

Investigating the Local Stress of Car Deck Ro-Ro 5000 GT

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Abstract

A deck construction must be strong enough that it will not suffer structural damage if it works under a given load. In this case, the strain stress becomes very important from the strength of the deck, as the one that affects the strength of the deck construction, one of which is the stiffener distance. This study aims to analyze the maximum strain stress on the deck of the Ro-Ro Ferry. The method used is Finite Element Method (FEM) by varying the stiffener distance in the deck construction. The research results obtained, namely the variation of the stiffener distance of 600 mm. 285.5 N/mm² and the maximum strain is 1.76 x 10⁻³ mm, at a variation of 700 mm stiffener distance the maximum stress is 378,075 N/mm² and the maximum strain is 1.77 x 10⁻³ mm, at a stiffener distance variation 800 mm the maximum stress released is 383,737 N/mm² and the maximum strain released is 1.78 x 10⁻³ mm, at 900 mm stiffener distance variations the maximum stress is 389,188 N/mm² and the maximum strain released is 1.79 x 10⁻³ mm, at variations in distance stiffener 1000 mm the maximum stress released is 425,388 N/mm² and the maximum strain released is 1.8 x 10⁻³ mm, The value of strain increasingly increases followed by the farther distance of the stiffener equal 0.6%, and the stress value is at a variation increasingly increases followed by the farther distance of the stiffener equal 12.24%.

Keywords: Car deck; stiffener; stress; strain

1. Introduction

Ro-Ro ferry is one of the means of transportation used for crossings in archipelagic countries such as Indonesia. This ship is used to transport people and their vehicles. On the deck, the ship receives a fairly large load. This requires that the ship is always in a safe condition, especially in terms of its strength of construction. The transverse strength of a ship is the ability of the transverse structure of the ship to maintain the cross-sectional shape of the ship against disturbances of loads acting on the ship such as deck loads, side loads, and bottom loads. So it is clear that the main components of the ship structure are the lower structure, side structures, and deck structures [1].

Factors that affect the strength of the construction include the distance between the tusks, the distance between the stiffeners, the unfolded length, the plate thickness, etc. The normal strength of a ship's steel structure has a minimum melting point of REH 235 N/mm² and a tensile strength of Rm 400 - 520 N/mm² (BKI, 2021). To meet the allowable stress (yield strength) in construction, it is customary to increase the

construction modulus value by adding a thick insert plate or longitudinal carling [2].

Types of structural problems include stress analysis, frame analysis, buckling, and vibration analysis [3]. Loads that can affect the local structure and must be considered in the design of the transverse construction of the ship consists of two parts, namely: buoyancy and gravity. The upward pressure results from the distribution of hydrostatic pressure in the outer plane of the immersed hull. Gravity is the largest downward force on ships and their contents [4]. As a result of these loads, all parts of the ship's construction experience some type of stress. There are several factors that cause the actual stress distribution to be different from the ideal stress distribution. Due to the transverse shear stress, distortion occurs based on the length of the hull girder cross-section [5].

In problems involving complex geometries, such as problems applying to complex structures, it is generally difficult to solve them through mathematical analysis. This is because mathematical analysis requires a quantity or value that must be known at each point in the structure under study. Solving the analysis of complex geometrical differential equations, complex loading, is not easy to obtain. Nevertheless, the formulation of the finite element method can be used to solve these problems [3].

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The new method based on virtual displacement is the world's last solution. Applied mathematics problems and solutions are still being developed along with the development of computer science [6]. Finite element analysis is a numerical technique. In this method, By using this package, one can analyze several complex structures [7]. As a numerical method, it is used to solve technical and mathematical problems of a physical phenomenon. The types of physical and mathematical problems that can be solved by the method are structural and non-structural analysis. By using the method, all the complexity of the problem, such as various shapes, boundary conditions, and loads can be maintained but the solutions obtained are only approximate. This is due to its diversity and flexibility as an analytical tool. Rapid improvements in computer hardware technology and reduction in computer costs have driven this method because computers are a basic requirement for the application of this method. A number of popular brand element analysis packages are now commercially available to simplify complex structural analysis [8].

In this study, the strength of the deck construction of ro-ro ferry will be examined by modeling it in the FEM application. Modeling is done to determine the amount of

stress and strain in construction. Stress is a static amount; it is a measure of the stress of structural materials. On the other hand, strain is total kinematic; it measures structural deformation. However, deformation depends on the loads acting on the structure. Therefore, stress and strain are not independent. The physical relationships that connect these numbers are called constitutive laws. It describes the structural behavior of the material under load. It depends on the material and can only be obtained with the help of experiments [9].

One of the assessments carried out to determine the strength of the construction is to estimate the stress ratio obtained by comparing the stress that occurs in the construction due to external loads working on the ship [10]. According to BKI 2021, a good stress ratio for working on ship construction is still smaller than 1 (<1) [11].

2. Methods

This research is a quantitative research that takes the sample ro-ro ferry. The object of research was the stiffener of the vehicle 01 deck on the Ro-Ro Ferry, namely KMP Legundi 5000GT as shown in Fig. 1.

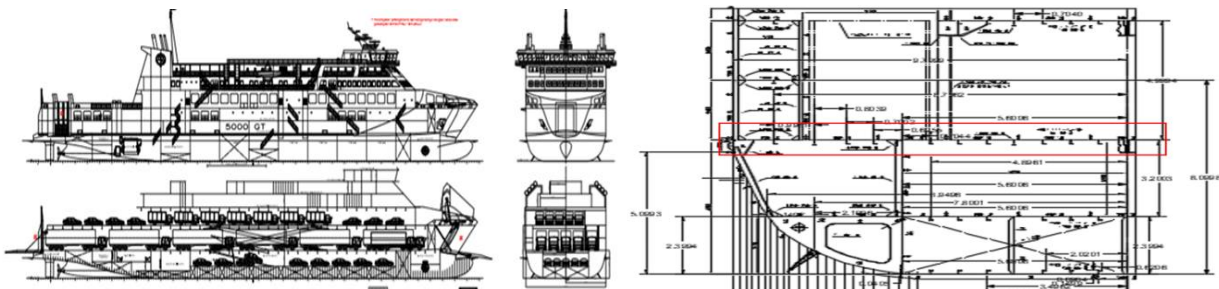


Figure 1. GA and midship construction of ferry ro-ro

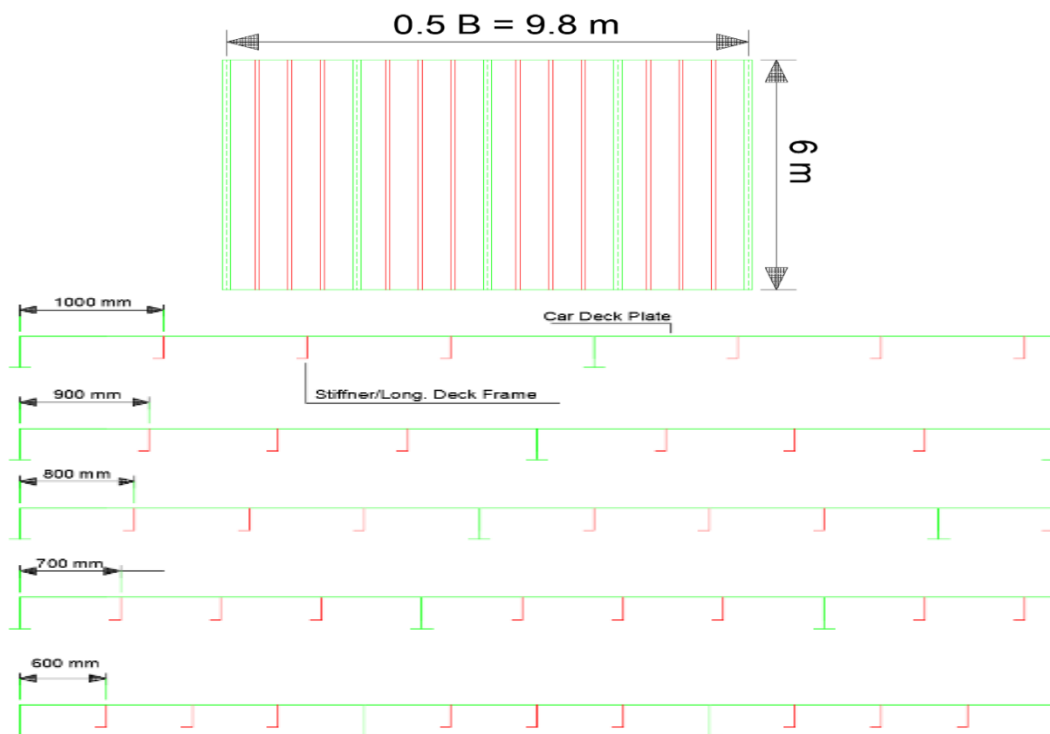


Figure 2. Plan view and transfer view of car deck

Figure 1 shows the red line marking on the vehicle deck which is the object of the study. The detailed illustration of the vehicle deck construction and the stiffener variation plan is shown in Fig. 2. Figure 2 is then converted to a 3D model using an FE-based application by taking the width of the ship on the ro-ro ferry car deck and the length of the deck model of 6 m then varying the stiffener distance shown in Fig. 3.

Furthermore, the meshing process is carried out on the 3D car deck model as one of the steps that are passed when using the FE analysis shown in Fig. 4. The mesh size used is 300 mm with the mesh type is hexahedron. As shown in Fig. 4. The next stage is to provide the boundary conditions on the 3D car deck model in the form of vehicle support and load shown in Fig. 5.

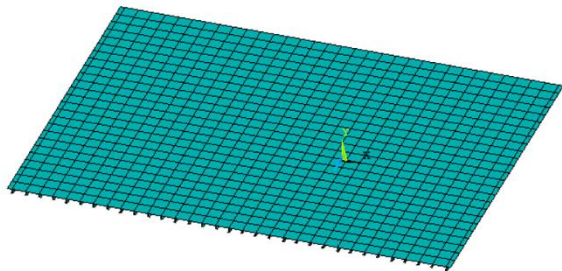


Figure 3. 3D modeling of car deck

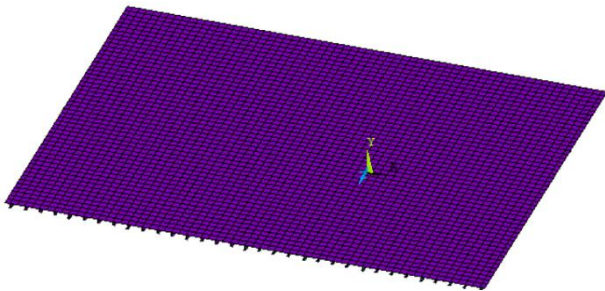
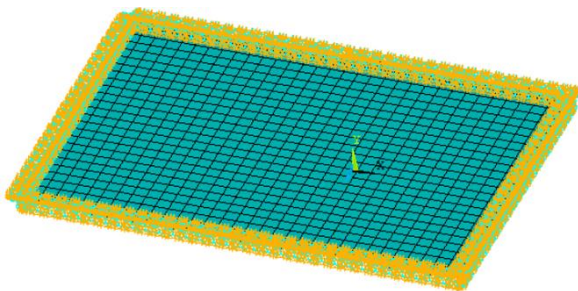
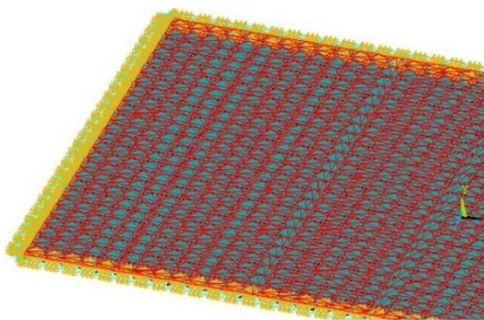


Figure 4. Meshing of 3D modeling car deck



(a)



(b)

Figure 5. (a) input fixed support; (b) input pressure load

Figure 5a shows the pedestal input in the form of fixed support given around the 3D car deck model. Whereas Figure 5b shows the load input given in the form of the total load of the trailer truck according to the load case during operation [12] which is on the car deck of $1.18 \times 10^{-2} \text{ N/mm}^2$ which form of load pressure. The results of the running of the FEM application are NLFEA in the form of maximum stress values. The output parameters used for each variation stiffener distance are the value of the maximum stress and strain against the maximum load acting on the car deck structure.

Stress is defined as the amount of force acting per unit area. There are two types of stress: normal stress and shear stress. Normal stress (σ) is a measure of the normal force or axial force per unit area [13]. Stress is the force of broad unity. When an object is subjected to a force, the stress is the ratio between the size of the force to the area to which the force is applied. If the force applied is perpendicular to the surface of the object (the area to be calculated), then the stress is normal stress. If the force applied to the object is tangential to the surface of the object, the stress is the shear stress [13].

$$\sigma = \frac{F}{A} \quad (1)$$

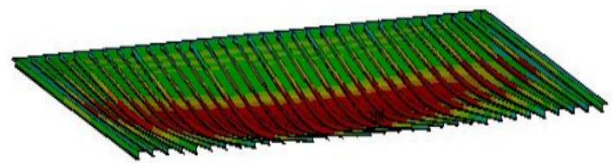
where σ = stress (Pa); F = force (N); A = cross-sectional area (mm^2). The strain (strain) is defined as the ratio between the increase in length or shortness of the stem and the size initially stated:

$$\varepsilon = \frac{\Delta L}{L} \quad (2)$$

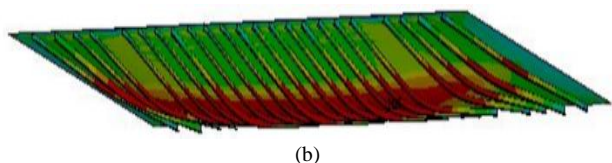
where ε = strain (mm); ΔL = increase in length (mm); L = initial length (mm).

3. Results and Discussion

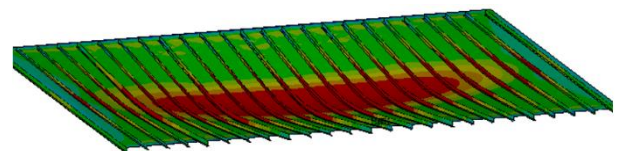
This research shows that the calculation of strength is obtained using an application based on the Finite Element Method (FEM) on the car deck of a ro-ro ferry. The simulation results at each variation of the stiffener distance can be seen in Fig. 6.



(a)



(b)



(c)

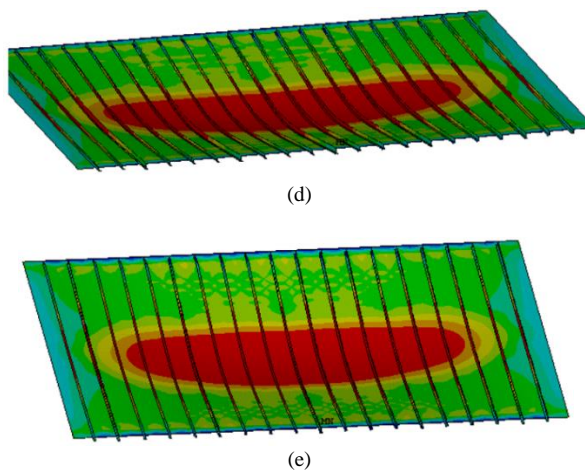


Figure 6. (a) 600 mm spacing; (b) 700 mm spacing; (c) 800 mm spacing; (d) 900 mm spacing; (e) 1000 mm spacing

Table 1 shows the value of von mises stress that occurs in the car deck model with variations in the stiffener distance starting from 600 ~ 1000 mm. Von mises stress and deformation values for each stiffener distance are summarized in Table 1.

Table 1 shows that the simulation results of the car deck stiffener distance variation of 600 mm, the maximum stress is 285.5 N/mm², and the maximum strain is 1.76 x 10⁻³ mm. For a stiffener distance of 700 mm, the maximum stress released is 378,075 N/mm², and the maximum strain released is 1.77 x 10⁻³ mm. For stiffener distance of 800 mm, the maximum stress released is 383,737 N/mm² and the maximum strain released is 1.78 x 10⁻³ mm. While the stiffener distance is 900 mm. The maximum stress released is 389,188 N/mm² and the maximum strain released is 1.79 x 10⁻³ mm and the maximum stress emitted is 425,388 N/mm² and the maximum strain released is 1.8 x 10⁻³ mm.

Based on the analysis, the results of the stress-strain acting on the car deck structure are obtained, by considering the boundary conditions, the stress-strain relationship curve for each stiffener distance variation is shown in Fig. 7.

Figure 7 shows the car deck with a stiffener distance variation of 600 mm with a stress value of 0 N/mm² to 221,798 N/mm², the car deck is still linear or within the proportionality limit and then when the car deck with a value of 223,095 N/mm² is already at the elasticity limit or the addition of the stress-strain value on the graph has reached non-linear and is in a plastic condition that will reach the ultimate stress.

Table 1. Von mises stress and deformation of car deck

Space of Stiffener (mm)	Von mises stress (N/mm ²)	Deformation (mm)
600	285.5	1.76 x 10 ⁻³
700	378.075	1.77 x 10 ⁻³
800	383.737	1.78 x 10 ⁻³
900	389.188	1.79 x 10 ⁻³
1000	425.388	1.8 x 10 ⁻³

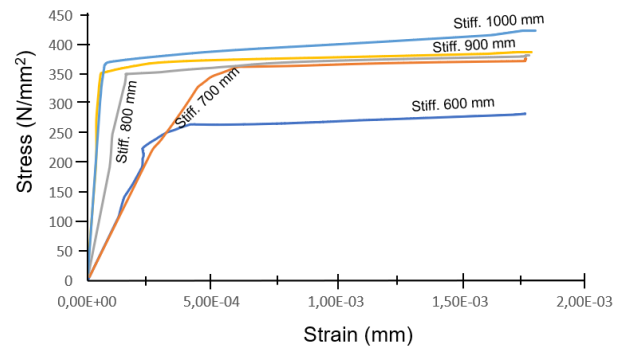


Figure 7. Stress-strain curve of car deck

The car deck with a stiffener distance variation of 700 mm with a stress value of 0 N/mm² to 313,414 N/mm² the car deck is still linear or still within the proportionality limit and then when the car deck ship with a stress value of 322,188 N/mm² is already at the elasticity limit or the addition of the stress-strain value on the graph has reached non-linear and is in a plastic condition that will reach the ultimate stress.

Car decks with stiffener distance variations of 800 mm with a stress value of 0 N/mm² to 340,605 N/mm² the car deck is still linear or within the proportionality limit and then when the ship car deck with a stress value of 345,746 N/mm² is already at the elasticity limit or the addition of the stress-strain value on the graph has reached non-linear and is in a plastic condition that will reach the ultimate stress.

Car decks with stiffener distance variations of 900 mm with a voltage value of 0 N/mm² to 345,832 N/mm² the car deck is still linear or still within the proportionality limit and then when the ship car deck with a stress value of 351,203 N/mm² is already at the elasticity limit or The added value of stress and strain on the graph has reached non-linear and is in a plastic condition that will reach the ultimate stress.

Car deck with stiffener distance variation of 1000 mm with a voltage value of 0 N/mm² to 362,864 N/mm² the car deck is still linear or still within the proportionality limit and then when the car deck ship with a stress value of 366,445 N/mm² is already at the elasticity limit or the addition of the stress-strain value on the graph has reached non-linear and is in a plastic condition that will reach the ultimate stress.

Based on the analysis, it is detected that the results of stress and strain acting on each of the elements in the car deck structure, by considering the variations in the stiffener distance that occur in each case, then a comparison of the stress values is obtained in Fig. 8.

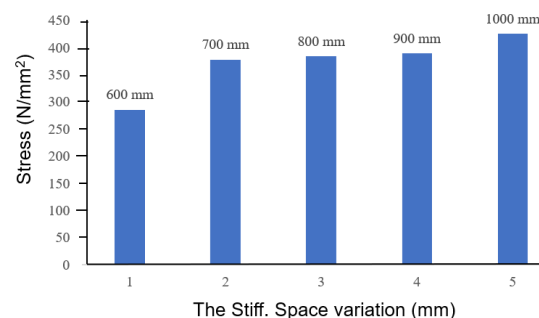


Figure 8. Stress influence of stiffener space

Figure 8 shows the stress value at the variation of the distance between 600 mm stiffener is 285.5 N/mm², the variation of the distance between 700 mm stiffener is 378,075 N/mm², the variation of the distance between 800 mm stiffener is 383,737 N/mm², at variations in the distance 900 mm stiffener is 389,188 N/mm² and the variation of the distance between 1000 mm stiffener is 425,388 N/mm². The highest stress value is in the variation of the distance between 1000 mm stiffener. There is an increase in the value of the stress as the distance between the stiffeners increases with an average percentage increase of 12.24%. This is in line with Amalia's 2019 research that the decrease in load is inversely proportional to the increase in frame distance, the farther the frame distance, the smaller the load required for the plate to buckle [14].

Based on the analysis, the results of the stress-strain acting on each of the elements in the car deck structure are obtained, by considering the variation in stiffener distance that occurs in each case, the comparison of the strain values is shown in Fig. 9.

Figure 9 shows the value of the strain at the variation of the distance between the stiffener 600 mm is 1.76×10^{-3} mm, the variation of the distance between the stiffener 700 mm is 1.77×10^{-3} mm, the variation of the distance between the stiffener 800 mm is 1.78×10^{-3} mm, The variation of the distance between 900 mm stiffeners is 1.79×10^{-3} mm, and the variation of the distance between 1000 mm stiffeners is 1.8×10^{-3} mm. There is an increase in the value of the strain as the distance between the stiffener increases with an average percentage increase of 0.6%. In line with Tumurang's 2016 research, the shear force of the beam with a stiffener that is installed close to the support area is getting smaller, while the shear force will increase if the stiffener is placed in the field area [15].

The results of the stress-strain acting on each element in the car deck structure are detected, taking into account the variations in the stiffener distance that occur in each case, namely the stiffener distance variations of 600 mm, 700 mm, 800 mm, 900 mm and 1000 mm, where the distance increases stiffener in the structure, the value of stress and strain continues to increase, this proves the decreasing of the strength level of the vehicle deck as the stiffener distance increases. Referring to the yield strength value of the car deck material 370 N/mm², the optimal stiffener distance can be determined where in this study the optimal distance of 600 mm is obtained when viewed from the resulting stress magnitude of 285.5 N/mm² which does not exceed the yield strength of the material.

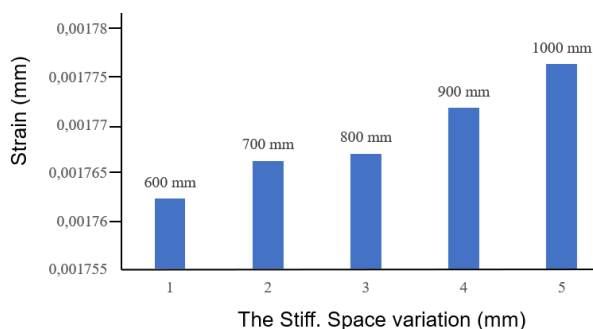


Figure 9. Strain influence of stiffener space

However, this value is not so accurate that further research is needed using a stiffener distance of 600 ~ 700 mm. This needs to be done because the simulation results are found with a stiff distance. 700 mm produces stress of 378,075 N/mm² which passes the yield strength of the material of 370 N/mm².

4. Conclusions

Stress-strain analysis on the car deck of the Ro-ro ferry ship which is influenced by variations in stiffener distance with a maximum evenly load condition of 1.18×10^{-2} N/mm², it can be concluded that at the variation of the stiffener distance of 600 mm the maximum stress detected is 285.5 N/mm² and the maximum strain released is 1.76×10^{-3} mm. At the variation of the stiffener distance of 700 mm, the maximum stress released is 378,075 N/mm² and the maximum strain released is 1.77×10^{-3} mm. For variations in the stiffener distance of 800 mm, the maximum stress obtained is 383,737 N/mm² and the maximum strain released is 1.78×10^{-3} mm. For the stiffener distance variation of 900 mm, the maximum stress released is 389,188 N/mm² and the maximum strain released is 1.79×10^{-3} mm. At the variation of the stiffener distance of 1000 mm, the maximum stress released is 425,388 N/mm² and the maximum strain released is 1.8×10^{-3} mm. The increase in the average stress value generated by 12.24% in the car deck construction is influenced by the increase in the distance between the stiffeners. Likewise, the value of the strain detected was increasing by an average of 0.6% with increasing distance between the stiffeners.

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