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The Effect of Variations in the Side Skeg Angle on Drag and Seakeeping of a Barge

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***Abstract*—** This study aims to analyze the effect of variations in the side skeg angle on the total resistance and motion response of a barge. The research subjects consisted of a barge model without a skeg and a barge model with a triple-skeg configuration at side skeg angles of 140°, 150°, 160°, and 180°. Numerical simulations were conducted using Maxsurf Resistance software to obtain total resistance values and the Hydrodynamic Diffraction method to evaluate sway and yaw motion responses. Resistance tests were performed under two loading conditions full load and light load with a speed range of 2 to 6 knots. Seakeeping analysis was performed at a speed of 6 knots with regular waves 1 meter high and wave incidence angles of 0°, 45°, 90°, 135°, and 180°. The results of the study show that the addition of a skeg increases total resistance by a relatively small percentage, namely 1.68% - 1.74% under full-load conditions and 2.60% - 2.83% under light-load conditions. From a seakeeping perspective, the addition of a skeg tends to slightly increase the sway response but effectively reduces the yaw response, particularly at a transverse wave angle of 90°. Based on the balance between increased resistance and reduced yaw response, the 150° side skeg configuration can be considered the most balanced option for improving the barge's directional stability without introducing significant additional resistance.

Keywords— CompreBarge; Side Skeg; Drag; Seakeeping

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I. INTRODUCTION

Barges are a common mode of maritime transport used to carry bulk, liquid, and general cargo. Unlike ships, which have their own propulsion systems, barges are generally operated with the assistance of tugboats, making the barge's drag performance a critical operational factor [1]. In addition, seakeeping performance must also be taken into account, as the barges ability to respond to waves will affect its directional stability and motion [2].

One additional component that can be used to improve a barge's directional stability is a skeg. A skeg serves as an additional structural element and hull section that contributes to improving the vessel's directional stability, particularly during yaw motion. Previous research has shown that skeg configurations can affect directional stability, drag, and flow patterns around the barge hull [3]. However, installing a skeg can also increase drag due to the hull's surface area that comes into direct contact with the water; therefore, the skeg design must be analyzed to strike a balance between increased drag and the vessel's maneuverability.

Although several studies have examined the effect of skegs on the resistance and seakeeping of barges, there are still few studies that specifically analyze variations in the angle of the side skegs in a triple-skeg configuration for oil barges.

A study on the effect of the side skeg angle on drag and seakeeping shows that changes in the side skeg angle can affect the hydrodynamic performance of the barge [4]. Therefore, this study aims to analyze the effect of side skeg angles of 140°, 150°, 160°, and 180° on total resistance and seakeeping response in terms of sway and yaw motion, in order to identify the triple skeg configuration with the most balanced side skeg angles in terms of resistance efficiency and barge motion response.

II. METHOD

This study employed a quantitative numerical simulation approach to investigate the hydrodynamic effects of side skeg angle variations in a triple-skeg configuration on barge performance. The research framework was designed to systematically evaluate the trade-off between resistance characteristics and directional stability through integrated resistance and seakeeping analyses.

A. Literature Review and Problem Identification
A comprehensive review of relevant literature was conducted to establish the theoretical foundation of the study, encompassing barge hydrodynamics, skeg design, resistance prediction, and seakeeping performance. This stage also served to identify existing research gaps regarding the influence of side skeg angle variations on triple-skeg barges and to formulate the research objectives.

B. Geometrical Modeling of the Barge

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A three-dimensional numerical model of a 300-ft oil barge was developed using Maxsurf Modeler. The baseline model was subsequently modified into four triple-skeg configurations with side skeg angles of 140°, 150°, 160°, and 180°. All principal dimensions and hydrostatic characteristics were maintained constant to ensure that any observed performance variation was solely attributable to changes in skeg geometry.

C. *Resistance Analysis*
Hydrodynamic resistance was evaluated using Maxsurf Resistance based on the Korean Register (KR Barge) methodology. Simulations were conducted under two loading conditions and within an operational speed range of 2–6 knots. The analysis aimed to quantify the influence of side skeg angle on total resistance and to assess the associated hydrodynamic penalties resulting from the installation of additional appendages.

D. *Seakeeping Performance Assessment*
The seakeeping behavior of each configuration was investigated through frequency-domain analysis using the Hydrodynamic Diffraction module. Simulations were performed under regular-wave conditions with a wave height of 1 m and wave headings of 0°, 45°, 90°, 135°, and 180°. Particular emphasis was placed on sway and yaw motions, as these parameters directly represent the directional stability and course-keeping capability of a towed barge operating in a marine environment.

E. *Numerical Validation*
To ensure the reliability and scientific rigor of the numerical model, validation was performed by comparing simulation outputs with established theoretical formulations and KR Barge calculations. The validation process assessed the level of agreement between numerical predictions and reference data, with an acceptable deviation limited to ±5%. This procedure ensured the robustness and credibility of the computational results.

F. *Comparative Evaluation and Optimization*
A comparative assessment was conducted to determine the most effective side skeg configuration. The evaluation considered both hydrodynamic efficiency and motion reduction performance by examining total resistance and Response Amplitude Operator (RAO) values. The optimal configuration was identified as the design that achieved the most favorable balance between minimizing resistance increase and maximizing directional stability improvement.

TABLE 1.
MAIN DIMENSION

Type of Ship	Oil	Barge
Dimensions	LOA	90,77
	B	23,9
	H	5,68
	T	4,25

The data obtained was then entered into the Maxsurf modeler by selecting the design barge. The hydrostatic data from Maxsurf is presented in the table below.

TABLE 2.
HYDROSTATIC DATA

No.	Hydrostatic Parameters	Value	Unit
1.	Displacement	8292	ton
2.	Volume Displacement	8090,049	m^3
3.	Lwl	91,010	m
4.	Beam	23,9	m
5.	Wetted Surface Area	2796,342	m^2
6.	Waterplane Area	2118,580	m^2
7.	Cb	0,875	
8.	Cp	0,878	
9.	Kb	2,228	m
10.	MTc	158,899	ton

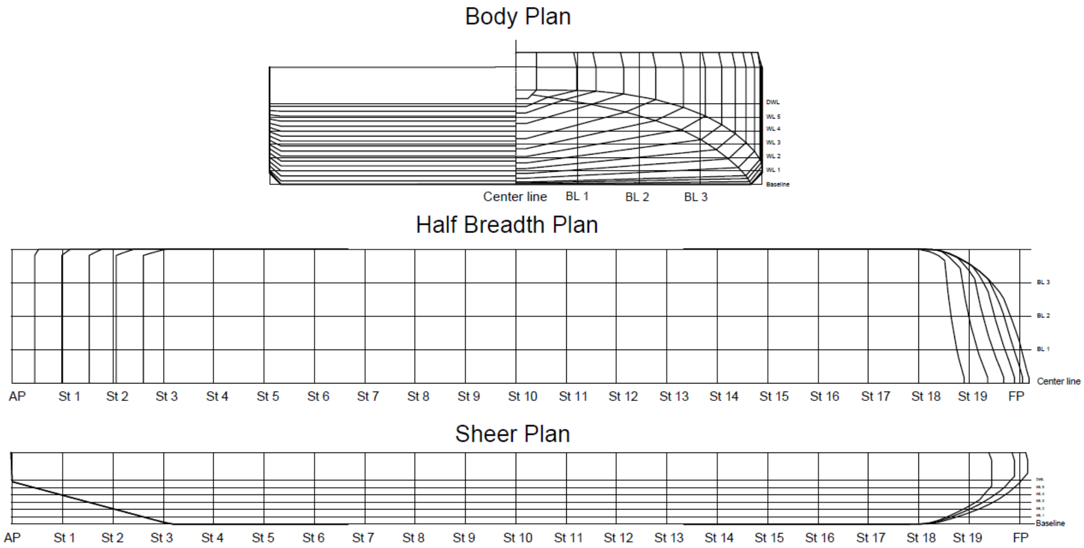

Figure. 1. Lines Plan

Figure 1 shows the barge's lines plan, which incorporates the previously created barge conditions. After creating a model using the MaxSurf Modeller software with a surface model, the next step was to create a surface model in STEP format for export to ANSYS AQWA. Specifically, the model variations have two conditions Condition 1 describes the waterline at the barge's highest draft, while Condition 2 describes the waterline at the barge's lowest draft, as shown in Figure 2 and Table 3.

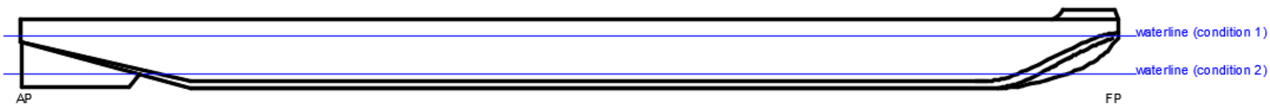

Figure 2. Variation conditions

A barge with three skegs, and side skeg angles of 140°, 150°, 160°, and 180°.

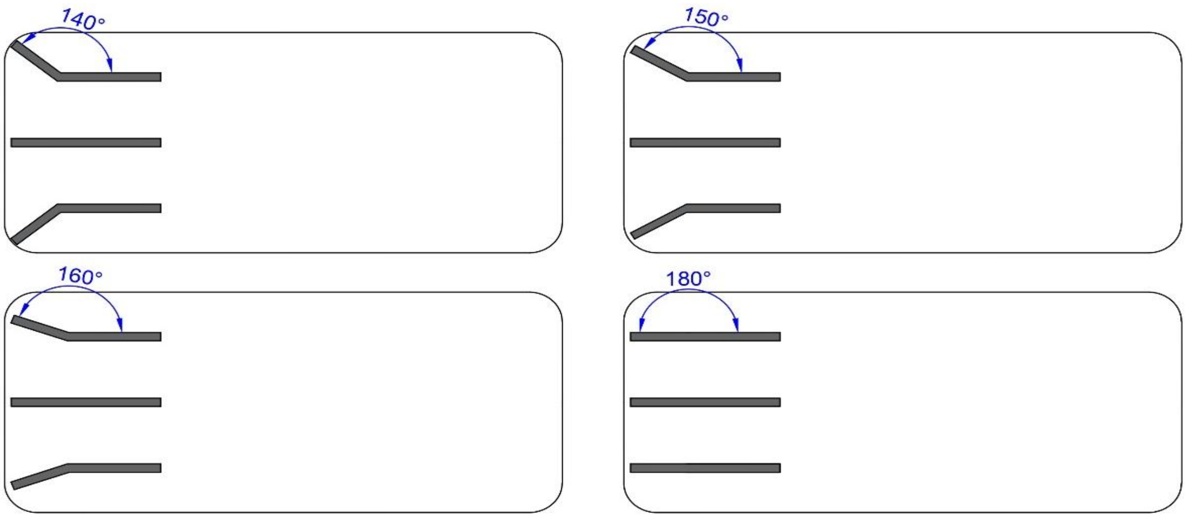

Figure 3. Variations in skeg angle

TABLE 3.
ANALYSIS OF BARGE DRAG AND SEAKEEPING CONDITIONS

Conditions 1	Conditions 2	Speed	Wave Height and Type	Waterline	Wave Heading
Without a skeg	Without a skeg	2,3,4,5,6	1 m (Reguler Wave)	4,25 m & 1,17 m	0°, 45°, 90°, 135°, dan 180°
Skeg 140°	Skeg 140°				
Skeg 150°	Skeg 150°				
Skeg 160°	Skeg 160°				
Skeg 180°	Skeg 180°				

To analyze the variations in the following skeg, the model was simulated using numerical analysis methods with Maxsurf Resistance software to determine the total resistance, and simulations were performed using CFD methods with ANSYS (Hydrodynamic Diffraction) software to determine the resulting motion response.

Total resistance was analyzed using Maxsurf Resistance. Validation was performed by comparing the results obtained from the software analysis with those from manual calculations.

The sway and yaw motions were analyzed using hydrodynamic diffraction in the RAO format. Validation was performed by comparing the results from ANSYS and Maxsurf Motion software.

Calculate the percentage difference in the validation test using the formula below [5].

$$\Delta RT\ (\%) = \frac{RT_{\text{With a } Skeg} - RT_{\text{Without a } Skeg}}{RT_{\text{Without a } Skeg}} \times 100\% \qquad (1)$$

Where $RT_{\text{With Skeg}}$ is the total resistance of the barge equipped with a skeg, and $RT_{\text{Without Skeg}}$ is the total resistance of the barge without a skeg.

The angular range of 140° - 180° was selected based on the actual side skeg angle configuration observed in the reference barge at the shipyard, where the originally planned side skeg is inclined at approximately 30° from the longitudinal axis (corresponding to 150° in the measurement convention used in this study). Variations above and below this reference angle were included to assess whether the planned configuration represents an optimal or sub-optimal choice. All side skeg variants share identical planform dimensions and plate thickness, so that the angular orientation of the side skeg is the sole independent geometric variable in this analysis.

TABLE 4.
WAVE PARAMETERS AND SIMULATION CONDITIONS

Parameter	Value	Unit
Water depth	40–60	m
Significant wave height (Hs)	1.0	m
Wave frequency range	0.1–3.0	rad/s
Wave heading	0°, 45°, 90°, 135°, 180°	°
Sea water density	1,025	kg/m³
Gravitational acceleration	9.80665	m/s²
WMO Sea State Code	3 (Slight)	-

The wave height of 1.0 m corresponds to WMO Sea State Code 3 (Slight), which is representative of typical operating conditions in the Java Sea, the primary deployment area for oil barges of this type. Regular wave excitation was applied to allow direct comparison of RAO values across all skeg configurations under controlled and repeatable conditions.

Resistance validation was carried out by comparing the total resistance from Maxsurf Resistance (KR Barge method) against manual calculations using the KR Rules empirical formulae, applied to the baseline without-skeg model at 6 knots and Condition 1 (T = 4.25 m) [6]. The comparison is presented in Table 5.

TABLE 5.
RESISTANCE VALIDATION

Method	Resistance (ton)	Resistance (kN)
KR Rules — Manual Calculation	29.11	285.45
Maxsurf Resistance (KR Barge Method)	29.59	290.20
Difference	0.48 ton	4.75 kN
Percentage Error		1.62%

The percentage error of 1.62% is well below the accepted threshold of ±5% [7], confirming that the Maxsurf Resistance results are consistent with the KR Rules theoretical calculation and may be used with confidence for comparative analysis across all skeg configurations.

Seakeeping validation was performed through cross-software comparison of the heave RAO from ANSYS AQWA and Maxsurf Motion for the without a skeg model at three wave headings. Heave motion was used as the comparison parameter because it is directly comparable between both solvers at the available simulation settings. Table 6 presents the results.

TABLE 6.
SEAKEEPING VALIDATION HEADING HEAVE

Wave Heading (°)	ANSYS AQWA (m/m)	Maxsurf Motion (m/m)	Error (%)
90°	1.168	1.224	4.79%
135°	0.998	0.976	2.20%
180°	0.996	0.968	2.81%

All percentage errors remained below the 5% threshold, with a maximum value of 4.79% at the 90° direction in the motion simulation, confirming that the ANSYS AQWA model produces results consistent with those of the independent solver Maxsurf Motion. This cross-software validation reinforces the reliability of the numerical framework used for all skeg variation analyses.

III. RESULT AND DISCUSSION

The analysis results show that the total resistance of the barge increases with increasing speed under both conditions. Under Condition 1, the barge without a skeg exhibits low total resistance, ranging from 30.7 kN at 2 knots to 290.2 kN at 6 knots. Adding a skeg at angles of 140°, 150°, 160°, and 180° slightly increased the resistance, but the differences between the angle variations were very small, so the addition of the skeg had an effect on total resistance but was not significant.

In Condition 2, although total resistance is lower due to the lowest loaded waterline, resistance increases from 13.2 kN at 2 knots to 128.3–128.4 kN at 6 knots after adding a skeg, and the differences between angles are very small. The following graph shows the total resistance patterns for both conditions:

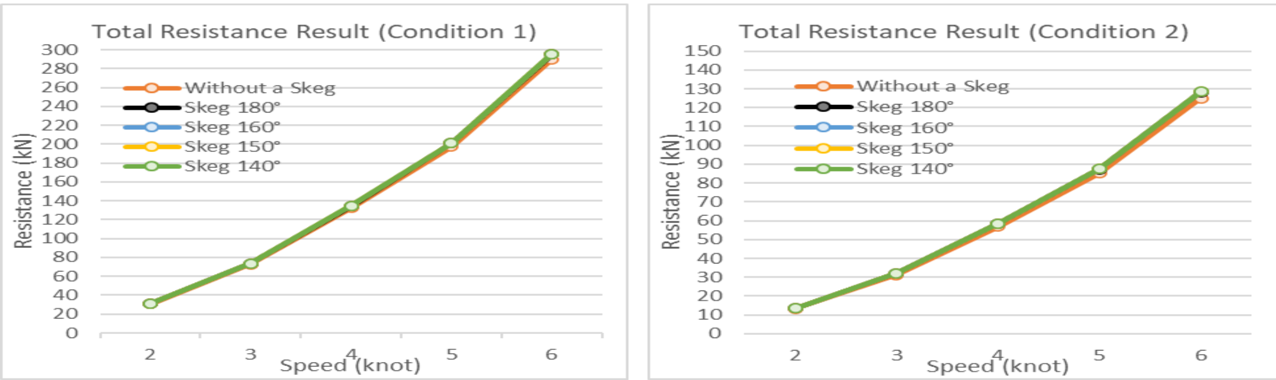

Figure 4. Graph of total resistance for both conditions

The seakeeping analysis shows that lateral motion (sway) and rotational motion (yaw) are influenced by the addition of three skegs. The highest sway values occur at a 90° wave angle for both conditions. Under load condition 1, the barge without skegs had a sway value of 3.568–3.569. Under condition 2, sway increased from 3.186 to 3.249–3.250 after the addition of skegs. The differences between variations in the side skeg angles were very small, so the effect on angular motion was insignificant.

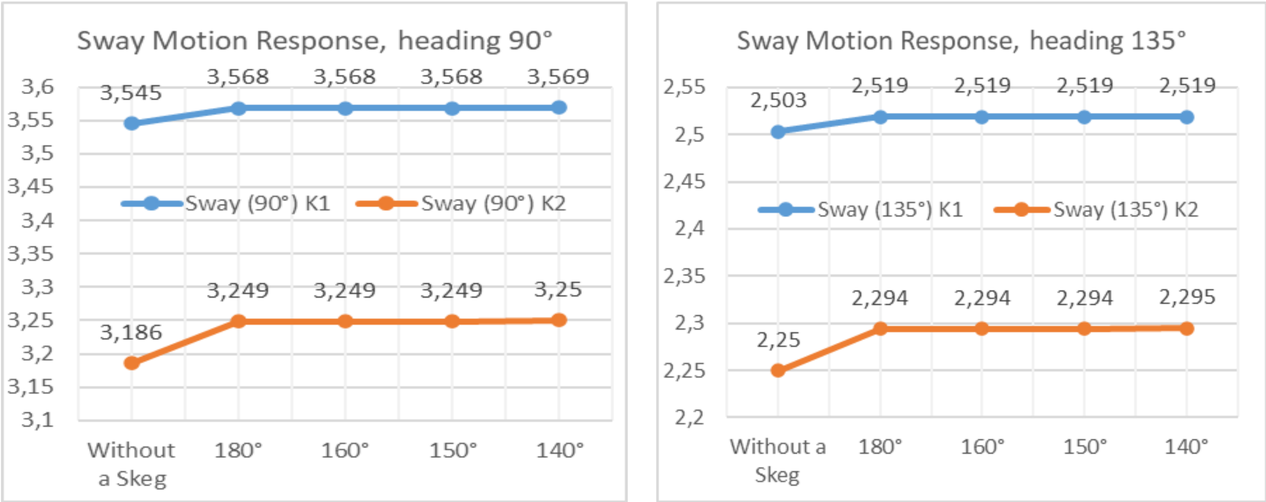

Figure 5. Sway Response Graph for Both Conditions

To make it easier to compare the performance of each skeg variation, Table 1 presents a summary of the total drag values and maneuvering response. The differences between the various angle variations are very small, and the addition of three skegs has a greater impact on the barge's hydrodynamic performance than the differences in skeg angle variations.

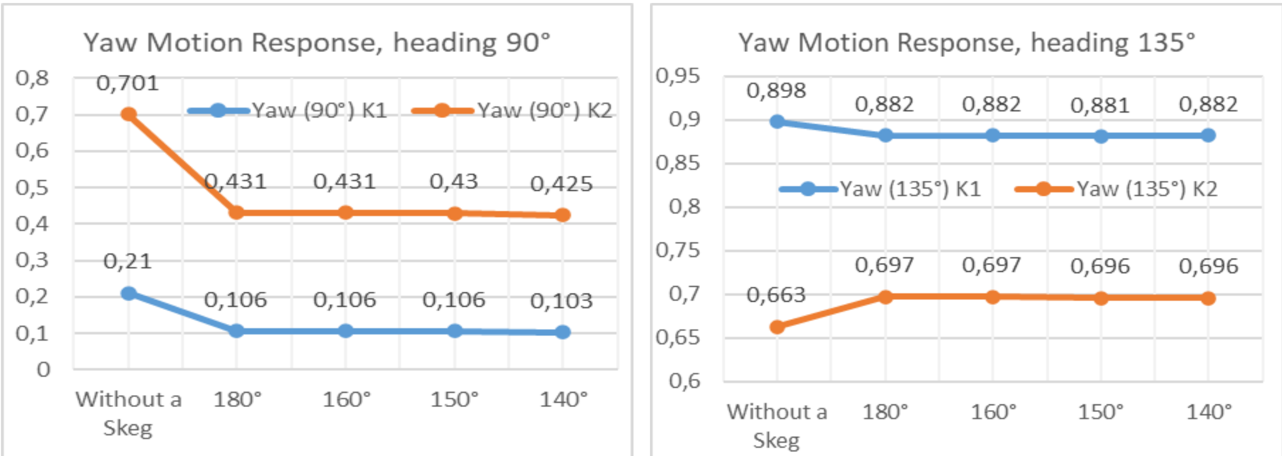

Figure 6. Yaw Response Graph for Both Conditions

Conversely, yaw motion decreases consistently with the addition of a skeg. At a 90° wave angle, the barge without a skeg produced a yaw of 0.210 under condition 1 and 0.701 under condition 2, while the barge with a skeg showed a reduction in yaw to 0.103–0.106 and 0.425–0.431.

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TABLE 7.
FINAL RESULTS FOR TOTAL RESISTANCE, SWAY, AND YAW

Side Skeg Variations	Total Resistance at Condition 1 (kN)	Total Resistance at Condition 2 (kN)	Respons Sway RAO (m/m)	Respons Yaw RAO (°/m)
Without a skeg	290,2	125,0	3,545	0,210
Skeg 140°	295,4	128,4	3,569	0,103
Skeg 150°	295,4	128,4	3,568	0,106
Skeg 160°	295,4	128,4	3,568	0,106
Skeg 180°	295,3	128,3	3,568	0,106

From the tables and graphs presented earlier, it is evident that adding three side skegs results in a consistent reduction in yaw, improving the barge's directional stability, while sway increases only slightly. Total resistance increases, but the differences between the various side skeg angles are very small, so the 150° angle can be considered the most balanced configuration between resistance and seakeeping performance.

IV. CONCLUSION

In conlusion, the use of a triple skeg configuration on oil barges has been shown to enhance directional stability and reduce yaw response, without causing a significant increase in total resistance. The sway response increases only slightly, and differences in total resistance among the side skeg angle variations (140°, 150°, 160°, and 180°) are minimal, indicating that the presence of skegs has a more dominant effect than variations in skeg angle. RAO analysis shows that the largest yaw occurs at a heading of 90°, while the maximum sway remains relatively small. Therefore, a triple skeg configuration, particularly at a 150° angle, is considered to provide the best balance between efficiency and seakeeping performance, supporting the design of a stable and efficient barge.

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REFERENCES

[1] Ali, S., Ramadani, F., Ali, S. A., & Syahputra, D. (2022). Analisis Ship Resistance Untuk Menentukan Daya Main Engine Kapal. Jurnal Inovasi Sains dan Tekonologi Kelautan, 3(2), 19–24.

[2] Purwoko, M. S., Nurhasanah, & Ikhsan, M. (2023). Analisa Peforma Olah Gerak Kapal Polbeng Ii. 9(1), 950–957.

[3] Im, N. K., Lee, S. M., & Lee, C. K. (2015). The influence of skegs on course stability of a barge with a different configuration. Jurnal Ocean Engineering, 97, 165–174. https://doi.org/10.1016/j.oceaneng.2015.01.017

[4] Wibowo, D. S., Akbar, A. K., Rosta, T. A. Da, Sukmawardana, H. N., & Rayhan, F. A. (2025). Effects of Transom and Skeg Angle on Barge Drag and Seakeeping Effects of Transom and Skeg Angle on Barge Drag and Seakeeping. https://doi.org/10.1088/1755-1315/1454/1/012012

[5] Shivacheva, E., Khorasanchi, M., Day, S., & Turan, O. (2020). Impact of trim on added resistance of KRISO Container Ship (KCS) in head waves: An experimental and numerical study. Journal Ocean and Marine Engineering.

[6] Register, K. (2022). *Rules for the Towing Survey of Barges and Tug boats*.

[7] Kurinawan, F. A., & Pranatal, E. (2024). Analisa Perhitungan Tahanan Kapal Tunda Karya Pacific 17 dengan Menggunakan Perbandingan Antara Metode Holtrop dan Software Maxsurf. Senastitan Iv.