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Thermo-mechanical analysis and estimation of turbine blade tip clearance of a small gas turbine engine under transient operating conditions (Article)

Kumar, R.[a], Kumar, V.S.[b], Butt, M.M.[a], Sheikh, N.A.[a], Khan, S.A.[c], Afzal, A.[d]

[a]Department of Mechanical Engineering, NIT Srinagar, Jammu and Kashmir 190006, India
[b]Propulsion Division, CSIR-National Aerospace Laboratories, Bengaluru, 560017, India
[c]Department of Mechanical Engineering, Faculty of Engineering, IIUM Kuala Lumpur, Malaysia

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Abstract

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Turbine blade tip clearance is one of the significant factors that influence turbine efficiency, Specific Fuel Consumption (SFC), Exhaust Gas Temperature (EGT), and emissions. Controlling these parameters in a small gas turbine engine (SGT) is a challenging task due to small blade height and viscous working environment. SGT are subjected to high-temperature gradients at the combustor outlet, which affects the turbine blade tip clearance . This paper presents the thermo-mechanical analysis of a typical SGT engine to study the blade tip clearance influenced by the deformation of turbine stage components (turbine rotor, nozzle guide vane (NGV) with integral blade shroud) during transient phases. ANSYS Workbench is used to perform transient thermal and structural analyses. The structural analysis is performed taking the material properties to be temperature-dependent. The SGT engine under consideration operates at a design speed of 45,000 rpm. Initially, steady-state thermal analysis and static structural analysis were carried out to understand the structural behaviour of the system under a thermal and centrifugal loading environment. Since different components of the engine assembly operate at different temperatures, the effects of convection and conduction at the interfaces influence the radial clearances between the static and rotating parts of the engine . A one-way coupled transient thermal-structural analysis was performed on a three-dimensional model to capture the actual behaviour of the tip clearance during transient operating conditions . Significant growth of blade and rotor was observed relative to the casing resulting in minimal clearances during these transient operations. Hence, it is important to estimate desired cold clearance , considering transient phenomena, to avoid mechanical blade rub with the shroud. It is observed that high-temperature gradients contribute primarily to the stresses and radial displacement of the rotor compared to centrifugal effects. The turbine rotor takes more time (t = 600 s) to reach steady-state temperatures compared to NGV (t = 120 s) due to the solid mass of the disc. The location and magnitude of maximum and minimum equivalent stress changes with time in NGV and rotor, and they experience maximum stress at the initial time steps compared to steady-state. © 2020 Elsevier Ltd

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Topic: Blade Tips | Winglets | Film Cooling

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Author keywords

Blade tip clearance | Deformation | Small gas turbine | Thermo-mechanical | Transient | Turbine

Indexed keywords

Engineering controlled terms: Aircraft propulsion | Fuel consumption | Gas emissions | Gas turbines | Structural analysis | Thermal gradients | Thermoanalysis | Turbomachine blades

Engineering uncontrolled terms: Convection and conduction | Static structural analysis | Steady-state thermal analysis | Thermal and structural analysis | Thermal-structural analysis | Thermo-mechanical analysis | Transient operating condition | Turbine blade tip clearances

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