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SIMULATIONS AND COMPARISONS OF D-SECTION CYLINDER IN THE DIFFERENT Re FLOW

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ABSTRACT

Positioning a splitter plate at the certain line in the wake of the cylinder is an effective method to reduce the acoustic drag force and lift force. The simulations of the flow past the only stationary D-section cylinder at different Reynolds number 400, 500, 600, 700, and 45000 are included here to have a study on the mechanisms of the D-section cylinder in the flow. Two-dimensional unsteady laminar flow over a semi-circular cylinder with a prescribed flexible foil was investigated numerically. The mechanisms of the single fixed D-section cylinder in the flow and the propelled foil will be studied and the interaction effect on both of cylinder and foil will be explored by setting the optimal parameters as different foil undulation frequency and gaps between them.

Keywords: D-section cylinder, Unsteady laminar flow, Semi-circular cylinder, Computational modeling.

1. COMPUTATIONAL DOMAIN AND BOUNDARY CONDITIONS

The case of flow around the fixed D-section cylinder is modeled as a two dimensional problem. The domain of the cylinder with boundary conditions is shown in Figure 1. The cylinder diameter D is 0.1m. A conical line is used as the upstream flow inlet boundary with the transverse distance 1.5D from the cylinder forward boundary. Fluid domain extent for the downstream of cylinder is taken as 4.5D and the width of the boundary is 4D.

Velocity inlet boundary condition is adopted for the flow at the transverse border and conic boundary. Outflow condition is considered for the outlet side. The cylinder surface is defined as non-slip wall condition.

2. GRID GENERATION

The domain of grid generation is as shown in the Figure 2. C-grid as the forward part in the domain is the structured mesh generation which is considered to have the better control on the mesh size is used in the wake area. And it is also chosen for the simplification of the mesh structure. The rectangular shape mesh is applied in the other parts of the domain field.

The total numbers of the mesh elements are 52 on the semicircular boundary of the D section cylinder and the upper conic inlet boundary. On the other straight boundaries, the size of mesh element is 0.003. The structure grids type of Map is defined in both of the two areas. The total number of cells, faces and nodes are 29200, 58735 and 29535 respectively.

3. COMPUTATIONAL SETTINGS

The analysis options of the FLUENT software are considered as the following:

4. FLUID FLOW MODEL

The laminar flow can be used to simulate the model and the water is the fluent fluid materials with the properties as following:

Density (ρ) = 1000 kg/m3

Dynamic Viscosity (μ) = 0.001 kg/ms-1

5. FLOW CONDITIONS

Velocities corresponding to the Reynolds numbers 400, 500, 600, 700 and 45000 are calculated for the problem geometry and applied as velocity inlet boundary condition.

The inlet velocities along with respective Reynolds numbers are presented in the Table 1

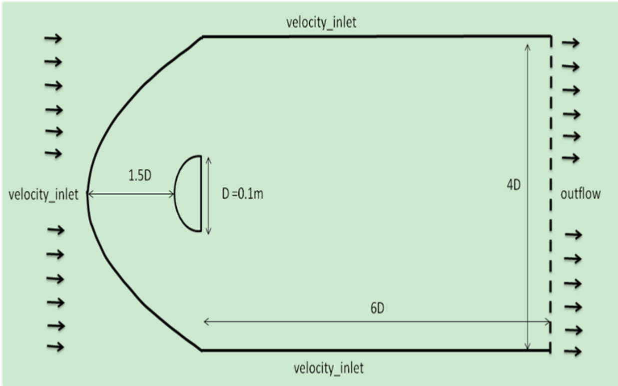


Figure 1. Computational domain for the D-section cylinder

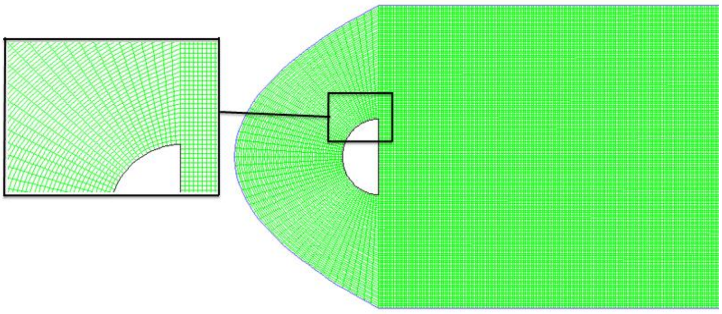


Figure 2. The Mesh distribution of the D-section cylinder

Table 1. The inlet velocities versus Reynold Number

Reynold Number	Inlet Velocity, U (m/s)
400	0.004
500	0.005
600	0.006
700	0.007
45000	0.45

Table 2. Solver parameters and discretization

Type	Chosen setting
Solver type	Unsteady
Solver formulation	Implicit
Unsteady formulation	First order implicit
Velocity formulation	Absolute
Gradient option	Cell-based
Pressure	Standard
Momentum	First order upwind

Outlet has been specified as the outflow with the flow weight rating to be 1.

6. SOLVER SETTINGS

The solver parameters and discretization schemes adopted for the present analysis are shown in the following Table 2.

7. TIME STEP

To reduce the effect of time step size difference, the time step size is taken as 0.03s for all the cases with different Re numbers.

8. RESULTS AND DISCUSSION

Since the simulations of the D-section cylinder in the different Re flow present the same trend, the case of Re=45000 can be taken as the example to specify the process of results analysis and the detailed results of the other cases with Re=400, 500, 600 and 700.

The residual plot periodically changed which means the numerical solutions are converged as shown in the figure 3.

The force coefficient is one of the important measurements for the vibration of the cylinder. The drag force coefficient and the lift force coefficient history with the Re =45000 are in the following figure 4.

The drag coefficient is oscillating around a nonzero mean value with a frequency twice that of the lift coefficient which is caused by the vortex shedding in the wake field. The instant vortex shedding process during one period T is plotted as in the following figure 5.

The regular pattern of vortices in the wake of the two-dimensional bluff body is typically known as the Karman vortex street. This periodic shedding of vortex occurs firstly from one side of the body, and then one from the other side with the opposite rotation direction.

When a vortex is shed, an asymmetrical flow pattern forms around the body, which changes the pressure distribution. The instant pressure distribution of the instant 0.2T, 0.6T, 1T during one period is shown in the figure 6. Compared with the vorticity contour picture in the figure 5, the pressure distribution on the right side cylinder boundary in figure 6 (d) clearly indicates the effect of the vortex reaction with on the cylinder. The boundary on the cylinder where the vortex generated has higher pressure.

The downstream spacing of the vortices is described by the cylinder wake wavelength λ, which is defined as the following equation

$$\lambda = \frac{U_f}{f} \qquad (1)$$

Where Uf is the nominal flow velocity and the f is the frequency of vortex shedding. The wake wavelength is shown as in the Figure 7.

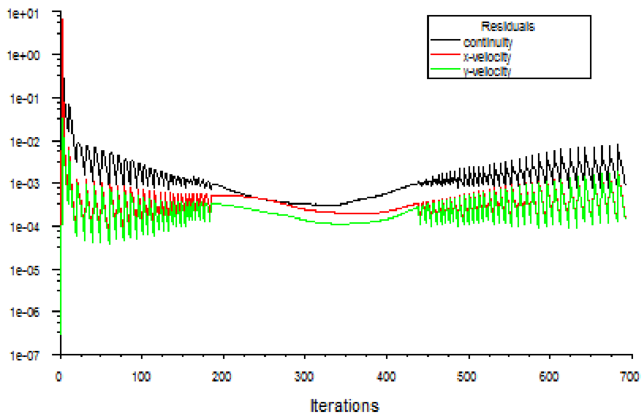


Figure 3. Residual plot for the D-section cylinder with Re=45000

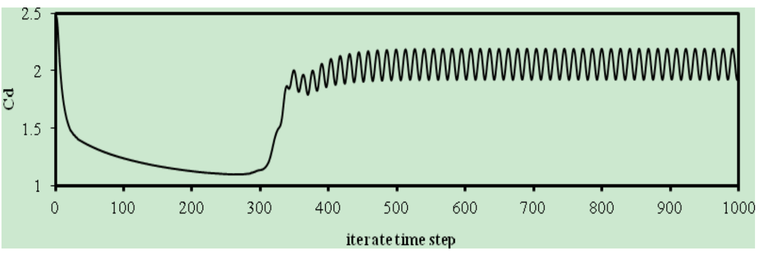


Figure 4. History plots of drag and lift coefficients of D-section cylinder with Re=45000

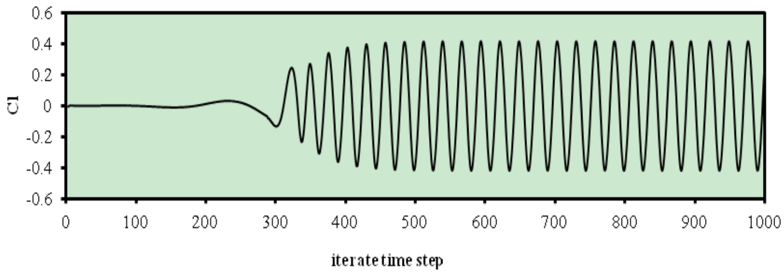
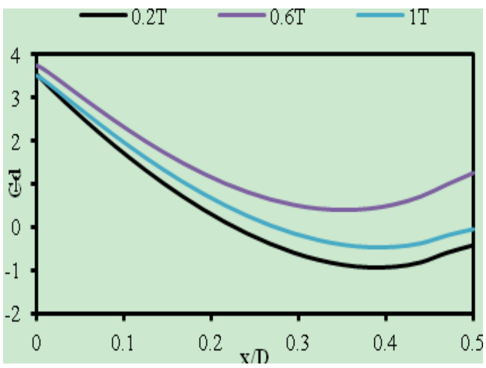
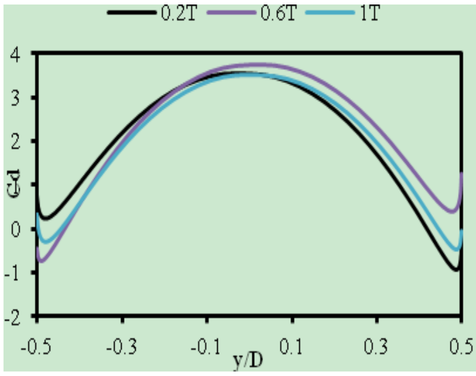


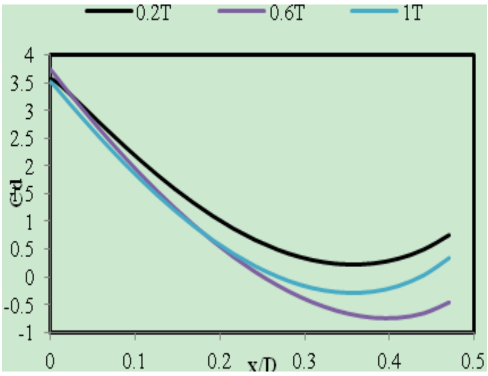
Figure 5. Vorticity contour for the D-section cylinder with Re=45000



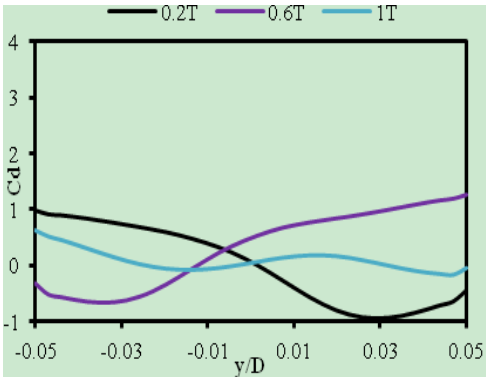
(a) Upper boundary



(b) Right side boundary



(c) Bottom boundary



(d) Left side boundary

Figure 6. Instant pressure distribution of cylinder in the instant 0.2T, 0.6T and 1T

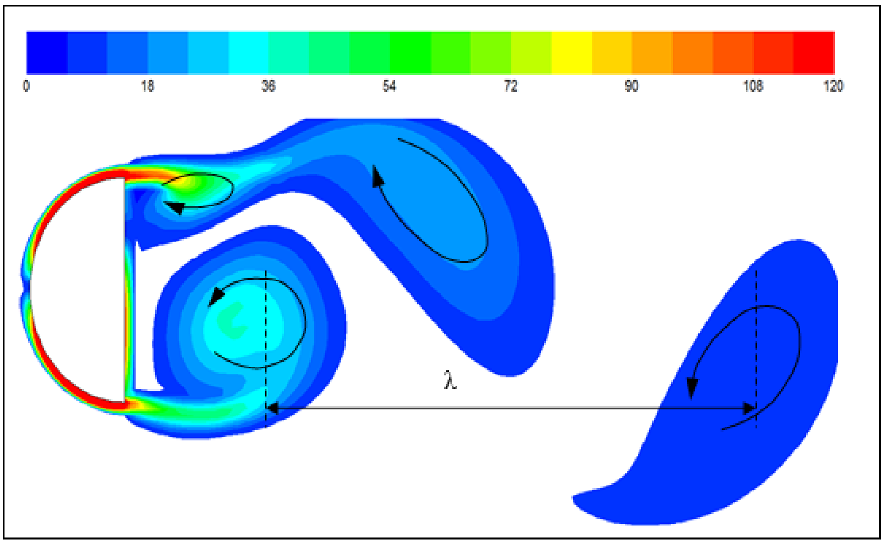


Figure 7. The wave length in the D-Section cylinder wake with Re=45000

Table 3. Summarized results for the D-section cylinder with Re = 400, 500, 600, 700 and 45000

Re Number	Flow Velocity	Vortex shedding frequency	Strouhal Number	Mean Drag Coefficeint,Cd	Lift force amplitude	Wake wave length
400	0.004	0.008	0.202	3.142	1.66534	0.496
500	0.005	0.010	0.199	2.970	1.67817	0.503
600	0.006	0.012	0.197	2.982	1.67125	0.509
700	0.007	0.014	0.201	2.970	1.656	0.498
45000	0.45	1.234	0.270	2.050	0.833	0.365

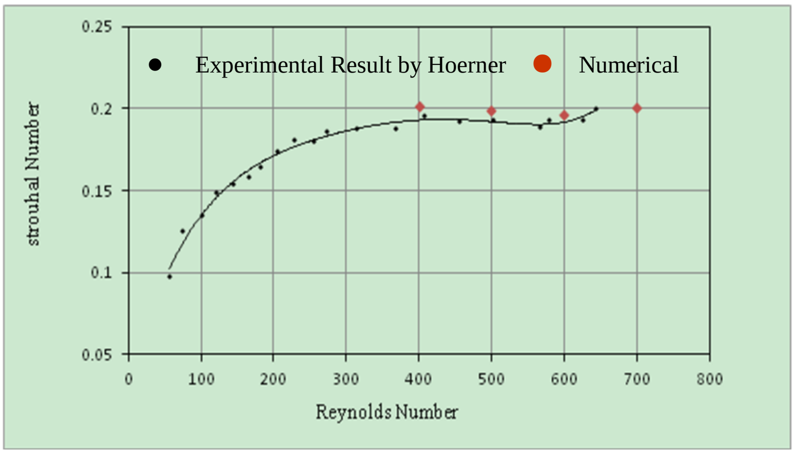


Figure 8. Comparison of Strouhal Number for D-section cylinder (Hoerner, 1965)

The vortex shedding frequency can be calculated by the equation

$$f = \frac{1}{T} \tag{2}$$

Where T is obtain from the Cd and Cl curve history by FFT function in the FLUENT software.

The results for the D-section cylinder with Reynolds number 400, 500, 600, 700 and 45000 are summarized in following Table 3.

9. CONCLUSION

The values of the Strouhal number of the D-section cylinder is similar to those of a circular cylinder. It is predicted that Strouhal number versus the Reynolds number for the D-section cylinder. In the Figure 8, the curve with the black pot is the experimental data from Hoerner, and the red dots are based on the above numerical simulation. The simulation results are investigated well by this comparison.

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