High-temperature fatigue testing of turbine blades

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Abstract

The power and efficiency of an aircraft engine mainly depend on the inlet gas temperature. Therefore, it is desirable to increase a temperature of the flue gas to the combustion temperature of aviation fuel, which is about 2300°C. However, the limitations are the strength properties of the alloys from which the blades are produced. Nickel superalloys are typically used in such conditions. Additional application of thermal barrier coatings (TBC) on nickel-based superalloys allows to increase the effective service temperature to 1300°C, while the temperature on the blade attachment does not exceed 300°C. An aggressive environment is another factor that affects a durability of the engine turbine blades. Fuel combustion products (e.g., Na_2SO_4, NaCl, V_2O_5), oxidation, hot corrosion, erosion, and foreign object damage could significantly reduce their service life. High-temperature fatigue testing of materials operating in aggressive environments is crucial in the service life assessment of high-strength materials used in aircraft engines. However, these strength characteristics are usually determined for standardized specimens, that do not reflect the complexity of turbine components. Such an approach provides only limited information about component behaviour since only material-related features could be revealed during testing. One should highlight, that the testing of the critical engine components should be performed under conditions reflecting actual ones. Therefore in this paper, an effectiveness of the patented grip for high-temperature fatigue testing was assessed to determine the fatigue strength of full-scale nickel-based turbine blades operating under their environmentally simulated conditions. Before fatigue tests, a bending test was performed to reveal the stress-displacement characteristics of the testing component. Subsequently, a series of fatigue tests were performed at a temperature of 950 °C under a cyclic bending load in a selected values of force amplitude (5.2 kN – 6.4 kN) using different frequencies (1 Hz – 10 Hz). The proposed setup involving a grip fixed to the conventional testing machine was successfully used during high-temperature experiments as the service life of the full-scale components was determined.