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Strength Analysis of LCT Lady Primus 39.5 m Ramp Door Structure Due to Changes in Tilt Angle Variations and Load Variations

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***Abstract*— Of the several cases of accidents, the fall of a vehicle from a ship during loading and unloading occurred due to a break in the clevis ramp door. This study focused on the construction of the ramp door of the ship LCT Lady Primus 39.5 m. The purpose of this study is to determine the voltage characteristics that occur in ramp door construction, determine the location of the most critical components in ramp door construction, and determine the safety factor value in ramp door construction under each loading condition. This research uses the finite element method (FEM) and refers to the Indonesian Classification Bureau (BKI) rules. The vehicle loads used in this study were the Uro Vamtac, Panser Anoa, APC Komodo, and BMP 3F Tanks. The variations given are in the form of angular conditions of +108, 08, and -108. Validation was carried out on the model by comparing the results of simulation calculations with analytical calculations, and an error value of 2.8% was obtained. The material used is KI-A36, with a yield voltage of 235 Mpa. The results of the FEM analysis (finite element method) obtained a maximum stress of 82.31 Mpa located on a stiffener length 3 precisely at node 1249. The most considerable strain of 1.929 mm is located on the top plate at node 20495. The research results on cargo variations and tilt angles of the LCT Lady primus 39.5 m ship ramp door have met the criteria of the Indonesian Classification Bureau (BKI) rules.**

Keywords— Landing Craft tank, Ramp door, Stress, Strain, Finite Element Method

I. INTRODUCTION

The mode of transportation in Indonesia is influenced by the geographical location of Indonesia itself, where Indonesia is a maritime country. This is done to facilitate the distribution of goods and people to improve the welfare of Indonesian citizens. In its development, there are various modes of transportation, one of which is the water transportation mode which is used as a link to land transportation modes from one island to another; one type of this mode of transportation is the LCT (Craft Tank landing) ship. The Landing Craft Tank (LCT) ship is a ship that loads heavy vehicles equipped with a ramp door design that bridges vehicles from the ship's deck to the dock.

On Thursday (27/12) 2018, the Ro-Ro (Roll On Roll Off) passenger ship Nusa Putera departed from pier 3 of Merak Port, Banten, to Pier III of Bakauheni Port, Lampung. During the loading process, in the form of a large HINO-type FG235TI truck was into the ship. The truck plunged into the sea due to a disconnection to the clevis ramp door [1]. A similar incident occurred in Lake Toba, namely a Toyota Avanza car that fell into Lake Toba when it was about to get off the Ihan Batak crossing motor boat (KMP); the incident began with the disconnection of the clevis connecting sling with the ramp door [2].

Aiming at Previous research that has been carried out is an analysis of the strength of the KM stern ramp door structure. Gambolo with load variations using the finite element method, which is focused on the construction of the stern ramp door, needs to be considered because if there is a change in the load of the truck being replaced by a large truck (tronton), the stern ramp door structure will receive a more load than a large truck (tronton), because initially the stern ramp door is planned to be passed by medium trucks and sedans, obtained stress results of sedan cars of 15.4 N / mm², medium trucks of 43.3 N / mm² and flatbed trucks of 112 N / mm² where the resulting voltage results are still in a safe condition, based on BKI rules regarding the permit voltage limit of 150 N / mm² [3].

Then based on the analysis of the strength of the ramp door construction on the 117 M landing ship tank (LST) ship with the finite element method, which uses grade A steel material BKI with a material permit stress value of 235 Mpa which has a length of 6130 mm, the width of 5100 mm, the height of 650 mm and plate thickness of 12 mm the most significant stress results were obtained,namely on the Leopard tank of 77.74 N / mm²

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and a deformation value of 17.23 mm. This stress is still safe after being compared with the permitted voltage based on the BKI rules of 150 N / mm2 and has a safety factor of 2.25 [4].

From the fatigue analysis of the strength of the stern ramp door due to dynamic loads on KM Kirana, with the finite element method, KIRANA I also produces the most critical condition of ramp door construction in the middle [5]. From the research on the strength analysis of the stern ramp door structure with variations in the shape of the clevis on the ro-ro 600 GT ferry, the results of the analysis of the variation of the clevis shape model have a safety factor above one, which means that all clevis models meet the criteria of the BKI [6].

Based on the case examples and research that has been carried out, which is the basis for conducting this research which will later be carried out several tests on the construction of ramp doors and in this study added research on clevis to find out how strong clevis is in holding loads during loading and unloading activities.

II. METHOD

A. *Object of Study*

Landing Craft Tank (LCT) ship is one type of ship used in commercial sea transportation because this ship is efficient in transporting bulldozers, heavy cargo, dump trucks, excavators, loaders, and various other heavy equipment. Landing Craft Tank is also an attack landing craft to land tanks on the shore. Landing Craft ships have a broad and flat deck, so they are suitable for transporting vehicles and logistics materials to mining areas, especially those located on islands or remote areas.

PT designed research on Landing Craft Tank Ships. Ratson Maritime Indonesia. The main sizes of the ship are:

Length Over All (LOA)	: 39.5 m
Length Between Pendicular (LPP)	: 34.46 m
Breadth (B)	: 10 m
Depth Moulded (D)	: 3 m

B. *Treatment Variations*

The treatment variations used in this final project study were in the form of angular variations and variations in load loads passing through the ramp door. The angular condition is assumed to be given, and it is assumed that when the state of the seawater recedes, then the shape of the ramp door is -108; when the state of the seawater is normal, then the condition of the ramp door is 08; when the sea water is high then the shape of the ramp door 108. So that the variety of treatments includes:

a. Ramp door tilt condition
   - Ramp door +108
   - Ramp door condition 08
   - Ramp door +108
b. Load variations
   - Uro Vamtac
   - Panser Anoa
   - APC Komodo
   - BMP 3F
c. Variation of loading conditions
   - Early (the condition of the front wheels of the vehicle passing through the ramp door).

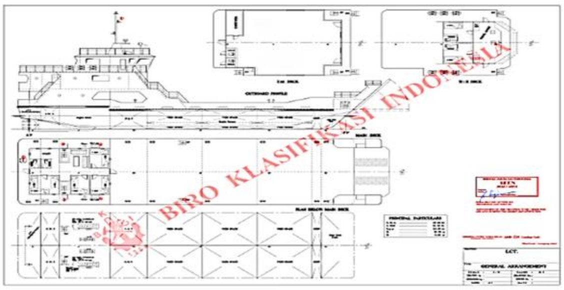


Figure. 1. *General Arragement* of Lady Primus 39.5 m

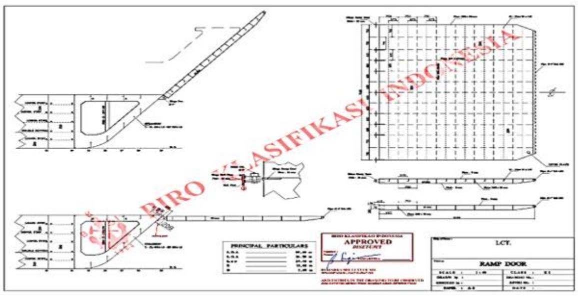


Figure. 2.Ramp doo r of Lady Primus 39.5 m.

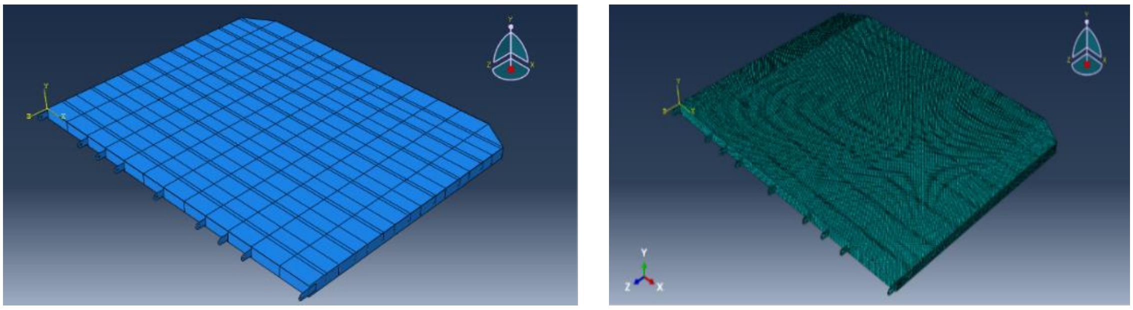


Figure. 3. Model ramp door and Meshing of Lady Primus 39.5 m

- Middle (the condition of all vehicle wheels passing through the ramp door).
- End (condition of the rear wheels of the vehicle passing through the ramp door).

C. Safety Factor

The safety factor is a factor that indicates the level of ability of an engineering material to receive loads from the outside, namely compressive and tensile loads. This factor is identical to the ratio between the allowable stress of the material and the maximum stress of the tensile rod:[7]

$$Sf = \frac{\sigma ijin}{\sigma ultimate} \quad (1)$$

Where σijin is the limit of the stress a structure allows and cannot pass, σultimate is the tremendous stress a structure experiences due to being subjected to a force or loading. A structure is said to be safe when the value of *Sf* >1. [8]

D. Deflection Calculation

The deflection calculation formula uses the following engineering mechanics formula:[9]

$$Deflection = \frac{F.L^3}{3.E.I} \quad (2)$$

Where F is the Force (N), L is the model length (m), E is the Modulus of Elasticity (Mpa), and I is the moment of inertia of the model (mm^4)

E. Model and Meshing

The construction design to be modeled includes deck plates, side plates, U profiles, and transverse and longitudinal counterparts following existing construction.

The initial stage in creating a model is the definition of a model from PDF images to 2D drawings with the help of *Autocad* software. Then, the 2D image will be translated into a 3D image of each part of the ramp door construction in the *Abaqus simulia* software, and in the meshing process, types of *quad* and *triad* elements will be used. After the meshing process is carried out, it is necessary to check the mesh to determine its quality of the mesh so that it can be analyzed correctly.

F. Material Definition

The material used in this research is KI -A36 steel. The properties of the KI-A36 material are as follows:

Modulus of Elasticity : 200,000 MPA
Ultimate Stress : 400 MPA
Yield Stress : 235 MPA
Poison ratio : 0.3
Density : 7.85 ton/m^3

III. Results and Discussion

A. Setup Boundary

After the model has completed the meshing process, the next stage is determining the boundary condition. These boundary conditions are adjusted to current conditions or according to requirements in the field to obtain more accurate results.

TABLE 1.
BOUNDARY CONDITIONS (TRANSLATION)

Location	X-axis	Y-axis	Z-axis
Clevis ramp door hole	Fix	Fix	Fix
The lower end of the stiffener is elongated	Fix	Fix	Fix

TABLE 2.
BOUNDARY CONDITIONS (ROTATION)

Location	X-axis	Y-axis	Z-axis
Clevis ramp door hole	Fix	-	Fix
The lower end of the stiffener is elongated	Fix	-	Fix

In tables 1 and 2, the fixed symbol states that the part is interpreted as locked, while in the part that is not given the selected character, it means that the part can still move, especially in the clevis hole, which can still move rotationally.

C. Model Validation

Model validation is done to determine the level of accuracy of a geometry model that has been created previously. One of the methods carried out is to compare the results of analytical and numerical calculations.

a. Analytics Calculation

Analytical validation of the model using the engineering mechanics deflection formula approach, with F (Force) 1,000 N, L (Model length) 6,100 mm, E (Modulus of elasticity) 200,000 Mpa, and I (Moment of Inertia) 46,025,755,979 mm^4.

$$Deflection = \frac{F.L^3}{3.E.I}$$

$$= \frac{1000 \times 6100^3}{3\ x\ 200000 \times\ 146025755979}$$

$$= 2.591\ .10^{-3}\ \text{mm}$$

b. Numerical Calculations

Figure 8 is a software calculation carried out with the Abaqus Simulia software according to the model that has been made. And the deflection result is 2.665 x 10^{-3} mm.

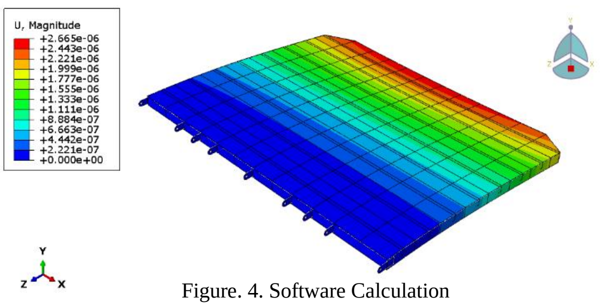


Figure. 4. Software Calculation

Table 4 is the result of a comparison between analytical and numerical calculation models; an error percentage of 2.8% was obtained. Model validation is said to be correct because the error percentage is still below the 5% range.

TABLE 4.
VALIDATION RESULTS.

Analytics Calculation	Numerical Calculations	Error
$2.591.10^{-3}\ mm$	$2.665\ .10^{-3}$ mm	2,8 %

B. Load setup

The load that works on the ramp door is the vehicle's load during the loading/unloading process. The vehicle load is assumed to be on each wheel above the deck ramp door. The following is the loading data for each wheel of the vehicle that shows in table 3.

TABLE 3.
LOADING VARIATIONS OF EACH WHEEL POINT

No	Vehicle Type	Front Wheel Load (N/m^2)	Rear wheel Load (N/m^2).
1	Uro Vamtac	68897.6378	68897.6378
2	Panser Anoa	133202.0997	66601.04987
3	APC Komodo	154330.7087	154330.7087
4	Tank BMP 3F	16968.51852	16968.51852

D. Analysis Results

In the presentation of data, the results of the study are presented in several conditions, which are shown in table 5 as follows.

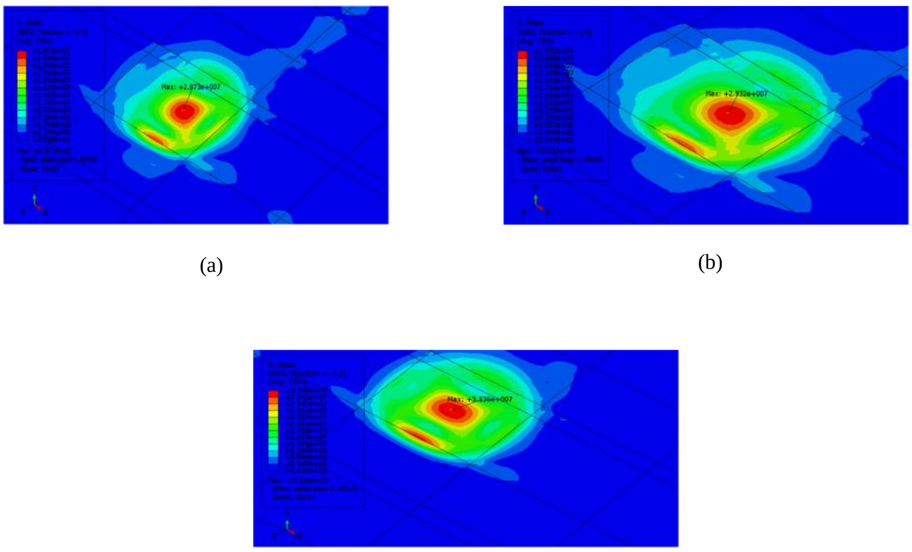
1. Uro Vamtac

Uro Vamtac vehicle analysis is simulated when the Uro Vamtac vehicle passes through the ship's ramp door during the condition of the front wheels, all wheels, and rear wheels.

The condition of the 1T1 assumed ramp door was given the load of the Uro Vamtac vehicle, the middle load (all wheels), at an angle of +108. As shown in figure 5a, The most significant stress experienced by the 1T1 condition of 28.73 Mpa is located on the top plate precisely at node 50491. The most considerable strain experienced in 1T1 conditions, which is 0.5591 mm, is located on the top plate precisely at node 50491.

TABLE 5.
DESCRIPTION OF LOADING CONDITIONS

No	Condition	Vehicle	Load conditions	Angle
1	1D1	Uro Vamtac	Front Wheels	+108
2	1D2	Uro Vamtac	Front Wheels	08
3	1D3	Uro Vamtac	Front Wheels	-108
4	1T1	Uro Vamtac	All Wheels	+108
5	1T2	Uro Vamtac	All Wheels	08
6	1T3	Uro Vamtac	All Wheels	-108
7	1B1	Uro Vamtac	Rear Wheels	+108
8	1B2	Uro Vamtac	Rear Wheels	08
9	1B3	Uro Vamtac	Rear Wheels	-108
10	2D1	Panser Anoa	Front Wheels	+108
11	2D2	Panser Anoa	Front Wheels	08
12	2D3	Panser Anoa	Front Wheels	-108
13	2T1	Panser Anoa	All Wheels	+108
14	2T2	Panser Anoa	All Wheels	08
15	2T3	Panser Anoa	All Wheels	-108
16	2B1	Panser Anoa	Rear Wheels	+108
17	2B2	Panser Anoa	Rear Wheels	08
18	2B3	Panser Anoa	Rear Wheels	-108
19	3D1	APC Komodo	Front Wheels	+108
20	3D2	APC Komodo	Front Wheels	08
21	3D3	APC Komodo	Front Wheels	-108
22	3T1	APC Komodo	All Wheels	+108
23	3T2	APC Komodo	All Wheels	08
24	3T3	APC Komodo	All Wheels	-108
25	3B1	APC Komodo	Rear Wheels	+108
26	3B2	APC Komodo	Rear Wheels	08
27	3B3	APC Komodo	Rear Wheels	-108
28	1D1	Tank BMP 3F	Front Wheels	+108
29	1D2	Tank BMP 3F	Front Wheels	08
30	1D3	Tank BMP 3F	Front Wheels	-108
31	1T1	Tank BMP 3F	All Wheels	+108
32	1T2	Tank BMP 3F	All Wheels	08
33	1T3	Tank BMP 3F	All Wheels	-108
34	1B1	Tank BMP 3F	Rear Wheels	+108
35	1B2	Tank BMP 3F	Rear Wheels	08
36	1B3	Tank BMP 3F	Rear Wheels	-108



(a) (b)

(c)

Figure. 5. Result of analysis of Uro Vamtac

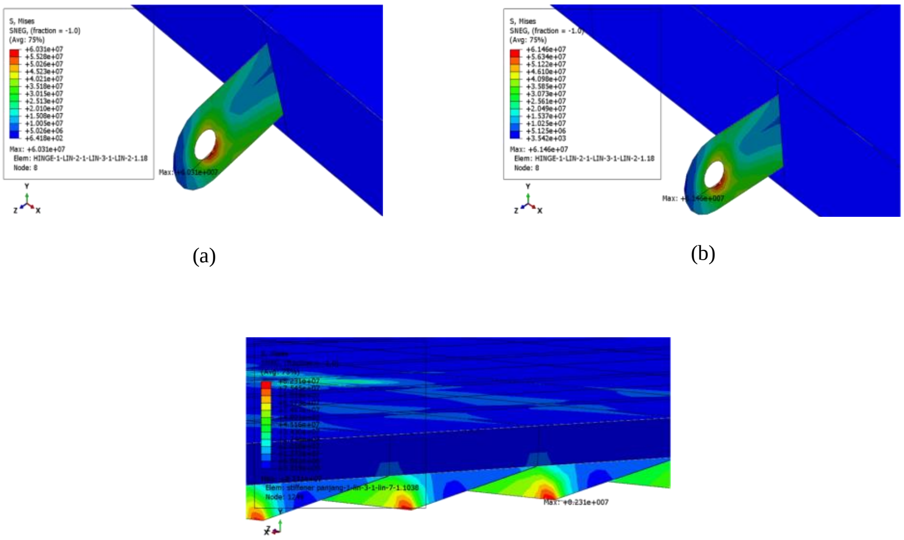
At the same time in the conditions, condition 1T2 assumed ramp door was given the load of the Uro Vamtac vehicle, the middle load (all wheels), at an angle of 08. As shown in figure 5b, The most significant stress experienced by the 1T2 condition of 29.32 Mpa is located on the top plate precisely at node 50491. The most considerable strain experienced in 1T2 conditions, which is 0.5705 mm, is located on the top plate precisely at node 50491.

Finally at the condition of 1B1 assumed ramp door was given the load of the Uro Vamtac vehicle, the end load (rear wheels), at an angle of +108. As shown in figure 5c, The most significant stress experienced by the 1B1 condition of 35.36 Mpa is located on the top plate precisely at node 50612. The most considerable strain experienced in 1B1 conditions, which is 0.6576 mm, is located on the top plate precisely at node 50612.

Finally at the condition of 2T2 assumed ramp door was given the load of the Panser Anoa vehicle, the middleload (all wheels), at an angle of 08. As shown in figure 6c, The most significant stress experienced by the 2T2 condition of 82.33 Mpa is located on the stiffener 3 precisely at node 1249. The most considerable strain experienced in 2T2 conditions, which is 1.929 mm, is located on the top plate precisely at node 20495.

3. APC Komodo

The condition of the 3T2 assumed ramp door was given the load of the APC Komodo vehicle, the middle load (all wheels), at an angle of 08. As shown in figure 7a, The most significant stress experienced by the 1B1 condition of 52.19 Mpa is located on the top plate precisely at node 50724. The most considerable strain experienced in 3T2 conditions, which is 1.016 mm, is located on the top plate precisely at node 50924.



(a) (b) (c)

Figure. 6. Result of analysis of Panser Anoa

2. Panser Anoa

The condition of the 2D1 assumed ramp door was given the load of the Panser Anoa vehicle, the early load (front wheels), at an angle of +108. As shown in figure 6a, The most significant stress experienced by the 2D1 condition of 60.31 Mpa is located on the hinge precisely at node 8. The most considerable strain experienced in 2D1 conditions, which is 1.460 mm, is located on the top plate precisely at node 49321.

At the same time in the conditions, condition 2D2 assumed ramp door was given the load of the Panser Anoa vehicle, the early load (front wheels), at an angle of +08. As shown in figure 6b, The most significant stress experienced by the 2D1 condition of 63.46 Mpa is located on the hinge precisely at node 8. The most considerable strain experienced in 2D1 conditions, which is 1.489 mm, is located on the top plate precisely at node 49321.

At the same time in the conditions,condition 3B1 assumed ramp door was given the load of the APC Komodo vehicle, the end load (rear wheels), at an angle of +108. As shown in figure 7c, The most significant stress experienced by the 1B1 condition of 52.02 Mpa is located on the top plate precisely at node 50792. The most considerable strain experienced in 3T2 conditions, which is 0.8644 mm, is located on the top plate precisely at node 50792.

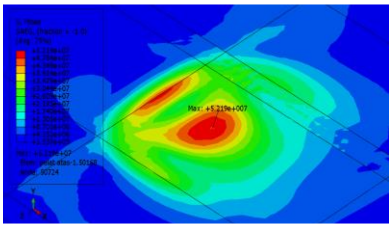
Finally at the condition of the 3B2 assumed ramp door was given the load of the APC Komodo vehicle, the end load (rear wheels), at an angle of 08. As shown in figure 7b, The most significant stress experienced by the 1B1 condition of 53.09 Mpa is located on the top plate precisely at node 50792. The most considerable strain experienced in 3T2 conditions, which is 0.8821 mm, is located on the top plate precisely at node 50790.

4. BMP 3F

The condition of the 4D2 assumed ramp door was given the load of the BMP 3F vehicle, the early load (front wheels), at an angle of 08. As shown in figure 8a, The most significant stress experienced by the 4D2 condition of 35.32 Mpa is located on the hinge precisely at node 8. The most considerable strain experienced in 4D2 conditions, which is 0.8589 mm, is located on the top plate precisely at node 50534.

At the same time in the conditions, condition 4T1 assumed ramp door was given the load of the BMP 3F vehicle, the middl load (all wheels), at an angle of +108. As shown in figure 8b, The most significant stress experienced by the 4T1 condition of 61.47 Mpa is located on the hinge precisely at node 8b. The most considerable strain experienced in 4T1 conditions, which is 1.544 mm, is located on the top plate precisely at node 49198.

Finally at the condition of the 4T2 assumed ramp door was given the load of the BMP 3F vehicle, the middle load (all wheels), at an angle of 08. As shown in figure 8c, The most significant stress experienced by the 4D2 condition of 62.73 Mpa is located on the hinge precisely at node 8.



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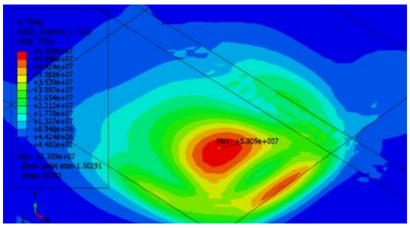

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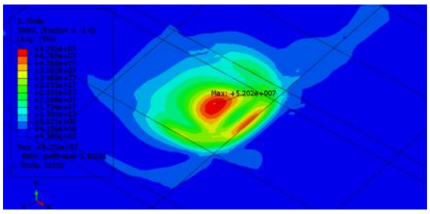
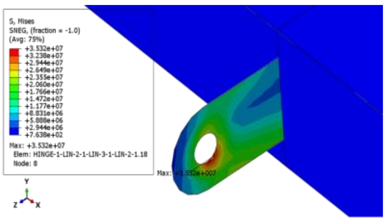


(c)

Figure. 7. Result of analysis of APC Komodo



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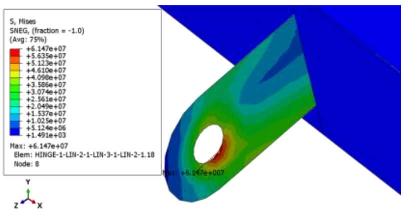

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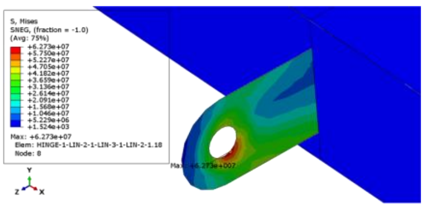

(c)

Figure. 8. Result of analysis of BMP 3F

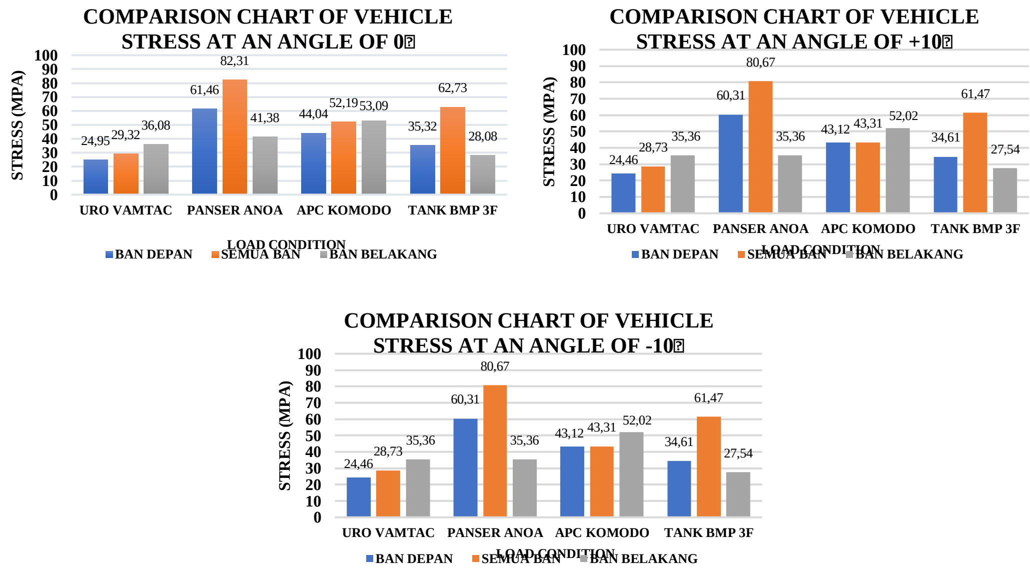

Figure. 9. Vehicle Voltage Comparison Chart At Each Angle Variation

TABLE.6
RECAPITULATION OF DECK RAMP DOOR ANALYSIS RESULTS

No	Condition	σmax (Mpa)	δmax (mm)	Safety Factor
1	Condition 1D1	24.46	0.489	9.608
2	Condition 1D2	24.95	0.559	9.419
3	Condition 1D3	24.46	0.658	9.608
4	Condition 1T1	28.73	0.499	8.180
5	Condition 1T2	29.32	0.571	8.015
6	Condition 1T3	28.73	0.671	8.180
7	Condition 1B1	35.36	0.489	6.646
8	Condition 1B2	36.08	0.559	6.513
9	Condition 1B3	35.36	0.658	6.646
10	Condition 2D1	60.31	1.460	3.897
11	Condition 2D2	61.46	1.891	3.824
12	Condition 2D3	60.31	0.947	3.897
13	Condition 2T1	80.67	1.489	2.913
14	Condition 2T2	82.31	1.929	2.855
15	Condition 2T3	80.67	0.966	2.913
16	Condition 2B1	40.56	1.460	5.794
17	Condition 2B2	41.38	1.891	5.679
18	Condition 2B3	40.56	0.947	5.794
19	Condition 3D1	43.12	0.909	5.450
20	Condition 3D2	44.04	0.881	5.336
21	Condition 3D3	43.12	0.864	5.450
22	Condition 3T1	43.31	0.928	5.426
23	Condition 3T2	52.19	1.016	4.503
24	Condition 3T3	43.31	0.882	5.426
25	Condition 3B1	52.02	0.864	4.517
26	Condition 3B2	53.09	0.881	4.426
27	Condition 3B3	52.02	0.864	4.517
28	Condition 4D1	34.61	0.839	6.790
29	Condition 4D2	35.32	1.544	6.653
30	Condition 4D3	34.61	0.621	6.790
31	Condition 4T1	61.47	0.856	3.823
32	Condition 4T2	62.73	1.575	3.746
33	Condition 4T3	61.47	0.634	3.823
34	Condition 4B1	27.54	0.839	8.533
35	Condition 4B2	28.08	1.544	8.369
36	Condition 4B3	27.54	0.621	8.533

E. Recapitulation of Deck ramp door Analysis Results

From the research that has been carried out, the results of safety factors in accordance with BKI regulations are shown in table 6.

From the graph, figure 9a summarizes the ramp door structure analysis results, namely at an angular condition of 08, with the most significant value, namely when loading the Panser Anoa vehicle of 82.31 Mpa during the middle load state (all wheels), figure 9b is a summary of the results of the ramp door structure analysis, namely at an angle condition of +108, with the largest value, namely when loading the Panser Anoa vehicle of 80.67 Mpa during the middle load state (all wheels).

Finally in figure 9c is a summary of the results of the ramp door structure analysis, namely at an angle condition of +108, with the largest value, namely when loading the Panser Anoa vehicle of 80.67 Mpa during the middle load state (all wheels).

VI. CONCLUSION

Based on the analysis of the calculation of the strength of the ramp door construction on the Landing Craft Tank (LCT) ship due to variations in loading and variations in angle tilt that have been carried out.

The maximum voltage occurs in 2T2 conditions, namely when the ramp door is loaded with a Panser anoa vehicle with a center load (all wheels), which is 82.33 Mpa is located at stiffeners 3 at node 1249. The most considerable strain experienced in 2T2 conditions, 1,929 mm, is located on the top plate precisely at node 20495.

The minimum voltage occurs in 1D1 conditions, namely when the ramp door is given an Uro Vamtac vehicle load with an initial load (front wheels), which is 24.46 Mpa located on the top plate on node 48642 and the minimum deflection with a value of 0.489 mm is located on the upper plate on node 48642.

The analysis results concluded that the strength criteria of the LCT Lady Primus 39.5 m ramp door construction met the regulations of the BKI and had a safety factor above 1. Incidents of ramp door breakage accidents are caused not by failures in construction but caused by several external factors, such as human errors or due to the age of the ramp door itself due to corrosion/rust processes.

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