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LES OF JET-CROSSFLOW INTERACTIONS: FLOW STRUCTURES AND HEAT TRANSFER CHARACTERISTICS

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ABSTRACT

The evolution of a normally injected jet and associated heat transfer over a semi-circular leading edge of a constant thickness aerofoil has been discussed here by Large Eddy Simulation. The setup is a simplified representation of film cooling near the leading edge of a gas turbine blade. Three-dimensional, unsteady, filtered mass, momentum and energy equations are solved for Newtonian incompressible flow on a Cartesian grid. To resolve the leading edge, details of film cooling hole along with plenum chamber, the Immersed Boundary method is used. The critical issues of various vortical structures, namely, counter rotating vortex pair, roller vortex, upright wake vortex, horseshoe vortex, Downward Spiral Separation Node vortex and hovering vortex associated with jets in crossflow (JICF) has been successfully resolved. Hairpins resolved may be considered as an overall signature identifying them as the primary coherent structure. Further, the vorticity and temperature field are highly correlated. Thus, evolution of hairpins, their stretching and convection control scalar (temperature) transport and mixing of JICF. Film cooling effectiveness becomes highly unsteady and is dictated by the dynamics of hairpins. A low value of effectiveness is observed below the head of the hairpin and immediate upstream due to jet lift off, while, the surface between two consecutive hairpins appears to have relatively high effectiveness as the horizontal legs of hairpin come closer to the wall. Further, the Kelvin-Helmholtz rolls shed from the upstream separated boundary layer induce oscillations of the ejected coolant jet resulting in temporal variation of near field effectiveness. This kind of interactions resulting in oscillation of injected jet has not been reported earlier and would be absent for film cooling when the approaching boundary layer is attached.