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Analysing the Effect of Heave Motion on the Dynamics of a Lifebuoy

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***Abstract*: Lifebuoy systems are efficient means of life saving equipment in the marine industry. Most marine-companies uses lifebuoy with mooring-line connections subjected to unpredictability of waves and non-linearities from mooring lines along with risk associated from fluctuating water waves. The suitability of the equipment due to heave motion can be assessed by the computation using Matlab software. There is a rapid fall in force on the bottom and top from a time frame of 5 to 10s and a maximum force of 5.8N and 7.6N was recorded respectively. A heave response of -0.15m to 0 was observed. During this analysis the lifebuoy will experience little heave response. A Matlab program was used in analysing this process**

I. INTRODUCTION

Lifebuoy is commonly used as a safety equipment to keep seafarer afloat during emergency or search and rescue operations. The Lifebuoy is held in place by mooring lines anchored to the seabed during operation, either in spread or turret mooring arrangement. When designing a lifebuoy, heave motion is a major factor that needs to be considered. In recent years, the maritime industry has seen an increased interest in the development of deep and ultra-deepwater fields. Lifebuoy is a safety device that is used on board a vessel. The Lifebuoy generally utilise a system of mooring lines anchored to the seabed to keep the platform in place. In shallow waters, the effects of its dynamic behaviour due to environmental forces are relatively small (Chen et al, 2001). Such systems may be satisfactorily predicted via computationally inexpensive quasi-static uncoupled analysis, or physical testing (Temarel et al. 2016).

In the past several decades various methods with different level of complexity have been developed for prediction of wave-induced ship motions and loads as described by the Committee on Loads of the International Ship and Offshore Structure Congress (Hirdaris et al. 2014). This project further explores the influence of heave motion on a Lifebuoy and its behaviour as shown in fig 1.

Fig 1: A Front View Lifebuoy

More recently, Castiglione et al (2011) investigated the seakeeping behaviour of a catamaran that includes a strip theory, and compared the results against CFD and experimental data. Despite the fairly good agreements, it became clear that strip theory over estimates the catamaran motions. Despite the limited application range, weather in terms of speed, weather due to its inability to properly account for the hull interaction. Such theories continue to be subject of investigation. This work was further developed during the following years and broadened to include any fast displacement catamaran design. Modules for the generation of hull forms and to handle the obtained design, including preparation of common naval architecture drawings were embed into the overall optimization procedure. Papanikolaou et al. (1990) presented a research paper that focused solely on the hydrodynamic module. To deal with the seakeeping problem, quasi 2-D (strip or slender body theory approach) and 3-D panel methods were used. Kukner and Sarioz (1995) proposed a forward/inverse methodology applied to high speed hull forms. In particular a speed patrol vessel, and developed realistic seakeeping criteria to investigate the possibility of improving existing designs.

Such criteria included minimizing heave/pitch peak RAOs and accelerations, as well as preventing extreme effects such as slamming and deck wetness.Considering the advantages of strip theories in terms of low computational effort, making them ideal for optimization procedures, particularly during early design stages and within academic contexts in which more research is encouraged in this field.

It seems clear that there still is room for improvement regarding its use to predict the dynamic behaviour of the lifebuoy due to heave motion.Computer aided software using Matlab is thus recommended, as the behaviour is analysed simultaneously, and the damping and added mass properties of the lifebuoy is taken into account. This project investigates the dynamic behaviour of a lifebuoy. The study utilizes the commercial software Matlab, with the lifebuoy model subjected to heave motion. The hydrodynamics analysis is analysed using Matlab. This result will highlight the significance heave motion on Lifebuoy during design stage.

II. METHODOLOGY

A. Heave Force

The degree of freedom (D.O.F) represented the possible translations and rotation of the life buoy. The heave force noted is shown in equation (1) and this defines the behaviour of the ship in seaway. The equation of heave force on the life buoy is solved.These equations are demonstrated as follows:

$$F_{dpz} = F_{top} + F_{bot} \quad (1)$$

Where

$\boldsymbol{F_{dpz}}$= Total vertical wave pressure force

$\boldsymbol{F_{top}}$= Force on top of the buoy

$\boldsymbol{F_{bot}}$= Force on the buoy bottom

Summing forces recognizing the directions

$$F_{top} = P_{top} * \frac{\pi}{4}(D_2^2 - D_1^2)cos(wt) \quad (2)$$

$$F_{bot} = P_{bot} * \frac{\pi}{4}(D_2^2)cos(wt) \quad (3)$$

B. Wave Amplitude

The wave exciting force developed from the wave height and period can be analysed using (4) to (5)

$$\zeta^* = \zeta_a e^{-kD} \cos(\theta) \quad (4)$$

Where

ζ^* = Wave elevation
ζ_a (a) = Wave amplitude
K = Wave number
D = Water depth

Calculation of the heave added mass (A_{33})

$$A_{33} = C_a \left[\rho \frac{\pi}{2}\left(\frac{B}{2}\right)^2\right] L \quad (5)$$

Where

Ca= Constant
B = Vessel breadth
L = Length of the vessel

Calculation of the heave potential damping coefficient (B_{33})

$$B_{33} = 2\sqrt{C_{33}(M + A_{33})} \quad (6)$$

Calculation of the heave restoring coefficient (C_{33})

$$C_{33} = \rho g A_{wp} \quad (7)$$

Where

A_ω = Vessel water plane area
D = Vessel draft
C_B = Block coefficient

Calculation of heave amplitude for consideration of a simple harmonic motion

$$Z_a = \frac{\frac{F0}{c} * \cos(wt)}{\sqrt{\left[1 - \frac{w^2}{wn^2}\right]^2 + \left(\frac{2w\varepsilon}{wn}\right)^2}} \quad (8)$$

Where

Z_a = Heave amplitude

C. Wave motion in heave

The motion effect of wave on the vessel in heave is shown in (9), this was used to analyse the wave effect as it affects the pipe-laying vessel at different water depth and wave position

$$F_{\omega 3} = (M + A_{33})\ddot{Z} + B_{33}\dot{Z} + C_{33}Z \quad (9)$$

(Lars, 2009; DNV, 2011; Yuming, 2011)

III. RESULTS AND DISCUSSION

The overall performance of life buoy depends on its ability to stay afloat no matter the ocean condition where its mother vessel is designed to operate. The seakeeping performance procedure is based upon the probability of exceeding specified vessel motions in a sea environment particular to the vessel's mission (the same three ideas explained in previous section, but with other wording).

Given the operational area of the vessel, the percentage of time the vessel operates in a particular sea state can be determined from an oceanographic database through application of the heave response. The predicted responses in motions are compared to the motion limiting criteria to obtain the operability indices. However, the operability indices are strongly affected by the chosen limiting criteria. Therefore, it is required to describe three principal concepts in order to understand the seakeeping performance or in another words, seakeeping analysis is essentially a three part problem, as it is further described.

The analysis of the effect of heave motion show in APP B is determined in heave force acting on the life buoy. The phase shift was analysed and to determine heave response. Also, the heave and hydrodynamic force acting on the interpolated vessel is estimated using matlab source.

A. Heave Force

The heave force at various wave times is shown in fig 2 to fig 5 using a wave length of 6m tidal wave as a case study. As

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shown in figures the time increases the heave response displacement reduces until 5s. There is a rapid fall in heave force from a time frame of 5 to 10s. The heave force as observed tends to increase again from 0 to 5s.

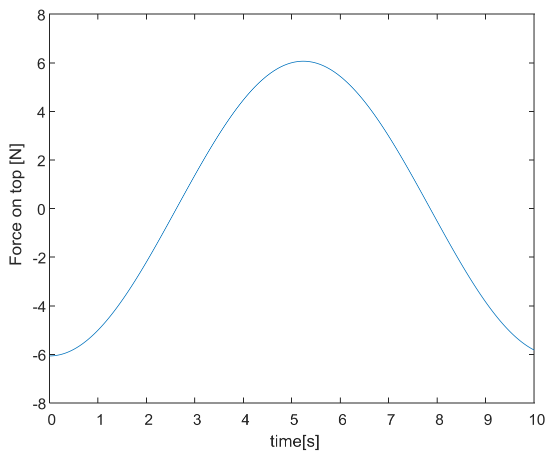

Fig 2: heave force on top against time

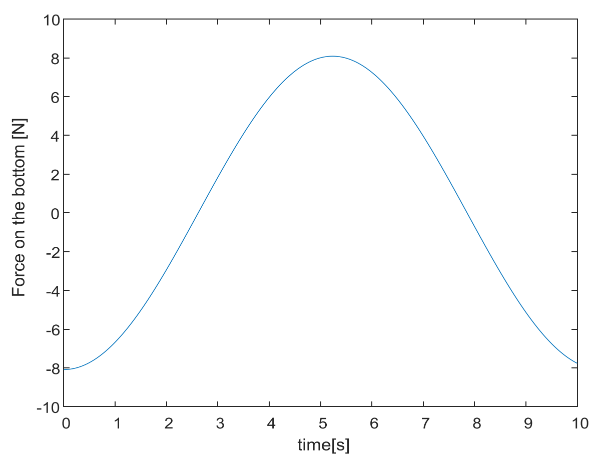

Fig 3: heave force on the bottom against time

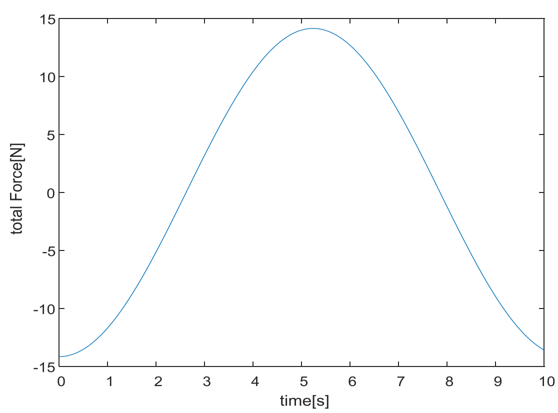

Fig 4: heave total force against time

As shown in fig 4 the total heave force of the life buoy is 15N as the wave time increases from 0 to 5s and it also decreases from 5 to 10s. The heave force is observed forms a quadratic curve from 0 to 10s. The displacement directly specify the motion and the force with which the safety apparatus response.

B. Heave Amplitude

The heave Amplitude on the ship response was analysed at varying time (0 to 10s) and at a wave frequency of 0.6Hz as shown in fig 5. The heave amplitude of the vessel is shown in fig 4 experiences a spike at 0 to 2.5s and the heave response shows no significant upward movement.

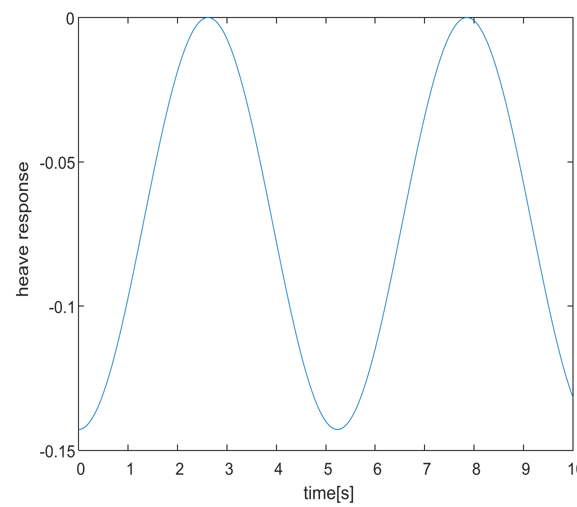

Fig 5: heave response of the FOP at shallow water

IV. CONCLUSION AND RECOMMENDATION

1. Conclusion

The ability of life buoy to float crew members overboard along with its sea worthiness of the operational life cycle is of paramount importance not just to the crew members but also to in its ability to save life. This is why the designer takes into consideration the possibilities of reducing the heave amplitude effects of the life buoy which can considerable increase the discomfort of the crew. Heave motion have been considered relatively ease to control and a lot of work have been put into damping the effects ranging by analysing its effect on life buoy. The seakeeping analysis showed a drop and rise in its heave response.

2. Recommendations

This project gives an overview of the different simulation on seakeeping analysis of a life buoy. The following recommendations can be pointed out as follows:

- The effect of other ship motion should be analysed and its result should be compared to that of heave.

- Other numerical model of the vessel heave responses can be considered. This can give more room for future studies.
- Variations with other shapes especially life raft should be considered at least for further investigations.

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