CFD Simulation of the Vortex Induced Motion of a Caisson during Installation in Current

Jin Chen1,2,3, Lin-Wang Su1,2,3, Min Chen4,*, Ming-Yue Liu5
1.CCCC Fourth Harbor Engineering Institute Co., Ltd., Guangzhou, Guangdong, China
2.CCCC Key Lab of Environmental Protection & Safety in Foundation Engineering of Transportation, Guangzhou, Guangdong, China
3.Southern Marine Science and Engineering Guangdong Laboratory (Zhuhai), Zhuhai, Guangdong, China
4.Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangzhou, Guangdong, China
5.State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University, Shanghai, China

ABSTRACT

This paper presents the CFD investigation of the vortex induced motion (VIM) of a caisson model during the installation phase. The simulations were performed by solving the unsteady 3D Navier-Stokes equation. The Dynamic Fluid-Body Interaction (DFBI) tool is utilized to simulate the motions. Typical draft conditions of a caisson during installation process are considered. The present methodology is verified through the free decay and the VIM of a cylinder simulations in two-dimension. Free decay simulations show that the natural frequency decrease with the increasing draft of the caisson. Maximum response amplitudes occur in the range of 10<\(V_c<13\) for both the draft \(D_p=0.1m\) and \(D_p=0.12m\). The resonance occurs when the crossflow response frequency \(f_y\) is very close to the natural frequency \(f_n\). The inline/crossflow response frequency increases as the draft increases at the same reduced velocity \(V_c\). The response frequency in the inline direction is double of that in the crossflow direction. The oscillating lift force dominates the crossflow oscillatory motion. Eight-shaped trajectories are observed the maximum displacements in the crossflow direction increase as the drafts increase.

KEY WORDS: caisson; vortex induced motion; spectral characteristic; CFD; installation process.

INTRODUCTION

Flow-induced vibration typically arises as a result of vortex shedding. The vibration is called vortex induced motion (VIM) for large-volume floating platforms, and vortex-induced vibration (VIV) for the long slender cylindrical structures such as risers. Vortex shedding of the caisson generates periodically alternating forces and motions. The motion responses extremely large in the occurrence of a resonance, when the vortex shedding frequency is close to the natural frequency. VIM is an important issue during the caisson installation process, as it impacts the integrity of the mooring system and pose a threat to the construction safety. It is challenging to predict the VIM and capture its physical behavior accurately.

Numerical and experimental studies have been carried out widely on VIMs of floating structures. A number of experiments were conducted to evaluate the impact of key parameters on VIMs, such as different arrangement of a pair of cylinders(Assi 2009), inclined angle of cylinders(Franzini et al. 2009), and a varying aspect ratio of a cylinder (Rahman and Thiagarajan, 2015). Gonçalves et al.(2013) investigated the vortex-induced vibration of circular cylinders with very low aspect ratio and small mass ratio. Blevins et al.(2009) measured vortex-induced vibration of an elastically supported cylinder in water with different flow velocity, damping, mass ratio, combined inline and transverse motions, Reynolds numbers, and strake configurations. Gonçalves et al.(2018) carried out VIM model tests with regular and irregular waves collinear to the current conditions to study the behavior of large-volume semi-submersible platforms.

Computational Fluid Dynamics (CFD) is a powerful tool to reveal the mechanism of VIMs. Researchers are involved in studying VIMs of typical offshore structures using CFD recently. Gu et al.(2018) simulated the VIM of a new type of deep draft multi-columns FDPSO, and studied the effects of current incidence angles and reduced velocities on this platform's sway motion response. Liu et al.(2017) adopted the detached eddy simulation method to realize parametric analysis of VIMs of various semi-submersibles with different column rounded ratios and pontoon rounded ratios. Xie et al. (2017) performed 3D CFD simulation of the flow-induced response especially the yaw motion of a buoyancy can by utilizing an in-house code. Huang and Chen(2020) investigation of mooring damping effects on vortex-induced motion of a deep draft semi-submersible by coupled CFD-FEM analysis. Kharazmi and Ketabdari (2022) demonstrated the possibility of Spar VIM response reduction due to the improving design of Spar strakes. Ding et al.(2022) simulated the vortex-induced vibration of rotating circular cylinder in shear flow. Ming-Ming et al.(2022) investigate the vortex induced vibration of a main circular cylinder with multiple small control rods. Further detailed CFD studies have been carried out focusing on VIM modeling sensitivity, such as turbulence model, mesh refinement, Reynolds number and external damping(Kim et al, 2015 and Koop et al, 2016).

VIM phenomenon often appears as a consequence of currents past a caisson during installation process. And yet, very little research has examined the underlying mechanisms of VIMs of the caisson in the sinking phase. CFD provide a good tool to understand the flow characteristics and motion behaviors in this process. In the present work, CFD simulations of the VIM of a caisson during the installation process are performed. The caisson is the deep foundation of the Changtai Yangtze River Bridge, and Zhang et al.(2022) presented the principle dimensions of caisson structure and the construction process. Three drafts \(D_p = 0.1m, 0.12m\) and \(0.14m\), and reduced velocities ranging from 4 to 13 are considered to cover all the conditions during