COMPUTATION OF FLOW AND HEAT TRANSFER IN ROTATING CAVITIES WITH PERIPHERAL FLOW OF COOLING AIR

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Rotating-disc systems can be used to model the flow and the heat transfer that occurs in the internal cooling-air systems of gas turbines. The flow and the heat transfer between corotating compressor or turbine discs modelled by a rotating cavity. The main parameters that effect the distributions of the cavity local heat transfer coefficient are coolant flow rate, disc temperature, rotation speed, and cavity configuration.

The geometries in real engines are very complicated. In order to understand the flow over these complicated surfaces, it is usual to simulate the geometries by plane rotating-disc systems, as shown in Figure 1. The free disc, Figure 1.(a), provides a base for all rotating-disc systems. As mentioned above, a turbine disc usually rotates next to either a stationary or another rotating disc, and these can be simulated with a rotor-stator system or a rotating cavity as shown in Figures 1.(b) and 1.(c-f), respectively.

As shown schematicaly in Fig. 1(f), in some gas turbine designs, the cooling air for the rotating turbine disks is supplied through a stationary casing at the periphery of the disks. Cooling air enters the annular rotating cavity between the disks through nozzles in the stationary casing and leaves through the small clearances between the disks and the casing.

Mirzaee et al.[1] reported a combined computational and experimental study of the heat transfer in a rotating cavity with a peripheral inflow and outflow of cooling air for rotational Reynolds numbers up to $Re_\phi = 1.5 \times 10^6$ and flow rates up to $|C_w| = 3000$. Computations and measurements of the velocity showed that there is radial outflow in thin boundary layers on the disk and radial inflow in the core between the boundary layers. In the core, the tangential component of velocity is invariant with z and the measured values V_ϕ conform to a combined free and forced vortex, or Rankine vortex (see Owen and Rogers[2]), where

$$V_\phi \,/\, (\Omega r) = A\, x^{-2} + B$$

and the coefficients A and B depend on C_w and Re_ϕ. Although, the measured values of $V_\phi \,/\, (\Omega r)$ show a Rankine-vortex behaviour that is not accurately captured by the computations in their study. The use of a "Richardson correction" in the Launder-Sharma low Reynolds number k-ε turbulence model improves the agreement between the computed and measured values of $V_\phi \,/\, (\Omega r)$. The measured and computed Nusselt numbers show that Nu increases as Re_ϕ and $|C_w|$ increase. Their computed results for the Nusselt numbers showed the measured trends but tend to underestimate the measured values of Nusselt numbers at the larger values of x.

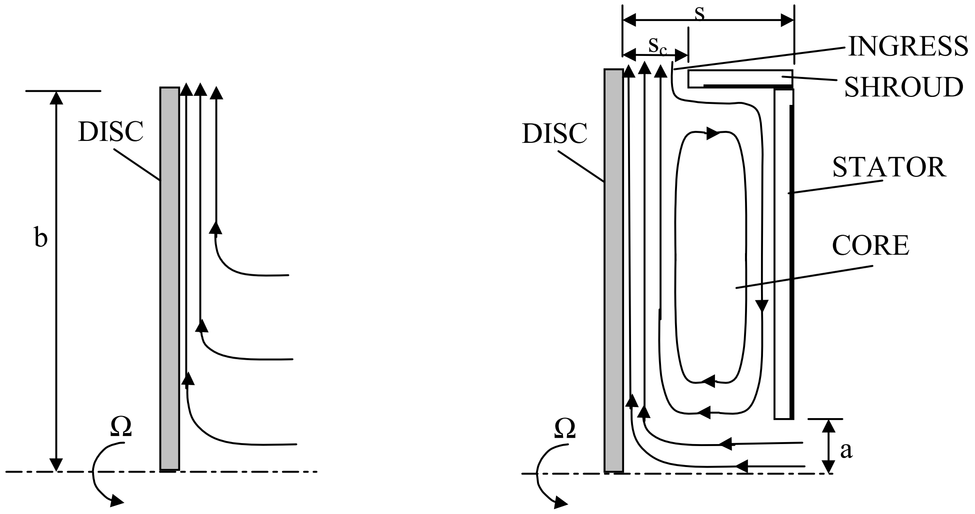
In this paper, an extension of the study of Mirzaee et al.[1] is presented. A computational study of the flow and heat transfer is presented for rotating cavities with peripheral inflow and outflow of cooling air for rotational Reynolds numbers up to $Re_\phi = 1.5 \times 10^6$ and flow rates up to $|C_w| = 3000$.

The computer code used is a modified version of finite-volume, elliptic multigrid solver, details can be found in the references Kılıç[3], Kılıç et al.[4], Gan et al.[5]. In cylindrical-polar coordinate system, the time averaged, axisymmetric, steady-state conservation equations for mass, momentum, energy, and the turbulence quantities turbulence kinetic energy, *k*, and its dissipation rate, ε, together with a low-Reynolds number k-ε turbulence model, are solved to predict the flow and the heat transfer in the cavity.

Comparisons with the available flow and heat transfer measurements are performed. Satisfactory agreement between the numerical and experimental results are obtained. Details of the study will be explained and discussed in the paper.

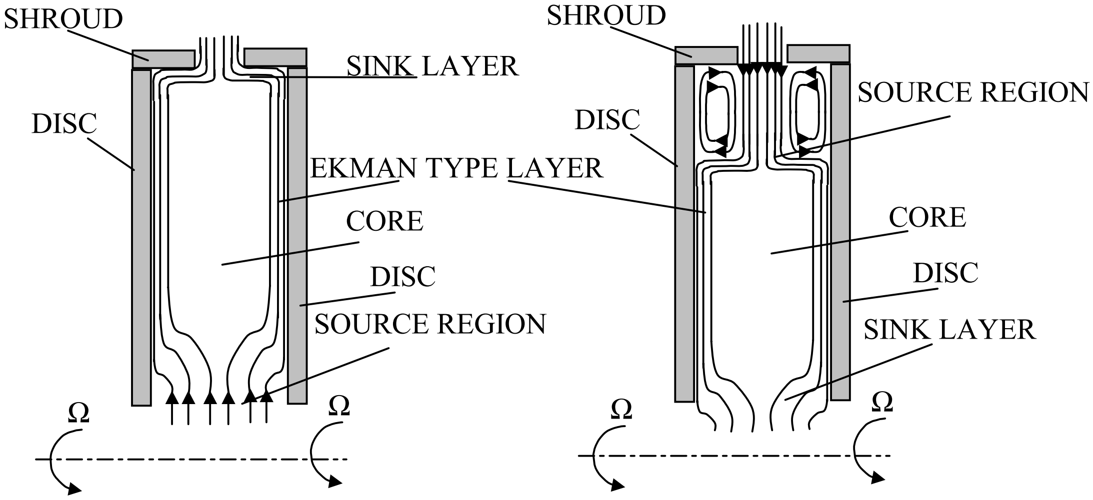
REFERENCES

1. Mirzaee, I., Gan, X., Wilson, M. and Owen, J.M., Heat transfer in a Rotating cavity with a Peripheral Inflow and Outflow of Cooling Air, *J. Turbomachinery*, vol. 120, pp 818-823, 1998.
2. Owen, J.M. and Rogers, R.H., *Flow and Heat transfer in rotating systems. Vol 2: Rotating-Cavities*, Research Studies Press, Taunton, U.K.,1995
3. Kılıç, M., Flow Between Contra-Rotating Discs, *Ph.D. Thesis*, University of Bath, Bath, UK ,1993.
4. Kılıç, M., Gan, X. and Owen, J.M., Transitional Flow Between Contra-Rotating Discs, *J. Fluid Mech.*, Vol. 281, pp.119-135,1994.
5. Gan, X., Kılıç, M. and Owen, J.M., Superposed Flow Between Two Disks Contrarotating at Differential Speeds, *Int. J. Heat Fluid Flow*, Vol.15, pp.438-446, 1994.



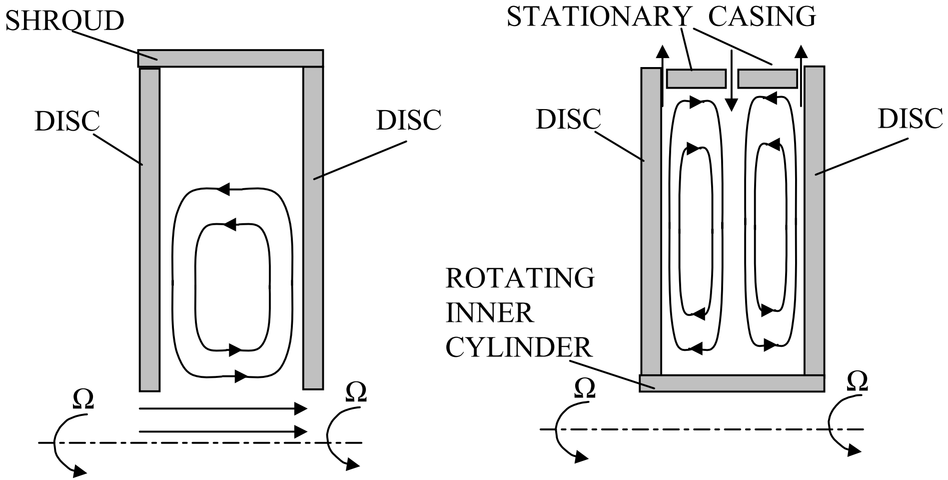
(a) Free Disc

(b) Rotor-Stator system



(c) Rotating-Cavity With Radial Outflow

(d) Rotating-Cavity With Radial Inflow



(e) Rotating-Cavity With
Axial Throughflow

(f) Rotating-Cavity With
Peripheral Flow of Cooling Air

Figure 1. Schematic diagram of rotating-disc systems.