The Effect of Inlet Conditions on Heat Transfer in a Rotating Cavity With a Radial Outflow of Fluid1

John W. Chew,2 Some interesting experimental results and comparisons between theory and measurements have been presented in this paper. Although the authors claim reasonable agreement between theory and experiment some discrepancies between the predicted Nusselt numbers and the measurements are apparent. For example, most of the experimental results in Long and Owen’s Figs. 9, 10, and 11 show that for $a/b = 0.5$ the Nusselt numbers on the outer part of the disk are considerably lower than for $a/b = 0.1$; in contrast, the predictions for the two cases tend to converge at higher values of $x$.

Although the agreement between experiment and theoretical heat transfer results is probably as good as could be expected for $a/b = 0.1$ (where the measurements are affected by the wall jet in the source region) the level of disagreement for the case $a/b = 0.5$ is disappointing. At the higher radius ratio the inner shroud could be expected to produce a reasonably uniform inlet flow, which is closer to the mathematical model. If the fluid rotates at disk speed as it enters the cavity at $r/b = 0.5$, the convective heat transfer can be expected to be small at this radius. This effect is reflected in the theoretical Nusselt numbers, but, at high Reynolds numbers, the measurements show that the Nusselt number close to the inlet is of order half the peak measured value.

It is of interest to examine the sensitivity of the integral method predictions to inlet conditions. Figure 1 shows heat transfer predictions for $a/b = 0.5$, $C_w = 3500$, $Re = 8 \times 10^5$ for different values of the temperature and tangential velocity of the fluid at inlet. These conditions correspond to Long and Owen’s Fig. 9(ii). The integral method used here is described by Chew (1984) and differs only in some relatively minor aspects from that of Rogers used by Long and Owen. It appears that a 5K error in specifying the inlet temperature (which does not seem unlikely for this experiment) has little effect on the predictions. Reducing the inlet swirl from disk speed to half disk speed produces a considerable increase in Nusselt number in the source flow region.

The disparity between theory and experiment for the Nusselt number results for $a/b = 0.5$ is over 100 (compared to a peak Nusselt number of about 300). The question arises: Can this level of disagreement be attributed to experimental uncertainty, or should it be concluded that there are some shortcomings in the mathematical model?

I would like to thank Drs. Long and Owen for a preprint of their paper and for supplying their experimental data.

References


Authors’ Closure

The “experimental” Nusselt numbers were obtained using numerical differentiation of the computed temperature distribution within the heated disk. This is an error-prone process (Owen, 1979; Long, 1985), and the authors are pleased that the agreement between theory and experiment is as good as it is! In tests conducted on another rig in the Thermo-Fluid Mechanics Research Centre, where fluxmeters were used, the agreement is even better.

The question that should be asked is: Can these integral equations be used to predict, with acceptable accuracy, the temperatures of gas turbine disks? The authors [11] have shown that relatively crude approximations to the Nusselt numbers can produce “reasonable” estimates of the temperature distribution for plane disks, and Motoren- und Turbinen-Union [16] have produced acceptable results for compressor disks. It would appear, therefore, that the answer to the above question is yes.

References
