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THE PHYSICS OF FILM COOLING FLOW AND HEAT TRANSFER

Sumanta Acharya
Ring Companies Chair
Mechanical Engineering Department
University of Memphis, Memphis TN 38152
Email: S.Acharya@memphis.edu

ABSTRACT Modern gas turbine airfoils are subject to gas temperatures in excess of 3000^0 F that are well above the material limits for reliable operation. The airfoils have to be therefore actively cooled to prevent engine failure. Film cooling is commonly used and involves pushing the coolant air through inclined holes drilled on the airfoil surface. While there is a significant body of experimental and computational literature on the film cooling problem, most of the effort has been focused on improving geometric designs to enhance cooling effectiveness and in developing correlations or the predictive capability for use in turbine design. A fundamental understanding of the flow structures and their relationship with the surface heat transfer is largely missing. In this paper, attention is focused on the flow physics of film cooling flows, and the current understanding of this flow physics is reviewed. Large Eddy Simulation (LES) results are analyzed to understand the origin and development of flow structures. The spectral characteristics of both the flow and thermal fields will be studied in order to identify the frequencies associated with these structures and to examine which of these play an important role on the temperature distributions near the surface (or the cooling effectiveness). These results indicate that low frequency modes play an important role in near wall mixing and temperature distributions. An alternate geometry is explored where the hole exit is embedded within a V-shape crater. For different crater depths the low frequency structure modes are dramatically altered, and have a significant and beneficial impact (three-fold improvement) on the cooling effectiveness.