Study on Marine Pipelines Forced Vibration and Vortex-Induced Vibration in Uniform flow and Combined Flow at Different Reynolds Number

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ABSTRACT

In this paper, the forced vibration and vortex induced vibration of a cylinder under the combined action of uniform flow and oscillatory flow were numerically simulated by using dynamic grid technology. The effects of the distance between the cylinder and the wall and the number of model grids on the numerical simulation results were analyzed. The drag force and inertial force were separated by programming with C++, and the oscillating force, drag force, velocity and acceleration curves were analyzed. The variation of drag force coefficient and inertia force coefficient under different frequency ratio was studied. The wake shedding of cylinder in superimposed flow field was investigated. It is found that the wake shedding of cylinder in superimposed flow field is different from that of uniform flow and oscillatory flow. The oscillating flow was added from the inlet through C++ programming.

KEY WORDS: Marine pipelines; risers; circular cylinder; uniform flow; oscillatory flow; VIV; lock-in.

INTRODUCTION

Marine pipelines and risers are affected by the complex marine current. More and more cylindrical structures are used in marine engineering equipment to stand the test of the ocean. At present, many researches are focused on the hydrodynamics of cylinder in different flow fields. Gu et al. (1994) found that vortex from one side of the cylinder to the other reach to a high degree of concentration of vorticity next to cylinder when the frequency ratio \( f / f_s \) increased \( f \) is the oscillating frequency of cylinder, \( f_s \) is the shedding frequency for the fixed cylinder. Lu and Dalton (1996) studied the vortex shedding from a transversely oscillating circular cylinder in a uniform flow by numerical simulations. The effect of increasing the amplitude of an oscillating cylinder and the Reynolds number value were shown to lower the value of \( f / f_s \) at which vortex switching. Meneghini and Bearman (1995) obtained the boundary of lock-in for small amplitudes of oscillations. \( f / f_s \) varied from 0.7 to 1.15 and \( A / D \) from 0.025 to 0.6 in their simulations. Anagnostopoulos and Bearman (1992) conducted experiments about the vortex induced transverse oscillations of a circular cylinder at low Reynolds number ranging between 90 and 150. The amplitude of the lift force in phase with the circular cylinder velocity was maximum at the lower limit of the lock-in region. Zhao and Chen (2006) reproduced these results with an Arbitrary Lagrangian Eulerian (ALE) method. Zhao et al. (2010) investigated Combined steady and oscillatory flow past a circular cylinder by three-dimensional Direct Numerical Simulation. Raghavan and Bernitsas (2011) found that the Reynolds number has significant effects on the response of an elastically mounted cylinder in cross-flow, but didn’t involve combination of uniform and oscillating flow. Low et al. (2016) studied VIV fatigue reliability analysis of marine risers with uncertainties in the wake oscillator model. Navrose et al. (2017) explored the existence of multiple responses in vortex-induced vibration of a circular cylinder in the laminar flow regime by carrying out computations with different initial conditions for several mass ratios. In addition to primary and secondary hysteresis near the ends of the lock-in regime, multiple states of the fluid-structure system existed in the middle of the lock-in regime as well. Deng et al. (2019) carried out numerical simulations on VIV of a cylinder experiencing an oscillatory flow by the in-house VIV-FOAM-SJTU solver. Results showed that the oscillatory period is relevant to the width of ‘lock-in’ in half period. Vibration features such as ‘intermittent VIV’, mode transition and the VIV developing process of ‘building-in’, ‘lock-in’ and ‘dying-out’ were observed. Zhang et al. (2020) tested a pipe under coupled uniform and shear oscillatory flow, with Reynolds number ranging from 2000 to 24000. When combined with uniform flow, the identification of time-varying frequency and amplitude modulation was significantly enhanced by uniform flow with lower velocities while the top-end surge mainly affects the vibration instability in higher-velocity uniform flow. Wang et al. (2021) numerically investigated the cross-flow VIV of a cylinder in oscillatory flow. The results showed that the oscillatory flow can excite the cylinder multi-mode vibration and that a