INFLUENCE OF LONGITUDINAL VORTICES ON THE STRUCTURE OF THE THREE DIMENSIONAL WAKE OF A PARTIALLY ENCLOSED BODY

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Introduction

The structure of the 3D-flow around a circular cylinder built in a rectangular channel is highly complex. Horse shoe vortices appear on the top and bottom walls in the stagnation zones. Depending on the Reynolds numbers and geometry, a Karman vortex street may appear on the midplane. Between the midplane and the bottom or the top wall, a helical vortex tube appears in the wake /1/. The geometrical configuration of a channel with a tube models a cross flow fin-tube heat exchanger where the channel walls represent plate fins. The three dimensional structure of the wake determines the heat transfer between the fluid and the fin in the wake. The structure of the wake can be controlled and the separation on the cylinder surface can possibly be avoided by introducing longitudinal vortices in the flow. The longitudinal vortices can be generated by deforming part of the channel wall in form of a wing or winglet. In previous works, the structure of the laminar flows in a rectangular channel with a built-in circular cylinder and in a channel with built-in vortex generators were investigated /1, 2/. The purpose of the present work is a numerical investigation of the interaction of the longitudinal vortices with the wake of a cylinder in a channel.
Basic equations and method of solution

Figure 1 shows the computational domain consisting of a rectangular channel of height \( H \), width \( B = 10H \), with a built-in cylinder of diameter \( D \) and a pair of delta winglets of height of \( H \) and span of \( 0.5D \) in the wake of the cylinder. The flow field in this domain is calculated by solving complete unsteady Navier Stokes equations for incompressible fluid with constant viscosity. Uniform parallel flow is used as initial condition at the channel inlet. No-slip condition is used at the top and bottom walls of the channel and the symmetry condition is used at the side boundaries. At the channel exit, the second derivatives of velocity components are taken equal to zero. Previous computations for flows in a channel with a cylinder with \( H/D = 1 \) and the Reynolds number based on \( H, Re_H = 1100 \) showed unsteady wake /1/. With \( H/D = 0.4 \) and \( Re_H = 1000 \) we obtained steady symmetric wake. In the present work with \( H/D = 0.2 \) and \( Re_H = 600 \) (typical of a fin-tube heat exchanger) the wake will be steady. Hence the flow need to be calculated only in the half width of the channel (between the side wall and the dotted line) with symmetry condition on the middle.

The basic equations are solved by a modified version of the marker and cell (MAC) technique /3/. The computation is carried out in two steps. In the first step cartesian grids are used to discretize the channel and to simulate the circular cylinder. Once a steady or a periodic solution is obtained in cartesian grids, a second step of solution, in which the flowfield in the neighborhood of the cylinder is again computed in a polar grid, is performed. Details of the computational scheme can be found in refs. 2, 3.

Results and Discussion

Computations have been performed in the channel with 56\( \times \)42\( \times \)12 grids for \( Re_H = 600 \) and 1000. Figure 2 shows velocity vectors at the channel cross section at a distance \( D \) downstream of the cylinder (shown in fig. 1). The horse shoe vortex which forms in front of the cylinder bends around the cylinder and forms two longitudinal vortices on two sides of the symmetry plane.

The cross section of one of these longitudinal vortex is seen on the left side of fig. 3. The next vortex is the cross section of the longitudinal vortex generated by the winglet. At the extreme right