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MULTI-MODE OF VORTEX-INDUCED VIBRATION OF A FLEXIBLE CIRCULAR CYLINDER*

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Abstract: The vortex-induced vibration of a flexible circular cylinder is investigated at a constant Reynolds number of 1 000. The finite-volume method on moving meshes is applied for the fluid flow, and the Euler-Bernoulli beam theory is used to model the dynamic response of a flexible cylinder. The relationship between the reduced velocity and the amplitude response agrees well with the experimental results. Moreover, five different vibrating modes appear in the simulation. From the comparisons of their vortex structures, the strength of the wake flow is related to the exciting vibrating mode and different vortex patterns arise for different vibrating modes. Only 2P pattern appears in the first vibrating mode while 2S-2P patterns occur in the other vibrating modes if monitoring at different sections along the length of the cylinder. The vibration of the flexible cylinder can also greatly alter the three-dimensionality in the wake, which needs further studies in our future work, especially in the transition region for the Reynolds number from 170 to 300.

Key words: multi-mode, Vortex-Induced Vibration (VIV), three-dimensional instability, flexible cylinders, Euler-Bernoulli beam

Introduction

As were reviewed by Refs.[1,2], much progress has been made both numerically and experimentally, toward many fundamental insights into the vortex dynamics in the wake of a vibrating cylinder. Most of the previous studies were focused on the hysteresis phenomena, lock-in/lock-out region determination, hydrodynamic forces on the cylinder, vortex-shedding patterns, and the effect of the mass-damping parameters on the dynamic response of the cylinder. Aiming at the complicated nonlinear wake-body coupling characteristics in vortex-induced vibrations, semi-empirical models, such as wake-oscillator model based on the van der Pol equation, have been developped in recent studies[3-6].

The studies on Vortex-Induced Vibration (VIV) have been expanded into 3-D and flexible cylinders with the increasing demands for more comprehensive understanding of VIV in realistic engineering problems during recent years. Ren et al.[7] employed an Arbitrary Lagrangian-Eulerian (ALE) method in dealing with the flow-induced vibration of an elastic circular cylinder at $Re = 200$, in which the transition of the wake patterns or vortex shedding modes was captured. Deng et al.[8,9] investigated the wake characteristics of two circular cylinders arranged perpendicular to each other in a uniform flow and found that the peak amplitude of vibrations for the cruciform arrangement is lower than that of an isolated cylinder, and the resonance region is wider than that of an isolated cylinder, and the distinct vortex shedding patterns in the wake were studied as well. Flow-structure coupling problems in VIV have attracted more attentions, where the cylinders were flexible, differing from the rigid cylinders in previous studies. Except for the detailed hydrodynamic explanations that have been given by the laboratory experiments with spring-mounted rigid cylinders and for first mode standing wave vibrations of flexible cylinders, the authors[10] have recently conducted experiments on very long flexible cylinders in the ocean, as well as by laboratory experiments. These experiments have revealed

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