AERODYNAMIC PERFORMANCE INVESTIGATION OF FIXED RIB-ROUGHENED COOLING PASSAGES

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In modern gas turbine engines, an efficient blade cooling is absolutely mandatory to allow high turbine inlet temperature and thermodynamic efficiency. A complete and correct understanding of the convection mechanisms associated to the applied cooling techniques is therefore of major importance. The present experimental study is dealing with the detailed aerodynamic investigation of the turbulent flow inside a rib-roughened turbine blade cooling channel. Inside the passage, the forced convection cooling process is significantly enhanced by the presence of the ribs (turbulence promoters) installed on one wall of the channel. The effects of the rib size and orientation on the flow behaviour and therefore on the heat transfer and pressure distribution on the channel walls, are closely related to the safe operation of HP gas turbine blades.

The present research effort is devoted to the experimental analysis the flow inside a cooling channel on the basis of detailed aerodynamic measurements performed by Particle Image Velocimetry (PIV). The principal aims are to provide new information about the behaviour of such a complicated flow, useful for its understanding, to complement the wall heat transfer coefficient distributions already available and to create a wide and reliable data base for numerical code validation.

The experiments are carried out on a scaled up model of a turbine nozzle blade cooling channel, working in geometrical and flow similarity conditions. Inside the channel ribs are installed on one wall. The ribs have an angle of attack with respect to the "mean" flow direction equal to 90° and a blockage ratio equal to 30%.

A global three dimensional view of the flow was attempted by measuring the whole flow filed in between two consecutive ribs over different and mutually perpendicular planes. Where the data were available, those measurements were compared with previous ones, showing a remarkable agreement, and with some numerical of the flow. Moreover, analyzing of the experimental data in different planes, a lot of information regarding particular flow structures in terms of their localization and size, was found, as shown in the figure below. For some of them, a model describing their evolution was proposed.

The combined interpretation of the PIV results and of the available heat transfer measurements on the channel walls, allowed to highlight the existing links between the aerodynamic and thermal behaviour of the flow. The non-isotropic nature of the turbulent phenomena was found to be of fundamental importance in the heat transfer process. In particular, high levels of heat transfer were found to be consistent with high levels of the shear stresses component computed with velocity fluctuations normal to the wall. This behavior is justified looking at the wall events effective on the heat transfer, such as ejection, sweeps, out- and inward events. For the first time a correlation to estimate the heat transfer field from the aerodynamic data is presented for the high blockage rib roughened channel flow.

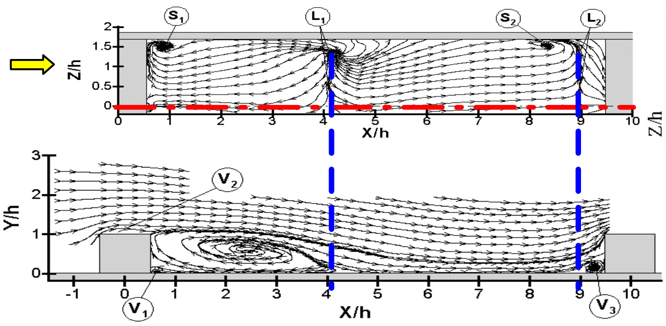

Figure 1: Time averaged velocity field in the symmetry the ribbed wall of the channel.

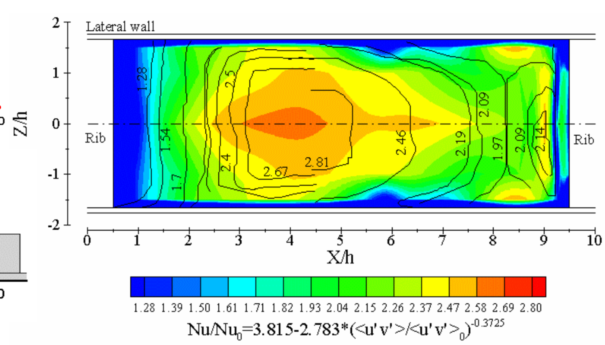

Figure 2: Comparison between the distribution on the ribbed wall of the measured Nu number (iso-lines) and the Nu number computed from the aerodynamic field (contour-plot).