Case 7.2: Two-Dimensional Flow and Heat Transfer over a Smooth Wall with Square Sectioned Ribs

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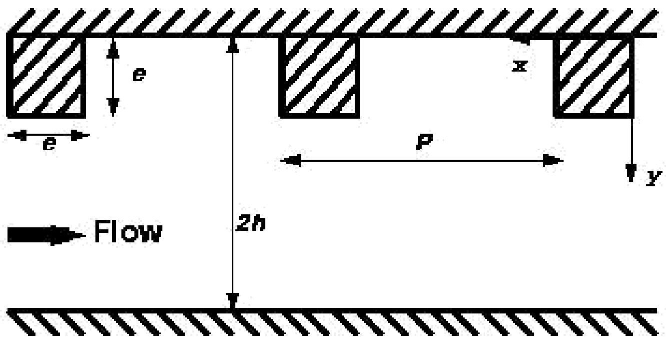

Description of the flow field

The situation considered is fully-developed flow through an axisymmetric pipe or infinite plane channel, where the heated wall is "roughened" with a series of square sectioned ribs, to enhance heat-transfer.

Flow Parameters:

The experiments were conducted in air and data is available at a Reynolds number based on incoming bulk velocity and twice channel width of 37200 (for the dynamic field) and 12600 for the heat-transfer. The geometric parameters are:

Channel half width:	h=2cm
Pitch to height ratio:	P/e=7.2
Rib height:	e/h=0.4

Measurement Techniques:

The channel flow was studied by Drain & Martin who performed LDV measurements of the velocity field in a fully-developed water flow. Corresponding heat-transfer measurements for the same geometry in an air flow were obtained by Liou et al using holographic interferometry. Again, measurements were taken at downstream locations where the flow had become fully developed and periodic.

Instructions for Computers

Note that the Reynolds numbers quoted in the experiments are based on the hydraulic diameter of the channel without the ribs. In terms of the above diagram, this corresponds to $Re=4hU_b/\nu$, where U_b is the bulk velocity through the unblocked channel.

Boundary Conditions:

The flow can be assumed to be periodic in the streamwise direction so, for example, a domain extending from the leading edge of one rib to the leading edge of the next can be taken. Periodic boundary conditions can be applied between the upstream and downstream boundaries of such a domain (in the case of the temperature, allowance has to be made for the heat introduced into the flow through the wall).

For the thermal boundary condition, the non-ribbed wall is insulated, so an adiabatic boundary condition should be applied. In the experiments, the ribbed wall was constructed of aluminium which was heated by a thermal film attached to its underside. From a computational point of view, the most convenient method is probably to apply a constant heat flux through this wall. For the ribs themselves, the best practice is probably to assume the same uniform heat flux applied at their base, and to solve the conduction equation across the rib area protruding into the fluid. Alternative approaches are, of course, possible, and it is left to participants to select (and report) the exact treatment , or treatments, they employ.

Data for Comparison:

The main quantity of interest in this flow is the Nusselt number distribution along the ribbed wall and over the ribs. Mean velocity and some some turbulence profiles are also available which we plan to use for additional comparisons.

Download Available Data:

Note: these are more complete datasets than the ones available earlier, containing mean velocity and Reynolds stress profiles.

case7_2b.tar.gz (for gunzip)

case7_2b.tar.Z (for uncompress)

References

Liou, T.M., Hwang, J.J., Chen, S-H 1993 "Simulation and measurement of enhanced turbulent heat transfer in a channel with periodic ribs on one principal wall" *Int. J. Heat Mass Transfer*, **36**, 507-517.

Drain, L.E., Martin, S. 1985 "Two-component velocity measurements of turbulent flow in a ribbed-wall flow channel" *Int. Conf. on Laser Anemometry - Advances and Applications*, Manchester.

For some recent computations in similar geometries, see

Iacovides, H., Raisee, M. 1997 "Computation of flow and heat transfer in 2-D rib-roughened passages" *Proc. 2nd Int. Symposium on Turbulence, Heat and Mass Transfer*, Delft.
