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Planning Study of Fender Spacing at Semayang Port based on PIANC

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KEYWORDS
Fenders
Super Cone
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Impact energy
Distance fenders

ABSTRACT – Fender is one of the facilities whose role is very important for a dock. With the availability of a fender that can help absorb the energy of the ship's collision with the dock and can reduce the risk of damage to the dock structure and the ship's body. In the case found at Semayang Port Balikpapan, the fender is damaged due to the difference in the dock level with the docked ship. The position of the ship at the highest tide exceeds the limit set on the fender so that there is a difference that makes the fender work not optimally. The purpose of this research is to plan a fender system that is integrated into the dock structure. The method in this research is the finite element method with data processing and collecting primary data by making direct field observations. While secondary data in the form of ship data, wind, currents, and tides are obtained through the BMKG website and related agencies. The selection of the fender system is based on the calculation of the ship's impact energy on the Semayang Balikpapan pier. So that the results of the calculation of impact energy on the Fender amounted to 1844 kNm and obtained the type of fender, namely SCN 800 at 22 m for each fender with many 8 fenders.

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INTRODUCTION

Sea transportation is a means of transportation that is very important in helping human activities such as carrying out activities of raising and lowering passengers where sea transportation is called a ship [1]. When the ship docks at the pier, there is energy acting on the ship caused by the energy from the ship's engine. Therefore, to reduce the impact energy that occurs when the ship hits the pier, fenders are used to reduce this energy. The main cause of fender damage is when a collision energy that occurs is very large so that the fender receives too much load so that the fender cannot withstand and receive the impact energy that occurs from the size of the fender, causing damage to the fender [2]. Based on the main causes of fender damage, there are also several factors that cause fender damage, such as environmental factors that the fender receives. The environmental factors that cause the fender to be damaged are wind speed, tides and waves which can affect the motion of the ship when it is leaning which will have an impact on the fender. The types of fenders used at the RoRo ship crossing docks generally use a type of rubber fender where to determine the optimal type one must calculate the impact energy that occurs on the ship and then calculate the optimal distance before determining the type of fender used after being able to determine the distance and energy values. the collision that occurs can determine the type of fender used which at the roro ship crossing pier uses a cell type fender css 300 which is mounted vertically on the front side of the pier. When planning a Fender system, it is possible to calculate the energy of collisions that occur on the ship as well as determine the load that will be absorbed by the Fender, where the ship used has a size of 10,000 DWT. Therefore, it is also necessary to consider the distance between Fenders in order to determine the type of Fender, with the chosen type being KVF 600H.

In the case of the Semayang Balikpapan port, the facility and infrastructure have been investigated [3]. In the present study, fender construction will be studied, the fenders suffered damage caused by berthing forces and mooring forces (pull of the ship by wind, currents and waves). Therefore, the fender really needs to be adjusted to the type and weight of the leaning ship and the mooring ship, then the calculation of the ship's impact energy is carried out in order to get the energy received by the pier so that the fender functions optimally. Based on several previous studies, no one has discussed how the fender deformation and the stresses that occur in the fender when the ship impacts the fender. Then it is necessary to do modeling to see the visualization of changes in the shape of the fender when there is an impact energy which in this study uses a super cone fender type which is generally a type of rubber fender which can absorb impact energy optimally. The analytical method that will be used to conduct this research will use a quantitative descriptive analysis method by processing the required data are secondary and primary data. Primary data will be taken using observation, then secondary data includes ship data, wind.

METHOD

A. Data Used

The main data bellow is collected to solve the problem formulation in this study, while the secondary data obtained from the BMKG website and the official website as well as institutions related to metaocean data and journals that discuss conditions in the research area. For he Ship, we used RoRo ship that has weight 5814 DWT so that it is taken to be 6000 DWT for ease of calculation, where the reason is because this general ship's type lean more often at the Semayang port with various ship weight sizes. For the wharf Layout Data, the pier layout data at Semayang Balikpapan port was obtained directly from Pelindo Balikpapan, which obtained the overall length of the Semayang port pier of 491.5 m, where there were 8 piers, then piers 1, 2 and 3 which had a length of 60 m. For the Old Fender Data, we used the Pelindo's data ones in Balikpapan, especially at Semayang Balikpapan Port, is used as a reference for this research to determine the optimal fender type from the previous type of fender, where this data was obtained directly from Pelindo Balikpapan. Wind data, that've been used is in the form of wind speed and wind direction data obtained from the official BMKG website. Based on secondary wind data for the 2016-2022 timeframe obtained from the BMKG website. This wind data is used to find the value of the speed and direction of the wind which greatly influences the planning of the fender system where wind pressure can affect the movement of the ship when it is leaning on the pier when the ship is not loaded or has loads. The processing of the wind data uses the help of WRPLOT software with the conditions at the time of Blowing from.

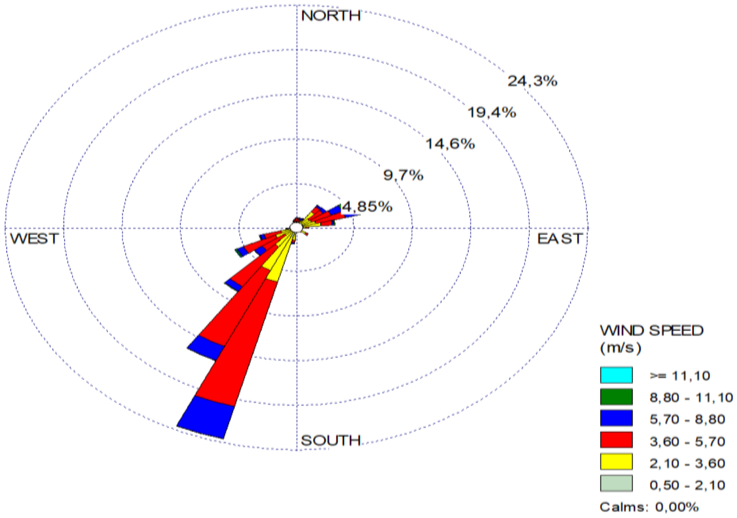

Figure 1. Diagrams of Wind Roses for the Last 6 Years (2016-2022)

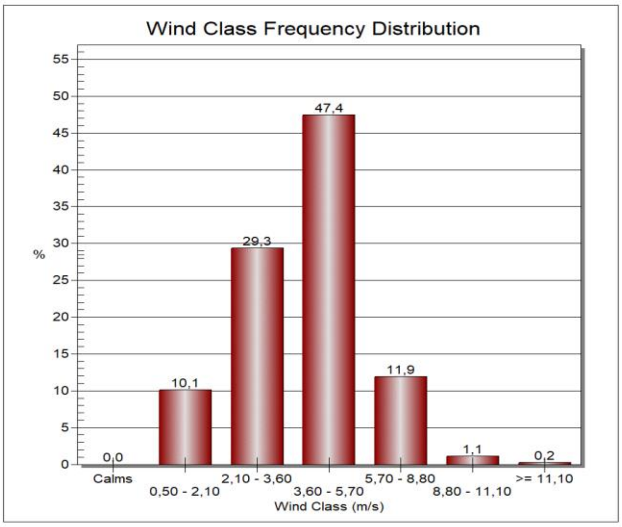

Figure 2. Percentage of Frequency Diagram of Wind Data for the Last 6 Years (2016-2022)

Secondary flow data is flow data obtained from the official website or from previous journals. Last, for the tidal data, the secondary tide data is tide data obtained from the official website or from previous journals in the form of water level elevation in meters. The tidal data used in this research uses secondary data obtained directly by the Semayang port manager, namely PT. Indonesian Port (Persero). Based on the tidal data that was obtained in March 2023, the data is processed using the Admiralty method which is to get the value of this tidal data which will be used to find the value of MSL (Mean Sea Level), HHWL (Higher High Water Level), MHWL (Mean High Water Level), MLWL, (Mean Low Water Level) and LLWL (Lower Low Water Level) and get tide charts where each value uses data for March 2023. Based on the tidal chart data that has been processed using the Admiralty method with the help of the Ms Excel application to help calculate the tidal value, the respective value for each tidal elevation in March 2023 is HHWL (Higher High Water Level) of 2.93 m. MHWL (Mean High Water Level) has a value of 2.44 m. MSL (Mean Sea Level) has a value of 2.54 m. MLWL (Mean Low Water Level) has a value of 0.41 m. LLWL (Lower Low Water Level) has a value of -0.076 m.

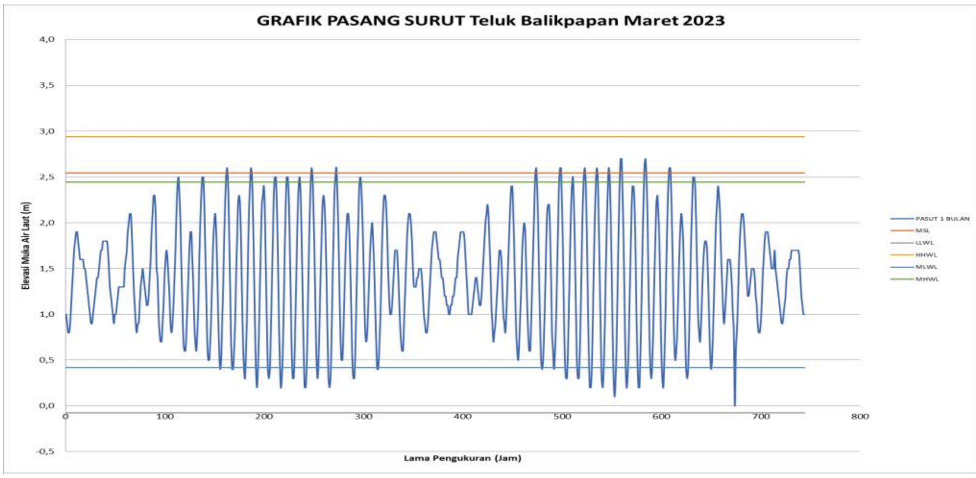

Figure 3. March 2023 Tide Chart

B. Research Procedure

At this stage it is carried out to determine concrete data results so that conclusions can be obtained in this final research. As for what needs to be explained in this data analysis as follows:

1. Calculation of the impact force of the ship:

Calculations are carried out to determine how much impact energy occurs between the Fender and the ship which will later be anchored at the port will burden the structure in the form of energy then the ship's impact force will be absorbed by the Fender because it is necessary to calculate some of these forces such as [4]:

$$E_N = \frac{1}{2} \times M \times V_B^2 \times C_M \times C_E \times C_C \times C_S \quad (1)$$

Where for,

E_N = Energy on the ship when docked normally (kN.m)
M = Displacement of the ship (overall weight of the ship)
V_B = Ship speed when leaning on the wharf (m/s)
C_M = Coefficient of virtual mass factor
C_E = Factor eccentricity coefficient
C_C = Berthing Configuration factor coefficient
C_S = Coefficient of softness factor

2. Calculating the eccentricity coefficient (C_E)

After determining the equation that will be used to calculate the energy of the ship's collision with the fender in equation 3.1, so that you can first determine the eccentricity coefficient value using the following equation [5]:

$$C_E = \frac{K^2 + K^2 + \cos^2 \varphi}{K^2 + R^2} \quad (2)$$

Where for,

B = Beam kapal (m)
C_B = Coffisen Block

LBP = Length between perpendiculars (m)
R = Centre of mass to point of impact (m)
K = Radius of gyration (m)
VL = Longitudinal Velocity

3. Calcution of Mass Coefficient (C_M)
After getting the value of the eccentricity coefficient in equation 3.2 above, then you can calculate the mass coefficient using the following equation:

$$C_M = 1 + \frac{2D}{B} \tag{3}$$

Where for,
D = Draught (m)
B = Beam (m)

4. Calculation of Hardness coefficient (C_S)
Based on the PIANC method, the hardness coefficient itself has a value of 1.0, which is the hardness coefficient of the standard Fender value, assuming no deformation occurs on the ship's wall.

5. Calculation of ship Docking Configuration coefficient (C_C)
Based on the PIANC method, the configuration coefficient value of the docked ship itself already has a value of 0.9 because the type of dock in the Semayang port is a closed dock type with the Velocity angle of the ship docked at 10 degrees [6].

6. Calculation of Berthing Velocity Variation (V_B)
After getting all the coefficient values, you can enter berthing Velocity values ranging from 0.1 to 0.35 m/s where these values are obtained through the Berthing Velocity graph on the PIANC method.

7. Calculation of abnormal energy (E_A)
After getting all the coefficients above, it can be calculated the energy of the ship collision using equation 3.1 then after getting the energy value of the ship collision with the Fender so that the calculation of the abnormal energy equation that occurs on the ship when leaning on the pier can be done using the following equation [7]:

$$E_A = F_s \times E_N \tag{4}$$

Where for,
E_A = abnormal energy of the ship when leaning is influenced by environmental factors (kN.m)
F_s = Ship safety factor for abnormal energy

8. Fender type
Fenders are useful for bearing a pier that has a layout in front of the pier. The fenders that act as bearings on the pier will reduce and withstand the collision energy of the ship on the pier. Fenders can also prevent damage to the hull of the ship and the hull caused by waves, currents and from the impact of the wind. Fenders must be applied and placed optimally along the side of the wharf so that they touch the entire hull of the ship. When the dimensions of the ship are too large, the Fender must also be designed slightly higher than the wharf side.The calculated value of the ship's impact force on the Fender that occurs, then it is known that the value of the Fender type and Fender dimensions can be determined then it can determine the type of Fender that is determined using Fender catalogs such as catalogs from the Fender Team and Trelleborg Fender. The catalog generally contains the types and dimensions of Fenders and Fender performance charts [8].

9. Calculation of the number of fenders and the distance between fenders
After obtaining the type of fender and its type, you can then determine how many fenders are needed at the wharf and then calculate the optimal distance between the fenders so that the collision energy between the ship and the wharf is in accordance with the following calculations [9]:

$$L = 2\sqrt{r^2 - (r - h)^2} \tag{5}$$

Where for,
L = maximum distance between fenders (m)
R = radius of curvature of the bow side of the ship (m)
h = fender height (m)

10. Computer Modeling Analysis
After obtaining the distance, it can determine the deformation and stress from the energy obtained by the Fender in order to obtain an optimal safety factor with the help of Ansys Workbench Software to be able to see the shape of the Fender deformation and see the stress value on the Fender.

RESULTS AND DISCUSSION

Based on table 1 below, there is a fender type used at the Semayang port wharf which is currently damaged, namely the V 300 H type, where the number of fenders is 38 on piers 1, 2 and 3 which are 194 m long, where the distance between the fenders is 3 , 8 m which has been measured directly on the pier and this is done by calculating the distance between the fenders formula, the result is 4.5 m with a total of 38 fenders, which is not significantly different from the existing one at the port. Semayang so that this is obtained as a reference for planning a fender system at Semayang Port which will be taken into account.

Table 1. Existing fenders at Semayang Port

Fenders Type	As Built Number of Fenders	As Built Number of Fenders (m)	Total Equation	Max Distance Equation (m)
V 300 H	38	3.8~4	38	7,74

Based on the existing table above that is currently available at Semayang Port, a comparison is made of the fenders that will be used in planning the fender system at the current Semayang Port. The several types of fenders that will be used are as follows:

Table 2. Fender planning at Semayang Port

Fender Type Comparison	Comparison of Number of Fenders	Max Distance Comparison (m)	Absorption Energy of Each Fender (kNm)
SCN 500	38	19,83 (5)	49
SCN 800	8	23,90 (22)	234
SCN 1600	1	-	1867

In the comparison of the fenders above, the type of fender that will be used in this study is obtained, namely the SCN 800 type with a total of 10 fenders with a distance of 20 m per fender. Therefore, there are several factors to consider in choosing the SCN 800 fender type, namely the efficiency factor, the number of fenders used is too much, but if you use SCN 1600, even if it is only 1 fender, several factors must be considered, namely the magnitude of the overall uneven fender strength. later can damage the hull of the ship and damage to the hull. Then in the installation of the fender installation and maintenance of the SCN 800 fender that will be carried out later, not too much compared to the SCN 550. Then the factor of the distance between the fenders which is not too much different is significantly so that it becomes a factor for selecting the SCN 800 fender then the factor of the absorption energy of the fender from the SCN 800 which is much larger, namely 234 kNm which is quite different compared to the SCN 550 so that the following factors become reference in choosing the SCN 500 type fender.

Based on the Fender model used to carry out the analysis in this study directly using the help of Ansys Workbench Software, where the Fender model uses references in the Fender Trelleborg catalog. The Fender models used in this study have been calculated, namely the SCN 550, SCN 800 and SCN 1600, of which the three models selected and used in this study are the SCN 800. The SCN 800 Fender model is as follows:

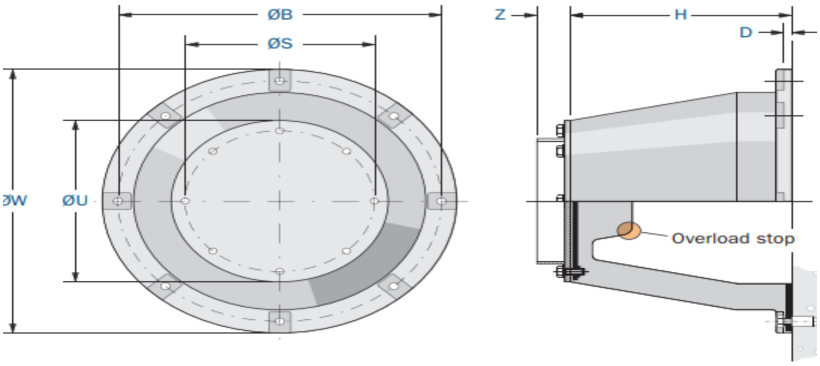

Figure 4. SCN Fender Dimensions and Design (Trelleborg, 2007)

Based on the picture above is an example of a Fender image with a Super cone type which has several sizes for each Fender which from this image can be used as a reference in modeling a Fender which will be carried out in an analysis to determine the Total Deformation value and the Stress value when given Force according to the absorption energy Predefined Fenders in the Fender Trelleborg catalog.

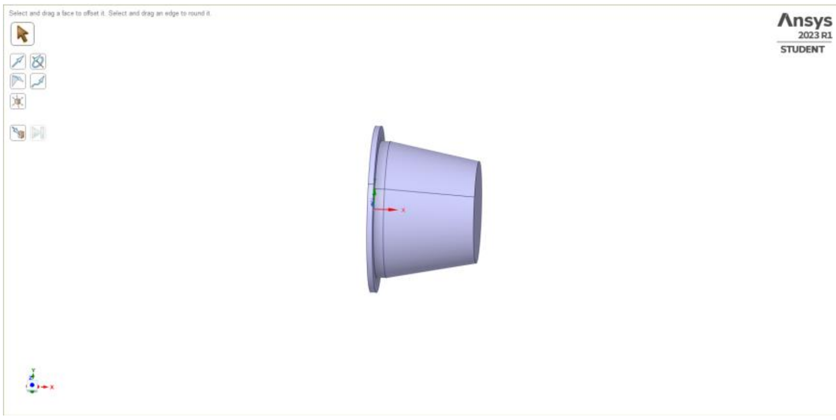

Figure 5. The SCN 800 Rubber Fender model uses Ansys Workbench

Based on the model above, it is a type of Fender Super cone 800 which has a height of 800 mm with a diameter of 42 mm which can absorb 234 kN of berthing energy.

There fore, in numerical analysis, good Mesh quality is very important to get accurate and representative results from the system being analyzed. Based on the fender structure in this study using the Hexahedral Meshing type with an element size of 0.05 m with a minimum edge length of 0.025 m. The Fender models with Meshing are as follows:

In the modeling structure section of the Fender section using the Ansys Workbench Software where each variation of the abnormal energy value will be simulated to see the deformation that occurs in the Fender from each Force Fender condition obtained. The Fender models given by Force are as follows:

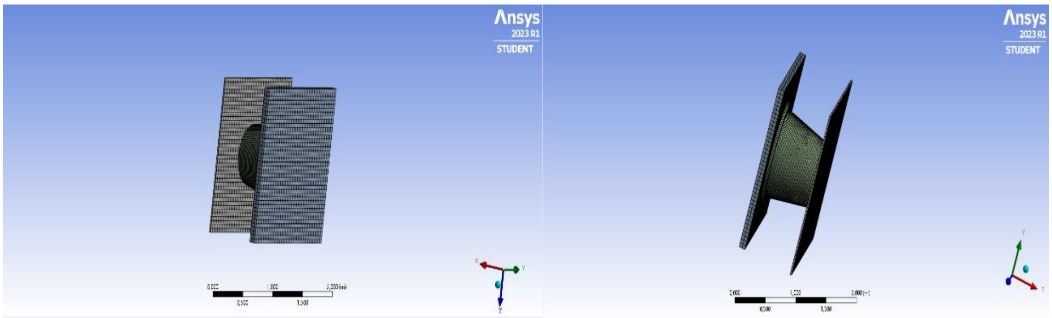

Figure 6. Meshing views in Fender SCN 800

In the Fender structure that has been modeled there are parts of the Fender that will be given Force and Fixed Support. Force is applied to the Fender panel with ASTM A36 Steel material type with a maximum value of the ship's berthing energy of 234 kN (see Table 4.4). Fixed Support is defined as a quay wall with a concrete material type.

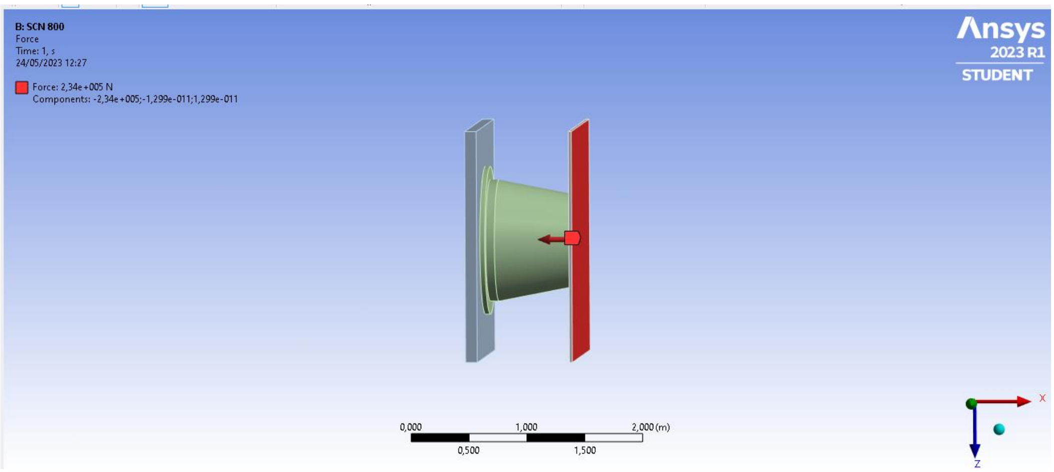

Figure 7. The direction of force given to the fender

Table 3. Total Deformation on Rubber Fender

Berthing Velocity (m/s)	Abnormal Energy (kN)	Force/ Fender SCN 800 (kN)	Total Deformation Fender (cm)
0,1	151	11	0,084
0,15	340	26	0,198
0,2	604	46	0,348
0,25	944	73	0,546
0,3	1359	104	0,771
0,35	1850	234	1,703

Based on the structural modeling section in the Fender section using Ansys Workbench Software where each variation of the abnormal energy value will be simulated to see the value of the Equivalent Stress where the Equivalent Stress is the total stress on a structure that occurs on the Fender when given different Force values according to variations in the berthing Velocity value of the ship. The table for the Equivalent Stress value is as follows:

Table 4. Equivalent Stress on Rubber Fender

Berthing Velocity (m/s)	Abnormal Energy (kN)	Force/ Fender SCN 800 (kN)	Equivalnet Stress (Pa)
0,1	151	11	160.280
0,15	340	26	387.240
0,2	604	46	687.850
0,25	944	73	1.090.100
0,3	1359	104	1.546.100
0,35	1850	234	3.382.300

Based on the results of the Failure Theory, a structure will fail if a plastic deformation occurs with the equation ($\tau_{oct} = 2^{\frac{1}{2}} \times \frac{S_{yield}}{3}$) which results in the analysis of a structural model that is modeled without failure because no deformation occurs plastic. With result of analysis that have been completed, (3.382e+6 Pa <5.35e+6 Pa), then it can be concluded that the structure has not failed so that the selection of the Fender SCN 800 is correct where the Equivalent Stress value is 3,382e6 which is smaller than the limit of the failure value on the Fender structure which has a value of 5,35e6. And it can be concluded that the greater the Berthing Velocity value, the greater the stress value on the Fender will be too.

CONCLUSION

Based on the research conducted, the following conclusions can be drawn as: 1) Based on the calculation of berthing energy according to PIANC, a value of 925 kNm for normal energy and 1850 kNm for abnormal energy was obtained. This research used super cone Fenders of alternative types SCN 550, SCN 800, and SCN 1600. The selected type for this study was SCN 800 at PT. Pelabuhan Indonesia (Persero), Balikpapan branch, with a ship size of 6000 DWT. 2) From the calculation of the distance between Fenders, the maximum distance between Fenders was found to be 22.67 m. The optimal distance used between Fenders was 15 m, and a total of 13 super cone 800 Fenders were used. 3) In the modeling results using the software Ansys Workbench, the maximum total deformation of the Fender was found to be 0.017031 mm, which is considered safe from deformation failure in the Fender structure. The maximum equivalent stress on the rubber Fender was found to be 3382300 Pa.

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