Turbulent Flow around Two Yawed Wavy Cylinders in Tandem Arrangement

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ABSTRACT

The turbulent flow around two yawed wavy cylinders in tandem arrangement is studied using three-dimensional large eddy simulation. A range of spacing (L) between the cylinders from 1.5 to 5.5Dm and yaw angle of α=0°, 30° are investigated with emphasis on identifying the effects of three-dimensionality, cylinder spacing ratio and yaw angle as well as their coupling effects. The detailed near wake flow patterns of the yawed cylinders are captured. The effects of vortices from the upstream cylinder on the fluid-dynamic forces acting on the downstream cylinder are discussed.

KEY WORDS: Yawed wavy cylinders; Turbulent flow; Large eddy simulation; Vortex shedding.

INTRODUCTION

Multiple cylindrical bodies in tandem configurations are widely used in engineering applications, such as in cable suspension bridges, overhead cables, tow cables, chimney stacks, towers, offshore structures, etc. Many vibration problems have been experienced by such structures, when they are exposed to strong wind or high ocean currents. How to fully understand the complicated flow phenomena around such yawed or unyawed cylindrical cables and how to suppress their vortex induced vibration problems are important for many engineering applications. In fundamental research, Van Atta (1968) and Ramberg (1983) experimentally investigated flow past a yawed circular cylinder. They found that the drag coefficient and the Strouhal number, which are normalized by the velocity component perpendicular to the cylinder, are basically independent on the yaw angle of the circular cylinder (Independence Principle). Lucor and Karniadakis (2003) and Marshall (2003) also showed such phenomena by using numerical method. Moreover, extensive investigations on the cross flow past two circular cylinders and their fluid-dynamic forces have been performed through experimental and numerical methods: e.g., Lin et al. (2002), Papaioannou et al. (2006), and Kitagawa and Ohta (2008). Thakur, et al. (2004) also studied flow past two parallel yawed circular cylinders. The quasi-two-dimensional flow pattern characteristics are captured for both the single cylinder and cylinder pairs. The drag coefficient and Strouhal number are also obtained. On the control of vortex induced vibration of cylindrical structures, many investigations have been carried out. Lam and Lin (2008; 2009) introduced a special type of cylinder namely wavy cylinder for the suppression of vortex induced vibration. By using the numerical simulation, the detailed three-dimensional wake structures behind the wavy cylinders were captured and the optimal values of spanwise wavelength λ/Dm for the control of vortex induced vibration were found. By using the large eddy simulation method and experimental measurements, Lam et al. (2009) found that a wavy cylinder with spanwise wavelength λ/Dm=6 could lead to a significant drag reduction and suppression of vibration at the subcritical Reynolds number range. Furthermore, for small yaw angles, the drag coefficient and vibration of a yawed wavy cylinder are less than those of a corresponding circular cylinder at the same flow conditions.

Previous investigations have been concentrated on the study of flow past different types of single circular or wavy cylinder with different yaw angle in a wide range of Reynolds numbers. The effects of flow interference with a neighboring wavy cylinder and the vortex shedding phenomena for such flows at different angles of attack remain unanswered. Multi-cylindrical structures are very common in offshore structures and risers. The study should give further insight to the understanding of vortex induced vibration of multi-wavy cylindrical structures with different spacing ratios during yawed and unyawed conditions. The present work focuses attention on the flow past a tandem arrangement of two stationary wavy cylinders with different yaw angles of attack. It aims at finding whether this type of wavy cylinders configurations when using at yawed and unyawed conditions can suppress vortex induced vibration or not. By using large eddy simulation, the complex instantaneous three-dimensional wake patterns can be captured. The vortex shedding characteristics, flow patterns and force characteristics of wavy cylinders at different yaw angles can be obtained. The relationship between wavelength, yaw angle and force reduction can be fully examined. Such study would also provide further understanding and discovery on the physical mechanisms of vortex induced vibration and suppression, drag reduction and the three-dimensional wake vortices interactions of the two wavy cylinders at different yawed angles. Moreover, the circular cylinders at the same arrangements are computed for comparison. The effects of the vortices from the upstream cylinder on the fluid-dynamic forces acting on the