INTERNATIONAL JOURNAL OF METACENTRE
MARITIME APPLICATION, TECHNOLOGY, ENGINEERING, AND TRANSPORTATION
http://ijm-nasp.unhas.ac.id. eISSN : 2809-8307

Experimental Study on Bow Slamming of a Ship

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Received: 10/01/2023
Revised: 25/03/2023
Accepted: 10/05/2023
Published:28/06/2023

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Abstract

This study discusses about the critical issue of slamming phenomena in ship design, emphasizing its impact on ship safety, environmental concerns, and fuel consumption. The drop tests has been used to investigate bow slamming pressures and internal strain at various drop angle. The results indicated peak pressures at different sensors, with higher drop angles resulting in increased impact pressures and internal strains due to augmented velocity, angular momentum, surface area contact, hydrodynamic effects, and gravitational forces.

Keywords: Bow slamming; Drop test; Pressure; Internal strain.

1. Introduction

Due to the interaction between the wave and the body, the slamming phenomena is one of the classical issue in the ship design. recurring impact force, which is related to ship safety. To maintain the safety of the ship when extreme slamming occurs, ship speed needs to reduce significantly, then it will have an indirect impact on the marine environment and an increase in ship fuel consumption. Additionally, in order to design the plates and stiffeners in the ship's bow requires accurate estimation of the slamming load. Local structural damage when ship sails through high wave conditions can be caused by fatigue due to repeated slamming loads.

Rosis et al [1] studied the response of the suitable structure to impulse load due to impact on the free surface of a weakly compressible viscous fluid by using Lattice Boltzman to examine the fluid flow and examined the structural response through the finite element method.

S. Baso et al [2] experimentally verified the influence of impact angle in bow slamming with a drop test on the free-falling body in towing tank by measuring slamming impact pressure around the bow flare with attaching Piezoelectric sensors. To check the dependency of the bow slamming pressure quickly and efficiently at the preeliminary design step to predict the design slamming load on numerous geometric and physical parameters can be used a one – way coupled CFD-based method. Dae et. al [3] using Computational Fluid Dynamic (CFD) to estimated the bow slamming pressure at container ship.

Figure 1. Slamming Phenomena (Veen, 2010 [2])

The impact loads and flow fields around bow – flare sections during water entry can be examined with Smoothed Particle Hydrodynamics (SPH) method, increasing the roll angle correlates with amplified dimensions of spray jets on one side of the structure causing flow separation and the maximum impact pressure concentrated on the keel's frontal area. H.Cheng et al [4].

H.Xie, at al [5] conducted drop tests utilizing a complex 3D bow flare model offer insights into impact hydrodynamics and emphasize the significance of 3D effects near the bulbous bow, that result pressure distributions influenced by drop heights and impact locations, emphasizing the sensitivity of pressure to water entry velocities and effective impact angles.

Frequently observed in turbulent wave, slamming poses a considerable threat to ships, often inflicting substantial damage, particularly in the bow region where relative velocity between the ship and the water surface is greatest. These studies aim to predict and analyze the impact pressures and internal strain around biw section at ferry ro-ro by considering the drop angle of the bow.

2. Methods

2.1 The model

In this study, we used ferry ro-ro steel model with the scale 1 : 60 and the weight of the model is 20 kg, the main dimension of the model shown in Table 1, and the detail of the body plan illustrated in Fig.1

Table 1. Principal particulars of ship and model.

Description	Actual Ship	Model
	m	m
Length overall/Loa	76.72	1.28
Length between perpendiculars/Lbp	70.20	1.17
Breadth/B	12.00	0.23
Draught/D	4.60	0.08
Draft/d	3.30	0.14

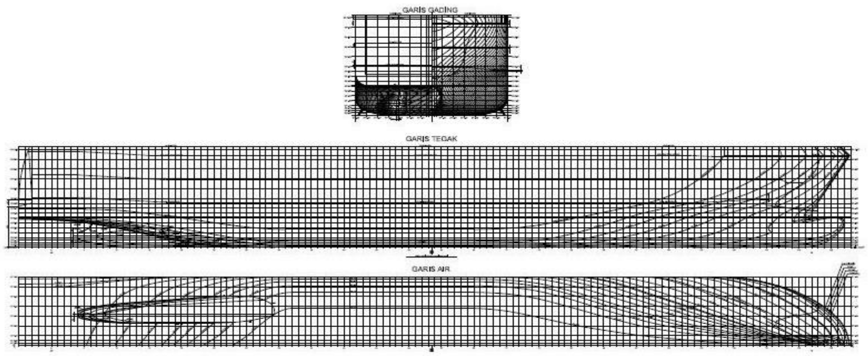
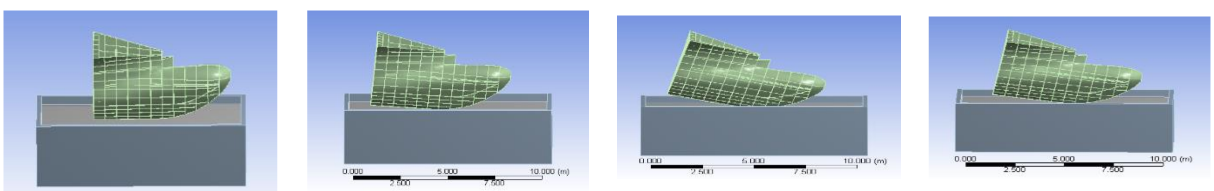


Figure 1. Lines plan Ship Ferry ro-ro

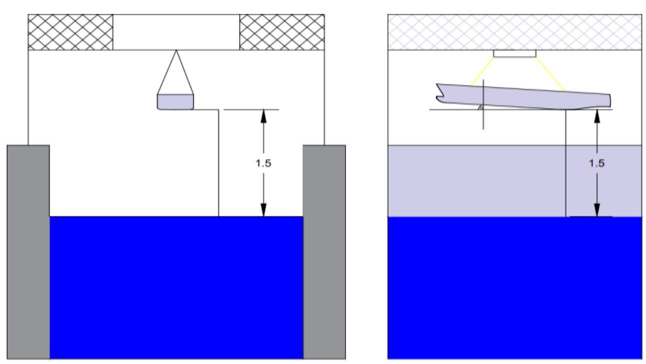
2.2. Experimental Set-up

The experimental test with a steel model was carried out by drop test in the towing tank at Hydrodynamic Laboratory of Naval Architecture at Hasanuddin University, its size is 40 meters, 8 meters wide and 3 meters draught. The various drop angle of the initial model positions are 0 deg, 5 deg, 10 deg, and 15 deg as shown in the Fig.2. The model was dropped from 1.5 m above the water level as displayed in the Fig.3, three times repeatedly to validate the experimental result.



(a) (b) (c) (d)

Figure 2. Initial position of the bow angle (a) 0 deg ; (b) 5 deg ; (c) 10 deg ; (d) 15 deg .

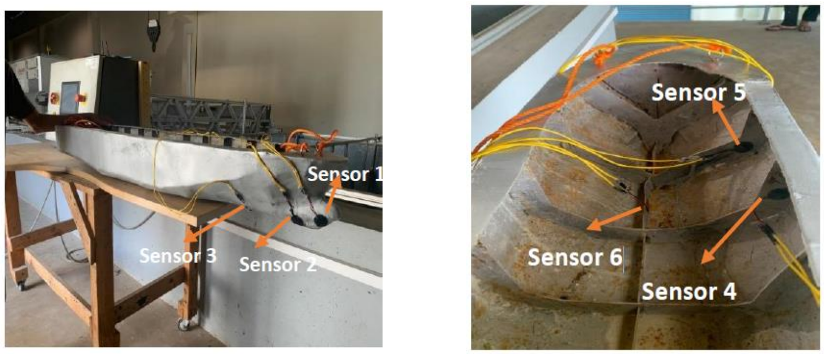


(a) (b)

Figure 3. The drop position of the model (a) Front view and (b) Side view

The model incorporates six piezoelectric, and maximum voltage of the piezo electric is 5V. Its positions are illustrated in the Fig. 4.

Piezoelectric transform mechanical stress or pressure into electrical signals, and its data converted to pressure units in force (N) using a force sensor connected to the Xplorer GLX, it device can be seen in Fig.5.



(a) (b)

Figure 4. (a) Sensors in the bow (b) sensors on the frame on the construction.

(a) (b)

Figure 5. (a) Xplorer GLX and (b) Force sensor

The model was initially installed at the carriage, then elevated to predetermined drop height. Once the model into the water, the sensor will capture and record the pressure data upon impact with the water surface. The collected pressure data on the bow slamming area as a plot pressure variations over time to visualize the impact force, and the internal strain.

3. Results and Discussion

The obtain result are discuss accordingly, and the Fig.6 presents snapshots illustrating the ship model's behavior during the drop test for drop angle 5 degree. The initial positions of the drop angle are 0 deg, 5 deg, 10 deg and 15 deg, but there are alteration drop angle position upon the model's impact with the water. The new drop angles are 0.88 degree, 1.9 degree, 3.49 degree, and 5.36 degree. The shift position is primarily affected by the force of impact, and the model's initial orientation, and the hydrodynamic forces acting on the model uipon entry into the water.

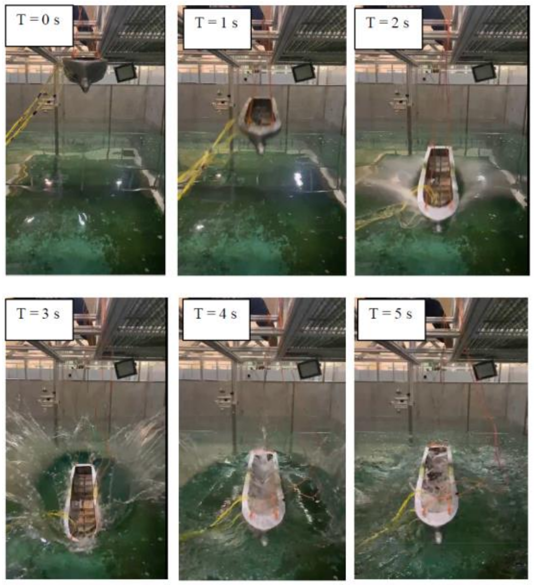
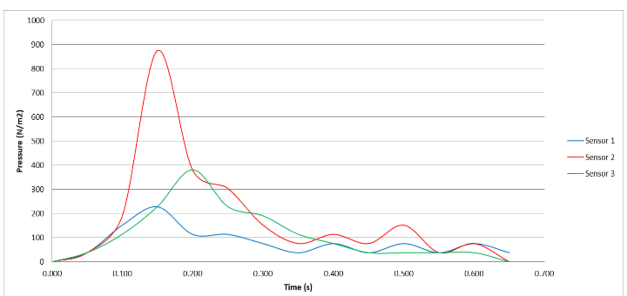
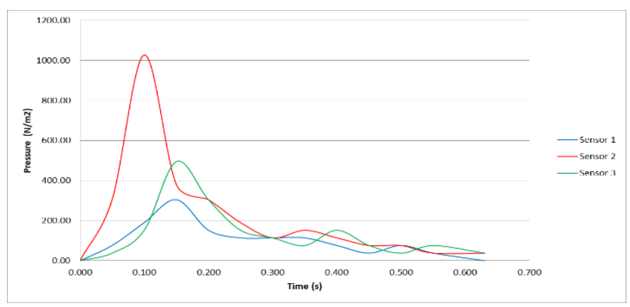


Figure 6. *Droptest* at drop angle 5°

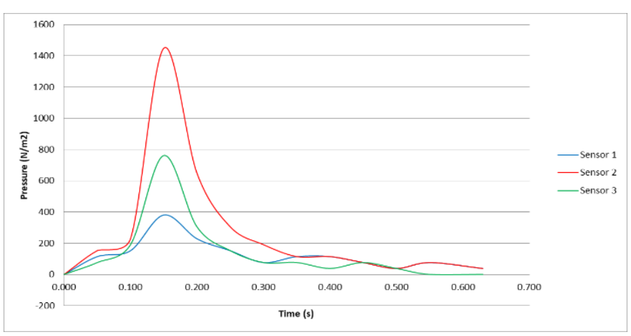
The time histories of the impact pressure for the various drop angle are shown in the Fig. 7. The results recealed the sensor 2 records the peak pressure while the first sensor captures pressure upon the model contact with the water surface, and the peak pressure occurring within time range 0.01 – 0.025 s. The highest pressure observed at sensor 1,2,3 for drop angle 15 degree. Increasing drop angle usually implies higher impact pressures due to increased velocity, angular momentum, surface area contact, hydrodynamic effects, and the gravitational force acting on the model during the drop test.



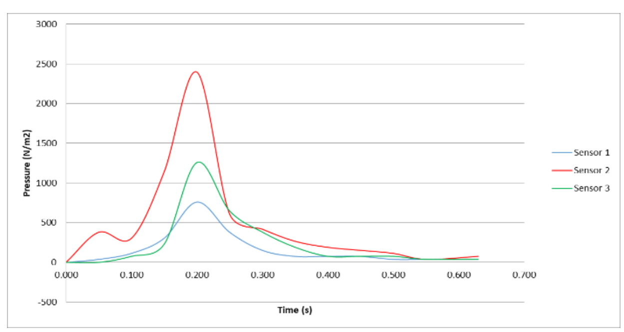
(a)



(b)



(c)



(d)

Figure 7. The time histories of the impact pressure distribution (a) 0 deg ; (b) 5 deg ; (c) 10 deg ; (d) 15 deg .

Fig.8 shows the result for the internal strain at sensor 4, sensor 5, and sensor 6, increased drop angles can lead to increase internal strain during drop test. The concurrent effect of increased impact force, angular momentum, greater deformation, intensified hydrodynamic effects, and the gravity contribute to the elevation of internal strain in the ship's structure during drop tests with higher drop angles.

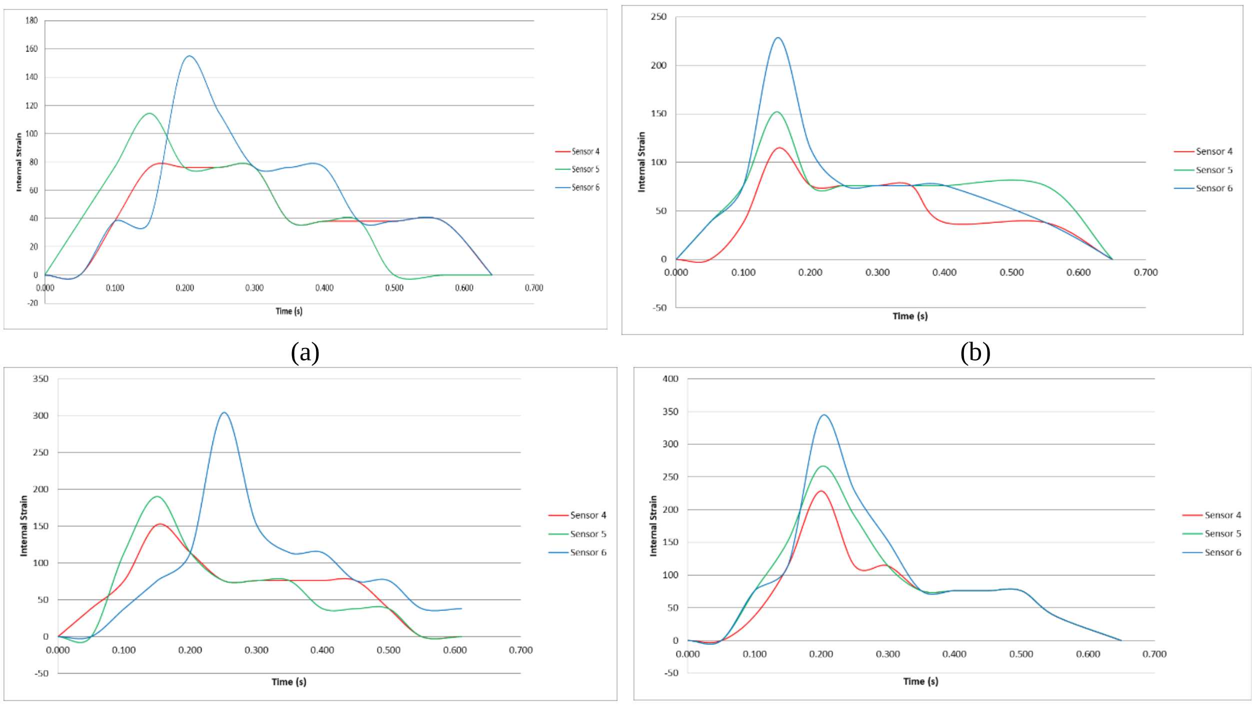


Figure 8. The time histories of the internal strain (a) 0 deg ; (b) 5 deg ; (c) 10 deg ; (d) 15 deg .

4. Conclusions

This study conducted the drop tests at varied initial drop angles (0°, 5°, 10°, and 15°) while observed by alterations in the drop angle positions upon the model's water impact, resulting in new angles (0.88°, 1.9°, 3.49°, and 5.36°). According to these condition, these shifts were primarily influenced by impact force, initial model orientation, and hydrodynamic forces during water entry. On the other hand, pressure histories revealed that the sensor 2 recorded peak pressure, with the first sensor registering pressure upon initial contact. By Increasing the drop angles, such as 15 degrees, led to heightened pressures, affected by augmented velocity, angular momentum, surface contact, hydrodynamic effects, and gravitational forces. Additionally, higher drop angles is able to increase the internal strain in the ship's structure due to the collective impact of increased force, momentum, deformation, hydrodynamic effects, and gravity during the drop tests.

Acknowledgements

The authors would like to thank Engineering Faculty, Hasanuddin University for its research grant under the scheme of Labo Based Education (LBE) Research in 2022 so that this research work can be done authors would like to thank Muhammad Miftach and Ode Gaffar Rakha for their kind help in experimenting.

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