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An Experimental Study on Stern Slamming of a Ship with Steel Model

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Abstract

This study discusses the phenomenon of experimental-based slamming carried out on a towing tank using a piezo sensor placed on a 0.15 L plane measured from the AP. This research measures the pressure on the ship's hull and internal strain with a steel model. This study aims to determine the amount of pressure and distribution on the ship's hull and the internal strain that occurs. This study's results indicate that the value of internal stresses and strains increases with each increase in the aft angle given in the drop test. The greatest pressure occurs at sensor 2 in the bottom area, which first touches the water surface with an average increase in pressure of 23.89% and internal strain occurs at sensor 6 in the ivory construction at the stern of the ship with an average increase of 24.49% so that These areas need special attention in Typical frame section location for stern slamming and structure of the ship to minimize the damaging effects of the slamming phenomenon.

Keywords: Stern slamming; Piezo sensor; Pressure; Internal strain.

1. Introduction

Slamming impacts the bottom structure of a ship to the sea surface. It is mainly observed when sailing in waves. The bow and stern of the ship can sometimes emerge from the wave and re-enter the wave. Slamming causes very high loads, and impulse loads with high-pressure peaks to the ship's structure in a condition of interest are the impact loads such as bow flare slamming, bottom slamming, and stern slamming, which are considered when designing ships.

On Jan 16 2021 a cargo ship was broken in two by a huge wave off Turkeys black sea, ship condition after the wave snapped its keel near the bow effect slamming phenomenon, as captured can see in Figure 1.

(a) Before accident

(b) After accident

Figure 1. The ship experienced the phenomenon of slamming.

The magnitude of the wave load on the ship structure has been widely carried out using a numerical computational approach and experimental. The computational approach finite element method and lattice Boltzman were carried out by Rosis et al [1].

The slamming phenomenon can also be detected with smoothed particle hydrodynamics (SPH) in the particle-based Lagrangian Method [2]. H. Cheng, et al. [3]. Conducted research by focusing on the flow-separating phenomenon and the spray jet on the free surface using the SPH method. Experimentally, S. Baso et al [4] conducted a drop test in towing tank to investigate the effect of bow slamming on the impact angle and the effect of model weight by measuring the pressure around the bow flare using Piezoelectric knock sensors, Sensor Piezoelectric also used to measure Stress Intensity factor (SIF) which has been done D.R Santoso [5].

Another study was slamming experiments on a ship model using pressure cells (Druck PDCR 200) mounted on the bow and stern of the ship [6]. This study aims to determine the ship's slamming load (vibration, girder fatigue, and main strength).

High slamming pressure can be experienced on the stern and bottom hull structures. Due to the tren and bottom slamming, two noticeable effects may occur, local structural effects in the stern and bottom that experience large slamming. In the guidance for slamming load and strength assessment American Bureau of Shipping, stern slamming occurs in vessels such as container carries with the significant overhanging stern of liquefied gas carries with relatively flat stern cross sections at a distance of 0.15 L from after perpendicular (AP) [7] can be seen in Figure 2.

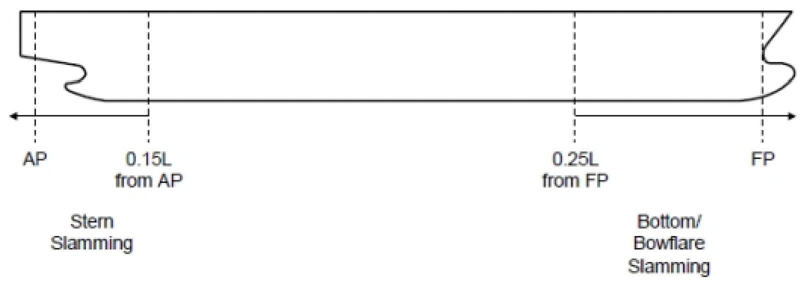


Figure 2. The extent of hull structure for slamming

Typical frame section station and panel locations for stern slamming can be seen in Figure 3.

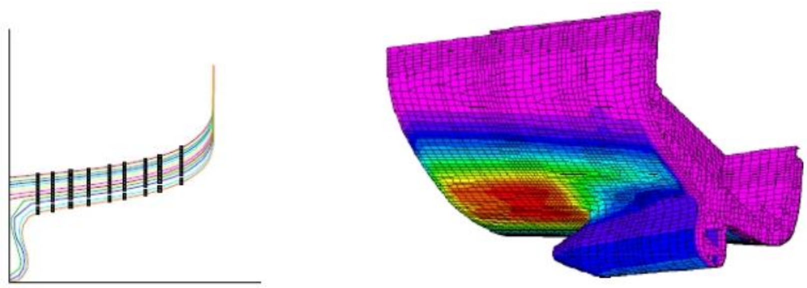


Figure 3. Typical frame section location for stern slamming

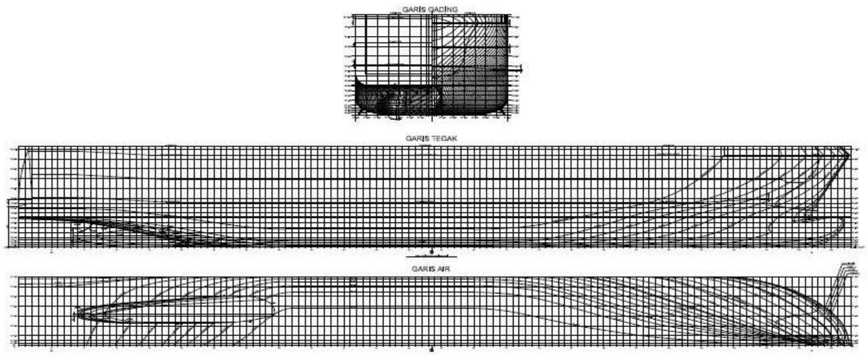
Based on this research, the authors are interested in conducting a similar study with experimental, namely investigating the pressure or water impact caused by slamming but focusing on the stern only by considering parameters such as healing degree and the shape of the structure of the ship ferry ro-ro.

2. Methods

In this present study, an Experimental study on stern slamming of a ship with a steel model was carried out by drop test on the Towing Tank Hydrodynamic Laboratory of Naval Architecture at Hasanuddin University. The tank size is 20 meters, 1.5 meters wide and 1.3 meters draught. The ship type in ferry ro-ro, the main dimension of the ship, and the body lines plan are shown in Table 1 and Figure 1, respectively. For the geometry, the scale of the ship model is 1: 60. The ship model was made of steel.

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



(a)

(b)

Figure 4. (a) Lines plan Ship Ferry ro-ro and (b) Model Ship Steel

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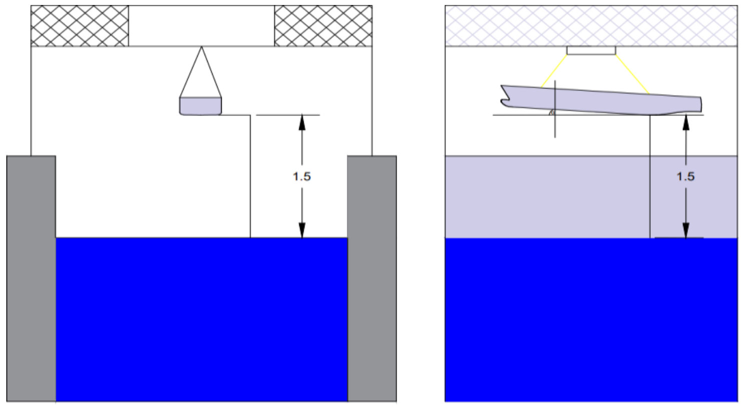
2.1. Experimental Set-up

The drop test is done by hanging the ship model on the towing carriage, equipped with a piezo sensor, which can be seen in Figure 9. Piezo sensor to measure the pressure that occurs as a transducer converts mechanical energy into electrical energy. The angle of the stern of the ship model is set using two ropes tied at the back and front of the model and then dropped from a height of 1.5 meters. The model's position is set according to the test scheme, with the initial position drop at the stern of the ship with various angles of stern angle 0 deg, 5 deg, 10 deg, and 15 deg. More detail can be described in Figure 5.

After the model ship touches the water's surface, the piezoelectric sensor will work according to the front installation position and issue digital data, which will be converted to a pressure value. After the test, data analysis is carried out to get the total pressure and stress against the unit of time (second). The pressure value is then made into a graph of total pressure and internal strain to the value of the increase in the drop angle. This is done to see the effect of the hull's behaviour on the variation angle of the striping test model.



(a) (b)

Figure 5. (a) Front view and (b) Side view

The Piezoelectric device circuit consists of an open-source microcontroller that functions to control various types of sensors, motors and other types of actuators in this study using a Piezoelectric sensor, and Piezoelectric device circuits are assembled based on block diagrams that have been made, the circuit can be seen in Figures 6 and 7.

(a) (b)

Figure 6. (a) Sensor Piezoelectric and (b) Piezoelectric device

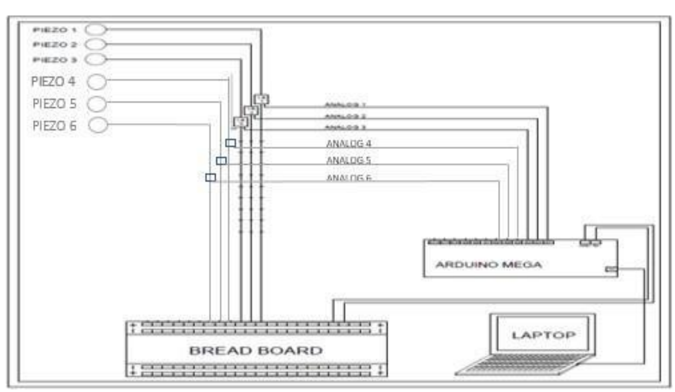
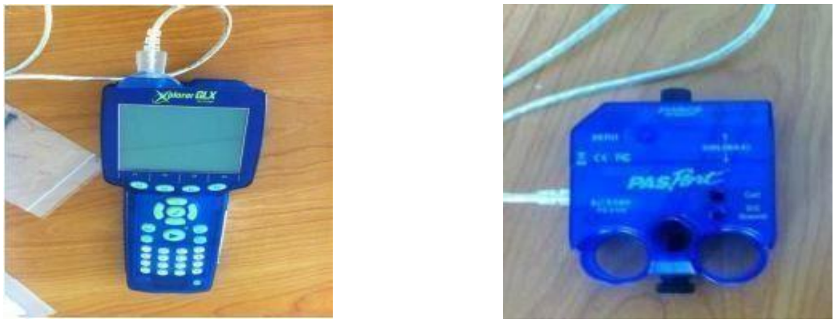


Figure 7. Block diagram of piezoelectric device circuit.

Sensor piezo output data is digital data in the form of electrical voltage (v), so it needs to be converted to pressure units in force (N) using a force sensor connected to the Xplorer GLX. Xplorer GLX and the force sensor can output a graphic display of the force value obtained by calibrating the voltage value generated from the piezoelectric device, which can be seen in Figure 8.



(a) (b)

Figure 8. (a) Xplorer GLX and (b) Force sensor

As measured from the AP, the pressure review point and internal strain stress slamming at location 0.15L. It consisted of six points placed outside the hull: three points in the bottom area, as shown in Figure 9a. Three points on the inside of the hull or frame construction can be seen in Figure 9b.

(a) (b)

Figure 9. (a) Sensors on the bottom stern (b) sensors on the frame on the construction.

3. Results and Discussion

In this study, the dropping test was successfully carried out by dropping the model from the carrier with the impact angle and height set. Experimental data can be obtained according to Figure 10. Shows examples of the snapshots of the ship model during the dropping test.

The weighted ship model is 20 kg, and the vertical velocity of the model at each stern angle gets different results. The ship model touches the water-free surface at an angle of 0 deg, drop vertical speed reaches 0.288 seconds, 5 deg: 0.833 seconds, 10 deg: 0.527 seconds and 15 deg: 0.195 seconds dropped from a height of 1.5 meters. The difference is strongly influenced by the initial position of the model and the force of gravity.

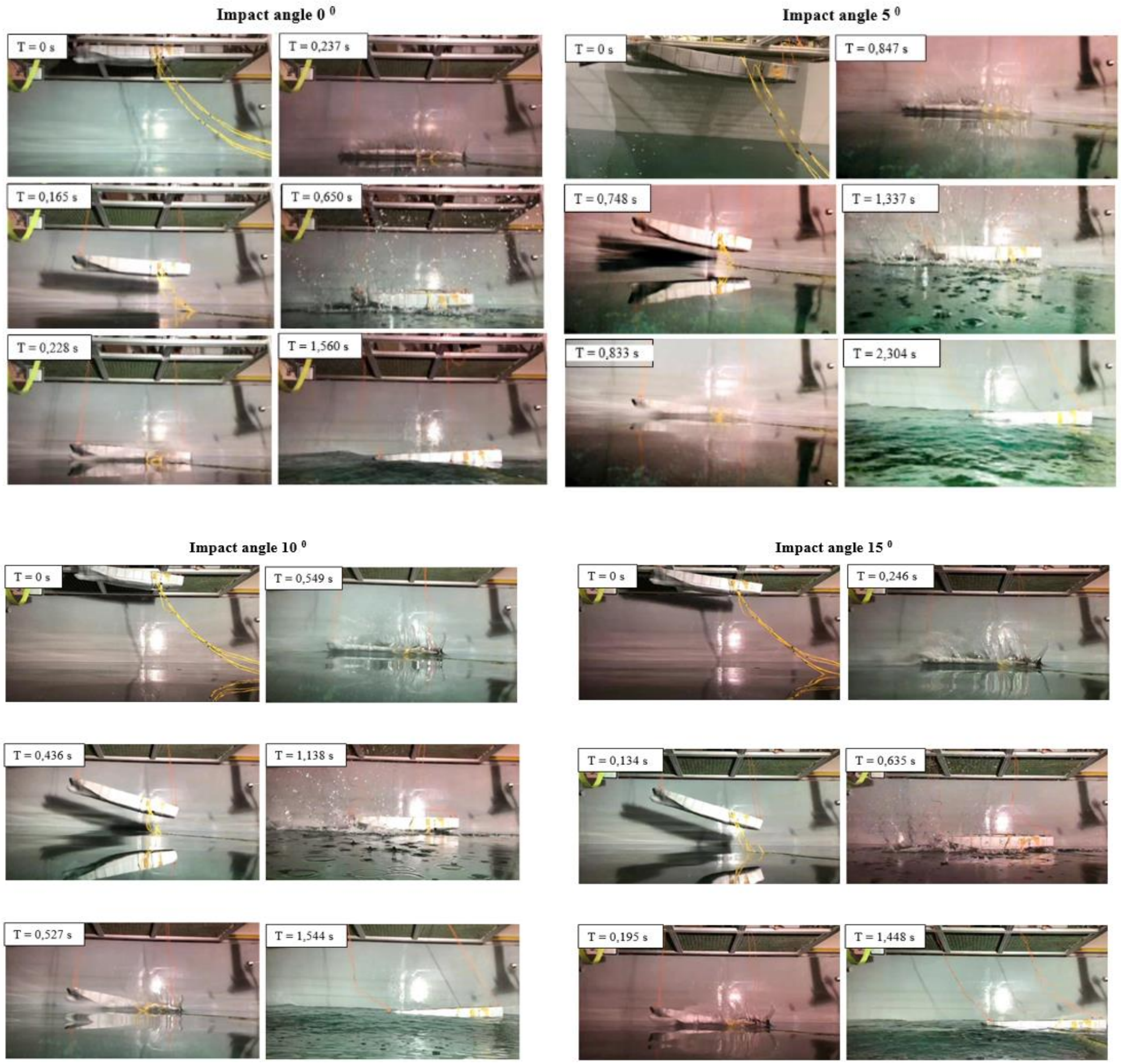


Figure 10. Snapshots of the ship model during the dropping test.

The initial position of the stern angle of the ship model is 0 deg, 5 deg, 10 deg and 15 deg, but in fact, the angle stern angle of the ship model is not the same as the initial conditions when touching the water surface the results obtained are a stern angle of 0 deg, the actual stern angle is 0,76 deg, for a stern angle of 5 deg the actual stern angle is 9.33 deg, for a stern angle of 10 deg the actual stern angle is 15.36 deg, for a 15 deg angle the actual stern angle is 19.25 deg at that position the pressure value can be measured.

Based on Figure 10, it can be seen that in the ship model, after touching the water free-surface occurs, splashes of water and the deck is wet during the model ship entering the water surface, after that the model will reappear on the water surface due to hydrostatic pressure along the part of the model that is submerged in water and the force acts perpendicular to the surface. Structure, in other words, the force is equal to the displacement weight of the model ship. The trend condition has risen above the water-free surface, such as the relative vertical movement of the stern over the water-laden stern.

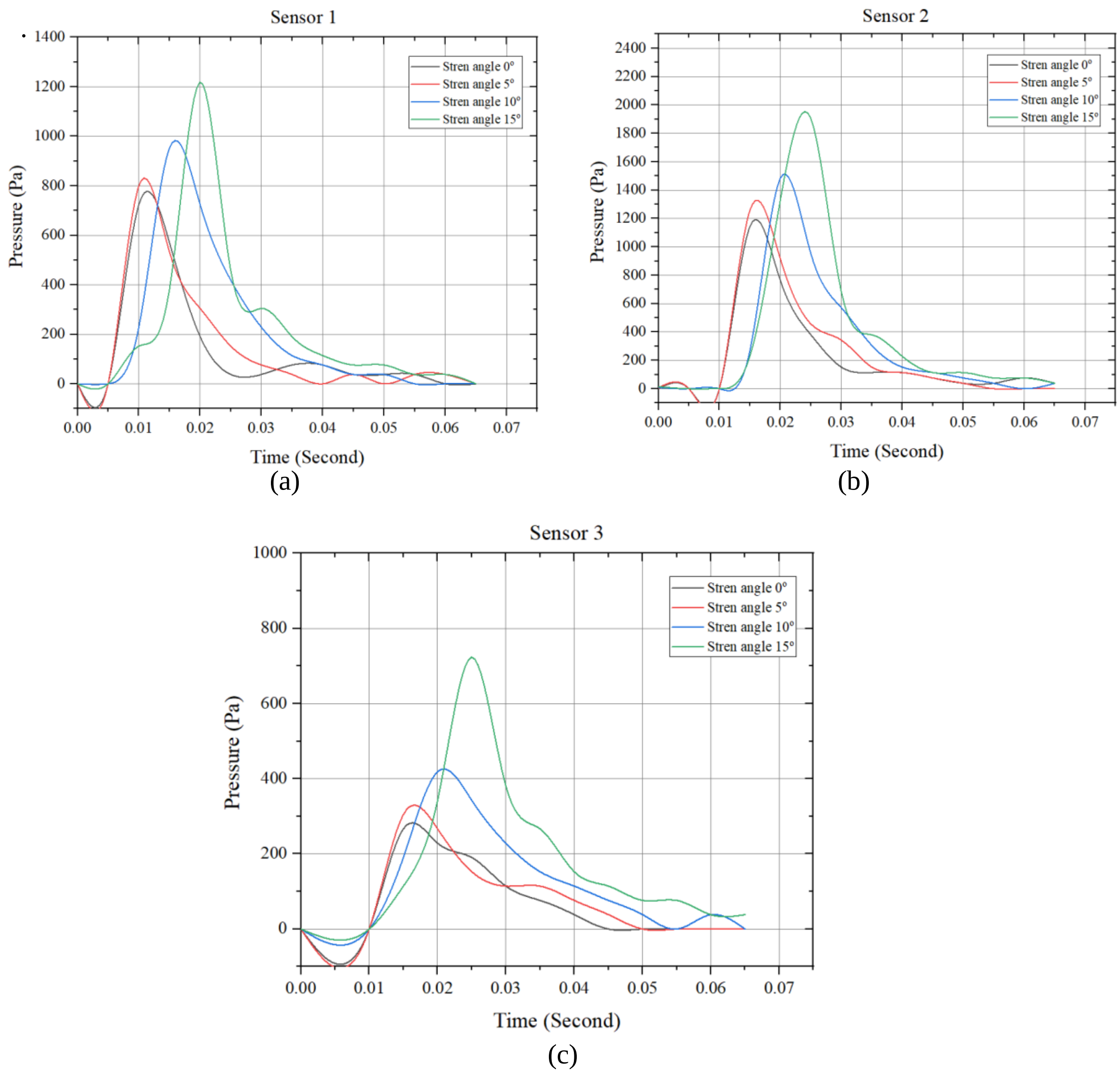


Figure 11. The time histories of the impact pressure (a) sensor 1, (b) sensor 2 and (c) sensor 3.

The time histories of the impact pressure are shown in Figure 11. Results obtained the greatest pressure occurs in the time history range of 0.009 – 0.025 seconds for all sensors. The greatest pressure occurs on sensor 2 because the position of the sensor is at the bottom of the stern, and the first sensor gets pressure when the model touches the water free-surface in that area [8].

The placement of the sensor greatly affects the pressure that occurs based on the trend of changes in the resulting data. The greater the trend angle, the greater the pressure that occurs. The smaller the stern angle, the time that occurs is faster than the larger stern angle

Based on the results of experiments that have been carried out at stern angles of 0 deg, 5 deg, 10 deg and 15 deg. The average pressure can be seen in Figure 12.

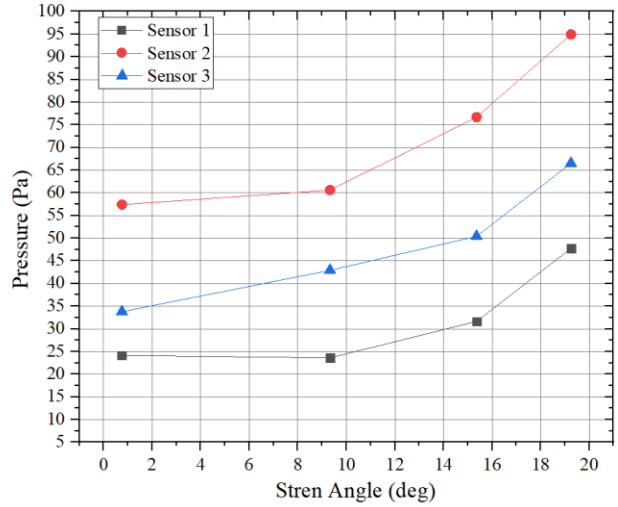


Figure 12. The value average of the pressure in each variation of the stern angle.

The average pressure at each aft slope can be seen in Figure 12. The average pressure value at each slope angle occurs on the sensor. The resulted value is a slope angle of 0.76º resulted in a maximum pressure of 57.382 Pa, a tilt angle of 9.33º resulted in a maximum pressure of 60.599 Pa, a tilt angle of 15.36º resulted in a maximum pressure of 76.688 Pa and a tilt angle of 19.25º resulted in a maximum pressure of 94.921 Pa. the trend of changes in pressure increases with increasing stern angle, increasing high pressure at the stern angle of 10 degrees to 19 degrees. The largest average pressure occurs on sensor 2 because the pressure position is at the bottom; the bottom area gets the greatest pressure impact because it is the first to hit the free surface of the water, so it is necessary to plan a good construction in sensor area 2.

After knowing the pressure around of stern, the internal stress is detected by installing a piezo sensor on the construction at the stern. The results obtained can be seen in Figure 13.

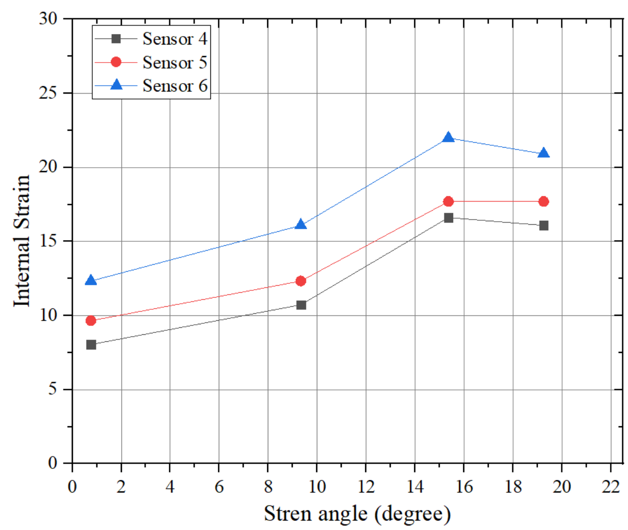


Figure 13. The value of the Internal strain in each variation of the stern angle

The maximum internal strain value at each slope angle occurs at sensor 6. The resulting value is a slope angle of 0.76º, which resulted in a maximum internal strain of 12.334, a tilt angle of 9.33º, which resulted in a maximum internal strain of 16.088, and a slope angle of 15.36º generated. The maximum internal strain is 21.987, and the tilt angle is 19.25º resulting in a maximum internal strain of 20.915. This is caused by the angle of impact between the model's stern and the water surface, so the highest internal strain value is found in sensor 6.

4. Conclusions

The value of internal stresses and strains increases with each increase in the aft angle given in the drop test. The greatest pressure occurs at sensor 2 in the bottom area, which first touches the water surface with an average increase in pressure of 23.89% and internal strain occurs at sensor 6 in the ivory construction at the stern of the ship with an average increase of 24.49% so that These areas need special attention in Typical frame section location for stern slamming and structure of the ship to minimize the damaging effects of the slamming phenomenon.

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References

[1] Rosis et.al. Hydroelastic Analysis of Hull Slamming Coupling Lattice Boltzmann and Finite Element Methods. Elsevier, 2014. Computers and Structures 138.p.24-35.

[2] Gupte, Tanmayee. Smoothed Particle Hydrodynamic, 2018. Thesis. Rochester Institute of Technology.

[3] H.Cheng. F.R. Ming, P.N. Sun., Y.T. Sui. A-Man Zhang. Ship hull slamming analysis with smoothed particle hydrodynamics method, Journal Applied ocean research, 2020. Vol. 101.

[4] S.Baso, A.N.Himaya, F.A.Samman, A.D.E.Anggriani, Rosmani. Experimental investigation of bow slamming on a ship; The effect of weight and impact angle. 2021, Journal of marine science and technology. Vol. 18, pp 51-57.

[5] Santoso D.R. Development of Instrumentation System for Stress Intensity Factor Measurement using Piezoelectric Material. 2005, The Japan Society of Naval Architects and Ocean Engineers. Japan.

[6] Rousset J.M., Pettinotti B., Quillard O., Toularastel J.L. Slamming Experiments On A Ship Model. 2020. [Online]. Tersedia:http://www.iwwwfb.or/iwwwfb20_53.pdf.

[7] Guide for Slamming Loads and Strength Assessment for vessels. 2021. American Bureau of Shipping. New York.

[8] Kapsenberg, G. K. On the slamming of ships: Development of an approximate slamming prediction method.2018. https://doi.org/10.4233/uuid:14eac2bb-63ee-47e4-8218-1ba3830a97b4.