

Experimental Study on Flow Induced Vibration of a Cylinder with Two Degrees of Freedom Near a Rigid Wall

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ABSTRACT

The flow-induced vibration of a cylinder with two degrees of freedom near a rigid wall under the action of steady flow is investigated experimentally. The vibration amplitude and frequency of the cylinder and the vortex shedding frequency at the wake flow region of the cylinder are measured. The influence of gap-to-diameter ratio upon the amplitude response is analyzed. The experimental results indicate that when the reduced velocity (Vr) is in the range of $1.2 < Vr < 2.6$, only streamwise vibration with small amplitude occurs, whose frequency is quite close to its natural frequency in the still water. When the reduced velocity $Vr > 3.4$, both the streamwise and transverse vibrations of the cylinder occur. In this range, the amplitudes of transverse vibration are much larger than those of streamwise vibrations, and the amplitudes of the streamwise vibration also get larger than those at the range of $1.2 < Vr < 2.6$. At the range of $Vr > 3.4$, the frequency of streamwise vibration undergoes a jump at certain values of Vr , at which the streamwise vibrating frequency is twice as much as the transverse one. However, when the streamwise vibration does not experience a jump, its frequency is the same as that of the transverse vibration. The maximum values of second streamwise and transverse vibration amplitudes increase with increasing gap-to-diameter ratios.

KEY WORDS: Flow-induced vibration; Cylinder near a wall; Two degrees of freedom; Streamwise vibration; Transverse vibration

INTRODUCTION

The flow-induced vibrations of a cylinder are a fluid-structure interaction problem, which have a wide practical background. For example, the bridges and chimneys under wind actions in civil engineering, the risers and pipelines in offshore engineering, the heat exchangers tubes in chemical engineering, are prone to flow-induced vibrations, which have attracted wide interests from numerous researchers, e.g., Sarpkaya (1979), Griffin & Ramberg (1982), Bearman (1984), Parkinson (1989), Sumer & Fredsoe (1997), Williamson & Govardhan (2004). Most of previous researches have mainly focused

on the transverse dynamic responses of the cylinder undergoing flow-induced vibration. Feng (1968) studied the flow-induced vibration of a cylinder with a single degree of freedom in the transverse flow direction, and demonstrated that the resonance of the cylinder will occur when the vortex-shedding frequency at the wake region of the cylinder is close to the natural frequency of the cylinder. The vibration amplitude branches were investigated intensively by Brika & Laneville (1993), Khalak & Williamson (1996) and Govardhan & Williamson (2000). Nevertheless, the studies on the flow-induced vibration of the cylinder with two degrees of freedom are scarce till now (Williamson & Govardhan, 2004). Moe & Wu (1990) found that the position of maximum amplitude of the cylinder with two degrees of freedom shifts to a higher value of reduced velocity and the maximum amplitude also reaches higher values, compared with those of transverse-motion ones, under the condition of different mass ratios and natural frequencies in the streamwise and transverse direction. Sarpkaya (1995) also drew a similar conclusion to that by Moe and Wu (1990). Jauvtis & Williamson (2003) studied the response of an elastically mounted cylinder with two degrees of freedom and low mass and damping. Their results indicated that the freedom to oscillate in-line with the flow affects the transverse vibration very little for the mass ratios larger than 5.0. The experimental results by Williamson & Jauvtis (2004) indicated that there exists much difference between the response of the cylinder with one degree of freedom and that with two degrees of freedom for the case of mass ratios less than 6.0. In the aforementioned work, the flow-induced vibrations are mainly under the wall-free conditions. Under some practical circumstances, the cylinders are close to a wall, e.g., the submarine pipelines installed upon the seafloor. The mechanism for flow-induced vibrations of a cylinder with two degrees of freedom near a wall is still desired to be revealed.

In this study, the experiments were conducted in a flume to further investigate the flow-induced vibration of a cylinder with two degrees of freedom near a rigid wall. The characteristics of the transverse and streamwise vibrations of the cylinder with the proximity to the rigid wall are analyzed in detail. Moreover, the present experimental results are compared with previous ones.