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Study on the Dynamics of Turret Moored FSRU in Waves

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ABSTRACT

The motion dynamics and mooring loads of a turret moored FSRU are studied by experiments. The FSRU is moored by turret and catenary mooring lines. It can weathervane to minimize the environmental loads exerted on the body. Therefore the heading changes according to wind, wave and current. The FSRU can reach an equilibrium yaw angle and oscillate in range of large amplitude of 10 to 40 degrees in regular waves. The yaw instability is also investigated in the present study as well. The horizontal motions and mooring loads are analyzed and compared for various environmental conditions. It was confirmed that the mooring loads are strongly affected by yaw angle

KEY WORDS: turret; mooring; catenary; yaw instability; experiment; heading analysis

INTRODUCTION

Recently a concept of FSRU (Floating Storage and Regasification Unit) is paid attention to by LNG industries due to its advantages in environment and safety terms compared with on-land LNG terminals such as no money for land, NYMBY, short construction time, etc. One of key issues for using FSRU is assurance of safe and reliable LNG offloading operation from LNGC to FSRU. The LNG offloading and loading operation are affected by many factors; sea state under operation, mooring system, loading arm and hydrodynamic interaction between FSRU and LNGC.

FSRU should be moored at operation site to conduct its functions. The possible mooring systems are STL (Submerged Turret Loading; Kaalstad and Hovde, 2004; Yang, Chezhian and Hovde, 2009), Internal/External Turret, YMS (Yoke Mooring System), SPM (Single Point Mooring) and spread mooring. The water depth in this study is about 50 m ~ 200 m and sites are GoM, East Asia, east and west coast of US etc. Since the water depth and environmental conditions of these regions are different, an adequate mooring system should be considered according to site and operation consideration. In this study, a disconnectable-typed turret mooring such as STL system is chosen which can be used in various water depths. STL has a function of connection and disconnect in underwater. This connection/disconnect can make FSRU to get mobility under harsh environment.

In this study, the motion dynamics and mooring loads of turret moored FSRU are studied. The motions of FSRU and loads of mooring lines are important design factors since they have a significant effect on operation and performance. Also, there are the important factors to be considered; slow drift motions and forces, surge damping, yaw instability and nonlinear mooring line dynamics. Surge, sway and yaw motions affect the performance of FSRU and become the basic data of DP design for heading control (Voogt, 2009). The turret allows the FSRU to be aligned with the resultant of the environmental forces, thereby minimizing motions and structural loads. FSRU may not be perfectly weathervaning into the sea but instead found equilibrium at an angle ranging from 10~40 degrees for certain range of incoming waves. Yaw instability in regular waves (Chillamcharla, Thiagarajan and Winsor, 2009; Yadav, Varghese and Thiagarajan, 2007) is interesting phenomenon observed in experiment and time domain analysis. This causes the increase of the magnitude of environmental loads on the hull, and is harmful to the position keeping.

Experiments were carried out at MOERI (Maritime and Ocean Engineering Research Institute) ocean engineering basin. The environmental conditions comprise regular waves, irregular waves and combined conditions; combination of wave, current and wind.

This paper consists of model experiment, results and conclusions. The first part presents the model, configuration and environmental conditions. The part of results describes the regular wave test, irregular wave test, and combined environmental test. The yaw instability in regular waves and the performance of station keeping in irregular wave and combined environments are focused.

MODEL EXPERIMENT

Experiments were carried out at MOERI ocean engineering basin. The basin is 56 m long, 30 m wide and a water depth of 3.2 m. The tests were carried out on a 1:60 scale model. The corresponding real water depth is 192 m. The contents of model test are made of the motion dynamics and the mooring load characteristics of turret moored FSRU in waves.

FSRU model

The main particulars are summarized in Table 1. Fig. 1 shows a model of FSRU. The model was fitted with bilge keels. The length in full