Heat Transfer in a Rib-Turbulated Passageways for Gas Turbine Applications

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The internal cooling of turbine blades is especially important to overall blade life as the inlet temperatures to typical gas turbine engines created by burning fuel is much beyond the melting point of the blade material. One method used to cool the turbine blades is to use rib turbulators inside the blades to increase the internal convective heat transfer coefficients. This research project, completed during the summer of 2004, measured heat transfer coefficients related to this turbine blade cooling method. In particular, it studied the heat transfer coefficients around a rib in a rib-turbulated passageway. The results of this study were needed to help turbine designers to understand the internal heat transfer inside turbine blades, allowing them to make more informed decisions about their blade designs.

The test rig used was a closed-loop design which consisted of a 2 horsepower fan, a heat exchanger, a nozzle, a tunnel with a 180 degree bend, and a venturi flowmeter. Two opposing walls had symmetrical rib configurations, while the other two walls were smooth. The cross-sectional flow area was square in shape with a hydraulic diameter of 0.15 meters. The ribs were evenly spaced, also at a length of 0.15 meters, and were square in cross-section with a height of 1.49 cm, giving a height that is 10% of the channel height. Two of the channel walls, one with ribs and one without ribs, were heated using resistive heaters made from Inconel foil. These resistive heaters were intended to provide a constant heat flux along the inside surface of channel walls.

Prior to making measurements, a benchmark study was completed to compare the friction factors associated with the ribs at various Reynolds numbers with that found in the literature. Good agreement was found between measurements made using pressure taps along the centerline of the smooth wall with that reported in the literature. After completing the benchmark study, the test rig was operated at various Reynolds numbers, heating one wall at a time. An infrared camera was used to take temperature measurements of the heated walls. Knowing the wall temperatures and wall heat flux, the convective heat transfer coefficients associated with every point on the walls could be calculated.

The resultant convective heat transfer coefficients matched well with those found in literature and with computational simulations. As shown in Figure 1, the areas of highest heat transfer on the smooth wall are on the upstream corner of the rib. The lowest convective heat transfer coefficients are located immediately downstream of the rib, as well as along the centerline of the channel, as expected. The computational fluid dynamics model predicted a minimum Nusselt number of 1.2, whereas experimental results showed it to be 1.6 at a Reynolds number of 20,000. Along the ribbed wall, the highest convective heat transfer coefficients were located along the centerline of the channel, midway between the ribs. The lowest values occupied an area approximately the length and width of a rib, directly following the rib, as shown in Figure 2. Also, as the Reynolds number increased, the convective heat transfer coefficient and the friction factor decreased. This trend was also found in literature.

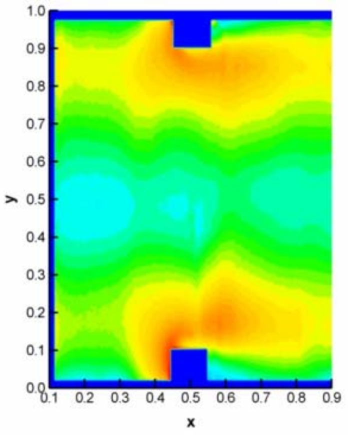
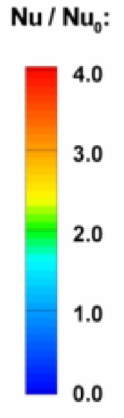


Figure 1: Experimental results at Re=20,000 of the normalized Nusselt number on the smooth wall



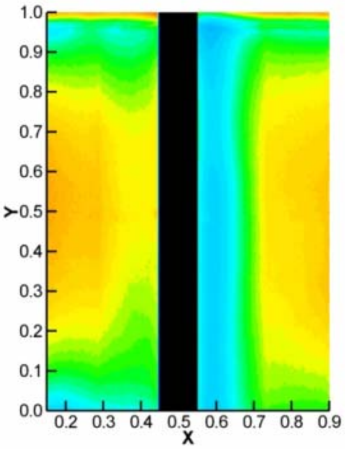


Figure 2: Experimental results at Re=20,000 of the normalized Nusselt number on the ribbed wall