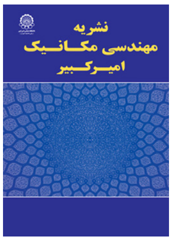

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Numerical Study on the Vortex-induced Vibration of Circular Cylinder

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ABSTRACT: In the vortex-induced vibration the structure interacts with the fluid flow that results in the vibration of the structure and sometimes leads to the destruction of it. In this paper, the effect of the vortex-induced vibration on one and two cylinder(s) in the rotating and non-rotating states are studied, numerically. For the case of single non-rotating cylinder, the effect of the reduced velocity and damping ratio on the displacement and velocity of circular cylinder and also on the lift coefficient and its components are investigated. The cylinder displacement decreases by increasing the damping ratio. The vortex shedding pattern for all examined reduced velocity and damping ratio is in the 2S mode. In all cases, two patterns of vibration, harmonic and beating phenomena, can be observed. The maximum value of the vibration amplitude is related to the reduced velocity of 4 for $\zeta = 0$ and the minimum is belonged to the reduced velocity of 3. For the case of rotating cylinder, it is observed that the rotation of cylinder(s) affects the vortex shedding pattern and their strength, significantly. Therefore, the fluctuation of lift coefficient and vibration of cylinder(s) are reduced considerably.

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1- Introduction

Vortex shedding is a phenomenon in fluid dynamics that occurs when viscous fluid passes a bluff body at certain Reynolds number depending on the size and shape of the body. The shedding of asymmetric vortices from the bluff body results in oscillating hydrodynamic forces acting on the body and thus leads to its vibration known as Vortex-Induced Vibration (VIV). Whenever the frequency of vortex shedding becomes close to the natural frequency of the body, the Lock-in phenomenon takes place that causes to large amplitude of vibration.

In recent years, in some researches the effects of Reynolds number [1], number of cylinders [2] and the geometry and material of the cylinder [3] on the VIV phenomenon have been investigated. In this study, the fluid is taken as water, and different values of damping coefficient and the reduced velocity are considered. Also the effects of rotation of the cylinder and the presence of a second cylinder are investigated.

2- Methodology

The computational domain used in the present study for simulating the VIV of one and two cylinder(s) in fluid flow are shown as in Fig 1. The center of cylinder is placed in the middle of the height H. The values of x_d, L and H are considered $12D$, $48D$, and $24D$, respectively.

The cylinder vibration in transverse direction is predicted using a mass-spring-damping system as follows:

$$m_{eq}\ddot{y} + c_{eq}\dot{y} + k_{eq}y = f_L(t) \qquad (1)$$

where y, $\dot{y}$ and $\ddot{y}$ are the displacement, the velocity and the acceleration of the cylinder in the transverse direction of the flow, respectively. m_{eq}, c_{eq}, and k_{eq} are the mass equivalent, the damping factor equivalent and the spring stiffness equivalent of the vibration system, respectively. $f_L(t)$ is the lift force

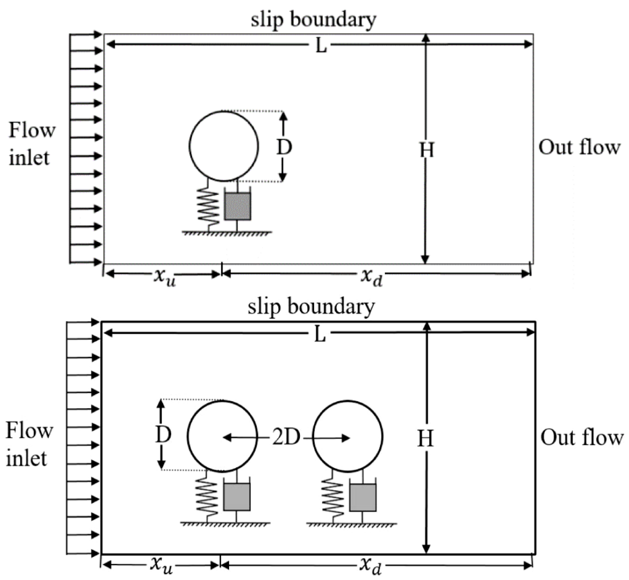

Fig. 1. The computational domain used in this study

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exerted by the fluid on the cylinder.

The boundary conditions are shown in Fig. 1. At the inlet, the uniform velocity boundary condition is used, whereas at the channel outlet, the homogenous Neumann boundary is implemented. On the top and bottom walls and surface of cylinder(s) the no slip boundary condition is applied. The smoothing method of the dynamic mesh which adjusts the mesh by moving the boundary is selected for cylinder motion. The governing equations are solved by the commercial software ANSYS FLUENT 17.0 in which the motion of the system is enforced by User-Defined Functions (UDFs) embedded in to the code.

3- Results and Discussion

The results of numerical solution are presented for U_r=3-8 and ς=0-0.1 at Re_D=150 and m^*=2. Fig. 2 shows the time histories of the cylinder displacement and FFT for U_r=4 at different damping ratio. The mean value of displacement in all damping ratio are zero, so the circular cylinder oscillates around its initial position, y^*=0. Two patterns of vibration, harmonic and beating phenomena, can be observed. For ς=0.05 the beating phenomenon occurs, in which the amplitude of cylinder displacement changes with time and several dominant frequency exist.

The effect of cylinder rotation on the VIV of one and two cylinder(s) are investigated. Fig. 3 shows the time histories of

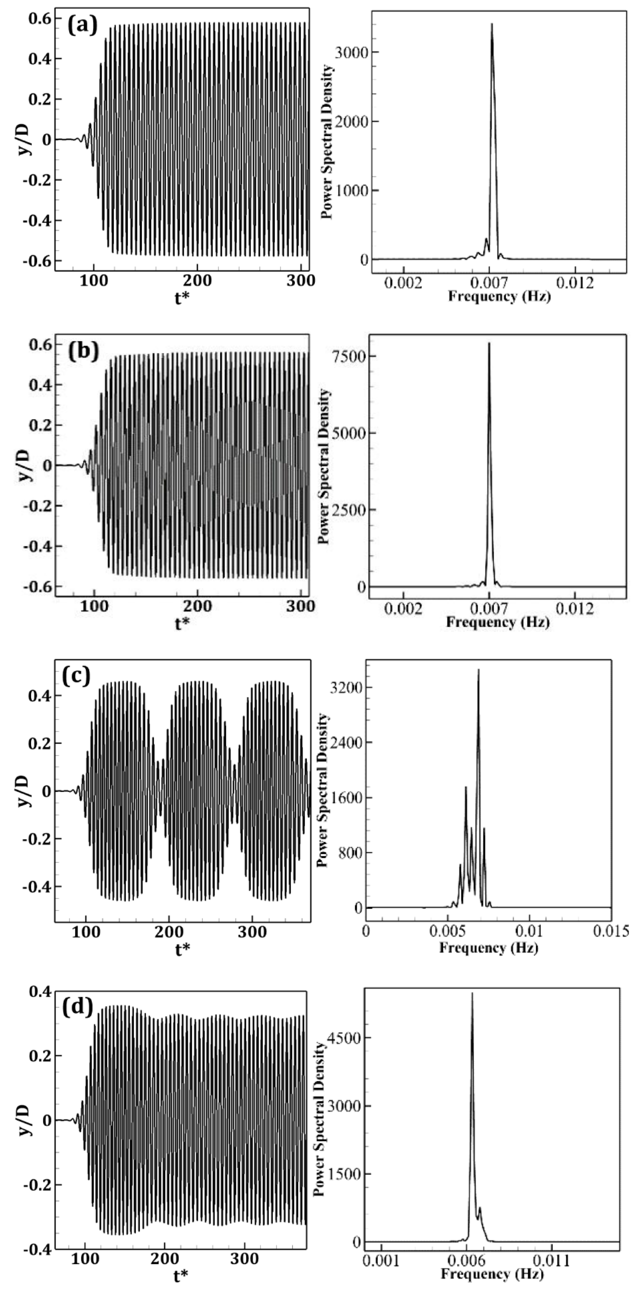

Fig. 2. Time histories of the cylinder displacement and FFT for the reduced velocity of 4 and the damping ratio of a) 0 , b) 0.01, c) 0.05 and d) 0.1

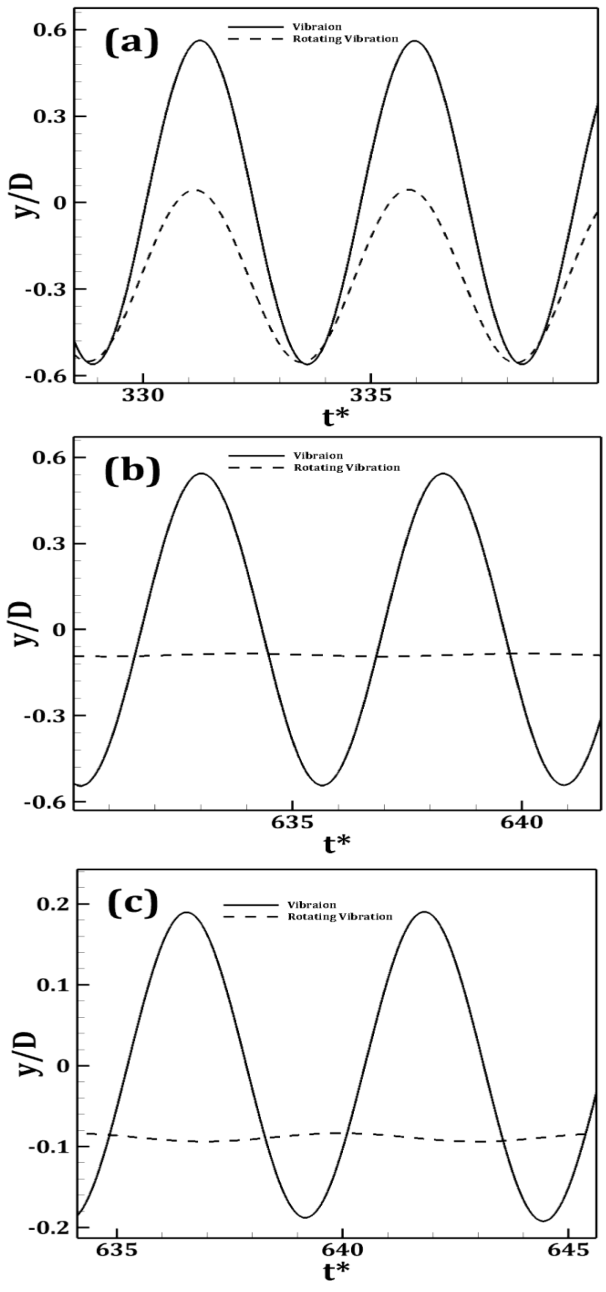

Fig. 3. Time histories of the cylinder displacement for a) the single cylinder, b) the front cylinder and c) the rear cylinder for two cylinders

the cylinder displacement at Re_D=150, U_r=4, ς=0.01, and α=1. In all cases at this speed of rotation, the cylinder displacement decreases. The effect of cylinder rotation on reducing the displacement of two cylinders is more than single cylinder. In the non-rotating two cylinders case, the displacement of the rare cylinder is much less than the front one.

4- Conclusions

The vortex-induced vibration of one and two circular cylinder(s) for rotating and non-rotating condition are investigated numerically over ranges of $3 \leq U_r \leq 8$ and $0 \leq \varsigma \leq 0.1$ at Re_D=150, and m^*=2. The reduced velocity and damping ratio impress on the vorticity formation and vortex shedding pattern and consequently on the cylinder displacement. The maximum value of the vibration amplitude is related to the reduced velocity of 4 for ς=0. For the case of rotating cylinder, it is observed that the rotation of cylinder(s) affect the vortex shedding pattern and the vibration of cylinder(s) are reduced considerably.

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