A Combined Numerical and Experimental Study of Heat Transfer in a Cooling Channel Roughened with 90^o Ramped Ribs

by

B. Ren and M.E. Taslim

Mechanical and Industrial Engineering Department

Northeastern University

Boston, Massachusetts, USA

m.taslim@neu.edu

Abstract

Varieties of cooling methods have been used to protect the hot sections in modern gas turbine engines so as to allow a higher inlet temperature for increasing turbine efficiency. One such method is to route the air through passages roughened with ribs within the airfoil and enhances heat transfer. Much work is reported in open literature dealing with a variety of rib geometries and flow arrangements. This study's focus is on the ramped-ribs. Both upstream and downstream ramps are investigated. The presence of these ramps could be by design or by the accumulation of micron-size external particles that pass through the gas turbine in hot and harsh environment operations. A square channel roughened with 90° ribs of three geometries was tested. Square as well as ramped (with decreasing or increasing slopes in the flow direction i.e. ramping up or down) ribs in a staggered arrangement were studied. Square ribs of the same height as the ramped-ribs were tested first to which the ramped-rib results were compared. The numerical models contained the all features of the tested geometries. The applied thermal boundary conditions to the CFD models matched the test boundary conditions. Numerical results were obtained from a three-dimensional unstructured computational fluid dynamics model with over 8 million hexahedral elements. For turbulence modeling, the realizable $k - \varepsilon$ was employed in combination with enhanced wall treatment approach for the near wall regions. In the experimental part, all these geometries were built and tested for heat transfer coefficients at a Reynolds numbers range from 10,000 to 60,000, using steady state liquid crystal thermography. Comparisons were made between the test and numerically-obtained results in order to evaluate the employed turbulence models and validate the numerically obtained results. The test and numerically evaluated results showed reasonable agreements between the two for ramped cases. Friction factors were also measured, and both heat transfer and friction factor results for the three rib geometries were compared. The results showed that the heat transfer coefficient are strongly affected by the rib shape and square ribs provide higher heat transfer enhancement and pressure drop than other shapes.