Numerical and Experimental Investigation on Hydrodynamic Characteristics of a 3000m Pipe-Lay Crane Vessel in Various Operation Conditions

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ABSTRACT

This paper presents analysis of results from both model tests and numerical simulations of a 3000m large pipe-lay crane vessel in irregular sea conditions of wave, current and wind. This new-designed vessel was improved on the basis of the HYSY 201 crane-lay vessel of CNOOC (China National Offshore Oil Company). All the experiments were performed in the multi-functional deep-water basin of Harbin Engineering University. Numerical models of the vessel were used to carry out simulations in both time domain and frequency domain. Numerical and experimental results were compared with methods of Fast Fourier Transformation technology and spectral analysis. The results of numerical simulations and model tests are in good accordance with each other, which proves the accuracy of numerical models, and reveals the susceptibility of roll motion to environmental condition’s changes in operation. Based on these models, the hydrodynamic performance of 4000t lifting operation and 10% pipeline installation, taking the couple effect of lifting module and pipeline, was predicted and compared with that of HYSY 201. The results show that roll motion of the new-designed vessel improves significantly which means new-designed vessel performs better than HYSY 201 in operation.

KEY WORDS: installation; S-lay; crane; sea keeping; model test; numerical simulation; hydrodynamics.

INTRODUCTION

The faster pace of modernization calls demands for more sufficient supplement for oil and gas, especially resource from ocean and ultra-deep ocean. Thus, the role of offshore structures and pipeline in production and transportation of oil and gas is becoming increasingly significant. However, installation of pipelines and offshore structures in hostile environment raises an array of serious technical and engineering challenges. Pipe-lay & crane vessel is a kind of well acknowledged ocean engineering vessel. These vessels are seen as the most vital method to implement subsea pipe-lay and lifting operation. Due to the floating structures’ differences, there exists pipe-lay barge and pipe-lay derrick. Additionally, pipe-lay barge can be further classified due to ship types, to be specific, ship-shape type, barge type and semi-submersible type. Viewed from installation approach, pipe-lay vessel can be categorized into S-lay, J-lay and reel-lay vessel. (Li, Wang, He and Zhao, 2008) Among all these kinds of pipe-lay barges, ship-type is the most widely used kind for that it is self-propelled and has a relatively larger carrying capacity.

According to the survey of worldwide offshore pipeline installation & burial contractors & vessels which was carried out by Offshore Magazine and Jerry Greenberg, 103 vessels, that had been registered to still serve the ocean engineering and other related fields worldwide, were investigated. Among them, 50 share the S-lay installation method, and only 14 out of the 104 enjoy the pipeline installation depth of 3000m in ocean. HYSY 201 was designed to serve as a multi-functional installation vessel for subsea pipeline and ocean structures in deep and ultra-deep water under various circumstances. However, compared with advanced operation vessel, such as SOLITAIRE from ALLSEAS, the operation capability of HYSY 201 is limited. For the sake of a better hydrodynamic performance and installation capability, an improved pipe-lay crane vessel is demanded to be designed and manufactured based on the HYSY 201. Therefore, researches are required to estimate the sea-keeping and hydrodynamic performance of the new vessel over HYSY 201.

Experimental and numerical comparison is instrumental in evaluating the sea-keeping and hydrodynamic performance of vessels. Former works on large pipe-lay crane vessels mostly focused merely on the numerical analysis while only a small fraction put emphasis on the comparison between experimental and numerical results. Numerical method basically was implemented on the basis of 3-D radiation-diffraction theory and Morison equation to calculate the wave exciting forces and radiation forces on floating bodies. Based on the theory, Van ’t Veer (2008) analyzed the hydrodynamic characteristic of a vessel with a stinger hinged under waterline. This paper put emphasis on calculation of stinger’s total force, when considering modeling of vessel-stinger dynamic interaction. From his work, the vessel motion and stinger’s total force was obtained. Yuan, Guo, Li and Wang (2011), Silva, Jr Lima and Jacob (2008) also did similar work in exploring numerical methods to analyze pipe-lay vessel hydrodynamic performance. Specifically, Clauss and Saroukh (1996) compared experimental results with numerical results to analyze the kinematical characteristic of a pipe-lay system, composed of a vessel and a rigid articulated stinger and pipeline. Lately, Li (2010) compared experimental results with numerical results of the HYSY 201 to evaluate its hydrodynamic performance in water depth of 2000m and 3000m in her master degree dissertation. Li’s work verified the influence of both stinger and pipeline on the vessel performance.