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Analysis of Structural Strength at the Stern with the Addition of Stern Roller on TB ASL Prosper VI Ship

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Abstract

This study analyzes the structural strength of the stern of the TB. ASL PROSPER VI vessel after the addition of a stern roller, a vital component for anchor handling that significantly affects load distribution. The analysis was carried out under three loading scenarios: Static load with the anchor resting on the roller, Dynamic load from soil during anchor retrieval from seabed, and extreme load according to ABS classification rules for stern roller. The stern roller was modeled in 3D and analyzed using the finite element method (FEM), with validation performed through analytical calculations. The results show that the designed stern roller has a total weight of approximately 3 tons. Under static conditions, the maximum stress was 2.35 MPa on the roller and 1.33 MPa on the stiffener, with a deflection of 0.69 mm and safety factors of 15.21 and 17.96, respectively, indicating a very safe condition. In the anchor lifting scenario, the stress increased to 12.45 MPa (roller) and 10.10 MPa (stiffener), with a deflection of 1.4 mm and safety factors of 12.05 (roller) and 14.98 (stiffener), which are still within safe operational limits. However, under the extreme ABS load case, the stress reached 110.74 MPa on the roller and 391.88 MPa on the stiffener, resulting in safety factors of 1.35 and 0.38, respectively, indicating structural failure in the stiffener. It can be concluded that the stern roller is structurally safe for normal operations and anchor handling, but reinforcement is required to ensure compliance with ABS standards under maximum load conditions.

1. Introduction

Indonesia is known as a country rich in natural resources, including oil and gas. Oil and gas mining activities are carried out in two main locations: onshore and offshore [1]. Offshore refers to drilling activities conducted in offshore waters in the oil and gas industry [2]. The oil and gas mining process involves several stages, starting from exploration, exploitation, processing, to the marketing of the products [3].

According to Law Number 22 of 2001 concerning Oil and Gas, Article 1, paragraph 9, exploitation is a series of activities aimed at producing oil and gas from a specific working area. These activities include drilling, well completion, construction of transportation, storage, and processing facilities for the separation and purification of oil and gas, as well as other supporting activities. In supporting offshore activities, transportation with appropriate specifications is essential, one of which is the use of ships. Ships function as means of transportation at sea, rivers, and lakes to carry people, goods, or other vehicles [4]. Offshore support vessels play a vital role in ensuring the sustainability, efficiency, and safety of offshore operations.

PT X is a shipping company operating in Samarinda, focusing on oil and gas services. One of its fleets is TB ASL Prosper VI, which is an Anchor Handling Tug vessel. This vessel is required to support offshore oil and gas drilling activities, as well as for the installation and lifting of anchors on crane barges during platform maintenance or subsea pipeline installation.

To improve the performance of TB ASL Prosper VI, the addition of a stern roller at the stern of the vessel is planned. A stern roller is an additional cylindrical device installed transversely at the stern of the ship [5]. The main function of a stern roller is to facilitate the rolling of wire ropes or chains from the deck into the sea. The use of a stern roller can reduce friction between the wire rope and the stern structure of the vessel, thereby minimizing wear on both the wire rope and the ship's structure. Existing literature on stern roller design is limited. Classification societies such as ABS [20] primarily provide guidance on minimum roller diameter for heavy-duty loading conditions rather than detailed structural design methodologies. Studies related to the loading mechanism, such as [21], focus on analytical estimation of anchor drag forces in seabed conditions, which form the basis of the loads acting on the roller. In addition, ABS (2018) provides criteria for allowable stresses in structural components, serving as a reference for strength assessment.

Although the addition of a stern roller can improve the vessel's work efficiency, this modification has the potential to alter the load distribution at the stern of the vessel. Therefore, further analysis of the structural strength in that area is essential. The installation of a stern roller may cause additional stress that could potentially result in excessive deflection or even structural failure, which could endanger the safety of the vessel and its operations. Thus, this paper investigates the structural strength of the stern section of the TB ASL Prosper VI ship with the incorporation of a stern roller.

2. Methods

2.1. Tugboat

A tugboat is a vessel designed to tow or push other ships, either in open seas or in restricted waters [6]. Tugboats are classified according to their functions, namely seagoing tugs for towing ships or barges in open waters, escort tugs for guiding large vessels through hazardous passages, and harbour tugs that operate in ports and coastal areas [7]. The TB. ASL PROSPER VI belongs to the Anchor Handling Tug Supply *(AHTS)* category (see Figure 1), a more complex type of tugboat designed not only for towing and pushing but also for anchor handling on offshore rigs or platforms, while simultaneously serving as a supply vessel. Anchor handling operations involve pulling and releasing very large anchors, which require special equipment at the stern, including a stern roller that facilitates the rolling of chains or wire ropes [8].

Figure 1. Tugboat of ASL PROSPER VI

Table 1. Principal Dimension

Item	Dimension
LOA	22.18 m
B	7.00 m
D	3.20 m
T	2.40 m

2.2. Stern Structure

The stern is the aft part of the ship, located behind the midship section, and serves as the continuation of the keel. Its construction generally consists of plates, profiles, and stiffeners assembled by welding, with the sternpost often enlarged or fitted with a boss in the propeller shaft area, particularly for single- or twin-screw vessels [9]. The design of the stern serves several key functions: reducing water resistance to increase speed [10], improving propulsion efficiency [11], and enhancing ship stability [12]. Important factors in stern design include streamlined shape and dimensions, selection of strong and corrosion-resistant materials [13]. and structural stability under operational loads. In practice, stern structures are often fabricated from cast steel welded together to achieve both optimal form and sufficient strength [12]. Consequently, the stern plays a critical role as the main support structure for the installation of the stern roller on Anchor Handling Tug Supply (AHTS) vessels, such as the TB. ASL PROSPER VI, which is the focus of this study.

2.3. Ship Construction

Ship construction is a discipline within maritime engineering that focuses on the design and fabrication of a ship's hull structure to withstand various types of loads, both from the marine environment and from cargo and onboard equipment. The construction process involves the assembly of steel plates, profiles, and stiffeners to form a strong and rigid framework [14]. Generally, the structural elements of a ship can be classified into three main framing systems: transverse, longitudinal, and combination systems, each with specific advantages and applications according to the ship's design requirements.

The transverse framing system emphasizes the placement of frames vertically or following the body plan. The ship's deck is supported by deck beams spaced parallel to the frames, allowing the loads acting on the hull to be distributed evenly throughout the structure. This system is illustrated in Figure 2, which shows the transverse construction.

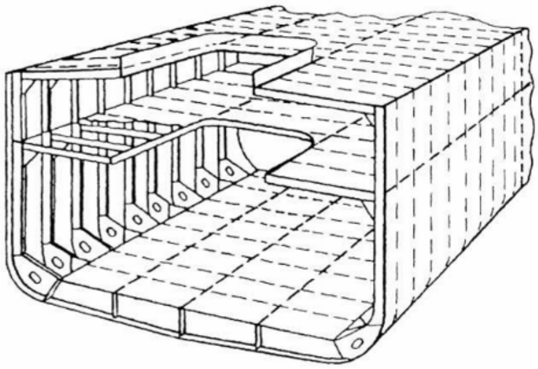

Figure 2. Transverse Framing System in Ship Construction [22]

The longitudinal framing system places the main frames longitudinally along the sides of the ship with vertical spacing of approximately 600 mm – 1000 mm, referred to as side longitudinals. At certain intervals (around 3–5 m), large frames are installed as side transverses, similar to the large frames in the transverse system, as shown in Figure 3.

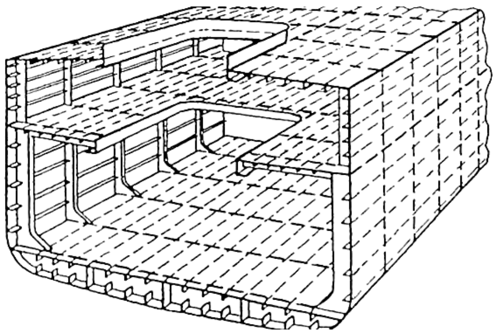

Figure 3. Longitudinal Framing System in Ship Construction [22]

The combination framing system integrates both approaches, where the deck and bottom follow the longitudinal system while the sides follow the transverse system. This system allows the ship to comply with classification requirements while maintaining optimal structural strength throughout the hull we can see in Figure 4.

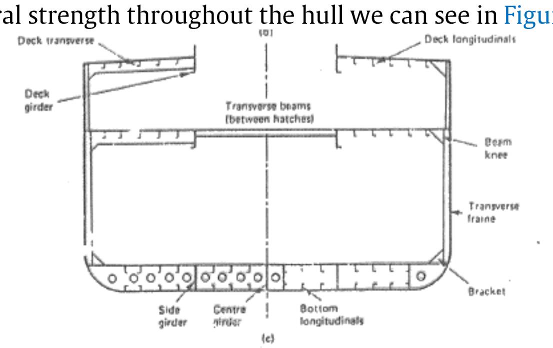

Figure 4. Combination Framing System in Ship Construction [22]

2.4. Loading Conditions of the Stern Roller

The stern roller is subjected to both static and dynamic loading conditions that significantly affect its structural performance. Static loads consist of the self-weight of the roller and the anchor weight when it rests on the roller surface. These loads are constant over time and can be calculated using static equilibrium principles. In contrast, dynamic loads arise during anchor retrieval, where tensile forces vary depending on seabed resistance, pulling speed, and vessel motion. Such loads may induce additional inertial and impact forces that require dynamic analysis [15].

Stress analysis under these conditions is essential to evaluate the roller′ s structural integrity. Normal stress (σ) due to axial and bending forces can be expressed as:

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

Where F is the applied force and A is the cross-sectional area [16]. Shear stress, particularly relevant under torsion and sliding actions, is determined by:

$$\boldsymbol{\sigma} = \frac{\boldsymbol{v} \times \boldsymbol{Q}}{\boldsymbol{I} \times \boldsymbol{b}} \quad (2)$$

With V as shear force, Q as the first moment of area, I as the moment of inertia, and b as section width. To asses′ material yielding under combined stresses, the Von Mises criterion is applied:

$$\sigma_V = \sqrt{\frac{1}{2}[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]} \tag{3}$$

The allowable stress is governed by classification society rules, where the maximum combined stress must not exceed the material′ s permissible limit:

$$\sigma v = \sqrt{\sigma L} + 3\pi L^2 \leq \frac{150}{k} \tag{4}$$

With k as the material factor determined from yield strength based on BKI, 2024.

Based on these formulations, three critical loading scenarios are considered in stern roller analysis: (1) anchor resting on the roller, (2) anchor retrieval from seabed, and (3) conditions required by ABS regulations. These scenarios ensure that both static and dynamic effects, including shock and inertial forces, are incorporated in evaluating structural safety.

2.5. Finite Element Method (FEM)

The structural analysis was carried out using the Finite Element Method (FEM), beginning with the three-dimensional modeling of the stern construction and stern roller. The material properties were defined according to ASTM A131 Grade A specifications, with yield and ultimate strength values analytically assigned into the simulation database [17]. Meshing was applied to discretize the model into smaller elements, with element size settings following the recommendations of DNV GL (2015) to ensure accuracy in areas with high stress concentration. A convergence test was performed by comparing results from various mesh sizes, where the analysis was considered convergent if the equivalent stress difference was less than 5% [18] [19]. Boundary conditions were assigned to represent actual operating conditions, including the load from the stern roller (3 tons) and the anchor (3.5 tons), as well as displacement constraints at the block connections. The analysis employed static structural analysis to determine stress distribution and deflection. The FEM results were then validated by comparing the maximum stress obtained from the simulation with analytical calculations, with a tolerance difference of less than 10% [17].

3. Results and Discussion

3.1. 3D Modeling

The first step before performing the structural load calculation of the stern roller and the structural strength analysis of the ship′ s stern due to the addition of the stern roller is to conduct 3D modeling of the ship′ s hull (specifically the stern area) and a 3D model of the stern roller to facilitate the calculation of structural strength. Figure 5 shows the result of the hull modeling at the stern section of the ship. This model was created using Maxsurf Modeler software.

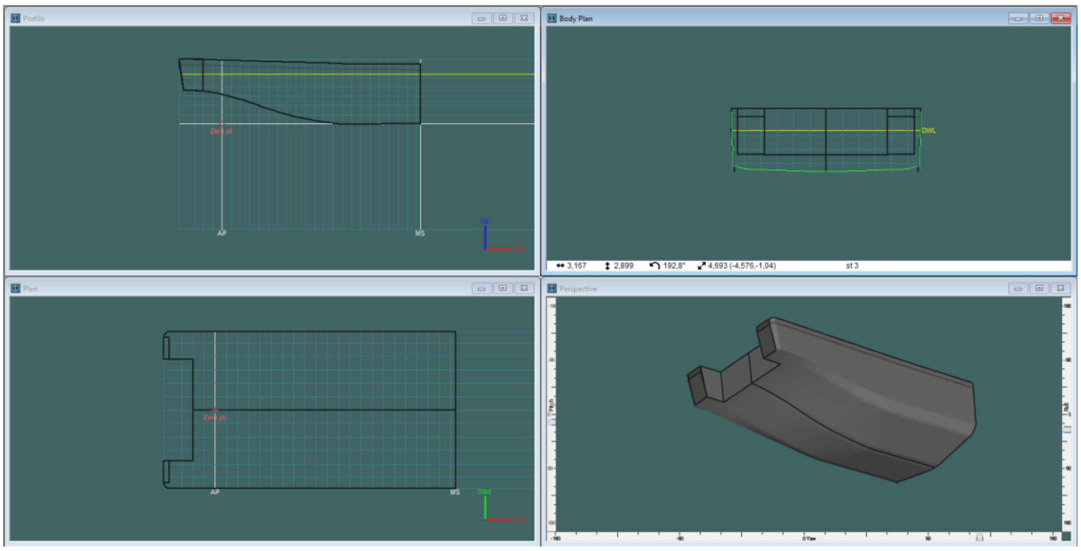

Figure 5. 3D Modeling of Ship Hull

After modeling the hull form of the stern section, the construction of the ship, particularly at the stern, was input. The construction of a ship is a very important aspect. In terms of strength, the ship′ s construction greatly affects the structural resistance against various pressures, both external and internal.

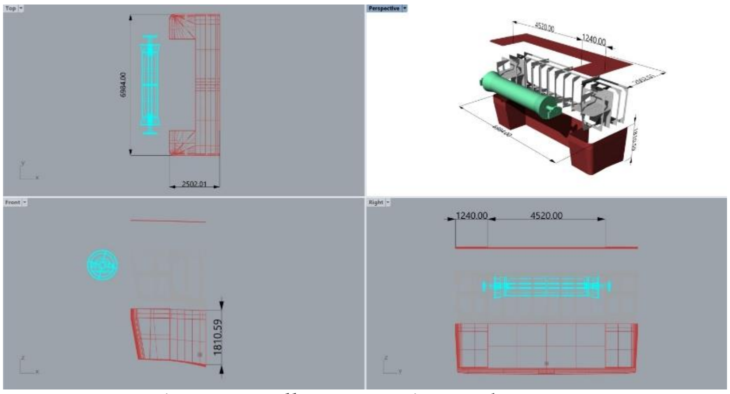

Figure 6. Hull Construction at the Stern

The 3D modeling of the stern roller was carried out using SolidWorks software with a per-part system, followed by assembly to form the overall construction. This modeling was conducted to facilitate the calculation of the stern roller structural load and also to perform the structural strength calculation of the ship's stern after the addition of the stern roller. The modeling results can be seen in Figure 7, Figure 8, Figure 9, and Figure 10.

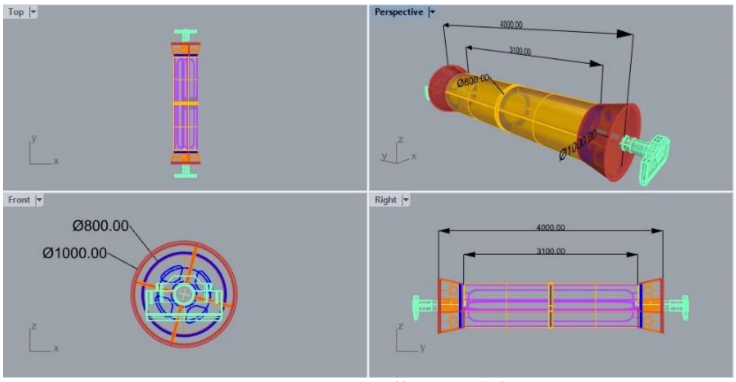

Figure 7. Stern Roller Modeling

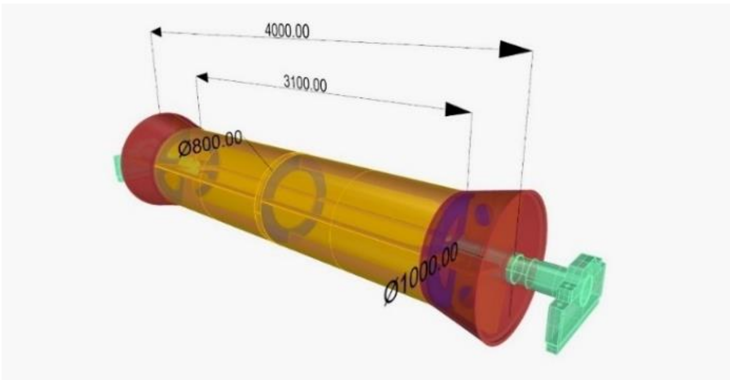

Figure 8. Stern Roller Dimensions

Figure 9. Roller Construction

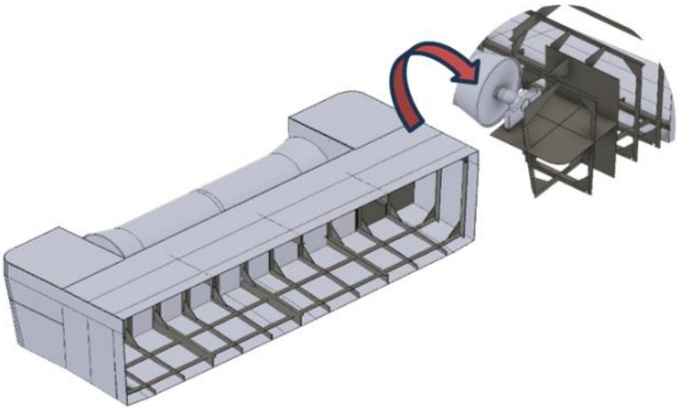

Figure 10. Hull and Stern Roller Construction of the Ship

3.2. Structural Weight Calculation of the Stren Roller

The structural weight of the stern roller was calculated using two methods: CAD-based 3D modeling and analytical calculation based on dimensions and material properties. The CAD design estimated the stern roller weight at 2997E+06 grams, as shown in Figure 11.

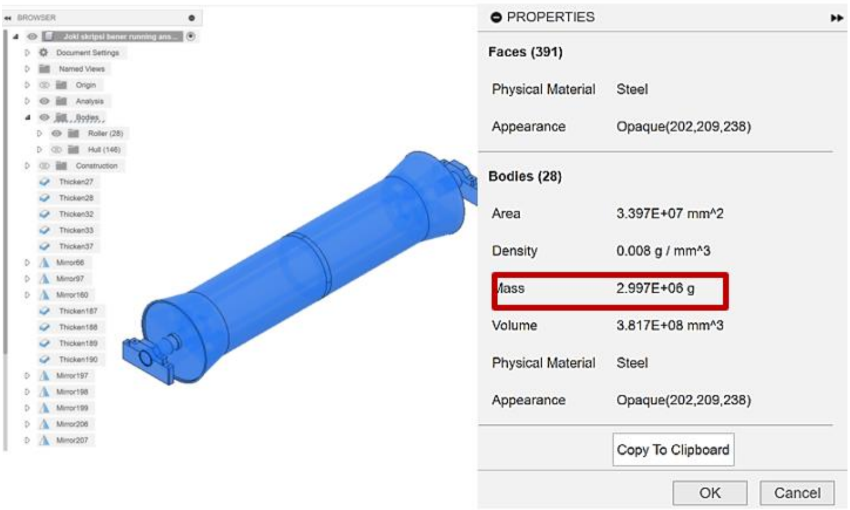

Figure 11. Weight Interface in CAD Software

The stern roller material is marine steel ASTM A131 Grade A, with specifications presented in Table 2.

Table 2. Material Specification

Physical Properties	Value	
Density	7,85	g/cc
Mechanical Properties	**Value**	
Tensile Strength, Ultimate	400-490	MPa
Tensile Strength, Yield	235	MPa
Elongation at Break	21%	
	24%	
Bulk Modulus	160	GPa
Shear Modulus	80	GPa
Elasticity Modulus	206	GPa
Poisson's Ratio	0,3	

The analytical calculation produced a total weight of 2993.6 kg, with detailed component values presented in Table 3

Table 3. Roller Load Calculation

Item	Area (m²)	Thickness (m)	Radius	Density (kg/m³)	Weight (kg)
Shell	0,071	0,012	2,514	7850	1408,92
Shell 2	0,010	0,012	2,514	7850	390,80
Stiffener 1	0,183	0,02	-	7850	57,37
Stiffener 2	0,183	0,02	-	7850	57,37

Item	Area (m²)	Thickness (m)	Radius	Density (kg/m³)	Weight (kg)
Stiffener 3	0,183	0,02	-	7850	57,37
Stiffener 4	0,183	0,02	-	7850	57,37
Bulkhead Plate 1	0,358	0,025	-	7850	70,16
Bulkhead Plate 2	0,358	0,025	-	7850	70,16
Bulkhead Plate 3	0,257	0,02	-	7850	40,40
Bulkhead Stiffener 1	0,094	0,025	-	7850	37,04
Bulkhead Stiffener 2	0,094	0,025	-	7850	37,04
Bulkhead Stiffener 3	0,094	0,025	-	7850	37,04
Bulkhead Stiffener 4	0,094	0,025	-	7850	37,04
Connecting Pipe 1	0,006	0,5	-	7850	44,39
Connecting Pipe 2	0,006	0,33	-	7850	29,30
Connecting Bar	0,023	0,92	-	7850	327,85
Bearing 1	-	-	-	7850	117,00
Bearing 2	-	-	-	7850	117,00
Total Weight(kg)					**2993,60**

The comparison of CAD and analytical results is shown in *Table 4.*

Table 4. Comparison of Analytical and CAD Software Weight Results

Item	Value	Unit
CAD Result	2997E+06	Gram
Analytical Calculation	2993.60	Kg
Difference	0.2134	%

The difference between the two methods is only 0.21%, which is below the 5% tolerance limit, thus validating the model for further structural analysis.

3.3. Stress Analysis of the Stern Roller and Stern Structure

Stress analysis on the stern roller and stern structure is a crucial aspect of structural engineering, aimed at evaluating the structural strength under various loading conditions as follows:

1. Condition 1 (Anchor on the roller)
2. Condition 2 (Anchor retrieval from the seabed)
3. Condition 3 (According to ABS requirements)

3.3.1 Stress Analysis of the Stern Roller and Stern Structure Condition 1 (Anchor on the Roller)

In determining the stress distribution, the author assumes that the stern roller and its support structure can be analyzed as a simply supported beam system. This approach was chosen to simplify the calculation process while obtaining a static strength estimation of the stern roller and its supporting structure. Prior to conducting a comprehensive structural strength analysis, several initial data are required, including support reactions, load distribution, sectional moment of inertia, and points of observation. These variables are then integrated into the calculation of the stresses acting on the analyzed structure.

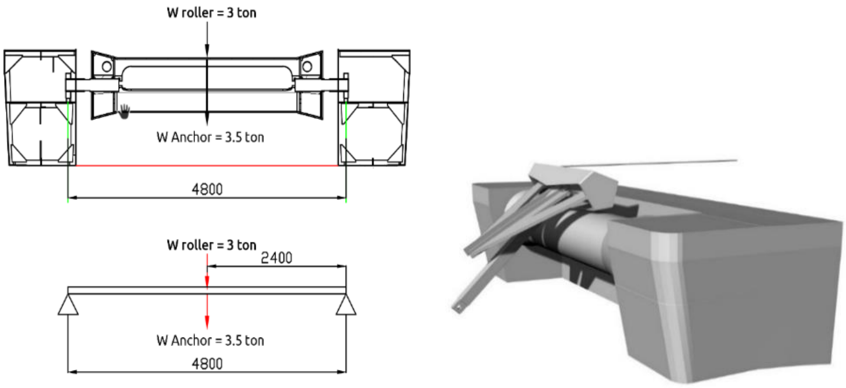

Figure 12. Simplified Loading Assumption

In this condition, the stern roller and its supporting structure were analyzed under the combined loads of the roller weight (29.43 kN) and anchor weight (34.34 kN). The roller system was modeled as a simply supported beam with central loading. The support reactions, shear force, and bending moment were first determined as a basis for stress calculations. The summary is presented in Table 5.

Table 5. Reaction Force Calculation

Parameter	Value
Roller Weight (Wroller)	29.43 kN
Anchor Weight (Wanchor)	34.34 kN
Total Load	63.77 kN
Support Reaction A (Rva)	31.88 kN
Support Reaction B (Rvb)	31.88 kN
Max Shear Force	±31.88 kN
Max Bending Moment	76.52 kNm

The cross-sectional properties of the roller were calculated, including moment of inertia, centroid, and section modulus as we can see in Table 6. These values were used for bending stress and shear stress determination.

Table 6. Section Properties of Stern Roller

Item	Area (mm^2)	y (mm)	I (mm^4)	Iadd (mm^4)	Itotal (mm^4)
Shell Plate	29,706	400	2.305×10^{9}	3.49×10^{6}	2.309×10^{9}
Face Plate (Stiffener)	276,598	388	1.472×10^{10}	3.75×10^{5}	1.472×10^{10}
Total	306,304	389.2	–	–	**1.703×10^{10}**

Using these values, the bending stress, shear stress, and equivalent von Mises stress were obtained as we can see in Table 7.

Table 7. Stress Calculation Results on Stern Roller

Parameter	Formula	Result
Bending Stress (σ)	$\sigma = M \cdot y / I$	1.80 MPa
Shear Stress (τ)	$\tau = V \cdot Q / (I \cdot b)$	0.88 MPa
Equivalent Stress (σeq)	$\sqrt{(\sigma^2+3\tau^2)}$	2.35 MPa

For the stern support structure (tanktop below bearing), section properties and stresses were also calculated as we can see in Table 8.

Table 8. Stress Calculation on Stern Support Structure

Parameter	Result
Centroid ($\bar{y}$)	1086.6 mm
Moment of Inertia (I)	3.35×10^{10} mm^4
Bending Stress (σ)	0.017 MPa
Shear Stress (τ)	0.77 MPa
Equivalent Stress (σeq)	1.33 MPa

Numerical validation using Finite Element Method (FEM) showed good agreement with analytical calculation, with deviations <2% as we can see in Table 9.

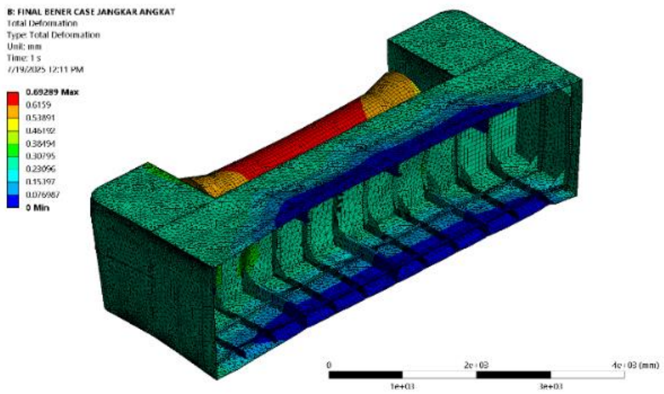

Figure 13. Global Deformation in Condition 1

Table 9. FEM Validation

Component	Stress Type	FEM (MPa)	Analytical (MPa)	Error (%)
Stern Roller	Shear	0.877	0.875	0.28
Stern Roller	Von Mises	2.350	2.347	0.13
Stern Support	Von Mises	1.305	1.329	1.83

Based on the allowable stress criterion (σv = 150 MPa), the safety factor was obtained as ≥15 for both stern roller and stern support, which indicates that the design is structurally safe.

3.3.2 Stress Analysis of the Stern Roller and Stern Structure Condition 2 (Anchor Lifting from the Seabed)

In this condition, the analysis focuses on the maximum vertical load generated by anchor retrieval from the seabed, which is governed by the anchor weight and soil holding capacity, this condition assumed the anchor have been embedded for roughly 14 days so the soil holding capacity will depend on the soil characteristics and duration of anchoring. The load is treated as quasi-static, as the objective is to evaluate the structural response of the stern roller under peak vertical resistance. The vertical resistance of the anchor was estimated using the holding capacity method [20], with soil parameters and the bearing capacity factor (Nc) from Kim (2005). The combined vertical load acting on the stern roller system reached 83,090 N (8.47 tons), as summarized in Table 10, and this load was applied in FEM analysis as a pure vertical force at the roller position.

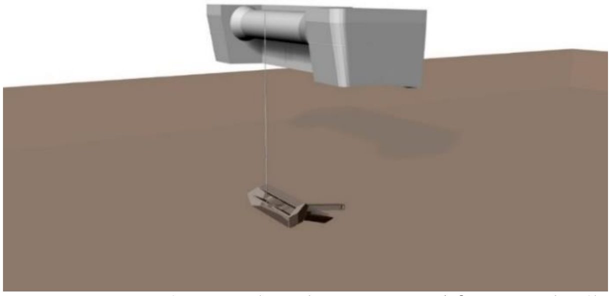

Figure 14 Condition 2 (Anchor Retrieval from Seabed)

Table 10. Vertical Load Calculation

Parameter	Formula / Value	Result	Unit
Roller Weight (Wroller)	3000 × 9.81	29,430	N
Anchor Weight (Wanchor)	3500 × 9.81	34,335	N
Anchor Resistance (Ranchor)	0.16 kPa × Afluke (280×222×0.5 cm²)	48,738	N
Total Vertical Load	Wanchor + Ranchor	**83,090**	N

In Condition 2, the loading scheme illustrates the situation when the AHTS vessel lifts an anchor embedded in the seabed, exposing the stern roller structure to significant vertical loads. This load consists of the anchor's weight of 3.5 tons and the soil resistance (holding capacity) of 4.97 tons, resulting in a total vertical force of 8.47 tons, equivalent to 83,090 N. In the FEM model, this force is applied through a remote point connected to the anchor line and directed perpendicularly downward to the ship's hull, representing a pure vertical pulling force. The weight distribution represented using a feature standard gravity with direction of -Z. This loading scheme is visualized in Figure 14 and Figure 15, which show the distribution of forces from the anchor to the stern roller as well as the boundary conditions used in the analysis.

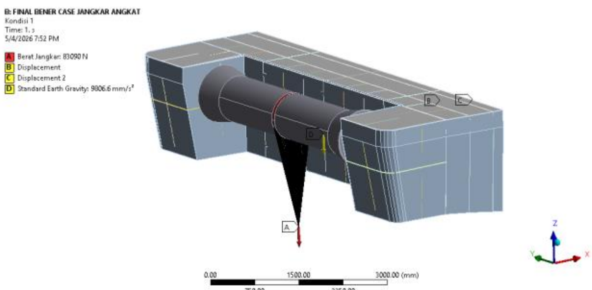

Figure 15 Boundary Condition

The FEM analysis showed a maximum von Mises stress of 22.67 MPa on the roller stiffeners and 160 MPa on the tanktop bearing support, with localized stress concentrations at geometric transitions, while most regions experienced low-to-moderate stress levels. The maximum global deflection reached 1.23 mm, as presented in Figure 16, Figure 17, Figure 18, and Table 11.

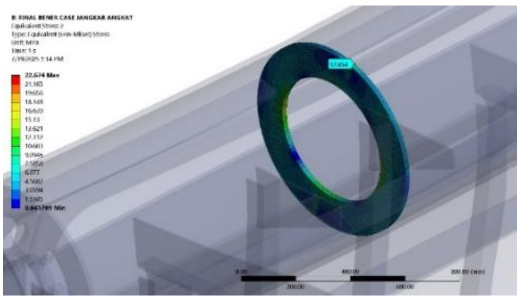

Figure 16. Von-Mises Ring Roller Stiffeners

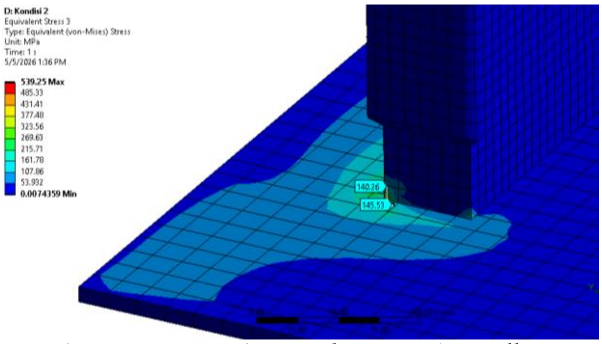

Figure 17. Von-Mises Tanktop Bearing Roller

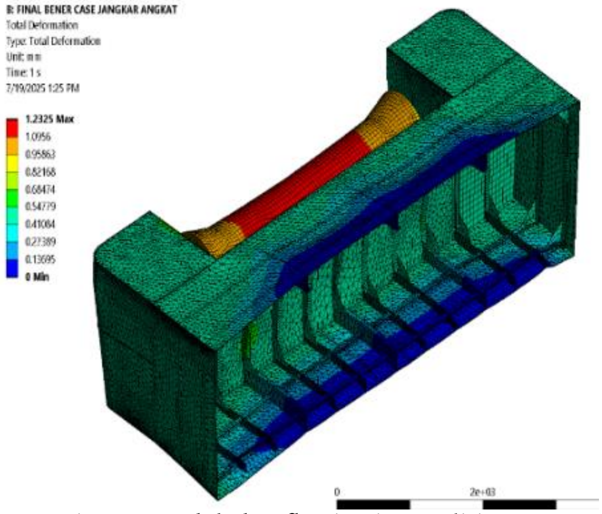

Figure 18. Global Deflection in Condition 2

Table 11. FEM Stress and Deflection Results (Condition 2)

Component	Max Stress (MPa)	Deflection (mm)	Remarks
Roller stiffeners	22.67	1.23	Safe, localized stress zones
Bearing support (tanktop)	145.53	0.9–1.2	Critical stress occured

To evaluate structural adequacy, the safety factor was calculated according to BKI (Vol. II Sec. 2), which prescribes an allowable stress of 150 MPa. As shown in Table 12, the roller achieved a safety factor of 12.05, while the support structure achieved 0.93, this indicate that the support need additional reinforcements to support this condition.

Table 12. Safety Factor Calculation

Component	Σ occurred (MPa)	Σ allow (MPa)	Safety Factor
Roller	12.45	150	12.05
Support structure	145.53	150	1.06

Overall, the roller structure remains safe under vertical loading during anchor lifting operations. However, stress concentrations around the bearing support indicated by the deflection zones especially on bearing foundation may require reinforcement to ensure safety during operations.

3.3.3 Stress Analysis of the Stern Roller and Stern Structure Condition 3 (ABS Class Requirement for Stern Roller Strength)

The third loading condition follows ABS (2017) requirements to evaluate whether the stern roller and its supporting structure can withstand forces up to the breaking load of the anchor line. As shown in Figure 20, an extreme load of 621 kN, corresponding to the maximum breaking load of the Kiswire anchor line, was decomposed into a vertical component of 537.8 kN and a horizontal component of 310.5 kN, with an additional winch load of 120 kN applied in the +X direction. The boundary setup was defined using remote points and remote forces to ensure that the applied loads comply with ABS class criteria. This loading scheme represents an emergency condition in which the stern roller and its supports must sustain extreme loading, ensuring that the structural failure does not occur before the anchor line itself breaks.

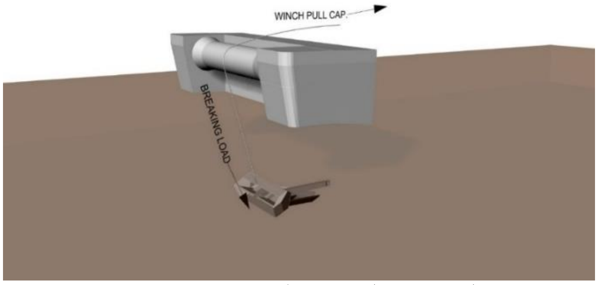

Figure 19. Condition 3 (Extreme)

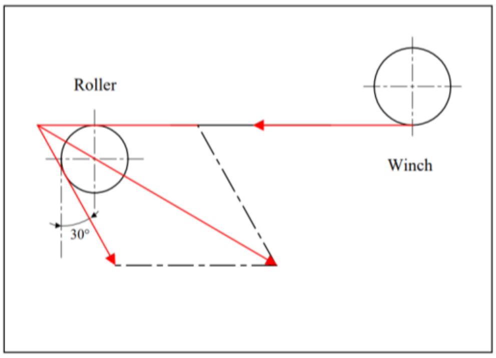

Figure 20. Extreme Loading Condition

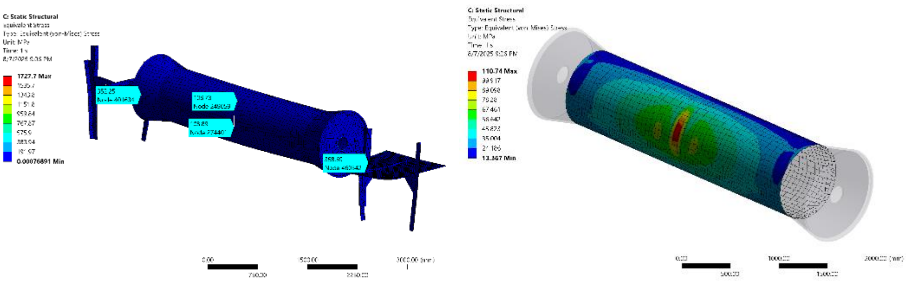
Figure 21. Running Result

Material properties were based on ASTM A131 Grade A with a yield strength of 235 MPa. According to ABS criteria, the allowable stress limits are 176.25 MPa for normal stress and 105.75 MPa for shear stress. Figure 21 presents the stress distribution under the applied loading condition using two levels of visualization. The left figure shows the global model, where high stress concentrations (hotspots) are observed primarily at structural discontinuities and support regions. These localized peaks are influenced by geometric constraints and are not representative of the stress distribution in the roller itself. The results, summarized in Table 13, show that the stern roller remains within the allowable limit, with a Von Mises stress of 110.74 MPa, a safety factor of 1.35, and a maximum deflection of 9.17 mm. In contrast, the support structure experienced excessive stresses, with a Von Mises value of 391.88 MPa and a critically low safety factor of 0.38, despite a lower deflection of 4.70 mm.

Table 13. Summary of FEM Results Under Extreme Load for ABS requirements

Item	Shear (Mpa)			Normal (Mpa)			Von-Mises (Mpa)	Deform (mm)
	xy	yz	xz	x	y	Z		
Roller	18,039	-37,367	41,686	-53.65	-33.60	-51.37	110.74	9,17
Sternpost Construction	32,871	142,47	86,926	-60.52	-251.68	-334.13	391.88	4,60

Note : Allowable (green)
Exceeding (red)

In summary, the roller structure satisfies ABS requirements under extreme loading, while the support structure does not, indicating the necessity for reinforcement or redesign to ensure compliance with class standards.

3.4. Impact on the Structure due to the Addition of the Stern Roller

The addition of a stern roller at the ship's stern has a direct impact on the strength of the local structure, particularly on the roller and its support components. Evaluation was carried out through analytical analysis and FEM simulation under three loading conditions: normal operation (Condition 1), anchor lifting (Condition 2), and extreme load in accordance with ABS class requirements (Condition 3). The analysis results are presented in Table 14.

Table 14. Analysis Results

Item	Von Mises Stress (MPa) Roller	Von Mises Stress (MPa) Support	Safety Factor Roller	Safety Factor Support
Condition 1	2.35	1.33	>15	>15
Condition 2	12.45	145.53	1.03	14.85
Condition 3	127.22	391.88	1.17	0.38

Overall, the stern roller is considered safe for normal operations and anchor lifting under Conditions 1 and 2. However, the support construction under extreme loading (Condition 3) requires structural reinforcement to meet ABS class requirements for maximum load conditions.

4. Conclusion

The study concludes that the stern roller design for TB ASL PROSPER VI was successfully modeled in 3D using CAD software, representing a cylindrical structure installed transversely at the stern, with total component weight results from CAD (3000 kg) and analytical calculation (2993.6 kg) differing by only 0.21%, indicating high accuracy. Stress and deflection analysis showed that under Condition 1, maximum Von Mises stress was 2.35 MPa (roller) and 1.33 MPa (support) with a deflection of 0.69 mm and a safety factor above 15, proving the structure highly safe. Under Condition 2, stress increased to 12.45 MPa (roller) and 145.53 MPa (support) with 1.4 mm deflection, and safety factors of 1.03 and 14.98, both still safe. However, under Condition 3, stress rise significantly to 110.74 MPa (roller) and 391.88 MPa (support), with deflections of 9.17 mm and 4.70 mm, resulting in safety factors of 1.35 and 0.38, indicating structural failure. Therefore, while the stern structure is safe under normal operations and anchor handling, the support construction is not adequate for extreme conditions and risks failure before the anchor wire rope breaks, thereby not fulfilling ABS requirements. For future work, it is recommended that more realistic dynamic conditions be incorporated, including wave- and wind-induced loads, to better capture the behavior of the anchor lifting process and its interaction with the stern roller and supporting structure. In addition, further studies may extend the analysis to vessel stability during anchor handling operations, evaluating the dynamic effects of load transfer through the stern roller and their influence on overall operational safety and performance.

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