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EXPERIMENTAL INVESTIGATION OF STRENGTH AND STRESS-STRAINED STATE OF TURBOMACHINE BLADES

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Results obtained from calculated-experimental studies in lowcycle fatigue of gas-turbine engine blades under multifactorial loading are considered.Equation of limiting state under thermovibrocyclic loadings are obtained.

Keywords: lifetime,strength,stress-strained state,blade

Turbine blades of modern high temperature gas turbine endines with high service life are subjected in service operation to complex loading including static, vibrational and cyclic loads applied in non-isothermal conditions.

Metallographic analysis of turbine fractured blade micro-sections in most cases shows that the cause of blade failure was joint action of the above-mentioned types of loads.In connection with this a problem is appeared to develop methods of full-seale structures durability estimation and to define the conditions of their limiting state at multifactor non-isothermal loading solving this problem is possible on the basis of extensive design-experimental investigations.

This article concerns an attempt to develop method of estimation of turbine blade durability at multifactor non-isothermal loading on the basis of results of design-experimental studies of turbine blades from heat-resistant nickel base alloy of ZhS class.

Blade durability investigation in thermocyclic and thermovibrocyclic loadings was on test-bed VL-2.

Blade heating performed profiled inductor the form of which and location relative to blade profile was determined by the requirement to provide necessary temperature fields with maximul blade edges heating.In half cycle of blade cooling the blade was blown over by air flow from the nozzle.Vibrational loading was performed by means of blade one of characteristic ration modes excitation generated by electrodynamic vibrator.

Blade evolution in stress-straned state in the process of loading was designed using packeted application programmes including programmes for design of blade non-steady thermal state and kinetics of non-elastic distortion of blade section at cyclic nonisothermal loading; programme of blade durability design at multifactor nonisothermal loading and programme of automated processing and graphical presentation of design results.

In estimation of blade section non-stationary thermal state it was considered that:

- blade heating comes from the surface, sources of internal heating are absent;

- a portion of blade section subdivision is of constant theickness temperature of portion section surface is constant and equal to temperature in the middle point of portion surface;

- heat overflow between portions are absent.

With the mentioned assumptions the problem of estimation of blade section non-steady thermal state can be reduced to solving a number of problems of non-stationary thermal conduction, enunciated for every blade section portion, presented as plane wall.

Thermal conduction equation for every blade section portion is as follows

$$\frac{\partial T(x,t)}{\partial x} = a^2 \frac{\partial^2 T(x,t)}{\partial t^2} .$$

For mathematical description of initial and boundary conditions the results of blade section thermometry were used.

Stress-straned state parameters at cyclic loading were defined from design of blade section non-elastic distortion kinetics.Non-linear boundary-value problem in every computation step was solved with method of additional distortions. Computation was made in accordance with beam theory that gives results of satisfactory accuracy for edges - blade elements with highest load.

Structural model of elastoviscoplastic medium on the basis of material element representation as a set of sub-

Blade test programme consisted of the following stages:

1. Investigation of initial characteristics of blade high-cycle fatigue strength in isothermal conditions with temperatures T=950,1000,1050,1100 °C.

2. Investigation of blade thermal fatigue characteristics for maximum cycle temperatures T_{max}=950,1000,1050,1100 °C and minimum temperature T_{min}=350 °C with maximum temperature exposure during 30 s.

3. Investigation of blade durability for various combinations of thermocyclic and vibrational loads with static damage due to maximum temperature exposure during 30 s.

On the bases of these results a relation is proposed for blade durability estimation at non-isothermal multifactor loading:

$$Z_{H\Phi} = Z_p \left[1 - \left(\frac{\sum^{Z_{H\Phi}} \tau_i}{\tau_p}\right)^{\beta}\right]^{1/\alpha} \left[1 - \left(\frac{\sum^{Z_{H\Phi}} N_i}{N_p}\right)^{\eta}\right]^{1/\xi} = Z_p K_\tau K_N ,$$

where Z_p - durability at thermocyclic loading;

K_τ and K_N - coefficients taking into account the effect of static and vibrational loading correspondingly on durability exhaustion.

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