Structural and Hydrodynamic Impacts of Lengthening a Field Support Vessel: Implications for Energy Efficiency and Sustainability

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Abstract

The lengthening of vessels represents an efficient solution to enhance operational performance and reduce environmental impact by optimizing hull design and reducing emissions. This study analyzes the structural and hydrodynamic effects of a 5-meter lengthening for a Field Support Vessel (FSV) intended for offshore operations in Talara, Peru. The structural analysis, conducted with DNV's Poseidon software, confirms the feasibility of the lengthened design, showing a 14% increase in the required sectional modulus and a significant improvement in load capacity. The vessel's maximum allowable length is determined as 76 meters, with an optimal sectional modulus of 0.90 m^3. The hydrodynamic analysis, conducted with the Maxsurf Motion software, highlights significant improvements in seakeeping performance. The lengthened design decreases rolling amplitude by 10% and pitching by 5% under critical conditions, particularly in beam and heave seas. Although the calculated freeboard suggests a draft of 5.58 meters, an operational draft of 4.25 meters at a speed of 14 knots is selected to ensure optimal performance under the maritime conditions of the region. This study demonstrates that hull lengthening not only enhances operational efficiency but also contributes to the environmental sustainability of offshore operations.

Key words: original, lengthening, structure, hydrodynamics, Maxsurf, Field Support Vessel, Energy efficiency, sustainability.

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Introduction

In the modern maritime industry, achieving energy efficiency while maintaining high performance has become a priority due to environmental regulations and operational costs *(International Maritime Organization, 2021)* [8]. Various strategies can be employed to minimize fuel consumption and reduce emissions without compromising vessel performance. One of the most impactful approaches is optimizing hydrodynamic design, reviewing the hull form to reduce resistance, such as redesigning the bow to lower wave-making resistance or incorporating a bulbous bow to decrease drag at cruising speeds.

Improvements to the stern, including the use of stern flaps and energy-saving devices (ESDs), can minimize wake turbulence, further enhancing efficiency. Advanced anti-fouling coatings also play a vital role by reducing biofouling-induced friction. Another key area lies in propulsion systems, upgrading to controllable pitch propellers (CPP) that can enhance propulsion efficiency across varying operational conditions is a significant advantage for vessels experiencing fluctuating loads. Energy recovery systems at the stern, which capture and reuse energy lost in the wake, also contribute to improved performance. *(Wärtsilä, 2021)* [7].

The integration of hybrid propulsion systems—combining traditional engines with electric motors—enables vessels to operate on electric power during low-speed or light-load scenarios, thus substantially reducing fuel consumption. The addition of batteries further provides flexibility to meet peak power demands without overburdening the primary engines [7]. Additionally, transitioning to alternative fuels such as Liquefied Natural Gas (LNG) or methanol can achieve significant reductions in greenhouse gas emissions due to their lower carbon intensity compared to traditional marine fuels like heavy fuel oil (HFO) or marine gas oil (MGO) [8][9].

This study focuses on applying these energy efficiency principles through the structural modification of a Field Support Vessel (FSV) designed to withstand the extreme conditions of the North Sea. Specifically, it examines the effects of lengthening the vessel by five meters, an approach that aligns with the broader goals of enhancing operational performance and sustainability. The FSV, whose main features are listed in Table 1, operates near the coast of Talara, Peru and is equipped with advanced dynamic positioning technology, towing capabilities, fire control systems, and accommodations for up to 300 people during rescue operations. These features make the vessel an invaluable asset for offshore activities.

Table 1. Main features of the F.S.V.

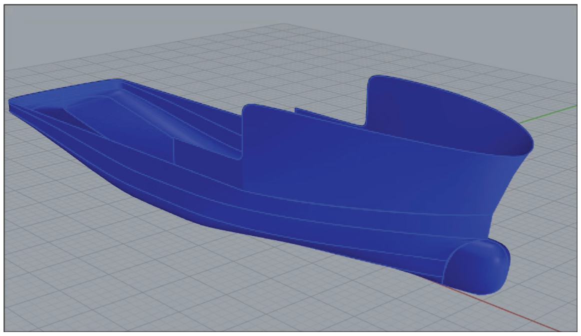
PSM system	SSM system	Variation
Length Overall	66.80	m
Length Between Pp	63.00	m
Beam	16	m
Depth M. D.	6	m
Depth U. D.	8.7	m
Draft	4.25	m
Deadweight	900	tons
Gross Tonnage	1800	tons
Engines	2xMAN 9L21/31	
Power	2x1935 @ 1000	kW @ RPM
Speed	14	Knots
Propeller Diameter	2.8	m
Bollard pull	65	tons

Methodology

Stability Analysis

According to Ignacio et al., 2025 [6], the stability analysis demonstrated that the five-meter lengthening of the vessel significantly enhances its deck cargo capacity and energy

Fig. 1. 3D model FSV.



efficiency. The cargo capacity increases by 24.44% (an additional 138 tons), alongside a 19.67% improvement in the Energy Efficiency Design Index (EEDI). In terms of stability, the transverse metacentric height (GMt) increases from 2.49 m to 2.57 m, ensuring intact stability, and the righting arm curve parameters meet the requirements of the 2008 Intact Stability Code. However, the lengthening results in greater resistance at lower speeds and a 2.23% increase in brake power demand at 14 knots. These findings highlight the modified vessel's viability as an efficient and sustainable option for offshore platform support operations.

Regression Analysis

Linear regressions were conducted to ensure that the original vessel falls within a statistical range of vessels with similar characteristics. Additionally, an analysis of freeboard, propulsion system, and structural integrity was performed. This approach ensures that the original vessel complies with the typical design and operational specifications of the fleet before proceeding with the analysis of the effects of lengthening.

Freeboard Calculation

This calculation allows us to estimate the waterline height, as the original information is confidential. The procedure of the International Convention on Load Lines (2014) [5] was used to calculate freeboard, ensuring the vessel's safety and stability under various loading conditions.

- Length of the waterline at 85% of the depth
- Displacement at 85% of the depth
- Area demarcated by the half waterline measured from the bow
- Superstructure dimensions

Structural Analysis

The structural analysis of the original and lengthened vessel was developed by using the rules of the classification society DNV [1] to calculate the midship section modulus as a function of vessel length.

The required sectional modulus - Zo is calculated as follows:

$$Z_o = C wo\, L^2 B\, (C b + 0{,}7)\ [K N . m] \tag{1}$$

Where:

L = lenght of the ship at 96% [m]
B = breath of the ship [m]
Cwo = wave coefficient 5,7 + 0,022L
Cb = block coefficient, 1,179-2,025 v/√9,81.Lwl
V = ship speed [knots]
Lwl = waterline lenght [m]

Structural Analysis (Poseidon Software)

Using Poseidon software of DNV [4], the structural design of a ship can be calculated using the criteria outlined in the DNV Rules [1], which are internationally recognized standards for safety and performance. This software facilitates detailed structural assessments, ensuring that all components meet the required strength and standards. It supports a wide range of vessel types and structural configurations, providing a reliable framework for achieving compliance with the classification society's requirements while optimizing the design for cost and performance.

Hydrodynamic Analysis

Hydrodynamic analysis is a process used to evaluate the vessel's dynamic behavior in water, understanding how it interacts with the surrounding fluid and predicting its performance during navigation.

For this analysis, the investigation was done under the weather conditions in Talara – Peru, where sea state 5 has been recorded, with an average wave height of 4 m. With this information, Maxsurf Motion allows us to evaluate ship accelerations for different positions heights when sailing with head, beam and following waves [3].

Results

It was verified that the lengthened vessel remains within the parameters for this type of ship despite only modifying the length. The original vessel was modeled in Maxsurf Modeler to determine the necessary characteristics for the subsequent calculations, which are summarized in Table 2 below:

Table 2. Main Features Comparison.

INPUT DATA COMPARISON	Original	Modified
Breadth [m]	66,8	71,8
Breadth [m]	16	16
Depth M.D. [m]	6	6
Draft [m]	4,26	4,23
Volume [m3]	28940	32350
Cb	0,600	0,630
Cm	0,950	0,950
Cp	0,650	0,660
Cwp	0,840	0,840
KMT [m]	8,36	8,30
KB	2,44	2,41
KG	5,87	5,73

The summer draft obtained for the lengthened vessel changes by 0.5% from the original ship as shown in Table 3 and Fi. 9 in the annexes show the simulation of the Plimsoll disk calculation.

Table 3. Summer draft and freeboard results.

	Original	Modified
FREEBOARD [m]	0,421	0,389
DRAFT [m]	5,589	5,621

As mentioned in the study of the propulsive efficiency of the propeller and engine from Ignacio *et al.*, 2025 [6]. The existing propeller is suitable for the lengthened design and any adjustment required. According to their ship model test, for a draft of 4.25, the ship can sail at 14 knots; this condition was used to evaluate the lengthened model. However, for higher speeds, it will be necessary to gain more power when comparing the original and lengthened model due to the increase in resistance in the Holtrop method [2] of resistance estimation applied in that study, where the increase in wetted surface in the middle body also heightens the resistance at speeds over 14 knots. The stability and maneuvering analysis, considering the impact of the center of gravity, the turning radius, and the response to steering control, showed that the lengthened ship improves in maneuverability and longitudinal stability with a small increase in GMt.

Table 4 shows the required midship section modules according to equation 1.

Table 4. DNV Sectional Modulus comparison.

	Original	Lengthened (+5 meters)
L [m]	66,80	71,80
Cwo	7,11	7,22
Cb	0,60	0,62
Z_{req} [m3]	0,66	0,77

As displayed in Table 4, the lengthening of the vessel increases the required sectional modules by an additional 14 % compared to the original vessel. However, the available sectional modulus of the structure should not change since the configuration or orientation of the internal structure of the hull is not continuous.

The main differences between both ships are the DWT, Block coefficient, and length. However, the draft and speed remained constant in both vessels.

Fig. 2 shows the Poseidon software [4] inputs and the dimensions of a mid-section block.

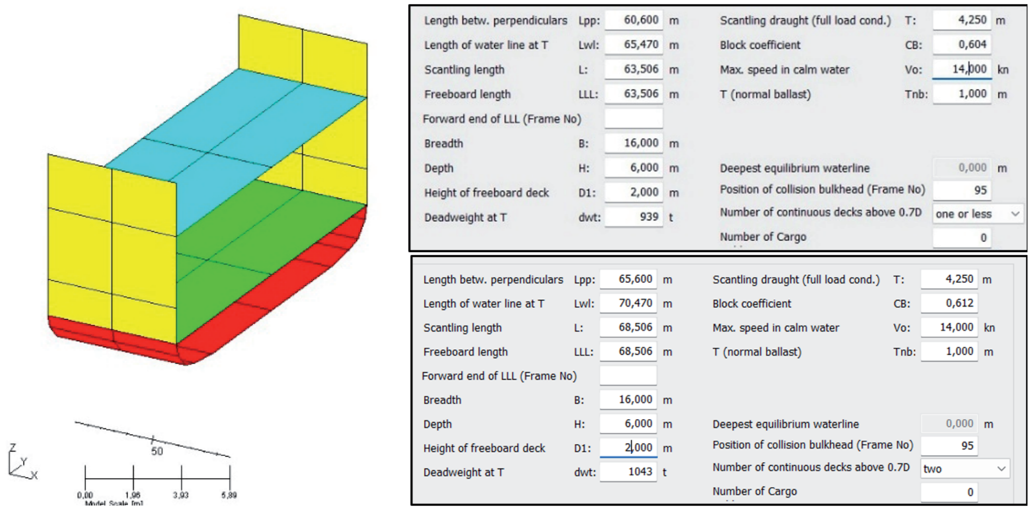
In this case, the vessel was analyzed as a hull-girder, including the side, bottom and deck plates without stiffeners using DNV [1] formulations obtaining the required thicknesses for midship section, as shown in the Table 5:

Table 5. Estimated Thicknesses for FSV plates.

PLATE	THICKNESS [mm]
BOTTOM	12
SIDES	10
MAIN DECK	10
DOUBLE BOTT.	10

These values are used in the DNV software, which calculates the minimum required sectional modules for the frame as well as the sectional modulus for the designed frame. The results for both the original and lengthened vessel are showcased in Fig. 3. With the expression of ABS and DNV to calculate required sectional modules, a curve was obtained showing how the vessel's sectional modulus changes with the length. It is shown in Fig. 4, where the sectional modulus remains constant regardless of the length.

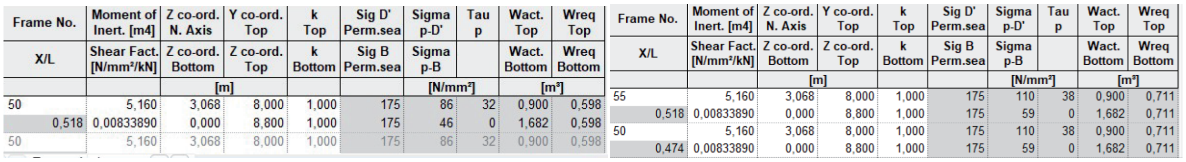
Fig. 2. Poseidon model- Frame 50 and Frame 55.



Length betw. perpendiculars Lpp: 60,600 m
Length of water line at T Lwl: 65,470 m
Scantling length L: 63,506 m
Freeboard length LLL: 63,506 m
Forward end of LLL (Frame No)
Breadth B: 16,000 m
Depth H: 6,000 m
Height of freeboard deck D1: 2,000 m
Deadweight at T dwt: 939 t
Scantling draught (full load cond.) T: 4,250 m
Block coefficient CB: 0,604
Max. speed in calm water Vo: 14,000 kn
T (normal ballast) Tnb: 1,000 m
Deepest equilibrium waterline 0,000 m
Position of collision bulkhead (Frame No) 95
Number of continuous decks above 0.7D one or less
Number of Cargo 0

Length betw. perpendiculars Lpp: 65,600 m
Length of water line at T Lwl: 70,470 m
Scantling length L: 68,506 m
Freeboard length LLL: 68,506 m
Forward end of LLL (Frame No)
Breadth B: 16,000 m
Depth H: 6,000 m
Height of freeboard deck D1: 2,000 m
Deadweight at T dwt: 1043 t
Scantling draught (full load cond.) T: 4,250 m
Block coefficient CB: 0,612
Max. speed in calm water Vo: 14,000 kn
T (normal ballast) Tnb: 1,000 m
Deepest equilibrium waterline 0,000 m
Position of collision bulkhead (Frame No) 95
Number of continuous decks above 0.7D two
Number of Cargo 0

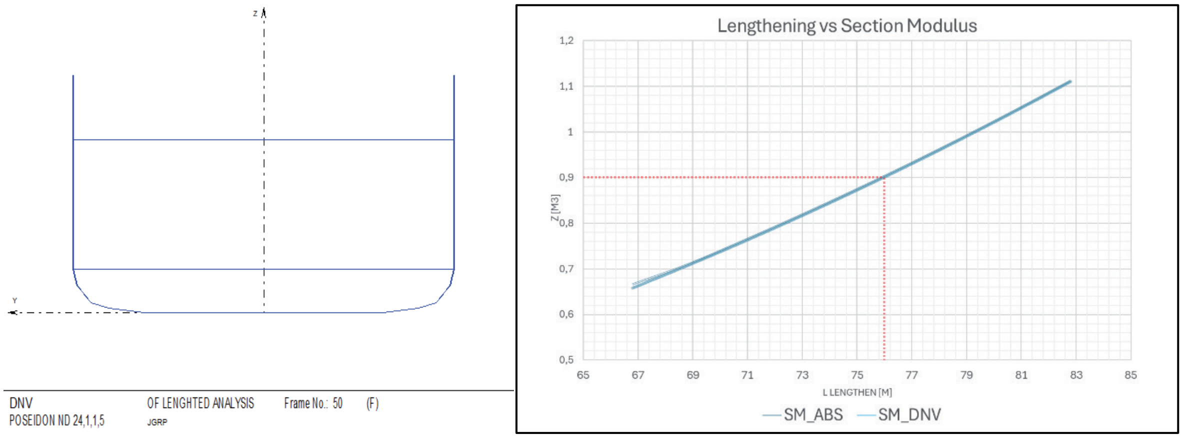
Fig. 3. Results of Sectional Modulus for FSV (left) and lengthened FSV (right).



Frame No.	Moment of Inert. [m4]	Z co-ord. N. Axis	Y co-ord. Top	k Top	Sig D' Perm.sea	Sigma p-D'	Tau p	Wact. Top	Wreq Top
X/L	Shear Fact. [N/mm²/kN]	Z co-ord. Bottom	Z co-ord. Top	k Bottom	Sig B Perm.sea	Sigma p-B		Wact. Bottom	Wreq Bottom
		[m]				[N/mm²]		[m³]	
50	5,160	3,068	8,000	1,000	175	86	32	0,900	0,598
0,518	0,00833890	0,000	8,800	1,000	175	46	0	1,682	0,598
50	5,160	3,068	8,000	1,000	175	86	32	0,900	0,598

Frame No.	Moment of Inert. [m4]	Z co-ord. N. Axis	Y co-ord. Top	k Top	Sig D' Perm.sea	Sigma p-D'	Tau p	Wact. Top	Wreq Top
X/L	Shear Fact. [N/mm²/kN]	Z co-ord. Bottom	Z co-ord. Top	k Bottom	Sig B Perm.sea	Sigma p-B		Wact. Bottom	Wreq Bottom
		[m]				[N/mm²]		[m³]	
55	5,160	3,068	8,000	1,000	175	110	38	0,900	0,711
0,518	0,00833890	0,000	8,800	1,000	175	59	0	1,682	0,711
50	5,160	3,068	8,000	1,000	175	110	38	0,900	0,711
0,474	0,00833890	0,000	8,800	1,000	175	59	0	1,682	0,711

Fig. 4. Maximum length vs Minimum required section modulus.



Once it was verified that the sectional modulus and stability were satisfactory for the lengthening, the analysis in Maxsurf Motion was carried out following the steps explained in its manual [3]. The analysis was conducted at three relative locations, as outlined in Table 6. Input Data for Maxsurf Motions and longitudinal remote locations are shown in Fig. 5.

The maximum speed is considered to be 14 knots in both models. Head, beam, and stern waves were considered for the calculation.

Table 6. Input Data for Maxsurf Motions.

Method	JHOSWAP
Wave height [m]	4
Wave period [s]	10,85
Relative location	Bridge Load Area Midsection
Wave directions [deg]	180 90 0

Fig. 5. Locations of remote points.

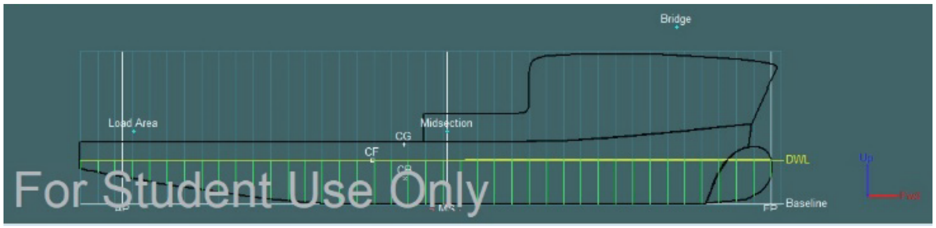
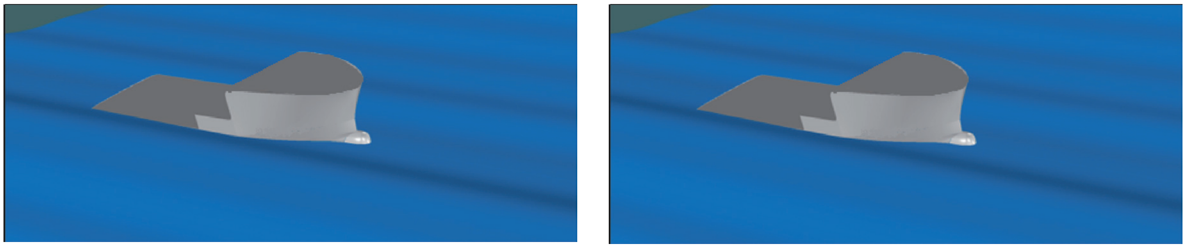


Fig. 6. Simulation of head and beam waves.



Hydrodynamic analysis showed that critical conditions are head and beam waves as outlined in Fig. 6. SOLAS indicates that the crew's level of discomfort depends on the exposure time, shortening the acceleration observed on the ship. The results obtained for the lengthened vessel are shown in Figure, while a comparison between the two models across additional parameters can be seen in the annexes.

Fig. 7 presents the acceleration in three motions, while Fig. 8 showcases the comfort levels for heave and beam waves; in both cases, only the modified FSV is considered.

Table 7 shows MSI values for the original and lengthened vessels at each location, demonstrating that the comfort requirement has not been met, the heave higher accelerations were in the highest area of the ship (bridge), being 1.40 m/s^2 for the original FSV and 1,3 m/s^2 for the lengthened vessel, exceeding the 1/2 hours limit for the crew in beam waves. However, the lengthened vessel has an 8% decrease in heave accelerations. On the other hand, roll accelerations remain almost at the same level of 0.5 m/s^2 for both models, with a slight increase in the

Table 7. MSI Comparison [m/s2].

Wave	FSV	FSV +5 m.	MSI- ISO 2631 Discomfort
Head wave: Bridge	1.40	1.30	> 30 min
Beam wave: Load Area	0,50	0.51	> 2 H

Fig. 7. Acceleration on Heave, Roll and Pitch of lengthened FSV.

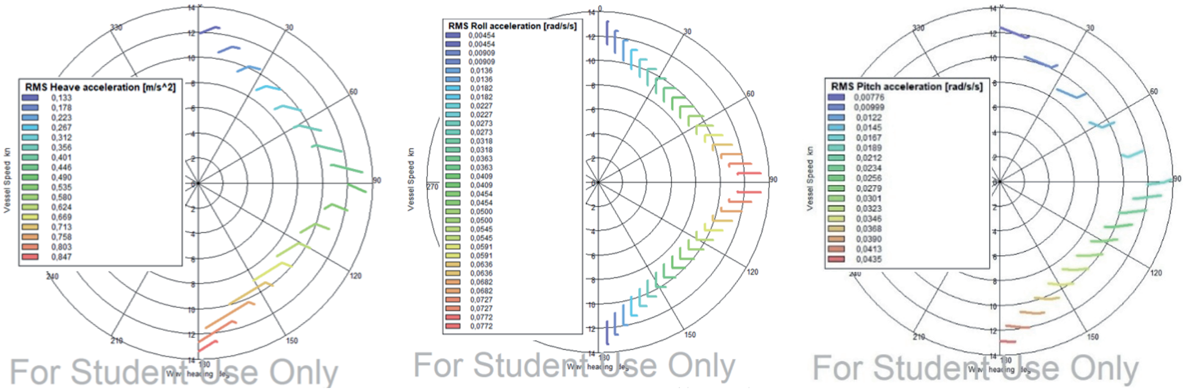
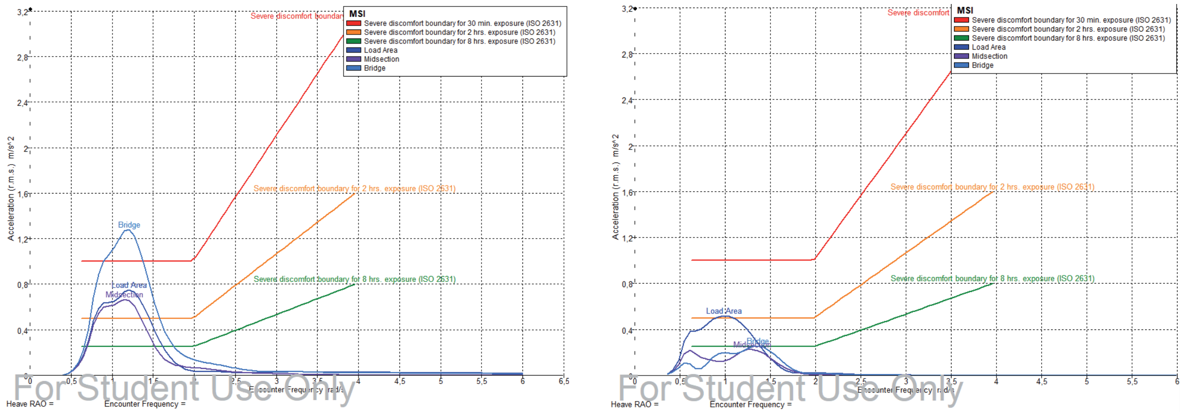


Fig. 8. Acceleration and comfort on head and beam waves in lengthened FSV.



lengthened model, fulfilling the 2-hour limit. Figs. 10 and 11 in the annexes list comparisons of Maxsurf motions results.

Analysis of Results

By using DNV rules, Fig. 4 shows the structural assessment of the vessel involved, evaluating its permissible lengthening, constrained by the sectional modulus of the original vessel, and estimating that the vessel could be lengthened up to 76 meters.

The dynamic analysis indicates that the lengthening of the vessel leads to a reduction in some key parameters, including pitching and heaving accelerations. Table 7 compares the MSI of the original and lengthened vessels, showing a reduction in heave acceleration. However, the impact on rolling acceleration depends on the vessel's loading condition, as it is closely linked to the vessel's metacentric height (GMt), which is, in turn, influenced by the vertical center of gravity (KG).

In terms of crew and passenger comfort, the analysis reveals that while the lengthened vessel offers slight improvements, the MSI limit established by ISO 2631 is not satisfactory for the lengthened ship. For instance, the bridge area, being the most critical for MSI comfort during heave exceeds the 1 m/s² threshold for discomfort after 30 minutes of exposure, even in the lengthened configuration. In contrast, the cargo area and midship region evince discomfort only after 2 hours of exposure. The cargo area, located at the stern, is on the edge of the 1 m/s² threshold after 2 hours, whereas the other areas might experience discomfort after 8 hours of exposure to these conditions.

Given the vessel's height, a dynamic positioning system (DPS) could significantly enhance operational comfort by reducing the effects of these accelerations, particularly on long-duration voyages. The DPS would help mitigate the discomfort by compensating the motion, thus ensuring better stability for both the crew and passengers during extended journeys in operations in Talara.

Limitations

Despite the comprehensive analyses, the study faced certain limitations. The structural evaluation primarily focused on plating thickness and did not account for detailed contributions of longitudinal stiffeners, which could influence the vessel's capacity for lengthening. This approach may underestimate the structural demands of the modification, especially for extended service life under variable loading and environmental conditions.

Furthermore, the hydrodynamic analysis relied solely on computational simulations under idealized conditions. The absence of experimental validations, such as tests in hydrodynamic tanks or real-world trials, limits the ability to confirm the predicted reductions in vessel motions and accelerations. These limitations underscore the need for further studies that integrate empirical data and more complex modeling scenarios.

The study's original contribution is the 5-meter lengthening of the vessel to enhance its performance. However, a broader discussion could be included on other potential energy efficiency improvements, such as integrating hybrid propulsion systems, renewable energy solutions (like solar or wind power), and energy-saving technologies (such as advanced hull coatings). These alternatives could complement or even surpass the benefits of the lengthening by reducing fuel consumption and operational costs. This expanded discussion would provide a more comprehensive perspective on how different strategies contribute to both operational efficiency and sustainability.

The analysis confirms that the 5-meter lengthening of the field support vessel is structurally feasible and enhances its hydrodynamic performance. The extended vessel achieves a new overall length of 71.80 meters and remains within the sectional modulus requirements of the classification society. This modification results in increased buoyancy and displacement while reducing freeboard, without compromising stability.

From a hydrodynamic perspective, the lengthened vessel exhibits improved heaving and pitching motions, with minimal impact on rolling accelerations under controlled loading conditions. However, further adjustments, such as optimized load distribution and possible integration of stabilizing technologies, may enhance performance in real-world operations.

Ultimately, the proposed lengthening aligns with the operational demands of offshore activities in Talara and demonstrates a balance between structural integrity, hydrodynamic performance, and comfort. However, addressing the study's limitations through additional research and technological advancements will further optimize the design and ensure long-term success in challenging maritime environments.

Contributions

- Franklin Domínguez: Research focus, supervision of research progress and restructuring, manuscript editing, and review.
- Jean Carlos Guerrero: Stability analysis using Maxsurf Motion, structural calculations using DNV Poseidon, maximum lengthening assessment, manuscript writing, and data analysis.
- Raul Gonzalo Pesantes: 3D modeling with Maxsurf and Rhino, sectional modulus and plate thickness calculations, vessel freeboard analysis, manuscript writing, and data analysis.

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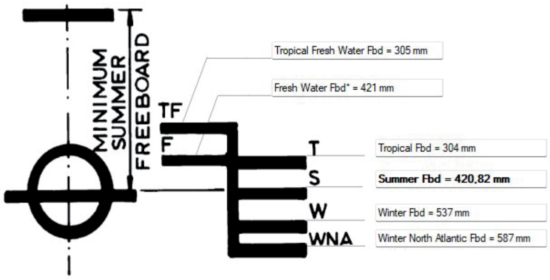
Annexes

Annex 1. FSV Original.



Annex 2. Lengthened FSV.