


EVALUATION OF CREEP AND CREEP LIMIT OF STRUCTURAL ELEMENTS BY THE METHOD OF CHARACTERISTIC PARAMETERS, COMMUNICATION 2

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On the examples of calculation of creep and creep limit of a cylindrical pipe under internal pressure and of a rotating disk, the present communication presents an additional analysis and some analytical generalizations of the hypothesis of the existence of a characteristic point. The dependence of the position of the characteristic point on the selection of the equivalent stress in the determining equations is established.

In analyzing and evaluating the process of strain in creep and creep limit, we will henceforth avoid identifying the parameter of damageability with the magnitude of energy density in creep because this is well confirmed only in the region of ductile fracture. As a measure of damageability we introduce some structural parameter \( \omega \) (not endowing it with a definite physical meaning [1]) determined in accordance with the equation of damageability \( d\omega/dt = f(\sigma_{eq}, \omega) \), where \( \sigma_{eq} \) is the equivalent stress with the same cumulative damage (and consequently, also time to rupture) under conditions of various states of stress. The parameter \( \omega \) varies within the limits \( 0 \leq \omega \leq 1 \).

We assume as correct the regularity of flow along the normal to the contour of the equivalent stress \( \sigma_{eq} \) in proportion to \( W = \varepsilon_{ij}a_{ij} \):

\[
\varepsilon_{ij} = \frac{\partial \sigma_{eq}}{\partial a_{ij}}.
\]  

(1)

This last hypothesis is fairly well confirmed experimentally in the region of ductile fracture [2].

The equation of state in the general case has the form \( W = \varphi(\sigma_{eq}, \omega) \). We concretize the equations of state and of damageability by an exponential function in the form

\[
W = B_{1}\sigma_{eq}^{2}\lambda/(1 - \omega)^{m};
\]  

\( \omega = B_{2}\sigma_{eq}^{2}/(1 - \omega)^{k}. \)  

(2)

If we multiply the left-hand and right-hand parts of relation (1) by \( a_{ij} \) and contract it according to exponents, we find, taking the first ratio (2) into account, the coefficient \( \lambda \). We use the system of determining equations (1)
Fig. 1. Distribution curves of stress intensity over the radius of a thick-walled pipe under internal pressure, at different instants. (Dashed line: calculation by the procedure of steady state; dot-dash line: initial elastic distribution.)

\[ f_c (0) = \int_0^1 x^{-2n-1} dx = 1, \quad \omega (x, 0) = 0, \] analogously to what was done in [3, 4] for the determining equations that were homogeneous with respect to \( \sigma/(1-\omega) \) (\( m = n, q = k \)) and in [5] for the case when condition (8) is fulfilled:

\[ f_c (t) = \int \left( \frac{V^3}{2} \right)^{1/3} \frac{\rho^{1/3}}{\beta} \left( x^{-2n} \left( \frac{f_c}{T} - 1 \right) \right)^{1/3} + \]

\[ \omega (x, t) = 1 - \int \left( 1 - \frac{T}{T} x^{-2n} \left( \frac{f_c}{T} - 1 \right) \right)^{1/3}. \]

In view of Eqs. (5), (10), (11) it is easy to convince oneself that at the point

\[ \bar{x} = (f_0)^{1/3} \]

the stress intensity is constant with time \( \partial (\omega / \partial t) \) \( q_1 (x, t) = 0, \) although for the stress components separately, this condition is not fulfilled. Moreover, the stress intensity (5) at this point in the course of the deformation process is equal to the stress intensity of the "steady state" (\( m = k = 0 \)) at the same point:

\[ \bar{\sigma}_i = \frac{V^3}{2} \rho \left( \frac{\rho}{f_0} \right)^{1/3} = \frac{V^3}{2} \frac{T}{T} x^{-2n} \left( \frac{f_c}{T} - 1 \right)^{1/3} = \bar{\sigma}_{0e}. \]

We substitute the relations (10) into (11) for \( x = \bar{x}, \) and with a view to (13) we determine the parameter of damageability at the characteristic point:

\[ \bar{\omega} = 1 - \left( 1 - \frac{T}{T} (k + 1) B_2 B_1 \right)^{1/3}. \]

Expression (14) is the integral form of writing down the process of damageability under conditions of uniaxial load because it was obtained by integrating the equation of damageability (2) in the case of replacing \( \phi_{0e} \) by \( \bar{\sigma}_{10} = \text{const} \) at the characteristic point. Through the parameters of damageability (11), (14) and, that means, also found by the procedure of the "steady-state" solution of the problem \( q_{10}, \bar{\epsilon}_{10}, W_0, \) it is easy to obtain the values

\[ \sigma_i = \sigma_{10} (1 - \omega)^{\mu / (1 - \omega)^{\mu / (1 - \omega)}}; \]

\[ \bar{\epsilon}_i = \frac{B_2 \sigma_i^{\mu}}{(1 - \omega)^{\mu / (1 - \omega)}} = \bar{\epsilon}_{10} / (1 - \omega); \]

\[ W = \frac{B_2 \sigma_i^{\mu + 1}}{(1 - \omega)^{\mu}} = W_0 / (1 - \omega). \]

Hence follows that the values \( \bar{\epsilon}_i \) and \( \bar{W} \) and, that means also \( \bar{\epsilon}_i, \) at the characteristic point obey the laws of uniaxial strain at a stress equal to the characteristic stress, which remains constant during the process of strain.