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Experimental Research on Water Column Oscillations in Moonpool of a Drillship in Downtime Period

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Abstract— A drillship is a kind of merchant vessel with a self-propulsion unit and drilling equipment used for oil exploration. The major difference with the merchant vessel is the moonpool. A moonpool is a vertical opening from the continuous deck to the keel plate of the vessel for drilling operations and other applications like the launching of measuring instruments. This moonpool opening allowing the entry of water into the vessel. The water motion within the moonpool is mostly related to the encountering wave frequency, the geometry of the moonpool and the draft condition of the vessel. The major amplitude of the water particle motion within the moonpool, either may be in the sloshing mode or in piston mode. This water motion leads to the entry of green water on the deck during the rough weather condition. This is known as the downtime period of a drillship, during this time the operation of the drillship is in off-mode. This paper presents the study about the downtime period of drillship experimentally with rectangular moonpool.

Keywords: Drillship, Moonpool, Piston mode, Sloshing mode

I. INTRODUCTION

Drillships are equipped with drilling equipment and moonpool. Moonpool mostly located at the center of the vessel. The sidewalls of the moonpool are strengthened against the hydrodynamic loads. The opening at the bottom of the moonpool creates a major impact on vessel motion both in operating condition and the forward motion of the drillship. In operation mode, a large quantity of water may enter into the moonpool and induce additional motion to the vessel. The sloshing mode of water oscillation increases the vessel surge motion and the piston mode of oscillation increase the heave motion of the vessel. If the geometry of the moonpool is rectangle, the effect of sloshing creates standing wave on the inner sidewalls of the moonpool. In forward motion, the water motion with in the moonpool gives additional resistance to the vessel motion. Another important problem with this water motion is resonance with the vessel natural period.

This large quantity of water flux motion within the moonpool creates an uncomfortable situation to crew members working on the deck and downtime of the vessel. Therefore this water motion or water oscillation inside the moonpool is one of the main issues in drillship.

II. LITERATURE REVIEW

Research conducted [1] with different shapes of moonpool geometry to know the behavior of water motion. Experiments carried out [2] to investigate the hydrodynamic properties of moonpool and a numerical model generated to find the water motion relative to the mean level. According to[3] study indicates that the performance of the moonpool in drillship operations it suggested that geometry plays a major role in the efficiency of moonpool. An experimental study [4] conducted on circular moonpool with baffle plates to find the damping and added mass. In another study [5] experiments to find the water particle displacement within the moonpool region. The vertical mode of water oscillation[6] in moonpools studied. An infinite-dimensional model[7] study based on the Bateman-Luke variation principle, the water flex movement within the moonpool region in sloshing mode. Resonance frequency[8] in piston and sloshing water flux motion derived with the reference of the potential flow method. According to[9] numerical study conducted on moonpool to find the low-frequency resonant mode. An experiment [10] conducted on moonpool with attached devices to reduce the water column oscillation. The study mainly focused on the water particle oscillations within the moonpool in two cases; one is at the resonant condition of oscillation when the vessel at stationary condition encountered by waves and the second one is oscillations are observed in forward speed condition. The 2D water motion within the moonpool was formulated by experimental and numerical methods. An experiment[12] conducted in 2D wave flume on moonpool with different l/b ratio of moonpool for the reduction in water motion within the moonpool region. The effect of water particle movement within moonpool [13] of a drillship studied in the resonance region. Mentioned by [14] the sloshing effect of fluid-particle motion within a rectangular tank with an additional attachment like baffles was studied.

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The study performed in different aspects like the number of baffles, positions, and direction of baffles. The main outcome from this numerical study was the resonant frequency for all the orientations were investigated also the optimum position for the baffles to reduce the sloshing motions are recommended. The baffle plate position increases from the bottom will decrease the sloshing motion inside the two-dimensional rectangular tanks. According to [15] carried out a study in a modern drillship with moonpool found the resonance frequency in piston and sloshing mode. An experimental study [16] suggested that additional units like cofferdam reduce the sloshing mode of oscillations inside the moonpool.

The number of studies carried out in the same area with respect optimization of moonpool geometry, additional attachment inside the moonpool, etc. In this study attention paid on the downtime period of drillship due to water particle motion within the moonpool region. For that, a drillship hull with rectangular moonpool had taken and the experimental study carried out in wave flume. The body plan of the bare hull is given in Figure 1.

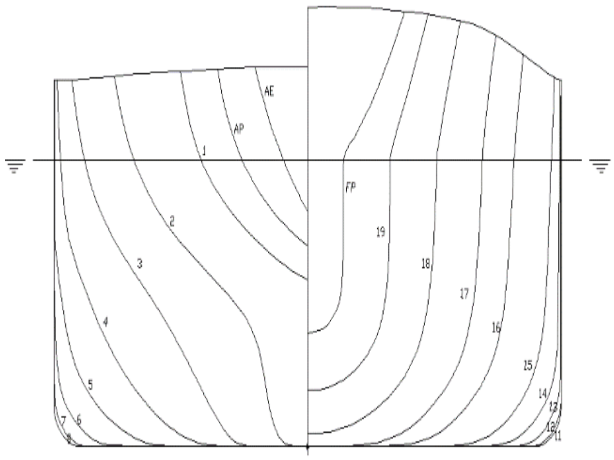

Fig 1: Body plan of the drillship

III. THEORETICAL BACKGROUND

Consider a three-dimensional floating body in progressive waves. The body is in free-floating condition. Here the depth of water is finite(H). The body is subjected to hydrodynamic pressure, different kinds of environmental loads. The induced pressure and the velocity in the fluid are sinusoidal in time with respect to circular frequency ω. In this medium, the diffraction velocity potential is proportional to the incident wave amplitude. The radiation velocity potential is proportional to the amplitude of ship motion. The overall velocity potential includes the diffraction potential, incident wave potential, and radiation potential. The free surface elevation in this medium is directly proportional to the total velocity potential describedbed in equation (1).In equation (1) 'P' define any point on the free surface.

$$\eta(P) = -\frac{i\omega}{g}\left[\frac{ga}{i\omega}(\varphi_0+\varphi_7)+\sum_{j=1}^{6} i\omega X_j\varphi_j\right] \quad (1)$$

Where

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

The equation (1) gives the free surface elevation at any point inside the moonpool.

IV. EXPERIMENTAL INVESTIGATION

A. Experimental Setup

The experimental study conducted in wave flume of 4 m wide, 90 m long and 2.5 m water depth. One end of the flume have the wavemaker and the other end beach is there to absorb the wave energy. The schematic diagram of the model with rectangular geometry moonpool is given in Figure2. The flume parameters with wavemaker details are given in Table1.

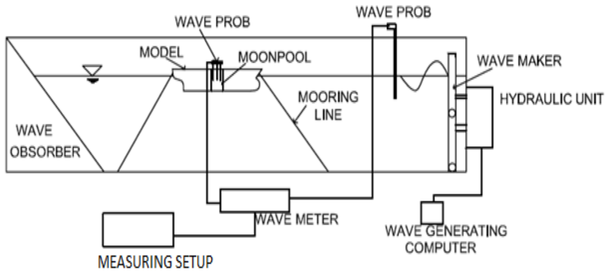

Fig 2: Schematic representation of model testing setup in a wave flume

Table 1

Flume particulars		Wave maker particulars	
Length	90m	Type/Stroke	Twin flap
Breadth	4m		
Depth	2.5m	Frequency range	0.3Hz to 1.7 Hz

B. Prototype and Model Details

The model used for the experimental study and its prototype details is given in Table 2. The prototype is converted drillship from tanker ship. The model made up of fiber-reinforced plastics (FRP) used for the study with free surface measuring setup is given in Figure 3.

Table 2

Specification	Prototype	Units	Model(1:100)	Unit
Length(LOA)	292	m	2.92	m
Length(LBP)	280	m	2.8	m
Breadth	50	m	0.5	m
Depth	25.48	m	0.255	m
Draft	16.5	m	0.165	m
Displacement	194156	tonne	202	kg

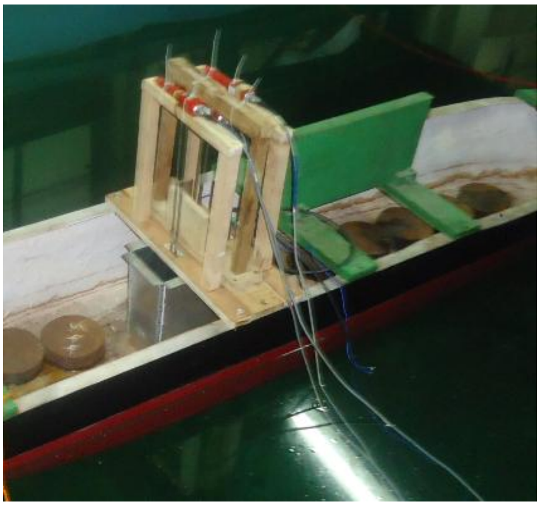

Fig 3 Drillship model with moonpool

C. Moonpool Particulars

In this study rectangular moonpool of length 24 m and breadth 12 m used and which is located at the center of the vessel. The moonpool wall height up to the continuous deck level. Aluminum material of thickness 3mm is used for the construction of moonpool.

D. Experiment

In this study FRP model of 1:100 ratio with rectangular moonpool is used to find the free surface elevation. The model is kept before the wavemaker at some distance in a free-floating condition. This free-floating condition is achieved by 4 mooring cables, two at forward and two at the aft end. There are three-wave probes were used to measure the free surface elevation inside the moonpool. The wave probes are fixed with wooden setup and the entire arrangement is positioned along the length of the moonpool. The output from the wave probes was connected with the wavemeter. The output from the wavemeter is given to the oscilloscope. The final output from the oscilloscope is converted as an elevation by the use multiplication factor. This factor found from the calibration of wave probes. The test draft condition and the wave conditions are given in Table 3. The solid ballast weights are used to maintain the draft.

Table 3

Draft(cm)	Wave period(sec)	Wave height(cm)
16.5, 13.75, 11, 8.25	0.9	4,5,6,7
16.5, 13.75, 11, 8.25	1.0	4,5,6,7
16.5, 13.75, 11, 8.25	1.1	4,5,6,7
16.5, 13.75, 11, 8.25	1.2	4,5,6,7
16.5, 13.75, 11, 8.25	1.3	4,5,6,7
16.5, 13.75, 11, 8.25	1.4	4,5,6,7
16.5, 13.75, 11, 8.25	1.5	4,5,6,7
16.5, 13.75, 11, 8.25	1.6	4,5,6,7

V. RESULTS AND DISCUSSION

In rectangular moonpool, the effect of the sloshing mode of particle motion is more than that of the piston mode. The water motions inside the moonpool have maximum amplitude at a lower wave period and it is minimum at a higher wave period. If the incident wave height increases the water motion inside the moonpool also increased and the green water may come out from the moonpool to the deck. Usually, at this sea state, the drillship may be stopped from its operation. This period is called a downtime period of the drillship. In the downtime period, green water entry to the deck is more and it may cause an uncomfortable situation to the crew members to work on the deck. This drastic variation of elevation raises inside the moonpool also causees resonance. This resonance oscillations caused by the vortices. The formation of vortices depends on the change in geometry at the bottom of the ship. In drillship, it mainly depends on the moonpool opening area at the bottom.

The water column oscillation inside the rectangular moonpool recorded by the wave prob at the different locations for the wave period of 1 second and wave height 4cm and 5 cm is given Figure 4 and Figure 5. It shows that the elevation at the upstream end of rectangular moonpool is higher than other places of moonpool.

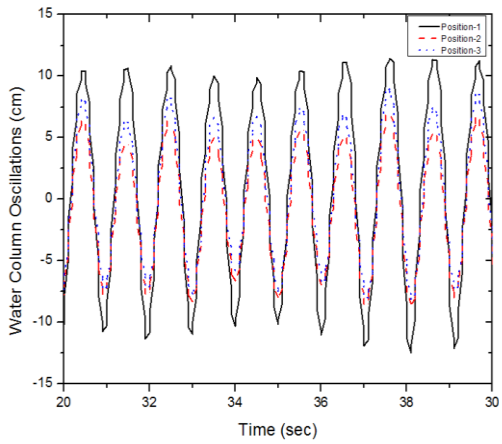

Fig 4 :Water column oscillations for 4 cm wave height

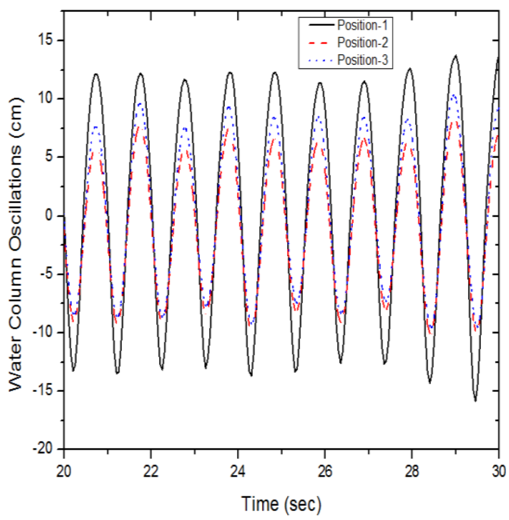

Fig 5: Water column oscillations for 5 cm wave height

From the water column oscillation result, we can conclude that once the wave height increases, outside of the moonpool that directly affects the moonpool water motion even for the same wave period.

If the wave height keeps on increases that create the water entry to the drillship through moonpool opening, that could be seen for wave height of 7 cm of wave period one second, given in Figure 6. At this condition, a considerable quantity of water entry was there inside the ship model through the upstream sidewall of the moonpool. This is the downtime period of the model in this wave condition. This result shows that there is a perfect sloshing mode of oscillation inside the rectangular moonpool and standing waves in both the upstream and downstream end of the moonpool. Initially, inside the moonpool, the water entry likes a piston mode of oscillation, after that, it moves towards the sidewalls of the moonpool and forms the standing wave. The occurrence of this particular wave conditions in the real case should be carefully handled to save the drillship crew members from accidents.

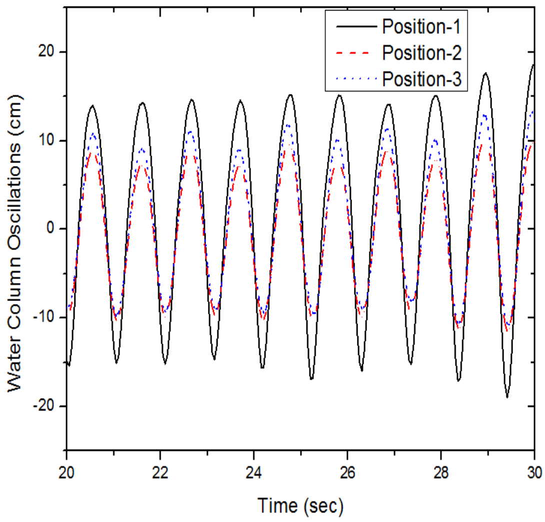

Fig 6: Water column oscillations for 7 cm wave height

VI. CONCLUSION

In this study, the water particle movement inside the rectangular moonpool in head sea conditions with the impact of regular waves was studied. The impact of the incident wave within the moonpool was addressed. The main conclusion from this study is the downtime period of the drillship. This water particle motion within the rectangular moonpool causes the water entry into the drillship when it crosses 7 cm wave height at the maximum loaded draft condition of the drillship. This water entry gives the indication to close the moonpool doors to save the drillship and crew members from the severe weather conditions.

Increment in wave period also shows the decrement in free surface raise within the moonpool for the constant wave height, also the draft of the vessel is one of the major phenomena to increase the wave elevation. This draft change is a usual happening in vessels, it depends on the loading condition.

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