

Strength Analysis of Deck A KM. Dharma Kencana V Due to The Addition of Construction With The Finite Element Method

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KEYWORDS

Deck
Stress
Construction
Finite Element
Method

ABSTRACT – The Dharma Kencana V passenger ship is a type of crossing ship owned by a Japanese shipping company which was later acquired by an Indonesia shipping company whose planned shipping route crosses from Surabaya to Makassar. With the transfer of the ship's shipping route, repairs and the addition of new construction in the deck A area were carried out so that the addition of the new construction increased the load the ship received. This study aims to determine the allowable stress allowed by the Indonesian Classification Bureau (BKI) Rules for Hull 2022 [1] from the stress results due to new construction on the deck. The analysis was carried out using the finite element method with numerical modeling using Ansys Static Structure student version software with a division of elements (meshing) size 200 mm on deck A frame 13 to 85. Based on the results of the element division of deck KM. Dharma Kencana V into 44767 elements at nodes 45384 and the maximum stress at 77.41 MPa. The allowable stress limit based on the BKI standard does not exceed 230 MPa, [1] so a safety factor of 2.97 is obtained so it can be concluded that the strength of the construction of deck A KM. Dharma Kencana V is still a safe category.

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INTRODUCTION

The Dharma Kencana V passenger ship is a crossing vessel that has been repaired and modified with additional new construction on the deck A superstructure in frames 13 to 85 to support passenger facilities so that changes in cargo will affect the stability and strength of the ship's construction. Especially for the deck A construction section, it will greatly affect the construction of the deck of the ship which directly supports the cargo due to the addition of new construction. So the description above triggers the formulation of problems about stress and the location of critical points and deflection results on the deck. Based on the formulation of these problems, the authors really need to conduct further research and studies on the strength of the deck using the finite element method. The simulation to find the stress value refers to the safety factor in several related research literature such as M.H Pratama, 2020 "Analysis of Car Deck Construction Strength of 1000 GT Ferry due to Load Changes with the Finite Element Method" [2] with the conclusion that the maximum stress on frame 63 is 173.048 MPa with a deflection of 19.2 mm. The smallest stress occurs in frame 31 of 40.969 MPa with a deflection of 5.017 mm, according to BKI strength criteria all conditions meet the requirements. As well as literature from A.I Wulandari, 2021 "Stress-Strain Analysis on Deck and Bottom Plates of Ro-Ro Ferry Vessels Using Finite Element Method" [3] with the conclusion that the results of 100% and 90% of plates do not exceed the allowable stress while for 80% and 60% of plates exceed the allowable stress according to BKI. With a similar case study it can be seen the results of stress and deflection on deck A KM. Dharma Kencana V on Frame 13 to 85 whether it complies with the criteria of the BKI classification rules allowable stress, so that these results can reduce the risk of accidents and ensure the safety of ship operations.

METHODS

The research methodology for this analysis focuses on the stress evaluation of Deck A KM. Dharma Kencana V from frames 13 to 85, consisting of several stages beginning with the collection of secondary and primary data. Secondary data include literature studies derived from journals, books, and classification society rules that serve as the theoretical foundation for this research. One of the referenced studies, "Effect of Lifting Lug Hole Diameter Size on Strength Performance in Ship Block Lifting Process," also employed the Finite Element Method (FEM) [4] as an analytical approach to assess structural performance under various loading and geometric conditions, reinforcing the reliability of FEM in marine structural analysis. Meanwhile, primary data consist of the ship's principal dimensions, material specifications, and general arrangement drawings. The details of the obtained primary data are presented in the following section.

Data Collection

The main size data of the ship is used to ensure that the ship has the appropriate dimensions so that it can be used as a reference in the ship construction process to ensure that the ship is built according to specifications. Specification of the main size of the ship data in Table 1.

Table 1. Main Size of the Ship

Ship Main Data	Size	Unit
Length Over All (LOA)	170,18	m
Length Between Perpendicular (LBP)	156,41	m
Breadth Moulded (B)	27	m
Depth Moulded (T)	6,50	m
Height Moulded (H)	17	m

The new construction on deck area A uses KI-A36 material applied to the entire deck. The plate type of the material refers to the BKI rules so that the stress due to the load applied to the plate must meet the allowable stress [1]. The complete specifications of the plate material are detailed in Table 2.

Table 2. Ship Material Data (KI-A36)

Description	Size	Unit
Modulus Elasticity	200	GPa
Shear Modulus	79,3	GPa
Poison Ratio	0,3	
Density	7850	kg
Yield Stress	235	MPa
Ultimate Stress	400	MPa

Deck Construction Modeling

The reference for modeling deck A is obtained from general arrangement data for deck modeling and ship scantling data for construction profiles. The stage starts from a 2-dimensional (2D) image of the general arrangement [5] as in Figure 1. and Figure 2. The 2D image is the basis for measuring the deck of the ship as well as the position and number of construction profiles so that the precis layout can be made with certainty [6]. Then the 2D image is converted into 3D so that the visualization of the KM deck. Dharma Kencana V can be read clearly when loading and the impact of the stress result value can be known [7].

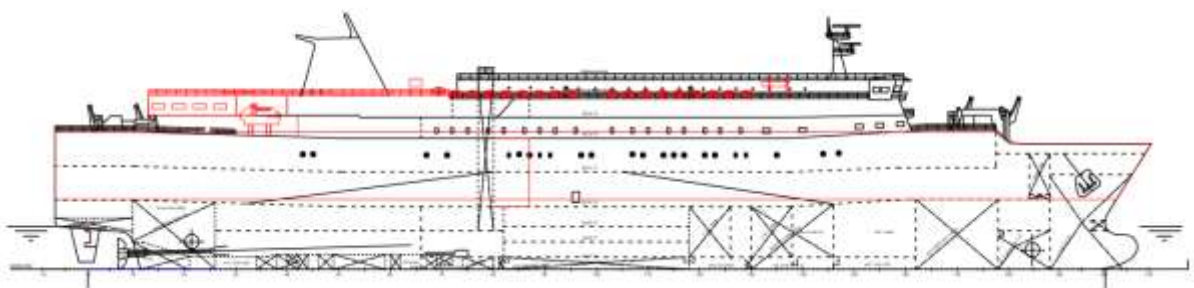


Figure 1. General Arrangement of KM. Dharma Kencana V

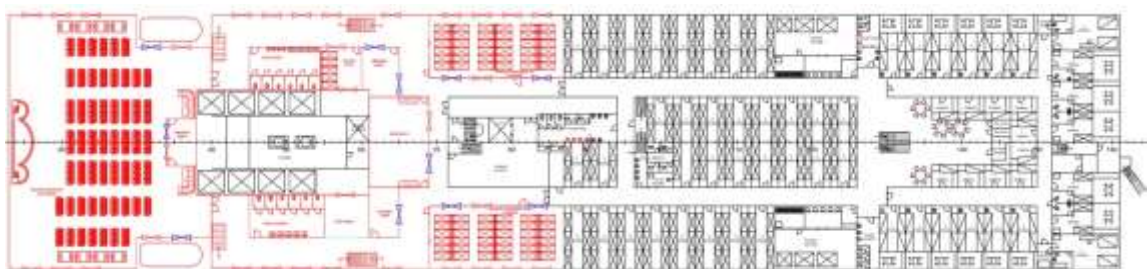


Figure 2. Deck A Construction KM. Dharma Kencana V

Stress Permission

Allowable stress is a value to determine the working stress limit experienced by the structure. In accordance with BKI Voll. 2 sec. 24 [1] the maximum allowable combined or von Mises stress shall not exceed the value of the following formula:

$$\sigma_y = \frac{230}{k} \quad (1)$$

Where :

σ_y = Von Mises Stress (Mpa)
 k = Material Factor

According to BKI Vol. 2 sec. 2 the value of the material factor (k) is the material value factor based on the yield stress value. The hull structure material value has a yield stress point of 235 Mpa and 400-520 Mpa for tensile strength [1]. This rule applies to KI-E, KI-D, KI-B, KI-A class materials.

Safety Factor

Safety Factor is a value used to measure the safety level of a structure against failure. It is used to evaluate the planning of construction elements in order to ensure their safety with the stresses they receive, according to BKI *rules for hull 2022*. The *safety factor* can be calculated by dividing the strength of the material or structure by the applied load, or often by dividing the design limit value by the applied load [8]. The higher the *safety factor*, the greater the safety level of a system. Usually, a larger *safety factor* value indicates that a system has a higher resistance to failure or damage. The *safety factor* is formulated as follows:

$$SF = \frac{\text{Stress Permission}}{\text{Stress Maximum}} \quad (2)$$

RESULTS AND DISCUSSION

The analysis carried out at this stage is focused on the allowable stress value using the Ansys Static Structural Student Version software model simulation [9]. The allowable stress value is determined through the stages of the research methodology above, so the steps are as follows.

Load Calculation

The *deck building load* consists of 3 *decks*, namely *compass deck*, *navigation deck* along *frames 73 to 85*, and *deck A* along *frames 13 to 85*. Calculation of the *deck building load* requires the material specifications of each *deck* (kg) obtained from the shipbuilding *scantling* data and measured from the *general arrangement* which is then multiplied by the acceleration of gravity (9.8 m/s^2) [10]. The detailed results of each *deck building* are in Table 3.

Table 3. Building and Passenger Deck Load Calculation Results

Frame	Room	Room Size and Passenger Capacity (m)	Plate Specifications and Number of Passengers	Load (N)
73-85	Compas Deck	8,8 x 27	6 x 1,8 x 6mm	113.190
73-85	Navigation Deck	52,9 x 27	6 x 1,8 x 6mm	680.426,25
73-85	Crew CS 4P	4,4 x 2,4 x 2,91	6 x 1,8 x 6mm	195.18.98
73-85	Ruang Jacuzzi	8,8 x 4,8 x 2,91	6 x 1,8 x 6mm	585.56,96
73-85	Crew GS 4P	4,4 x 2,4 x 2,91	6 x 1,8 x 6mm	195.18,98
13-85	Deck A	52,9 x 27	6 x 1,8 x 6mm	680.426,25
13-85	Tatami	13,6 x 6,7 x 2,91	6 x 1,8 x 6mm	122.556,48
13-85	Smoking Area 1	3,2 x 5 x 2,91	6 x 1,8 x 6mm	295.74,22
13-85	Smoking Area 2	4 x 5,3 x 2,91	6 x 1,8 x 6mm	391.85,84

Frame	Room	Room Size and Passenger Capacity (m)	Plate Specifications and Number of Passengers	Load (N)
13-85	Massage Room	4,4 x 4,5 x 2,91	6 x 1,8 x 6mm	375.78,1
13-85	Mens's Room	7,6 x 4,5 x 2,91	6 x 1,8 x 6mm	649.78,9
13-85	Ladies's Room	7,6 x 4,5 x 2,91	6 x 1,8 x 6mm	649.78,9
13-85	Mushola	6,4 x 9,6 x 2,91	6 x 1,8 x 6mm	113.565,01
13-85	Barber Shop	3,2 x 5,3 x 2,91	6 x 1,8 x 6mm	313.48,67
13-85	Cafeteria	4,8 x 4,5 x 2,91	6 x 1,8 x 6mm	399. 25,2
13-85	Passengers		250 people	138.503,4

The deck construction profile load is calculated based on the *general arrangement* data of KM. Dharma Kencana V which refers to the BKI 2019 rules for hull (part 1, volume II) midship section. The types of deck construction profiles consist of *deck beam*, *deck longitudinal*, *deck side & center girder* attached to the entire *compass deck*, *navigation deck*, and *deck A* [11]. The results of the data are obtained in Table 4.

Table 4. Deck Construction Profil Load Results

Frame	Profile Name	Shape	Size	Total	Load (N)
73-85	Deck Side & Center girder	T	125x6 / 75x8	5	444,44
73-85	Deck Beam	T	200x6 / 100x8	2	177,77
73-85	Deck Longitudinal	L	50x50x6	32	2844,44
73-85	Side Plate & Wall		8 mm		
73-85	Ordinary Frame Side	L	90x90x9		115,74
73-85	Web Frame Side	T	200x6 / 100x8		92,59
73-85	Deck Plate		6 mm		
73-85	Web Beam Deck	T	400x10 / 175x16	2	177,77
73-85	Deck Longitudinal	L	60x60x6	32	3555,55
73-85	Center Girder & Side Girder	T	200x6 / 100x8	5	444,44
73-85	Side Plate & Wall		8 mm		
73-85	Ordinary Frame Side	L	100x100x10		129,90
73-85	Web Frame Side	T	250x6 / 125x8		103,88
13-85	Deck Side & Center Girder	T	400x6 / 150x8	5	2935,83
13-85	Deck Beam	T	400x10 / 175x16	17	11743,33
13-85	Deck Longitudinal	L	90x90x9	32	18788,8
13-85	Pelat Deck		6 mm		

The total loading results are obtained from the total summation in Table 3. and Table 4. as well as other capacity loads, so that the results that have been obtained from the overall deck load can be inputted into the simulation of the finite element method with units of newtons [10] in Figure 6. The total loading results are in Table 5.

Table 5. Total Loading Results

Frame	Deck Name	Mass (kg)	Load (N)
73-85	Compass Deck	1.5017,00	147.166,6
73-85	Navigation Deck	8.3776,00	821.004,8
13-85	Deck A	13.9277,00	136.4914,6
13-85	Deck A Construction Profile	3415,09	334.67,96
Total :		238.070,00	2.366,553,97

Modeling The Deck Construction

In this study, the modeling of deck A along with its construction profile from frame 13 to 85 uses Autocad software with the extrude command which produces Figure 2. into 3D. The distance between longitudinal decks is 0.8m and the distance between deck beams is 3.2m this refers to the BKI rules for hull 2022 [1]. The specifications Figure 3. In accordance with the construction profile in Table 5. Based on Figure 3. The model is already in 3D form with several supporting profiles, namely longitudinal deck profiles, deck beams, deck side & center girder. Load on deck A KM. Dharma Kencana V there are 2 load input points, namely on frames 13 to 72 and frames 73 to 85 according to the Newton load in Table 5.

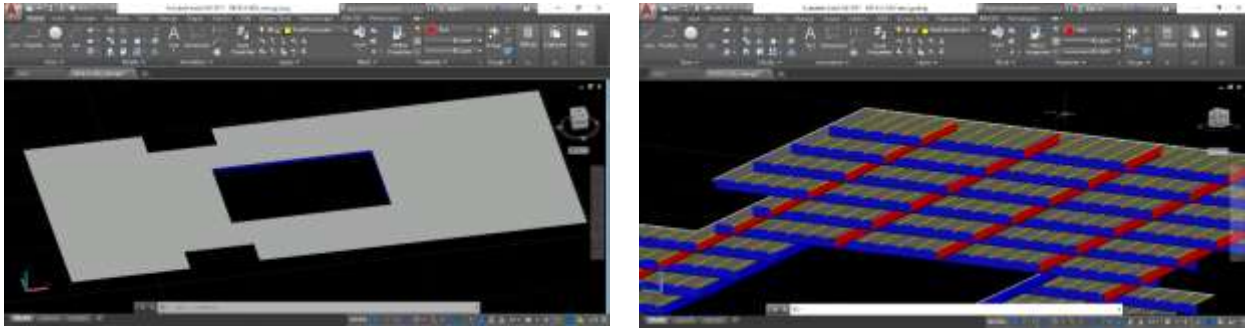


Figure 3. 3D Result of Deck A KM. Dharma Kencana V Frame 13-85

Finite Element Method Simulation

The analysis process was conducted after the 3D AutoCAD model was imported into ANSYS Workbench using the Static Structural module, allowing simulation based on the Finite Element Method (FEM). This approach facilitates a more accurate and detailed evaluation of the structural response by inputting specific engineering data into the analyzed geometry. The use of the finite element method greatly simplifies the design and verification process, enabling engineers to predict stress distribution, deformation behavior, and overall structural integrity effectively before physical implementation [12]. *Engineering data* is filled with values that match the material used in the simulated model. In this research, *deck A* of KM. Dharma Kencana V uses KI-A36 type material based on Table 2.

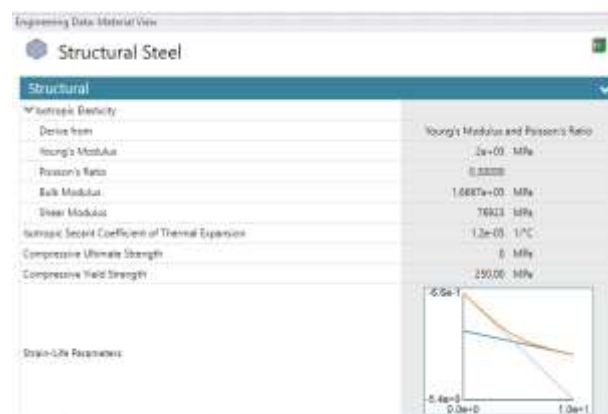


Figure 4. Engineering Data

3D deck A model from *Autocad* that will be analyzed is *exported* in the form of an IGES file (igs.). *Geometry* that is already *solid* and connected to each other, then the *meshing* process is carried out, namely dividing the *geometry* into several small elements to optimize the simulation results [13]. *The meshing* process requires determining the size of the elements needed because the smaller the *mesh size*, the more detail. In this study, the type of element used is a *tetrahedron* with a size of 200 mm.

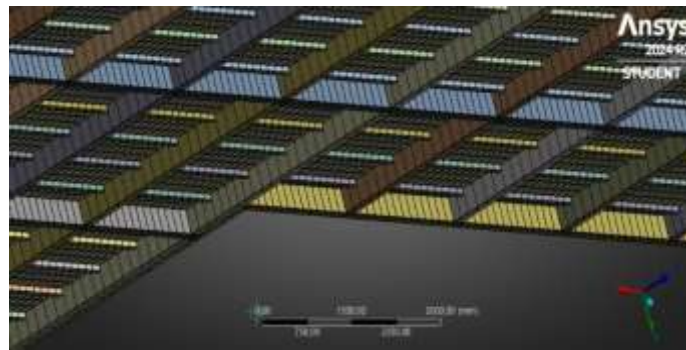


Figure 5. Meshing Details

The load applied to *Deck A* is placed at two points, *frames 13 to 72* and *frames 73 to 85*, with the total load results shown in Table 5. The type of input in giving the load is a *force* with the direction of the down arrow (-Z) to get the pressure from the top of the *deck* by the load [14]. Based on Figure 6. The provision of load at 2 points of the *deck*, namely at *frames 13 to 72* with a value of 1398382.57 N and at *frames 73 to 85* with a value of 968171.4 N. Where the *force* has been determined in the *midship section scantling* data and the calculation of the total load of *deck A*.

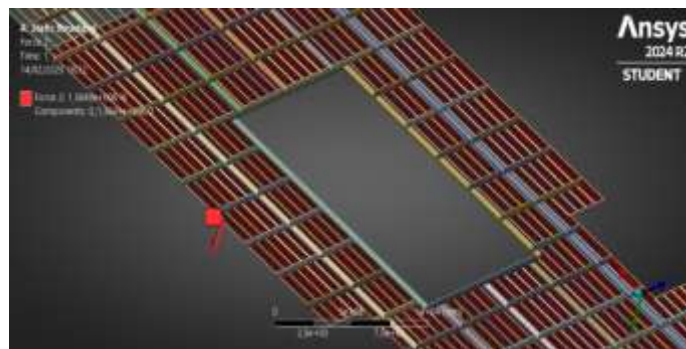


Figure 6. Force Frame 13-72

The boundary conditions in this study use edge and vertex-type fixed supports that aim as force limitations and support points for decks that are applied around the edges and funnel holes of *deck A*.

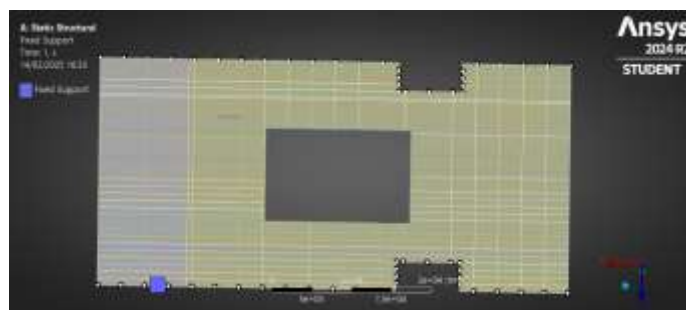


Figure 7. Fixed Support Vertex Frame 13-85

Solution Result

In this research, the *solution* selection consists of *total deformation*, *equivalent stress*, and *safety factors*. The results of the analysis show the position as well as the minimum and maximum stress values that occur on *deck A* due to the new construction loading on the *deck* [15].

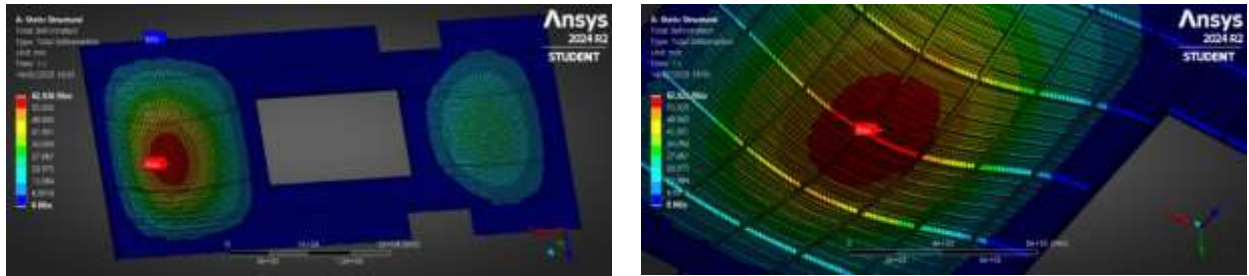


Figure 8. Total Deformation

Based on Figure 8, the results of the maximum total deformation occur in the T *deck beam* profile *frame 74*. Where in that area is the location of the maximum stress when analysis. This happens because the *frame area 73* to *85* supports the heaviest load, namely from the *compass deck* and *navigation bridge deck* so the maximum affected area is visualized in red in that area. The result of the maximum stress value of total deformation is 62.92 mm, while the *frame area 12* to *72* does not really show the maximum visualization until red because the *frame area* contains new construction *deck A* which is not too burdensome for the geometry. While the location of the maximum stress is marked with a red color area, where in that area the maximum stress is affected on the T *deck beam* profile and the T *deck sider girder* profile. The visual impact of deformation that is centered on the *deck* is due to the fact that this section is concerned with the heaviest load, resulting in a depth of deformation that is centered.

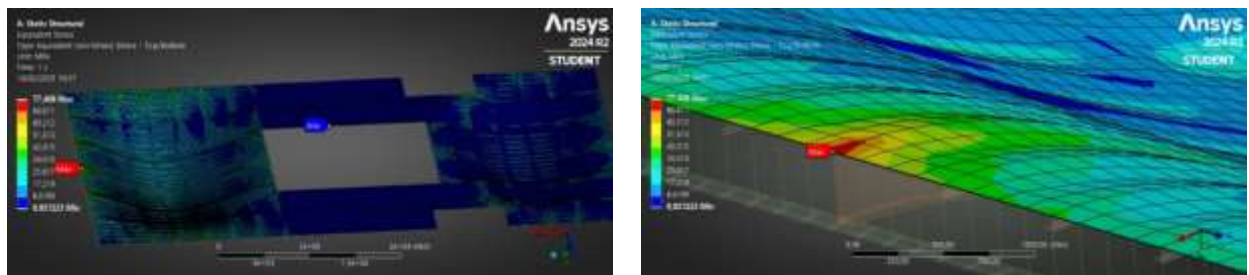


Figure 9. Equivalent Stress

The results of the *equivalent stress* on *deck A* occur in the T *deck center* profile section. This is the location of the maximum stress from the simulation in this study. The result of the maximum value of *equivalent stress* is 77.40 MPa, which is marked with a red visualization, which is the area affected by the maximum stress that does not show serious critical results. This is due to the presence of boundary conditions in the area around the *deck*.



Figure 10. Safety Factor

The results of this simulation show a value of 15 mm for the *safety factor* with the overall load supported by *deck A*, so if the *deck* exceeds the *safety factor* limit value it is likely that the *deck* will experience structural failure. Visualization of color effects in the *Ansys static structure solution* results shows the impact of different geometries, namely red shows areas with high stress, green and yellow show areas with medium stress, and blue shows areas with low stress. The *safety factor* graph shows the fatigue strength factor by *default* or no surface defects in the *geometry* and can be observed from the *constant amplitude load* with a completely constant graph. This shows that the actual force applied is 2366553.97

Newton which is represented by a *scale factor* of 1 on the positive and negative sides so that the line on the graph becomes up and down which indicates the combination of *force* and material experiencing stability.

Analysis Stress Permission

After knowing the stress results of each loading that has been *run*, then determine the allowable stress limit that can be experienced by a structure so that the *safety factor* value of a structure can be determined from the allowable stress value divided by the maximum stress. In accordance with *BKI Vol. II Sec. 24* combined stress or *von Mises* stress. Simulation results using Ansys Static Structural Student Version visualization show the results at *node* 45384 and total *elements* 44767 the maximum stress at 77.40 MPa and the allowable stress limit value of 230 MPa, then a *safety factor* of 2.9715 is obtained. Based on the stress values obtained, the analyzed structure can be categorized as safe because according to *BKI rules for hull 2022 sec. 24* factors of the allowable stress results are on a scale of 1 to 10, if below the predetermined scale, it can be concluded that the structure has failed. This shows that the construction structure of deck A frame 13 to 85 KM. Dharma Kencana V has the ability to withstand the given load without experiencing significant damage, but it is necessary to carry out regular monitoring and maintenance to ensure that the structure remains in good condition. Based on this research, it is recommended that further research be added to the variation of wave loads [16] as well as variations in wave direction and the implementation of sandwich plates [17] so as to create a real visualization of the ship's motion [18].

CONCLUSION

The analysis results indicate that the maximum equivalent stress on the deck center girder of Deck A KM. *Dharma Kencana V* reached 77.41 MPa, with the visualization showing that the critical stress levels under even load distribution were not severe, largely due to the applied boundary conditions around the deck area. The total deformation analysis showed a maximum deformation of 62.92 mm across frames 13 to 85 under overall loading, where critical points were observed around the T-deck beam profile and the deck side frame 74 under a centralized load, yet no significant deflection occurred in those regions. Furthermore, the meshing process divided Deck A into 44,767 elements and 45,384 nodes, producing a maximum stress value of 77.41 MPa, which remains well below the allowable stress limit of 230 MPa as defined by BKI standards. Therefore, with a safety factor of 2.97, it can be concluded that the structural strength of Deck A KM. *Dharma Kencana V* is within the safe category and meets the required design standards.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude for the support and assistance to all parties involved in this research process, especially the University of Jember. Their extensive resources, expertise and motivation have contributed significantly to the success of this research. With the achievement of the objectives of this research, hopefully, the help and support will be a good deed for all of us.

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