INFLUENCE OF RUNNING TIME UNDER SERVICE CONDITIONS AND THERMAL CYCLING ON THE FATIGUE LIFE OF THE WORKING BLADES OF GAS TURBINE ENGINES

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The development of methods of quantitatively assessing the damage suffered by the jet and working blades of gas-turbine engines used in various forms of transport is extremely important in connection with determining the reliability and working life of the engines as a whole. For studying the damage suffered by the materials of the hollow jet blades, which is largely associated with transient thermal loads, the method of studying the low-cycle fatigue of samples cut from blades which have already been run in service conditions [1] may be recommended.

The disadvantage of this method lies in the fact that, in cutting the blades apart, it is impossible to study the most loaded and hence most damaged parts of the cross section (the edges), owing to the impossibility of preparing samples from these.

It is extremely difficult to apply such methods for studying the damage suffered by the working blades during service owing to the complicated form of their plumes.

In this case, in order to assess the accumulated damage it is more appropriate to use the "complete fracture" method in order to determine the residual life of the working gas-turbine blades under consideration.

In the present investigation we studied the working blade of the first stage in a marine gas-turbine engine made from the chromium — nickel alloy É1826 (Fig. 1). This was first run under service conditions in the actual engine, and also in a gasdynamic test-bed which applied cyclic thermal loading to the blade in a gas flow of variable parameters simulating the most dangerous transient working conditions of the engine: starting (mode I) and stopping (mode II). Tests in the gasdynamic test-bed were also carried out under boosted conditions (mode III).

The ranges of variation of the flow temperature were respectively 150 — 700°C, 820 — 150°C, 150 — 1250°C.

The forms of thermal loading were described in more detail earlier [2, 3].

The residual service life was determined by the complete-fracture method, using a VL-1 electrodynamic vibratory test machine [4].

The blade was fixed to the movable table of the vibratory machine (Fig. 2) in a special resonance clamp. The natural vibration frequency of the head of the clamp, together with the fixed part, relative to the base equalled the natural vibration frequency of the blade under test, which in this case played the part of a shock absorber for the vibrational energy of the massive head of the clamp.
This arrangement increases the efficiency of the vibratory machine by a factor of several times, which is especially important when testing parts having a high natural vibration frequency, for the working blades commonly employed approximately 1800 Hz.

The dynamic system of the test-bed was supplied from an amplifier controlled by an acoustic generator of the TESLA type.

Dynamic calibration of the blade was effected by means of wire-type strain-gauge resistors, a tensometric amplifier of the TA-5 type, and an N-102 loop oscillograph.

The strain-gauge resistors were bonded to the sample at the places at which fatigue cracks were expected, being oriented perpendicularly to the cracks formed in the paint coating.

During the operation of the system, the operating conditions of the test were monitored by reference to the amplitude of the vibrations at the end of the blade, as measured with a binocular microscope of the MBS-2 type.

Figure 3 shows the fatigue curves obtained for untested working blades and for blades already run in the engine, following a program which included the main transitional processes (starting, stopping, etc.) and steady-state conditions at full or almost full power of the engine to an extent corresponding to the reserve life.

as in the case of the jet blades [1], subjection to service conditions on the basis under consideration does not produce any serious fall in the fatigue strength of the working blades.

It is a characteristic feature that the slight increase in this parameter which appears in working blades already run under service conditions is more substantial at high loading levels.

Figure 3 also shows the residual working life of blades previously tested in the gasdynamic test-bed (with cyclic temperature variations) for 2500 cycles (mode I), 1500 cycles (mode 2), and 11,000 cycles (mode III).

Complete-fracture tests were conducted at a single load level, close to the fatigue limit of new blades (~26 kg/mm²).

Analysis of the results showed that the residual life of the blades which had already experienced service differed very little from that of blades tested in modes I and II. This indicates that the conditions under which the blades were operating in the test-bed simulator were almost exactly the same as those encountered in practical service.