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PROCEEDINGS

Experimental and Numerical Methods for Characterizing Thermal Gradient Induced Stress in Elevated Temperature Fatigue Testing

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ABSTRACT

Advanced air-cooling turbine blades are capable of operating above the melting temperature of Nickel-based superalloy, which accordingly withstand complex thermomechanical fatigue loads during service life. This paper considers the problem of realizing gas turbine representative thermal gradients in the elevated temperature fatigue test, while ensuring the thermal gradient induced stress inside the specimens. For this purpose, a novel temperature control device utilizing impingement cooling, which supplies cooling air inside the gauge section and releases toward the inner wall, was constructed in tubular fatigue specimens. A single induction coil was arranged outside the gauge section, providing heat sources to establish thermal gradients toward the center. To accurately evaluate the temperature field in the tube, electromagnetic-fluid-thermal analyses was utilized, which allows taking into account influences of induction heat source and impinging heat transfer. Impinging flow correlation has been found, with the participation of a similarity test rig, to calibrate the heat transfer coefficient distribution on the inner wall of specimens. The credible temperature field was then introduced into a thermal-structure interaction analysis to investigate the thermal gradient induced stress. Ultimately, the stress distribution was studied by experimental measurements using high-temperature strain gauges. It is found that jet impingement can prominently enhance the cooling efficiency on the inner wall, which induces the maximum thermal gradient and tensile stress in the gauge section. In particular, the inside tensile thermal stress is almost inversely symmetric with the outside compressive thermal stress, the magnitude of which is positively correlated with the heat flux.

KEYWORDS

Elevated temperature fatigue; impingement cooling; electromagnetic-fluid-thermal analysis

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