Optimization of Turbine Film Cooling Using Navier Stokes Equations

By

Eng. Ahmed Mohamed Elsayed Ahmed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
AEROSPACE ENGINEERING

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Title of Thesis: Optimization of Turbine Film Cooling Using Navier Stokes Equations

Key Words: cooling, blade, optimizations, simplex, leakage, tip

Summary: There is a need to have an efficient cooling system engineered in a way such that the maximum blade surface temperature during the engine operation does not exceed the maximum allowable temperature of the blade material. In addition, the tip leakage flow across the turbine blade reduces its aerodynamic performance and causes blade-tip overheating due to this high speed flow and the existence of a thin boundary layer. In the current study, film cooling on a flat plate is studied numerically to select the different parameters of the compound-hole shape that could enhance the cooling effectiveness. The flow on the flat plate with film cooling is numerically simulated using the steady, compressible Navier-Stokes equations with turbulence modeling. The flow solver is coupled with an optimization technique to obtain the cooling parameters. The simplex algorithm is used for the optimization procedures. The cooling-hole shape is defined in terms of four variables which are the streamwise angle, the lateral diffusion angle, the forward diffusion angle, and the coolant blowing ratio. Different blade-tip configurations are used in turbines including flat tip, single squealer and double squealer. The effect of these configurations on the turbine losses is investigated numerically on GE-E3 turbine blade.The results indicate that, five stagger cooling arrays on the pressure side and three stagger cooling arrays on the suction side with LFDCA-9.3-14.6 hole-shape are enough to have good cooling of the two sides using 2.17% bleed air of the engine.

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