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NUMERICAL ANALYSIS OF FLOW-INDUCED VIBRATION OF TWO CIRCULAR CYLINDERS IN TANDEM AT LOW REYNOLDS NUMBERS

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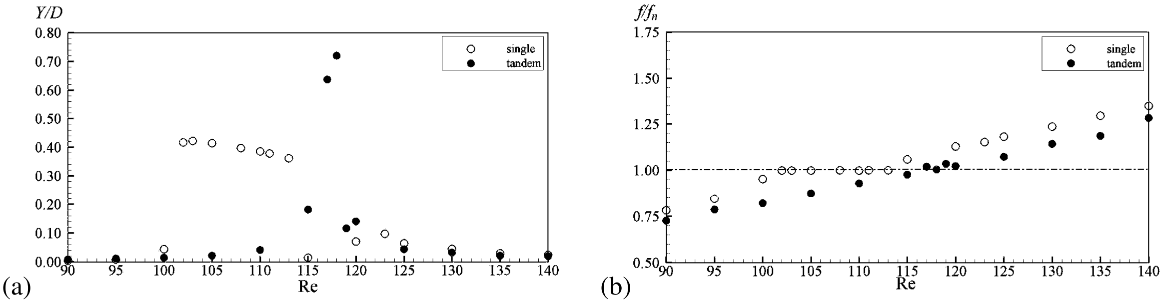
The vortex-induced vibration phenomenon can occur as a result of the action of wind on bridges, slender buildings, chimneys and energy transmission cables besides the action of water flow on pipelines and risers, among other cases. The wake around circular cylinders due to a uniform flow leads to variety of complex phenomena. Despite the simplicity of geometry, the flow around cylinders is very complicated and of particular importance, since it may induce unsteady forces on structures associated with vortex shedding. This paper describes the study of two circular cylinders in tandem arrangement subject to bi-dimensional uniform laminar flows at low Reynolds numbers (from 90 to 140). Cases with distance between cylinders (L) equal to 5.25 diameter (D) for both fixed cylinders and for upstream cylinder fixed and downstream one elastically mounted in transversal direction are analysed. The numerical model Ifeinco [1] which is based on the finite element method and uses a partitioned scheme that consider two-way interaction of fluid flow and structure is employed for the analysis. The fluid flow model uses a semi-implicit two-step Taylor-Galerkin method to discretize the Navier-Stokes equations and the arbitrary Lagrangean-Eulerian formulation to follow the cylinder motion. The classical Galerkin weighted residual method is applied to the space discretization and a triangular element is employed. The cylinder movement is carried out by using the one DOF dynamic equation for the transverse direction discretized in time by the implicit Newmark method.

Both cylinders are immersed in the water and they have diameter D = 0.0016 m. The downstream cylinder (mass m = 0.2979 kg) is elastically mounted in transversal direction (spring stiffness, k, equal to 579 N/m and damping coefficient, c, is equal to 0.0325 kg/s). The computational domain consist of a rectangle whose its sides have the minimum distance from the cylinders of 100D. The cylinder boundary is discretized in 200 segments and the size of the first element around the cylinders is 0.016D.

Numerical simulations considering stationary cylinders in tandem arrangement (L/D = 5.25) showed that the Strouhal numbers are approximately 10.2% lower than single cylinder one along the Reynolds number range. The root mean square (rms) of the lift coefficient (C_{Lrms}) for the downstream cylinder is almost constant and their values are around four times the single cylinder ones.

When downstream cylinder is elastically mounted, an increase of C_{Lrms} from Re = 110 (1.001) to 119 (1.701) and an abrupt decrease at Re = 120 (0.687) is observed. This phenomenon is a characteristic of the resonance (lock-in) and also occurs in the single cylinder, but with some differences in coefficient magnitude and Reynolds number range. Figure 1 shows the dimensionless amplitude (Y/D) and the vortex induced vibration frequency (f/f_n) for downstream cylinder and a comparison with single one. It can be noticed that the resonance occurred for Reynolds numbers between 102 and 113 for single cylinder case in which the vibration amplitude is higher and the vortex frequency is approximately equal to the natural frequency (f_n) of the dynamic system. In tandem arrangement (L/D = 5.25), the downstream cylinder experiments the resonance in a shorter range of Reynolds number, between 115 and 120. Furthermore, the maximum dimensionless amplitude is 0.721 for Re = 118 and this is very higher than the one for single cylinder (0.422 for Re = 103). The interaction between cylinders changes the Strouhal number in relation to the single cylinder one and this is the reason of differences between lock-in regions. Figure 2 shows vorticity and streamlines around cylinders for Re = 118 at instant that occurs the maximum vibration amplitude (Y/D = 0.721). The vortex shedding occurs for both cylinders as expected for gaps $L/D > 4$ and the wake behind the downstream cylinder is formed by combination of vortex shed from both cylinders.



(a) (b)

Figure 1. Dimensionless amplitude (Y/D) (a) and vortex shedding frequency (f/f_n) (b) versus Reynolds numbers

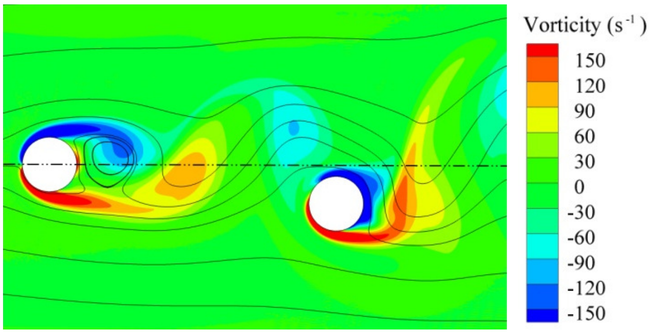


Figure 2. Vorticity and streamlines around cylinders for Re = 118 at the instant that occurs the maximum vibration amplitude

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