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Numerical Analysis of Flow around Rectangular Cylinders with Various Side Ratios

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Abstract

Three-dimensional numerical analysis of the flow around rectangular cylinders with various side ratios, D/H, from 0.2 to 2.0 is carried out for Reynolds number of 1000 by using multi-directional finite difference method in multi-grid. The predicted results are well compared with the experimental data. It is found that fluid dynamics characteristics alternate between high pressure mode and low pressure mode of the base pressure for rectangular cylinder of D/H=0.2-0.6.

Keyword: *Separated Flow, Wake, Vortex, Fluid Force, Rectangular Cylinder*

1. Introduction

Some interesting phenomenon whereby flow patterns and aerodynamic characteristics such as lift and drag forces, base pressure, and Strouhal number of rectangular cylinder are strongly dependent on the Reynolds number and it's side ratio of D/H, where D is the depth and H is the height of rectangular cylinder, have been found through experiments. Especially, the experiments of Nakaguchi et al. [(1)] showed that the base pressure coefficient and drag force coefficient takes the peak value for a rectangular cylinder with a side ratio of D/H=0.6. Since then, many experimental studies have been carried out to investigate this phenomenon. Okajima et al. [(2)] experimentally studied the flow around a rectangular cylinder with D/H=0.4-3.0 includes the low Reynolds number, and showed that the base pressure coefficient changes depended on the Reynolds number.

In this paper, the three-dimensional flow around rectangular cylinder with D/H=0.2-2.0, including the critical side ratio D/H=0.6, has been computed to investigate the change of the flow characteristics against the side ratios. The result was compared with past experimental studies, and the cause of this phenomenon was investigated

2. Numerical method

The governing equations for three-dimensional flow around a bluff body are a continuity equation and Navier-Stokes equation. In a finite difference scheme of these equations, third order upwind scheme [(3)] is applied for the approximation of convective term, and all other terms are approximated by second order centered differencing. These spatial differential terms has been discretized on the regular meshes with multi-directional-finite-differencing scheme [(4)], First-order Euler implicit scheme is used for the time integration. MAC algorithm is used for the coupling of velocities and pressure. Boundary conditions of no slip are imposed on the surface of the cylinder. The flow is undisturbed and uniform at the upstream inlet, and the conditions at the down stream exit and side are given by the use of zero-gradient boundary conditions. Cyclic conditions are obtained for span-wise boundary. Calculation domain is separated to 4 blocks. The block is equally divided for all spatial directions. The multi-grid method is used to combine these blocks.

3. Results and Discussions

Figure 1 shows the comparison of the computed values of Strouhal number with the experimental values. Computed results show good agreement with the experimental ones. Figure 2 shows the variation of the base pressure coefficient by the side ratio D/H. In the present results, the low pressure mode, which the base pressure coefficient is low and the drag coefficient is large, and the high pressure mode, which is the reverse of the low pressure mode, appear alternately for time with D/H=0.2-0.6 cylinders (Figure 3). Compared with the past experimental results of D/H=0.4 cylinder, our calculation result excessively estimates the base pressure coefficient. On the other hand, our results of D/H=0.6-2.0 cylinders have a good agreement with experimental ones. Also Enya et al.[5] found by LES calculation in high Reynolds number that the base pressure has two modes, high and low ones, for these cylinders, our results show the same phenomenon occurs in low Reynolds number. For the cylinders over the side ratio of D/H=1.0, this phenomenon does not occur, the fluctuating amplitudes of the base pressure are constant.

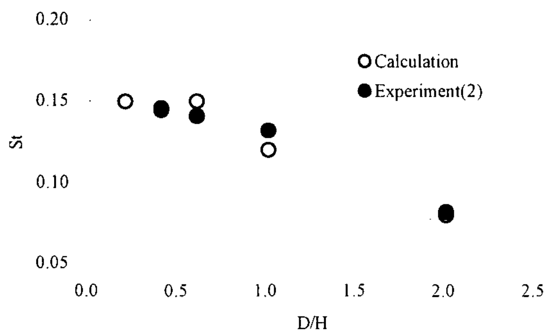


Fig. 1 The Strouhal number variation with side ratio

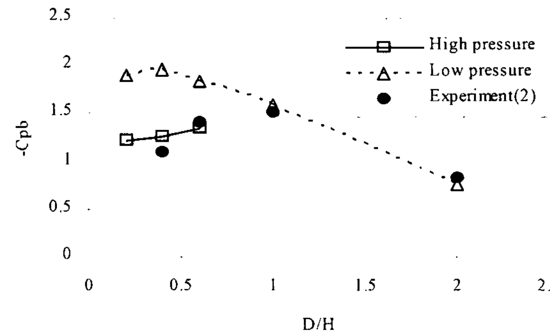
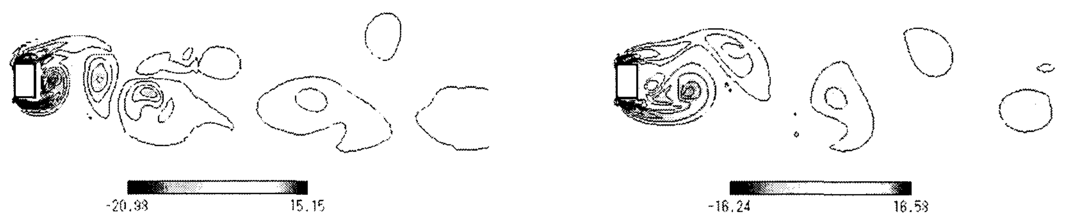


Fig. 2 The mean base pressure coefficient variation with side ratio



(Low pressure mode) **(High pressure mode)**

Fig. 3 Flow patterns around D/H=0.6 cylinders

4 Conclusion

The numerical simulation of the flow around rectangular cylinders with the side ratio of D/H=0.2~2.0 were carried out. The computed results show good agreement with the experimental ones, and also, the results show that the base pressure and the drag coefficients change alternatively between two modes, high and low ones.

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