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Numerical Investigation of Flow over Cylinders with and without Grooves

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Abstract

The flow around cylinder open the path for studying more complex shape bodies that still keep in their external flow properties the combinations of the flow properties of simpler bodies like flat plates, cylinders, ellipses. The aim of this study is to describe flow around cylinders with and without grooves based on numerical simulations. The two positions of groove were taken. The inlet flow properties are velocity of 10 m/s, density of 1.225 kg/m^3, static pressure of 101325 Pa.

Keywords: cylinder, grooves, numerical simulations

1. Introduction

A cylinder represents a very basic geometry and different types of flows over a cylinder have been experimentally and theoretically studied over the years. Recently, a book has been published on low speed flows around a circular cylinder [1]. Interesting experimental results can be found in Album of Fluid Motion by van Dyke [2], see also [3]. The analytical solution for incompressible inviscid flow over a cylinder resulted in D_Alembert paradox. Flow over a rotating cylinder is used to explain the Magnus effect and the generation of lift. Compressibility effects have been studied by Janzen, Rayleigh, Imai and others [4]. The critical Mach number was predicted accurately by van Dyke using computer series extension techniques [5]. Numerical solutions of Euler equations are reported in many papers, see for example [6–9].

The flow over circular cylinder had been subjected to intensive research for a long time. A circular cylinder produces large drag due to pressure difference between upstream and downstream direction of the flow. The difference in pressure is caused by the periodic separation of flow over surface of the cylinder. Periodic separation induces fluctuations in the flow and makes the cylinder vibrate. To reduce the amount of drag or the drag coefficient of a cylinder various active and passive flow control methods have been employed and tested successfully. These methods include roughened surfaces [10], [11], dimpled surfaces [12]-[15], trip wires [16] and active blowing and suction of air [17].

2. Numerical Analysis

For numerical calculations, two dimensional geometry, steady flow, no-slip walls, laminar models for the airflow were considered. The three geometries have chosen to instigate numerically.

2.1. Geometry Selection

The cylinders with and without grooves are chosen to do numerical investigation. The three cases are shown in Fig 1.

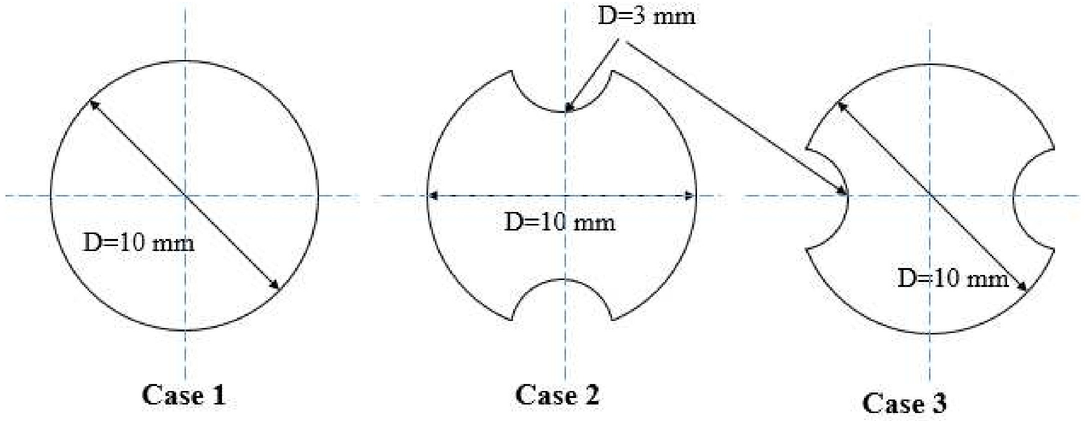

Fig. 1. Cylinder (left) and cylinder with grooves (right)

2.2. Computational Domain

Several computational domains with structured grids were constructed and tested in order to get gird independent result. The domain system shown in Fig. 2 gave the best result and was used for further investigations.

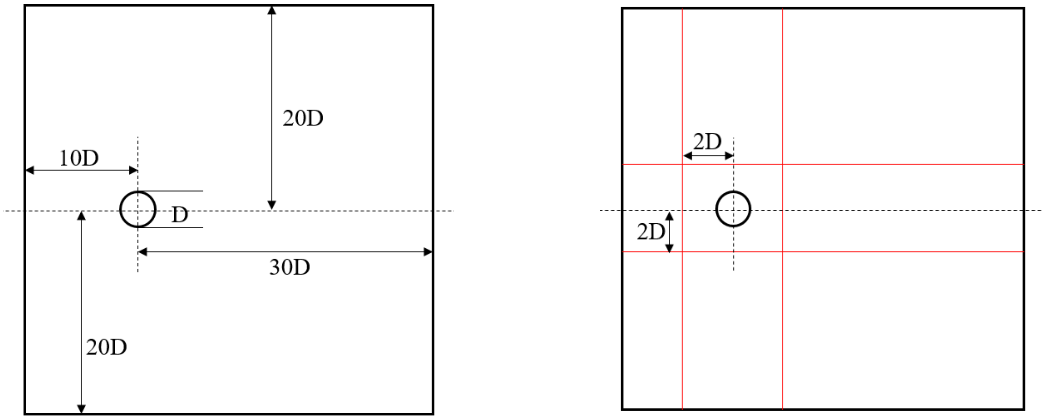

Fig. 2. Computational domain of a cylinder

2.3. Meshing

For two dimensional computations over the model, a structured grid consisting of quadrilateral cells were used. The grid independence test must be done by transforming the generated physical model into a mesh with different number of node points. It is said to be grid independence when the result doesn't change with increasing grid numbers. The result obtained for this mesh is considered to be the best.

It was found in Fig. 3 that a medium grid of 51369 has a very close fit with a fine grid of 75720 quadrilateral cells. A coarse grid of 30892 quadrilateral cells also showed close approximation with the other two grid levels. Therefore, the medium grid level is adopted for all cases considering numerical stability and minimum computational cost. This medium grid resolution used here is sufficient to capture the physically relevant features.

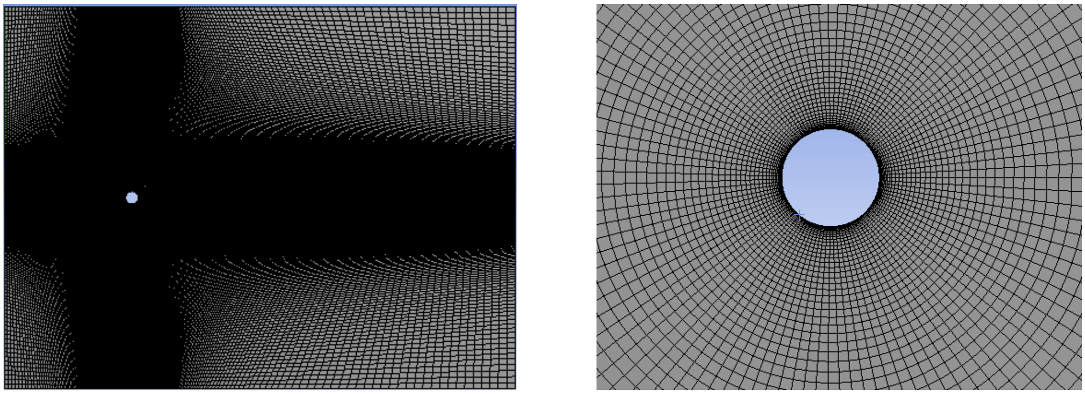

Fig. 3. Medium mesh for circular cylinder

2.4. Boundary Conditions

The computational domain is bounded by velocity inlet, no-slip walls and pressure outlet as shown in Figure 4.

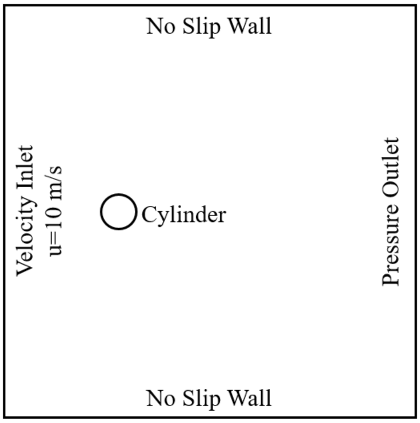

Fig. 4. Boundary conditions of a cylinder

3. Results

3.1. Coefficient of Lift over Cylinders

As shown in Fig 5-7 the lift coefficient over cylinders are small amount between -0.01 to 0.01. The fluctuation of curves shows the effect of Von Karman Vortex especially case (1) and case (3).

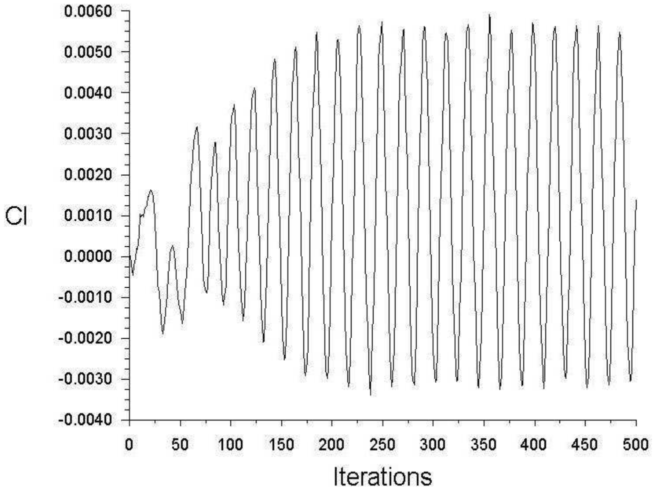

Fig. 5. Variation of lift coefficient of lift through 500 iteration for case 1

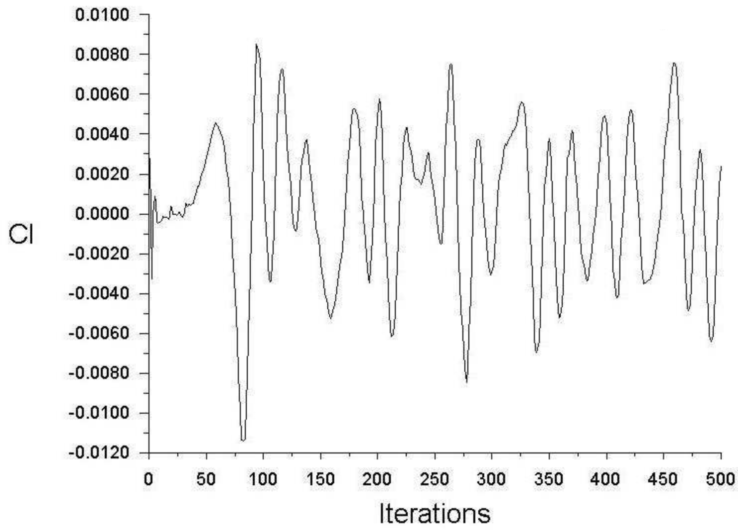

Fig. 6. Variation of lift coefficient of lift through 500 iteration for case 2

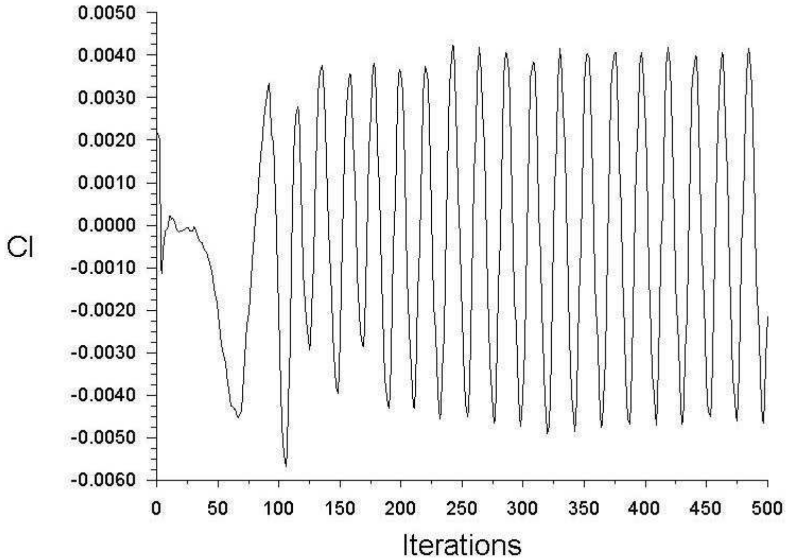

Fig. 7. Variation of lift coefficient of lift through 500 iteration for case 3

3.2. Velocity Contours

The velocity contours are almost the same especially case 1 and case 3 that can be seen in Fig 8 and Fig 10.

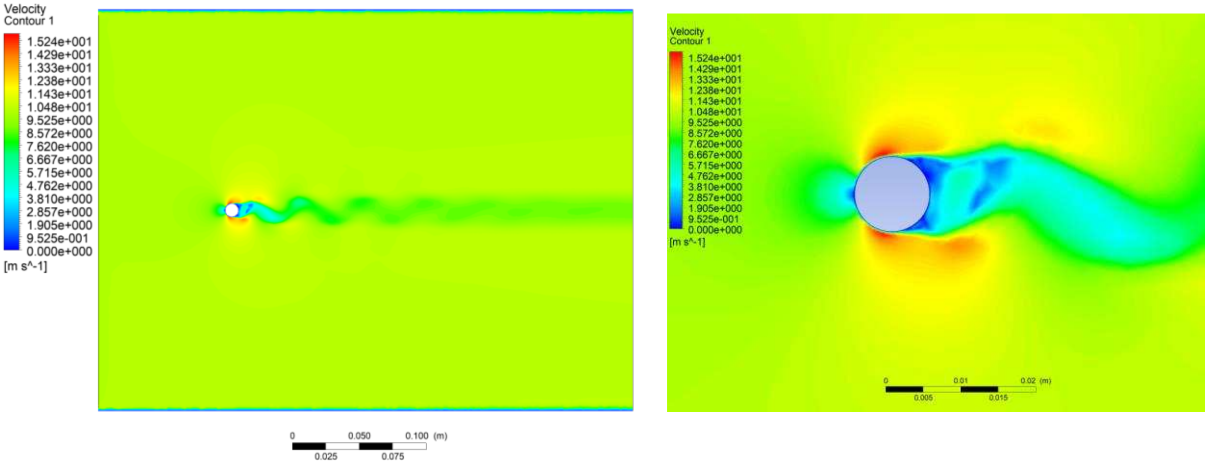

Fig. 8. Velocity contour for case 1

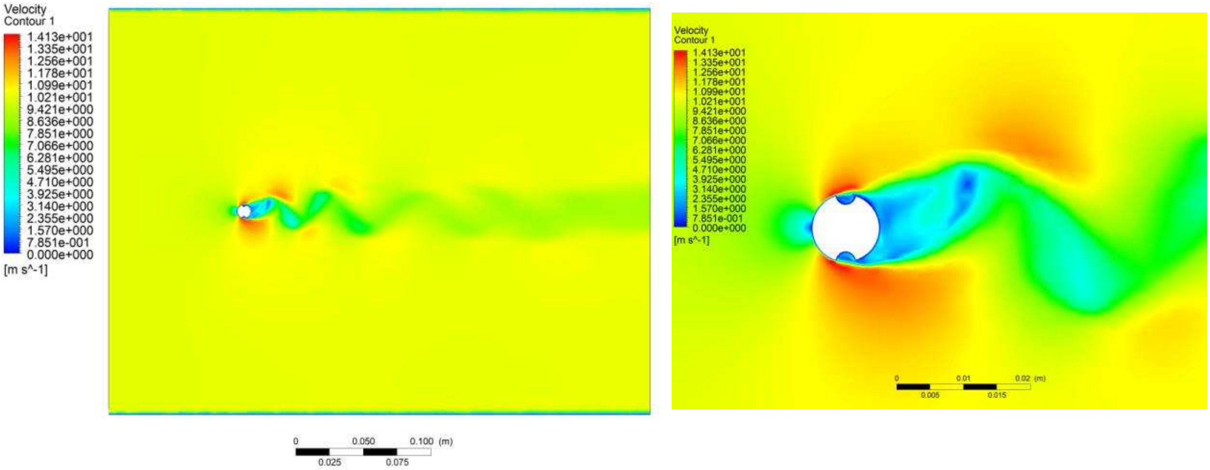

Fig. 9. Velocity contour for case 2

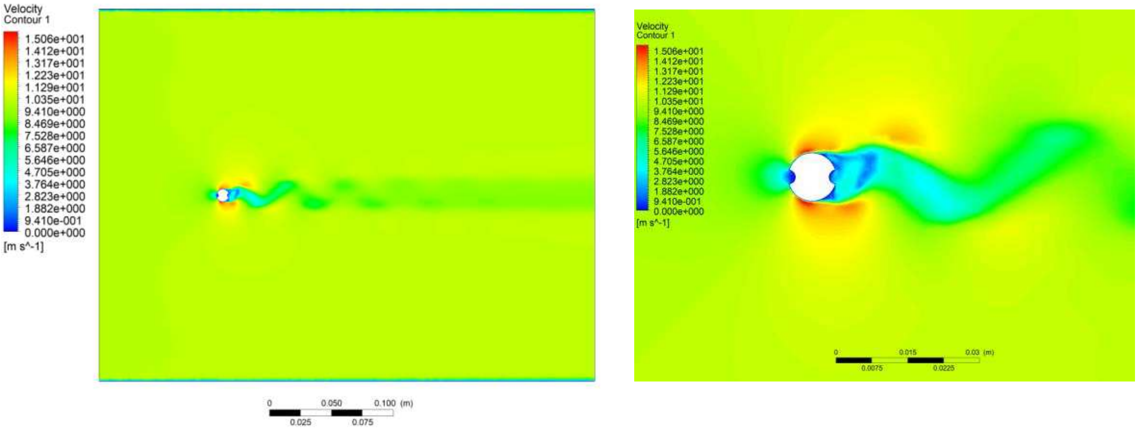

Fig. 10. Velocity contour for case 3

3.3. Velocity Streamlines

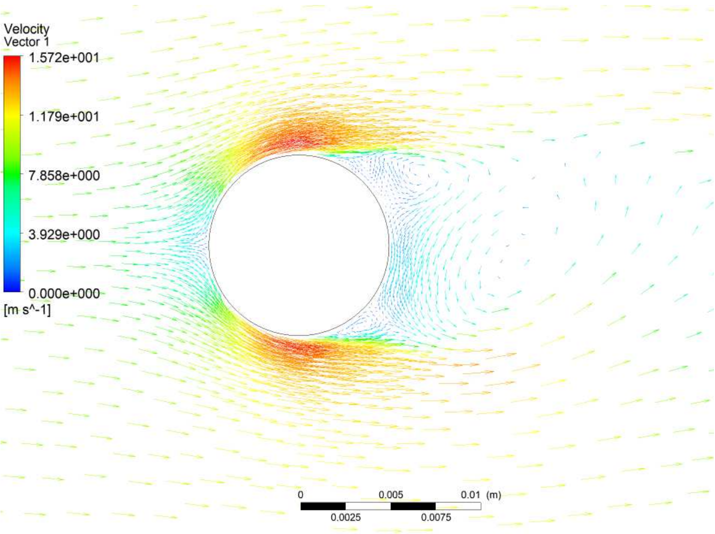

Fig. 11. Streamlines for case 1

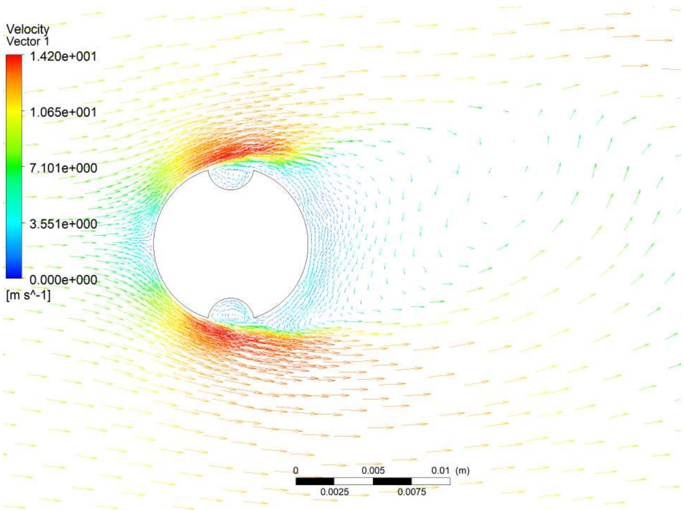

Fig. 12. Streamlines for case 2

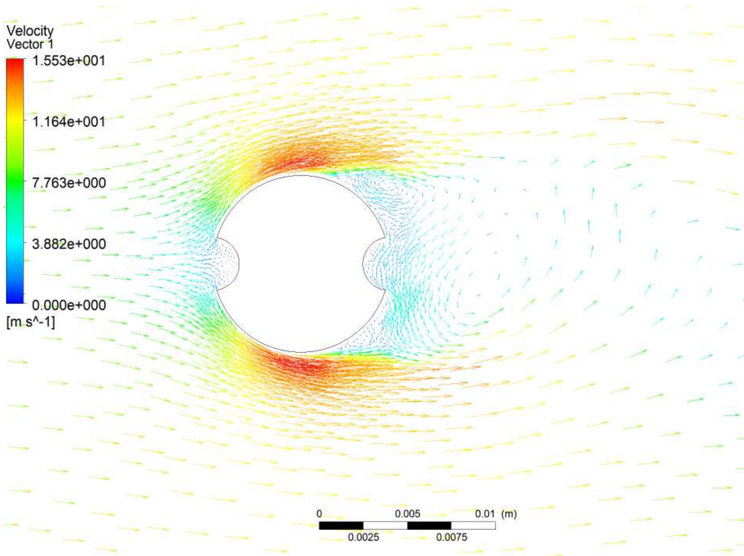

Fig. 13. Streamlines for case 3

4. Conclusion

A cylinder represents a very basic geometry and different types of flows over a cylinder have been experimentally and theoretically studied over the years. By these results the flow fields of various cylinder are not very differ each other at upcoming velocity of 10 m/s, cylinder diameter of 10 mm, groove diameter of 3 mm, laminar flow and steady conditions. But the separation patterns behind the cylinder are not similar with each other.

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