Numerical Simulation of the Heat-Fluid Flow Behavior Around the Cylinder with the Controller Wire

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1. Introduction

The study of fluid flow and heat transfer on various objects is widely used in engineering industries such as heat exchangers, construction, and nuclear reactor pipes. External flows over solids with different shape cause a region with some vortices. This region is created after separation point. Therefore, the control of separation point is very important for flow over different objects as airplanes, vehicles, etc. In this study, the results for a single cylinder was validated by other research results. Then, the flow over two parallel cylinders in the stationary state and in the distance range of 1.5 <L / D <4 was simulated, and the critical distance between the two cylinders was obtained between 3.5 and 4. Then the influence of the oscillating cylinder on the flow pattern was investigated. The distance between the two cylinders was L/D = 2, Reynolds number was 100, and the amplitude of oscillation (A/D) was considered 0.3 according to previous studies. Also, the relative frequency (F = f/fs) varied from 1.5 to 7.

2. The Governing Equations and Solving Method

According to the considered Reynolds number, the flow regime is laminar flow with heat transfer. The governing equations are the Navier-Stokes equations with the energy equation, which are solved numerically in this paper. In the final part of this paper, the upstream cylinder has a vertical motion with this equation.

$$Y(t)=A\sin(2\pi f_0 t) \quad (1)$$

where A is the Oscillation range, f_o is the Forced oscillation frequency and t is the time. Laminar Flow over two cylinders was simulated in this work. The flow domain and its boundary conditions are shown in Figure 1.

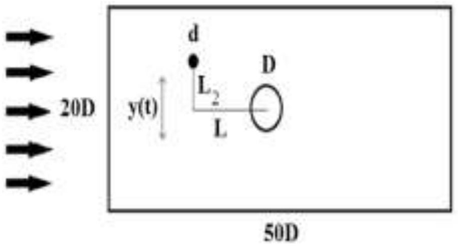

Figure 1. The flow domain and its boundary conditions

Flow enters horizontally from the channel input and exits at the end. The velocity and temperature were given at the inlet as boundary conditions. These are constant and do not change in y direction. The velocity is considered zero at walls according to the non-slip condition. The walls are considered insolated. The relative pressure is considered zero at the outlet as another boundary condition. All boundary conditions are steady and do not change during time. The triangle unstructured grids are used for numerical simulation in this work. The generated grids are closed to each other in the boundaries for more accuracy.

3. Results and Discussion

Flow over two cylinders were simulated in different boundary conditions. The streamlines, isotherms, the place and shape of vortices were obtained by numerical simulations and are displayed in different figures. Moreover, drag coefficient and Nusselt number in each simulation were calculated and compared with those of single cylinders. Figures 2 to 5 are examples of these results.

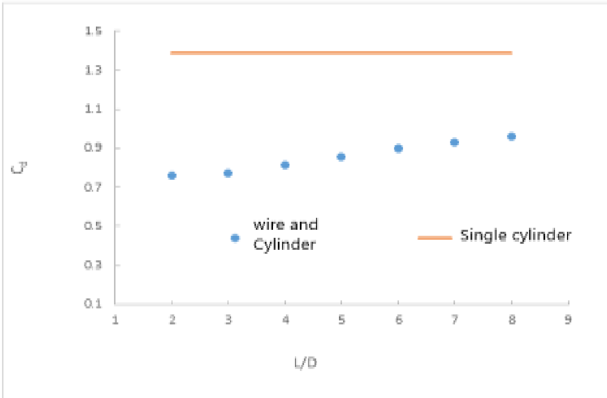

Figure 2. Drag coefficient variation with L/D at Re=100 and d=0.3D

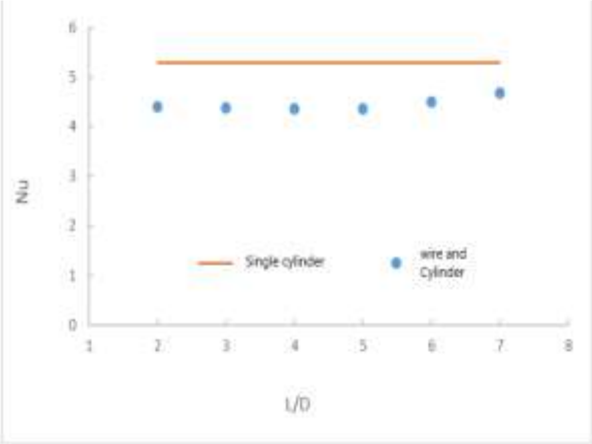

Figure 3. Nusselt number variation with L/D at Re=100 and d=0.3D

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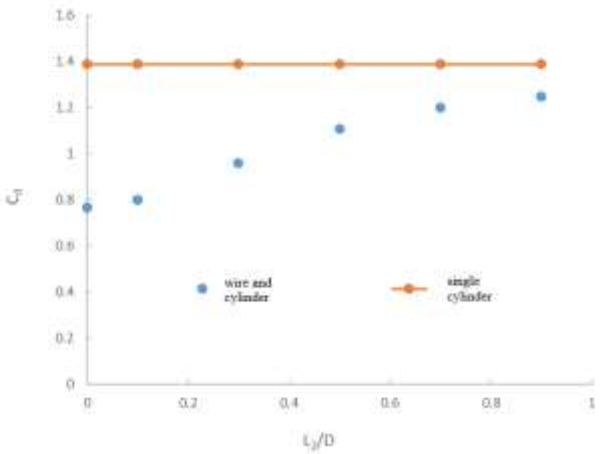

Figure 4. Drag coefficient variation with L2/D at Re=100 and d=0.3D

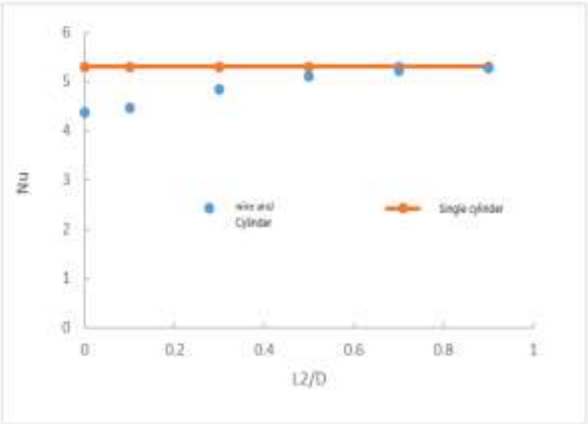

Figure 5. Nusselt number variation with L2/D at Re=100 and d=0.3D

4. Conclusion

In this study, the effect of the presence of a control wire on the thermo-fluid characteristics of flow over a cylinder was investigated and analyzed at Re=100. The results showed that by increasing the horizontal distance of the control wire from the cylinder, the drag coefficients and Nusselt number changes slightly. Although the presence of wire reduces the drag coefficient and Nusselt number of the cylinder, by increasing the vertical distance, these parameters increase slightly and become closer to these parameters on the single cylinder. Investigation of the effects of wire diameter size on the heat-fluid parameters of a cylinder showed that by increasing the wire diameter in a fixed horizontal position, the drag coefficient of the cylinder decreases. The increase of the low-pressure area in front of the cylinder and the decrease of the pressure difference between the two sides of the main cylinder, and as a result, pressure drag forces decreases. The pressure drag force is the main part of total drag force. In addition, heat transfer rate and mean Nusselt number increase in this state according to the same reason. Results showed that there is not any vortex between two cylinders up to the h=8D while the first cylinder is stationary. While the first cylinder starts to sinusoidal oscillation with amplitude 0.25, the vortices create. In other words, the oscillation of the wire accelerates the creation of vortices in the space between the cylinder and the wire.