AN EXPERIMENTAL ANALYTIC METHOD FOR EVALUATING THE THERMAL-FATIGUE STRENGTH OF STRUCTURAL MEMBERS UNDER NON-STEADY-STATE THERMAL LOADING

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Research on and operation of structural members indicate that thermal-fatigue damage in the presence of a nonuniform temperature distribution is usually localized in definite regions, those of greatest thermal stress. Propagation of thermal-fatigue cracks, which is accompanied by a change in the thermal-stress pattern of the member, soon ceases as the crack apex moves into the zone of lower thermal stresses. Proceeding from this type of thermal-fatigue damage, it can be assumed that simulation only of the thermal-stress conditions in the danger zones (when these do not coincide with the remainder of the model) is sufficient for study of the thermal fatigue of the structural member as a whole.

The problem thus reduces to modeling of the thermal and stress patterns of individual characteristic points and regions of the member under investigation. In this case, the similarity invariants are written in the form

\[ \frac{\sigma_\beta}{E_\beta} = \text{idem}; \quad \frac{\gamma_\beta}{E_\beta} = \text{idem}; \quad \frac{\alpha_\beta T_\beta}{E_\beta} = \text{idem}. \]  

(1)

If the materials of the original and model are identical, i.e., E, G, and \( \alpha \) are identical in both, process similarity occurs for similar points in both when

\[ \sigma_\beta = \text{idem}; \quad T_\beta = \text{idem}. \]  

(2)

In the general case of a complex stress pattern, process similarity occurs when the stress deviators at the points in question in the original and model are equal.

Confirmation of the theoretical possibility of obtaining equal thermal and stress patterns simultaneously can be provided by the results of certain tests conducted in the gas-dynamics facility of the Institute of Strength of Materials, Academy of Sciences of the Ukrainian SSR, using original turbine blades and wedge-shaped specimens [1].

It must be noted that the approach based on evaluation of the onset of component fracture through examination of the similarity of the thermal-stress patterns at the points of greatest stress is justified if there is no plastic deformation during cyclic loading. It is otherwise necessary to consider a certain region with identical thermal and stress patterns, which must include all points of the member where residual deformation can occur. Then, when there is a certain geometric parameter in common as well as the basic conditions, we can speak of similarity of the deformation processes and the character of the stress redistribution in the region under consideration.

As an example of the feasibility of such modeling, Fig. 1 shows the temperature distribution and Fig. 2 the stress distribution in the vicinity of the blade edge and the wedge for different times.

On the basis of the foregoing, we can propose a method for composite experimental-analytic investigation of the thermal-fatigue strength of structural members during non-steady-state thermal loading. This method presumes three basic stages of the investigation.

The first stage is experimental determination of the thermal state of the original subject under real operating conditions and under conditions as close as possible to them. The subject must be subjected to thermometry under natural or laboratory conditions. The results obtained are used to calculate the thermal stresses by the most accurate method currently available. Analysis of the resultant temperature and stress distributions makes it possible to determine the most critical points and regions of the member.

The second stage consists in selection of the model and test regime. Bodies such as cylinders,