Effect of Turret Location on Hydrodynamic Motion of Ship-Shaped FPSO

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ABSTRACT

As Malaysia has started deep water oil exploration near offshore Sabah, more floating structures have been installed. However, less study has been conducted on FPSO with turret mooring system in Malaysia seawater especially in offshore Borneo. Even though offshore Borneo is part of South China Sea, the environmental condition is milder and its exhibit strong current from depth 50m to 150m. Hence, the present study analyzed the influence of turret location to surge, sway, heave, pitch, roll and yaw motions effect on the FPSO Kikeh operating in Kikeh Field. A simulation on FPSO Kikeh with five different turret locations in regular wave and collinear sea states have been done. From the analysis on the simulations, it is found that yaw motions become critical as turret distance from bow increases. Besides that, roll motion increases as yaw motion increases and this is due to coupling effect. Turret at bow is the best design for FPSO operating in Kikeh because it has the lowest structure excursion and lowest mooring lines tension. In addition, the environmental force exerted on the structure also low.

KEY WORDS: Turret Mooring System, Location, FPSO, Malaysia.

NOMENCLATURE

API American Petroleum Institute

1.0 INTRODUCTION

All floating structures must have mooring system. Mooring system is important because it function as station-keeping. Mooring system consist of hanging lines connecting the offshore platform to anchors at the seabed. Mooring designer must ensure the mooring system could avoid excessive forces on the platform and making it stiff enough to prevent excessive offset.

Most of the FPSOs used turret mooring as their mooring system compared to spread mooring system [1]. Advantage of turret mooring system is vessel can weathervane freely and helped to reduce the environmental loads caused by sea waves, current and wind. Besides that, turret mooring is more economical and reliable than single point mooring [2]. There are two types of turret mooring system; internal turret and external turret. Internal turret system is a turret system that is integrated into the hull structure at the bow of the vessel. It can be used for harsher environments and allow for the inclusion of a greater amount of risers. However, the installation cost is higher because of the complex hull integration. Besides that, it reduced the cargo space and volume. External turret mooring system is a turret system that is located at the extreme end of an outrigger structure attached to the bow of the vessel. It is suitable for mild to medium environments. The cost for installation is lower compared to internal turret and it is easy to integrate into the vessel. However, the disadvantages of external turret are it required a cantilever to
avoid risk of anchor legs/hull interference and limited number of risers can be installed on the turret. Besides that, it has higher motions owing to the distance between the turret axis and the vessel mid-ship.

A lot of studies have been conducted on single point mooring system. Wichers (1988) [3] has initiated a numerical simulation for horizontal motion of turret moored FPSO in irregular waves. O'Donoghue and Linfoot (1991) [4] has conducted an experiment on a turret moored vessel in irregular waves and reported that turret location has influence to vessel motions and mooring line tensions. E. W. Huang et al. (1993) [5] has conducted a study on turret moored FPSO in South China Sea. The analytical calculation of green water effects, vessel and turret motions, and turret and mooring lines load are compared with the model test. Jiang et al. (1995) [6] has numerically conducted the horizontal motions and mooring line loads of single point moored tanker. Liu et al. (1999) [7] has conducted a model testing of a moored monohull with varying turret locations to examined the yaw motion of the monohull in regular wave. Thiagarajan and Finch (1999) [8] has conducted an experimental investigation of the influence of turret locations on the FPSO to the vessel vertical motions and accelerations. K. Huang (2000) [9] has identified critical issue related to mooring system design for turret moored FPSO. Soares et al. (2005) [10] has conducted an experiment to study the dynamic of the mooring system in vertical motions and green water effect. Tahar and Kim (2003) [11], Kim (2004) [12] and Kim et al. (2005) [13] has developed a program to analyse the global motions and mooring line tension of a turret moored FPSO in non-parallel environment. Kannah and Natarajan (2006) [14] has conducted an experiment on influence of internal turret locations to FPSO motions and mooring line forces under regular sea waves. Cho et al. (2013) [15] has performed an experiment to analyse the horizontal motions and stability analysis in regular waves for turret moored vessel. Ismail and Koto (2014a) [16] and Ismail and Koto (2014b) [17] has conducted an experimental investigation and computational analysis on turret moored twin hull FPSO to compare the dynamics behavior to the FPSO and it mooring lines. Xie et al. (2015) [18] has conducted a study on the effects of turret locations in irregular waves to the horizontal stability of the turret moored FLNG. The coupled analysis has including the vessel motions and mooring dynamic. The study is designed to be in South China Sea.

From the literature review, it is found that less study has been conducted on FPSO with turret mooring system in Malaysia seawater especially in offshore Borneo. Even though offshore Borneo is part of South China Sea, the environmental condition is milder and it exhibit strong current from depth 50m to 150m. Hence, the present study analyzed the influence of turret location to surge, sway, heave, pitch, roll and yaw motions effect on the FPSO Kikeh operating in Kikeh Field

2.0 METHODOLOGY

To investigate the influence of turret locations on FPSO response, a numerical simulation by using ANSYS AQWA will be performed. From the literature review conducted, coupled dynamic analysis will give better and more accurate results for FPSO operating in deepwater because it captured the direct environment loads and damping forces due to the mooring lines.

FPSO Kikeh has been selected for this project. FPSO particulars are shown in Table 1. This FPSO is operating in Kikeh Field and has external bow turret with catenary mooring system. The design environment for this project is offshore Borneo because Kikeh Field is located at Sabah and South East Asia sea conditions are difference from the South China Sea conditions. The analysis will be conducted in regular waves for easy comparison and to get the maximum value of motion [19].

<table>
<thead>
<tr>
<th>Table 1: FPSO Kikeh Particulars</th>
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<tbody>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Breadth</td>
</tr>
<tr>
<td>Depth</td>
</tr>
<tr>
<td>Draft</td>
</tr>
<tr>
<td>Mass displacement</td>
</tr>
<tr>
<td>Kzz</td>
</tr>
<tr>
<td>Kxx</td>
</tr>
<tr>
<td>Kyy</td>
</tr>
</tbody>
</table>

Five turret locations has been chosen for this study. Internal turret and external turret mooring system will be used for this study. All vessel conditions during this study are in full laden.
In this study, 100-year return sea-state lasting for 3 hours (10,000 seconds) has been chosen to investigate the hydrodynamic performance of the FPSO vessel during its operation. Regular wave and collinear sea states have been adopted. Details about the environment parameters are shown in Table 2.

Table 2: Environmental Load Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water depth</td>
<td>1,350 m</td>
</tr>
<tr>
<td>Significant wave height, $H_s$</td>
<td>6 m</td>
</tr>
<tr>
<td>Wave Period, $T_p$</td>
<td>11.7 s</td>
</tr>
<tr>
<td>Wind Speed, $V_w$</td>
<td>19 m/s</td>
</tr>
<tr>
<td>Current Speed, $V_c$</td>
<td>1.46 m/s</td>
</tr>
<tr>
<td>Wave, wind and current attack</td>
<td>Head seas</td>
</tr>
</tbody>
</table>

FPSO Kikeh used permanent mooring line with 10 anchor legs with 4-3-3 configuration. The material for mooring line in this project is combination of chain-wire-chain with diameter 127 mm for chain and 98mm for wire. Turret weight is 2,300 tonnes [20].
3.0 RESULTS AND DISCUSSION

Figure 7 shows the RAO of FPSO in each motion. The RAO of the FPSO with five different turret locations were plotted in the same graph for easier comparison of the RAO tendency obtained at five different turret locations.

From the graphs, it can be observed the patterns for all motions are similar even though the turret locations are different. For pitch RAO, turret at bow has the highest RAO. This is due to VCG of external turret is higher compare to internal turret. Besides that, the radius of pitch gyration ($K_{yy}$) is also big.

Structure excursion is the position of the vessel after expose to environment load. A good mooring system is the system that results on minimum excursion to the FPSO.

Figure 8 until Figure 10 show the structures excursion in surge, sway and yaw motion for five different turret locations. FPSO with turret at bow has the smallest excursion in horizontal plane motion. Whereas, FPSO with turret at midship has highest excursion in transient state, small excursion in steady state, except for yaw motion. This is due to the system is unstable in the original position of equilibrium, the FPSO reached a new condition of equilibrium with a vessel ship heading of about 90 degrees. In this new position, it is exposed to beam wind, waves and current. This has caused the sway and surge motions are lower than FPSO with 50% and 75% turret from bow during steady state.

In Figure 10, it can be observed also FPSO excursion in yaw motion increases as the turret location from bow increases. This is because of wave spreading effect. Hence, when the distance of turret location from bow increases, the yaw vessel magnitude increases. Therefore this gives effect to vessel roll motion.

Table 3 shows maximum cable forces for each condition. Cable force is force occurrence by the cable to withstand the environmental load and to keep the FPSO stationery and stay on the same coordinate.

5.0 CONCLUSIONS

FPSO responses on influence of turret locations in regular wave have been considered. Results show that FPSO with turret at the bow is the best design for FPSO operating in Kikeh Field. FPSO excursion when turret located at the bow is the smallest. Besides that, the mooring lines force to counter the environmental load also less. Hence, objective of the study to analyze the influence of turret location to the FPSO response has been successfully conducted.

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REFERENCE


APPENDIX

(a) Surge RAO

(b) Sway RAO

(c) Heave RAO

(d) Roll RAO
Figure 7: RAO motions for FPSO with five different turret location
Figure 8: Structure Excursion in Surge Motion
Figure 9: Structure Excursion in Sway Motion

(a) Turret at Bow

(b) Turret 25% from bow

(c) Turret 50% from bow

(d) Turret 75% from bow

(e) Turret at Midship
Figure 10: Structure Excursion in Yaw Motion
Figure 11: Cable forces for Turret at Bow

Figure 12: Cable forces for Turret 25% from Bow
Figure 13: Cable forces for Turret 50% from Bow

Figure 14: Cable forces for Turret 75% from Bow
Figure 15: Cable forces for Turret at Midship