Effects of a higher Reynolds number and introduced perforation on flows past the conic cylinder

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ABSTRACT

Through numerical simulations, effects of a higher Reynolds number ($10^5$) and the introduction of perforation at a lower Reynolds number ($10^4$) on flows past a circular cylinder with the conic disturbance are investigated. Particularly, circular holes are located on and uniformly distributed around the peak of the conic shroud. Results have been shown that the higher Reynolds number of $10^5$ has little effect on qualitative variations of the drag and lift coefficients and the frequency of vortex shedding in most cases, which are almost similar to those at lower Reynolds numbers, as well as the introduced perforation. Nevertheless, there are still several exceptional cases with different hydrodynamic parameters resulted from the introduction of perforation. And different disturbance regimes and vortex patterns in the near wake for these cases are identified and presented in detail.

KEY WORDS: Numerical simulations; circular cylinder; conic disturbance; perforation; vortex-induced vibration.

INTRODUCTION

A straight and long cylinder is a common structure as a bluff body in many engineering applications, such as mooring cables, flexible risers and pipelines in the platform of oil production and marine engineering, suspension bridges. The incoming flow past such cylinder results in the unsteady wake and alternatively shedding vortex behind the body. Consequently, the body would be vibrated due to the unsteady fluid forces acted on the body, called vortex-induced vibrations (VIV). In particular, as the frequency of vortex shedding approaches the natural frequency of structure, the lock-in of frequency is occurred with the resonance. Meanwhile, the structural oscillating amplitude, as well as the fluid force, would be grown rapidly. This further leads to high possibility of structural fatigue damage and dangers the safety of people, even production activity. Hence, a great number of researches have been published in understanding the dynamics of VIV in a half century. Comprehensive reviews can be referenced in Sarpkaya (1979), Sarpkaya and Isaacs (1981), Sarpkaya (2004), Williamson and Govardhan (2004, 2008), and Gabbai and Benaroya (2005).

With the aim of weakening unfavorable effects of VIV and improving structural validity, many methods have been proposed over recent several decades. The physical mechanism is mainly attributed to control the wake dynamics through weakening the vortex shedding, even totally suppressed, as well as amplitudes of fluid forces, or mismatching the frequency of vortex shedding far away from the natural frequency of structure. For example, the surface control bump spirally distributed around the cylinder, proposed by Owen et al. (2001), could reduce the drag about 47%. At a certain wave steepness, defined by the ratio of the wave height to the wavelength of such disturbance, any sign of vortex shedding was no longer detected. However, such device was mainly effective in the higher mass-damping parameter. Two small rotating cylinders arranged in the boundary layer of the cylinder, proposed by Korkischko and Meneghini (2012), could delay the separation of the boundary layer away from the surface of cylinder. The drag reduction was also reached up to almost 60%. As a kind of the passive control method, the triple-starting helical grooves (Huang, 2011), multiple control rods (Wu et al., 2012) and ventilated trouser (King et al., 2013) were recently proposed and investigated. So far, the streamline fairing (Lee and Allen, 2005) still exhibits a very good aerodynamic performance due to the streamlined outer shape and the resultant of the delay of the flow separation. Similarly, splitter plates can effectively delay the interaction between upper and lower shear layers too and therefore the formation of vortex shedding (Assi et al., 2009). Due to the uncertainty of ocean flow direction, the rotatable device is commonly applied for the streamline fairing and splitter plates. This then would introduce a new dynamical instability. Helical strake (Trim et al., 2005; Korkischko and Meneghini, 2010), as a way of disturbance on spanwise uniformity of vortex shedding, is the most widely used presently. More information about them can be found out in review works by Sarpkaya and Isaacs (1981), Kumar et al. (2008), and Wu and Sun (2009).

On the other hand, there is another VIV suppressing method proposed by introducing three-dimensional geometric disturbance, such as a wavy front surface (Bearman and Owen, 1998) and totally wavy cylinders (Owen et al., 1999; Darekar and Sherwin, 2001; Lin et al., 2010). Such disturbance is introduced in a streamwise-spanwise plane and thus sensitive to different flow directions. So, A new idea of disturbance introduced in a radial-spanwise plane, called radial disturbance, was proposed by Lin et al. (2011, 2012), based on the Bernoulli equation and the effect of geometric disturbance on the flow.