FATIGUE STRENGTH TESTING OF TURBINE BLADE SIMULATORS IN A GAS FLOW

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In connection with the expanding stock of aircraft engines and the general trend toward higher operating gas temperatures ahead of the turbine, the fatigue strength and durability characteristics of elements in the "hot" part of the engine acquire an ever increasing importance.

As is known, the parts which determine to a large extent the reliability and durability of gas-turbine engines (GTE) are the turbine blades. For reliable estimates of the fatigue strength and durability of turbine blades, the heat-resistant blade materials and structural elements must be investigated under conditions approaching the operating conditions [1-3].

Since the durability of turbine blades is considerably affected by the static tensile loads created by centrifugal forces, the fatigue strength of blades must be investigated with an allowance for these loads if the testing conditions are to be realistic. Therefore, we used blade simulators (Fig. 1), which made it possible to reproduce in fatigue tests the tensile stresses due to centrifugal loads in the operating cross section of the simulator.

The blade simulators were made of the ZhS6-K nickel-based cast alloy, which is widely used for turbine blades in GTE's. The simulators consisted of blades with two locking elements and a constant transverse cross section in the operating part. The operating part of the simulator had the same profile as an actual GTE blade in the region of the lowest safety factor. The operating part of the simulator passed smoothly into the profile of an actual blade at the root section. The treelike locking elements, provided at both ends of the blade simulator, served for mounting it in special grips. The transition of the profiled part at the root section into the intermediate shelf, the shelf itself, and the treelike locking element were made to conform to the dimensions of an actual blade.

The center of gravity of the operating section was on the longitudinal axis of the locking element, which prevented bending of the simulator in cyclic extension. The length of the simulator's profiled part was determined with an allowance for heat transfer to the locking elements in order to secure a small temperature gradient along the profile and normal temperature conditions for the locking elements.

The blade simulators were made according to the technology used in manufacturing cast GTE blades [4].

Fig. 1. Turbine blade simulator.
The heat treatment conformed to the standard conditions used for the ZhS6-K alloy. The dimensions of the profiled part were checked by means of master forms. Moreover, the blade simulators were checked for cracks by using the color-luminescent flaw detection method. Technological annealing in an argon medium was performed after mechanical finishing in order to remove the cold hardening and residual stresses. The chemical composition and the mechanical properties of the blade material conformed to the specifications for the ZhS6-K alloy.

The blade simulators were subjected to fatigue tests in a TsDM Pu-10 universal testing machine, which reproduced the tensile stresses in the blades resulting from centrifugal forces and also applied variable loads.

Special grips made of the 1437B heat-resistant alloy were designed for fatigue tests at elevated temperatures. Treelike grooves were made in the grip heads for mounting the blade simulators. During the experiments, the blade simulators with the heat-resistant grips were inserted in the grips of the TsDM Pu-10 testing machine.

Under cyclic constant-sign tensile loads, the absence of blade bending was ascertained by means of tensometric measurements. Eight resistance strain gauges with a 15-mm spacing were pasted on the surface of the operating profiled part (Fig. 2). Standard equipment was used for the tensometric measurements: a TA-5 tensometric post and an N-700 loop oscillograph.

In order to find the simulator position in which the line of load application passed through the center of gravity of the profile, the blade simulators were moved along the profiled grooves in the grips and were periodically loaded. This position was fixed in the grips. Investigations showed that the normal stresses were uniformly distributed over the section of the simulator's profiled part, while they slightly decreased at the edges (see Fig. 2). The nominal stresses for the operating blade section were used in plotting the fatigue curves.