Vortex shedding for flow over a square cylinder close to a moving ground

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Abstract

Numerical study on fluid flow produced by a square cylinder in close proximity to a flat surface which travels at a uniform speed, namely the speed of the oncoming free stream of fluid is considered. Flow has been considered in the laminar Reynolds number (based on cylinder length) range. The main practical motivation however comes from the automotive industry where a moving ground simulation is essential. Numerous studies have been made of flows past models, of various degrees of complexity, for cars including the considerable effects from the presence of the ground. But most of the studies limited to evaluate the body forces. In the present study, the governing unsteady Navier-Stokes equations are discretised through the finite volume method. A SIMPLER algorithm has been used to compute the discretised equations iteratively. We considered various values of the ground to cylinder separation length and Reynolds number. A non-uniform grid distribution is considered in the computation. Effect of grid size on the solution is considered (see Fig.1) and an optimal grid distribution is obtained. We have compared our solution with the previously published results on vortex shedding in a uniform stream and found them in good agreement (Fig.1).

Present flow field is governed by two parameters, namely, the Reynolds number and the ground to cylinder gap length ratio which is nondimensionalised by the length of the cylinder. A uniform velocity profile equal in speed of the wall speed impinges on the cylinder. A negative vortex is generated at the front top corner of the cylinder and moves behind the cylinder as it grows. The lower downstream corner of the cylinder induces a strong positive vortex. These vortices attain the maximum strength before being sheded. A negative vortex forms along the moving wall below the positive vortex close to the cylinder lower shear layer. Due to the absence of classical boundary layer on the moving wall, the secondary vortex strength is greatly reduced compare to the case of stationary wall. This negative vortex interacts with the vortex pair and influences the shedding process. An alternate negative and positive vortex shedding occurs behind the cylinder. The negative vortex on the wall shear layer grows in size and remains attached to the wall without being shedded. A region of separated flow along the moving wall is found in the downstream region. Fig.2 shows the vorticity contours when the drag experienced by the cylinder is maximum. Unlike the stationary ground case where the vortex suppression occurs beyond a critical value of gap length, here the vortex shedding takes place even at low gap length ratio 0.1. Our results show that the vortex shedding occurs even at the gap length 0.1. The variation of Strouhal number with Reynolds number is shown in Fig.1. We find that cylinder experiences a downward force at higher values of Reynolds number. The gap flow between the sliding wall and the lower face of the cylinder is strong and the velocity profiles overshoots its free stream value within this region. The core flow under the cylinder resembles to that of flow in a channel. The change in average drag experienced by the cylinder due to the change of gap length ratio is not significant.

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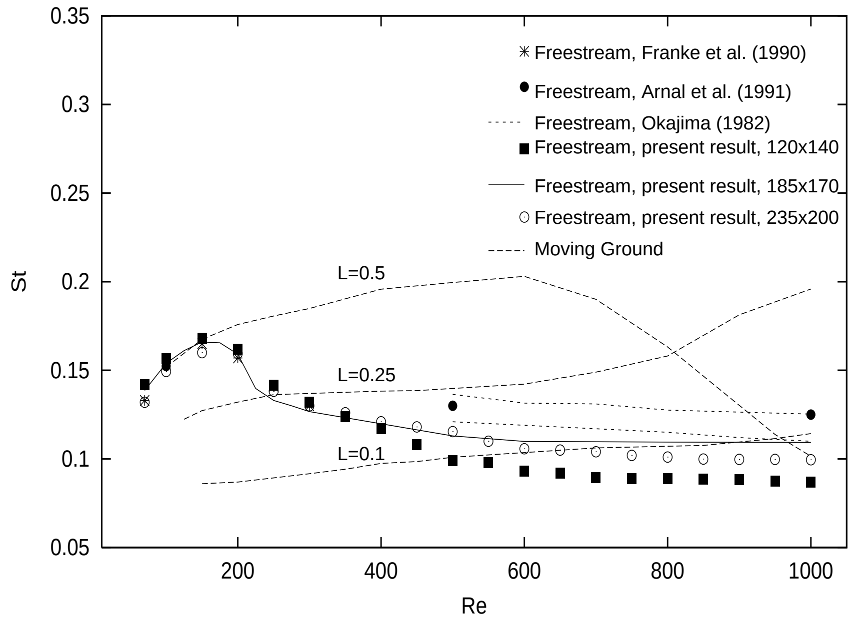

Figure 1: Variation of Strouhal number with Reynolds number at different gap ratio (L)

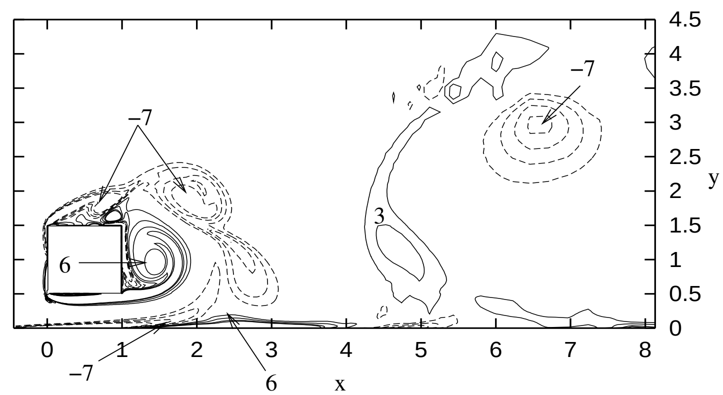

Figure 2: Iso-vorticity contours at Re=500, L=0.5 at the starting of shedding cycle