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Numerical Simulation of a Large-scale Riser with Vortex-induced Vibration

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ABSTRACT

ANSYS multi-physics software was applied to a Fluid-Structure Interaction (FSI) task, a large-scale riser with vortex-induced vibration (VIV) undergoing shear inflow environment. The purpose of this paper is to evaluate the performance of the FSI software and to provide the model test some supplementary information, such as the hydrodynamic visualizations of vortex wake and some dynamic characters of the pipe. Basic frequency analysis has been done first to make sure that the ANSYS FSI solution strategy is competent to give a reliable simulation to this pipe system, and then the RMS value of instantaneous amplitude and vortex shedding visualization under different input velocities are provided. Visualization of the vortex wake indicates a hybrid mode of vortex shedding along the pipe in those simulation cases. In this paper, an instantaneous amplitude definition is introduced to give a reasonable conception of RMS for instantaneous amplitude of multi-model VIV.

KEY WORDS: Vortex-induced vibration; CFD; ANSYS; CFX; FSI; vortex mode; instantaneous amplitude.

INTRODUCTION

Flow around a fixed or oscillating cylinder has received much attention in the past few decades. With the development of modern ocean engineering, the need to enhance our knowledge about vortex-induced vibration (VIV) for elastic pipe has greatly risen due to deep-water oil extraction and massive use of underwater cables. These flexible risers/ pipes are readily subjected to shear and oscillatory flows due to currents and waves with high degree of complexity, and with intensity and direction changes according to water depth. Among those influencing factors, vortex-induced vibration plays a leading role in determining the life span of marine risers. A better comprehension of the vortex dynamics causing vibration and fatigue to risers is necessary.

Numerous contributions to flow-induced oscillations in general and to VIV in particular have collectively defined the objectives of the current VIV research and have guided the acquisition of design data through physical and numerical experiments, theoretical analyses, and physical insight. For numerical simulation attempt, semi-experiment models, DVM as well as industrially significant fluid–structure interactions solution packages have been introduced for reasonable and feasible results, partly through the use of direct numerical simulations (DNS) (Dong and Karniadakis, 2005), large eddy simulations (LES) (with improved sub-grid scale models) (Al-Jamal and Dalton, 2004; Fujisawa, Asano, Arakawa and Hashimoto, 2005), Reynolds-averaged Navier–Stokes equations (RANS) (Saghafian and Ansby, 2003; Guilmineau and Queutey, 2004; Wanderley, Souza and Levi, 2006), vortex element methods (VEM) (Mittal and Kumar, 2001; Nobari and Naredan, 2006) and their various combinations.

Semi-empirical models such as Wake–oscillator models, Sdof models and Force–decomposition models could give reasonable numerical simulation results in a special Reynolds number range, but can not provide valuable visualization of fluid domain. The discrete vortex model (DVM) achieved reasonable success after judicious selection of a series of the controlling parameters. However, we can not dwell on simulations at Reynolds numbers smaller than 1000 with it. DVM may be of interest in assessing a given numerical scheme at a given Re, but not necessarily to predict VIV at more realistic Reynolds numbers (Sarpkaya, 2004).

The numerical simulation of flow past a circular cylinder undergoing VIV is complicated by some of the most difficult problems of fluid mechanics such as separation excursions, the coherence length based on a yet unexplained coupling mechanism between the dynamics of the near-wake and that of the structure. Fluid-structure interaction (FSI) occurs when a fluid interacts with a solid structure, exerting pressure that may cause deformation in the structure, and then alter the flow of the fluid itself. Numerical simulations of vortex-induced vibration have been failing to accurately duplicate experimental data mostly due to the complexity of the physics involved in the real problem. Therefore, a careful and comprehensive investigation on CFD algorithms is required to indicate the most suitable numerical scheme to handle such a complicated problem. Due to the limitation of calculation ability and some shortages of CFD software package itself, most numerical results rested on 2D vortex simulation and then integrate the hydrodynamic forces to 3D fluid domain (Yamamotoa, Meneghinib, Saltarab and Fregonesib, 2004). Some attempts to simulate vortex-induced vibration with very large aspect ratio are indeed a 2D numerical simulation task (Holmes, Owen, Oakley and Yiannis, 2006).