Strength Analysis of Navigation Board Structure on Fast Ferry Vessels Using Finite Element Method

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Abstract. Fast Ferry Ship is a ship used to carry passengers who will cross between islands. This ship prioritises passenger comfort and safety. Planning the supporting parts of the ship must refer to and comply with applicable regulations and classification standards. One of the important parts that must be present on a ship is the Navigation board. Therefore, the author analyses the planning of the Navigation board on the fast ferry which is reviewed based on the loads that occur with several different types of materials during ship operations, both during sailing and during operations at the port. Uneven load distribution and irregular seawater waves on the ship cause stress and strain on the ship structure that holds the Navigation board. One of the stresses acting on the Navigation board is Stress on the material. Stress analysis of materials is one of the most important things in determining the strength of the construction structure on the Navigation board. This will be applied to the planning of the Navigation board located on the Main deck. The classification regulations in ship design refer to the calculation of structural components described in the Classification calculation method and can be analysed using the Finite Element Method. Classification regulations used in the design of Fast Ferry Ships are using the BKI (Indonesian Classification Bureau). By analysing the strength of the Navigation board located on the Main deck of the Fast Ferry ship, the strength and simulation of the structure that can withstand the load of the components contained in the Navigation board itself under static conditions is obtained. In carrying out the analysis, the values of the safety factor in the ship are included where to keep the structure safe but the strength of the structure is not excessive. So that the design of the Navigation board design on the Fast Ferry ship with several different materials using the Finite Element Method is obtained with the form of stress distribution and structural deformation that is still permitted.

Keywords: Navigation board, loading, structure, finite element analysis.

1. INTRODUCTION

The process of designing a ship includes various aspects of both technical, economic and exploitation. The strength of the construction structure on the main deck is one of the technical aspects that contribute to the level of ship safety when exploiting both in calm and rough sea conditions. The ship's construction structure will experience various loads including internal loads caused by loading on the ship and external loads such as sea waves and the position of the ship against the waves themselves and

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also the wind. The benchmark that can guarantee the strength of the Navigation board structure is the stress experienced. A Fast Ferry type passenger ship with engineering construction that has complementary parts of a building or structure must be given certain physical sizes. The parts must be properly measured to be able to withstand the forces that are actually or may be imposed on them. Similarly, the parts of a composite structure must be sufficiently rigid that they will not buckle or warp excessively when working under a given load. In this case one of the important parts found on a Fast Ferry Ship is the Navigation board. In this structural behaviour analysis, the strength of the Navigation board design of the Fast Ferry ship will be discussed and analysed using the Finite Element Method. The design analysis in this loading uses static loading and uses several different types of materials. By analysing the Navigation Board with the loading that occurs on the Navigation board forming structure itself, the appropriate Navigation board design is obtained on the Fast Ferry ship (Taggart, 1980). This aims to anticipate the possibility of structural failure on the ship's Navigation deck which can cause accidents on the ship and keep the structure safe but the structural strength is not excessive. So that the design of the Navigation board structure on the Fast Ferry ship using the Finite Element Method is obtained with the form of stress distribution and structural deformation that is still permitted (Ville Valtonen, 2020). In the analysis of the behaviour of the structure using a structural analysis program package based on the Finite Element Method. With this analysis, structural behaviour is obtained which can be seen in the form of deformation and stress distribution in the construction of the Navigation board under static loading conditions.

2. INITIAL DESIGN

2.1 Cradle

Navigation board is a construction made of certain materials that is used as a basic place for storing and placing navigation tools on ships. We often know the shape of the Navigation board is like a table. Navigation board is able to withstand heavy or light navigation equipment placed on the table. Located on the Navigation deck or the captain's wheelhouse, but on this Fast Ferry ship it is located on the main deck. In general, the construction used uses steel plate material or marine-used wood that is certified according to the provisions of the applicable classification regulations. so as to ensure strength and withstand the load on it.

2.2 Loading Condition

The loading that occurs on the Navigation board structure on the ship is static load. Static loads are loads that change when the total weight of the ship changes, as a result of loading and unloading activities, fuel consumption or changes to the ship itself. Static loading is a type of loading that is fixed. In this case is the navigation board loading with the assumption that the magnitude does not change. Static loading received by the navigation board includes the load of navigation equipment and the force of the navigation equipment operator.

2.3 Stresses

Stress indicates the strength of the force that causes a change in the shape of the object. Stress is defined as the ratio between the force acting on the object and the cross-sectional area of the object. Mathematically it is written:

$\sigma = F/A$ .... (1)

with detail:

- σ =stresses (Pa)
- F = force (N)
- A = section are (m2)

The SI unit for stress is pascal (Pa), with the conversion: 1 Pa = 1 N/m2

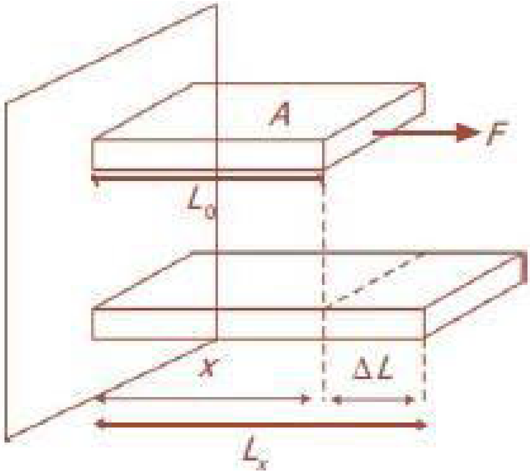

Fig. 1. Elastic body with length increase ΔL.

2.4 Deflection and strain

Deformation in continuum mechanics is the transformation of an object from its original state to its current state. The meaning of "state" can be interpreted as the set of positions of all particles in the body. A deformation can be caused by external forces, internal forces (such as gravity or electromagnetic forces) or temperature changes within the body (expansion). Strain is a subset of deformation, described as the relative change of the particles inside an object that is not a rigid body. Other definitions of strain can vary depending on what plane the term is used in or from and to which point the strain occurs.

In a continuous body, the deformed plane results from an applied stress due to a force or expansion within the body. The relationship between stress and strain is expressed as a constitutive equation, such as Hooke's law of linear elasticity. A deformed object can return to its original state once the applied force is removed, and it is referred to as elastic deformation. However, there is also irreversible deformation even when the force is removed, called plastic deformation, which occurs when the object has crossed the elastic or yield limit and is the result of slip or dislocation mechanisms at the atomic level. Another type of irreversible deformation is viscous deformation or viscoelasticity deformation result. In the case of elastic deformation, the response function related to strain versus stress is described in terms of Hooke's law tensor expression

2.5 Finite Element Analysis

The finite element method extends the displacement matrix method to structural continuum analysis. The elastic continuum of a plate is replaced by a surrogate structure, which consists of discrete elements interconnected only at node points. These connections are such that the actual stress and displacement continuum of the slab can be approximated by the displacements of the element nodes.

2.6 Material Properties

Material Properties A rigid material certainly has flexibility even though the material is made of steel. Steel material even if loaded with a large load will certainly have an elasticity value even though it is small so that it can change its shape slowly. The stiffness of a material is very important in the design of a construction component, because the stiffness will later cause problems due to large loads. To overcome this, each material of a construction component has a Young's Modulus value which is different for each material.

- Toughness

Toughness is the ability or capacity of a material to absorb energy until it breaks or the resistance of a material to break in two, with a transverse crack called a "crack" and absorb energy. The amount of energy absorbed during cracking depends on the size of the component that breaks into two. The amount of energy absorbed per unit area of the crack is fixed for the specified material and this is called toughness as well.

- Elongation

Elongation to failure is a measure of the plasticity of a material, in other words it is the amount of strain that a material can undergo before failure in a tensile test.

- Density

Density is a measure of how much an object weighs for a specified size, namely the mass of material per unit volume. Temperature changes do not steadily (significantly) affect the density of a material even though the material increases in area when heated, the change in size is very small.

- Resilience

Resilience is the ability of a material to absorb energy when the material undergoes elastic deformation.

- Ductility

Ductility is a measure of the degree of plastic deformation that has been experienced during fracture. Materials that experience high plastic deformation are called ductile materials. While materials that experience little or no plastic deformation are called brittle materials.

2.7 Safety factor

The factor of safety is a factor that indicates the level of ability of an engineering material to accept external loads, namely compressive and tensile loads. The force required for the optimum level of material to withstand external loads until it finally breaks is called the ultimate load. By dividing this ultimate load by the cross-sectional area, we will obtain the ultimate strength or ultimate stress of a material. For the design of structural parts the stress level called allowable stress is made strictly lower than the ultimate strength obtained from "static" testing. This is important for various considerations. The amount of force that can act on a designed building is rarely known with certainty. Since stress multiplied by area equals force, the ultimate allowable stress can be converted into the ultimate allowable force or load that a bar can withstand. An important ratio can be written SF.

3. METHODOLOGIES

The use of the Finite Element Method with structural analysis program packages is the most common tool for analyzing stresses that occur in structures, essentially by the following steps:

- Design modelling

The design to be analyzed is modelled first. which will be analyzed on the Navigation Board structure on the Fast Ferry ship.

- Determination of design type by study

Before the analysis process is carried out, the name of the problem (study), the type of analysis required (analysis type) must be determined.

- Determination of material type

The material used is BKI grade A marine used. In this step, mechanical properties are entered to determine the stress limitations possessed by the material.

- Load determination

The loading must be determined in accordance with the actual situation. In the analysis of the behavior of the navigation board structure, the load analyzed is a static load. The loading is assumed to be an even and centralized load.

- Determination of boundary conditions

Determine the boundary conditions on the navigation deck structure connected to the navigation equipment given the boundary conditions of the placement, so that it resembles the actual conditions on the navigation board structure (Budianto T. W., 2018).

- Meshing

Simulations are made in three-dimensional form, so a solid mesh is given which is the recommended meshing type.

- Analysis

In the analysis of the behavior of the navigation board structure, post processing analysis is carried out with static loading simulation.

4. RESULT AND DISCUSSION

The magnitude of the von Mises stress value that occurs in the navigation board structure on the fast ferry for each type of material Structural steel, Stainless steel, Aluminium can be shown with the following analysis results:

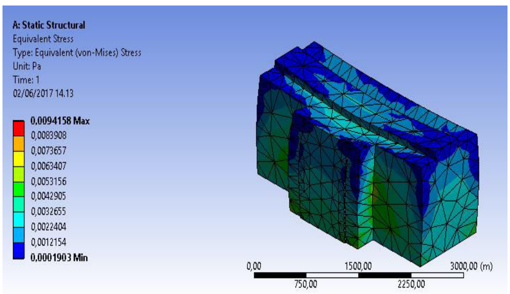

Fig. 2. Von Mises Stress of Steel

From the analysis picture above, it can be seen that the maximum von Mises stress that occurs is 0.0094158 N/m².

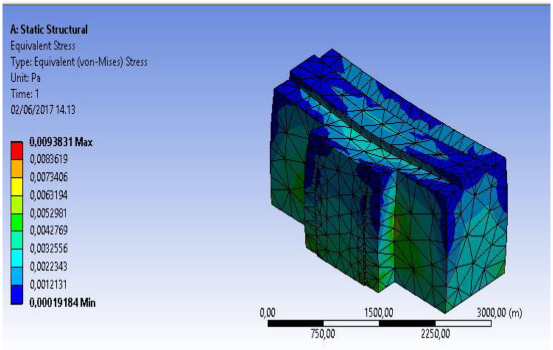

Fig. 3. Von Mises Stress of Stainless Steel

From the analysis picture above, it can be seen that the maximum von Mises stress that occurs is 0.0093831 N/m².

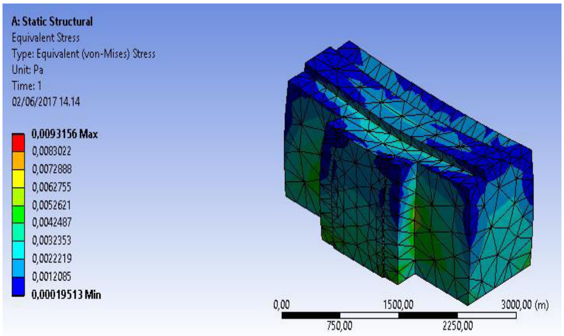

Figure 4. Von Mises Stress of Aluminium

From the analysis figure above, it can be seen that the maximum von Mises stress that occurs is 0.0093156 N/m².

The graph below shows a comparison of the maximum von Mises stress that occurs against different types of materials used. Where with structural steel material is 0.0094158 N/m², the maximum Von Mises stress that occurs with stainless steel material is 0.0093831 N/m² and the maximum Von Mises stress that occurs with aluminium material is 0.0093156 N/m².

To find out which material is stronger to withstand the load of navigation equipment and the force exerted by the captain of the ship is shown in the following table:

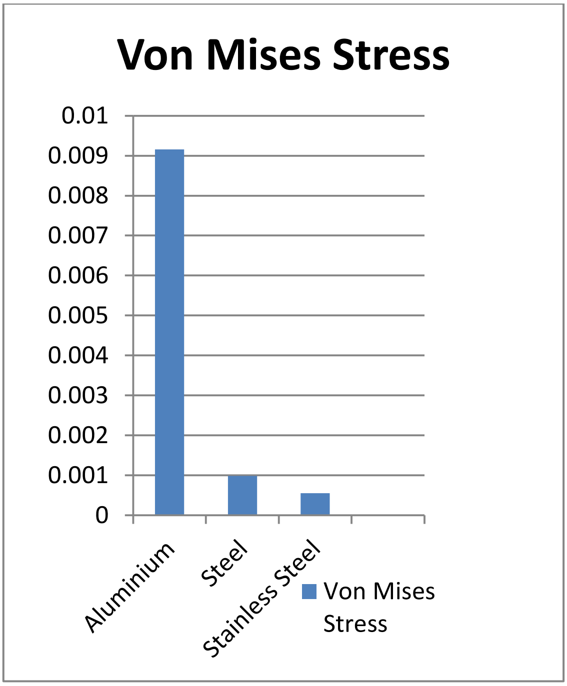

Fig. 5. Graphic Comparison of von Mises Stress with different materials

5. CONCLUSIONS

The cradle is designed with ASTM 36 Steel material with 6 different models, where in the analysis results the six models are in the conditions allowed by regulation. of the six models, model 3 has a relatively lower stress value than all models with a value of 0.098 N/mm^2 and also has a relatively lower displacement value than all models with a value of 0.005 mm. So that model 3 has a tendency to be used as a reference model in making the cradle because it has a higher strength than all the models made.

The 3rd concept cradle is made in the form of a girder I shape. This concept shoes sled is given a reinforcement construction with a square box pattern made of 12 mm thick plate and for the middle reinforcement made of 10mm thick plate, both of which have been adjusted to the position of the welder during welding.

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