parameter $\mathbf{\Omega}$ are as follows

$$\dot{\Omega}_i = d\Omega_i/d\bar{t} = \begin{cases} C\cdot\left(\sigma_i/\left(\sigma_b-\sigma_i\right)\right)\cdot f\left(\bar{c}_m\left(\bar{t}\right)\right) & \text{if} \quad \sigma_i > 0 \\ 0 & \text{if} \quad \sigma_i \le 0 \end{cases} \qquad i = 1,\ 2,$$

where Ω_i - damage vector projection on i - th axis of the coordinate system,

$\Omega = \sqrt{\left(\Omega_1\right)^2 + \left(\Omega_2\right)^2}$, $\Omega\left(\bar{t}=0\right)=0$, $\Omega^* = \Omega\left(\bar{t}=\bar{t}^*\right)=1$ - fracture criterion.

RESULTS AND CONCLUSIONS

As a result of the obtained formulas and the numerical calculation the time to fracture when a scalar damage parameter is used is less than when a vector damage parameter is used for different values $\zeta = M_2/M_1$.

Sequential decrease (increase) of the stress leads to an increase (decrease) of the time to fracture and increase (decrease) the sum of the partial times which reflect the principle of linear summation of damage.

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