Construction strength analysis of landing craft tank conversion to passenger ship using finite element method

Mohammad Nurul Misbah¹, Dony Setyawan², Wisnu Murti Dananjaya³
1,2,3Department of Naval Architecture, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111 Indonesia
E-mail: mnmisbah@na.its.ac.id

Abstract. This research aims to determine the longitudinal strength of passenger ship which was converted from Landing Craft Tank with 54 m of length as stated by BKI (Biro Klasifikasi Indonesia/ Indonesian Classification Bureau). Verification of strength value is done to 4 (four) loading conditions which are (1) empty load condition during sagging wave, (2) empty load condition during hogging wave, (3) full load condition during sagging wave and (4) full load condition during hogging wave. Analysis is done using Finite Element Analysis (FEA) software by modeling the entire part of passenger ship and its loading condition. The back and upfront part of ship centerline were used as the boundary condition. From that analysis it can be concluded that the maximum stress for load condition (1) is 72,393 MPa, 74,792 MPa for load condition (2), 129,92 MPa for load condition (3), and 132,4 MPa for load condition (4). Longitudinal strength of passenger ship fulfilled the criteria of empty load condition having smaller stress value than allowable stress which is 90 MPa, and during full load condition with smaller stress value than allowable stress which is 150 MPa. Analysis on longitudinal strength comparison with entire ship plate thickness variation of ± 2 mm from initial plate was also done during this research. From this research it can be concluded that plate thickness reduction causes the value of longitudinal strength to decrease, while plate thickness addition causes the value of longitudinal strength to increase.

1. Introduction
Refering to Directorate General of Sea Transportation Decree Letter SK.885/AP.005/DRJD/2015 issued on March 19th 2015 about Prohibition of Landing Craft Tank (LCT) Usage as Ferry Boat causes many LCT in Indonesia unable to operate as it should be. Company who operates LCT as ferry boat would be sanctioned according to Law Number 17 Year 2008 Article 289 on Shipping, and Government Regulation Number 20 Year 2010 on Sea Transportation. According to Ministry of Transportation Decree Number 39 Year 2015 on Standard Procedure of Ferry Boat Passenger, and Directorate General of Land Transportation Decree Letter SK. 4608/AP.005/DRJD/2012 Year 2012 on Standard Procedure of Ferry Boat, the ship that carries passenger and also motor vehicle should at least have 2 (two) ramp doors which would be used as entrance & exit path of vehicle, also the ship should has double bottom.

Many occurrences of sinking LCT ship in Indonesia waters were the reason behind law regulations as mentioned above. It is because LCT ship was not designed and produced to become passenger ship. Meanwhile, numerous LCT ships are still operating as ferry boat for passenger and also freight carrier inter-island in Indonesia. Automatically it would affect all LCT ships and causes disadvantage to its owner. In order to make the ship operates as it used to, it needs to be converted to become passenger
ship. However, to ensure that the ship could fulfill its function well and safely, the conversion should be done with precise analysis, most importantly on the calculation of longitudinal strength.

This research will be focused on finding out the importance of internal load in the form of cargo and superstructure to the entire load condition. An analysis of longitudinal strength is also in order as the ship was the conversion result of Landing Craft Tank. Generally the ship production process has been planned and calculated in accordance to regulations. However in this research since the passenger ship is a conversion result from LCT, longitudinal strength re-calculation is needed as the load condition is different from the previous ship type. Load condition differences will be the consideration on how often inspection should be done in order to prevent structural failure. Stress analysis of the passenger ship will be done with finite element method.

2. Literature study

2.1. Definition of landing craft tank
Landing Craft Tank is an assault craft to land tank on the seashore. This kind of ship existed during the time of World War II and was used by the United States Navy and the Royal Navy of United Kingdom. The US Navy later used it for other purposes during the time of Korean and Vietnam Wars. The ship was known as LCT at the time of World War II.

![Figure 1. Trisna Dwitya LCT (source: MarineTraffic.com).](source)

Nowadays, while still using the LCT name, there are many ships operating commercially in the waters and river way to carry various big freights (e.g. as dump truck, dozer, excavator, construction equipment, steel structure, boiler, turbine engine, rig equipment, transformer, project material, etc.) all over Indonesia, specifically to mining site or project location which happened to be located in islands or near to river way. LCT is also used as ferry boat for inter-islands transportation. Another function of LCT is to carry fresh water and distribute fossil fuel to fulfil demands in remote areas around Indonesia. (Wikipedia, 2016).

2.2. Definition of passenger ship
Passenger ship is the kind of ship which uses permanently built motor as its propulsion force. To improve efficiency and serve broader purpose, the ship could be in the form of Ro-Ro ship, or in the form of ferry ship for short course (Wikipedia, 2016).
2.3. Definition of longitudinal strength
Longitudinal strength is a ship strength measured lengthwise to sustain the freight load and the vessel load itself. The calculation is done accordingly to the vessel dimension and scantling (profile and plate size) used in the vessel. The inertia force of scantling will be calculated to obtain stress and moment value as the result of freight and wave loads. Under the article it is assumed that moment distribution of gravitation load and the buoyancy lengthwise of vessel fulfilled the second stability requirement which is the center of gravity and buoyancy is located on the same vertical line (Santosa, 2013).

2.4. Finite element method
Finite element method is a numerical method used to complete problems in engineering such as geometric, loads, and complex properties of material. These kinds of things are not easy to be solved with mathematical analysis solution. An approach using finite element method utilizes information on the node. The process of determining node is called discretization, a diversification of system into smaller parts, in which problem solving is done and later will be collected as a whole (DNV-GL, 2015).

2.5. Hogging conditions
In this research, the ship shape structure deformation caused by wave load could be explained by assuming the vessel moves on regular wave, where wave length is equal to the vessel length. This will caused vertical moment to happen. Assuming the hull as a beam, then the possibilities of condition are hogging condition.

Hogging condition is a kind of ship deformation forming a convex shape. Hull girder is supported on midship with the wave crest. In this condition, even though ship total weight is equal to buoyancy, there is buoyancy overbalance found on the midship and overweight found on bow and stern parts. As a result, the ship tends to move downward on the bow and move upward on the midship.

Figure 2. Conversion result of LCT Trisna Dwitya.

Figure 3. Hogging condition (source: Barrass, 1999).
2.6. Sagging condition
Sagging condition is a kind of ship deformation forming a concave shape. Hull girder is supported on stern and bow with 2 wave crests. There are overweight on midship and buoyancy overbalance on bow and stern. As a result, the ship tends to move upward on the bow and downward on the midship.

![Figure 4. Sagging condition (source: Barrass, 1999).](image)

3. Methodology
In this step a modeling of ship structure will be done in order to analysis longitudinal strength of the ship using finite element method. Modeling of entire ship section will be done using finite element analysis software (FEA software). The objective of structure modeling is to obtain the value of ship stress with 4 variation of load conditions.

3.1. Geometric modelling
In this research, several modeling methods were used to make geometric image of passenger ship according to existing data. It should be noted that during structure modeling for global analysis, surface model (area) is more recommended as opposed to solid model (volume). According to literature about ship global modeling based on class and other references, modeling method is determined as follow:

- Girder, modeled with 2D surface for the web section and 1D line for the face/ flange
- Stiffener, modeled with 1D line
- Plate (for hull and separator) modeled with 2D surface (Figure 6)

![Figure 5. Girders and stiffeners modeling.](image)
3.2. Meshing

The type of meshing used in this research is coarse mesh, where element dimension is relatively big (not smooth). The reason behind choosing this kind of meshing is because for analysis which results in global meshing calculation, coarse mesh is the most effective, as also recommended by class authority. Element dimension is limited to the size of scaffold which is 600mm due to researcher’s computer limited capability. Too much fine mesh will overload the computer and causes error.

3.3. Boundary condition

Boundary condition in the form of support structure is needed in FEA. If there is no boundary condition then the FEA software would not run properly and resulting in an invalid value. The boundary condition in this research is in the form of 2 support structures. The first point is located behind ship centerline, and the second point is located in front of ship centerline. Degree of Freedom (fixed) on both point heads to the Z-axis (vertical).
3.4. Loading
As mentioned before, all loading conditions should be in balance position. In order to achieve balance condition, downward working load should have equal value with the upward working loads. The downward working load consists of the weight of steel and freight. The upward working load is buoyancy or the hydrostatic pressure. This research uses both downward working load and upward working load.

The downward working load consists of freight load, tanks load, machine load, and superstructure load 1, 2, and 3. The upward working load consists of hydrostatic load, which refers to the actual wave condition. Loadings are given in the form of pressure on the surface.

3.5. Loading condition variation
In this research there are 4 (four) loading conditions analyzed with finite element method to obtain primary respond in the form of longitudinal stress. The following are the 4 (four) loading conditions variation:

- Case 1: the condition in which passenger ship is in sagging wave condition with no freight load inside.
- Case 2: the condition in which passenger ship is in hogging wave condition with no freight load inside.
- Case 3: the condition in which passenger ship is in sagging wave condition with freight load inside.
- Case 4: the condition in which passenger ship is in hogging wave condition with freight load inside.

4. Result and analysis

4.1. Reaction forces verification
Upon going through result analysis, verification to the result is needed by overviewing the result with boundary condition as mentioned before. Ideally, all boundary condition should have zero reaction to ensure the load working downward is equal to the load working upward, as in reality there is no such thing happening on floating structure like passenger ship. For research purpose, the value of reaction which will be focused on is the force reacting vertically, or in other word, the force in Z-axis as the main forces working on the structure is the forces working upward and downward. The following are the value of reaction for each boundary condition:

| Item          | Reaction force (N) | Weight (Ton) | Percentage (%) |
|---------------|--------------------|--------------|----------------|
| Reaction force 1 | 141950             | 14.470       | 1.440%         |
| Reaction force 2 | -142200            | -14.495      | -1.442%        |
| Item       | Reaction force (N) | Weight (Ton) | Percentage (%) |
|------------|--------------------|--------------|----------------|
| Reaction force 1 | 127250             | 12.971       | 1.291%         |
| Reaction force 2 | -127370            | -12.984      | -1.292%        |

Table 3. Calculation of reaction value for boundary condition case 3 full sagging load.

| Item       | Reaction force (N) | Weight (Ton) | Percentage (%) |
|------------|--------------------|--------------|----------------|
| Reaction force 1 | 221840             | 22.614       | 1.485%         |
| Reaction force 2 | -221850            | -22.615      | -1.485%        |

Table 4. Calculation of reaction value for boundary condition case 4 full hogging load.

| Item       | Reaction force (N) | Weight (Ton) | Percentage (%) |
|------------|--------------------|--------------|----------------|
| Reaction force 1 | 210380             | 21.445       | 1.408%         |
| Reaction force 2 | -209990            | -21.406      | -1.405%        |

4.2. Stress

After verification of boundary condition reaction is done, the next thing to do is analysis of stress result. The following are the result of stress presented in 4 (four) cases:

![Figure 10](image1)

Figure 10. Stress results; (a) case 1, (b) case 2, (c) case 3, (d) case 4.

4.3. Finite element with plate thickness variation analysis result

After software running and analyzing stress result of 4 (four) load conditions variation, the next step is to do stress analysis to the passenger ship if the ship is under ± 2 mm variation of plate thickness from the initial thickness. Plate thickness addition analysis is done to measure the escalation of
longitudinal strength after plat thickness alteration, and also to be used as reference for ship plate reparation. Plat thickness reduction analysis is done to measure the reduction of longitudinal strength after plat thickness alteration, and also to be used as reference when the entire part of the ship has corroded as a result of aging and ship condition during sailing.

In the research, explanation about longitudinal strength analysis with plate thickness variation is also shown in graph. The objective is to facilitate research analysis understanding. Analysis result of this sub-chapter is divided into 2 (two) sections of analysis, which is analysis based on ship plate thickness and analysis based on ship freight condition. The following is the longitudinal strength analysis result with ± 1 mm plate thickness variation as shown in graph:

![Figure 11. Graph of ± 1mm plate thickness variation.](image1)

Below is the longitudinal strength analysis result with ± 2 mm plate thickness variation as shown in graph:

![Figure 12. Graph of ± 2 mm plate thickness variation.](image2)
Analysis based on freight condition will be divided into 2 topics, which are empty load condition and full load condition.

![Graph of longitudinal strength stress](image)

**Figure 13.** Graph of longitudinal strength stress.

### 5. Conclusion

Referring to ship load modelling, the results can be summarized into points as follow:

1. Maximum stress on all 4(four) load conditions happened on parallel middle body each with the value of 72,393 MPa, 74,792 MPa, 129,29 MPa, and 132,40 MPa.

2. Reduction of plate thickness about -1 mm to -2 mm from the initial thickness also caused the value of longitudinal strength to decrease. The analysis could be used as reference when the entire part of the ship has corroded as a result of aging and ship condition during sailing.

3. Plate thickness addition about +1 mm to + 2 mm from the initial plate also caused the value of longitudinal strength to increase. When the entire part of the ship has corroded to the point of critical condition as a result of aging, the analysis could be used as reference for plate maintenance and reparation schedule, and ship condition during sailing.

4. Stress value on plate thickness variation of -2 mm from initial plate during empty load condition is still accepted even though the value is higher than allowable stress which is 90,079 MPa for hogging wave, because the stress value is still under the material yield strength which is 235 MPa.

5. Stress value on plate thickness variation of -2 mm from initial plate during full load condition is still accepted even though the value is higher than allowable stress which is 155,50 MPa for sagging wave, because the stress value is still under the material yield strength which is 235 MPa.

### References

[1] Barras 1999 *Ship Stability for Master and Mates* (Oxford: Elseiver)
[2] DNV-GL 2015 *Class Guideline – Finite Element Analysis* (DNV-GL)
[3] Lee, H.-H 2012 *Finite Element Simulations with ANSYS Workbench 14* (United States of America: SDC Publications)
[4] Santosa, B 2013 *Diktat Kekuatan Kapal* (Surabaya: Institut Teknologi Sepuluh Nopember)