Numerical Simulation of Vortex-induced Vibration of Side-By-Side Circular Cylinders

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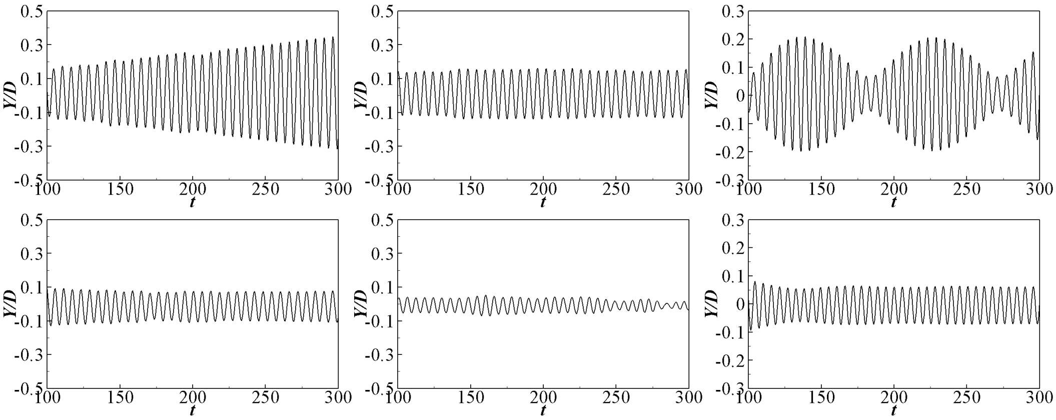
Extended Abstract

Two side-by-side cylinders in a cross flow is one of the most basic and revealing cases for multiple structures in a cross flow, particularly at the intermediate spacing ratio. It has been well known that the gap flow at spacing ratio of 1.2 ~ 2.0 is a bistable and biased flow (Ishigai et al., 1972; Bearman and Wadcock, 1973 and Liu et al., 2001). Ishigai et al. (1972) and Quadflieg (1977) suggested that the biased gap flow was due to Coanda effect, i.e. the gap flow attaching itself to the curved surface of one cylinder than the other due to asymmetric separation. Bearman and Wadcock (1973) found that the asymmetry was due to a near-wake phenomenon and not to the position of the boundary layer separation. On the other hand, Williamson (1985) found the existence of harmonic vortex-shedding modes behind a pair of cylinders, and observed that the shedding frequency on one side of the wake was a multiple of that on the other. Sumner et al. (1997, 1999) studied the fluid-structure interaction phenomenon in a water tunnel. They found that the reported bistable nature of the biased flow was not detected in the water tunnel experiments. Consequently, they questioned whether this was a coincidence or whether there was a deeper underlying reason. In a word, cross flow past two rigid side-by-side cylinders has been extensively analyzed. However, the actual situation is not completely rigid, cylinders are generally elastic structure. Due to the fluid structure interaction, the vortex-induced vibration will be caused. In this numerical work, vortex-induced vibration of two elastic circular cylinders in side-by-side arrangement is studied. The simulations were carried out with Galerkin finite element method at Reynolds numbers 200 for two degree of freedom. The cylinder spacings were chosen, T/D =1.5, 2.0 and 3.0. The mass ratio is m^* = 20.0, and three reduced velocities were chosen, Ur = 4.0，6.0 and 8.0. The characteristics of flow-induced oscillation, including wake flow pattern, displacement amplitude of oscillation, lift and drag coefficients, were examined systematically.

Figure 1 show the transverse displacement of two cylinders changing with time. Generally, the amplitude of lower cylinder was significantly smaller than the upper cylinder and the vibration of lower cylinder was in a “lock-in” state, i.e., their amplitudes changes periodically. Three different vibration modes can be analyzed out: (1) (Figure 1 a) the vibration amplitude of upper cylinder is increasing gradually. This kind of phenomenon is produced by resonance. (2) (Figure 1b) the vibration amplitude of upper cylinder was in a “lock-in” state too. (3) (Figure 1c) the vibration pattern is called “beat” mode, the vibration amplitude of the upper cylinder change significantly and periodically.



(a) *T/D* = 1.5 (b) *T/D* = 2.0 (c) *T/D* = 3.0

Figure 1 the transverse displacement of two cylinders changing with time

In this paper, the following conclusions can be reached:

(1)The vortex-induced vibration can improve biased flow phenomenon, at the same time, has destructive effect on regular structure of non-interference zone.

(2) For *Ur* = 6, *T/D* = 1.5, 2.0 and 3.0, three vibration phenomenon, resonance, “beat” and “lock-in” mode, have been captured.

(3) For *T/D* = 3, *Ur* = 4, 6 and 8, lift and drag coefficients have been weakened when compared to still situation. The frequency of vibration is reduced gradually with increasing reduced velocity. For the transverse vibration, when *Ur* change from 4 to 6 then 8, the vibration mode of upper cylinder change with different forms of “beat” while the vibration mode of the lower cylinder change with low-amplitude, “beat” and “lock-in” mode respectively. For longitudinal vibration, when *Ur* change from 4 to 6 then 8, the vibration mode of upper cylinder change with resonance, “beat” and “lock-in” mode respectively while the vibration mode of the lower cylinder always remain “lock-in” mode.

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