Thermomechanical Fatigue Analysis of an Aircraft Engine Turbine Blade

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Abstract:

Aircraft engines are inherently subjected to various types of failures due to foreign object damage, vibration-induced mechanical issues, high-temperature-related corrosion, and fatigue. Among the engine components, the turbines are notably affected by these failure mechanisms. In aircraft engines, turbine blades are subjected to extremely high temperatures. Throughout all phases of flight, from take-off to landing, turbine blades are influenced by a wide range of thermal and mechanical loading cycles, which significantly impact their structural integrity. Owing to the critical role these cycles play in the operation of aircraft engines, the failure mechanisms of turbine blades have been established as an important area of research. Numerous experimental studies and tests have been performed to analyze the thermal and mechanical fatigue of turbine blades. Due to the complexity and high cost associated with replicating all thermal and mechanical cycles, a significant number of numerical studies have also been carried out.

In this study, a turbine model consisting of a turbine blade and its dovetail, including the fixturing conditions to the turbine disk, are developed using ANSYS Workbench. Once the model is created, the thermal, aerodynamic, and mechanical loading cycles corresponding to various flight stages are applied and evaluated using appropriate tools within ANSYS.

It has been documented that turbine blades in aircraft engines can be exposed to temperatures as high as 3500°F. Additionally, centrifugal loads are generated on the blades due to rotational motion. During take-off and landing cycles, turbine blades are further subjected to varying aerodynamic loading conditions. These loading scenarios are segmented according to different flight stages and analyzed individually. Subsequently, the cumulative low cycle fatigue (LCF) behavior of the turbine blade model is examined. Various failure criteria are considered throughout the evaluation. To ensure a comprehensive analysis, the interaction between the turbine blade and disk is also simulated.

Keywords:

Thermomechanical fatigue, tubine blade, finite element.