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Planning of Fender at Shipyard Dock for 10000 DWT Oil Tankers in Indramayu Regency, West Java

Muhamad Kemal Idris[a], Silvia Dewi Kumalasari[b], Taufik MR[c] , Ibnu Fajar[d]
[abcd] Institut Transportasi dan Logistik Trisakti, Jakarta, Indonesia
Corresponding author: idriskemal1@gmail.com

Abstract: Indramayu Regency has been selected as a location for the national industrial area development plan, including shipyard industry. This research focuses on the dock in a planned shipyard area by simulating berthing of a 10000 DWT oil tanker. The background of this research is the lack of studies related to fender planning for shipyard docks The aim of this research is to calculate the required berthing energy. The results of this research shows normal berthing energy (E_N) of 292,5 kN was adjusted for safety, resulting in an abnormal berthing energy (E_A) of 511,8 kN. Based on these calculations, the study selected the Foam Fender Series, SeaGuard model by Trelleborg, which meets the required energy absorption capacity. The recommended fender dimensions are 2 m x 4 m, with an energy capacity of 540 kN, suitable for absorbing the calculated berthing energy.
Keywords: *Fender, Berthing Energy, Dock, Indramayu Regency*

1. Introduction

Geographically, Indramayu Regency is located on the northern coast of Java Island, spanning 11 villages that border the sea, with a coastline of 147 km. This makes Indramayu Regency an area with significant investment potential, which could be developed across various business sectors by both the government and the private sector as part of efforts to accelerate industrial distribution, promote economic equality, and create job opportunities (Ministry of Industry, 2015). Utilizing Indramayu's strategic geographical position on the northern coast of Java as a realization of the plan to harness its investment potential, a strategic step has been taken by the Indramayu Regency Government by allocating a special area of 20,000 hectares for various industries, such as the automotive, agriculture, and maritime sectors. It is expected that the industries developed will be technology-driven, environmentally friendly, and labor-intensive to attract potential investors (Indonesian Ministry of Industry, 2019). This land is now ready with spatial planning and regulatory changes to accommodate the industries that will be developed. One such industry focuses on ship construction and building by a national private company (Rahman, 2020).

The plan to build a shipyard at the designated investment potential site will be carried out by a national private shipbuilding company. This plan is a strategic initiative aimed at optimizing the region's maritime potential. The process of building a ship requires a facility called a shipyard. In the shipyard construction planning area, there are facilities located in the waters, such as docks for ship berthing, ship launching, and sea trial sessions (Molland, 2011).

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A dock is equipped with various supporting facilities, one of the most important being ship berthing infrastructure in the form of fenders. Even though a ship moves at a low speed, the impact created still generates a significant force due to the ship’s own weight. Therefore, fenders act as cushions placed in front of the dock to absorb the impact energy between the ship and the dock (Triatmodjo, 2010).

The plan to construct the dock for the shipyard by the national private company is the background of this case study research. This is due to the lack of studies regarding fender system planning for docks in shipyards in Indonesia. Therefore, the author conducted simulations and calculations related to the use of fenders with a chosen location at the dock owned by a private shipbuilding company in Indramayu Regency, West Java.

2. Literature review

Fenders are crucial components in the design of docking facilities as they protect both the vessel and the dock from potential damage during berthing operations. The primary function of a fender is to absorb the kinetic energy of a vessel as it comes into contact with the dock, minimizing the impact on both structures. To design an effective fender system, the calculation of berthing energy is essential, as it forms the basis for determining the appropriate size, type, and configuration of fenders. The guidelines provided by the PIANC: Guidelines for the Design of Fender Systems, 2002 and British Standard 6349 Part: 4 - Maritime Works Code for Design of Fendering and Mooring Systems, 2014 offers standardized approach for calculating berthing energy and selecting fender pitch systems for maritime infrastructure.

3. Research method

This research adopts a quantitative method to assess the berthing energy and evaluate the effectiveness of the fender system in absorbing impact forces during vessel docking operations. By calculating the kinetic energy generated by the vessel, this approach allows for a detailed analysis of the fender's ability to mitigate potential damage to both the dock and the vessel itself. The study focuses on various factors influencing berthing energy, such as vessel mass, speed, and angle of approach.

3.1. Data collection

All the data used are secondary data obtained from the relevant fender manufacturer. For other supporting data, the standards and variables used are refers on PIANC: Guidelines for the Design of Fender Systems, 2002. The types of data collected for analysis include:

1. Target ship data: the typical specifications for a 10,000 dwt oil tanker such as length overall (L_{OA}), length between perpindicular (L_{BP}), draft load, beam, ship’s masses, and various coefficients.
2. Fender specifications: specifications are obtained through fender manufacturer.
3. Environmental data: depth of research area were obtained to calculate berthing energy of ship.

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3.2. Instruments and tools

The research was carried out using the following tools:

1. The Google Workspace Suite, including Google Docs, is used for drafting and writing the research, while Google Sheets is utilized for data calculations, data corrections, and data evaluations.

3.3. Research variables

Independent variable:

1. Ship's specification

Dependent variables:

1. Berthing energy
2. Type and models of the fender

3.4. Data analysis

Independent variable:

1. Berthing energy: Most ship docking processes will have energy less than or equal to the normal berthing energy (E_N). Therefore, we need to determine the value of the normal berthing energy (E_N) and abnormal berting energy (E_A) when normal berthing energy exceeds the energy absorbed by the fender during docking. This can happen for various reasons.
2. Fender pitch: As a guideline for determining the distance between fenders, the British Standard 6349 Part 4: Maritime Works Code for Design of Fendering and Mooring Systems recommended that the distance between fenders be 15% of the ship's overall length (L_{OA}).
3. Fenders quantitiy: The number of fenders used is a ratio of the dock length to the distance between fenders. Therefore, International Maritime Organization, 1998 provides guidelines for planning the dock length.

4. Results and discussion

4.1. Ship specification

Table 1. Ship dimension

Descriptions	**Result**
Length overall (L_{OA})	127 m
Length between perpendicular (LBP)	121 m
Draft load	7,9 m
Beam	2,3 m
Mass	14300 tonnes

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4.2. Normal berthing energy

Based on the formula from (PIANC, 2002), the equation to calculate the normal berthing energy is as follows:

$$E_N = 0.5 \times M \times V_B^2 \times C_M \times C_E \times C_C \times C_S \quad (1)$$

Description:

E_N = normal berthing energy (kN)
M = ships's mass (tonne)
V_B = berthing velocity (m/s)
C_M = added mass coefficient
C_E = eccentricity coefficient
C_C = configuration coefficient
C_S = softness coefficient

The following is an explanation of the normal berthing energy calculation for each variable:

1. Ship mass (M).
   According to (PIANC, 2002) at (Table 1) the typical mass for an oil tanker with a size of 10,000 DWT is 14300 tons.
2. Berthing velocity (V_B).
   Berthing velocity (V_B) closely related to the berthing speed of the ship as it approaches the dock, which is based on several important factors such as the condition of the surrounding water at the dock when the ship is docking, guidance from the tugboat during docking, and the size of the ship itself. The determination of variables for these conditions is usually divided into five categorical factors (PIANC, 2002) as shown in the (Table 2). For the berthing conditions themselves, the researcher will consider the berthing type "difficult, sheltered" because the 10,000 DWT ship docking will not be assisted by a tugboat, and the area around the dock is already protected from natural shape of the landscape.

Table 2. Berthing conditions combination

	Berthing conditions
a.	Easy, sheltered
b.	Hard, sheltered
c.	Easy, exposed
d.	Mediocre, exposed
e.	Hard, exposed

Berthing velocity itself is divided into several classes based on the ship's size in Dead Weight Ton (DWT), and according to docking conditions as shown in (Table 2). Below is the table (Table 3) of berthing velocity values provided by (PIANC, 2002).

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Table 2. Berthing velocity based on ship's size and environmentak conditions

DWT	Berthing Velocity, V_B (m/s)				
	a	**b**	**c**	**d**	**e**
1000	0,17	0,34	0,51	0,66	0,86
2000	0,15	0,29	0,44	0,57	0,72
3000	0,13	0,26	0,40	0,52	0,64
4000	0,12	0,25	0,37	0,48	0,59
5000	0,11	0,23	0,35	0,45	0,55
10000	0,09	0,19	0,28	0,37	0,44
20000	0,07	0,15	0,22	0,30	0,35
30000	0,06	0,13	0,19	0,36	0,30
40000	0,05	0,11	0,17	0,23	0,27
50000	0,05	0,11	0,16	0,22	0,25

3. Added mass coefficient (C_M)
   The water displaced by the ship during the process of moving towards the dock also contributes to the increase in the ship's mass. This water, carried along with the ship's movement, is stopped by the fender, which acts as a barrier between the ship and the dock. This thrust adds resistance to the ship's movement and effectively increases the total mass that the ship must accommodate. For the added mass coefficient (C_M) values, use the equation provided by (PIANC, 2002).

   For K_C / D $\leq$ 0.1 use C_M = 1,8 (2)
   For K_C / D $\leq$ 0.1 use C_M = 1,875 – 0,75 [K_C/D] (3)
   For K_C / D $\geq$ 0.1 use C_M = 1,5 (4)

   Where K_C (Underkeel clearance) of the area is 9.2 meters deep. Therefore K_C / D = 0.14.

   Since K_C / D value is 0,14, added mass coefficient of the ship is:
   C_M = 1,875 – 0,75 × (0,14)
   = 1,74

4. Eccentricity coefficient (C_E)
   Value of the eccentricity coefficient impact energy lost due to the ship's rotation when coming into contact with the fender. The equation for obtaining the eccentricity coefficient C_E is already known in (equation 5). However, the variables K and R are still unknown, with K being found in (equation 6). To determine K, there is the variable CB, which can be calculated using (equation 7), and the variable R is found in (equation 8). There is also the variable y, which can be determined using (equation 9). Therefore, added mass coefficient could be obtain by this equations:

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$$C_E=\frac{K^2+R^2\times\cos\alpha}{K^2+R^2} \tag{5}$$

To find the value of C_E in (equation 5), the values of K and R are needed. The equation used to determine the value of K in C_E.

$$K = (0{,}19 \times C_B + 0{,}11) \times L_{BP} \tag{6}$$

Where C_B (Block coefficient) are:

$$C_B=\frac{MD}{\mathrm{LBP}\ x\ B\ x\ D\ x\ \rho\mathrm{sw}} \tag{7}$$

In addition to the value of K, the value of R is also needed to find C_E (Equation 5) is the equation used to determine the value of R in C_E .

$$R = \sqrt{y^2 + \left[\frac{B}{2}\right]^2} \tag{8}$$

Where, the value of y is:

$$(L_{BP} / 2 \text{ or } L_{BP} / 3 \text{ or } L_{BP} / 4) + y = L_{BP} / 2 \tag{9}$$

Description:
α = velocity vector angel of ship
K = radius gyration (m)
M_D = ship's ius draft (loaded)
L_{BP} = beam (m)
D = draft (m)
B = beam (m)
ρsw = density of seawater (1.025 t/m^3)
R = point of contact to centre of mass (m)

5. Berth configuration coefficient (C_C)
According to (PIANC, 2002), the value of the berth configuration coefficient (C_C) is obtained based on the type of dock structure being planned. For open dock structures, the value is (C_C =0,9), while for closed dock structures, the value is (C_C =1). The dock structure type for the shipyard dock is planned to be of the sheet pile wall construction type, where the sheet pile wall dock is classified as a closed structure. Therefore, the value is (C_C = 0,9).

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6. Softness coefficient (C_S)
   The value of the softness coefficient (C_S) for fenders, according to (PIANC, 2002), is (C_S= 1). This is because modern and latest fenders are of the soft fender type (δt > 150 mm). For hard fenders, the value is (C_S= 0,9), this is because older fender models has ($\delta t \leq 150$ mm). where δt= deflection capability.

4.3. Abnormal berthing energy

Factors that may cause abnormal berthing energy include human error, bad weather conditions, equipment malfunction, or a combination of these causes. The abnormal berthing energy can be calculated using the following formula:

$$E_A = F_S \times E_N \tag{10}$$

According to (PIANC, 2002), the safety factor values (F_S) can be found in (Table 3).

Table 3. Safety factor based on ship types

Ship type	Size	F_S
Oil tanker, bulk	Largest	1,25
	Smallest	1,75
Container	Largest	1,5
	Smallest	2
General cargoo	-	1,75
Ro – ro, ferry	-	> 2
Tugboat, boat	-	2

Referring to (Table 3), a 10000 DWT oil tanker is classified as a small oil tanker. Therefore, the safety factor value used is (F_S= 1,75). Therefore, the abnormal berthing energy value is the one that will be used in the berthing energy calculation. The value can be seen below:

$E_A = F_S \times E_N$
$= 1,75 \times 292,5$ kN
$= 511,8$ kN

4.4. Selection of fender type and model

The absorption capacity for the ship's berthing force under abnormal berthing conditions (E_A) is 511.8 kN. This abnormal berthing energy (E_A) will be used to determine the appropriate fender type for a 10,000 DWT oil tanker, ensuring that the fender selected can adequately absorb the energy generated during docking.

Fender Manufacturer =Trelleborg
Fender Type = Foam Fender

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Fender Model = SeaGuard
Dimensions = 2 m x 4 m
Abnormal Energy (EA) = 511,8 kN
Fender Energy Capacity (E) = 540 kN
Fender Reaction Force (R) = 1005 kN

Since, fender energy capacity > abnormal energy (540 kN > 511,8 kN) the fender is sufficent to withstand the berthing energy. In this study, the Foam Fender Series with the SeaGuard model was selected because Trelleborg, as the provider and manufacturer, recommended this type of fender for applications in oil and gas terminal activities, ship-to-ship operations, shipyards, and military needs.

4.5. Fender pitch and quantity

As a guideline for determining the distance between fenders, the British Standard 6349 Part 4: Maritime Works Code for Design of Fendering and Mooring Systems recommended that the distance between fenders be 15% of the ship's overall length (L_{OA}). Thus, the distance between fenders is calculated as (0,15 × 127 m = 19,05 m). Proper fender spacing not only prevents damage to the dock but also ensures that the fenders can effectively absorb the energy generated during berthing.

International Maritime Organization, 1998 provides guidelines for planning the dock length. The result of the planned dock length calculation with a single mooring point, for one ship during mooring, is as follows:

$$L_P = n \times LoA + (n + 1) \times 10\% \times LoA \tag{11}$$

Description:
L_P = dock length (m)
n = number of berthing ship
LoA = ship's length overall (m)

From the above equation, the calculated dock length is:

$$L_P = 1 \times 127 + (1 + 1) \times 10\% \times 127$$
$$= 152,4 \text{ m}$$

The number of fenders used is a ratio of the dock length to the distance between fenders. Therefore (152.4 : 19.05 = 8 unit of fenders).

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5. Conclusion

The berthing energy for a 10000 DWT oil tanker was calculated using various coefficients. The normal berthing energy (E_N) was determined to be 292,5 kN, and after applying a safety factor, the abnormal berthing energy (E_A) was found to be 511,8 kN. Based on the calculated abnormal berthing energy, the Foam Fender Series with the SeaGuard model from Trelleborg was selected. The fender's energy capacity of 540 kN exceeds the calculated abnormal berthing energy, indicating its suitability for the shipyard's requirements. The distance between fenders was calculated to be 19,05 meters, following the recommendation of 15% of the ship's overall length. The planned dock length was determined to be 152,4 meters, accommodating one ship with the necessary fender spacing. This translates to the use of 8 fenders based on the ratio of dock length to fender spacing.

6. Implications

For stakeholders, the study provides a detailed analysis of fender system requirements tailored to the specific needs of docking facilities handling 10000 DWT oil tankers. Implementing the findings can enhance the safety and efficiency of operations, reduce maintenance costs, and extend the lifespan of the dock infrastructure.

7. Research limitations

One of the primary limitations of this research, is its reliance on the typical oil tanker size provided by PIANC for calculations. Specifically, the research uses a standard oil tanker size of 10000 DWT. However, this typical size may not accurately reflect the dimensions and characteristics of oil tankers operating in Indonesia. The actual sizes and masses of oil tankers in the Indonesian maritime context might differ due to regional variations in ship design, operational requirements, and shipping practices. Consequently, the fender design and planning may not fully account for these local differences, potentially affecting the accuracy and applicability of the results

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