

Numerical Simulation of Flow Around Elastically Mounted Cylinder

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ABSTRACT

The flow around a single cylinder free to vibrate in the transverse direction is investigated employing the 2-D Discrete Vortex Method. The simulations are carried out for a mass parameter and Reynolds number that are typical of the flow around an oil extraction riser. Results of amplitude of induced vibration as a function of reduced velocity are compared with experimental data from Khalak and Williamson (1996). It is found that the maximum calculated amplitudes of vibration are lower than the experimental ones, but the simulations with the 2-D Discrete Vortex Method proved to be inexpensive and well suited to qualitative studies and the development of strip-theory solvers capable of simulating a long marine riser installed in ultra deep waters.

INTRODUCTION

In recent years, the need to improve technologies in the field of deep-water oil extraction has led to an increased interest in studies of the vortex-induced vibration (VIV) phenomenon. Some challenging VIV problems have become common in specific engineering areas. One of those is in the field of deep-water oil extraction. Recently, offshore oil platforms have been installed in water depths of over 2,000 m. Flexible pipes known as risers are used to link the seabed to the offshore platform for oil production. Risers are cylindrical bodies subjected to vibration due to vortex shedding, and one of the main effects of this vibration is to shorten their durability. There is then great interest in the development of tools to estimate the characteristics of VIV, and to evaluate its effect on the fatigue of structures and their life expectancy.

In order to calculate the cylinder response to the flow, one needs to solve the flow around the body. In the last several years, research has concentrated on solving the unsteady Navier-Stokes equation through finite-element or finite-volume methods. Through the flow solution at a given time, it is possible to have the pressure and viscous tension distribution around the cylinder. Consequently, one can evaluate drag and lift forces on the body. The forces are then used to solve the motion of the cylinder. In this way, it is possible to obtain time histories of the drag, lift and position of the cylinder.

This approach has a major drawback: Finite-element and finite-volume methods are grid-dependent solving methods. They are well suited to the solution of the flow around a single free vibrating cylinder, but they are cumbersome when we seek the solution of the flow around more than one free cylinder. In this case, fixed meshes cannot be used.

In order to develop a more flexible solver, we decided to use the Lagrangian Discrete Vortex Method. This method of flow solution employs a moving grid composed of vorticity-carrying particles, the discrete vortices, and the vorticity transport equation can be solved simply by tracking the movement of these particles. As there is no fixed mesh, the method is well suited to the

simulation of the flow around multiple moving bodies. It is also a simpler method than the finite-element and finite-volume methods. Although our objective is to solve the flow around a single cylinder, we assume that the development of a tool that can be easily used to simulate the flow around multiple moving cylinders is desirable in order to expand further research.

Flow-induced Vibration

Vibrations induced by vortex shedding have been a main subject of research in the field of fluid-structure interactions. These vibrations are usually modeled through a spring-mass-damper system. If the cylinder is free to vibrate only in the transverse direction in relation to the flow stream, as in Fig. 1, the movement of the cylinder is given by the equation:

$$m\ddot{y} + c\dot{y} + ky = F_y \quad (1)$$

In the equation above, F_y is the lift force acting on the cylinder, calculated through the integration of pressure and viscous stress on the cylinder surface.

According to Blevins (1977) and Khalak and Williamson (1996), the amplitude of vibration A/D is a function of the mass parameter m^* , the damping ζ and the natural frequency ω_n of the cylinder. The mass parameter is the relation m/m_d , where m_d is the displaced fluid mass $\rho\pi D^2/4$. In general, experiments for given values of ζ are carried out, and curves of A/D as a function of the reduced velocity V_r are plotted. The reduced velocity is given by $V_r = U_\infty T_n/D$, in which U_∞ is the free-stream velocity, and T_n the natural period associated with ω_n .

Feng (1968) and Brika and Laneville (1993) carried out experiments for high mass parameters. The main difference between the

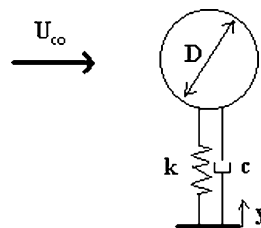


Fig. 1 Cylinder free to vibrate in transverse direction

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