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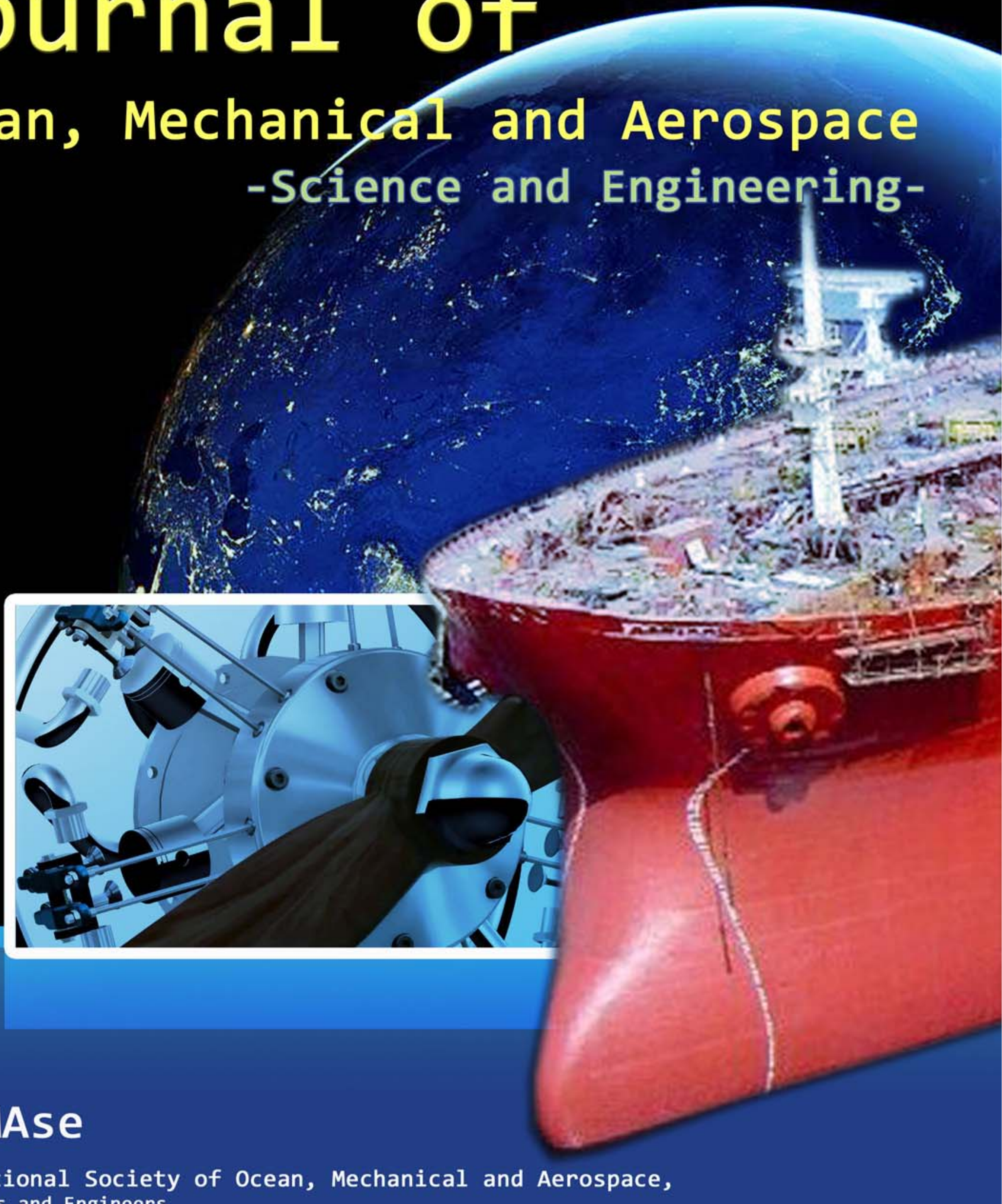

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International Society of Ocean, Mechanical and Aerospace, Scientists and Engineers

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Study on Model Scale Rounded-Shape FPSO's Mooring Lines

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ABSTRACT

This paper is proposed to discuss the model scale mooring line selection process and preparation for hydrodynamic model experiment. The model scale mooring line should be proper select for model experiment and the error should be minimized because the error in model scale mooring line will be enlarged by the scale factor and influence the design in full scale model. In this study, tensile test experiment for model scale wire ropes was conducted to collect the material properties data of the wire ropes. The data collected from the tensile test is applied to obtain the stiffness of mooring lines in the model scale. To achieve the target to select the model scale mooring lines, the minimum breaking load of the wire ropes and the elongation curve of the wire ropes are collected from tensile test for each wire rope sample. By applying catenary theory and the data from tensile test, the stiffness curve of the mooring line in model scale was estimated. The Difference between the stiffness curve between model scale and full scale is within acceptable at the required experiment range.

KEY WORDS: *Tensile Test, Wire Rope, Mooring Line, Catenary Mooring System, Model Experiment.*

1.0 INTRODUCTION

In recent development, Liquefied Natural Gas, LNG becomes an important energy source for human and the demand to the LNG is increasing from year to year.The development of offshore structure suitable for LNG exploration is very challenging and it required complexity analysis and high accurate result in design. To ensure the offloading process which involved multiple floating structures arrangement in small air gap can be safe when the FLNG is operated in open sea, the mooring system for the FLNG must be designed not only able to withstand in rough sea condition also must be able to provide enough restoring force to the FLNG when the shutter tanker come close to the structures.

To ensure the structures design and mooring system design can be worked according to the design condition, model test can be carried out to estimate the safety of whole system before fabricate of the full structure. The model test which completed with the mooring lines and rise in model scale is more preferred if the laboratory facilities are allowed. This is because the involved all the system in the model test can illustrate the response of the structures with more realistic condition when receiving the external load such as wave, wind and current.

In this study, the model scale mooring lines design is focused in this paper. The procedure to selected the model size mooring line and the scaling rule apply is highlighted here. Due to the limited of the reliable data for the suitable wire rope in model size, the tensile test also conducted by this research to collect information to simulate curve of mooring lines. The precaution to conduct the tensile test so the reliable data can be obtained also presented in this paper.

Finally, this paper will also presented the final designed mooring line and the stiffness of the mooring line between model size and full size. The difference between the stiffness of full size and model size stiffness is within the acceptable range and assumed will not cause large difference to the motion response of the model scale experiment which will conduct as the next step in the structures mooring design.

2.0 MOORING MODELLING

2.1 Scaling Rule

In this study, the mooring lines in model scale are scaling follow the Froude similarity. Froude's law of similarity is the most appropriate scaling law applicable for the free and moored floating structure experiments. The Froude number has a dimension corresponding to the ratio of u^2/gD where u is the fluid velocity, g is the gravity acceleration and D is a length of the model or prototype. The Froude number Fr is defined as $Fr = u^2/gD$.

Let the subscripts p and m stand for prototype and model respectively and λ is the scale factor, then the scaling for length, speed, mass and force is shown in Table 1.

Table 1: Scaling law between model and prototype

Dimension	Scaling equation
length, l (m)	$l_p = \lambda l_m$
speed, u (m/s)	$u_p = \sqrt{\lambda} u_m$
mass, m (kg)	$m_p = \lambda^3 m_m$
Force, F (N)	$F_p = 1.025\lambda^3 F_m$
Mooring line segment weight in water, K (N/m)	$K_p = 1.025\lambda^2 K_m$

2.2 Modeled Parameter for Mooring Lines

There are three important parameter must be scaled correctly to ensure the mooring lines are properly scaled for the selected environment and the simulation of the structure response is properly scaled to the model size. The parameters of the mooring lines must be scaled as follows [1]

- Pretension of Mooring line
- Stiffness of the mooring designed for the selected site condition
- The restoring force generated by the mooring lines to limit the movement of structures due to external load.

All the three parameter of the mooring system must be scaled to the model scale appropriately to ensure the experiment result is correct represent the structures response.

2.3 Catenary Theory

In the preliminary design, static catenary design method is typically selected to design the catenary type of mooring system for floating structure. To able apply this method to design a mooring system, few assumption of must be applied to the design. The assumptions as follows [2]:

- The seabed condition is fully flat and horizontal
- Bending stiffness of the mooring line can be neglected.
- The mooring lines is only in a vertical plane where involved with X-Z plan only.

The second assumption assumed that the bending stiffness can be neglecting is typically agreed forchain type mooring line. If wire rope mooring line is used in the mooring system, it must be ensure that the curvature curve is small.

The catenary model of mooring lines and the axial force acting onevery segment of mooring line is illustrated on Figure 1 and Figure 2respectively.

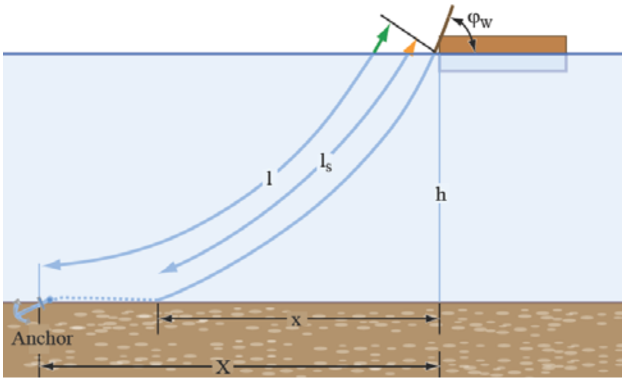


Figure 1: Single Mooring lines [3]

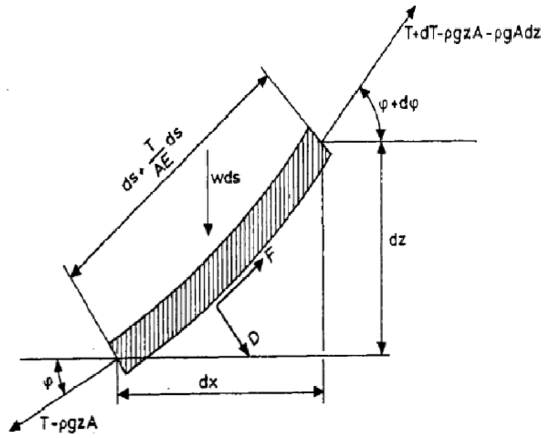


Figure 2: Segment tension of the mooring line

From the Figure 2, w is submerged unit weight/length of mooring line, A is mooring line cross-section area, $E$is the modulus elasticity of mooring line and T is tension force in line.

The axial tension of mooring line in the segment of mooring line in Figure 2 in static equilibrium condition can be estimated by the following equation [2].

$$dT - \rho gAdz = \left[w \sin\varphi - F\left(1 + \frac{T}{AE}\right)\right] ds \quad (1)$$

$$Td\varphi - \rho gAzd\varphi = wcos\varphi + D\left(1 + \frac{T}{AE}\right) ds \quad (2)$$

To solve the above equation, the effect from current, D is ignored, hence the equation become

$$T' = T - \rho gzA \quad (3)$$

By solving the equation above, the segment tension of the mooring line become as follow.

$$T = T_H + wh + (w + \rho gA)z \quad (4)$$

In equation (4), h is water depth, T_H is the horizontal tension of mooring line.

The vertical tension of the mooring can be calculated by equation (5)

$$T_z = wl_s \tag{5}$$

If the maximum external load, T_{max} act on the mooring line is known, then the minimum mooring lines length,l_{min} required to ensure the whole mooring line do not fully raise up can be calculated by equation (6)

$$l_{min} = h\left(2\frac{T_{max}}{wh} - 1\right)^2 \tag{6}$$

Also, the restoring coefficient, C generate by the design mooring line can be calculated from the equation (7) to (9) [3].

$$X = l - l_s + x \tag{7}$$

$$X = l - h\left(1 + 2\frac{T_H}{wh}\right)^{\frac{1}{2}} + \frac{T_H}{w}cosh^{-1}\left(1 + \frac{wh}{T_H}\right) \tag{8}$$

$$C = \frac{dT_H}{dX} = w\left[\frac{-2}{\left(1+2\frac{T_H}{wh}\right)^{1/2} + cosh^{-1}\left(\left(1+\frac{wh}{T_H}\right)\right.}\right]^{-1} \tag{9}$$

2.4 Mooring Line Material Properties Test

From the section 2.3, it is presented the mathematical solution to obtain the mooring line curve and horizontal tension. The required information need to obtain before the mathematical model at section 2.3 are the design parameter such as the length of mooring line, water depth, mooring line material properties.

To obtain the mooring lines material properties, tensile experiment should be conducted to obtain the required information.The information targeted to collect from tensile test are breaking load of wire rope and modulus of elasticity. The example stress-strain curve for wire rope tensile test is shown in Figure 3.

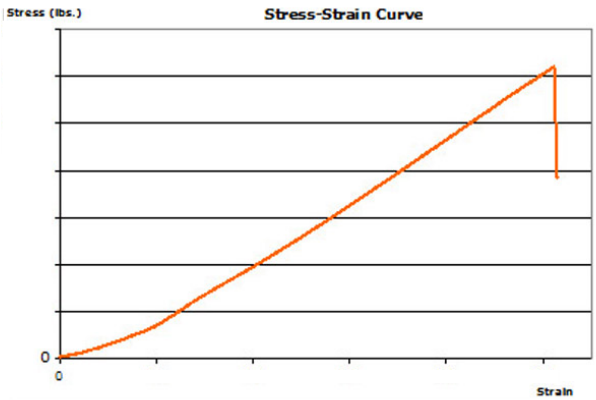


Figure 3: Wire Rope Tensile Test Stress-Strain Curve.

From the Figure 3, the breaking load of the wire rope sample can be obtained from the maximum load apply to the cable. To obtain the modulus of elasticity from the tensile test, Hook law can be applied [4]. According to Hook law, stress is directly proportional to strain.

$$\sigma = E.\varepsilon \tag{10}$$

Where, σ is stress, E is modulus of elasticity and ε is strain. The stress apply in the wire rope can be calculated by equation (11)

$$\sigma = \frac{F}{A} \tag{11}$$

Where, F is the tension force applies to the wire rope, A is the cross section area of wire rope. Also the strain from wire rope can be calculated by equation (12)

$$\varepsilon = \frac{\Delta l}{l_0} \tag{12}$$

Where, Δl the wire rope elongation and l_0 is the initial length of wire rope.

By rearrange equation (10), the modulus of elasticity for the sample wire rope can be calculated as in equation (13)

$$E = \frac{\sigma}{\varepsilon} \tag{13}$$

3.0 WIRE ROPE TENSILE TEST

Difference to the solid bar tensile test, tensile test for wire rope required more precaution to obtain acceptable result. This is because the wires rope is the roll together by several numbers of strands of metal wire laid. In this situation, the clamping tool for the tensile test and the preparation to the sample need to ensure the load apply to the wire rope can be fully distributed to all strands of metal wire laidand without concentration of force in the single strands of metal wire laidto avoid the wire rope break at the lower tension load condition due to bad distribution of force to all strands of metal wire laid.

To ensure the tension force can be distributed to all the wires in the wire rope, the wire rope end termination is claimed at both the end point of wire rope and then tensile test machine will claim at the wire rope end termination to apply the load to the wire rope during tensile experiment. The end termination applied in this experiment is showed in Figure 4, while the claimed wire rope before the experiment start is showed at Figure 5.

Figure 4: Wire rope with end termination.

Figure 5: Wire rope tensile experiment setup

Besides, there are many factors can be leaded to the failure of tensile test. From the previous experiment, it is facing few failures due to improper experiment setup. The failure face are non-uniform distribute of tension force, breaking in end termination before the wire rope failure and slip. Examples of failure tensile experiment are shown in Figure 6 and Figure 7.

Figure 6: Sample of failure tensile experiment due to breaking of end termination.

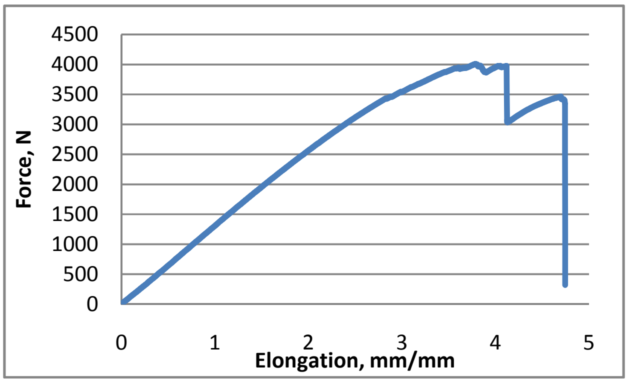
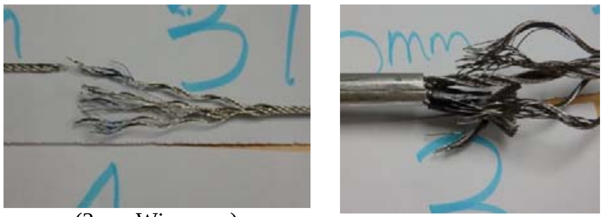


Figure 7: Sample of failure tensile experiment data.

In the tensile experiment, stainless steel wire rope with length of 200mm and nominal diameter of 2mm, 2.5mm, 6mm and 8mm were tested. Sample of success tested wire rope is showed in Figure 8 and the result from the tensile test for the wire rope nominal diameter 2.5mm and 6mm is showed in Figure 9 and figure 10 respectively.



(2mm Wire rope) (6 mm wire rope)

Figure 8: Tested wire rope samples.

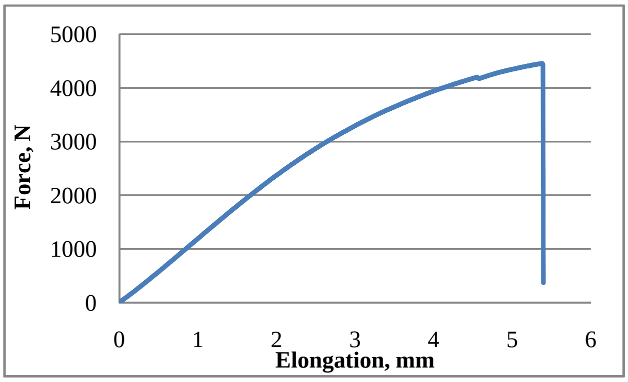


Figure 9: Tensile test result of 2.5 mm nominal diameter wire rope.

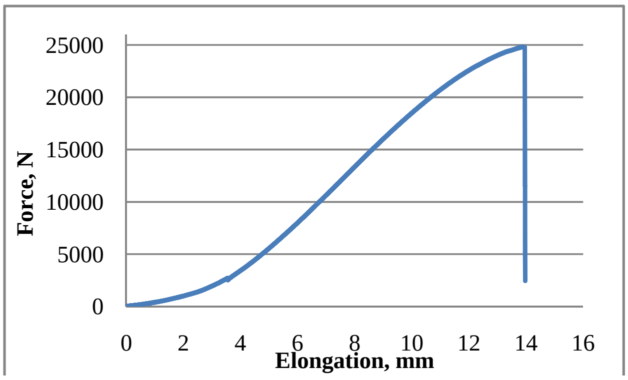


Figure 10: Tensile test result of 6 mm nominal diameter wire rope.

From the tensile test, it is obtained that the modulus of elasticity for the 6-strands wire rope is 61.0 GPa while the standard result for this type of wire rope based on specification is 58.86 GPa [5]. Besides, the minimum breaking load of the wire ropes of nominal diameter 2mm, 2.5mm, 6mm and 8mm are 3.6 KN, 4.5 KN, 24.89KN and 36.25 KN.

4.0 MOORING STIFFNESS

To simulate the effect of mooring to structures motion, the stiffness of mooring lines must be scaled properly. After the elasticity modulus and breaking load of wire ropes in model scale is knew, the calculation on mooring stiffness can be made based on the mathematical model in section 2.3. The final selection of the mooring lines and its properties is showed in Table 2 and Figure 11. And the stiffness is presented in figure 12.

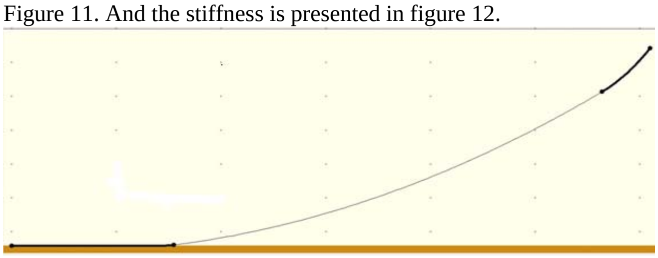


Figure 11: Mooring line profile

Table 2: Mooring line segment information

Particular	**Segment A**	**Segment B**	**Segment C**
	Model	Model	Model
Nominal Diameter (mm)	3.0	3.0	3.0
Type	Chain	Wire Rope	Chain
Segment Length (m)	4.2	11.3	1.4
Air Weight (kg/m)	0.16	0.0369	0.16
Water weight in water (kg/m) Model scale water density: 1000kg/m^3	0.1425	0.03119	0.1425
Breaking Load (KN)	10.79	5.40	10.79
Modulus Elasticity (GPa)	114.59	61.00	114.59

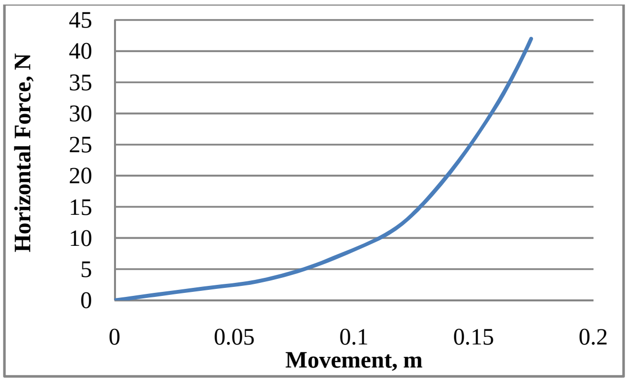


Figure 12: Restoring force from mooring line in model scale.

Besides, the comparison of horizontal restoring force generated by the model scale mooring lines and prototype is showed in Figure 13. The predicted motion of floating structures for the motion experiment is up to 8.5 meters. In the comparison, it can predicted that the motion of floating structures in model scale will slightly larger compared to the actual due to the lower restoring force provided by the model scale mooring lines.

The slightly difference between both mooring lines is expected because it is impossible to scale the entire particular from full scale to model scale. As example, the scaling of elasticity modulus is difficult to achieve because it involved the material properties of the mooring lines. To ensure the result from the model experiment is reliable, the different of the mooring lines horizontal stiffness is tried to keep as same as possible between models and prototype at the selected test range.

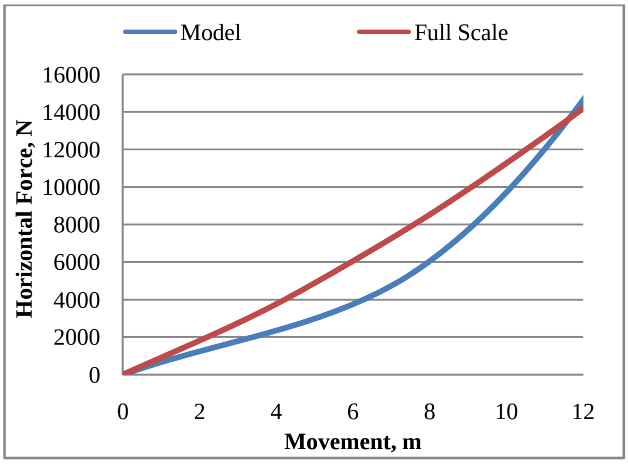


Figure 11: Comparison of horizontal restoring force generated by the model scale mooring lines and prototype.

5.0 CONCLUSION

This paper presented the mooring line preparation to conduct the hydrodynamic tank test. In this study, the static catenary theory is applied to predict the mooring lines stiffness and it generated restoring force to the structure. To able the calculation of mooring lines stiffness be conducted, tensile test of the model scale mooring lines are conducted to obtain the required information such as breaking load of the wire ropes and modulus of elasticity. The precaution of the tensile experiment is taken in this study to ensure the tensile test data is reliable to the calculation. Finally, the comparison of the mooring lines stiffness between model and prototype showed that the model size mooring lines is slightly less stiffness compared to the prototype, however, the difference is still within the acceptable for the range of restoring force required by the tank experiment.

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Issue in Design of Indonesian Traditional Ships

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ABSTRACT

Traditional ship-building is still widely practiced in Indonesia, Indonesia. Every province and regions has different characteristics in the design of ships in the traditional ships. The procedure to build traditional ships is far from the influence of technology. These provide a weakness on the safety for the design and operation. Current research seeks to promote a better understanding on design process in traditional shipbuilding in Bintan Island, Indonesia. The result is a comparison to current concept of design process in modern shipbuilding and recommendation for the traditional shipbuilding and local government.

KEY WORDS: *Ship Design; Traditional Shipbuilding.*

1.0 INTRODUCTION

Indonesia is a maritime country that most of its territory consists of the waters stretching from Sabang to Merauke. With large Indonesian waters will require a means of transportation form of the ship. Ship is a floating building used by humans as a means to carry out activities in the waters, both as a means of marine transport and fishing effort. Materials used for the construction from the wooden the ship began then continued with the iron after the discovery of iron ore, and the use of composite materials such as fiberglass.

Construction of the ship are very diverse, starting from those that are traditional to modern, utilizing advanced technology in line with the development of the technology itself. Wooden ship is one of the ships building construction that most of the material derived from wood and traditionally made. Wooden boat building techniques are different with modern shipbuilding techniques. The construction of wooden ship, do not use the latest technology. Use special expertise that exists in wooden shipbuilding. Until now the traditional ship-building is still widely practiced in Indonesia and in fact the ships that are made traditionally can be used as a means of transportation and fishing as well as all modern ships constructed.

Current research seeks to promote a better understanding on design process in traditional shipbuilding are on the Bintan island, Riau Archipelago, Indonesia (Fig 1.). Research carried out by coming directly to the wooden shipbuilding, with data collection through interviews and documentation. The result is used as a comparison to current concept of design process in modern shipbuilding and recommendation. This article will be of interest to academic readers, professionals and practitioners alike, even across policy domains.

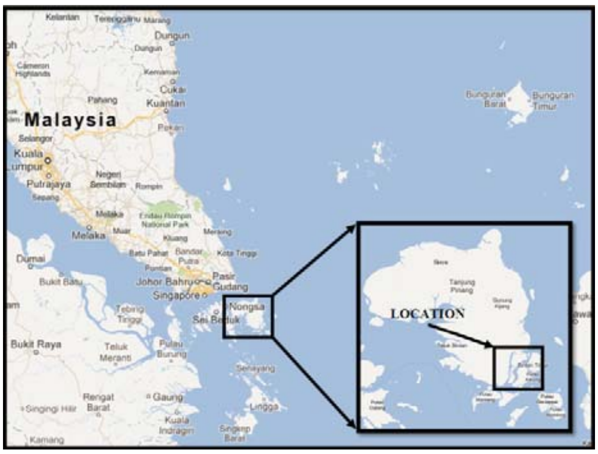

Figure 1: Location of Research at Bintan Island, Indonesia.

2.0 METHODOLOGY

This research uses descriptive method with the technique of semi-structural interviews and direct observation in the field. Research conducted at the Bintan Island, Riau Archipelago Province, Indonesia. Subject of this study is a traditional shipyard worker. The observed object is the process of design and construction in traditional boat building. Observed variable is the knowledge worker in a traditional shipbuilding in making traditional boats, which include: (i) models of traditional boats and function and (ii) the process of making traditional boats. The result is used as a comparison to current concept of design process in modern shipbuilding and recommendation.

3.0 TRADITIONAL SHIPBUILDING

Research in the field of traditional shipbuilding is very rarely found in journals and conferences. There are several institutions of higher education, particularly in Indonesia, doing research on traditional shipbuilding, such as the Bogor Agricultural Institute. The research conducted by undergraduate students such as Arofik (2007) and Umam (2007). Both conduct research on traditional shipbuilding with redesigning the ship and analyze the process of traditional ship construction.

There are also some researchers from higher education institutions in Indonesia which conducted the study in the same field such as Aji (2000) conduct research on local knowledge of traditional boat building by Biak tribe in the warsa district Biak Numfor regency with descriptive methods of data collection through a structural interview technique. Putri (2009) has conducted risk management of Phinisi shipbuilding on project implementation. This study used descriptive research methods and approaches based on risk analysis through surveys, observations and interviews.

Maidin (2003) studies the institution of boat-building by covering the way Malay boat-builders acquire knowledge, polish skills, organize their work, and the differences they show in their work, based on an in-situ observation and on interviews with boat-builders in Terengganu. Salam and Katsuya (2008) analyzed the transformation process of wooden boats in the second half of the twentieth century, in which modern technology played an important role, in order to understand the technological adaptation of the local people to the changing situation.

Current study seeks to promote a better understanding on design process in traditional shipbuilding are on the Bintan island, Riau Archipelago, Indonesia. Research carried out by coming directly to the wooden shipbuilding, with data collection through interviews and documentation. In this study the design process in traditional shipbuilding is divided into two section, (i) method and (ii) tools.

3.1 Method

Existing traditional boats and have been built on traditional shipbuilding rely on a particular techniques which is inherited skill from generation to generation. Working patterns which rely more on "instinct" a builder is tends to result product inherent with the features culture-based rather than technology-based product. The result of the ship design in traditional shipbuilding provides weakness on the safety. There is no consideration of the safety factor based on the numerical approach or rule.

3.2 Tools

The process of building traditional ships is far from the influence of technology. They do not know the numerical formulations and aids of computer. In the process, possessed only includes expertise of instinct, learned from the experience and expertise of derived from precursor workers.

With the use of simple tools and by instinct, the shipbuilder can build a ship appropriate with the orders of the owner of the vessel. In this process, the shipyard has a tool that is functioned as a drawing tool. The tools called “mal” show in the Fig.1. This mal functioned as a master or in the modern shipbuilding as database. They draw the pattern of the ship using this mal. To define the small and big the pattern is based on the instinct from the worker. Another tool used is the “meter” show in Fig. 2, function to determine the shape of the hull. Determination of the hull form is also based on the instinct of the workers. the bigger the ship, hull shape will tend to U form. The smaller the vessel, hull shape will tend to V form. Fig. 4 shows the traditional ship in the development process.

Figure 2: “Mal”

Figure 3: "Rule"

Figure 4: Traditional Ship on development process

4.0 MODERN SHIPBUILDING

The tools and techniques used to design ship structures have evolved over the last forty years, from producing blueprints on the drafting board to the digital design of today (Karr et al, 2009). Blue print made using a numerical approach and translated in the form of two-dimensional image. This numerical approach of the scientists obtained through natural phenomena translated into mathematical equations. From the mathematical equations can be specified the design safety factor.

Digital design begins with the discovery of the computer as a tool for ease of manual design work. Use of computers as a tool in the design actually comes from a mathematical equation in the form of two-dimensional images and three dimensional. The latest technology used in the ship design is proposed by Shin et al (2012), which is develop a prototype of ship basic planning system for the small and medium sized shipyards based on the internet technology and concurrent engineering concept.

4.1 Method

There are 5 type methods that used for the comparison with the traditional ship design as follow:

a. Conventional

The conventional method for ship design is use numerical approach provide from many book, literature and reference nowdays. The design using a equation such as weight equation and volume equation. Make a calculation of the resistance of the ship,then draw two-dimensional ship to be a lines plan. From the lines plan then calculate the seakeeping and manouvring the ship. Then design the structure of the ship and then make a general arrangement. From the general arrangement can start with shipbuilding process.

b. Memory based learning method

Lee and Lee (1999) proposed on the use of case-based reasoning for selecting reference ships in conceptual design stage. They developed a memory based learning method that can build an effective indexing scheme for retrieving good reference cases from a case base of previous ship designs as design candidates. Of the design candidates obtained by indexing process, their priorities are determined according to similarity assessment derived through the nearest neighbor matching algorithm. As a result of this work, a reliable design support system is now available which greatly helps ship designers perform the conceptual design using existing mother ship data.

c. Case based reasoning approach

Turan, Aksu, and Cui (2006) propose a case based reasoning decision support system for ship design by using of the existing designs. The case based approach provides a very quick determination of dimensions and ship characteristics, which are suitable for the new design requirements.

d. Ruled based approach

Rule-based approach at each stage of model development is cross all disciplines, from early design to manufacturing output. By using the same properties and geometry throughout each stage of the design, the rules can make consistent selections, and can be used to automatically update those selections due to design modifications. (Cochran, 2007).

e. Knowledge-base engineering method

Wu and Shaw (2011) propose a basic ship design process using knowledge-based engineering methods. The main benefit of the KBE system is its extensibility and highly editable rules. Thus, when we modify the design logic, design parameters, and formulas, complex system program revisions are unnecessary; all of the tasks may be performed through the rule editor interface, where users add or modify rules. Generally, this mode efficiently reduces the program development skills needed by the engineer and the development work by program developers.

4.2 Tools

The tools for each 5 method are following:

a. Conventional
In the numerical approach the tool for design a ship is use drawing tool and computer-aids design. This is the conventional way on the design of the ship. For computer-aids design, nowdays there are many software for ship design. The functioan of the computer-aids design is as a tool to simplify the work in ship design. Special skills required in designing the ship using computer-aids design.

b. Memory based learning method
Computing the degree of match by using the algorithm is straight-forward and easy. Indexing and retrieving processes are suitable tools to assist a designer in conceptual design process and as the interactive intelligent conceptual design system is integrated with case base, database, and interactive conceptual design program by API module, it is possible to support the process of design intelligently.

c. Case based reasoning approach
Using a software tool developed for the application of case based reasoning (CBR). The software is developed in a flexible fashion in order to implement different similarity functions and adaptation algorithms of CBR.

d. Ruled base approach
Using a computer-aided ship modeling SmartMarine 3D. SmartMarine 3D relies on a series of connections that are created between model objects in the early and detailed design stages. The connections drive user-customizable code, and the code uses model geometry, properties, and user input to make decisions about feature placement and manufacturing output.

e. Knowledge-base engineering method
The design information is managed a document-based approach, which requires the conversion of the original documents into the XML (eXtensible Markup Language) format, and compiles rules for the basic design process. With process store the design information using a document-based approach, which analyzes document formats and data and uses the XML format to manage the documents for delivery to the sales department and ship owners after applying the modules. Furthermore, the documents ontology structure allows data to flow down stream to provide later design reviews such as with the KBE inference system or design tool output. (Wu and Shaw, 2011).

5.0 DISCUSSION

As described in the previous section on how to design a ship from traditional shipbuilding and modern shipbuilding, this section conducted a comparison between traditional and modern shipbuilding by looking at two aspects, as follow (i) method and (ii) tools. Comparison design between traditional and modern shipbuilding are shown in Table.1 and Table.2.

Table 1: Comparison of Ship Design between Traditional and Modern Shipbuilding

No	Aspect	Traditional	Modern	
			Conventional	Lee and Lee (1999)
1	Method	Instinct	Numerical	Memory based learning method
2	Tools	Mal	Drawing Tool and CAD	Indexing and retrieving processes

There is some research on the traditional ship that currently use a modern shipbuilding approach. The research conducted by undergraduate students of Bogor Agricultural University, Indonesia. one of which is research conducted by Arofik (2007) and Umam (2007). Both conduct research on traditional shipbuilding with redesigning the ship and analyze the process of traditional ship construction. process Redesign carried out by numerical calculations approach based on the calculation is common in ship design. The results obtained in the form of a line plan show on Figs 5-6.

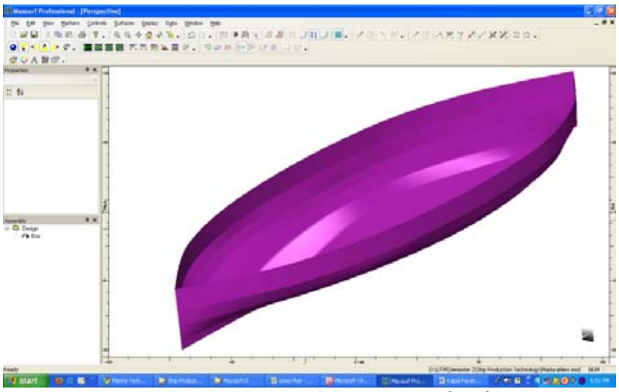

Figure 5: Payang Ship Model on Maxsurf Software.

One issue on traditional Shipbuilding is the use of technology as a design tool. In the traditional Shipbuilding there is no use of computer-aided design tools. One of the functions of computer aids design is as a store of data. By using the line plan of Figs. 5-6, then conducted modeling in Maxsurf software for the collection ship as shown on Figs 7-8.

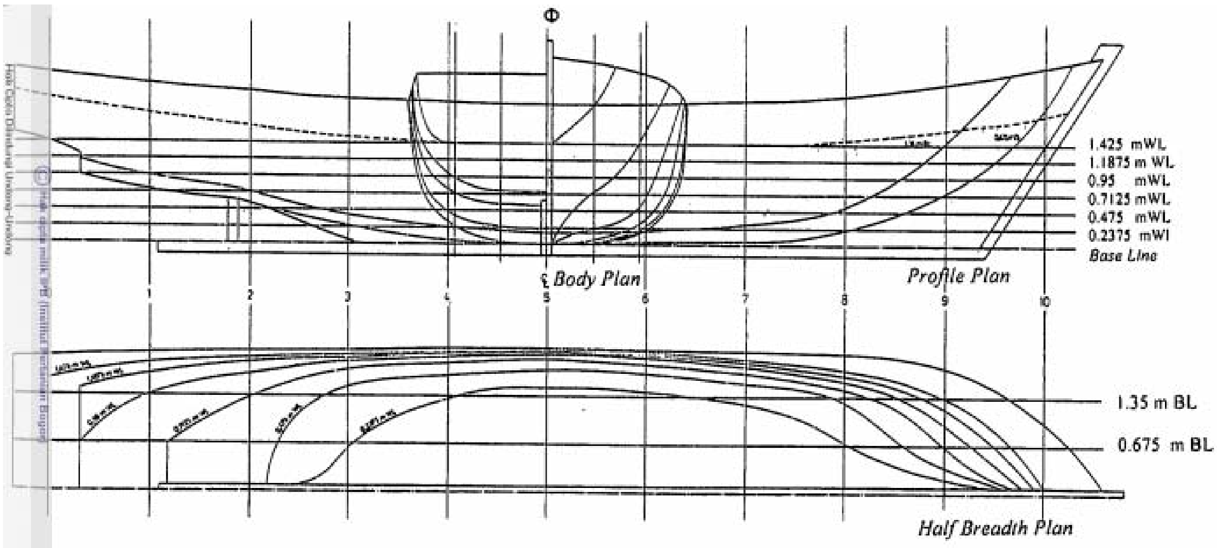

Figure 6: Lines Plan of Payang Ship on Pamekasan, Madura, Indonesia (Arofik, 2007).

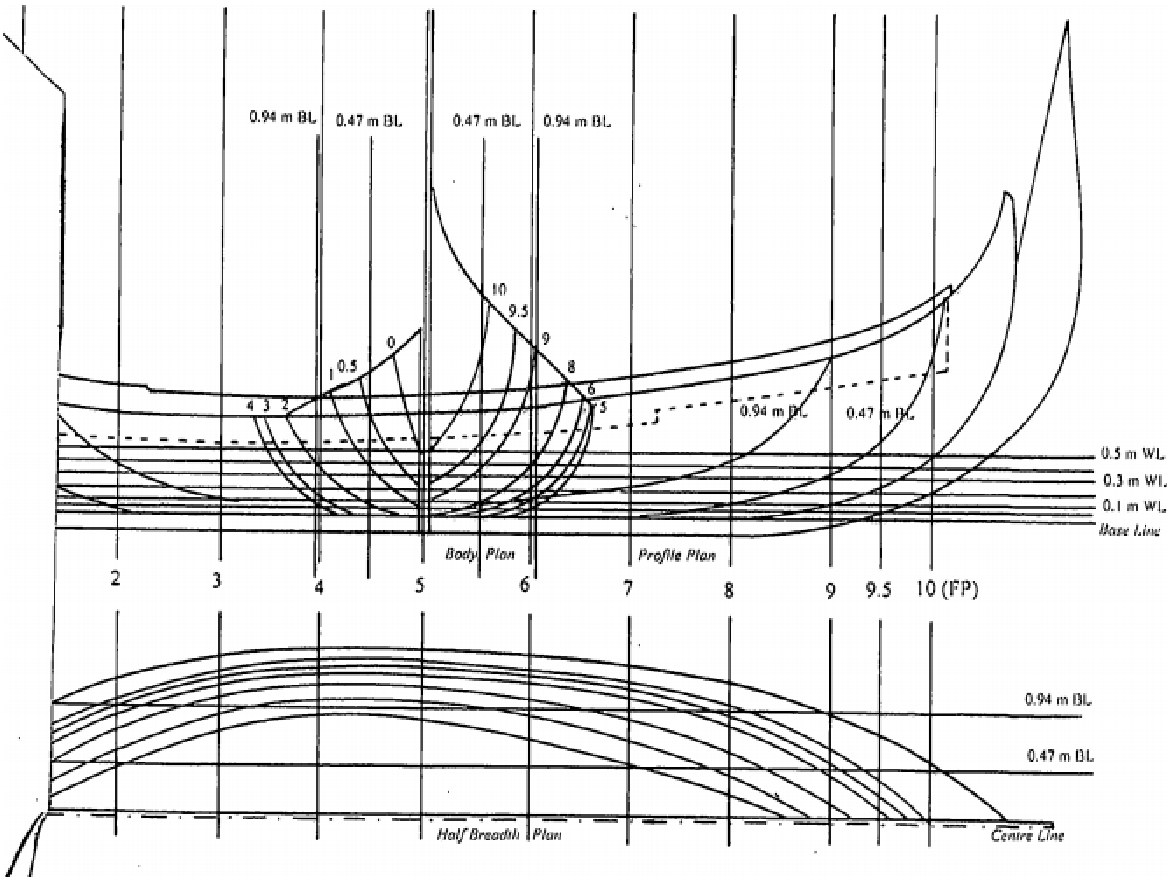

Figure 7: Lines Plan of “Semangat Baru” Purse Seine Ship on Tidung Island Shipbuilding (Umam, 2007).

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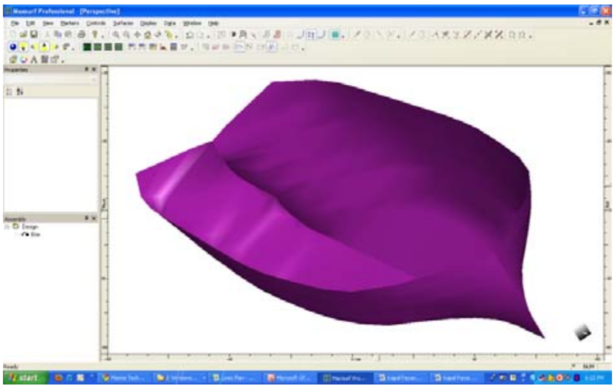

Figure 8: "Semangat Baru" Ship Model on Maxsurf Software.

The different between the traditional and modern shipbuilding is obvious. The difference is the technology used from each of the shipbuilding. In the traditional shipbuilding is very far from the use of technology. Technology used to build the ship is use a special expertise in the form of instinct gained from experience and its predecessor workers. Disadvantages of this method are the safety factor is not taken into consideration in designing the ship. In another side, the modern shipbuilding uses the latest technology where safety factor is included into consideration in designing the ship.

Table 2: Comparison of Ship Design between Traditional and Modern Shipbuilding (contd.)

No	Aspect	Modern		
		Turan, Aksui, and Cui (2006)	Cochran (2007)	Wu and Shaw (2011)
1	Method	Cased based reasoning approach	Ruled based approach	knowledge-based engineering methods
2	Tools	Software	SmartMarine 3D	document-based approach

Weakness owned by of traditional design should be given priority improvements, leaving the side of the revolutionary tradition. To improve safety factor, it can be recommended to use one of the four ways on the modern shipbuilding. Can also be combined from the four ways in order traditional shipbuilding can compete.

5.0 CONCLUSION

The procedure of building ships at traditional shipbuilders is far from the influence of technology. These provide a weakness on the safety for the design and operation. Current research provides the design process in the traditional shipbuilding in Bintan Island, Riau Archipelago Province, Indonesia. The result is a comparison to current concept of design process in modern shipbuilding and recommendation for the traditional shipbuilding and local government. The recommendation is use one of the four ways on the modern shipbuilding or combined from the four ways in order traditional shipbuilding can compete.

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Pressure Distribution at Water Entry of a Symmetrical Wedge

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ABSTRACT

In current study, numerical and experimental investigations about water entry problem were conducted for a symmetrical wedge. The water entry problem for different geometries is one of the classical methods for determination of pressure distribution and loads around the hull of marine vehicles. These data can be used for optimum structural design of vessels particularly for high-speed crafts, which are very sensitive about the weight. In addition, the quantity of load can be considered in the equation of motion for analyzing the seakeeping performance of such vessels. In this research, the numerical analysis of free falling wedge with 30° deadrise with constant weight was done and for validation of results, it was followed by experimental tests. The outputs of this study consist of some graphs for comparison of trends for pressures respect to impact time, which can be used for signification of loads on hulls during the water entry phase.

KEY WORDS: *Water Entry, Wedge, Pressure Distribution.*

NOMENCLATURE

h_w	Height of water (m)
h_C	Width of channel (m)
h_D	Drop height (m)
C_p	Pressure coefficient (-)
P	Pressure (Kpa)
V	Velocity (m/sec)
Greek symbols	
α	Deadrise angle (Degree)
ρ	Water density (Kg/m^3)

1.0 INTRODUCTION

In recent years, the application of high-speed crafts has expanded in different fields and despite these applications relevant topics such as loading estimation, structural design, motion control and etc. became important for researchers more than past.

High-speed crafts encounter wide range of impact loads during their lifetime because of jumping through the waves and coming back to water surface in various sea-states. So the water entry problem can be used as a basic solution for estimation of loads on their hull. Besides that, the slamming phenomenon, which is considered as a limitation for structural design, can be predicted in this way.

Water entry problem was known as a useful way for prediction of pressure on the hull of seaplanes by Von-Karman [1] in 1929 and he conducted some theoretical models for calculation of maximum pressure for that vessels. After him, in 1932 Wagner proposed an analytical method for modeling of water entry problem with some modifications on Von-Karman's model [2]. Dobrovolskaya [3] in 1969 with an analytical method based on similarity solution studied about falling of a wedge into water with constant speed. In 1988 Payne [4], Korobkin and Pokhnachov [5] established some studies about impact of water on rigid bodies.

In recent years, researchers followed up the process of water entry evaluation by different numerical methods. For example, Zhao and Faltinsen [6] worked on Wagner's theory through conformal mapping and conducted an approximation in 2D cases. This strategy was continued by Mei [7] in 1999. In new studies some additional effects during impact problem, was considered such as hydroelasticity. For example Zamani-rad and Seif [8] was done simulation of hull water impact based on numerical methods for study of hydroelastic effect during the slamming process of wedge-shaped bodies.

Besides these theoretical investigations, some experimental developments had done on water entry problem of different geometries. In 1950, Bisplinghoff and Doherty [9] had done experimental tests on wedges and proposed a theory for prediction of free surface during water entry. In 1970, Chuang [10] started experimental tests on wedges with different deadrise angles and measured maximum pressure on them. Chaung also in 1967 [11] studied about the impact of plane's surface on still water and evaluated the effect of trapped air between water surface and hull in small angles. Ochi and Bonilla in 1970 [12] and Chaung in 1973 [13] studied about penetration speed and water impact on complex geometries such as boat's hull. Greenhow and Lin [14] in 1983 continued the experiments for some different wedges and focused on water current around the hull.

In 1994, Lin and Ho [15] had done some experimental tests for impact of 2-D wedges in different heights and compared the results with numerical analysis based on boundary element method. They showed that the maximum impact pressure in shallow water is greater than similar condition in deep water. In 1997, Zhao [16] proposed two methods for water entry analyzing with non-linear simulation of Laplas equation and analytical solution of Wagner and validated the results with experimental tests of 30° wedge with results of pressure coefficient, slamming force, impact velocity and water level condition. The studies of Ming-Chung Lin and Li-Der Shieh in 1997 [17] prepared experimental results on round hull pressure distribution during water entry. Study about impact of surface plane and water level was continued by Engle and Lewis [18] in 2003 and they compared the results of numerical and experimental methods for maximum pressure due to water impact for symmetrical wedge in different initial speed. These studies showed the validity area and accuracy of various methods. In 2004 Faltinsen [19] studied about some important application of water entry problem such as wetdeck slamming, green water, tank sloshing and etc. Also in this year Wu [20] conducted some experimental tests on wedges with 20 and 45 degree deadrise and compared the results with numerical data of complex method of analytical and BEM solutions. Yettou et al in 2005 [21] had done some experimental tests on different wedges for calculation of pressure coefficient with different weights and heights. They showed that deadrise angle has more importance effect on pressure in comparison with weight and drop height. In 2010, Sayeed et al [22] evaluated of slamming force on wedge with 10° deadrise and their results showed good correlation with Chaung's data. Javaherian et al [23] had done parametric experimental study about pressure distribution of pressure during water entry for 3 deadrise angle which dropped into water from various heights. They proposed some graphs for pressure coefficient respect to time and they compared the data with other references.

Figure 1 shows the effective parameters such as peak pressure, position of it and the schematic view of pressure profile as important items in water entry process.

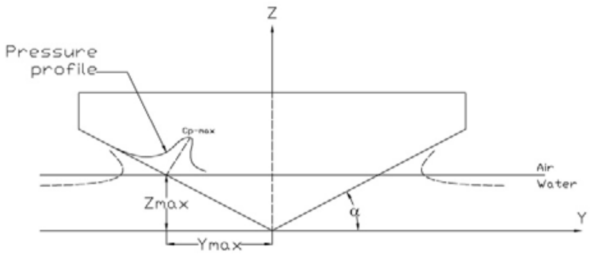

Figure 1: Slamming pressure's parameters during water entry

The time variation in short period is one of the problems for solving the water entry process and measurement of pressure need accurate numerical simulation and special experimental facilities. In real condition, the rapid transient pressure changes cause some difficulties in process conditions.

In this paper for a symmetric wedge with 30° deadrise and constant weight, the pressure distribution was discussed through numerical and experimental analyzing. In addition, a configuration of experimental test setup which designed for testing of hydrodynamic loads on basic geometries during water entry was explained that can be used in future researches of similar problems. Based on the results, estimation for hydrodynamic loads on 2-D sections can be proposed which may use in design of high-speed crafts and similar structures.

2.0 NUMERICAL ANALYSIS

After modeling of geometry according to Figure 2, numerical analysis started when the wedges contact the water surface. The weight was considered about 38 kg. For meshing of analysis domain, the 2D structural mesh was used and the upper border of model was considered as atmospheric pressure. The surface of wedge was assumed as a no slip area.

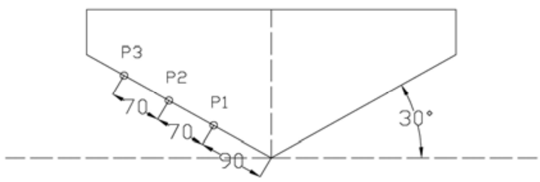

Figure 2: General view of model and position of pressure sensors (Dimensions in mm.)

Figure 3 shows the simulation of water entry and the spray at the moment of impact can be clearly observed.

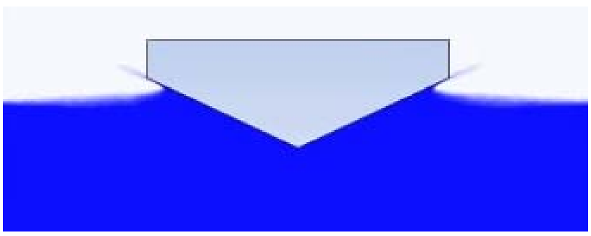
Figure 3: Free surface of liquid for impact of wedge during water entry

3.0 EXPERIMENTAL TESTS

The test set-up configuration is shown in Figure 4. A vertical guide is fixed to the wall of channel for both side of wedge and it can move freely with two sliding guides. The water level was considered at 1 m and maximum height of drop was set to 1-1.3 m. The wedge was made from the fiberglass material.

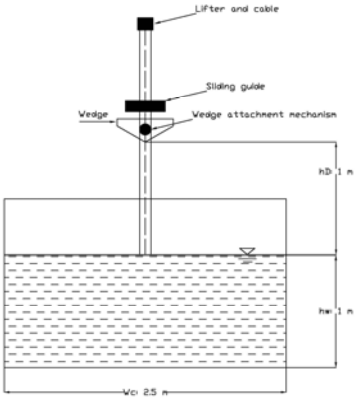

Figure 4: Illustration of test set-up's main elements and basic dimensions

The length of channel is 25 m and the width and height of it are 2.5 m and 1.5 m respectively. It was located in marine laboratory of mechanical faculty of Sharif University of Technology and general view of test set-up is shown in Figure 5.

Figure 5: General view of test set-up after installation in channel

Three pressure transducers were installed on one side of wedge according to Figure 2. These sensors can measure the pressure up to 1000 psi with accuracy range of 0.001 psi. In addition, a suitable data acquisition system with three channels was constructed for receiving of data from sensors. Sensors have the capability of measuring the 25000 data in second. The tests were done for a weight of 38 kg which was adjusted with extra weights on the it. Test's parameters are shown in Table 1.

Table 1: Test's parameters

Deadrise (Degree)	Weight (Kg)	Drop height (m)
30	38	0.2

The wedge was dropped vertically under effect of its weight and each test was repeated five times. The average of results was used as final data. When the wedge contacts the water surface, sensors can register the pressure's changes over time and with having the data the pressure coefficient can be calculated with following equation:

$$C_p = \frac{P}{\frac{1}{2}\rho V^2} \qquad (1)$$

4.0 RESULTS AND DISCUSSIONS

The estimation pressure at defined points of wedge during water entry is shown in Figure 6. It can be seen that the pressure for all points has an increasing trend until reaching a peak and after it decreases over the time. Also the points which were installed in higher heights encounter smaller peak pressure because of damping effect of water.

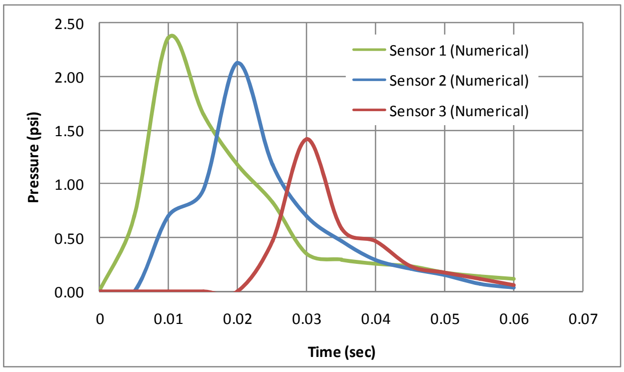

Figure 6: Pressure distribution in comparison the time during the numerical analysis for different points

Figure 7 shows the similar graphs from experimental test's data and equivalent trend can be seen in different position of measurement.

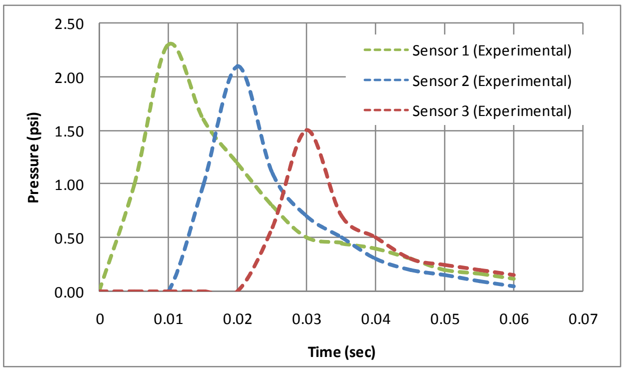

Figure 7: Pressure distribution in comparison the time during the experimental tests for different points

Figures 8, 9 and 10 depict a comparison for results of each point with numerical simulation and experimental results, respectively. It was clearly observed that the trend of results for both approaches are similar but there were some differences between them, which can be explained due to variations of modeling methods and assumptions.

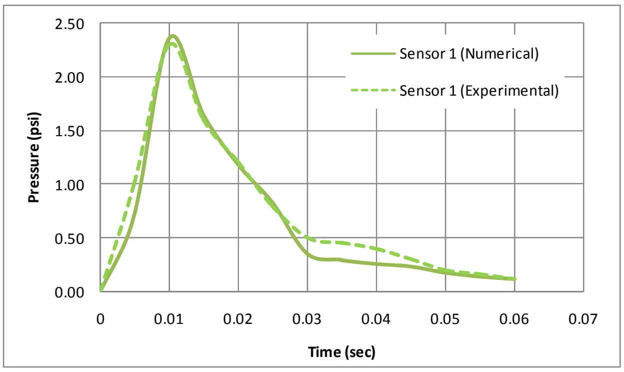

Figure 8: Comparison of results of numerical simulation and experimental test for pressure sensor no. 1

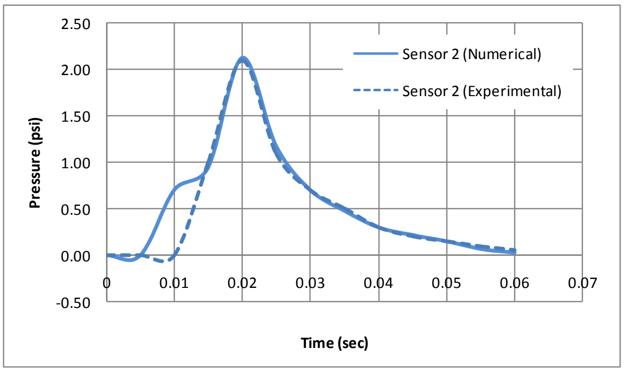

Figure 9: Comparison of results of numerical simulation and experimental test for pressure sensor no. 2

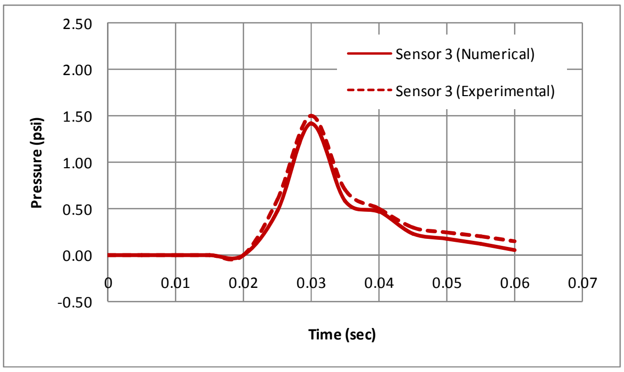

Figure 10: Comparison of results of numerical simulation and experimental test for pressure sensor no. 3

For future reference, these graphs can be used for deriving some parametric analysis for calculation of Cp and estimation of pressure for various points.

5.0 CONCLUSION

In this paper, Numerical analyses of water entry problem for a wedge were conducted by commercial software “Ansys” and followed by experimental tests with similar conditions. The results from this study can be used in the design phase of marine vehicles and other structures.

The results are evident of similarity of data by two methods. However, it can be seen that numerical method’s output gives underestimate values in comparison with the experimental results which should be considered in design phase. In addition, the correction factor of data for numerical analysis can be found as a useful parameter for future researches. In a nutshell, the selected software has been proven efficient for modeling water entry problem for wedge water entry subjects. This preliminary study will be followed up by future tests which will be carried out in the near future.

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Jacket Structure's Responses due to Ship Collision

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ABSTRACT

Jacket structure is affected by fluid load or external load when it operationed. One of external load that affect it is impact load subject to something collision. This examination talked about graded and velocity supply vessel influence to local and global structure damage subject to collision. Jacket structure in this examination is CONOCO BELANAK wellhead plaform, mass of supply vessel is 2500 tonnes, with tidal variation (such as: MSL, HWL, LWL) for scenario sideway and stern/bow impact for each normal and 10% exceedane velocity. Deformation type of landing platform impact load is dent subject to landing platform material unability to proof againts pressure. This examination refers to J.P. Kenny in 1988 with title Protection of Offshore Instalasions agains Impact. This examination uses 2 software are ANSYS LS-DYNA 9.0 version and GT-STRUDL 27.0 version. First of all, modeling geometry and loading in ANSYS LS-DYNA to acquired local deformation. Than modeling jacket structure in GT-STRUDL to acquired global deformation uses dynamic trancient analysis. Outside diameter of landing platform is 0.9144 m with wall thickness is 0.0381 m. Normal velocity in each sideway and stern impact is and 10% exceedance velocity is 0.28 m/s and 0.39 m/s. 10% exceedance velocity in each sideway and stern impact is and 10% exceedance velocity is 0.54 m/s and 0.73 m/s. The resutl of this examination is dent of landing platform for each normal and 10% exceedance is 0.2725 m and 0.2352 m, it must be repaired or changed because of it is 10% larger than spacing frame. Maximum displacement x, y, z direction is 0.2423 m on 0.38 s, 0. 0559 m on 0.39 s, 0.7492 m on 0.41 s. The deformation in landing platform and jacket structure is smaller than examination result indeed.

KEY WORDS: *Landing Platform; Impact; Dent; Eksplicit Method; Dynamic Respondes.*

1.0 INTRODUCTION

Development damage of offshore structure will be occur for along time. One of the large deformation is due to severe ship-platform collision. Such collision are considered to be a dynamic phenomenon that has costly consequences in material, environmental, and human terms. The dynamic collision response of platforms should be analyzed at the design stage. This precaution ensures that the structure has sufficient strength to withstand impact and therefore has a low probability of severe collision damage.

The secondary data is available in Kenny (1988) research report such as accident due to vessel and collision velocity scenario for collision details. There have been 3 reported incident of impact between very large vessels, such as semi-submersible work barges or drilling rigs, and jackets under construction. This type of impact is potensial cause of significant damage. Consequently, the construction period would appear to be a perticularly high risk period (Kenny, 1988).

The supported data such as ship displacement, ship velocity, record accident, and rules that get Kinetics Energy at structure collision than kinetics energy will be distributed to supply vessel and structure.

The paper presents the velocity effect and collision form of supply vessel to structure and the response and strength of the structure in extreme condition based on accident record at barge bumper and jacket leg. 2500 tonnes supply vessel is observed on the mean, low, and high sea water levels. Colision velocity at stern and bow impact for normal condition is 0.28 m/s and 0.39 m/s. Collision velocity at sideway impact for extreme condition is 0.54 m/s dan 0.73 m/s. Collision effect at landing platform and global jacket structure.

2.0 LITERATURE REVIEW

Offshore jacket platforms have been widely used in offshore oil and gas exploitation with complicated ocean environments. Besides the normal operational loads, the platforms are subjected to other loads, such as wind, wave, current and ice loads (Jin, 1996). At the same time, the platforms are also exposed to unexpected incidents inducing sudden loads due to collision of a vessel with the platform, or impact from a heavy object dropping from the top of the platform. These may result in crooking or buckling of some members, thus reducing their load bearing capacity and potentially affecting the safety and the integrity of the whole structure. To effectively repair the damaged members and restore the desired state of the structure requires a good assessment of the condition of the structural system after an accidental event (API RP-2A WSD, 2000).

The impacts between supply vessels and offshore structures were analyzed by Jorgen in 1983 with two particular areas which were energy dissipation in the ship's bow and stern structures and the deformation behavior of tubular bracings. Various mechanisms of energy dissipation in a ship structure subjected to collision loads were identified and described; design curves were proposed for bow and stern impacts with supply vessels. The different modes of energy dissipation were described, for assessing the load carrying capacity in the beam mode of deformation accounting for the detrimental effect of local indentation.

Jorgen.et.al in 1993 studied a numerical simulation of ship collision with a jack-up and a jacket platform focus on the effect of dynamic on the platform response in term of energy dissipation and load effect using Non-liner Finite Element USFOS. In the study, three factors seem to be important: the local strength of the platform and the strength of the ship relative to the overall strength of the platform, the duration of the collision relative to the fundamental period of the governing motion and the strength of the members transmitting forces needed to accelerate the deck. The jack-up behaves elastically for the design ship beam impact. The jack-up has little sensitivity to uncertainty in ship deformation characteristics and impact speed. The jacket response for impact scenario considered can be reasonably well predicted by static approach, because the impact duration is relatively long compared to the fundamental period of the governing motion and contact.

Zheng.et al in 2003, proposed a simplified method for determination of impact duration and transient dynamic response based on sixth degree of freedom (SDOF). Results of calculation using the method were compared with the results from a global jacket-topside non-linear dynamic analysis using program USFOS for validation. The analysis showed the non-linear dynamic analysis was time consuming and the threshold of using the program is still high. The SDOF approach may be a good engineering alternative for further design applications. Further verification works was recommended in order to quantity uncertainties associated with the SDOF approach.

Jin.et.al in 2005 evaluated damage to offshore platform structures due to collision of large barge. The study applied a non-linear dynamical analysis procedure for firstly determining the impact action based on the forensic evidence from the damaged components, and then evaluating the overall damage effects on the platform structure. The impact action of the barge is simulated with a triangle impulse load with different collision contact times. The curves relating the indentation deformations of the damaged member with different collision contact times were simulated using an estimated velocity of the impacting ship. The study found for the particular case, yielding occurred only for the diagonal brace member around its connections to the two legs, while the remaining part of the structure exhibited no inelastic response. Repairing and strengthening appears to be necessary only for the diagonal member which was directly hit during the collision.

3.0 SHIP COLLISION THEORY

3.1 Jacket

Jacket is made of steel substructure construction of pipelines that serve as templates for pilling up from the seabed to rise above sea level. This section is submerged in the water that serves for guidance and anchoring pile lateral forces to the stability of the construction. In addition it also provides a buffer for some equipment such as risers, caissons, boat landing and other.

3.2 Energy Mechanics

Concepts of basic physics, the conservation of mechanical energy of an object which is allowed to fall from a height h under the influence of gravity g, which because of air resistance is ignored, as shown in Fig.1.

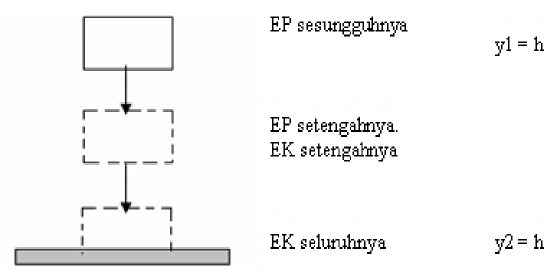

Figure 1: Energy Mechanics (Giancoli, 2001)

The object is initially at rest, only coined the potential energy (T). When dropped, the object T is reduced (because y is reduced). But the kinetic energy (V) increases to compensate, so the number of both remains constant. At each point of the trajectory, the total mechanical energy (E) given by (Giancoli, 2001):

$$E = T + V = mgy + \frac{1}{2}mv^2 \quad (1)$$

Just before falling to the ground, where y = 0, then all the potential energy is converted into kinetic energy.

$$0 + mgh = \frac{1}{2}mv^2 + 0$$

Thus,

$$T_2 = \frac{1}{2}mv^2 = mgh = V_1 \quad (2)$$

3.3 Collision Mechanics

According to the direction, the collision can be divided into two, the first collision is central if the center of mass in line with the direction of movement of the object and the second is if the center of mass collision obligue membetuk angle.

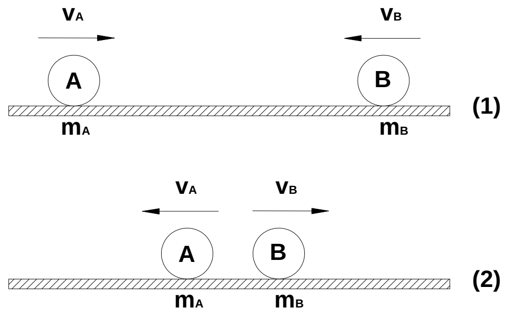

Figure 2: Collision of two objects: (1) Before the collision, (2) After the collision

In the case of the collision mechanism of momentum applies.

$$m_A v_A + m_B v_B = m_A v'_A + m_B v'_B \quad (3)$$

Of the concept of the collision mechanism, it is found that the coefficient of restitution is formulated according to the following equation:

$$e = \frac{(v_B - v_A)'}{(v_B - v_A)} \text{ dimana } 0 < e < 1 \quad (4)$$

For the case of perfect collision resilient (elastic) value of e = 1 to equation 2.2 becomes:

$$v_A - v_B = v'_B - v'_A \quad (5)$$

While for the case of collision does not eject (plastis) the value of e = 0 so that equation 2.3 becomes:

$$v'_B = v'_A = v \quad (6)$$

That means that after the collision of two objects moving with the speed and the same direction. In fact there are punches that punches eject some of that is the value of e ranges between 0-1.

3,4 Beam Centered Impact Problem

Before studying the impact on the pipeline due to trawling gear, conducted the discussion centered on the beam impact problem (affected beam impact in the middle(12)). It is assumed that the beam with a simple pedestal has a length L, which is exposed to impact loading in the middle by a rigid object with a moving mass mA constant initial velocity of vA.

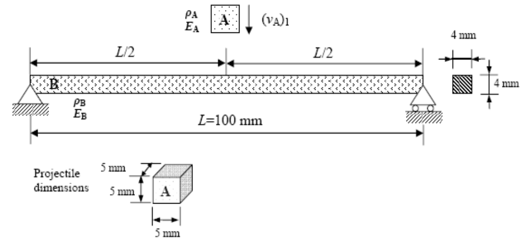

Figure 3: Beam impact problem

Because the impact occurred at one point, the problem can be solved by concentrating the whole mass of the beam at one point in the center of the beam, as shown in Fig.4.

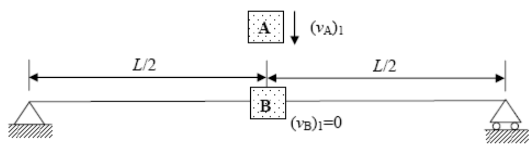

Figure 4: Simplification impact beam problem

Problem solution is divided into two stages. The first is the impact between two masses each have the early speed. At this level of impact force that occurs at the beam exactly equal to the force generated by the beam to an object against his fist. While the second stage is when the two move toward each other the mass and the same speed, for example at plastis perfect punches. Or in other words that the coefficient of restitution of the problem is e = 0. The determination of the restitution coefficient value has been paid to the concept of punching mechanism.

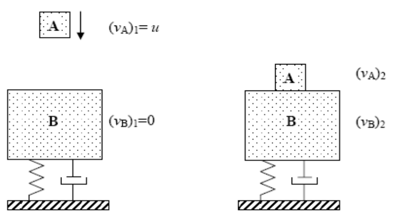

Figure 5: Plastic deformation after the collision

If the object is dropped from a height h, the speed of the object can be calculated with the energy conservation law, namely:

$$T_0 + V_0 = T_1 + V_1 \quad \rightarrow$$

$$0 + m_A gh = \frac{m_A v_A{}^2}{2} + 0$$

So,

$$m_A gh = \frac{m_A v_A{}^2}{2} \qquad \rightarrow (v_A)_1 = \sqrt{2gh} \tag{7}$$

Then use the principle of impulse and momentum. Obtained by integrating the equation of motion with respect to time. Motion equation can be written using Newton's laws II:

$$\sum F = m \cdot a = m \cdot \frac{dv}{dt} \tag{8}$$

Multiplying dt on both sides and integrate anatra limit v = v 1 at t = t1 and v = v2 at t = t2.

$$\sum \int_{t1}^{t2} Fdt = \int_{v1}^{v2} mdv = mv_2 - mv_1 \tag{9}$$

Particle initial momentum plus the total number of impulses that occur from t1 to t2 is equal to the particle momentum end. The principle of linear impulse and momentum in vector form is written with the following general equation:

$$\sum m_j \vec{vo}_j + \sum \int_{t1}^{t2} Fdt = \sum m_j \vec{vf}_j \tag{10}$$

Where $\vec{v_0}$ is the beginning of the velocity vector for mass j, $\vec{vf}$ is the end of the velocity vector for mass j after the impact and $\vec{F}$ the force vector transmitted during impact. Impulse is a vector quantity equal to the extent of area under the force-time curve in Fig.6.

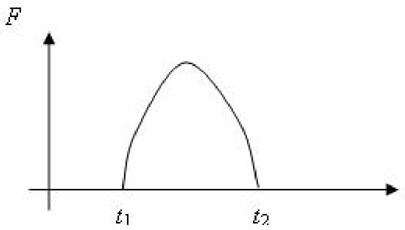

Figure 6: Impulse to force in function of time

In general, impact force varies with time. However, the impact is very short and the style is considered constant, as shown in Figure 2.8. For reasons of time-average force F_{ave} formulated:

$$F_{ave} = \frac{1}{\Delta t} \int_{t1}^{t2} \vec{F} dt \tag{11}$$

Where Δt = t2 - t1. So, the impulse equation:

$$I = \vec{F} \cdot \Delta t \tag{12}$$

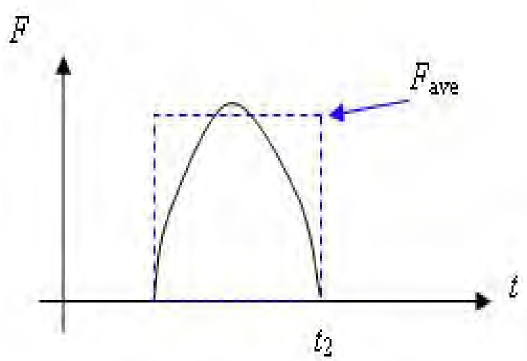

Figure 7: Average Impact Force

For this problem, the theory of impulse and momentum is divided into two parts, described in Fig.8:

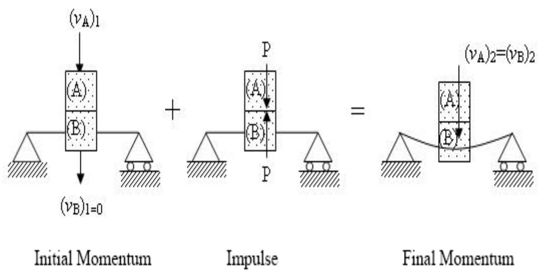

Figure 8: Visualization of the theory of impulse and momentum

Visualization diagram above shows the direction and magnitude of the initial and final particle momentum. Particle initial momentum plus the total number of impulses from t1 to t2 is the final momentum.

$$\sum m_j (v_j)_1 + \sum \int_0^t \vec{F} dt = \sum m_j (v_j)_2 \tag{13}$$

Where

$$m_A (v_A)_1 + 0 + 0 = (m_A + m_B) \cdot (v_A)_2 \tag{14}$$

A final velocity of the object beam is concentrated on the mass of B will be the same after the impact because the coefficient of restitution is zero is assumed for this problem. Final velocity can be calculated by:

$$(v_A)_2 = \frac{m_A}{(m_A + m_B)} \cdot (V_A)_1 \tag{15}$$

As a result of the concentration of mass at the midpoint of the beam, the model is similar to a damped vibration system with one degree of freedom (one degree of freedom damped vibrating system) as shown in Figure 2.9.

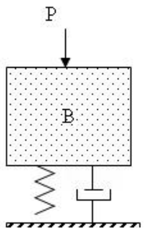

Figure 9: Damped vibration system with one degree of freedom

The principle of impulse and momentum for the above system is formulated as follows:

$$\int_0^{t_0} F(t)dt - \int_0^{t_0} kudt - \int_0^{t_0} cudt = (m_A + m_B)\cdot(v_A)_2 \quad (16)$$

Where t0 is the duration of impact. Because the impact is infinitsimal, it was found that the limit t0 close to zero as in the equation below. Function F (t) is assumed as the impulse - an average constant force acting during the time of impact as shown in figure 2.8. Containing integral damping and stiffness, for infinitesimal time, tends to zero. 2:17 So the equation becomes:

$$F_{ave}\cdot t_0 - 0 - 0 = (m_A + m_B)\cdot(v_A)_2$$

$$F_{ave} = \frac{(m_A + m_B)\cdot(v_A)_2}{t_0} \quad (17)$$

Substituting the final speed of the system (vA) 2 from equation 2:18, 2:16 into the equation yields:

$$F_{ave} = \frac{m_A(v_A)_2}{t_0} \quad (18)$$

Above equation has two unknowns, the average force and the time of impact. The impact can be sought from the LS-DYNA ANSYS software, so that force can be calculated using eq.18.

3.5 Impact Energy

Impact is a collision or a collision between two objects that occur within a very short time interval, during which the two bodies pressing each other with a relatively large force. In accordance with the above basic physics concepts, then the amount of energy which resulted in impact between the supply vessel and the platform is proportional to the change in kinetic energy from the supply vessel (Kenny, 1988).

The highest value of accidents due to collision energy will be absorbed by the installation, with a probability of occurrence for each platform 10-3 every year, which is 4 MJ. This value depends on the size of the vessel as described in formula (Kenny, 1988):

Energy absorbed = $0.5 + m^2(4.2\text{x}10^{-7} - 5.6\text{x}^{10\text{-}11}m)$ MJ (19)

With: m = *displacement* of the impacting vessel (tonnes)

The usefulness of the vessel displacement relationship and the absorbed energy can account for operational differences between areas in the North Sea. Since the serious events that occur because of errors in judgment, the size of the vessel is the most important parameter. Weather conditions did not become important due to the hard collision and are usually not included in the count on the installation of energy absorbed as a result of impact events.

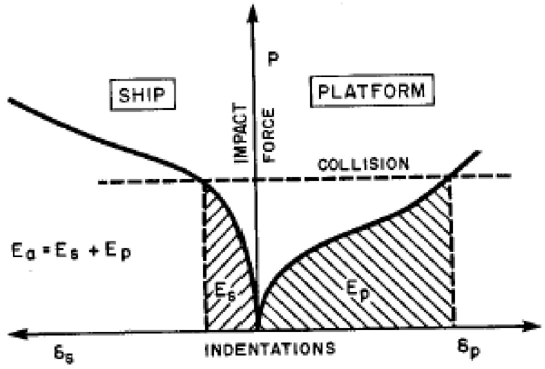

Figure.10 Tipical Energi Absorption (Kenny,1988)

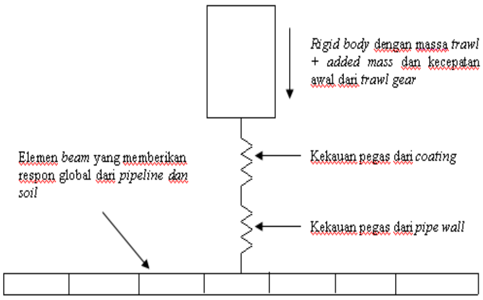

Figure.11 Schema simulation model

3.6 Accidental Impact Loading

Based on HSE, Load 2001, in cases where the stiffness of the impacted part of the Installation is very large in comparison to that of the impacting part of the vessel, as for example in collisions involving concrete Installations or fully grouted elements, the impact energy absorbed locally by the Installation may be very low and it is important to examine damage caused by the impact force.

In such cases, the impact force, F, may be taken as:

$F = P_o$ or $V\sqrt{c\,a\,m}$ (20)

Where

Po = the minimum crushing (or punching shear as appropriate) of the impacting part of the vessel and the impacted part of the installation (MN)
c = stiffness of the impacting part of the vessel (MN/m)
V = impact speed (m/s)
m = vessel displacement (kg)
a = vessel added mass coefficient
= 1.4 for sideway collision
= 1.1 for stern/bow collision

4.0 SHIP COLLISION SIMULATION

The steps to simulate the effect of the ship collision on jacket structure is shown in the Fig.12.

4.1 Landing Platform Modeling

Modelling geometry landing platform and pipe based on the scenario collision velocity data at Table.1.

Table.1 Scenario Velocity Collision (Kenny, 1988)

Impact Scenario	MSL		LWL		HWL	
	Normal Velocity (m/s)	Extreem Velocity (m/s)	Normal Velocity (m/s)	Extreem Velocity (m/s)	Normal Velocity (m/s)	Extreem Velocity (m/s)
Sideway Impact	0.28	0.54	0.28	0.54	0.28	0.54
Stern/Bow Impact	0.39	0.73	0.39	0.73	0.39	0.73

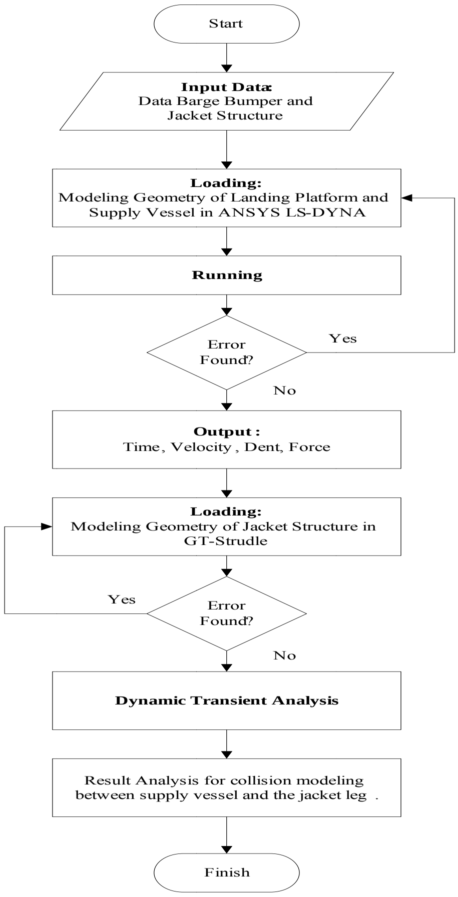

Figure 12: Flowchart of Research

Based on the data above then continue to modelling geometry in ANSYS LS-DYNA 9.0 version. Meshing model landing platform and vessel below:

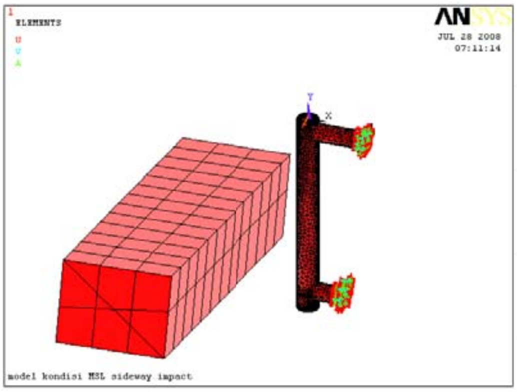

Figure 13: Meshing model landing platform and supply vessel.

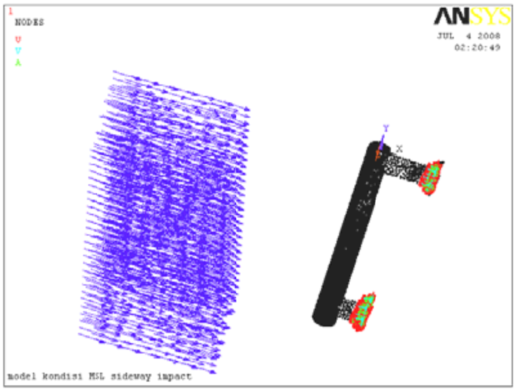

Figure 14: Specify Load when collision

4.2 Platform Structure Modeling

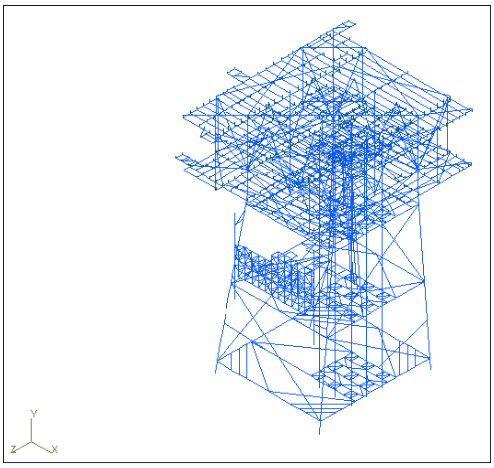

Figure 15: Model Line of Platform Structure.

5.0 RESULT AND DISCUSSION

5.1 The Landing Platform damage by Supply Vessel Collision

Based on modeling results obtained from ANSYS software dent depth for each model are:

General provisions of the jacket structure elements such as diagonal braces, horizontal braces, columns, and if the member had a large dent over 10% of outside diameter, then the elements must be repaired or replaced. Dent that occurred depth lies in the impact site, as shown in Figure 16 and Figure 17 and the dent is formed on the landing platform in Figure 18.

Table 2: Output of the dent depth ANSYS, voltage akipat Impact sideway collision conditions.

Scenario			Denting depth(m)	Extreem condition	Action
MSL	NORMAL	SIDEWAY	0.2027	Yes	Change
		STERN/BOW	0.2246	Yes	Change
	EXTREEM	SIDEWAY	0.2352	Yes	Change
		STERN/BOW	0.2725	Yes	Change
LWL	NORMAL	SIDEWAY	0.2027	Yes	Change
		STERN/BOW	0.2246	Yes	Change
	EXTREEM	SIDEWAY	0.2352	Yes	Change
		STERN/BOW	0.2027	Yes	Change
HWL	NORMAL	SIDEWAY	0.2725	Yes	Change
		STERN/BOW	0.2246	Yes	Change
	EXTREEM	SIDEWAY	0.2352	Yes	Change
		STERN/BOW	0.2725	Yes	Change

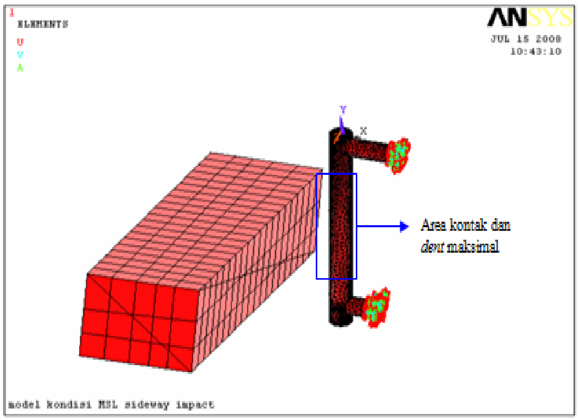

Figure 16: Location and contact area for maximum dent Impact sideway condition.

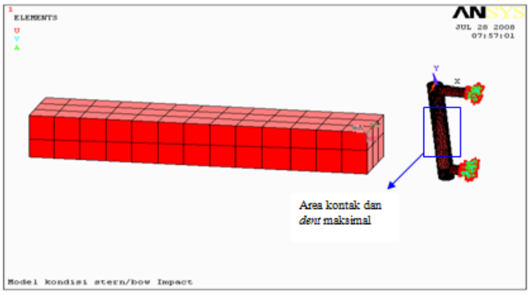

Figure 17: Location and contact area for maximum dent conditions Stern / Bow Impact.

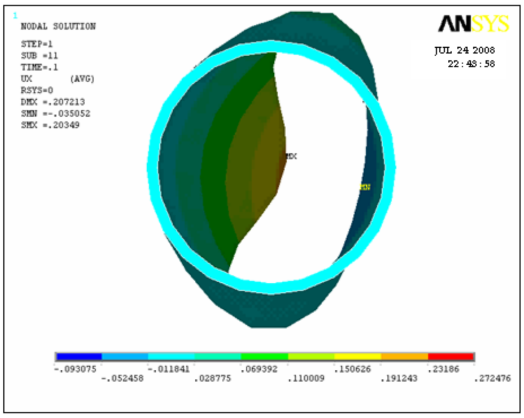

Figure 18: The maximum dent location (plan view x, y).

5.2 Response on Jacket Structure.

Based on the output of the GT-STRUDLE Software version 27.0, which occurred in the structure's response in this study on condition that can be considered to represent the HWL response structures. Jacket response that occurs in the load due to collision can be seen on the GT-STRUDL output version 27.0 as follows:

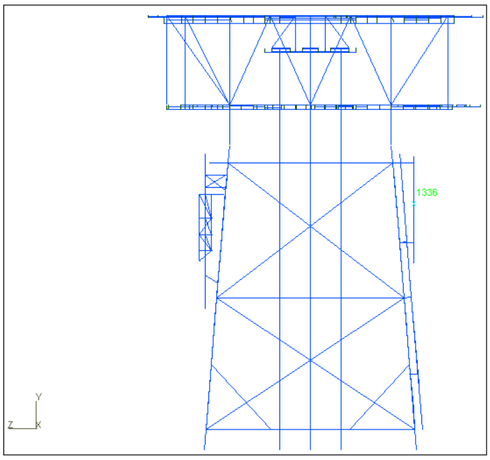

Figure 19: The location of the joint 1336 for HWL conditions (YZ plane).

Based on the output of dynamic analysis with the help of GT-STRUDLE Software version 27.0, which occurred in the structure's response in this study on the Impact sideway HWL conditions at speeds that exceeded 10% can be considered to represent the response of structures. Responses that occur in the Jacket due to impact load response can be seen in the following chart:

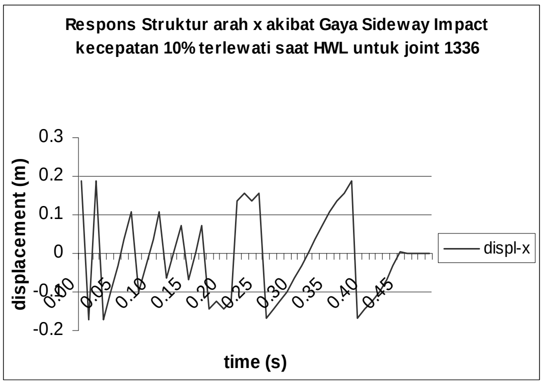

Figure 20: Response of the structure of the x-direction due to sideway style Impact conditions exceeded 10% at HWL.

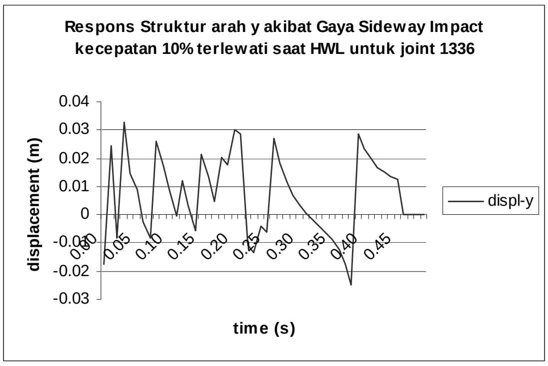

Figure 21: Response of the structure of the y-direction due to sideway style Impact conditions exceeded 10% at HWL.

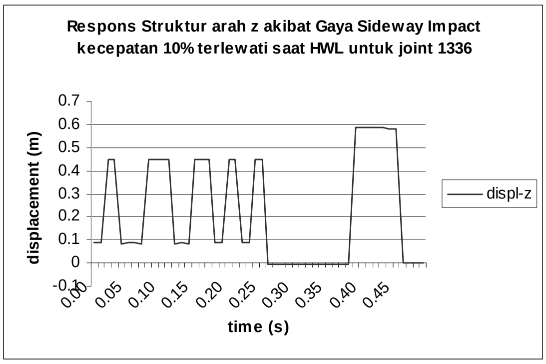

Figure 22: Response of the structure of the z-direction due to the style of the Stern / Bow Impact normal conditions when HWL.

Based on the API RP 2A WSD, the allowable value of unity check is less than 1:33 to extreme conditions and check the value of this research unty still meet the limit of API RP 2A-WSD, the structure is still safe. The following table shows the magnitude of unity check jacket structure:

Table 3: *Unity Check* untuk kondisi *Sideway Impact* HWL kecepatan 10% terlewati

CHORD	BRACE	JOINT	UNITY CHECK	REMARKS
JL-10	E15-1	635	0.4365	OK
JL-10	E15-2	635	0.5724	OK
JL-10	E15-3	635	0.4367	OK
JL-10	1767	635	0.2580	OK
JL-10	E15-3	635	0.2783	OK
JL-11	1767	635	0.4920	OK
JL-12	E50-2	809	0.1198	OK
JL-12	1472	809	0.7567	OK
JL-12	E50-104	809	0.6277	OK
JL-12	E50-2	809	0.2857	OK
JL-12	1472	809	0.3048	OK
JL-12	E50-104	809	0.2847	OK
JL-13	E50-2	809	0.8359	OK
JL-13	1472	809	0.7567	OK
JL-13	E50-2	809	0.2857	OK
JL-13	1472	809	0.3048	OK
JL-15	1741	1042	0.4089	OK
JL-16	E17-2	728	0.8350	OK
JL-16	E17-9	728	0.4900	OK
JL-16	1478	728	0.5327	OK
JL-16	1766	728	0.8108	OK
1136	1473	1336	1.2160	OK

Table 4: Unity Check for conditions Stern / Bow Impact HWL speed exceeded 10%.

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CHORD	BRACE	JOINT	UNITY CHECK	REMARKS
JL-10	E15-1	635	0.4515	OK
JL-10	E15-2	635	0.5874	OK
JL-10	E15-3	635	0.4517	OK
JL-10	1767	635	0.2730	OK
JL-10	E15-3	635	0.2933	OK
JL-11	1767	635	0.5070	OK
JL-12	E50-2	809	0.1348	OK
JL-12	1472	809	0.7717	OK
JL-12	E50-104	809	0.6427	OK
JL-12	E50-2	809	0.3007	OK
JL-12	1472	809	0.3198	OK
JL-12	E50-104	809	0.2997	OK
JL-13	E50-2	809	0.8509	OK
JL-13	1472	809	0.7717	OK
JL-13	E50-2	809	0.3007	OK
JL-13	1472	809	0.3198	OK
JL-15	1741	1042	0.4239	OK
JL-16	E17-2	728	0.8500	OK
JL-16	E17-9	728	0.5050	OK
JL-16	1478	728	0.5477	OK
JL-16	1766	728	0.8258	OK
1136	1473	1336	1.1341	OK

5.3 Validation results of the ANSYS Modeling

Calculation of the dent and the Impact force is highly dependent on the configuration parameters and the data type of the supply vessel and the mechanical material landing platform (a pipe). Mechanical properties of the material landing platform in Table 5 as follows:

Table 5: Mechanical properties of the material landing platform.

DESCRIPTION	Values	UNIT
PIPE NOMINAL O.D.	36	inch
PIPE NOMINAL O.D.	914.4	mm
WALL THICKNESS	38.1	mm
STEEL PIPE D/t RATIO	24	-
STEEL YIELD STRESS	448	Mpa
YOUNG MODULUS	207	GPa

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Table 6: Model validation results of the ANSYS LS-DYNA

Scenario			Force (N)	Force (N)	
			HSE 2000	ANSYS	Error (%)
MSL	NORMAL	*SIDEWAY*	317275000	131248250	0.5863
		STERN/BOW	36786750	44021600	0.1967
	10% EXEEDED	*SIDEWAY*	843750000	172872000	0.7951
		STERN/BOW	1082944954	44021600	0.9594
LWL	NORMAL	*SIDEWAY*	317275000	131248250	0.5863
		STERN/BOW	36786750	44021600	0.1967
	10% EXEEDED	*SIDEWAY*	1082944954	172872000	0.8404
		STERN/BOW	317275000	279346200	0.1195
HWL	NORMAL	*SIDEWAY*	317275000	131248250	0.5863
		STERN/BOW	36786750	44021600	0.1967
	10% EXEEDED	*SIDEWAY*	1082944954	172872000	0.8404
		STERN/BOW	317275000	4733333	0.9851

6.0 CONCLUSION

After analyzing the local structure and global structure of the jacket can be concluded that:Bentuk *dent* yang terjadi adalah *ellips* untuk 2 kondisi, yaitu:

1. Speed Sideway normal punches have a minimum depth of 0.2027 m, while the collision Stern / Bow has a minimum depth of 0.2246 m.
2. Speed of 10% exceeded the minimum depth Sideway punches 0.2352 m, while the collision Stern / Bow has a minimum depth of 0.2725 m.Respons struktur akibat beban benturan yaitu:
3. Maximum Displacement occurs in the direction of x is 0.2423 meters at the 0:38 second.
4. Maximum Displacement occurs in the y direction is 0.0559 meters at the 0:39 second.
5. Maximum Displacement occurs in the direction of z is 0.7492 meters in 0:41 seconds
6. Check that produced the Great Unity of more than 1 but still within the limits of tolerance for extreme conditions that is equal to 1:33.

Predictions are used in this study in a safe condition as:

1. In the local analysis of the structure, the energy is absorbed entirely by the landing platform
2. In the global analysis of the structure, the energy is absorbed entirely by the global structure of the Jacket.

Thus, the deformation that occurs in the structure of the landing platform and Jacket is actually smaller than the results of the study

7.0 RECOMMENDATION

1. Further research needs to be held simultaneously with the modeling to account for the attenuation received by the local

structure of the components of the landing platform and the overall structure of the Jacket.

2. Further research needs to be held simultaneously with the modeling that can calculate the percentage of energy absorbed Jacket structures and supply vessel.

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