In engines, the effectiveness of cover-plate systems will be reduced by heat transfer from the turbine disk to the cooling air. For direct-transfer systems, the ingestion of disk-cooling air and mainstream gas into the blade-cooling passages is likely to have an even greater effect on the temperature of the blade-cooling air. However, even when heat transfer is significant, the adiabatic effectiveness provides a useful datum from which to measure preswirl performance.

6 Conclusions

Computations, made using an elliptic solver incorporating the Launder–Sharma low-Reynolds-number turbulence model, and velocity measurements, made using an LDA system in a purpose-built experimental rig, have been used to study the flow in an adiabatic cover-plate system.

The computations confirm that the flow between the cover-plate and the rotating disk is similar to that in a rotating cavity with a radial outflow of air. For sufficiently large values of $\lambda_{T,b}$, the source region fills most of the cavity and, outside the boundary layers, the flow behaves as a free vortex. The agreement between the measured and computed values of $V_\phi/\Omega r$ in the rotating cavity is mainly very good. Supports, attached to the cover-plate on the experimental rig, could disturb the flow when $V_\phi < \Omega r$ in the vicinity of the supports; at the design preswirl ratio ($\beta_{p'} = 2.5$), the effect of the supports was insignificant. The computed values of $V_\phi/\Omega r$ approximated to a free vortex with an effective preswirl ratio of $\beta_{p,\mathrm{eff}}$. For $\beta_{p'} > 1.25$, the ratio of $\beta_{p,\mathrm{eff}}/\beta_{p'}$ is less than unity and it decreases as $\beta_{p'}$ increases.

Values of the computed nondimensional preswirl effectiveness, Θ, were compared with theoretical values, Θ', obtained from a thermodynamic analysis of an adiabatic system. The analysis shows that Θ' depends only on the parameter $\beta_{p'}(r_p/r_b)^2$, and for $r_p/r_b = 0.45$ and $0 \le \beta_{p'} \le 4.6$ the numerical error between Θ' and Θ was less than 2 percent of the "dynamic temperature," $\Omega^2 r_b^2/2c_p$.

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DISCUSSION

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The definition of flow and heat transfer in a preswirl rotor–stator cavity system using a cover-plate or direct injection to supply blade cooling air via the disk rim is critical to the design of an energy-efficient high-pressure turbine system. We in the advanced turbine design group follow the work of Professor Owen with great interest.

With respect to the cover-plate system described in Fig. 1(*b*) and for preswirl ratios greater than one in order to reduce the relative air temperature at the blade cooling passage radius of the model, to what extent would the increased radial inflow in the boundary layer offset the reduction in relative air temperature at the rim? Is there a drop in absolute air temperature on board the blade cooling passage for swirl ratios greater than one at the radius? How would you expect the disk radial Nu variation to compare with the free-disk prediction?

Referring to the direct feed system of Fig. 1(*a*) and described in Paper No. 95-GT-239, the free-disk heat transfer distributions are at least 25 percent higher even at the preswirl radius. How would this result change if: (*a*) the disk-cooling air were also preswirled, and (*b*) the stator were also a rotor?

Authors' Closure

We thank Dr. Mirzamoghadam for his comments and questions.

With respect to the cover-plate system, the results obtained in Section 2.1 are not affected by the radial inflow in the boundary layers on the rotating disks. The effectiveness defined in Eq. (7) depends on the end states of a thermodynamic process and not on the process itself: The radial inflow in the boundary layers will influence the effective preswirl ratio, $\beta_{p,\mathrm{eff}}$, but it will not affect T_{r2}, which depends on β_p' and not on $\beta_{p,\mathrm{eff}}$. According to Eq. (10), $T_{r2} < T_{01}$ when $\beta_p'(r_1/r_2)^2 > 0.5$; it follows that $T_{02} < T_{01}$ when $\beta_p'(r_1/r_2)^2 > 1$. This implies that $T_{02} < T_{01}$ when $V'_{\phi 2} > \Omega r_2$, where $V'_{\phi 2}$ corresponds to an "ideal free vortex." (As $\beta_{p,\mathrm{eff}} < \beta_p'$, the actual value, $V_{\phi 2}$, will be less than the ideal value, $V'_{\phi 2}$.) Radial distributions of Nu for the cover-plate system are presented in the paper by Pilbrow et al. (1998).

With respect to the direct transfer system, Paper No. 95-GT-239 is now cited as Wilson et al. (1997) in the references given above. (*a*) If the disk-cooling air were preswirled, this would reduce the work done and, as the disk-cooling air is ingested into the blade-cooling passages, this should reduce the temperature of the air that flows into the turbine blades. Preswirling the disk-cooling air would also be expected to reduce the heat transfer from a hot disk to the air, and this would further reduce the temperature of the blade-cooling air. (b) If the "stator were also a rotor," this would be a cover-plate system with a large inlet radius: for the adiabatic case, Eq. (9) applies, but the authors have no experience of heat transfer in a large-radius cover-plate system.

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