and with curved loading paths of constant curvature but different values of the parameter \( 0 \leq \chi_0 \leq 2 \), characterizing the relative curvature of a complex loading path, show the significant effect of complex loading on basic creep characteristics.

The data obtained have made it possible to determine the limits of applicability of existing creep equations (6) and (7) in the case of curved loading paths, i.e., with complex loading paths.

It was established that if \( 0 \leq \chi_0 \leq 1 \), then the loading paths can be considered to be of small curvature, and Eqs. (6) and (7) can be used with a significant degree of accuracy. When the parameter \( \chi_0 > 1 \), it is necessary to perform calculations with refined equations (9) and (10), which consider the curvature of complex loading paths.

**LITERATURE CITED**


**METHOD OF DETERMINING THE RESIDUAL LIFE OF METALLIC MATERIALS**

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Problems of predicting the residual life of metallic materials which have exhausted their design service life under creep conditions in structural elements of machines and yet remain functional have become particularly important in heat and power engineering in connection with the continuous increase in the number of power plants which are approaching or have reached their design life of \( 10^5 \) h.

Some believe that prediction of the residual life of materials damaged in service requires that they be experimentally studied for rupture strength and creep in a manner similar to that used to test the material in its original state.

Specific recommendations at the standards level are needed for methodological aspects of studying residual life, such as selection of temperature ranges for the tests, the duration of the tests, and methods of extrapolating the results, the establishment of correlations between heat-resistance characteristics of the material in the initial state and after service, and determination of the dependence of the predicted strength and ductility characteristics of the service-damaged material on time of service, as well as determination of the reliability of the solutions obtained in relation to the method by which they were obtained. The present article is devoted to the formulative aspect of these problems.

Attempts have been made to use the principle of relative lifetime summation in the following form to determine residual life:

\[
\frac{\tau_{\text{res}} + \tau_s}{\tau_{\text{res}}} = N, \tag{1}
\]

where \(\tau_{\text{res}}\) is the time to rupture at the service temperatures and stresses, determined from the rupture-strength curve of the material in its initial state; \(\tau_s\) is the duration of the service of the structural element; \(\tau_{\text{res}}\) is the residual life of the material in the structure; \(N\) is a durability parameter, taken equal to unity but not reaching this value in the stress region typical of the service of the structural element. In connection with this, as was shown in [1], durability characteristics found from Eq. (1) differ by a factor of two to ten from those established on the basis of experimental results of laboratory tests of specimens of service-damaged material.

Reliable solutions can be obtained for the service-stress region in relation to time of service in developing methods of predicting the parameter \(N\) which do not use Eq. (1).

Since experimental determination of residual life involves a great deal of time and since testing time is limited by standards not to exceed \(10^8\) h (1 yr and 52 days), one cannot avoid using methods of extrapolation to calculate rupture-strength and creep characteristics of service-damaged materials. The Larson-Miller method of linear extrapolation in logarithmic coordinates is presently widely used for this purpose. However, both methods give overstated extrapolated results [1].

Linear extrapolation and parametric methods such as the Larson-Miller method may lead to contradictory results when the test data is associated with a small base (2000-7000 h), as is shown by the data in [2]. This data is depicted in Fig. 1, from which it is evident that all of the rupture-strength curves extrapolated from the Larson-Miller relation for different service times (curves 2-6) intersect from below the rupture-strength curve of the material in its original state 1, which was constructed from tests results on a base of \(10^5\) h (without extrapolation).

Is it possible that a material which has seen service could exhibit a higher strength in later tests than in its initial state if it is given on optimum heat treatment? This question can be answered only on the basis of tests longer than those used in [2], i.e., longer than \(10^8\) h, and at several temperatures in order to allow prediction by nonparametric methods.

Similar test results were obtained in works such as [3] (Fig. 2), but damage to the material here was studied after four service periods. The test results after 6500 h coincide with the initial data, while after 12,000 and 20,000 h the corresponding curves intersect the