SIMPLIFICATION BY MATHEMATIC MODEL TO SOLVE THE EXPERIMENTAL OF SLOSHING EFFECT ON THE FPSO VESSEL

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ABSTRACT
This study considers the experimental and numerical method (MAT-LAB) analyzing. The FLNG was considered to be rigid body supported by non-permanent pole with distributed spring damper. For the case of fluid level on 30 % of the cargo tank and various, wave amplitude. The paper describes a study on model test experiment in maneuvering and ocean engineering basin (MOB) at the Indonesian Hydrodynamics Laboratory (IHL) in Surabaya, with a wooden barge at scale of 1 to 70. In the model test experiment, special care of sloshing on the pressure impact was taken into consideration. By using high speed video, the wave front formed by the bore of FLNG in resonance is observed and the impact to the hull is measured. It is used to analyze the response amplitude operator (RAO). In general, both methods (model test and MAT-LAB) demonstrated such a good agreement, particularly in the consistent trend of RAO.

Keywords: sloshing, global motion, translation, rotation, validation.

1. Introduction

There are two primary concerns related to sloshing flows in ship hydrodynamics: the prediction of sloshing-induced impact loads on ship structures, and the dynamics of ship motion coupled with sloshing-induced excitation (Faltinsen, 1978). The former is an important task in the design of internal cargo structure. In particular, this is an essential element in the design of membrane-type liquefied natural gas (FLNG) carriers or FLNG platforms. The latter has been of interest for the prediction of dynamic behavior of ship motion. Meanwhile, the design load of the main hull structure is governed by the external wave load and inertial load due to shipmotion, the sloshing impact load due to liquid motion inside the tank governs the design load for the FLNG containment system and surrounding bulkheads.

Many studies on the ship sloshing problem were carried out in 1970s and early 1980s for the design of FLNG carriers. Recently, the demand of sloshing analysis has increased significantly, especially for the design of larger FLNG carriers and LNG floating-production-storage-offloading (FPSO) vessels. Many numerical studies on sloshing flows have been reported during the last two decades. Some representative works have been introduced by (Faltinsen, 2000; Bridges, 1982; Mikelis, 1984;Wu et al, 1998;Kim et al, 2004). Despite numerous studies, not many methods are applicable for actual engineering use such as the simulation of violent flows and the prediction of impact loads.

Nonetheless, recent experimental and numerical study shows that even at the milder sea states, the sloshing load at the filling level near the 30% of tank height can be as high as the sloshing load at the high filling level at the North Atlantic (Monaghan, 1994; Dillingham, 1981).This study aims to observe the physical phenomena involved in violent sloshing flows, and the development of proper numerical models for practical use. To this end, both the experimental observation and numerical computations were carried out (Rognebakke & Faltinsen, 2003; Sinaga et al, 2014).

2. Methodology

2.1 Model Test

The FLNG model was produced according to a scale of 1 to 70 .The model consists of hull body (barge shape structure) completed with cargo tank, normal bilge tank (Figure 1).The FLNG model was made from wood and steel frame which is required strengthen the hull body. The model should be statically and dynamically balanced to adjust the position center of gravity and radii of gyration. The cargo tank is made of acrylic transparent glass of 1 cm wall thickness. Table 1showed the principal dimension of FLNG with scale factor, the position of the model in MOB tank with two various heading angle at 90 and 135 degrees was shown in Figure 2.

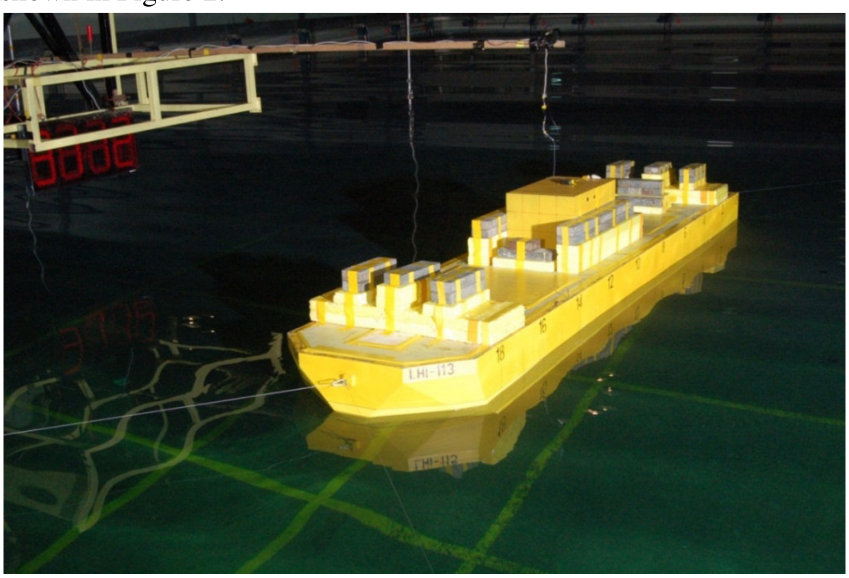
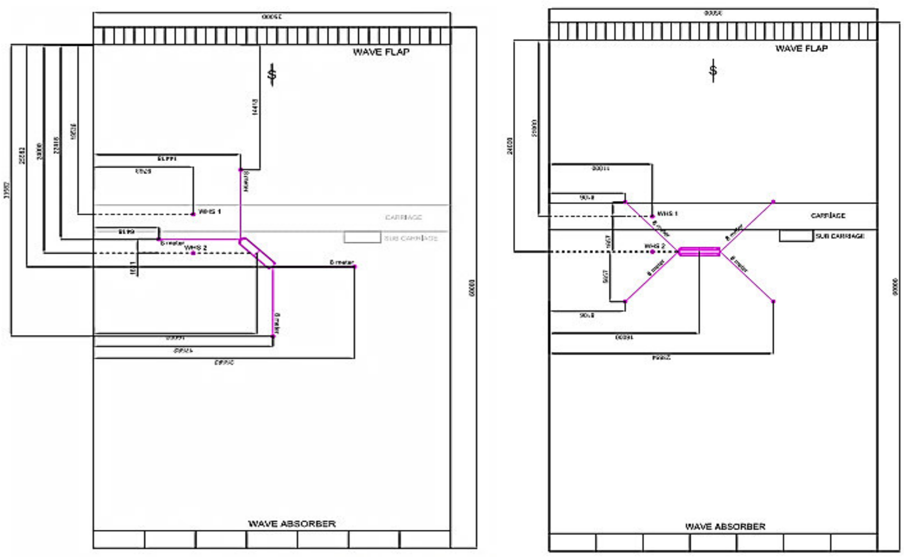


Figure 1Model of FLNG



(a) (b)

Figure 2.Set-up position of FLNG model in MOB:(a) 90 degrees (beam sea), (b) 135 degreed (quartering sea)

Table 1 Principal Particular

Description	Symbol	Full scale	Model of scale
Length Overall	LOA	= 350,000 m	500,000 cm
Length Between Perpendiculars	LPP	= 330,000 m	442,000cm
Breadth Mid Ship Section	B	= 66,000 m	92.86 cm
Depth	D	= 27.30 m	39.66 cm
Draft	T	= 13.200 m	19.71 cm
Displacement	Displ	=71.260.600,000 Kg	77156 Kg
Length Centre of Gravity from AP	LCG	= 150583 m	215.32 cm
Centre of Gravity from Keel	LCG	= 21.800 m	31.14 cm
Length Center of Bouyancy From AP	LCB	= 180.585 m	215.12 cm
Vertical Centre of Bouyancy	KB	= 6.999 m	10.00 cm
BM Trans	BMv	= 26.745 m	36.78 cm
BM Long	BMl	= 571.173 m	81.596 cm
Roll Radius of Gyration	Kxx	= 24.850 m	34.36 cm
Pitch Radius of Gyration	Kyy	= 74.400 m	106.29 cm
Keel to Meta centric	Km	= 32.745 m	46.76 cm
Transverse GM	GMt	= 10.945 m	15.64 cm
Calculation Roll Natural Period	Troll	= 17.300 m	2.07 cm

Table 2 Tests with regular wave

No	Filling of level (%)	Bilge Keel Type	Heading (deg)	AMPLITUDE (m)	Period (s)	NUM OF Oscillation
1	30	Normal	90	2	14.5	15
2	30	Normal	90	2	16.3	15
3	30	Normal	90	2	17.3	15
4	30	Normal	90	2	18.3	15
5	30	Normal	90	2	19.0	15
6	30	Normal	135	2	14.5	15
7	30	Normal	135	2	16.3	15
8	30	Normal	135	2	17.3	15
15	30	Normal	135	2	18.3	15
10	30	Normal	135	2	19.0	15

The model test (Table 2) wascarried out in regular and random waves. The random waves were adjusted to represent Pierson-Moskowitz wave spectrum. The waves in basin were generated by means of a wave generator.

Notation

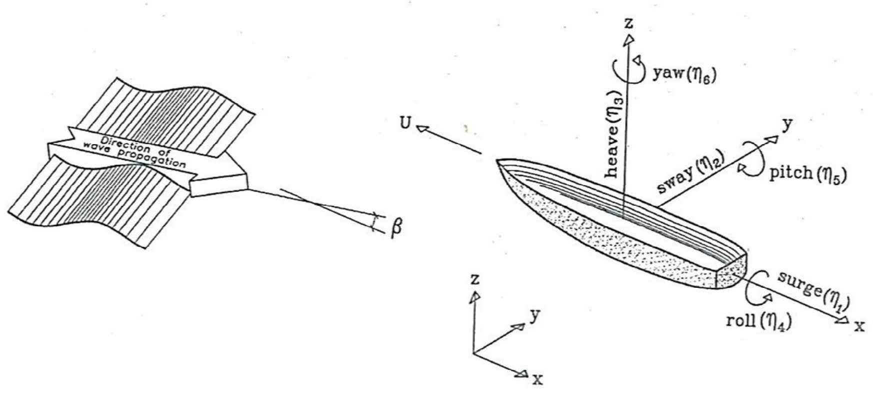


Figure 3 Model-fixed system of axes

The notation of the motion (Figure 3) and force components was taken in relation to their directions with respect to the model system of axes. The following notations and sign conventions are applicable:

Translation

Each translation was considered positive when, from zero position, the movement was in the positive direction of the respective axis

x : surge in x-direction, y : sway in y-direction, z : heave in z-direction

Rotation

Each rotation was considered positive when from the zero position it was clockwise about the respective axis when looking into the positive direction of that axis.

ϕ :rollabout x-axis, θ : pitch about y-axis, ψ:yaw about z-axis

2.2 Mathematical Modelling by MAT-LAB

The problem coupled with ship motion is also considered as shown at Figure 4.

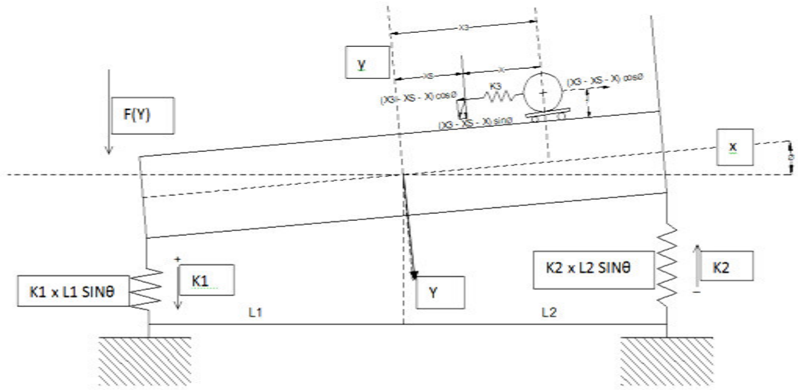


Figure 4. Model mathematical

Equation mathematical model of floating body

$$(M+m+A)\ddot{Y} = B\int_{-x}^{x} y\{(k_1+k_2)+(k_1.l_1-k_2.l_2).\emptyset+k_3(x_3-x_s-x)\times \cos\emptyset\} - C.\{y(k_1+k_2)+(k_1.l_1-k_2.l_2).\emptyset+k_3(x_3-x_s-x)\times \cos\emptyset \qquad (1)$$

$$(J+j+a)\ddot{O} = b\int_{-\emptyset}^{\emptyset} \emptyset\,[2.\{(k_1.l_1^2+k_2.l_2^2).\emptyset-(k_1.l_1-k_2.l_2).y\}-k_3(x_3-x_s-x)\sin\emptyset.d + (x_3-x_s-x)^2.\cos\emptyset] - c[2\{(k_1.l_1^2+k_2l_2^2).\emptyset-(k_1.l_1-k_2.l_2).y.\emptyset+(k1.l1-k2.l2).y\}] - k_3(x_3-x_s-x)\{(\sin\emptyset.d)-(x_3-x_s-x).\cos\emptyset\} \qquad (2)$$

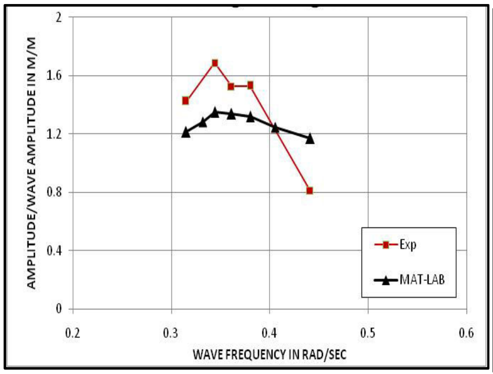
Matrix equation model of floating body

$$\begin{pmatrix} M\,J\,A \\ m\,j\,a \end{pmatrix} = \begin{pmatrix} C \\ c \end{pmatrix}\begin{pmatrix} -\ddot{Y} & \ddot{o} & \sin\emptyset \\ -\ddot{Y} & \ddot{o} & \cos\emptyset \end{pmatrix}\begin{pmatrix} P \\ Q \\ R \end{pmatrix} \qquad (3)$$

$P = k_3(x_3-x_s-x)$, $Q = (k_1.l_1-k_2.l_2)$, $R = (k_1+k_2)$

3. RAO Analysis and Discussions

The prediction of responses structure of an FPSO is generally made in regular wave. In currently work various heading angle (90,135) degree, wave height 2 m and filling of the storage tank 30 %, period (see tables 2 test with regular wave) In this model test sort term response calculation of linier is given natural Response Amplitude Operator (RAO) of FPSO. Based on linier theory it is assumed that for each wave period the relation between input wave amplitude and motion always the same. The result are for RAO translation force heaving (see Figure 5) speciallycurve trends is similar but in an experiment RAO of motion higher than RAO of motion in Mat-Lab. Because of effect from damping and added mass. For the translation forces 135 degrees (see Figure 8) trend curves are similar but RAO curve trend experiment higher then Mat-Lab. Also result of moment pitching (see Figure 7) are trend similar in Mat-Lab. But experiment is increase very high and trend curve is different.. The moment pitching at heading 135 degree (see Figures 8) the curve trend RAO pitch heading 135degree is same but for pitching RAO more then 0.4 wave frequency lower then MAT-Lab. That mean the curve not consistence



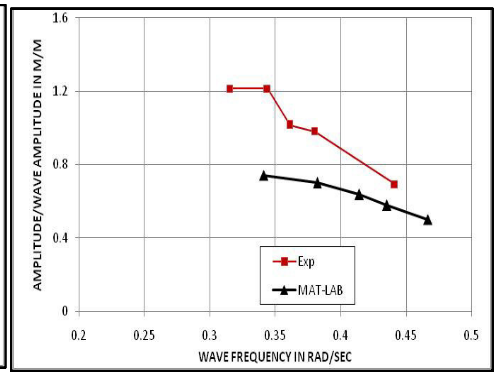
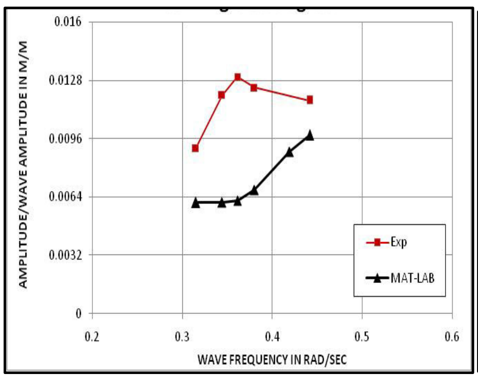


Figure 5 RAO of Heave 90 degrees Figure 6 RAO of Heave135 degrees



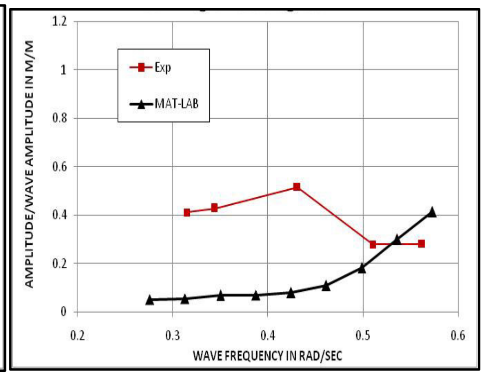


Figure 7 RAO of Pitch 90 degreesFigure 8 RAO of Pitch 135 degrees

The wave breaking and splashes are typical phenomena observed in violent sloshing flow. Figure 9 shows three of snapshots of sloshing flows at 30 % storage tank filling. A typical process of impact at 30 % filling condition is (i) formation of strongly non linier free surface flow, (ii) impact on side wall, and (iii) wave run-up along wall and splashes generation. It is apparent that splashes provide a significant contribution to impact or global motion.

(a) (b) (c)

Figure 9 Splashes after side impact occurrence at model 30 % storage filling tank

4. Conclusions

In the present study, the physical and technical issues of sloshing flows in ship cargo are described. The physical phenomena in violent sloshing flows have been carefully observed in experiments, and proper numerical models are proposed. Numerical method (MATA-LAB) is applied to solve violent sloshing flows in the IHL Laboratory and ITS models. Based on the present study, the following conclusions are made:

- Couple Motion (heave and pitch) experiment and MAT-LAB result shows have same trend curves, but for MAT-LAB result shows the RAO curves is consistent below of the experiment due to dampingand viscous of water it is not parts of the MAT-LAB calculation
- Pitch motion on 90 degrees there is no apparent movement so need for further investigation. Nonlinear Equations sloshing flow is necessary to be able to calculate the amount of movement of the ship
- The nonlinearity of sloshing flow plays a critical role in the ship motion coupled with sloshing. The sloshing-induced force and moment are not linearly proportional to excitation amplitude. Therefore, the ship motion coupled with sloshing does not vary in a linear manner with respect to wave amplitude.
- The coupled problem is well predicted by the linear theory based on the impulsive response function. This method is accurate and robust, and particularly very efficient in computational time.

5. Acknowledgements.

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