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SHIP STRUCTURAL INTEGRITY OF ALUMINIUM STIFFENER PANEL FOR CONSEQUENCE REDUCTION

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Abstract

The aluminium stiffener panels in ship structure are paramount to ensure safety and to guarantee the structural strength and integrity of the ship. The aluminium stiffener panel is very important to ship building, especially when the ship faces collision or unstabilized structure; the aluminium stiffener panel tends to increase bending moment, vertical shear force and stresses. This study investigates the strength of the aluminium stiffener panel at the amidship bulkhead with different shapes and typesin order to determine the strength of the aluminium stiffener from its features. *AA 5083-H116* aluminium stiffener panel used has been approved by the recognized organization for shipbuilding. The aluminium stiffener panel has been tested using bending moment test and compressive load to obtain the highest endurance. Three types of aluminium stiffener panels, which are a flat shaped, L-shaped and T-shaped panel, are used in order to obtain the best panel ability for a better ship structural system. The aluminium stiffener panel is tested at the area where it is different to determine area where they are affected by extreme heat due to the welding results and fabrication. The result has showed that the aluminium stiffener panel in shipbuilding process effect in an area without extreme heat is more stable.

Keywords: ultimate strength, heat affected zone, collision damage, aluminium stiffener panel, bulkhead, amidships.

Introduction

Background

The stiffener panel on ship structure is one of the support element from basic of building ship structure such as type flat bar, T bar and L bar used in shipbuilding construction, they are used commonly in the bulkhead and amidships. Study on ship strength and integrity determined from life cycle of ship and return of investment leads to ship own or spending more money on maintenance. Stiffened plates in ships revealed that other structures may be exposed to complex stress patterns due to simultaneously acting in-plane biaxial and shear stresses in design of such elements, buckling and ultimate strength are important issues researched by Brubak, L. and Hellesland J. (2008). Stiffened plates are required to resist extreme loading conditions, for example in term of axial compressive loads or lateral pressures studied by Khedmati M.R., and Ghavami K. (2009). The principal variables studied are the plate thickness, boundary conditions and the stiffener geometries beside the geometrical imperfection, the width of the welding heat-affected zone (HAZ) and welding residual stresses are also examined.

The study involved of ship structure construction and testing of different part of aluminium stiffener panel to investigate be more strength because they can cause support load weight on the ship such as machinery, fuel, oil and other equipment. Aluminium stiffener should be more strengthen for support the ship body, Therefore, it is important to find ship structure in respect to fatigue todetermine structural integrity.

Inherent Problem Associated with Ship Structure integrity

i. The variation in the buoyant forces increased the bending moment, vertical shear force, , stresses and amidships the buoyancy forces design in such situation will tend to 'hog' the vessel, if the trough is amidships the buoyancy forces will tend to 'sag' the ship.
ii. The stiffness against bending tend to increased by a hollow section with space between the stiffeners which is reduced by the twin-wall section shape compared to the single-wall stiffeners such as T-shaped or L-shaped stipulated by Ye N. and Moan T. (2007).
iii. Fatigue becomes the governing criteria in the design of the mid-ship stiffener/web frame connections at the top and bottom has studied by Ye N. (2007).

The study asses ship structurereliability strength of aluminium stiffener panel from outside pressure and consequential damages. The study investigated the aluminium stiffener strength by shape and type of stiffener at bulkheads and amidships and determined reliable effect of aluminium stiffener strength from their behavior.

Methodology

The study process involves the following stages:

Theoretical Modeling

The theory of stress and strain is compared with the value of lab test for validation purpose to deduce and recommendation as required. Compressive stress acts to reduce the length of the material (compression member) in the axis of the applied load is modelled.

Field Work at Shipyard

The plate of aluminium alloys 5083-H116 was prepared at shipyard before the construction the aluminium stiffener panel. The plate is cut and preparedto get the dimension based on the ship requirement. Aluminium stiffener is resized to deduce the parameter smaller than panel dimension suitable for the tester machine. The methods for fabricating aluminium stiffener panel are presented by MIG welding technique.

Laboratory Test Panel

The aluminium stiffener panel work at shipyard as followed by determination of the type and dimension. A three panel with L-shaped, T-shaped and flat shaped stiffeners fabricated from extruded aluminium profiles in alloy AA5083-H116, joined by welding, was defined.

Compression Test

The method of research to determined behavior of materials under crushing loads. Compressive stress and strain is calculated and plotted as a stress-strain diagram test purposed to determine ultimate strength of aluminium stiffener panel under load. The result determined when the frequency of breakage or limit of aluminium stiffener panel test. The specimen was prepared to test at universal testing machine the best environmental condition. For aluminium stiffener, good condition and room temperature to avoid the other effect on the test specimen is providing for the test.

Bending Test

Three-point bending test involve involved simple two-dimensional analysis of a simply supported aluminium stiffener panel loaded. The formation of the process zone and failure of the specimen are simulated in aluminium stiffener dimension steps, controlled by the displacement under the applied load. The load-displacement diagram is deduced as final result for bending test.

Heat Affected Zone Test

The test specimen was conducted by hardness test to find the material properties in aluminium stiffener panel and material composition in the welding process.

The Vickers hardness test is conducted to measuring and assesses the extent of the structural weakness. The Hardness test required for welding process for construction of all type of aluminium stiffener panel. The Vickers Hardness test measurement was produced at allocated aluminium stiffener panel welding process for measurement on effected zone on panel extrusion.

Data Acquisation and analysis

The analysede for bending, compression test and Vickers hardness measurement has provided. The numerical analysis based on the result that was obtained from the compression test is provided. The theoretical modeling provided thetheoretical and formulation of aluminium stiffener panel compressive strength. The comparison data from the compression test deduced the different of imperfection and fatigue of material strength. The reliable effect on aluminium stiffener panel from their behaviour with the characteristic of each type of stiffener panel dimension has determined.The classification society validation requirement process approval the license and ship seaworthiness is used for necessary checking of the result.

Result and discussion

Stiffener Panel Dimension

Stiffener panel dimension is calculated theoretically according to suggested requirement and comparison is made. The bending test require the dimension of aluminium stiffener panel the values of thickness and area of body applied load, A. The length of specimen, L is same and width of specimen, b. The range of dimension L/b is 6.9 of each specimen. The total overall dimension for aluminium stiffener panel is likely to be the same with the bending test. The measurement weight of specimen, W slightly different and thickness of stiffener is also different. The flat bar (fb) is 3mm, T-bar (tb) is 4mm and angle bar (lb) is 5mm. The range of measurement is L/b that is 0.9 respectively. The aluminium stiffener panel has a cross sectional area with their body platting, have the area of dimension, sectional dimension of stiffener panel and type stiffener panel difference values and arrangement. The cross sectional area is analysed in Table 4.3 with specimen is considered.

Table 2.1. 1: Cross-Sectional Area Type Of Aluminium Stiffener Panel

Type specimen	**Cross-section (nominal values)**						
	a (mm)	b (mm)	t (mm)	t_w (mm)	h_w (mm)	t_f (mm)	b_f (mm)
Flar bar (fb)	345	50	4	3	51	-	-
T-bar (tb)	345	50	4	4	47	4	50

Angle bar (lb)	345	50	4	5	46	5	50

The requirement of body plate used is similar to other but structural strength of stiffener panel is slightly different compare to research by Khedmati M.R. et al. (2009). Table 4.4 shows the type of aluminium stiffened plate by type of stiffener panel. The used of average value of initial deflection in ship plating is investigated and evaluated by Khedmati M. R. et al as $W_0^{max} = 0.05ß^2t$. The material properties were taken from the previous study. The Young modulus and the Poisson ratio of the material are 70 GPa and 0.33, respectively.

Table 2.1. 2: Type Of Aluminium Stiffened plate

Type Specimen	**Stiffened plate**				
	I (mm^4)	*r*	*ß*	λ	W_0^{max}/L ($\times 10^{-3}$)
Flar bar (fb)	33162.7	5.6604	0.87966	0.001023	0.449
T-bar (tb)	34607.6	5.0077	0.65974	0.001157	0.252
Angle bar (lb)	40556.7	4.8488	0.52779	0.001195	0.161

Ultimate Strength And Maximum Load On Aluminium Stiffener Type

Bending Test

Graph 4.1 shows the result of angle bar type of stiffener panel in called L shaped. The initial angle bar specimen test has a disturbance of stresses between 0-1mm on deflection body because the material of plate has higher load better than load applied from the machine test. The result of the ultimate load of structural body is a 1083.69 kN.

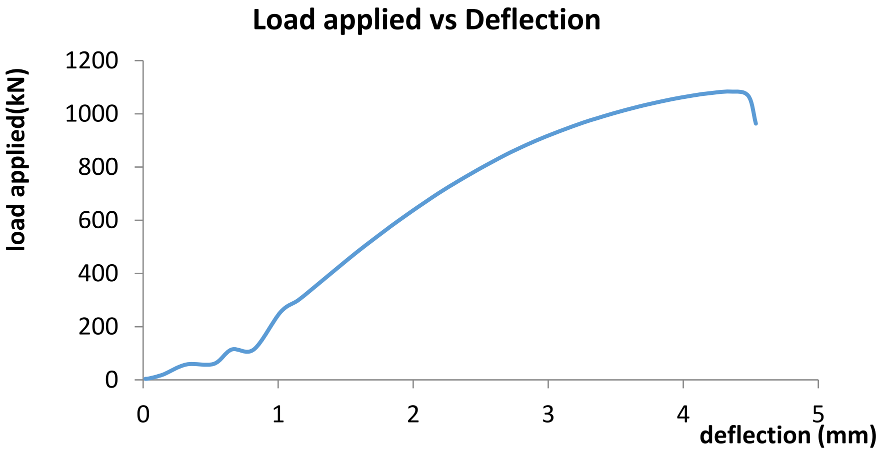

Figure 2.1. 1: Graph Load Applied Against Deflection Of Angle Bar

Figure 2.1.1 has shows the graph of flat bar (fb) type of stiffener panel, the load applied against deflection has proved the deflection of stiffener in the initial of bending test for flat bar specimen has a disturbance area of body plate between 0-0.7mm on deflection body.

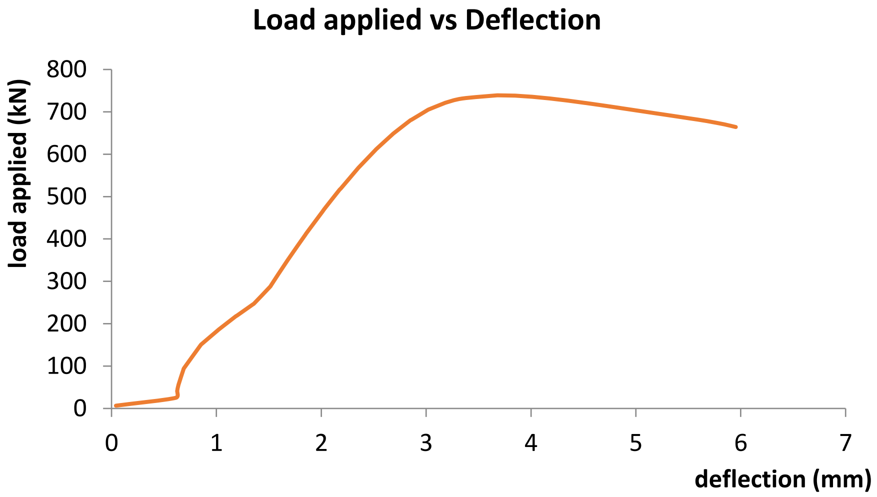

Figure 2.1. 2: Graph Load Applied Against Deflection Of Flat Bar

Figure 2.1.2 has shows the graph result of T-bar (tb) type of stiffener panel on the load applied against deflection has proved the deflection of stiffener. The T-bar result shows that the ultimate load of structural body is a 4089.146 kN. The percentage of successful of damage body required 5.12 % in area of deflection.

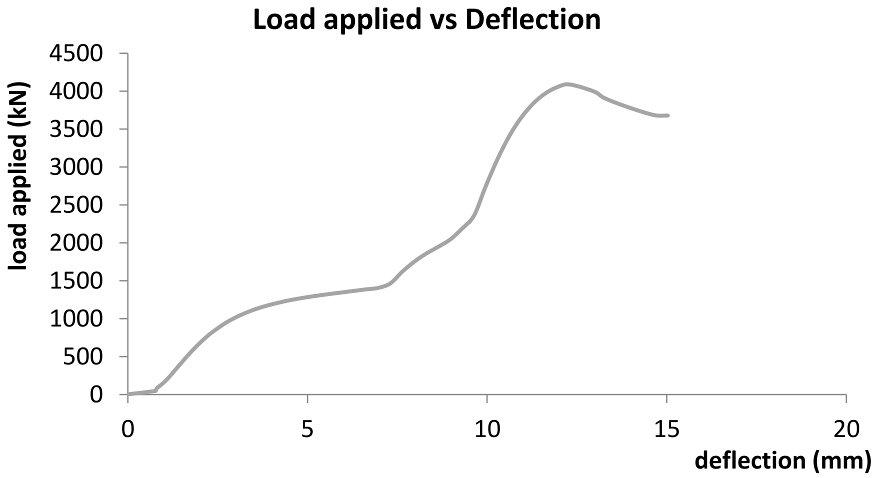

Figure 2.1. 3: Graph Load Applied Against Deflection Of T-Bar

The final value of test response by bending test is shown in Table 2.1.3 This is required to determine the ultimate capacity load with the sample of specimen. The comparison has achieved their properties and strength values, the ultimate strength break the applied load with the stiffener panel.

Table 2.1. 3: The Final Value Of Test Response By Bending Test

Type	**Test Response**				
specimen	Max. Load,k (N/mm²)	Deflection (mm)	Break k (N)	Elastic Modulus,E (N/mm²)	Yield Strength (N/mm²)
Flat bar	0.051	5.952	6513.113	0.091	0.16
Tbar	0.185	15.030	36077.32	0.332	0.184
Angle bar	0.042	4.537	9445.379	0.076	0.114

The aluminium stiffener is the most important in the local strength because the part is stable in that area and produced the higher strength and very reliable to use in the bulkhead amidships to prevent the consequential damage from outside.

Compression Test

The result of angle bar process has show that is 8.671 kN was used to pressure the aluminium stiffener panel for testing the strength of aluminium stiffener panel. The higher load required for machine needs more applied load to damage their body until 4742.487 kN recorded. Finally the ultimate load applied with the body 5233.571 kN for the angle bar specimen has recorded. The graph of compressive load against strain is shown in figure 2.1.4.

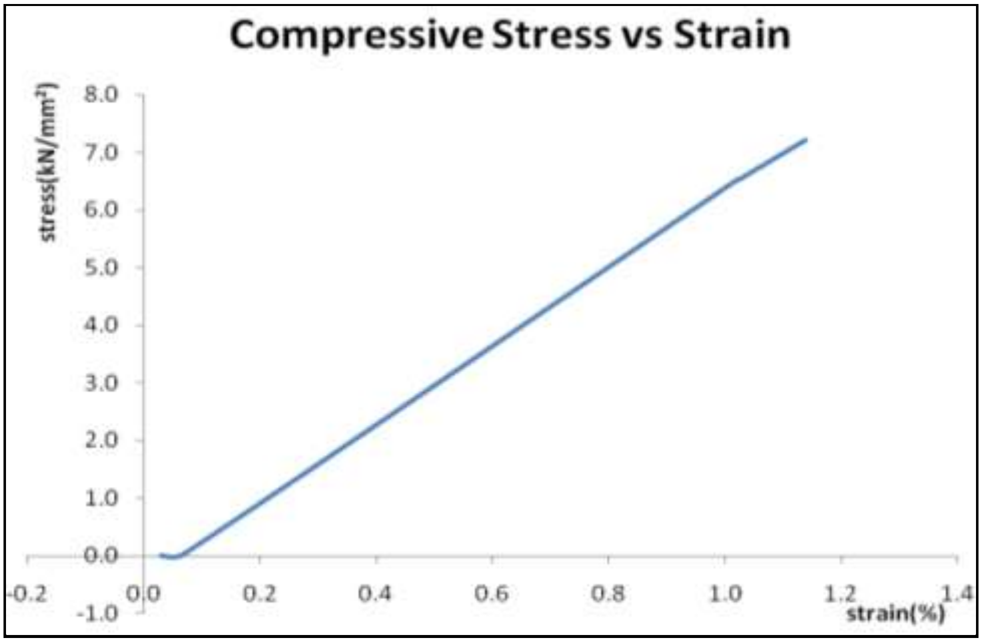

Figure 2.1. 4: The Graph Compression Test Of Angle Bar

The experiment of flat bar is shown, when the first value 5.017 kN was used to pressure the aluminium stiffener panel. The higher load required for machine because the strength of body needs more applied load to damage their body until 1946.741 kN recorded. Finally the values of flat bar totally reduce down because of the fatigue and failure mode on the structure. The graph compressive load against strain of flat bar is represented in Figure 2.1.5.

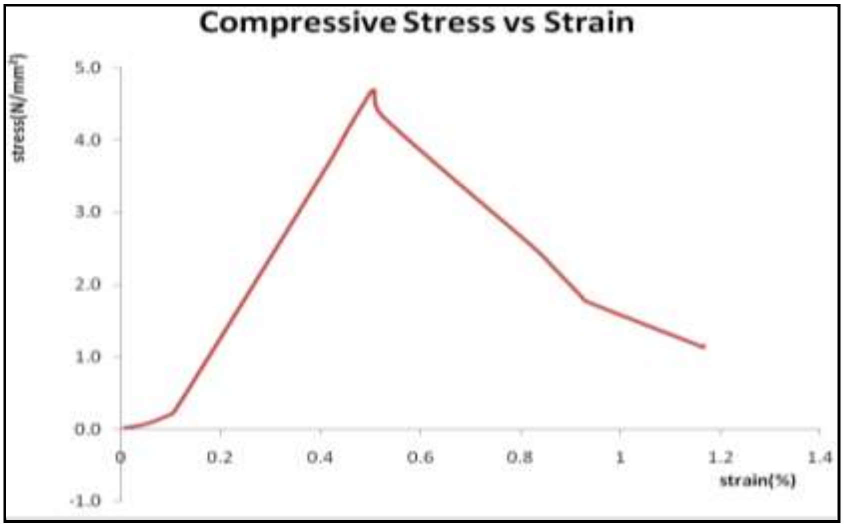

Figure 2.1. 5: The Graph Compression Test Of Flat Bar

The experiment has shows, that at first value of T-bar it only 2.733 kN used to pressure the aluminium stiffener panel. The higher load required for machine because the strength of body needs more applied load to damage their body until 5225.155 kN recorded. The T-bar has most structural stiffener panel in stay in the good condition because the stability of aluminium stiffener panel is covered all of body plate. The final load of aluminium stiffener panel of T-bar becomes 5189.425 kN. The graph compressive load against strain of T-bar has shown in Figure 2.1.6.

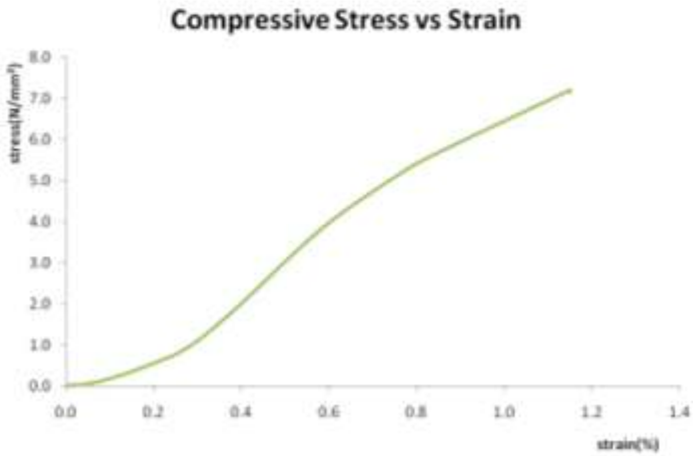

Figure 4.6 : The Graph Compression Test Of T-Bar

Table 2.1.4 shows the final result for compression test for requirement of test response determined a functional of each specimen in various side.

Table 2.1. 4: The Final Test Response of Compression Test

	Test Response							
Type	E (N/mm²)	Yield point (N)	Max.load Fu (N/mm²)	Break (N)	Extension Vu (mm)	Stress σ_u (kN/mm^2)	Strain $\acute{\varepsilon}_u$ (%)	kb/EA
(fb)	20.701	19090	0.23	4696	4.661	4.690	1.165	27.33
(tb)	38.692	51449	0.43	50890	4.583	7.157	1.151	90.71
(lb)	38.138	46681	0.424	51323	4.553	7.218	1.138	92.81

The result has expected the difference in type of aluminium stiffener panel iss defined and determine the strength of aluminium stiffener panel in difference of ultimate strength.

The Effect on Reliable of HAZ at Aluminium Plates and Stiffener Panel

The measurement of HAZ modeling with type of specimen based on distance from weld centre was used to find the reliable effect of HAZ on the characteristic of each specimen type. The Figure 2.1.6 shows the hardness of measurement by flat bar type of specimen.

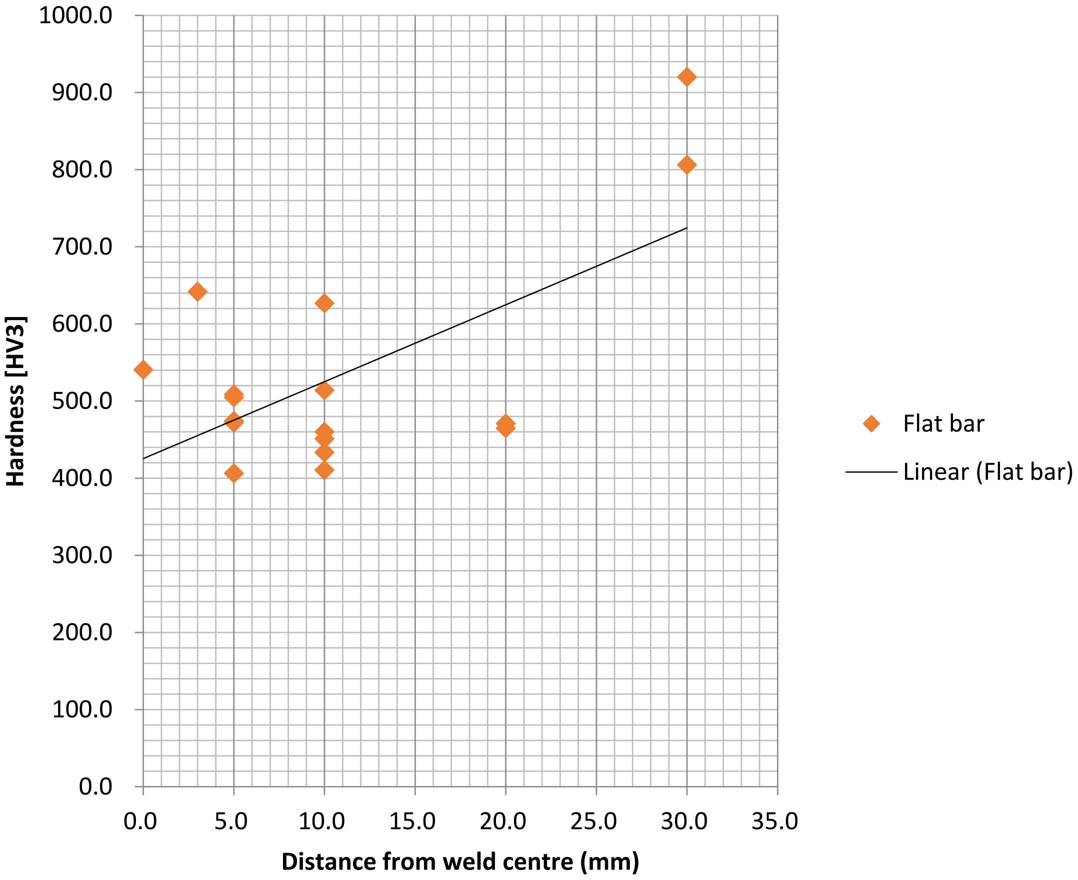

Figure 2.1. 6: The Hardness Measurement Of Flat Bar

Figure 4.8 has shown the hardness of measurement by T-bar type of specimen. The linearity graph shows that the value of HAZ is higher that very far distance over than nearest of distance weld centre with the influence of HAZ is very reliable because of effect of heat temperature of stiffener panel.

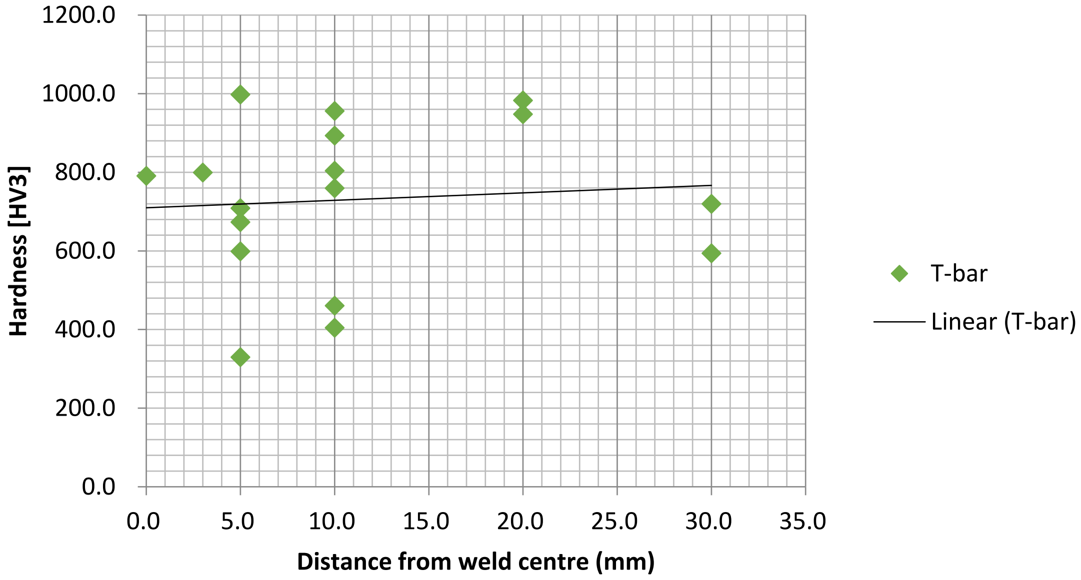

Figure 2.1. 7: The Hardness Measurement of T-Bar

Figure 2.1.8 shows the hardness of measurement by angle bar type of specimen with values of HAZ.

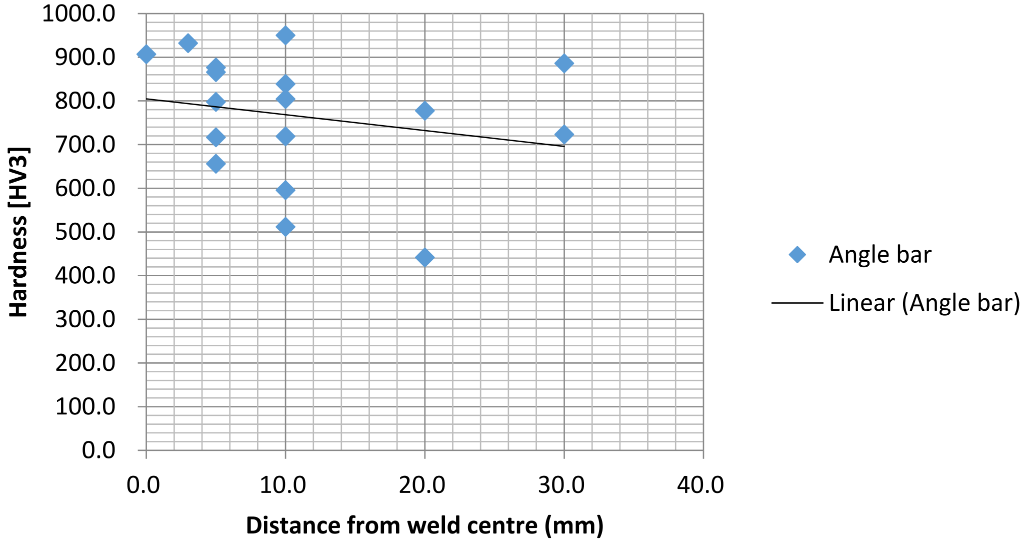

Figure 2.1. 8: The Hardness Measurement of Angle Bar

The hardness measurement in units HV3 use the 3kg load in Hardness test. The T bar graph show the concentration value from the distance weld centre, it is observed that the highest point in the hardness test produced 997.9 in 5mm from weld centre.
The Energy of Collision Stiffener Panel and Ship Structure

Table 4.11 : Calculation Of Energy Of Load Applied, Energy Of Collision

Specimen	**E (kN/m²)**	**M_{stiff} (kg)**	**F_u (kN)**	**V_u**	**Tonnage of ship (ton)**	**E_T (mJ)**	**E_{load} (mJ)**
Flat bar	2.07	0.38	19.09	0.16	1000	14.08	211.43
					2000	28.16	422.86
					3000	42.24	634.28
					4000	56.32	845.71
					5000	70.4	1057.14
T-bar	3.81	0.72	51.44		1000	14.08	1987.18
					2000	28.16	3974.36
					3000	42.24	5961.54
					4000	56.32	7948.72
					5000	70.4	9935.90
Angle bar	3.87	0.64	46.68		1000	14.08	1627.92
					2000	28.16	3255.85
					3000	42.24	4883.77
					4000	56.32	6511.69
					5000	70.4	8139.61

The variable of aluminium stiffener panel has required the energy of load collision in ship structure requirement of structural damage has reconsidered by owner ship to determine a value and loss of damage in their body. In the element of load of collision, the theoretical modeling energy of ship tonnage and energy load of collision is provided by the equation:

$$E_T\ (\mathrm{mJ}) = \tfrac{1}{2} \times (M_{stiff}\, V^2)\ k \qquad (1)$$

$$E_{load}\ (\mathrm{mJ}) = E_T/2\ (M_{stiff}\, V^2) \qquad (2)$$

Conclusion and recommendation

Conclusion

The result showed that the aluminium stiffener panel area with lower heat is more stable and has reliability for approve in ship structural system. The stiffener panel strength isdetermined by the ultimate strength of the load collision applied. The effect of stiffener height on average tears length for the weld configuration shows increasing tearing threshold for a decreasing stiffener height. The deformation is slightly a symmetric with the centre in the plate and proceeds along the stiffener, when the tear reaches the weld it deviates around the weld and then proceeds along the weld and plate intersection. The importance of structural dimension of specimen prevents the outside pressure from structural damage and collapse.

Recommendations

The following recommendation is proposed for future improvement of this study: Firstly, the actual design study compared application to a ship structure design. Also, prediction of the possible impact on structural design, development arising from these conditions is that navies have increasingly turned to the application of classification society processes and resources to help them in establishing and applying technical criteria for naval ship design and construction including those related to the ship structure. Furthermore, the study of innovative designs for maximum the crashworthiness in an accidental impact is necessary. Lastly, probabilistic approach to consequent evaluation of damaged stability and vessel survivability can be researched from this study.

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