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Numerical Investigation of Drillship Response with the Addition of Baffle Plates in the Moonpool

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Abstract
A moonpool is an opening in drillship from continuous deck to keel to access to the underwater part from the onboard ship. Moonpool creates additional motion to the vessel while the drillship in operation, which leads to a larger quantity of green water on the weather deck. Therefore, the minimization of water motion is an important task in drillship. This paper presents a numerical study of the water motion on baffle plates, which are fixed on the inner walls of the moonpool. The results from the study show that fixing of baffle plates improve the performance of the moonpool to a great extent.

Keywords:*Drillship, Moonpool, Piston mode, Sloshing mode, Response Amplitude Operator (RAO)*

I. INTRODUCTION

In drillship, the moonpool opening for underwater operations influences the vessel hydrodynamic characteristics. The water motion in the moonpool affects the structure also green water enters into the deck. This water motions in irregular fashion inside the moonpool. This causes uncomfortable conditions for the crew members. Therefore the water column motions inside the moonpool should be minimized to a great extent.

II. LITERATURE REVIEW

Research [1] conducted on moonpool with damping plates and the damping effect observed in the case of water motion. Computational Fluid Dynamics(CFD) study [2] on moonpool with cofferdam point out the impact of attachments in the reduction of water motion in the moonpool. Drillship model with different geometry moonpool[3] shows the effect of geometry in the behaviour of water particle movement in the moonpool. Experiments [4] conducted on moonpool with different kinds of attachment to reduce the motion. The surface elevation from the draft level on the moonpoolevaluated[5] in drillship. Moonpool resonance frequency[6] at the various heading of encountering frequency evaluated and the same had derived for both the modes of oscillations numerically[7] using potential flow theory. The length to breadth ratio of moonpoolmodified[8] and the nature of the free surface evaluated within the moonpool region. Sivabalan and Surendran[9 &10] carried out the numerical and experimental study on moonpool and suggested the modification in geometry to minimize the water motion within the moonpool. The modification in geometry [11] performed in the moonpool model and the performance evaluated in forwarding speed condition. The resonance frequency of moonpool[12] in the piston and sloshing mode with cofferdam performed. Based on previous studies, it can be concluded that the flow inside the moonpool mainly based on geometry and attachments. This paper addressed the reduction of free surface with fixed baffle plates.

III. NUMERICAL MODELING

A. Drill Ship Model

The models used for the numerical analysis with baffle plates using Multisurf shown in Figure 1. A drillship model used for the analysis has the length between perpendiculars (LBP) value of 280m with moonpool dimensions of 24x12m at the center.WAMIT version 6 software is used for the numerical analysis. The numerical analysis conducted for the wave period up to 30 seconds and the heading angle of 0-180 with a 45-degree interval.

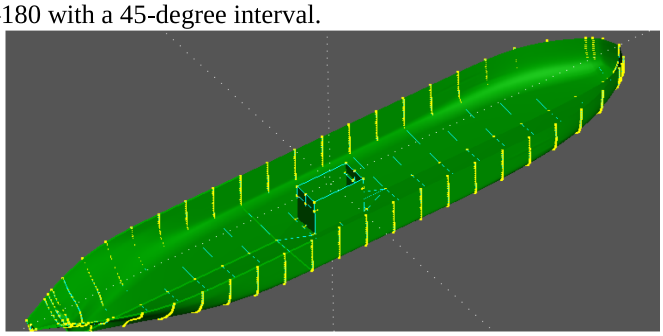

Fig 1: Drillship with moonpool and baffle plates

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IV. MATHEMATICAL MODEL

A. Velocity potential

Consider a three-dimensional floating body in progressive waves in water of finite water depth H. It is subjected to hydrodynamic pressure, different environmental loads like wind, wave, and current. As well as the induced velocity and pressure in the domain with circular frequency 'ω'. The value of diffracted wave potential is proportional to the incident wave amplitude and is that of radiation velocity potential. Also, this is proportional to ship motion amplitude in all degrees of freedom. The total velocity potential includes the incident wave potential, diffraction potential, and radiation potential. This resultant potential increases the amplitude of waves inside the moonpool. The elevation at any point 'P' inside the moonpool is given by

$$\varphi(P) = \frac{ag}{i\omega}\{\varphi_0(P) + \varphi_7(P)\} + \sum_{j=1}^{6} i\omega X_j \varphi_j(P) \quad (1)$$

a- Wave amplitude
ω- Wave frequency (rad/sec)
g- Acceleration due to gravity

φ_0 -Incident wave potential

φ_7 -Diffraction potential

X_j -The motion of the body in all six degrees of freedom

φ_j - Radiation potential

B. Equation of motion of the ship

The response of the ship in waves is described by means of a spring-mass system. The body motions in all six degrees of freedom can be obtained from the equation of motion. From Newton's law

$$\sum_{j=1}^{6}\left[\left(m_{ij} + A_{ij}\right)\ddot{X}_j + B_{ij}\dot{X}_j + C_{ij}X_j\right] = F_i$$

$$i=1\sim6 \quad (2)$$

Where

m_{ij}-Body inertia matrix including moments of inertia for rotational modes.

A_{ij}-Added mass coefficient matrix.

B_{ij}-Damping coefficient matrix.

C_{ij}-Restoring force coefficient matrix.

F_i- Exciting force and moments.

X_j-Amplitude of the body motion.

C. Moonpool parametric studies

In this numerical study, the water motion within the moonpool and the response of the drillship for various wave periods were studied. The drillship considered for the study has a rectangular moonpool. The motion of the fluid inside the moonpool reduced by means of baffle plates installed on the inner sides of the moonpool. A profile view of drillship with moonpool is given in Figure 2. A profile view of moonpool with sample baffle at various depth(h) on the moonpool is given in Figure 3. In this 'l' is the moonpool length, 'w' is the baffle width and 'T' is the water level inside the moonpool.

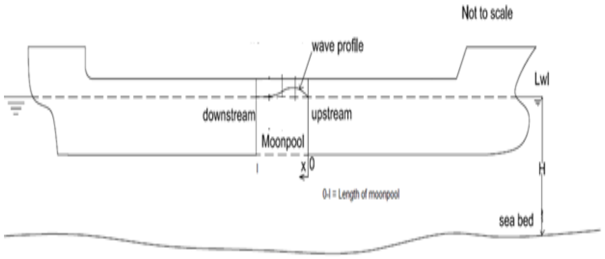

Fig 2: Profile view of drillship with moonpool

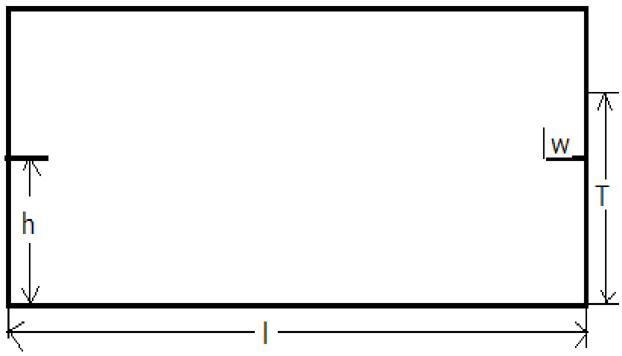

Fig 3: Moonpool with baffle blades

The baffle plates were fixed horizontally in various positions of the moonpool along with its depth(h). In this paper the h/l ratio taken to be 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7. The width of the baffle plate is taken as 1m. The impact of baffle plates was evaluated for all the configurations.

V. RESULTS AND DISCUSSION

A. Drillship response

The response of the drillship with baffle plate configurations and without baffle plates are found from the numerical study. Basically, RAO is the response of the vessel to the amplitude of the incident wave. The study conducted at the stationary conditions for various heading angles. A numerical study has been carried out for all the baffle plate configurations in the moonpool and the results are plotted. The reduction in the peaks in the heave RAO and surge RAO represent the effect of baffle plates on reduction in water motion inside the moonpool. The effect of moonpool in drillship as shown in Figure 4.

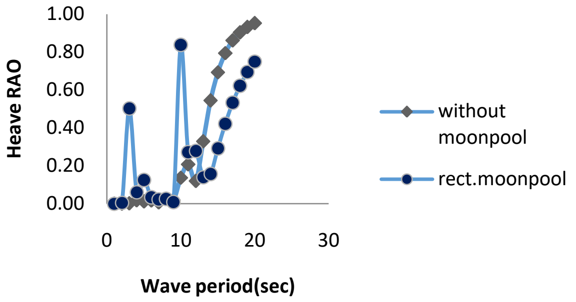

Fig 4: Heave RAO of the drillship

The heave RAO of the drillship for various h/l ratios with the heading angles 135 degrees and 180 degrees are shown in Figures 5 and 6. In both the heading angle, the response of the drillship is reduced to a great extent due to the fixing of baffle plates in the moonpool.

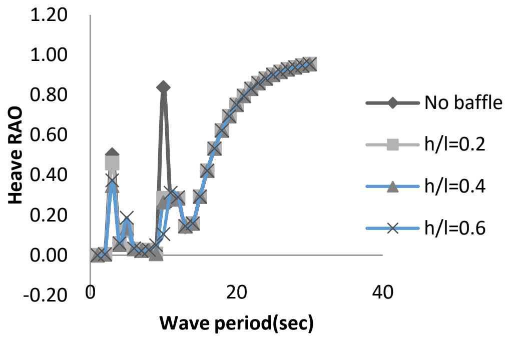

Fig 5: Heave RAO for heading angle 180 degree

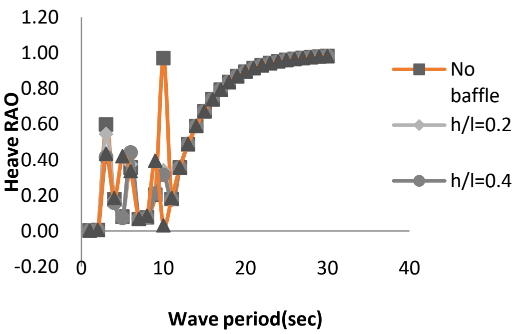

Fig 6: Heave RAO for heading angle 135 degree

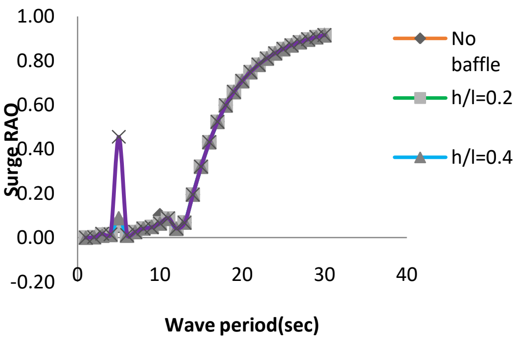

Fig 7: Surge RAO for heading angle 180 degree

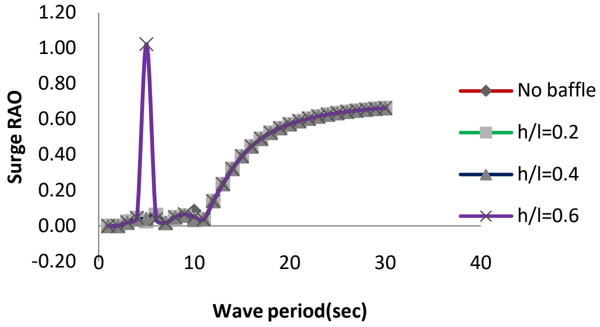

Fig 8: Surge RAO for heading angle 135 degree

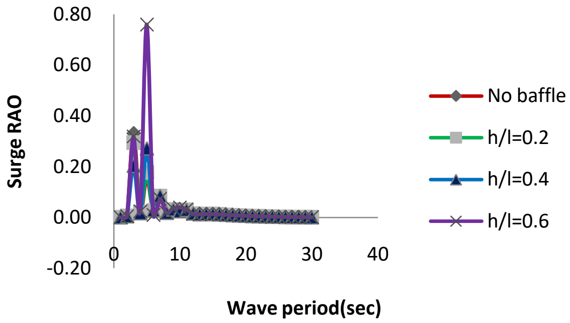

Fig 9: Surge RAO for heading angle 90 degree

In rectangular moonpool, the horizontal mode of water motion more than that of piston mode. The surge RAO for various heading angle with different h/l ratio of baffle plates is given in Figure 7-9. Baffle plates near the entrance level of the moonpool have good performance than above the draft level of the drillship.

VI. CONCLUSION

From this study, the drillship response in different heading angles was numerically studied with different baffle plate configurations The natural period of drillship considered for the study is 10 sec. Baffle plates are giving a damping effect to the moonpool response to reduce the overall response of the drillship. It also reduces the value of the peak that occurred at the natural period of the drillship. Baffle plates reduce the value of the peak of piston mode of around 10 sec and sloshing mode of around 3 sec. Reduction in oscillations, improves the moonpool efficiency and continuous usage of moonpool for operation, even in rough weather conditions.

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