Numerical simulation of flow interaction between stationary and downstream elastically mounted cylinders at low Reynolds numbers

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ABSTRACT

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 others. Despite the simplicity of the geometry of the circular cylinders, the uniform flow around them is very complex and important, 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 200). The numerical model Ifeinco [1], which is based on the finite element method and uses a partitioned scheme that considers two-way interaction of fluid flow and structure, has been employed in the analysis. The fluid flow model uses a semi-implicit two-step Taylor-Galerkin method to discretize the Navier-Stokes equations whereas the arbitrary Lagrangean-Eulerian formulation to follow the cylinder motion. This movement has been described by the one DOF dynamic equation for the transverse direction discretized in time by the implicit Newmark method.

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

Firstly, stationary cylinders in tandem arrangement for Re = 100 are analysed for L/D from 1.5 to 6.0. Results of lift and drag coefficients and Strouhal number are compared with other numerical results and good agreement is found. These analyses show that the vortex shedding occurs for both cylinders as expected for gaps $L/D > 4$ and the wake behind the downstream cylinder is formed by the combination of vortex shed of both cylinders.

Numerical simulations considering downstream elastically mounted cylinder for L/D = 5.25 show that the resonance occurred for Reynolds numbers between 115 and 120, unlike the range obtained for a single cylinder [2], from 102 to 113, submitted to the same conditions. Furthermore, the maximum dimensionless amplitude of oscillation is 0.721 for Re = 118, which is much higher than the one of the single cylinder (0.422 for Re = 103). The interaction between cylinders changes the Strouhal number in relation to the one of the single cylinder; because of this, there are differences between the lock-in regions.

REFERENCES

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