International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 30, No. 4, December 2020, pp. 447–455; https://doi.org/10.17736/ijope.2020.ts21
http://www.isope.org/publications

A Model Test on the Response Characteristics of a Free Hanging Riser

Yong-Ju Kwon, Dongho Jung†, Byeongwon Park, Jae-Hawn Jung and Seunghoon Oh
Korea Research Institute of Ships and Ocean Engineering (KRISO)
Daejeon, Korea

A series of model tests were performed to investigate the response characteristics of a free hanging riser under forced oscillation conditions. The boundary conditions were considered to be fixed/free (fixed at the top and free at the bottom). The top end of the riser was fixed to the forced oscillator to give the effects of horizontal vessel motion. The model test was performed at the Ocean Engineering Basin of the Korea Research Institute of Ships and Ocean Engineering (KRISO). In this study, the displacements along the riser length were measured using underwater camera systems. Various oscillation conditions were considered in order to investigate the effects of period and amplitude. The oscillation period was determined considering the eigenvalues in the in-line (IL) response. The IL responses of the experiment were compared with the time simulation results of OrcaFlex. The responses of two results had a good agreement on time series, statistical value, and snapshot. The cross-flow (CF) responses along the riser length in the experiment were determined by the Keulegan–Carpenter number at each point of the riser. A comparison result of the IL and CF responses shows that they were excited by different dominant frequencies from the top-end motion and vortex shedding, respectively. While one top-end oscillation frequency appeared in the IL, multi-peak frequencies were investigated at all positions along the riser length in the CF, which is induced by traveling waves.

INTRODUCTION

Ocean risers are typically used to transfer oil and gas from the seabed to floating structures. The configuration of the riser is determined by the purpose of the riser and by responses under ocean environmental loads such as waves, currents, etc. Free hanging risers are widely used in cold water pipes in ocean thermal energy conversion (OTEC), mining risers of manganese nodules, and intake risers of coolants in floating liquefied natural gas (FLNG) (Pettersen et al., 2013). Fatigue damage and stress are important parameters governing the safety of ocean risers. When ocean risers are connected to a floating structure, they are damaged not only by waves and currents but also by the motion of the floating structure. Because the motion of the floating structure causes damage to the riser, it is necessary to investigate the effects of the motion of the floating structure on the riser.

Free hanging risers have been studied since the 1980s. Patel and Jesudasen (1987) studied the IL response based on the finite element method (FEM). The dynamic responses were predicted with the two-dimensional element. The experimental results were in close agreement with the FEM results, but some discrepancies were found in predicting structural damping. Chung et al. (1980) studied the nonlinear transient motion of deep ocean mining pipes. They modeled the pipe with three-dimensional beam finite elements such as coupled axial, bending, and torsional deformations. Chung and Felippa (1981) introduced the concept of a drag force along the pipe for accurate analysis. They discussed the three major factors related to drag forces. The effects of the axial stress on pipe design were pointed out. Chung and Cheng (1996) investigated the effects of elastic joints along pipes with eigenvalue analysis. They studied the modeling and boundary conditions of the elastic joints. The dynamic responses could be reduced with multiple elastic joints, avoiding the resonant frequencies away from the pipe system. Blevins (2001) classified the cross-flow (CF) responses according to the Keulegan–Carpenter number (KC number) in oscillating flow. The lift forces were produced by vortex shedding, and the vortex-shedding characteristics were reviewed based on the range of the KC number. Jung et al. (2005) conducted an experimental and numerical study on highly flexible free hanging risers. They focused on the in-line (IL) displacement along a riser. The experimental and numerical results of displacements at the upper and the middle parts of the riser were found to be in good agreement, but some difference was found at the bottom end, owing to the interaction of the IL motion and vortex-induced vibration (VIV). Jung et al. (2012) studied VIV for risers under low KC numbers, and they investigated the response peak in the IL and CF responses. The CF responses were closely related to the KC numbers. Traveling waves were also found along the risers. Kwon et al. (2015) studied the dynamic behavioral characteristics of a free hanging OTEC riser and performed model tests under forced oscillation in current conditions. A comparison was made between the IL and CF responses. Multiple times the oscillation frequency was found for the CF response with high KC numbers. Wang et al. (2017) investigated the VIV characteristics via the motion of the floating structure. They carried out model tests on a free hanging riser under forced oscillations and considered several conditions with various KC numbers and uniform currents. The strain data on the IL and CF responses were compared according to response frequencies and time series. A transition phenomenon was found when the KC numbers were high. Kwon et al. (2018) performed model tests to investigate the IL responses of free hanging risers under forced oscillations. They studied the effects of the oscillation periods according to the modal characteristics. VIV characteristics of floating body motion were also investigated on another type of riser. Yin et al. (2018) studied the VIV characteristics on the top tensioned riser

†Corresponding author.
Received April 16, 2019; revised manuscript received by the editors December 28, 2019. The original version was submitted directly to the Journal.
KEY WORDS: Response characteristics, model test, free hanging riser, forced oscillation, VIV, vortex-induced vibration.