CONJUGATE HEAT TRANSFER INVESTIGATION OF A FIXED RIB ROUGHENED COOLING CHANNEL

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In turbine cooling channels, pressurized compressor air is routed through various cooling channels and is ultimately discharged into the external hot gas path, thereby extracting thermal energy from the airfoil based on internal forced convection. These serpentine passages are commonly equipped with repeated flow perturbators in order to enhance convective heat transfer by promoting turbulence, at a cost of pressure drop penalty. In addition, to protect the outer layer of the turbine blade from beyond material limit gas temperatures, an external film cooling is also commonly employed via bleeding holes connecting the internal passages to the exterior.

The study is in part geared towards quantifying the effects of internal coolant flow implications of film cooling holes. In this regard, tests are conducted in a generic cooling channel model, with evenly distributed rib type perturbators along with surface-perpendicular film cooling holes. Through liquid crystal thermometry measurements, the aero-thermal effects of a change in purge rate are contrasted for various configurations. At increased purge rate, the size of the separation bubble downstream of the rib is observed to diminish, triggering globally earlier reattachment, in addition to low-momentum hot fluid purge through the film cooling suction. Hence, in the presence of active purge flow, higher overall heat transfer characteristics are observed throughout the channel. Moreover, the findings are generalized via friction factor and Nusselt number correlations, along with an analytical 20-pitch passage model.

In addition, investigating a model of an internal cooling channel, the reproduced thermal boundary conditions should resemble the engine environment. The heat transfer process exhibits a coupled character, involving convection in the fluid domain and conduction in the solid, the impact of which can be large in case of large spatial thermal gradients and/or geometrical asperities. In purely convective studies, where uniform heat flux is imposed along the wetted surface, the thermal boundary conditions are clearly not realistic; the effect of the thermal history of the flow field is neglected. In this regard, the present investigation focuses on a deeper understanding of the conjugate heat transfer phenomenon by conducting experiments conducive to fundamental understanding, as well as creating a baseline database for numerical investigations. Through infrared thermometry measurements over the wetted surface and via energy balance within the solid, conjugate heat transfer coefficients are calculated over a single rib-pitch. The local heat extraction is demonstrated to be a strong function of the conduction effects, observed more dominantly in the rib vicinity. In addition, the different heat transfer enhancement effects of various aerodynamic flow structures are investigated. Furthermore, the results are contrasted with the iso-heat-flux wetted boundary condition test case. Neglecting the thermal boundary condition dependence, and thus the true thermal history of the boundary layer, is demonstrated to produce large errors in heat transfer predictions.

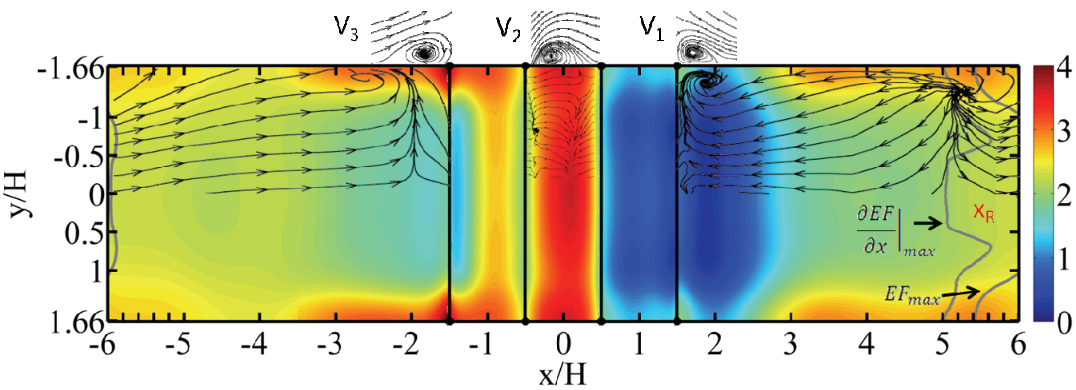

Figure 1 : Pitch Conjugate Enhancement Factor Distribution