Three-Dimensional Modeling of Flow-Induced Vibration for an Elastic Cylinder in a Cross Flow

Yang Liu, Ronald M.C. So and Chuhua Zhang
Department of Mechanical Engineering, The Hong Kong Polytechnic University
Hung Hom, Kowloon, Hong Kong

Abstract

A three-dimensional flow-induced vibration problem for an elastic circular cylinder with end-plates in a cross flow is solved by an arbitrary Lagrangian-Eulerian Finite Volume Method. The coupling of the fluid flow and cylinder response is fully counted by iteration at each time step. The present study focuses on a circular cylinder with fixed-fixed end plates in a cross flow. As vortices are shed from the cylinder, they induce a periodic lift force at the shedding frequency and a periodic drag force at twice the shedding frequency. The fluctuating forces cause the structure to vibrate at a dominant frequency equal to that of the shedding frequency. In turn, the motion of the structure affects the vortex shedding. The periodic forces play a very significant role when their frequencies approach the natural frequencies of the different modes of vibration of the combined fluid-structure system. Moreover, the end plates can suppress the vortex shedding for a low aspect ratio structure. Therefore, this study will focus on the effect of end plates and resonance on the three dimensional fluid-structure interaction. The objective is to fully study the three dimensional fluid-structure interactions, particular the effect of end plates. As a first attempt, the calculation is carried out at Reynolds number of 100 and 300 with aspect ratio of 16.

Governing Equations

The Navier-Stokes equations on ALE frame is

$$\nabla \cdot \mathbf{u} = 0, \qquad (1)$$

$$\frac{D_m \mathbf{u}}{Dt} + \nabla \cdot (\mathbf{u} - \mathbf{u_m})\mathbf{u} = -\nabla p + \frac{1}{\mathrm{Re}}\nabla^2 \mathbf{u}, \qquad (2)$$

The cylinder dynamic equation is

$$\frac{\partial^2 \boldsymbol{\delta}}{\partial t^2} = (2\pi a f_0)^2 \frac{\partial^2 \boldsymbol{\delta}}{\partial z^2} + \frac{\mathbf{C_F}}{2M^*} \qquad (3)$$

Preliminary Results

The preliminary results show that the structural properties have significant influence on the lift distribution along the span of the cylinder. Figure 1 shows the lift contour at Re = 300 along the span of the cylinder.

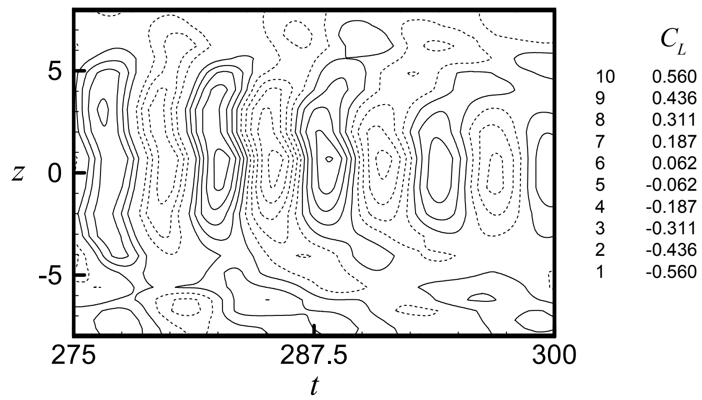

Figure 1 C_L contour at Re = 300.

Figure 2 shows the vortex formation behind an elastic cylinder.