ABSTRACT

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HEAT TRANSFER FROM ROTATING SHORT RADIAL BLADES

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Analytical and experimental studies of fluid flow and convective heat transfer from rotating short radial blades were undertaken. The three dimensional hydrodynamic boundary layer equations and the thermal boundary layer equation, in the absencee of angular symmetry and referred to a co-ordinate system rotating with the blade, were solved by Von Kármán-Pohlhausen integral technique, without neglecting the effects of cross-flow. The analysis is valid when the relative fluid motion is laminar, and the angle of incidence of the blade is zero.

The results of theoretical analysis indicate that when the included angle of the blade is amall, namely, θ_o less than 0.3 radians, the rate of momentum and heat transfer is comparable to that from a flat plate of characteristic length $r_m\theta_o$; when the included angle is large, θ_o greater than 1.8 radians, the transport rates are comparable to those from a rotating disk of radius r_m. For blades of included angles intermediate to the above values, the transport rates are higher than those for the corresponding values for a flat plate or a disk. The average value of the transport rate from a blade of large included angle is higher than that from a disk

of equal area, due to the effects of leading edge in the former.

Experiments with blades of small included angles corroborated the theoretical predictions of heat transfer for the laminar regime within a variation of 10 per cent. For blades of larger included angles the variation is about 50 per cent. In both cases, the experimentally observed values are higher than the theoretically predicted values. Transition to turbulent regime was observed to have taken place at $\overline{Re}_\theta \simeq 5 \times 10^3$ for $\theta_o \leq 15^o$ and at $\overline{Re} \simeq 6 \times 10^4$ for $\theta_o \geq 0.8$ radians. The experimental values of average heat transfer rate, for zero angle of incidence, could be correlated as $\overline{Nu}_\theta = 0.72\ (\overline{Re}_\theta)^{0.5}$ in the laminar regime, and as $\overline{Nu}_\theta = 0.06\ (\overline{Re}_\theta)^{0.8}$ in the turbulent regime, for blades of small included angles. The corresponding values for blades of large included angles were $\overline{Nu} = 0.95\ (\overline{Re})^{0.5}$ and $\overline{Nu} = 0.0415(\overline{Re})^{0.8}$, while those for the blades of intermediate included angles were $\overline{Nu} = 1.275\ (\overline{Re})^{0.5}$ and $\overline{Nu} = 0.0435\ (\overline{Re})^{0.8}$, respectively, for laminar and turbulent regimes.

Experiments were also performed with blades of small included angles, at incidence angles (other than zero). It was observed that the heat transfer rate is increased, compared to the zero angle of incidence case, when the value of incidence angle is exceeded beyond a threshold limit of $\alpha_o = 25^o$. All these experimental results correspond to air as the ambient fluid and isothermal blade surface, whereas the theoretical analysis includes results for fluids of different Prandtl numbers.

Limited experiments were performed with blades rotated inside enclosures, where the blade sweep to enclosure clearance was varied. Results for these experiments, though preliminary in nature, indicate that there is slight decrease of heat transfer rate due to the presence of an enclosure.

For performing the experiments, an instrumentation cum power supply slip ring apparatus was designed, fabricated and used. The design and calibration of this apparatus is described in the thesis.

Preliminary design for, and fabrication of, a rotating evaporator, suitable for a refrigerating system, using short rotating blades are also reported. From the experiments carried out, it is concluded that the satisfactory operation of the rotating evaporator can be ensured when all components of this system are made rotating, primarily to eliminate leakage that is inherent in a partially stationary and partially rotating system. It is envisaged that a rotating heat exchanging surface has merits over its stationary counterpart, due to higher transport rates and due to the fact that the blades of such heat exchanging surface can also be used to simultaneously handle the ambient fluid with lesser pressure drop, thus obviating or reducing the need for a separate fluid handling device.