ABSTRACT

The broad objectives of the study have been (i) to evolve correlations, by theoretical and/or experimental means, for convective heat transfer in external flow past an arbitrary two dimensional body, and (ii) solve the conduction equation in a multiply-connected domain that represents the crossection of the arbitrary body including coolant holes of different shape and size.

The external heat transfer rate is considered to be expressible as

$$Nu_s = f(Re_s, Pr, P_s, Tu)$$

Cubic spline method has been used to generate the contour of the arbitrary body from a given set of boundary points. The spline method has been gainfully used for carrying out numerical differentiation of calculated or measured parameters e.g. free-stream velocity and static pressure at discrete points.

Potential flow past a so generated body is next analysed using the Panel method with flow singularities assumed to be located at the control points of straight panels that are tangent to the body contour. The region of validity of the Panel solution is established by comparing with wind tunnel experiments on a cylinder and three

aerofoils: one symmetric and two cambered. Typically, the theoretical and experimental results of the pressure gradient parameter P_s agree within $\pm$ 5 percent for a cylinder from the stagnation point upto around $\Theta = 45^{o}$.

A differential thermocouple heat flux sensor was designed, manufactured, calibrated and used for making local measurements of heat flux and temperature at a point simultaneously, by a three wire arrangement. The linear range of operation was both analytically and experimentally established to be $Bi \leq 0.16$ for which the sensitivity factor is $S^{*} t^{*} = 0.25$.

The measured values of local heat transfer from a cylinder in cross-flow, together with literature information on heat transfer from a flat plate, wedges of different included angle and ellipses, led to the following correlations for laminar heat transfer from an arbitrary body shape. The free-stream turbulence causes an apparent transition in the laminar thermal transport at an approximate value of $Tu \sqrt{Re_D} = 6$.

$$\frac{Nu_s}{Re_s^{0.5}\ Pr^{0.33}} = 0.343\ (1+P_s)^{0.7} \times [1+0.22\ \log_{10}(1+Tu\ \sqrt{Re_D})]$$

for $Tu \sqrt{Re_D} \leq 6$

and $$\frac{Nu_s}{Re_s^{0.5}\ Pr^{0.33}} = 0.343\ (1+P_s)^{0.7} \times [0.67+0.63\ \log_{10}(1+Tu\ \sqrt{Re_D})]$$

for $6 \leq Tu\sqrt{Re_D} \leq 25$

The local heat transfer measurements on symmetric and cambered aerofoils indicated that the turbulent convection can be summarized as ;

$$Nu_s = [0.029\ Re_s^{0.8}\ Pr^{0.33}] \times [(1+P_s)^{-0.212}] \times [1.45\ Tu^{0.08}]$$

When the cambered blades were experimented with in cascade arrangement, the agreement of measured values with the laminar and turbulent correlations given above was better than when the blades were configured singly.

A finite difference scheme was developed to solve the two dimensional Poisson's equation in a multiply-connected domain. The domain boundaries are first sketched by cubic splines, passing through the sets of prescribed boundary points. The programme is capable of handling non-nodal intersections and general boundary conditions, including both the Neumann and Dirichlet types. Typical results are given for concentric and eccentric annuli including plots of isotherms in a cambered aerofoil with coolant holes. Shifting a coolant passage from near the stagnation point towards the trailing tip has the effect of lowering the thermal gradients in a blade crossection.