

Numerical Investigation of the Cooling of a Horizontal Plate by Mixed Convection Flow

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Extended Abstract

The heat transfer due to mixed convection flow past a heated horizontal plate is a fundamental problem of thermal management. The buoyancy force, perpendicular to the plate, affects the flow indirectly through the perturbation of the hydrostatic pressure. The hydrostatic pressure difference at the trailing edge and across the horizontal thermal wake behind the plate induces a global perturbation of the outer potential flow [1]. Schneider [2] and Müllner [3] have shown analytically that the two-dimensional flow over the plate, and consequently also the heat transfer from the plate, is sensitive even to boundary conditions prescribed at very large distances from the plate. These findings have been confirmed numerically [4,5].

In the present talk, two different configurations will be considered, where the plate is located either in a horizontal channel or behind a vertical flow straightener. The effects of the buoyancy parameter (Richardson number) and of the height of the channel or the distance of the plate from the flow straightener will be demonstrated. Numerical results for very small Prandtl numbers and very small Richardson numbers (i.e., weak buoyancy effects) will be compared to the analytical solutions. In addition, numerical results for Prandtl numbers of the order of one and strong buoyancy effects will be presented.

For small Prandtl and Richardson numbers, the Nusselt number of the top surface of the heated plate agrees well with the analytical solution. Accordingly, it increases linearly with the Richardson number and logarithmically with the distance from external boundaries. On the other hand, the Nusselt number of the lower surface is lower as compared to the analytical solution. The discrepancy, which grows with increasing Richardson number, is attributed to viscosity effects and flow separation. The overall Nusselt number of the plate decreases with increasing distance of the external boundaries from the plate.

For Prandtl numbers of the order of one, the Nusselt number at both surfaces is significantly lower than in the vanishing-Prandtl-number case. The reason can be seen in the presence of the viscous boundary layer. Nevertheless, the difference between Nusselt numbers at the top and bottom plate surfaces, respectively, agrees well with the analytical solution up to Richardson numbers of the order of 0.1.

For Richardson numbers of the order of 0.1, buoyancy leads to a significant viscous drag reduction as compared to the corresponding forced convection flow. As in the case of vanishing Prandtl number [1], there is also nose suction, which is, however, much smaller than the viscous drag.

References

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