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Resistance due to Open Moonpools on Offshore Ships

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Introduction

A increasing number of offshore vessels are equipped with a moonpool to facilitate a range of maritime operations. By a moonpool we refer to a vertical well in the hull that is exposed to the sea, as seen in the following figure. The figure shows a typical construction vessel with a main working moonpool placed in the center of the vessel, and two smaller ROV-moonpools in the front of the vessel.

Problems

The problems related to the moonpools are typically categorised within the following points.

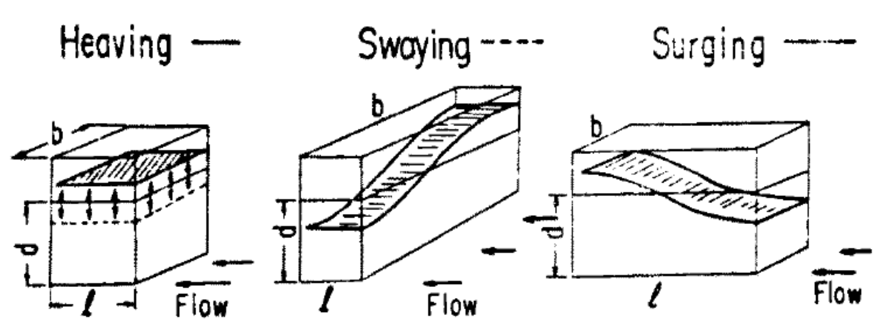
- Resistance on the hull
- Operability
- Green Water and Slamming

In this work we will investigate the resistance on the hull. The motivation of this is that it has been observed that it exists a number of vessel that is equipped with a moonpool, but it is seldom or never in use.
This raises the follow questions for a vessel owner:

- Is the resistance due to the existence of the moonpool easily quantifiable?
- Can this resistance be reduced without intervening with the operational intentions of the moonpool?

Moonpool Oscillatoins

The water in the moonpool can oscillate in two different patters. Either in a longitudinal or transverse sloshing, or a vertical piston-mode. The piston-mode has been connected to give a resistance on the hull, and it can be estimated to the change in momentum required to "suck" the water up in the moonpool.



The eigen frequency for the piston-mode is given as follows;

$$\omega_0 = \sqrt{\frac{c_{33}}{m + a_{33}}} = \sqrt{\frac{\rho g S}{\rho d S + \rho \kappa S \sqrt{S}}} = \sqrt{\frac{g}{d + \kappa \sqrt{S}}} \quad (1)$$

S refers to the cross-sectional area, the rest should be known. The term κ is related to the added mass and can be found in formulas based on experiments in the range of $0.39 - 0.45$. There are also some litterture that operates with a κ equal to zero.

Literature on piston-mode in moonpools show that this can be a phenomena in a velocity interval, expressed in the reduced velocity, from $0.35\omega_0 l$ to $0.7\omega_0 l$. This will for a normal construction vessel with 7,2 x 7,2 m moonpool, equal to the range of 5,0 - 10,0 knots. Note that this is based on calm-water experiments.

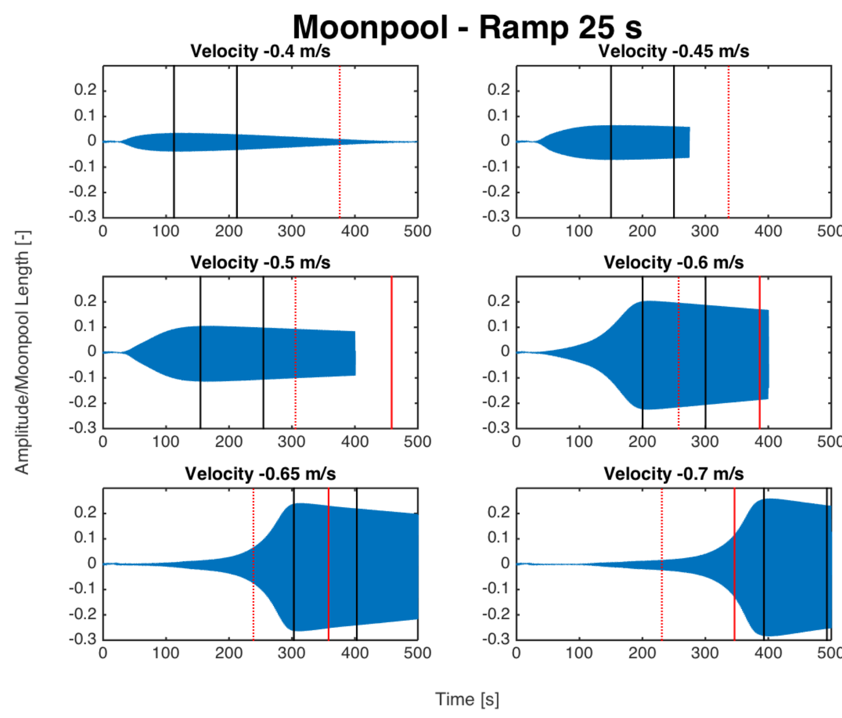
CFD Campaign

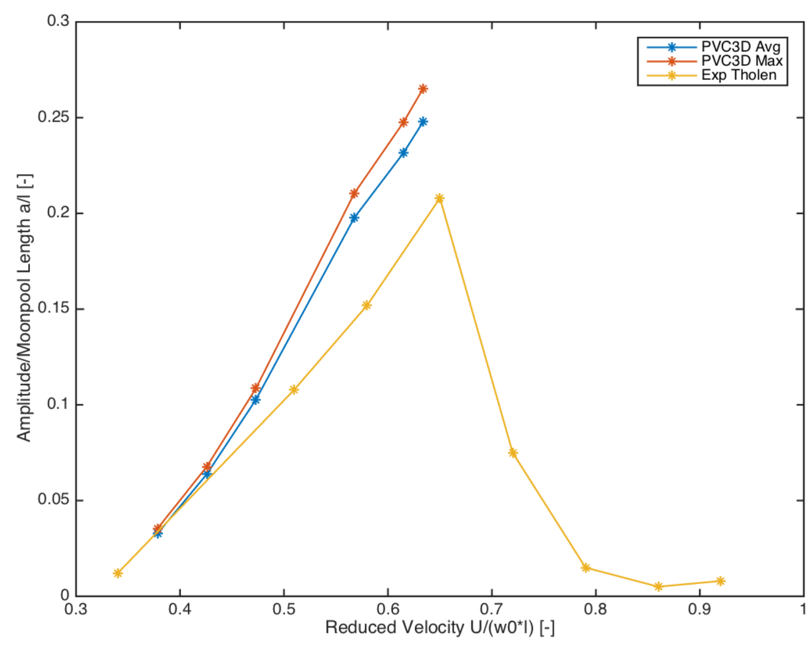
In order to understand the phenomena of the piston mode due to forward speed, a CFD campaign was conducted. As a reference a Dutch experimental campaign conducted on a drillship model was chosen, see vanŕ Verr & Tholen - Added Resistance of Moonpoools in Calm Water (proceeding OMAE2008). Our simulations were performed with a hybrid solver developed by MARINTEK called PVC3D. We would like the opportunity to thank all the guys at MARINTEK for all the excellent support in this work.

The experiments involved a 1:50 scale model of a drillship of 210 m with a square 12,8 meters moonpool, and were performed in a 142 meters towing tank at Delft University. The data we want to compare is the significant amplitude of the moonpool oscillation, and it is stated that this was the measured mean in a 60 seconds window, starting when the observed amplitude reach a maximum.

In our CFD model, we observed a different oscillation that in the experiments. Thus for equality in the results, the sample window and the length of the run (towing tank) was extended. The eigen period was 50 % longer in the CFD, thus a 50 % increase in the CFD time variables.

In the figure to the left we see how the vertical oscillation amplitude evolves over time. The sample window is marked with black stripes, the first red dashed-line is when the end of the real towing tank was reached, while the solid red line is the extended CFD towing tank.





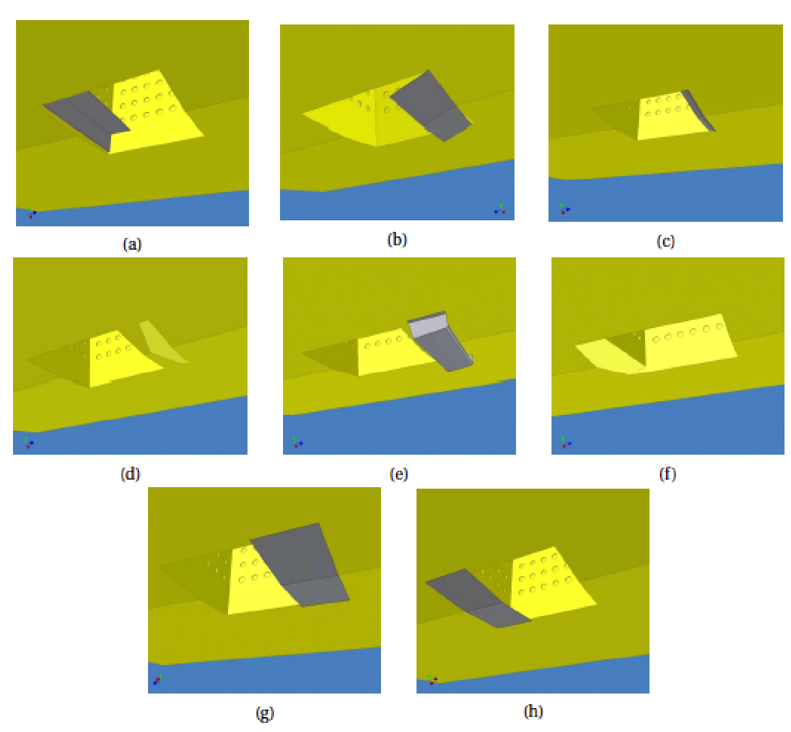
The figure to the right shows how these findings agrees to the physical experiments. The CFD model was only in 2D, and thus a lot more idealised with regards the vortex creation in a 3D real life experiments. This can explain the higher results. The onset velocity of the phenomena is captured, but the offset velocity might be a question of definition.

Resistance Reduction

There exists several attempts and ideas for how the resistance can be reduced be either altering the flow over the moonpool or adding damping to the system.

In this study there was not found any proposal that satisfy all the demands for such a solutions, as given from a vessel owner. The main purpose of the moonpool is operability, and many of the hatch-designs, found raised questions related to the reliability to a hydraulic closing mechanism submerged in water. For the alterations of the hull, as shows in this figure, the problems raises from the necessity to tune the angles of a foil-like system, to complications with regards to dry-docking.

Note that the moonpool normally comes with a cover that can be hoisted up by the vessel crane, and manually welded shut. Due to the welding operation this requires normally a full day to execute, and the results are that these covers are left at the home base and never used.



Conclusion

In this work we have found that the resistance on a vessel due to a moonpool can be divided into two parts. First due to the existence of the moonpool as a alteration of the hull, and secondly due the energy involved in the water column oscillations.

On a light interventional vessel it has been found in a earlier master-thesis that the moonpool (without oscillations) increases the resistance of 6%. Introduce some efficiency coefficient, and we get close to the 10 % increased fuel consumption that has been used in the industry as a rule of thumb.

Secondly the vertical oscillation might introduce a significant resistance for the vessel. A oscillation with a amplitude of 1 meter, will in accordance with linear momentum introduce a increased resistance of 150 kW. But since the phenomena is just observed in a range of velocities (in calm waters) that is below the normal operational velocities, these contributions might be neglect-able from a operational point of view.

However from a hydrodynamic and economical point of view, this is a area that might deserve more attention.