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Comparative study on a jacket launching operation in South China Sea

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ABSTRACT

Launching is an essential initial operation for mega deep-water jackets. The forces and motion responses of key points were measured during such a launching operation, which can serve as a benchmark for the experimental and numerical results and hence can provide more confidence in following operations. This paper presents a comprehensive study in which field measurements, numerical and experimental results are compared to investigate the dynamic process of launching a mega jacket. The differences between the field measurement data and experimental results are investigated. The sensitivity analyses including the barge trim and draft and the friction coefficient along the skid-ways are performed using the calibrated numerical model. Attempts are made to clarify the effect of the drag coefficient in the Froude-similarity models through a comparison of the scaled model tests and the specific numerical simulations.

1. Introduction

Launching is one of the critical tasks during offshore installation of a jacket and involves considerable risks and technical challenges, particularly for mega jackets. As the jacket slides along the skid-ways, the draft and trim of the launching barge keep changing, thereby affecting the motion response of the barge. Once the jacket begins to tip on the rocker arms, which is the most hazardous stage of the operation, the rocker arm loads reach their peak values. After separating from the barge, the jacket oscillates and dives to reach its maximum dive depth, where it could collide with the seabed. Therefore, it is important to reliably predict the forces and motion responses of such a launching system.

To correctly predict the key motion responses, numerous studies of jacket launching operation have been conducted. Hambro (1982) proposed a method to compute the jacket motions by differentiating the constraints of the mechanical systems twice. A model test was selected to determine the accuracy of the numerical simulations. Liu et al. (1986) established three-dimensional equations of motion for a jacket by combining quadratic differentiation of the restraints with momentum equations. Good agreement was achieved between the numerical and experimental results. Based on the Kilauea jacket launching, Sircar et al. (1990) described the method and results of the transportation, launching, self-upending and set-down stability analyses. Honarvar et al. (2008) compared a model test and a numerical simulation of jacket launching operation. The differences between the experimental and numerical results were identified, and the correlation between the Reynolds number (Re) and the hydrodynamic drag coefficient (C_D) was discussed.

When considering the structural loads and the motion responses, model tests and numerical simulations were also performed for the launching operation. Jo et al. (2001) presented the effects of various parameters (the dimensions of the barge and jacket and the initial condition of the barge) on the launching operation based on the analysis software SACS. The results showed that the mean load and impact load acting on the jacket could be reduced by increasing the draft and trim angle, whereas the trim angle and draft had a marginal effect on the dive depth of the jacket. Xiong et al. (2013) investigated a typical jacket launching process by comparing model tests and numerical simulations. These authors reported good agreement between the amplitudes of the pitch motion and structural load using two different methods. A time delay was also observed in the model test due to the scale effect. He et al. (2010) presented an optimization study and a parametric sensitivity study of 3-D time-domain launching and self-upending analyses through the commercial software MOSES. In the optimization study, the optimal initial conditions were determined for the jacket launching and upending.

To obtain a better understanding of jacket launching, efforts have been made to develop reliable techniques for field measurements. Based on the field measurements of the Liwan 3-1 mega jacket launching, a series of the jacket launching analyses was conducted. He et al. (2013) performed a comparative study based on numerical analyses and field measurements, which indicated that the effect of the kinetic friction coefficient (C_f) along the skid-ways was significant. Zhang et al. (2013) conducted an experiment to investigate the launching trajectories and further

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compared the experimental results with field measurements. This study indicated that C_f along the skid-ways should be reduced to 0.04 to ensure kinematic similarity. A method of processing the original data from the field measurement was proposed by Chen et al. (2013). In their study, the composite Simpson's rule was applied to obtain the trajectory motions of the jacket and barge. These trajectory motions were obtained from the field measurement of the Liwan 3-1 jacket launching and were presented by Chen et al. (2014b).

Field measurements of offshore structures and their dynamic responses in real sea states are desirable for validating numerical simulations and for applying to marine engineering design problems (Drazen et al., 2012). However, due to various technical and economic challenges, more emphasis has been placed on the in-operation platform monitoring than on the field measurements of offshore installation procedures, such as jacket launching.

This paper presents a comparative study of field measurements, scaled model tests and numerical simulations based on the field measurements obtained from the launching of the Panyu 34-1 mega jacket. Section 2 briefly describes the jacket launching system in terms of the launching stages, the launching barge and the jacket and the initial launching condition. The experimental setups are briefly presented in Section 3. The environmental conditions during the launching operation are also clarified in this section. To validate the experimental results and to further understand the dynamics of the launching, the field measurements were performed and time series of the barge and jacket motions and the rocker arm loads were measured as part of the field measurements. Section 4 discusses the configuration of the field measurement system. It is extremely important to ensure that the measurements obtained during the jacket launching operation are sufficiently reliable and valid and thus the measurement equipment and measurement errors are also given in Section 4. Based on the field measurement data, the numerical simulations are validated and calibrated. Section 5 briefly gives the theoretical background of the jacket launching under the assumption of the stationary sea state and two-dimensional motion. By means of the calibrated numerical model, sensitivity analyses are performed to clarify the influences of the barge trim angle and draft, the jacket center of gravity (COG) and the kinetic friction coefficient along the skid-ways. The drag coefficients in the scaled models and prototype are discussed and the effects of C_D in the Froude-similarity models are also investigated in Section 6. Conclusions are presented based on the results and discussions to guide safe launching operations, and for the future offshore installations.

2. Jacket launching system

The jacket was successfully launched and installed in 190 m-deep waters with the assistance of the launching barge. To describe the motion of the jacket launching system, two coordinate systems are introduced: the global coordinate system ($o_g - x_g y_g z_g$) and body-fixed coordinate system. As shown in Fig. 1, the former system is fixed with respect to the earth, and its x–y-plane coincides with the water surface. The jacket-fixed coordinate system ($o_j - x_j y_j z_j$) moves with the jacket and its x–y-plane coincides with the jacket waterline. In addition, the barge-fixed coordinate system ($o_b - x_b y_b z_b$) moves with the barge and its x–y-plane coincides with the barge keel. The origin of each coordinate system is located in the central plane for simplicity.

2.1. Launching barge and jacket

The T-shaped launching barge features its narrower bow half and wider stern half, which contributes to a larger displacement and a better transverse stability (Xu et al., 2013). Its trim angle can be adjusted using the ballast tanks to initiate launching and to ensure the stability of the entire launching system. The transverse metacentric height of the barge is 11.6 m in the initial launching condition (draft = 11.12 m, trim = 4.25°). The barge is equipped with skid-ways, two identical rocker arms and installation aids and ancillary equipment. Tilting beams and a pair of rocker arms are attached in the stern of the barge. The length of each rocker arm is 41.14 m and the depth of the tilt beam is 7.54 m. The principal parameters of the barge are described in Table 1.

The eight-legged jacket is 203.5 m tall and is secured to the seafloor with 16 × ø108″(2743 mm) × 143.3 m foundation piles. Its reserve buoyancy is approximately 12.31% under the condition of void members. The principal parameters of the jacket are described in Table 2.

2.2. Launching condition

To initiate the launching, the barge was ballasted to the launching condition with the mid-ship draft of 11.12 m and trim of 4.25°. Fig. 2 shows the top view of the initial launching system. As shown in Fig. 2, the horizontal distance between the jacket COG and the mid-ship section is approximately 16.6 m.

There is a pair of steel skid-ways on the barge deck. The horizontal interval between the two skid-ways is 24 m and the overall length of each one is 150 m. Fig. 3 shows a cross section of the skid-way. As shown in Fig. 3, a pair of steel cradle is welded onto the jacket member and slides along with the jacket. The grease and Teflon coating are applied to the contact surface of the skid-ways and the launch cradles. The kinetic friction coefficient are in

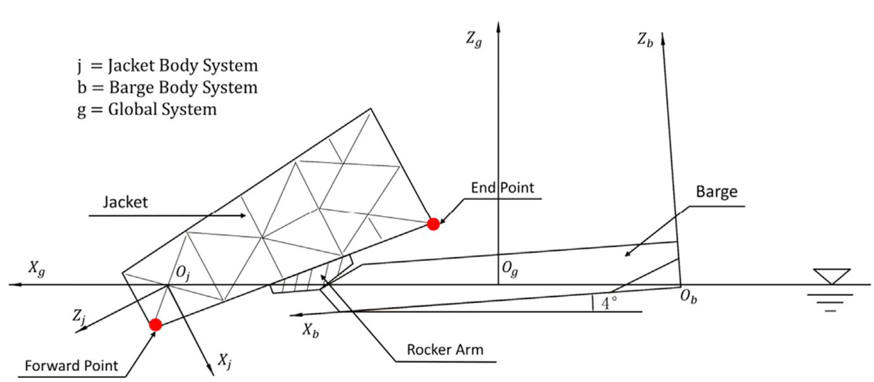

Fig. 1. Launching system configuration.