THE OPTIMIZATION OF TURRET LOCATION ON FPSO IN MALAYSIA SEAWATER

ADIBAH FATIHAH BINTI MOHD YUSOF

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Science (Ship and Offshore Engineering)

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JANUARY 2017

To my family,

This thesis is dedicated to them.

ACKNOWLEDGEMENT

I wish to express my gratitude to all those who helped me, in one way or another, to complete this project. I thank Allah who provided me with strength, direction throughout the project. Special thanks to my project supervisor, Dr. Eng. Jaswar Koto for all his patience, guidance and support during completion of this project. Special thanks also to my senior, Dr. Siow Chee Loon and friends for they helped on my simulations on this project. Through their expert guidance, I was able to overcome all the obstacles that I encountered in these project and managed to complete my project in a given time. Last but not least, I also would like to express deepest gratitude to all my family members' especially beloved parents Mohd Yusof b. Aibd Latif and Noorhayati bt. Zainal Abidin for their continuous support and encouragement in every aspect.

ABSTRACT

As Malaysia has start deepwater 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; turret at the bow, midship, 25%, 50% and 75% from the bow, in regular wave and collinear sea states have been done. From the analysis of 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 the coupling effect. The turret at the bow is the most prefered 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.

ABSTRAK

Memandangkan Malaysia telah mula melakukan proses carigali minyak di lautan dalam, lebih banyak struktur terapung telah dipasang berhampiran luar persisiran Sabah. Walau bagaimanapun, kurang kajian telah dijalankan ke atas FPSO dengan sistem tambatan menara kecil di lautan Malaysia terutamanya lautan Borneo. Walaupun lautan Borneo adalah sebahagian daripada Laut China Selatan, keadaan lautan Borneo kurang ganas sedikit berbanding Laut China Selatan dan mempunyai arus yang kuat pada kedalaman 50m hingga 150m. Oleh itu, kajian ini telah menganalisis kesan lokasi tambatan menara kecil kepada "surge", "sway", "heave", "roll", "pitch" dan "yaw". Simulasi ke atas FPSO Kikeh dengan lima lokasi Menara tambatan kecil telah dilaksanakan. Keputusan analisis menunjukkan gerakan "yaw" bertambah apabila kedudukan menara tambatan kecil dari haluan kapal bertambah. Selain itu, gerakan "roll" juga bertambah apabila gerakan "yaw" bertambah dan ini disebabkan kesan ganding dua gerakan. Keseluruhannya, kedudukan menara tambatan kecil di hadapan kapal adalah rekabentuk yang terbaik untuk FPSO operating in Kikeh Field kerana mempunya pergerakan FPSO yang paling rendah dan ketegangan tali tambatan yang rendah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The offshore industry is a very successful industry with a very rapid development. New technologies have been introduced every year in order to explore and produce more oil in the inaccessible area. Nowadays, due to depletion of oil in offshore shallow water, offshore exploration has started advancing to focus on offshore deep water and ultra-deep water in a very fast pace.

An offshore structure is a large structure to drill wells, to extract and process oil and gas, to store temporary before it has been offloaded to shuttle tanker to be brought to onshore to sell. There are two types of offshore structures; fixed structure and floating structure. For fixed offshore structure, there are two types; jacket platform and jack-up platform. These two platforms are commonly used in shallow water. For floating offshore structure, there are 4 types; Floating Production Storage and Offloading (FPSO), Mobilize Offshore Drilling Unit (MODU), Spar and Tension Leg Platform (TLP). Floating offshore structures have been used in deep water and ultra-deep water. FPSO is a ship-shaped structure used for processing and storage of oil and gas. Most of the traditional tanker is converted to FPSO to be used in deep water and ultra-deep water oil exploration because it is more economical. Hence, effective mooring system has been developed to ensure these FPSOs can withstand all sea conditions and environments during their operation.

All floating structures must have mooring system. Mooring system is important because it functions as station-keeping. There are two types of moorings, single point mooring (SPM) and spread mooring. The mooring system consists of hanging lines connecting the offshore platform to anchors at the seabed. The hanging

lines either in catenary form or taut form. The 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 (Paik & Thayamballi, 2007). The advantage of turret mooring system is vessel can weathervane freely and this 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 (Chakrabarti, 2005).

There are two types of turret mooring system; internal turret (Figure 1.1) and external turret (Figure 1.2). 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 the internal turret and it is easy to integrate into the vessel. However, the disadvantages of the external turret are it required a cantilever to avoid risk of anchor legs/hull interference and a 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.

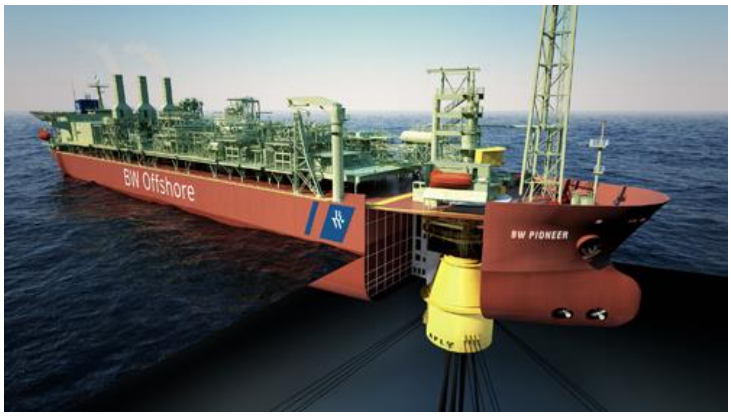

Figure 1.1 : Internal Turret Mooring System

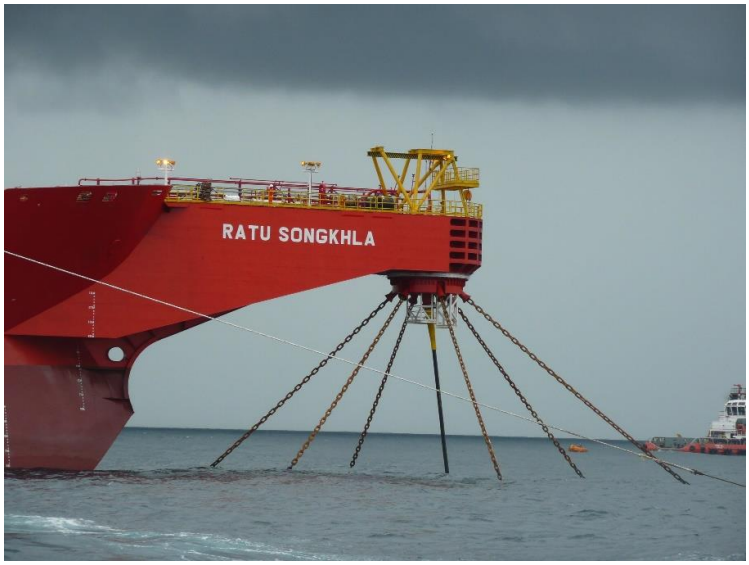

Figure 1.2 : External Turret Mooring System

A lot of studies have been conducted on single point mooring system. Wichers (1988) has initiated a numerical simulation for horizontal motion of turret moored FPSO in irregular waves. O'Donoghue and Linfoot (1991) 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) has conducted a study on turret moored FPSO in the 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) have numerically conducted the horizontal motions and mooring line loads of single point moored tanker. Liu et al. (1999) has conducted a model testing of a moored monohull with varying turret locations in Ocean Wave Basin at HR Wallingford to examined the yaw motion of the monohull in the regular wave. Thiagarajan and

Finch (1999) has conducted an experimental investigation of the influence of turret locations on the FPSO to the vessel vertical motions and accelerations. K. Huang (2000) has identified critical issue related to mooring system design for turret moored FPSO. Soares et al. (2005) have conducted an experiment in the Offshore Wave Basin of the Danish Hydraulic Institute Water and Environment to study the dynamic of the mooring system in vertical motions and green water effect. Tahar and Kim (2003), Kim (2004) and Kim et al. (2005) has developed coupled dynamic analysis program to analyze the global motions and mooring line tension of a turret moored FPSO in the non-parallel environment of Gulf of Mexico. Kannah and Natarajan (2006) has conducted an experiment on an influence of internal turret locations to FPSO motions and mooring line forces under regular sea waves. Cho et al. (2013) have performed an experiment to analyze the horizontal motions and stability analysis in regular waves for turret moored Floating Storage Regasification Unit (FRSU). Nik Mohd Khairuddin Nik Ismail and Jaswar Koto (2014) and Nik Mohd Khairuddin Nik Ismail and Jaswar Koto (2014) has conducted an experimental investigation and computational analysis on turret moored twin hull FPSO to compare the dynamics behavior to the FPSO and its mooring lines. Xie et al. (2015) have 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 the South China Sea.

1.1 Problem Statement

Horizontal motions and vertical motions of turret moored FPSO give difference dynamic response to the vessel and mooring system. By changing the turret location on the FPSO, it also will affect the horizontal motions and vertical motions of the FPSO and mooring system. This will give influence to the FPSO weathervane ability. The environmental condition such as wind, wave, and current also will determine the best turret location on the FPSO. Most of the studies conducted on turret moored FPSO are focusing in the Gulf of Mexico and South China Sea. However, less study has been conducted in South East Asia or offshore

Borneo. As Malaysia has start offshore exploration in deepwater and Kikeh Field is the first Malaysia deepwater project located in offshore Borneo, more study is needed to understand FPSO dynamic response in this type of environment condition. Hence, a study is required to analyze the influence of different turret locations to the dynamic response of FPSO and mooring system when operating in Kikeh Field.

1.2 Purpose Statement

The purpose of this study is to understand the effect of turret locations on the dynamic behavior of the FPSO and mooring line system.

1.3 Objective

Objective of this research are as below;

i. To analyze the influence of turret location to surge, sway, heave, pitch, roll and yaw motion effect on the FPSO operating in Kikeh Field.

1.4 Scope of Study

The scope of study covers the following;

i. External and internal turrets mooring system
ii. Locations of turrets; midship, 25%, 50% and 75% from bow
iii. Study on Malaysia sea water in Kikeh location

REFRENCES

Ahmed, M. (2013). *Catenary mooring with its dynamic effects.* Universiti Teknologi Malaysia, Faculty of Mechanical Engineering.

Ansys, A. (2014). Theory Manual: Release.

cargo-vessels-international.at. (2008). FPSO Kikeh. Retrieved March 25th, 2016, from http://cargo-vessels-international.at/FPSO_KIKEH_IMO7351812.pdf

Chakrabarti, S. K. (1987). *Hydrodynamics of offshore structures*: WIT press.

Chakrabarti, S. K. (1998). *Physical model testing of floating offshore structures.* Paper presented at the Dynamic Positioning Conference.

Chakrabarti, S. K. (2005). *Handbook Of Offshore Engineering* (Vol. 1). The Boulevard, Langford Lane, Kidlington, Oxford OX5 IGB, UK: Elsevier Ltd.

Chakrabarti, S. K. (2006). *Handbook Of Offshore Engineering* (Vol. 2). The Boulevard Langford Lane, Kidlington, Oxford OX5 lGB, UK: Elsevier Ltd.

Cho, S. K., Sung, H. G., Hong, S. Y., Kim, Y. H., & Choi, H. S. (2013). *Study of the Stability of Turret Moored Floating Body.* Paper presented at the Proceedings of International Ship Stability Workshop, Brest, ISSW.

Chung, J. S. (1994). *Added mass and damping on an oscillating surface-piercing circular column with a circular footing.* Paper presented at the The Fourth International Offshore and Polar Engineering Conference.

Davies, K. B., & Mungall, J. C. H. (1991). *Methods for Coupled Analysis of TLP's.* Paper presented at the Offshore Technology Conference.

Garrett, D. L. (2005). Coupled analysis of floating production systems. *Ocean Engineering, 32*(7), 802-816.

Gurumurthy, K., Ahmad, S., & Chitrapu, A. S. (2009). *Coupled dynamic analysis of mooring lines for deep water floating systems.* Paper presented at the Proceedings of International Conference in Ocean Engineering, ICOE.

Heurtier, J. M., Le Buhan, P., Fontaine, E., Le Cunff, C., Biolley, F., & Berhault, C. (2001). *Coupled dynamic response of moored FPSO with risers.* Paper presented at the The Eleventh International Offshore and Polar Engineering Conference.

Howell, G. B., Duggal, A. S., & Lever, G. V. (2001). *The terra nova FPSO turret mooring system.* Paper presented at the Offshore Technology Conference.

Huang, E. W., Beynet, P. A., Chen, J. H., Li, J. X., & Lu, Z. G. (1993). *FPSO Model Tests and Analytical Correlation.* Paper presented at the Offshore Technology Conference.

Huang, K. (2000). *Mooring system design considerations for FPSOs.* Paper presented at the The Tenth International Offshore and Polar Engineering Conference.

Islam, A. B. M. S., Jameel, M., Jumaat, M. Z., & Shirazi, S. M. (2011). Spar platform at deep water region in Malaysian sea. *International Journal of the Physical Sciences, 6*(30), 6872-6881.

Jameel, M., Saiful Islam, A. B. M., Jumaat, M. Z., & Ahmad, S. (2011). *Nonlinear analysis of fully coupled integrated spar-mooring line system.* Paper presented at the The Twenty-first International Offshore and Polar Engineering Conference.

Jiang, T., Schellin, T. E., & Sharma, S. D. (1995). Horizontal motions of an SPM tanker under alternative mooring configurations. *Journal of Offshore Mechanics and Arctic Engineering, 117*(4), 223-231.

Kannah, T. R., & Natarajan, R. (2006). Effect of turret location on the dynamic behaviour of an internal turret moored FPSO system. *Journal of Naval Architecture and Marine Engineering, 3*(1), 23-37.

Kim, M. H. (2004). Dynamic Analysis Tool for Moored Tanker-Based FPSO's Including Large Yaw Motions. *Final Report Prepared for the Minerals Management Service under the MMS/OTRC Cooperate Research Agreement*, 2-4.

Kim, M. H., Koo, B. J., Mercier, R. M., & Ward, E. G. (2005). Vessel/mooring/riser coupled dynamic analysis of a turret-moored FPSO compared with OTRC experiment. *Ocean Engineering, 32*(14), 1780-1802.

Kim, M. H., Tahar, A., & Kim, Y. B. (2001a). *Variability of spar motion analysis against various design methodologies/parameters.* Paper presented at the Proceedings of the ASME 20th International Conference on Ocean, Offshore and Arctic Engineering OMAE2001.

Kim, M. H., Tahar, A., & Kim, Y. B. (2001b). *Variability of TLP motion analysis against various design methodologies/parameters.* Paper presented at the The Eleventh International Offshore and Polar Engineering Conference.

Kurian, V. J., Wong, B. S., & Montasir, O. A. A. (2008). Frequency domain analysis of truss spar platform. *environment (Chakrabarti, 2005; Downie et al.; Sadeghi et al.; Wang et al., 2001, 2002), 5*(7), 11-13.

Liu, F., Brown, D. T., & Fang, J. (1999). Yawing of turret-moored monohull vessels in response to regular waves. *Journal of ship research, 43*(3), 135-142.

Lovie, P. (2010). Gulf of Mexico: The First FPSO in the US Gulf OF Mexico: The 14-Year Journay. *Journal of Petroleum Technology*, 36-39.

Low, Y. M., & Langley, R. S. (2006). Time and frequency domain coupled analysis of deepwater floating production systems. *Applied Ocean Research, 28*(6), 371-385.

Luo, Y., & Baudic, S. (2003). *Predicting FPSO responses using model tests and numerical analysis.* Paper presented at the The Thirteenth International Offshore and Polar Engineering Conference.

Ma, W., Lee, M.-Y., Zou, J., & Huang, E. W. (2000). *Deepwater nonlinear coupled analysis tool.* Paper presented at the Offshore Technology Conference.

Maimun, A., Yaakob, O., Kamal, M. A., & Wei, N. C. (2006a). *Evaluation of Seakeeping Analysis of a Fishing Vessel using a Wave Buoy and Onboard Motions Monitoring Device.* Paper presented at the 1st Regional Conference on Vehicle Engineering and Technology (RIVET 2006), Kuala Lumpur.

Maimun, A., Yaakob, O., Kamal, M. A., & Wei, N. C. (2006b). Seakeeping analysis of a fishing vessel operating in Malaysian water. *Jurnal Mekanikal, 22*, 103-114.

Nik Ismail, N. M. K., & Koto, J. (2014). Review On Dynamic Behaviour of Moored Twin Hulls FPSO. *Science and Engineering, 14*.

Nik Ismail, N. M. K., & Koto, J. (2014). Theoretical Study on Effect of Turret Location on Dynamic Response of Moored Twin Hulls FPSO System. *OMASE2014, 1*, 13.

Nishanth, R., John, K. V., & Whyte, A. (2016). Dynamic behaviour of FPSO in kikeh field under different loading conditions. *ARPN Journal of Engineering and Applied Sciences, 11*, 2302-2307.

O'Donoghue, T., & Linfoot, B. T. (1991). An experimental study of turret-moored floating production systems. *Applied Ocean Research*, 127-139.

Ormberg, H., & Larsen, K. (1998). Coupled analysis of floater motion and mooring dynamics for a turret-moored ship. *Applied Ocean Research, 20*(1), 55-67.

Paik, J. K., & Thayamballi, A. K. (2007). *Ship-shaped offshore installations: design, building, and operation*: Cambridge University Press.

Qiao, D., Li, B., & Ou, J. (2012). Comparative Analysis on Coupling Effects between an Innovative Deep Draft Platform and Different Mooring Models. *Brodogradnja, 63*(4), 318-328.

Qiao, D., Wu, F., & Ou, J. (2014). *Coupled Analysis of a Semisubmersible Platform with Two Types of Mooring Systems.* Paper presented at the The Twenty-fourth International Ocean and Polar Engineering Conference.

Ryu, S., & Kim, M. H. (2003). *Coupled dynamic analysis of thruster-assisted turret-moored FPSO.* Paper presented at the OCEANS 2003. Proceedings.

Sheikh, R., & Brown, A. (2010). *Extreme vertical deepwater current profiles in the South China Sea, Offshore Borneo.* Paper presented at the ASME 2010 29th International Conference on Ocean, Offshore and Arctic Engineering.

Siow, C. L. (2016). *Numerical Modelling For Hydrodynamic Behaviour of Round Shape FLNG Interacting with LNG Carrier.* (Doctor of Philosophy - Mechanical Engineering), University Technology Malaysia.

Soares, C. G., Fonseca, N., & Pascoal, R. (2005). Experimental and Numerical Study of the Motions of a turret Moored FPSO in Waves. *Journal of Offshore Mechanics and Arctic Engineering, 127*(3), 197-204.

Tahar, A., & Kim, M. H. (2003). Hull/mooring/riser coupled dynamic analysis and sensitivity study of a tanker-based FPSO. *Applied Ocean Research, 25*(6), 367-382.

Thiagarajan, K. P., & Finch, S. (1999). An Investigation Into the Effect of Turret Mooring Location on the Vertical Motions of an FPSO Vessel. *Journal of Offshore Mechanics and Arctic Engineering, 121*(2), 71-76. doi: 10.1115/1.2830080

Tuhaijan, S. N. A. B., John, K. V., & Liew, M. S. (2011). *Wave-current interaction on offshore spar platforms.* Paper presented at the National Postgraduate Conference (NPC), 2011.

Wichers, J. E. (1988). *A simulation model for a single point moored tanker* (Vol. 797): Technische Universiteit Delft.

Wichers, J. E., & Devlin, P. V. (2001). *Effect of coupling of mooring lines and risers on the design values for a turret moored FPSO in deep water of the Gulf of Mexico.* Paper presented at the The Eleventh International Offshore and Polar Engineering Conference.

Wodehouse, J., George, B., & Luo, Y. (2007). *The Development of an FPSO for the Deepwater Gulf of Mexico.* Paper presented at the Offshore Technology Conference.

Xie, Z.-T., Yang, J.-M., Hu, Z.-Q., Zhao, W.-H., & Zhao, J.-R. (2015). The horizontal stability of an FLNG with different turret locations. *International Journal of Naval Architecture and Ocean Engineering, 7*(2), 244-258.

Yaakob, O., Hashim, F. E., Omar, K. M., Din, A. H. M., & Koh, K. K. (2016). Satellite-based wave data and wave energy resource assessment for South China Sea. *Renewable Energy, 88*, 359-371.

Yang, M., Teng, B., Ning, D., & Shi, Z. (2012). Coupled dynamic analysis for wave interaction with a truss spar and its mooring line/riser system in time domain. *Ocean Engineering, 39*, 72-87.

Yu, R. (1995). *Dynamic response of a floating dock in regular and irregular waves.* Memorial University of Newfoundland.

Zhao, W. H., Yang, J. M., Hu, Z. Q., & Wei, Y. F. (2011). Numerical investigation on the hydrodynamic difference between internal and external turret-moored FLNG. *Journal of Shanghai Jiaotong University (Science), 18*, 590-597.