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NUMERICAL STUDY OF FLOW STRUCTURE AROUND TANDEM SQUARE CYLINDERS PLACED NEAR A MOVING WALL

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Abstract: A numerical investigation of flow past two square cylinders in tandem placed near a moving plane wall has been made. The flow is uniform and is the positive x-direction. The plane wall is also moving in the same direction as the fluid with the same velocity. The cylinder-cylinder gap ratio (S/D) and the cylinder-wall gap ratio (G/D) is varied in the range $0.5 \leq S/D \leq 5$ and $0.1 \leq G/D \leq 4$, respectively. Numerical simulations are performed for a fixed Reynolds number of 100 where the flow is laminar, two-dimensional and unsteady using a finite volume method based on SIMPLE algorithm. Vortex shedding is suppressed when S/D and G/D falls below a critical value. Drag and lift coefficient of the cylinder changes considerably when brought close to the moving wall compared to the isolated case.

Keywords: Cylinder, Numerical Investigation

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INTRODUCTION

Bluff body flow is an interesting research topic. Unsteady flow around isolated bodies, such as a square cylinder, and the resulting vortex shedding characteristics has extensively been investigated in the past [1]. When an otherwise isolated cylinder is brought either near a wall or another cylinder, vortex shedding is suppressed depending on cylinder-wall or cylinder-cylinder distance. The technique of placing a second cylinder close to the main cylinder has been effectively used for the control of vortex shedding [2]. When a square cylinder is placed near a moving wall, Vortex shedding is suppressed below a critical gap ratio of 0.3 at Re = 100 [3]. Parameters such as drag and lift coefficient are altered when the cylinder is brought in proximity to a moving wall [3,4]. In this study, effects of placing tandem square cylinders near a moving wall at various gap ratios are analyzed numerically. The gap between the cylinders is varied while they are gradually brought towards the moving wall.

Problem statement

Consider two square cylinders of size 'D' separated by a distance 'S' placed at a height 'G 'above a plane moving wall as shown in Fig. 1. The cylinders are placed in a fluid stream flowing with a uniform velocity U_∞. The plane wall is moving, in the positive x-direction, at a constant velocity same as that of the free stream. The gap ratio (G/D), defined as the ratio of distance between the bottom face of the cylinder to the moving wall, is varied from 0.1 to 4 while the gap ratio (S/D) between the first and second cylinder is varied from 0.5 to 5. Numerical simulations are performed at a fixed Re of 100. At this Re, flow around a isolated square cylinder is laminar, two-dimensional and unsteady. The effect of gap ratio (S/D) and space ratio (S/D) on the flow and vortex structure will be studied in detail. Numerical results for the drag coefficient, lift coefficient, pressure distribution around the cylinder, etc., will be presented for different S/D and G/D ratio.

Governing equations

The governing equations for the incompressible, unsteady, two-dimensional flow past tandem square cylinders near a moving wall are the continuity and momentum in the dimensionless form as presented below:

Continuity equation:

$$\frac{\partial U}{\partial X}+\frac{\partial V}{\partial Y}=0$$

Momentum equations:

$$\frac{\partial U}{\partial \tau}+U\frac{\partial U}{\partial X}+V\frac{\partial U}{\partial Y}=-\frac{\partial P}{\partial X}+\frac{1}{\mathrm{Re}}\left[\frac{\partial^2 U}{\partial X^2}+\frac{\partial^2 U}{\partial Y^2}\right]$$

$$\frac{\partial V}{\partial \tau} + U\frac{\partial V}{\partial X} + V\frac{\partial V}{\partial Y} = -\frac{\partial P}{\partial Y} + \frac{1}{\mathrm{Re}}\left[\frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2}\right]$$

Here, *Re* is the Reynolds number.

FIGURES

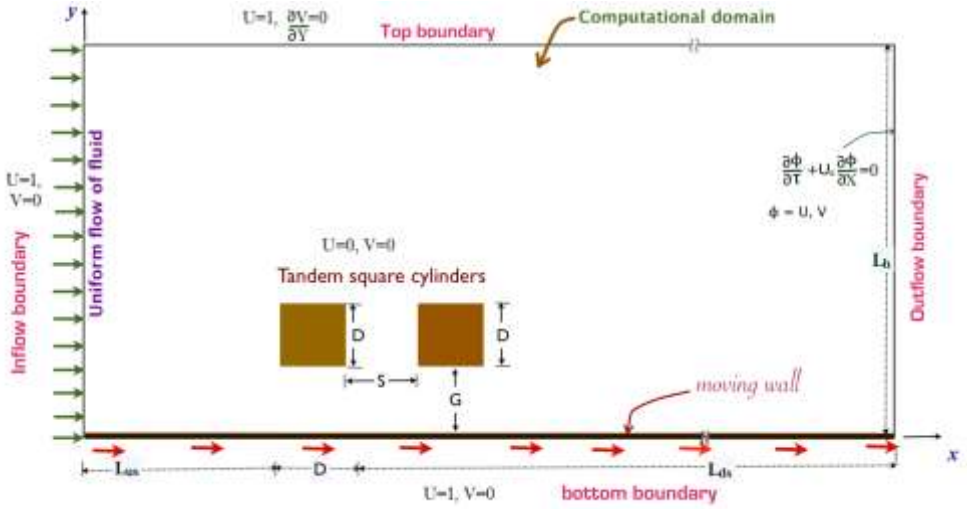

Figure 1. Schematic of the flow configuration for uniform flow past tandem square cylinders near a plane moving wall.

RESULTS

A numerical study of fluid flow around square cylinders in tandem, placed near a moving wall, is made using a finite volume method based on SIMPLE Algorithm at a fixed Reynolds number of 100. At a fixed spacing ratio of 5, vortex shedding phenomenon is observed from both the upstream and downstream cylinders when they are away from the moving wall at a gap ratio G/D = 4. At the same spacing ratio, when the cylinders are moved towards the moving wall, vortex shedding ceases from both the cylinder beyond a critical value of G/D. That is, flow reaches a steady state when G/D < 0.2 for all S/D. For large values of G/D, with decreasing spacing ratio (S/D < 5), vortex shedding from the upstream cylinder ceases after a critical value of S/D while vortices still emanate from the downstream cylinder. At large G/D values, the drag coefficient of the downstream cylinder is found to be negative as the cylinder gets attracted to the upstream cylinder. With decreasing G/D values, the drag coefficient of both the cylinders rises rapidly for all S/D values. The increase is more prominent when G/D < 0.3. A large stagnant region is observed behind the downstream cylinder when G/D = 0.1. Several other interesting features of the flow are presented in terms of instantaneous as well as time-averaged vorticity contours and streamlines.

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