Wake interference of an array of four independently supported cylinders

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Compared to an isolated cylinder, the dynamic flow interaction of a row of multiple cylinders or other clustered arrangement is much more complex. When a downstream cylinder is partly or fully submerged in the wake of an upstream cylinder, the effect of both proximity and wake interference can occur and combine. Consequently, large and divergent oscillations may be established, structural safety may be compromised and even collapse could arise. This interference-induced instability must therefore be considered early in the design stage.

Most previous wake interference studies focus primarily on configurations with two equally sized circular cylinders. The number of degrees of freedom also tend to be limited, with either the upstream or downstream cylinder fixed (Assi et al., 2006; Bokaian and Geoola, 1984a,b; Brika and Laneville, 1997; Hover and Triantofyllow, 2001). The current experimental study examines this simplification by investigating the influence of wake interference on the relative movement of a four in-line cylinder vector. Wind tunnel studies of two configurations will be presented: 1) free transversal vibration of all four independently spring mounted cylinders; 2) two tests with either downstream cylinder 3 or 4 free and the remaining cylinders fixed.

Tests were conducted in the upstream section of the BLWT (I) facility of the Wind Engineering Section, GDFA, at CEAMA, University of Granada, Spain. The experimental setup was designed to model the outer skin of a novel high rise façade system. A vector of four identical structurally rigid aluminum cylinders, with external diameter D=110 mm and length l=1340 mm were arranged in a tandem configuration. The centre-to-centre spacing between the cylinders was L=210 mm in the streamwise direction ($L/D \approx 1.91$), corresponding to the limit between the proximity and wake-interference regions established by Zdravkovich (1977, 1987).

A specifically designed section model rig allowed for each cylinder to be independently mounted on an elastic and low-damping suspension system. Each cylinder could also be fixed, resulting in a number of different tandem oscillating configurations. Along wind response was restricted by means of independent long wires linked to the side of each cylinder. Flow velocity at a number of positions and individual cylinder displacements were obtained by means of a single hotwire and an array of load cells.

The results of the four in-line cylinder vector were found to be similar to previous studies of two in-line vectors, validating the experimental setup of the current study. When all four cylinders are in motion, results suggest the behavior of cylinders 3 and 4 are governed by the phase of lock-in of cylinder 2 to cylinder 1, and varies considerably from their behavior when the remaining cylinders are fixed. In comparing the maximum vibration amplitude at equivalent reduced mean wind speeds, tests with only a single cylinder in motion (and the remaining cylinders fixed) can be considered conservative, giving amplitudes more than 100% larger than those registered when considering the relative motion between all cylinders. These effects may be similar to those triggered by an increase in the degree of structural damping.

REFERENCES

Assi, G., Meneghini, J., Aranha, J., Bearman, P., Casaprima, E., 2006. Experimental investigation of flow-induced vibration interference between two circular cylinders. Journal of Fluids and Structures 22, 819-827.

Bokaian, A., Geoola, F., 1984a. Wake-induced galloping of two interfering circular cylinders. Journal of Fluid Mechanics 146, 383-415.

Bokaian, A., Geoola, F., 1984b. Proximity-induced galloping of two interfering circular cylinders. Journal of Fluid Mechanics 146, 417-449.

Brika, D., Laneville, A., 1997. Wake interference between two circular cylinders. Journal of Wind Engineering and Industrial Aerodynamics 72, 61-70.

Hover, F., Triantafyllou, M., 2001. Galloping response of a cylinder with upstream wake interference. Journal of Fluids and Structures 15, 503-512.

Zdravkovich, M., 1977. Review of flow interference between two circular cylinders in various arrangements. Transactions of the American Society of Mechanical Engineers, Journal of Fluids Engineering 99, 618-633.

Zdravkovich, M., 1987. The effects of the interference between circular cylinders in cross flow. Journal of Fluids and Structures 1, 239-261.