An experimental bench for testing the cracks detecting technology in the blades of working aircraft engines

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Abstract. The work is devoted to the development of technology for detecting cracks in the aircraft engines blades during an airplane flight without stopping it. For these purposes, a method is proposed and an experimental installation is designed to verify it and obtain results for the application of this technology in practice. The main experimental tasks are set, which are planned to be worked out on this installation.

1. Introduction

The most loaded elements operating in very difficult conditions in aviation technology are the blades of turbine in aircraft engines. The blades of gas turbines are bodies of complex geometric shape made of heat-resistant nickel-based alloys with a large number of alloying additives. For the first stages of turbines, as a rule, hollow blades with perforated walls or an internal insert (deflector) are used to organize their cooling. The following factors have the main effect on the blades:

1) High main loads due to high rotation speeds and the resulting centrifugal forces.
2) Additional loads due to bending moments.
3) Thermal stresses arising due to temperature differences along the blade profile and height.
4) Stresses arising due to pulsations of the incoming gases flow and due to changes in engine operating conditions.

All this leads to a very strong uneven stresses at different times on the turbine blades, which cannot be accurately predicted in time. Additional complicating factors are blades vibrations and the high temperature of the gas flows washing the blade, because of which the blades working temperature can reach 1500–1600 °C. The currently accepted calculation practice estimates the strength of the blades according to the criterion of the material permissible long-term strength, taking into account some safety factors.

2. Materials and methods

Uncertainty of factors affecting the blades stresses and its random time change can lead to the fact that under certain conditions the real stresses values will exceed the calculated values taking into account the safety factors. The consequence of this may be the occurrence of fatigue cracks in the gas turbines blades of aircraft engines. The appeared crack may grow. The crack growth by the stress concentration arising near the blade peak is supported. A growing crack gradually spreads over large parts of the blade area. Ultimately, the remaining cross-sectional area of the blade becomes insufficient to withstand the existing stress from the loads and the blade or it part breaks.
According to [1], a blade or its part breakage occurs at a time when the crack length reaches 30 - 40% of the blade chord length. Practice shows that cracks can occur in any part of the blades: at the peaks, in the middle part and in the root part of the blades. The spreading directions of cracks are different. As a rule, cracks spread across the blades, but in the peripheral part of the blades there are cracks having a diagonal direction at an angle of about 45° to the blade nib profile.

The crack formation processes in gas turbine blades are discussed in detail in [2-4], and cracks examples and the consequences of it appearance are shown in figures 1-3.

Figure 1. The gas turbine blade with the destruction of the peripheral part.

Figure 2. The gas turbine blade with a crack in the root.
The crack growth process from the moment of its occurrence to the blade breakage or its destruction can take a sufficient amount of time, according to [1] is about of 5 to 25 hours. The following consequences are possible with the blade destruction or its breakage:

1) The engine continues to rotate. In this case, there is clap and flash with temperature increasing and possible engine ignition. As a rule, engine speed is reduced, increased vibration is appeared. Engine operation becomes unstable, traction is greatly reduced. It needs to stop it.

2) The destroyed parts of the engine blades, getting into the flow part, cause it to jam. The engine stops abnormally. This is accompanied by an increase in engine temperature and sometimes ignition.

3) When the blade breaks, it breaks through the external engine casing and the internal turbine casing. This leads to the release of hot gases, possibly to ignition of the engine and its emergency stop. In any case, the destruction of the blades in flight leads to the blade breakage or destruction can reduce the risk of emergency situations. This problem is especially relevant for single-engine aircraft.

In [5], a method for detecting microcracks is proposed by detecting microcracks in products, including the blades of working turbomachines. The essence of the method is as follows. Thin-walled capsules with the active substance are placed under pressure in the body of the blade (Figure 4).

When cracks appear that still do not lead to the destruction of the blade, the walls of the capsules are destroyed due to pressure difference between the capsule and the flow part, and the active substance enters the turbine flow part, where a recording device detects it.

To test this technology at Komsomolsk-on-Amur State University, an experimental installation the scheme is shown in Figure 5 has been developed and is being manufactured.

Installation works as follows. A fan 1 supplies air to the flow part, in which a sample with capsules of the active substance 2 is fixed. Microcracks can be applied to the sample. Using devices 3, it is possible to subject it to loading. Through the tube 6, fuel is supplied to the air, which is atomized by the nozzle and burns, and the temperature of the gases rises to the required value. The sensor 7 controls the temperature of the gases, which can be used as a thermocouple or thermistor. To register the active substance in the flow part, it is planned to use the following methods:

**Figure 3.** The gas turbine blade with a crack in the middle part.
1) A substance that is easily ionized at a relatively low temperature is used as an active substance. When moving in the flow part, it causes a current on the electrodes 4 installed in the flow part. The recording device 5 records this current surge. The recording device may be a writing oscilloscope, which will show the signal in the form of a step. By the magnitude and duration of the signal, we can determine the amount of active substance received in the flow part.

2) The active substance (for example, natrium) has characteristic spectrum lines in the radiation spectrum, which are recorded optically.

**Figure 4.** Diagram of a method for detecting microcracks.
1 - blade; 2 - capsules with the active substance.

**Figure 5.** Scheme of the experimental installation.
1 – fan; 2 – sample with capsules of the active substance; 3 – loading devices; 4 – flow part electrodes; 5 – recording device; 6 – fuel tube; 7 – temperature sensor.
The constructed experimental installation is planned to be used to solve the following research problems:

1) The choice of active substance type, in order to obtain the maximum recording signal.
2) Effect research of active substance concentration in the flow part on the value of the recorded signal.
3) A comprehensive effect research of shell thickness, active substance pressure in the capsule and crack width on the magnitude and duration of the recorded electrical signal.

3. Conclusion
The results obtained in experimental researches will practically recommend methods to improve the safety of aircraft engines in flight and reduce the accident rate of air transportation.

References
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