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Vortex Induced Vibrations and Galloping of Two Cylinders Placed in Tandem Arrangement

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ABSTRACT

Vortex-induced vibrations (VIV) and galloping effects are studied for the case of two cylinders in tandem arrangement. Both cylinders are allowed to move in X and Y directions and rigidity is kept the same for both directions. The cross-flow around moving cylinders is computed using a specifically designed numerical method which has been thoroughly validated through systematic comparisons between numerical and available experimental results. The motion of cylinders is computed with a 4th order explicit Runge-Kutta method. The coupling between flow and structural computations is semi-implicit in the sense that the potential part of the flow is implicitly taken into account by the structural solver. This confers the required stability to the coupling procedure.
After validation results, we present configurations for center-to-center distances L/D=2 and 4 and reduced velocities ranging from 3 to 10 at laminar Reynolds number of 200.

KEY WORDS: vortex-induced vibrations; circular cylinder; tandem arrangement; XY vibrations.

INTRODUCTION

Flow-Induced Vibrations of structures are a phenomenon well known to civil engineers since it may generate structural fatigue or threaten the integrity of the overall structure in extreme situations. For arrays of offshore risers, both VIV and fluidelastic instabilities, such as wake galloping, have been observed. If VIV for single circular cylinders are well documented, VIV, interference and galloping phenomena studies for arrays of cylinders remain sparse since Zdravkovitch (1985). Since then we may notice, for example, the investigation of Assi *et al.* (2006) concerning flow-induced vibration interference for a Cylinder free to move in the Y direction while the front cylinder is kept fixed. To our knowledge, there exists no numerical study of flow-induced vibration cylinder arrays.

In this paper we study VIV, interference and galloping phenomena occurring when two circular cylinders in tandem arrangement are placed in a uniform cross-flow. These configurations are evaluated numerically. Results are obtained with theXcyl code which can treat these configurations thanks to a mixed Eulerian-Lagrangian formulation. An eulerian method is used at proximity of bodies while a fast-vortex method handles wakes.

Experimental results by Jauvtis *et al.* (2003) have revealed that while an order of magnitude lower than Y vibrations for single cylinder cases, X vibrations plays a crucial role for the occurrence of super-upper vibrations (up to 1.5 diameter amplitude). Cables, risers and similar structures undergo two-degree of freedom motions. This supports the fact that XY must be modeled. In this study motions of cylinders are allowed in both directions. Rigidities are the same in both directions.

A parametric study is performed with respect to the reduced velocity $Ur=U/f_n^*D$, with U the uniform flow velocity, f_n^* the natural frequency of cylinders in still water, D their diameter, and L/D the non-dimensional center-to-center distance. Values of Ur are in the range 3 to 10 and those of L/D vary between 2 to 4. A Value of 200 and of the Reynolds number has been selected and the mass ratio $m^*=m/m_a+1=2$, with $m_a=\rho\pi D^2/4$.

DESCRIPTION OF THE APPROACH

We consider the flow two-dimensional due to the low values of Reynolds number considered and vibrations which enhance spanwise correlation of vertical structures.

The flow is represented by the two-dimensional incompressible Navier-Stokes equations based on vorticity and stream function formulation. A specific numerical method has been developed to solve this set of equations for the case of an arbitrary array of cylinders. We draw here only the main characteristics and all details can be found in Etienne (1999). The flow solver is composed of two methods. In annular regions around cylinders a finite volume eulerian formulation is used whereas the outer flow is solved with a Lagrangian vortex formulation.

In annular domains, the Poisson equation is solved in polar coordinates with a spectral method in tha angular direction and a 4th order Hermitian finite difference scheme in the radial direction. The vorticity transport equation is discretised with a finite volume technique. Convective terms are treated using QUICK and stabilized with a TVD scheme, while diffusion is evaluated using second-order centered