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INTERNAL COOLING IN RECTANGULAR (AR=4:1) PASSAGES WITH CORIOLIS AND CENTRIFUGAL BUOYANCY FORCES

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ABSTRACT

To improve the efficiency of gas turbines requires increasing the turbine inlet temperature. In order to combat high temperature on turbine airfoils, more effective and innovative cooling techniques have been studied. One of the most widely used techniques for blade cooling is to circulate coolant air through internal cooling passages within turbine blades. Maximizing the cooling efficiency and attempting to accurately quantify the performance of these passages for parameters relevant to engine operating conditions have been the primary focus of researchers for several decades. As a result, many researchers have focused their attentions on the configurations of the turbulators, which are manufactured on the passage walls to enhance the heat transfer, in square cross-sectional passages with or without rotation [1]-[3]. The studies with rotation have provided insights on the effects of Coriolis and centrifugal buoyancy forces on the flow and heat transfer characteristics for specific geometries, and have provided guidelines for implementing improved internal-cooling strategies.

However, the cross sections of the coolant passages in a realistic turbine blade airfoil ranges from tall passages (low aspect ratio) in the thickest portion of the turbine blade airfoil, to wide rectangular passages (high aspect ratio) in the trailing edge. The studies on the cooling passages with high aspect ratio are very limited [4]-[6], and the values of experimental parameters studied are much smaller than that of the realistic parameters. For instance, a maximum rotation number of 0.075 at Reynolds number Re=20,000, and a maximum rotation number of 0.038 at Re=40,000 have been reported [6]. While the realistic parameter ranges of interest include median Reynolds number of 25,000, and Ro of 0.2 to 0.4.

The configurations of interest in the present study are two-pass, rectangular coolant channels with AR = 4:1. Three test models are employed. The first model has smooth walls. The second model is similar to the first one, but has leading and trailing walls roughed with turbulators (ribs) normal to the flow direction. The last one is similar to the second model; the only difference is that the ribs are oriented at 45 deg to the flow direction. The experimental parameter ranges studied include: Reynolds number Re from 10,000-100,000, rotation number Ro from 0 to 0.6, and density ratio DR from 0.1 to 0.2, and buoyancy parameter Bo from 0 to 4.6. The effects of Coriolis force and centrifugal buoyancy force due to rotation are discussed for the three models, and compared to the previous results obtained from square internal coolant passages.

The results show that the heat transfer characteristics on the passage walls strongly depend on the Coriolis force (Ro) and centrifugal buoyancy force (Bo, or Ro and DR), and also depend on the flow direction. It is found that rotating enhances the heat transfer on the inlet trailing walls (high-pressure walls) in the three models, and also increases

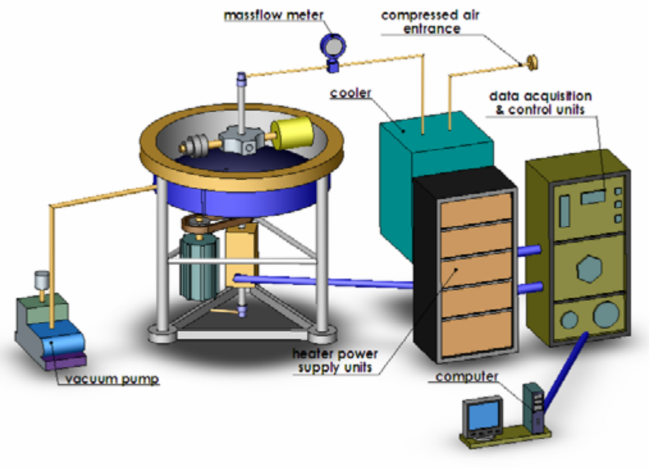


Fig. 1: Schematic of the experimental setup with the upper cover of the rotation rig removed. Test model is mounted and air-tighten sealed inside the yellow cylinder on the rotating arm.

the heat transfer ratio on the inlet-leading wall (the low pressure wall) in the smooth model, but decreases the heat transfer ratios on the two ribbed inlet-leading walls. The higher density ratio generally enhances the heat transfer on every wall for the three models. The buoyancy effects show the same trends as rotation effects. The results for the outlet passages are also provided. In addition, pressure drop are measured and the thermal performance factors are discussed. Compared to the square channels, the rotation effects on the present rectangular channels are much weaker.

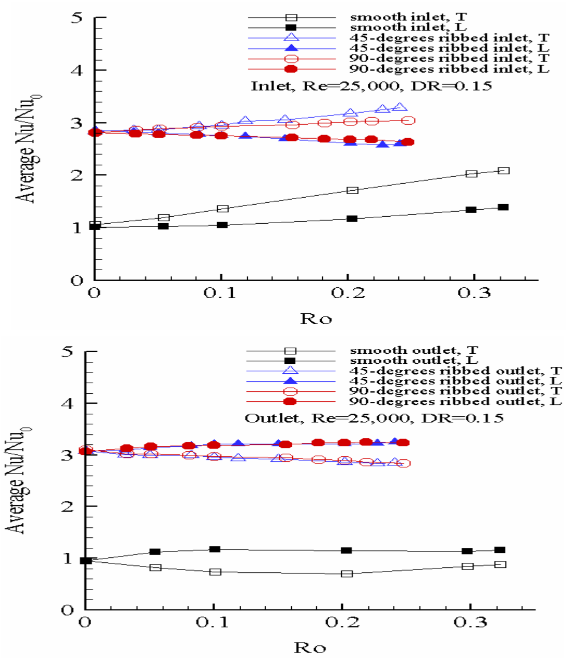
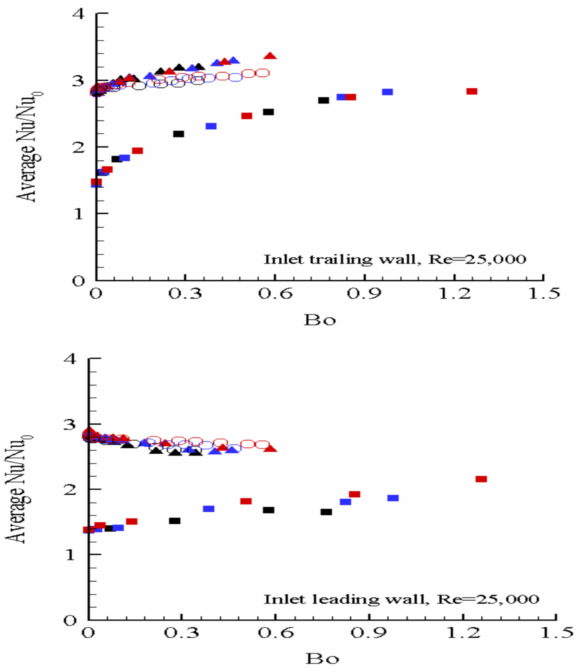


Fig. 2: Nu/Nu_0 vs. Ro, Re=25,000 (Re=20,000 for the smooth model), DR=0.15



LEGEND: square-smooth model, triangle-45-degrees ribbed model, circle-90-degrees ribbed model, black color-DR=0.10, blue color-DR=0.15, red color-DR=0.20

Fig. 3: Average Nu/Nu0 vs. Bo, Re=25,000 (Re=20,000 for the smooth model)

ACKNOWLEDGMENTS

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