Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Numerical Simulation of Vortex-Induced Vibration of Two Circular Cylinders of Different Diameters

Hongwei An, Liang Cheng and Ming Zhao
School of Civil and Resource Engineering, University of Western Australia
Perth, Western Australia, Australia

ABSTRACT

A numerical study of vortex-induced vibration (VIV) of two circular cylinders of different diameters in steady flow is carried out. The Reynolds-averaged Navier-Stokes equations are solved using a finite element method (FEM) with a *k-ω* turbulence closure. The numerical model is firstly validated against VIV of a single circular cylinder in steady flow. Then this model is employed to simulate the flow around two circular cylinders which are mounted elastically. The response amplitude, vibration frequency of the two cylinders and vortex shedding modes are analyzed. It's found that the fluid flow fields and the response behavior are more complex than those of an isolated cylinder. The gap distance and arrangement of the two cylinders affects the VIV significantly.

KEY WORDS: vortex induced vibration; finite element method; *k-ω* turbulence model; vortex shedding; two cylinders

INTRODUCTION

Extensive research work has been done on vortex-induced vibration (VIV) of an elastically mounted rigid cylinder with low mass-damping coefficient (restrained to move in cross-flow direction). Comprehensive reviews of work done so far can be found in Williamson and Govardhan (2004) and Sarpkaya (2004).

VIV of an elastically mounted cylinder is governed by a number of parameters, including mass ratio (m^*= (oscillatory mass)/(displaced fluid mass)), damping coefficient ζ, and the reduced velocity ($U_r = U_\infty / f_n D$, where U_∞ is incoming flow velocity, f_n is the natural frequency of the cylinder and D is the diameter of the cylinder). Three distinct branches (initial, upper and lower branch) of response were found corresponding to different values of reduced velocity ((Khalak and Williamson, 1996; Khalak and Williamson, 1999) for low mass-damping coefficients ($m^*\zeta$), while only two brunches (initial and lower) were found for high mass-damping coefficients (Feng 1968). The so-called "2S" vortex shedding pattern was found in initial branch ("2S" means two single vortices shed in each vibration), and "2P" vortex shedding regime ("2P" means two vortex pairs shed in each vibration) was found in both upper and lower branch. The three branches are non-continuous. A hysteresis was found during the transition between initial and upper branch, which is triggered by the competition between the "2S" and "2P" regime, while an intermittent switching was found in the transition between upper and lower branch corresponding to the 180 shift of phase angle of lift force and displacement of the cylinder. The maximum vibration amplitude (about one diameter) was found in the upper branch where the response frequency is locked on to the natural frequency of the cylinder. (Govardhan and Williamson, 2000).

A number of two dimensional numerical models have been developed to predict VIV of circular cylinder with low mass-damping coefficients (Newman and Karniadakis (1997) Saltara et al.(1998) and Blackburn et al. (2001)). Few of these two dimensional models were able to capture the upper branch and maximum vibration amplitude. Guilmineau and Queutey (2004) simulated a case that has been studied experimentally investigated by Khalak and Williamson (1996) using a RANS model. Their model appeared to predict a large amplitude response. However the numerical results were not consistent with the experimental results.

Hover et al (2004) carried out a series of experiments to measure the three-dimensional features of a circular cylinder undergoing VIV. Poor correlation along the spanwise was found in the range of $5.6<Ur<7.5$ which overlaps with the upper branch, however high spanwise coherence was found under other reduced velocity conditions. A wake velocity correlation coefficient (>0.9) was found for two sections with 22D separation in spanwise direction in the range of $3.6<Ur<5.6$. Such a high correlation coefficient suggests that well organized two-dimensional wake structures exist and 2D assumption be viable in numerical models. It is speculated that the three dimensional flow in the range of $5.6<Ur<7.5$ is the main reason for the missing of upper branch in 2D numerical simulations. The strong three-dimensional characteristics in upper branch has been demonstrated by the numerical simulation carried out by Lucor et al (2005)

VIV of multiple cylinders or tube bundle is expected to be more complex due to the interferences of the cylinders. Considerable investigation about this phenomenon has been carried out (Weaver and Fiztpatrick (1988), Moretti (1993)). Blevins (2005 and 2007) investigated the forces coefficients and stability of an elastically mounted cylinder in the wake of another fixed cylinder. Most of these work were concerned with cylinders of identical diameters. The research about VIV of two or more cylinders of different diameters is rare.