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HEAT/MASS TRANSFER IN LOW & HIGH ASPECT RATIO RECTANGULAR PASSAGES

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ABSTRACT

The paper presents an experimental study of heat/mass transfer coefficient in rectangular channel (1:4 and 4:1) with smooth or ribbed walls for Reynolds number in the range of 5000 to 40000 and Rotation numbers in the range of 0-0.12. Such passages are encountered close to the mid-chord sections of the turbine blade (1:4) and moving away from the mid chord towards the trailing edge of the blade the channel becomes more rectangular as the blade becomes thinner (4:1). Normal ribs (e/Dh=0.3125, and P/e=8) are placed on the leading and the trailing sides only. The experiments are conducted in a rotating two-pass coolant channel facility using the naphthalene sublimation technique. For purposes of comparison, selected measurements are also performed in a 1:1 cross-section. The local mass-transfer data in the fully developed region is averaged to study the effect of the Reynolds and the Rotation numbers. The span-wise mass transfer distributions in the smooth and the ribbed cases are also examined [1].

For a smooth channel, the 1:4 cross-section shows lower levels of enhancement along the destabilized surface, and higher levels of degradation along the stabilized surface compared to the 1:1 cross-section channel. Thus, for a specific parameter value, the 1:4 cross-section channel has lower heat transfer rates compared to the 1:1 channel.

For a smooth channel, the span-wise distributions along the destabilized surface show a peak at the center and decrease toward the corner. Along the stabilized surface, the center has the lowest heat transfer value and the values increase toward the corners. A crossover point is observed near the corners where the stabilized surface has higher heat transfer than the destabilized surface.

For the smooth duct, the Sherwood numbers are relatively insensitive to Re. For the ribbed duct, the Sherwood number ratios show a weak Re number dependence under stationary and rotating conditions, with Sherwood number ratios decreasing with Re.

At Re=30,000, as Ro is increased from 0 to 0.045, the 1:4 cross-section smooth duct shows roughly a 10-12% change in the inlet duct relative to the stationary case. For the ribbed duct, the corresponding change is about 18%. This observation is consistent with the square-aspect ratio results of Johnson et al. [2] who also show that 90-degree trips show a greater sensitivity to Ro compared to the smooth channel.

The span-wise distribution for the ribbed cases show fairly uniform distributions in the mid-span regions, and unlike the smooth channel case, the peak heat transfer rate on the stabilized surface is highest in the middle.

The mass transfer ratio gradually increases with increasing channel aspect ratio. This is because that, for the same rib geometry and flow condition, the high aspect ratio channels have wider ribbed side surfaces (i.e. narrower smooth side walls) to produce higher heat transfer coefficient, while the low aspect ratio channels have narrower ribbed side surface (i.e. wider smooth side walls) to produce lower heat transfer coefficients.

The Sherwood number ratio decreases with increasing Reynolds number. The centerline effect of rotation on the mass transfer ratio is strongly dependent on aspect ratio.

This study provides data for the study of the internal cooling of turbine blades and to validate the computational data. It also provides insight into the nature of flow and heat transfer in internal cooling passages as a function of design.

FIGURES AND TABLES

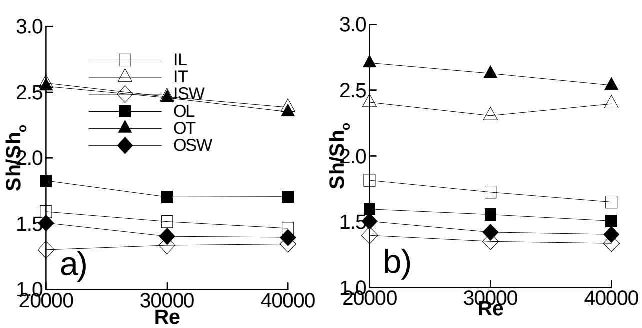

Figure 1: Effect of Reynolds number at Ro=0.025, AR=4:1(Fully developed averaged normalized Sherwood number a) Ribs on Trailing Side b) Ribs on Leading Side

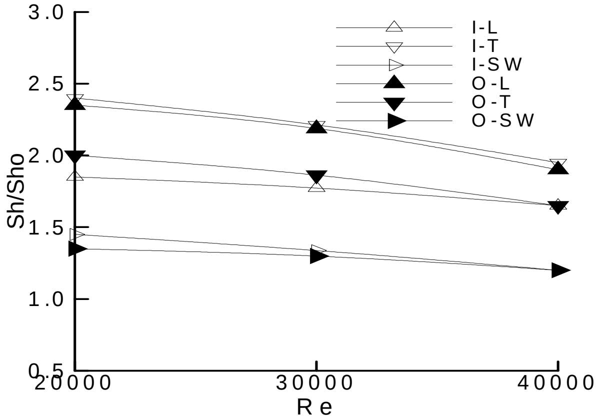

Figure 2: Fully developed mass transfer ratio in the inlet and outlet ribbed channel. AR=1:4, Ro=0.025 (average of inlet duct sidewalls and outlet duct sidewalls)

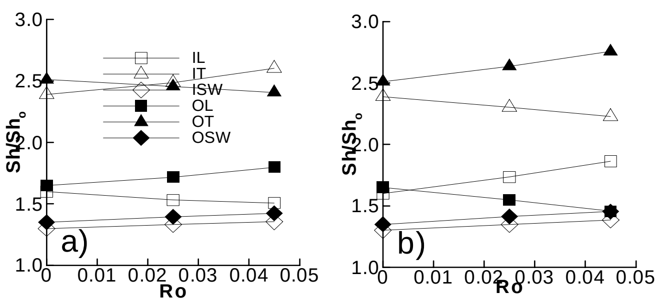

Figure 3: Effect of Rotation number at Re=30000, AR=4:1(Fully developed averaged normalized Sherwood number) a) Ribs on Trailing Side b) Ribs on Leading Side

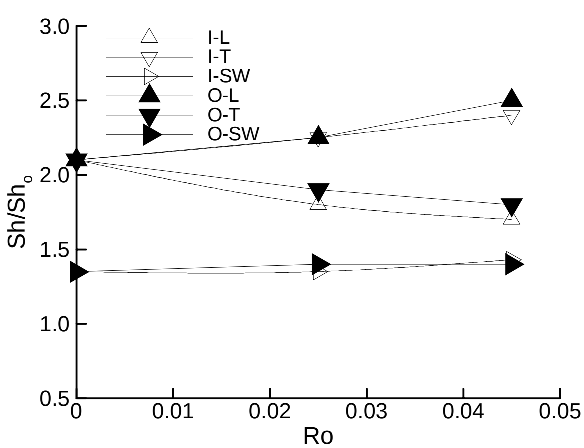

Figure 4: Effect of Rotation number at Re=30000, AR=1:4 (fully developed averaged normalized Sherwood number)

ACKNOWLEDGMENTS

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