Streamwise evolution of the screen cylinder wake

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Extended abstract

It is well known that a cylinder exposed to a steady current experiences vortex shedding for Reynolds Number, Re, greater than 40. This phenomenon results in periodic variations in the force components namely the drag and lift. If the cylinder is flexibly mounted, and the frequency of the resulting oscillating transverse force closely approximates the natural frequency of the cylinder, vibration of large amplitude is likely to occur which leads to lock-in phenomenon (Sumer and Fredsoe, 1998). Suppression of vortex shedding and vortex-induced vibration (VIV) has been one of the most active topics of research and patenting in fluid dynamics for many decades due to its significance in engineering applications. Previous investigations on control devices to suppress VIV have contributed significantly to the fields of buildings, bridges and marine. Many passive control methods are already proposed to regularize the vortex shedding and control VIV. Perforated shroud is one of the successful passive techniques. The use of a perforated shroud around the cylinder was evidently first tested by Price and Thompson (1956). The suggested shroud could break up the flow into a large number of small vortices; hence the periodic asymmetry of flow about the cylinder is minimized. Along the inner passage between the shroud and the cylinder, the growth of vortices would be restricted by forced mixing. A screen is a kind of perforated shroud as well. It is a device used to control velocity distribution of a fluid flow in which flow direction, time-mean velocity non uniformities and turbulence can be manipulated in a controlled manner (Law and Livesey, 1978). Common examples of screens are arrays of parallel rods, honeycombs, perforated plates and wire-gauze screens. Despite the nature of screen flow, little has been attempted to study the screen shroud as promising VIV suppression device. In addition, most studies failed to look at the mechanism of a perforated member independent of the solid body, in reducing vortex shedding. Therefore, in the present study, effort has been made to experimentally investigate vortex shedding, flow structures and their evolution in the streamwise direction of a screen cylinder. These results will be compared with those from a circular cylinder. The screen cylinder of diameter 23mm made of woven metal mesh with an aperture of 2 mm and an open area of 67% was tested in a wind tunnel at a free stream velocity of 4.56 m/s, which corresponds to a Reynolds number of about $Re = 7000$. For the solid cylinder, measurements were conducted at three downstream locations, i.e., x/d=10, 20 and 40 while for the screen cylinder wake, measurements locations are at x/d=5~60 at an increment of 5. For the purpose of examining the streamwise evolution of the wakes, a 1D vorticity probe was used to measure the velocity fluctuations in the flow. The vorticity probe consists of an X-probe straddled by a pair of parallel hot wires. Another X-probe located at y/d=4~7 from the wake centerline was used to provide a phase reference for the measured velocity and vorticity signals. The hot wires were etched from Wollaston (Pt-10% Rh) wires. Each of the two wires in the X-wire probe had a diameter of 5 μm. The angle calibration was performed over ± 20°.

The evolution of the vortex structures at various streamwise locations extending up to 60d is examined. The spectra ϕ_v for the solid cylinder and screen cylinder at various downstream locations are shown in Figure 1(a,b). For the sake of distinguishing different distributions easily, each spectrum has been shifted downwards by one order relative to the one above it. For the solid cylinder wake (Figure 1a), vortex shedding at x/d = 10 is apparent at a singular frequency, which corresponds to St or $f^* =$ 0.22, indicated by the sharp peak. This peak value is consistent with previous research for St in a solid cylinder wake. At further downstream location from the cylinder, e.g. *x/d* = 20, the peak height reduces and only a very minor peak is visible at *x/d* = 40. After this location, there is no peak on the energy spectra, indicating that the large-scale structures break down at this location.

In comparison, the energy spectra of the screen cylinder wake reveal no characteristic peaks at locations immediately downstream of the cylinder (at *x/d* = 5 and 10). This result suggests that vortex shedding is not apparent immediately downstream, which highlights the difference in the near-wake behaviour of both cylinders. These results are consistent with our smoke wire flow visualisation of the two cylinder wakes, which shows that in the near wake of the screen cylinder, there are small-scale vortices generated in the two mixing layers, and yet they do not interact with each other until at certain downstream locations from the cylinder (Photos are not shown here). Small broad-band peaks at f^* = 0.25 begin to emerge when *x/d* = 20, indicating emergence of some periodicity in the wake. After this location, the peak on the energy spectra at further downstream locations (*x/d* = 30 ~ 60) is stable and apparent, occurring at f^* = 0.25. The present study seems to suggest that the large-scale organised structures in the screen cylinder wake starts to emerge between *x/d* = 10~20. This finding is similar to available literatures on the wake of a porous body (Wygnanski et al., 1986; Cimbala et al., 1988), where the formation of a large structure was delayed at some downstream location. In particular, comparing the results presented by Huang and Keffer (1996) for a mesh strip with solidity of 60%, these authors found that the formation region of the large-scale structures can be extended to *x/d=20*. At *x/d* = 24, the peak on the spectra occurs at f^* = 0.188, which is slightly different from the peak observed from the screen cylinder. Nevertheless the difference in the shedding behaviour of both models could be related to their underlying shape and porosity difference. Moreover the magnitude of the peak for the mesh strip of Huang and Keffer (1996) at *x/d* =24 is significantly larger than the plateau region (about 100 times greater) while the peak observed at *x/d* = 20~60 for the screen cylinder is only marginally larger (~3.5 times greater) than the plateau region of the spectra. In the full paper, the evolution of the flow statistics in the streamwise direction will be discussed and the results will be compared with that of a smooth circular cylinder wake.

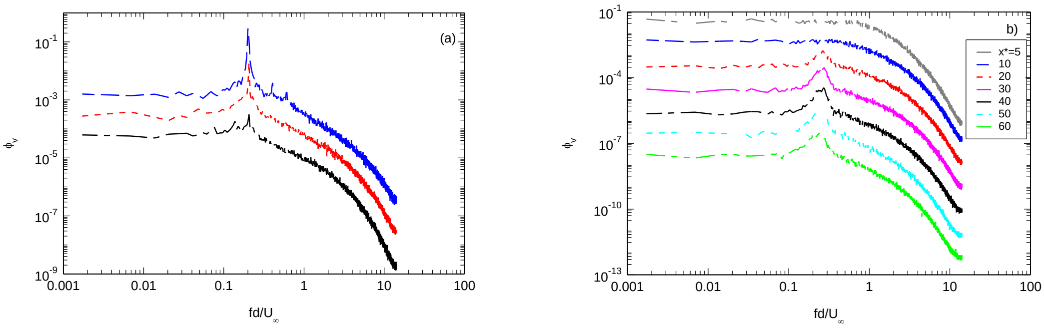

Figure 1 Velocity spectra in the wake of a) solid and b) screen cylinders at *y/d*=0.5 for Re=7000.

KEY WORDS: VIV; screen cylinder; vortex shedding; passive method.

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