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Effect of Pretension on Moored Ship Response

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Abstract

Moonpools are vertical wells in a floating body used onboard many types of vessels like Exploration and drilling vessels, Production barges, Cable-laying vessels, Rock dumping vessels, Research and offshore support vessels. Moonpool gives passage to underwater activities for different types of ships as per their mission requirements. It is observed that inside a moonpool considerable relative motions may occur, depending on shape, depth of the moonpool and on the frequency range of the waves to which the ship is exposed. The vessel responses are entirely different in zero and non-zero Froude number. Former situation is paid attention in this study as the mission requirement of the platform is to be in the particular location for long period of operation. It is well known that there are two modes of responses depending on the shape of the moonpool viz., piston mode for square shape and sloshing mode for rectangular shapes with different aspect ratios of opening like 1:1.5 and 1:2 ratios. Circular shaped moonpool is also tested for measuring the responses. The vessel moored using heavy lines are modelled and tested in the wave basin. The pretensions of the lines are varied by altering the touchdown points and the dynamic tensions on the lines are measured. The different modes of oscillations of water column are measured using wave gauge and the vessel response at a particular situation is determined. RAOs calculated for various situations provide better insight to the designer.

Keywords: Moonpool, Vessel response, Piston mode, Sloshing mode, Touchdown points, Pretension, Dynamic tension.

1. Introduction

An opening in the water plane area challenges the righting arm stability and reduces the reserve buoyancy of any floating platform. A permanent opening in the water plane area is required for special types of platforms and moonpools are provided for such ones. Such vessels can be self propelled or pushed after closing the bottom side opening of moonpools. Resistance is minimized under such conditions of voyage of platforms from point A to B, the point of destination. Power and hence fuel is saved by closing the opening of moonpool in the bottom side of the ship.

In the operating point the vessel is moored to sea bottom and the catenary of the mooring causes variable stiffness to the floating body. Floating body dynamics has been studied by Rameswar Bhattacharyya (1978) and is widely referred by Naval Architects and Ocean Engineers in search of the fundamental parameters of ship shaped floating bodies. Newman (1977) discussed marine applications for a variety of topics including viscous and viscous flow around a ship shaped body.

After fixing the bottom of all mooring lines, the vessel fitted with instruments suitably positioned to face the incoming waves. The catenary shape and sag of the mooring lines is maintained as per scaled down size. Inclinometer, accelerometer, wave probes and strain gauge on the upper part of line are connected to the circuitry through amplifiers and oscilloscope. Data acquisition system records all the digitized values of signals due to motion of platform by waves.

As drilling operations are conducted in deeper and deeper waters, it becomes very impractical economi-

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cally to construct such platforms. In such deeper waters it is becoming common practice to drill from floating vessels. One of the problems in drilling from floating vessels is to maintain the ship within the permissible excursions. One type drilling ship has a moonpool conveniently provided in the midsection of the ship. It is through this moonpool usual drilling operations are conducted. In this case it is desired that the moonpool stay in fixed position with respect to the parent ship. The main reason is that the ship can get aligned with the incoming or head-on waves. The ship is secured with the mooring cables connected to the sea bottom.

2. Moonpool and Mooring lines

Aalbers (1984) carried out model experiments at the Netherlands ship model basin in which the hydrodynamics with respect to a moonpool were investigated. A mathematical model describing the relative water motions inside a moonpool was developed. Day (1990) proposed a method for assessing the performance of the moonpool. Theoretical and experimental studies indicate possible geometries for the moonpool which may be used to improve the performance of the floating ship. Finally, a systematic procedure for designing moonpool is developed and illustrated with a worked example based on an actual design problem. English (1976) described a method of overcoming the oscillations without the use closing doors. Fukuda (1977) conducted experiments to show the behaviour of the water in the well (moonpool) and its effects on the motion of the ship, under forward motion. Fukuda and Yoshii (2009) discussed water motion in a two-dimensional vertical cavity with a free surface on the top and current on the bottom. Gaillarde and Cotteleer (2001) presented solutions to reduce the oscillations in the moonpool caused by the forward speed of the vessel. Numerical methods are also presented to solve the problem in transit and normal conditions in waves. Molin (2001) studied rectangular moonpools of large horizontal cross sections. The natural modes of oscillation of the inner free surfaces are determined, under the assumption of infinite water depth and infinite length and beam of the barges that contain the moonpools. The problem is treated in two and three dimensions, using linearized potential flow theory. Results are given for the natural frequencies and the associated shapes of the free surface, for wide ranges of the geometric parameters. Simple quasi-static analytical approximations are derived that yield the natural frequencies. Molin (1999) concentrated on estimating the natural frequency of the piston mode of a moonpool. The author paid attention to obtain the natural frequencies and Eigen vectors of the sloshing modes. van't Veer and Tholen (2008) conducted model tests on rectangular moonpools. The resonant oscillation mode can be piston or sloshing. The sloshing mode dominates in longer moonpool, while piston mode oscillations are dominant in shorter moonpool. Based on two model tests series carried out at Delft University of Technology, a resistance prediction model was constructed for piston type oscillations.

Inoue and Surendran (1994) paid attention to interaction of mooring line with the ocean bottom and discussed reduction in dynamic tension. The line is divided into finite number of lumped masses and linear springs without mass. Cross flow drag across line causes strain along the length due to stress caused by differential tensions at consecutive points. The surrounding fluid always tries to immobilise the moving chain. This process cause cross flow drag and creates further strain on the line. The line stretch and the resulting tension is dynamic in nature. This tension is composed of steady value, inertial effects and drag component. Such dynamic tension can be normalised by dividing by static tension value. The damping associated with the interaction of vibrating chain with the sea bed which was considered to be elastic, was incorporated in the computations. Surendran (1989) developed a computer program to determine the cable configuration, tension and various other parameters for safe tow. A number of curves have been presented based on different case studies to enable the designer to have better insight into the interesting behaviour of tow cables. Surendran and Goutam (2009) concentrated on the dynamic tension of upper point of cable fitted with a sub-surface buoy at a suitable location. Surendran and Pramod (2006) studied the non-linear behaviour of a moored floating platform in stochastic seaway generated using the Pierson-Moskowitz spectrum. Second-order wave or slow drift forces acting on the structure are considered as they contribute to a major percentage for the excursion of a large platform. Components of damping from wave friction and skin friction have also been considered in their study to arrive at the solutions.

Table1. Moonpool dimensions

Moonpool Shape	Ratio	Size (cm)
Rectangular	1:92	12.5x24
	1:1.5	12x18
Square	1:1	12x12
Circular	--	dia 12

Table 2: Model particulars

Frame details for scale 1:100	
Length overall	2.37 m
Length between perpendiculars	2.19 m
Breadth	0.36 m
Depth	1.89 m

From the above literature survey, it is evident that the determination of oscillations in moonpool has been attempted by researchers through experiments and numerical simulations. In this paper, experimental study has been done to pin point the critical situations of the vessel motion response due to moonpool, mooring line oscillations with different pretension and possible interactions.

It is understood that there are piston and sloshing modes of oscillations for the water trapped in the moonpool. The incoming waves interact with the moored floating body, and the water mass in the moonpool is excited and creating both circular and linear motions. Therefore the critical situations like resonant condition of heave, roll and pitch are to be investigated as they are important for a moored floating body. The mooring line in its catenary shaped stage exerts stiffness which is modified due to the excursions of the body by the hit of incoming waves. The tensions on the line can be modified influencing the total vessel response. The entrapped water in the moonpool shows different excitations depending on the shape of the moonpool. A few shapes with varied initial tensions are to be tested in the wave flume and whole details are provided in the following sections. Results are presented in the non-dimensional form so that anyone working in this topic can use the results presented for their work.

3. Experimental set up

In this study shapes and sizes of the moonpool considered are shown in Table.1

Main dimensions of a bulk carrier ship considered here is compatible with drill ships referred by Riaan Van‘t Veer and Haye Jan Tholen (2008). The prepared model is shown in Figure 1. The biggest size moonpool (12.5cm x 24cm) is fixed to the model with FRP sealing and other moonpool shapes are inserted in this and water sloshing is restricted with the help of wooden strips. Various moonpool shapes are shown in Figure 2. Table 2 shows the principal perticulars of model.

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Figure 1. Ship model

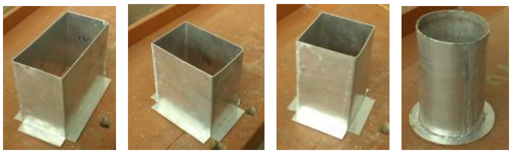

Figure 2. Different moonpool shapes

Figure 3. Ship model with moonpool

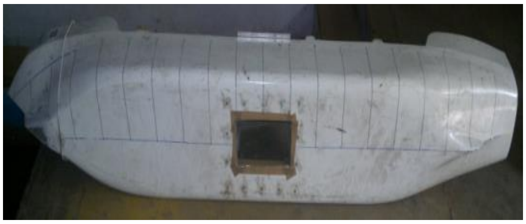

Figure 4. Opening at the bottom

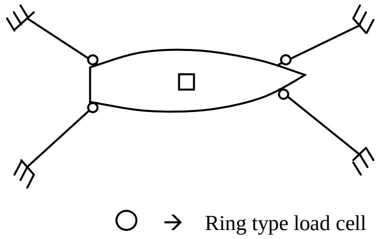

Figure 5a Plan view of model in the experimental setup

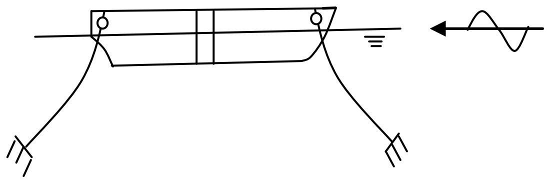
Figure 5b. Schematic sketch of the experimental set up

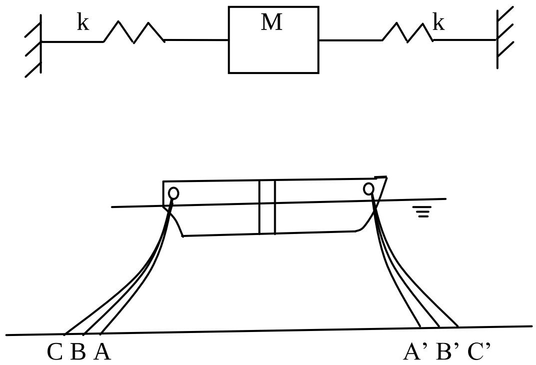

Figure 5c. Varying pretension in the mooring line by moving touchdown points (analogous to mass with two springs)

Figure 5c is analogous to a mass with two springs by varying spring stiffness.

Scaled down model of ship in 1:100 ratio is fabricated in Fiber Reinforced Plastic (FRP) and moonpool is fabricated using 3mm aluminium sheet. Ship model with moonpool is shown in Figure 3. Figure 4 shows the opening at the bottom.

Figure 5a is the plan view of the model in the wave flume. Figure 5b is the instrumentation and catenary of the floating system with end connection of mooring

The measured pretensions when the bottom of the catenary is at A-A’, B-B’ and C-C’ are shown in Table3.

Determination and analysis of vessel response with different moonpool shapes are done. The response reading are recorded in oscilloscope and analyzed as follows

Table 3. Distance between touchdown points

Sr.No	Distance between touch-down points (cm)	Pretension (kg)
A-A’	475	0.15
B-B’	490	0.3
C-C’	505	0.45

A, B, C and A’, B’, C’ are touchdown points

4. Results and Discussions

These model experiments were conducted in a 30m x 2m x 1m wave-current flume. The boundary effects are neglected, since distance between the model and the wall is more than the double the width of the model. The far end of the flume is provided with a rubble stone beach to absorb incident waves and to reduce reflection. Consequent waves are generated after reaching the calm water condition in the flume.

Experiments are done with different shapes of the moonpool and with different pretension in the mooring lines; the results are shown for the same. A detailed experimental set up is shown in Figure 6. Model connected with biaxial inclinometer, accelerometer and wave probe are shown in Figure 7.

4.1 Moonpool Wave with Respect to Incident Wave

Incident and water profile in the moonpool are measured for all the combinations with different wave probes but are plotted for a few sets only.

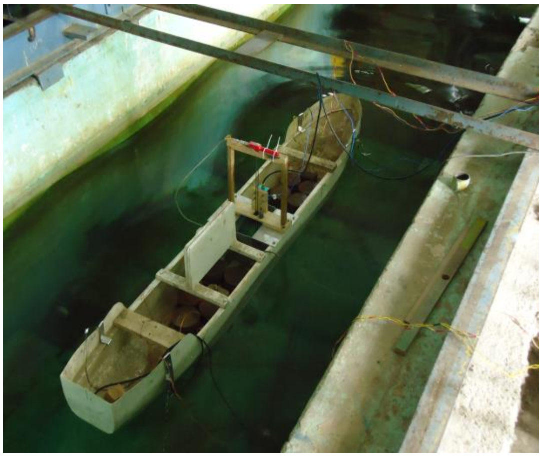

Figure 6. Experimental setup in wave flume

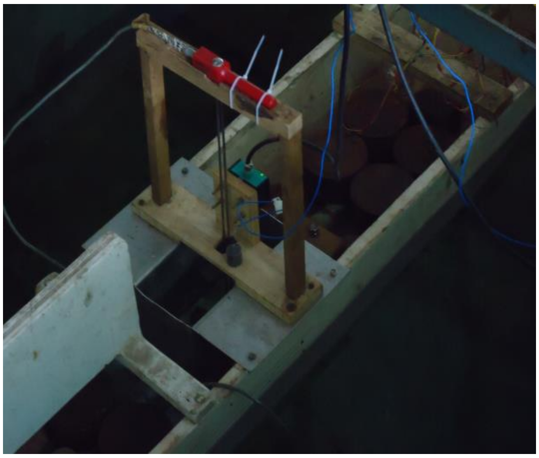

Figure 7. Ship model with instruments for measurements

Figure 8a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 8c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 2.0 second wave period.

Figure 9a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 9b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 1.6 second wave period.

Figure 9c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 2.0 second wave period.

Figure 10a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 10b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 1.6 second wave period.

Figure 10c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12.5x24cm (1:1.92) rectangular moonpool, 3cm wave height and 2.0 second wave period.

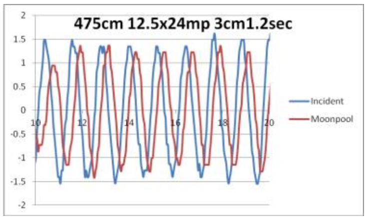

Figure 8a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

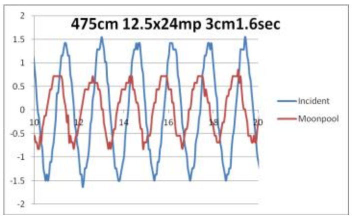

Figure 8b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

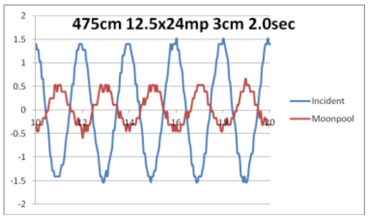

Figure 8c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period

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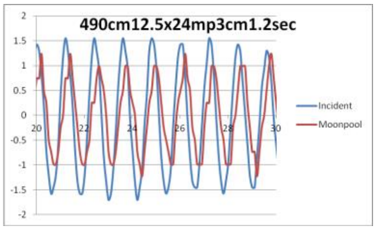

Figure 9a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

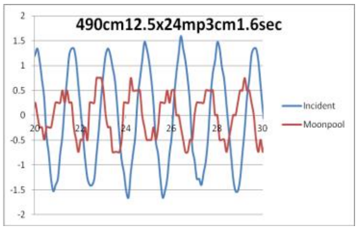

Figure 9b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

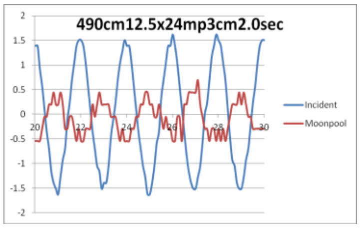

Figure 9c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

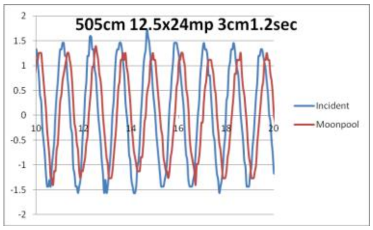

Figure 10a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period

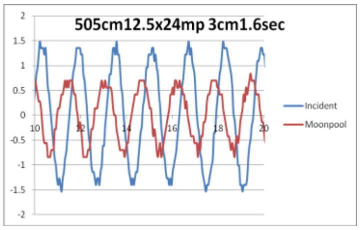

Figure 10b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

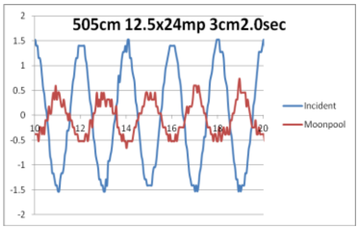

Figure10c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

Figure 11a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 11b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.6 second wave period.

Figure 11c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 2.0 second wave period.

Figure 12a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 12b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.6 second wave period.

Figure 12c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 2.0 second wave period.

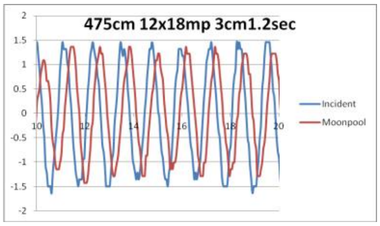

Figure 11a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period

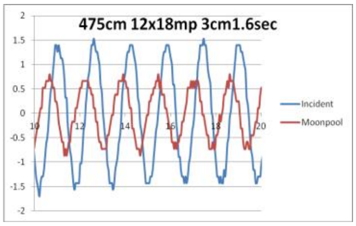

Figure 11b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period

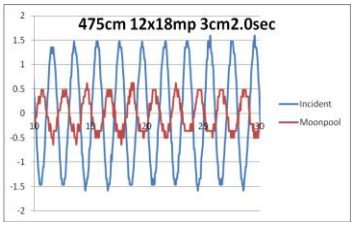

Figure 11c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

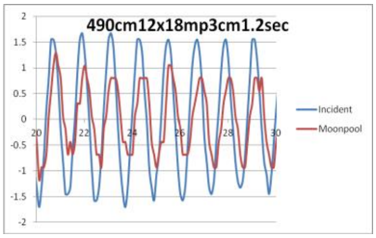

Figure 12a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

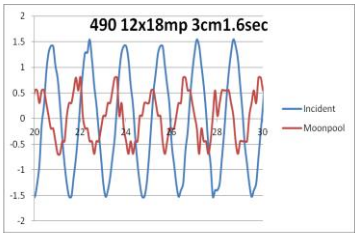

Figure 12b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

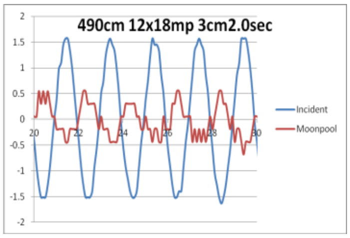

Figure 12c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

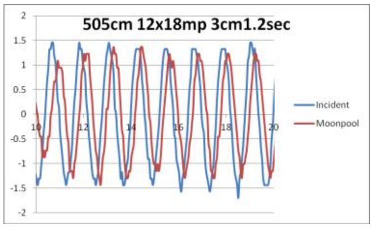

Figure 13a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period

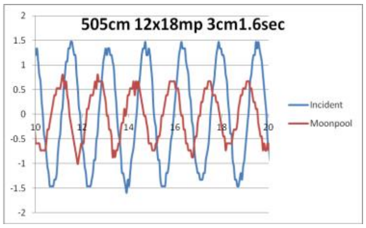

Figure 13b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

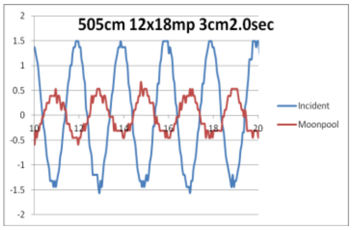

Figure 13c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

Figure 13a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.2 second wave period.

Figure 13b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 1.6 second wave period.

Figure 13c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x18cm (1:1.5) rectangular moonpool, 3cm wave height and 2.0 second wave period.

Figure 14a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.2 second wave period.

Figure 14b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.6 second wave period.

Figure 14c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, 12x12cm (1:1) square moonpool, 3cm wave height and 2.0 second wave period.

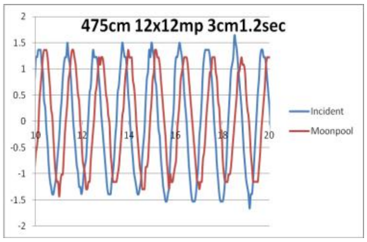

Figure 14a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

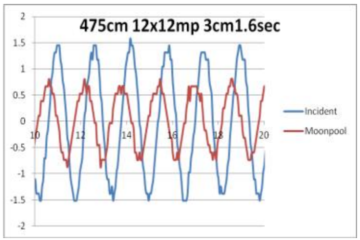

Figure 14b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

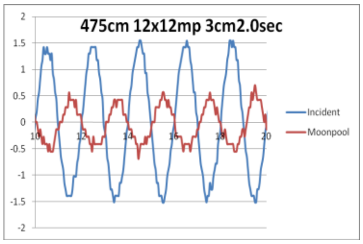

Figure 14c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

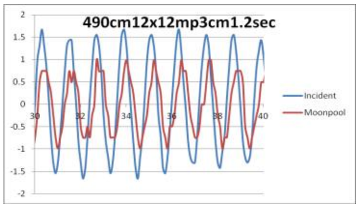

Figure 15a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

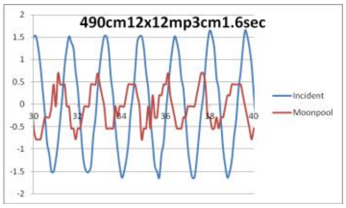

Figure 15b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

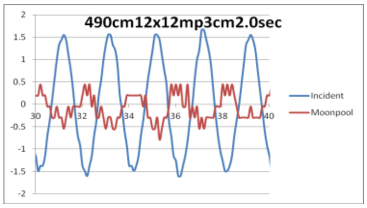

Figure 15c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

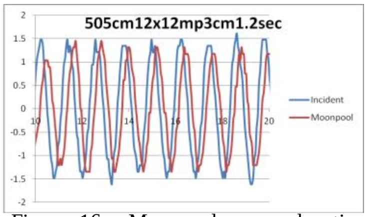

Figure 16a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

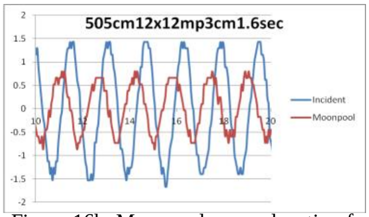

Figure 16b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

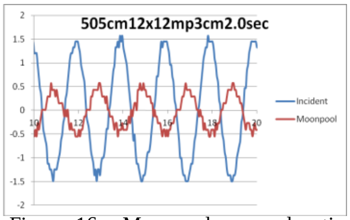

Figure 16c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

Figure 15a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.2 second wave period.

Figure 15b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.6 second wave period.

Figure 15c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, 12x12cm (1:1) square moonpool, 3cm wave height and 2.0 second wave period.

Figure 16a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.2 second wave period.

Figure 16b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x12cm (1:1) square moonpool, 3cm wave height and 1.6 second wave period.

Figure 16c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, 12x12cm (1:1) square moonpool, 3cm wave height and 2.0 second wave period.

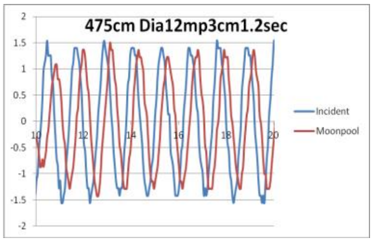

Figure 17a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

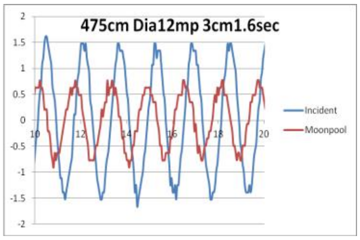

Figure 17b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

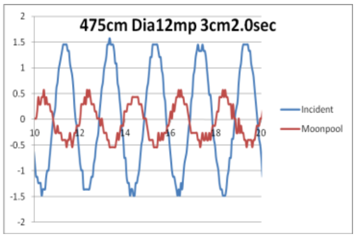

Figure 17c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

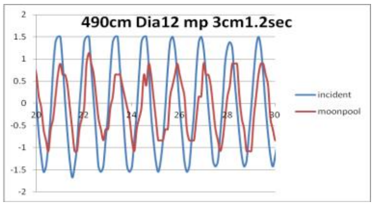

Figure 18a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

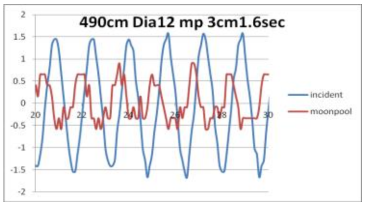

Figure 18b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

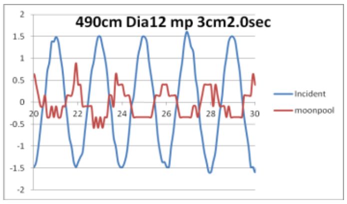

Figure 18c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

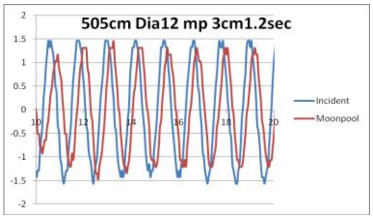

Figure 19a. Moonpool wave elevation for 3cm wave height and 1.2 second wave period.

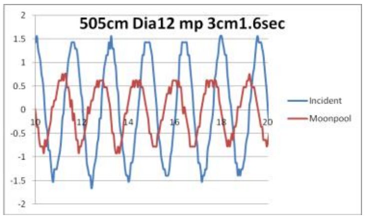

Figure 19b. Moonpool wave elevation for 3cm wave height and 1.6 second wave period.

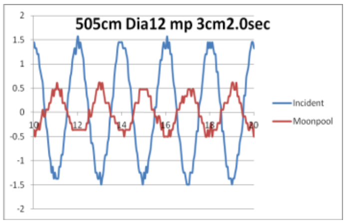

Figure 19c. Moonpool wave elevation for 3cm wave height and 2.0 second wave period.

Figure 17a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, Dia12cm circular moonpool, 3cm wave height and 1.2 second wave period.

Figure 17b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, Dia12cm circular moonpool, 3cm wave height and 1.6 second wave period.

Figure 17c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 475cm, Dia12cm circular moonpool, 3cm wave height and 2.0 second wave period

Figure 18a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, Dia12cm circular moonpool, 3cm wave height and 1.2 second wave period.

Figure 18b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, Dia12cm circular moonpool, 3cm wave height and 1.6 second wave period.

Figure 18c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 490cm, Dia12cm circular moonpool, 3cm wave height and 2.0 second wave period.

Figure 19a shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, Dia12cm circular moonpool, 3cm wave height and 1.2 second wave period.

Figure 19b shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, Dia12cm circular moonpool, 3cm wave height and 1.6 second wave period.

Figure 19c shows the variation of wave in the moonpool with reference to incident wave for distance between touchdown points equal to 505cm, Dia12cm circular moonpool, 3cm wave height and 2.0 second wave period.

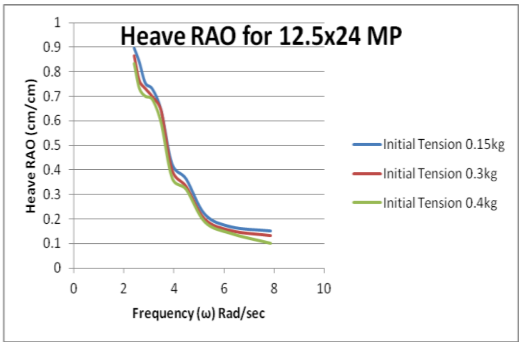

Figure 20a. Heave RAO for 12.5x24 Moonpool

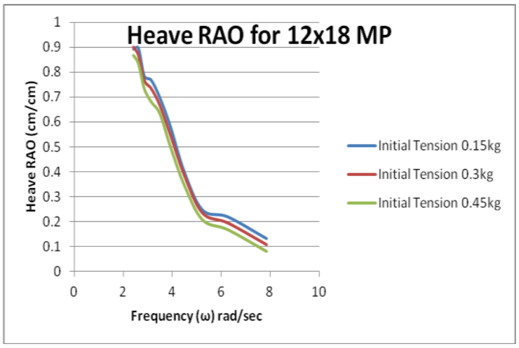

Figure 20b. Heave RAO for 12x18 Moonpool

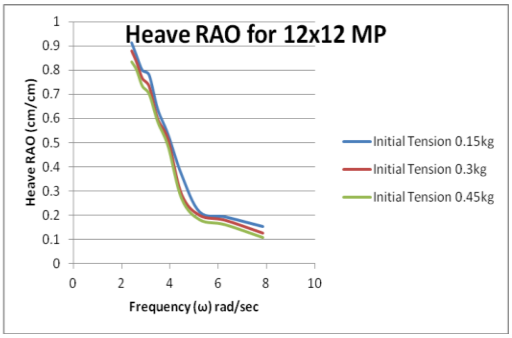

Figure 20c. Heave RAO for 12x12 Moonpool

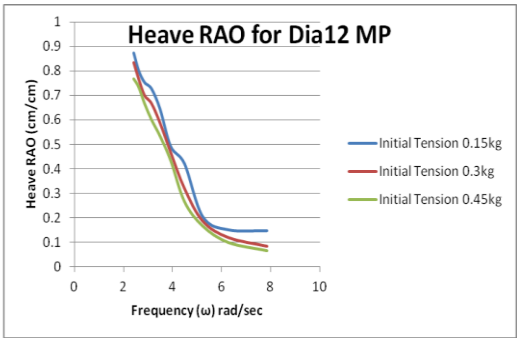

Figure 20d. Heave RAO for Dia12Moonpool

4.2 Heave RAO for Different Moonpool Shapes

Figure 20a shows the variation of heave RAO for 12.5x24cm (1:1.92) rectangular moonpool with different initial tension combinations.

Figure 20b shows the variation of heave RAO for 12x18cm (1:1.5) rectangular moonpool with different initial tension combinations.

Figure 20c shows the variation of heave RAO for 12x12cm (1:1) square moonpool with different initial tension combinations.

Figure 20d shows the variation of heave RAO for Dia12cm circular moonpool with different initial tension combinations.

4.3 Roll RAO for Different Moonpool Shapes

Figure 21a shows the variation of roll RAO for 12.5x24cm (1:1.92) rectangular moonpool with different initial tension combinations.

Figure 21b shows the variation of roll RAO for 12x18cm (1:1.5) rectangular moonpool with different initial tension combinations.

Figure 21c shows the variation of roll RAO for 12x12cm (1:1) square moonpool with different initial tension combinations.

Figure 21d shows the variation of roll RAO for Dia12cm circular moonpool with different initial tension combinations.

4.4 Pitch RAO for Different Moonpool Shapes

Figure 22a shows the variation of pitch RAO for 12.5x24cm (1:1.92) rectangular moonpool with different initial tension combinations.

Figure 22b shows the variation of pitch RAO for 12x18cm (1:1.5) rectangular moonpool with different initial tension combinations.

Figure 22c shows the variation of pitch RAO for 12x12cm (1:1) square moonpool with different initial tension combinations.

Figure 22d shows the variation of pitch RAO for Dia12cm circular moonpool with different initial tension combinations.

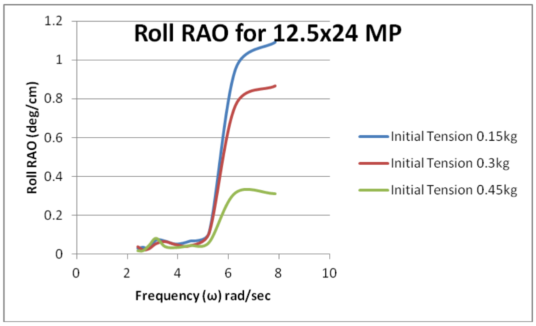

Figure 21a. Roll RAO for 12.5x24 Moonpool

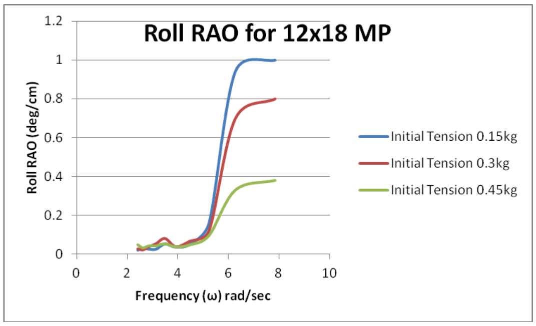

Figure 21b. Roll RAO for 12x18 Moonpool

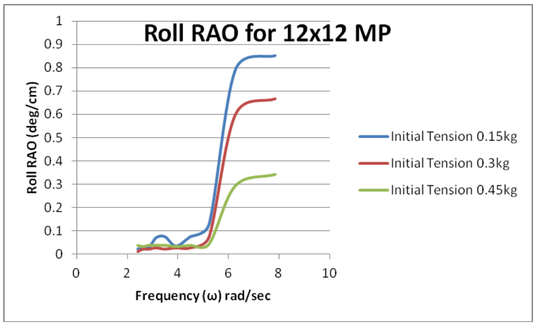

Figure 21c. Roll RAO for 12x12 Moonpool

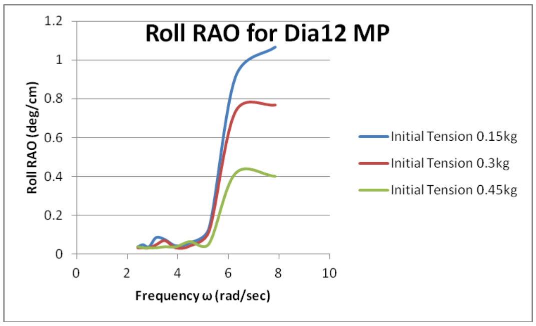

Figure 21d. Roll RAO for Dia12Moonpool

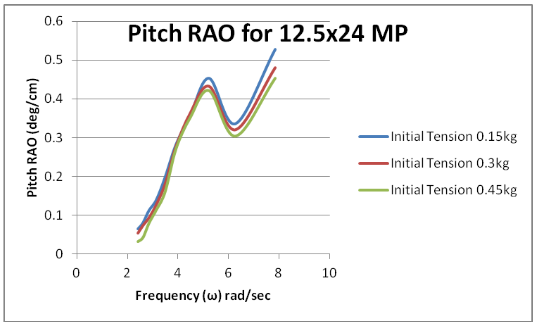

Figure 22a. Pitch RAO for 12.5x24 Moonpool

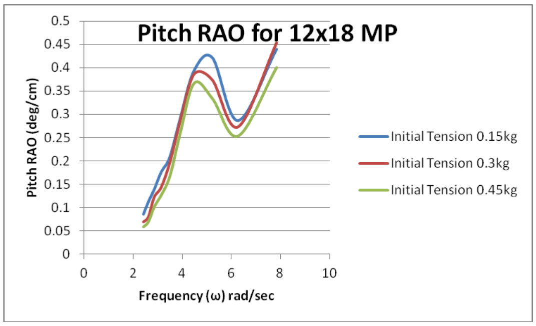

Figure 22b. Pitch RAO for 12x18 Moonpool

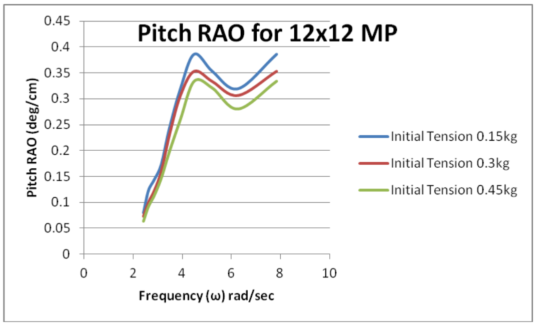

Figure 22c. Pitch RAO for 12x12 Moonpool

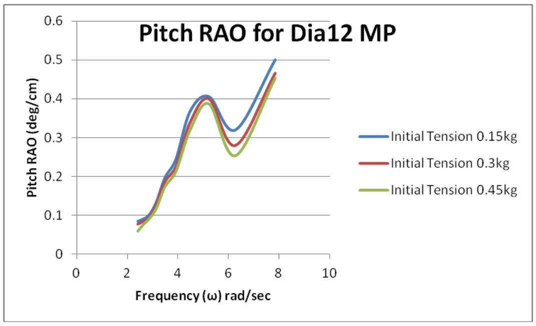

Figure 22d. Pitch RAO for Dia12 Moonpool

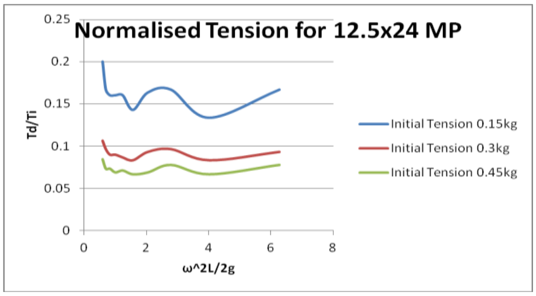

Figure 23a. Normalised tension for 24.5 x 12 Moonpool

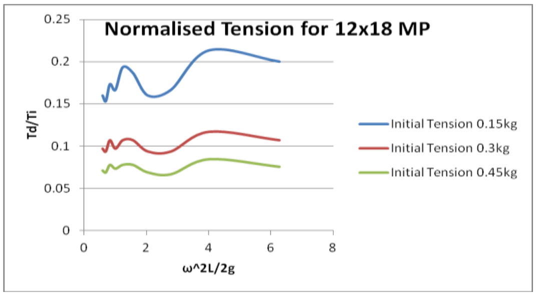

Figure 23b. Normalised tension for 12 x 18 Moonpool

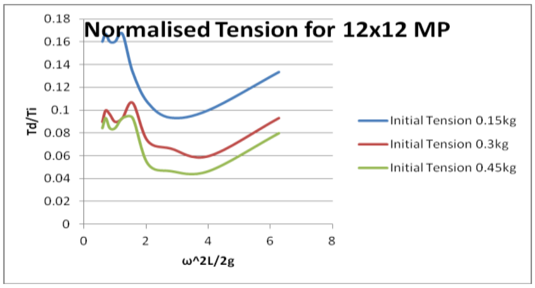

Figure 23c. Normalised tension for 12 x 12 Moonpool

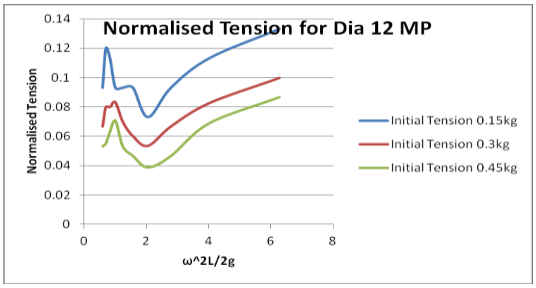

Figure 23d. Normalised tension for Dia 12 Moonpool

4.5 Frontal Normalised Mooring Line Tension

There are four mooring lines connected to the model as shown in schematic sketch 5a and 5b. Obviously when waves are created and hit to the model there will be more tension in the front mooring lines. One of the front mooring line tensions is shown in the figures 23a to 23d below. This dynamic tension is measured by ring type load cell. Normalised tension is obtained by dividing dynamic tension by initial tension in the mooring lines. The below graphs shows the variation of normalised tension verses non-dimensional wave frequency, this non-dimensional frequency is obtained by multiplying wave frequency with length of mooring line.

Figure 23a shows the normalised tension for 12.5x24cm (1:1.92) rectangular moonpool with different initial tension combinations.

Figure 23b shows the normalised tension for 12x18cm (1:1.5) rectangular moonpool with different initial tension combinations.

Figure 23c shows the normalised tension for 12x12cm (1:1) square moonpool with different initial tension combinations.

Figure 23d shows the normalised tension for Dia12cm circular moonpool with different initial tension combinations.

6. Conclusions

A water column oscillation in a moonpool is function of wave period rather than shape and size of the moonpool.

In case of 12.5x24cm (1:1.92) rectangular moonpool, as wave period increases from 1.2 to 1.6 seconds wave in moonpool decreases by 50 percent. Wave in moonpool decreases by 20 percent when wave period increases from 1.6 to 2.0 seconds. This is true for all three cases, namely distance between touchdown points are 475cm, 490cm and 505cm respectively.

In case of 12x18cm (1:1.5) rectangular moonpool, 12x12cm (1:1) square and Dia 12cm circular moonpool; percentage of reduction is almost same for distance between touchdown points equal to 475cm and 505cm. But in the case of 490cm the reduction in wave in moonpool is 25 percent when wave period increases from 1.2 to 1.6 second and 1.6 to 2.0seconds.

All motion responses like heave roll and pitch decreases with increase in mooring line tensions. This increase in mooring line tension increases the vertical stiffness of lines and consequently will restrict the model.

Heave response decreases for all moonpool shapes with increase in frequency of incident waves.

Roll response increases with increase in frequency. Roll RAO shoots to maximum at 6 rad/sec frequency. This may be due to the resonance in the water column.

But pitch response also increases with increase in frequency and has got peak and trough around 5 and 6 rad/sec respectively.

Normalized tension of frontal lines decreases as pretension increases.

12.5x24cm (1:1.92) rectangular moonpool normalized mooring line tension has a peak at non-dimensional frequency of 3.

12x18cm (1:1.5) rectangular moonpool normalized mooring line tension has two peaks at non-dimensional frequency of 1.5 and 4.

12x12cm (1:1) square moonpool normalized tension has trough at non-dimensional frequency of around 3.

Dia 12cm circular moonpool normalized tension has a peak at non-dimensional frequency of around 1 and trough at 2.

For rectangular moonpools normalized tension is almost constant for higher frequencies and it increases in case of square and circular moonpools. This may be because of piston mode oscillation in later cases.

Acknowledgements

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