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Effect of Hard Chine Planing Variations on Resistance and Stability of a Patrol Boat Hull

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KEYWORDS
Patrol Boat
Hard Chine Planing
Resistance
Stability
Maxsurf
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ABSTRACT – Patrol boat play a crucial role in maritime security and law enforcement, where optimizing hull performance is essential to achieve both efficiency and stability in various sea states. This study analyzes the influence of hard chine variations on the resistance and stability of a patrol boat hull. Four hull models single and double chine with angles of 0° and 10° were evaluated using Maxsurf Resistance and Stability. Total resistance was calculated at service speeds of 10 and 15 *knots*, while stability was assessed based on IMO Resolution A.749(18), Chapter 3. Results show that at 10 *knots*, the single chine 10° model produced the lowest resistance, whereas at 15 *knots*, the double chine 10° gave the best performance. Stability analysis indicated that all models met IMO criteria, with the double chine 10° achieving the highest *GMt*, maximum *GZ*, and angle of maximum *GZ*. The findings suggest that the single chine 10° is more efficient for calm-water operations, while the double chine 10° provides superior stability for rough-sea conditions.

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INTRODUCTION

This Patrol boats are widely employed for maritime security, surveillance, and law enforcement operations, requiring high speed and good maneuverability [3][4]. The hull form of such vessels significantly affects their hydrodynamic performance, particularly in terms of resistance and stability [1][2]. Resistance is a key factor influencing propulsion power and fuel efficiency, while stability determines the safety and operability of the vessel under various sea conditions [5].

Planing hulls with hard chines are commonly used for patrol boats due to their ability to reduce wetted surface area at higher speeds and to provide improved dynamic lift [7][8]. The configuration of the chine, including the angle and number of chines, plays a crucial role in balancing hydrodynamic resistance with transverse stability [10][11]. Most previous research on planing hulls emphasizes CFD simulation or experimental towing tests [7][9][11]. In contrast, this study explores chine angle variations through Maxsurf prediction [15], providing a more practical approach for early-stage design evaluation.

This study aims to investigate the effect of hard chine planing variations on the resistance and stability of a patrol boat hull using Maxsurf software. Four variations were analyzed, including single chine at 0°, single chine at 10°, double chine at 0°, and double chine at 10°. The results provide insight into the trade-off between minimizing resistance and maximizing stability, contributing to more efficient hull design for patrol vessels.

Most previous studies on planing hulls have relied on CFD simulations or experimental towing tests to evaluate resistance and stability characteristics. However, such approaches require significant computational resources and complex setups. In contrast, this study introduces a simplified evaluation of hard chine planing variations using the Maxsurf platform, allowing rapid prediction of hydrodynamic and stability parameters in the early design stage. This methodological distinction represents the novelty of the present work and provides practical insight for patrol vessel designers in achieving an optimal trade-off between resistance and stability.

METHODS

This study aims to analyze the influence of hard chine planing variations on the hydrodynamic resistance and stability characteristics of a patrol boat hull. The object of the research is a planing-type patrol vessel designed for high-speed operation, characterized by its flat bottom and hard chine geometry to enhance dynamic lift. The hull modeling process was performed using AutoCAD, where the baseline hull was developed as the foundation for subsequent chine modifications. The principal dimensions of the patrol boat used in this research are summarized in Table 1, which defines the fundamental geometric proportions that govern displacement, hull volume, and overall performance potential. These parameters including the overall length, beam, depth, and draft serve as the fixed baseline for all design variations analyzed in this study. By maintaining the same principal dimensions, the comparative assessment focuses solely on the hydrodynamic and stability effects produced by differences in chine configuration, ensuring that the analysis isolates the geometric impact of chine design without interference from scale or volumetric discrepancies.

Table 1. Table Principal Dimensions of the Patrol Boat

Description	Value
LOA (m)	16,70
LPP (m)	16,00
B (m)	3,80
T (m)	2,20
D (m)	0,70
Engine Power (HP)	3 x 300
FOT (liter)	2500
FWT (liter)	1000
Crew (person)	4
Passenger (person)	8
Vessel Speed (knots)	25

The principal dimensions shown in Table 1 were derived from an existing patrol vessel operated by the Indonesian Marine Police. These values were slightly adjusted to maintain proportional similarity and ensure compatibility with the Maxsurf simulation environment. This approach ensures that the model remains representative of real operational conditions while allowing consistent comparison across different chine configurations.

The baseline hull geometry, illustrated in Figure 1, represents a planing-type hull with a sharp entry at the bow, a relatively flat bottom surface, and prominent hard chines extending longitudinally from bow to stern. The forward section is designed with a fine shape to minimize wave-making resistance, while the midship region provides sufficient beam for stability and load capacity. Toward the stern, the hull transitions into a flatter form to enhance dynamic lift and reduce transom drag during high-speed operation. The chine lines are positioned at the bilge area, where changes in curvature create a flow separation boundary that contributes to spray formation and additional hydrodynamic lift. This geometric foundation serves as the reference model from which all chine variation cases single and double chines with different angles were subsequently developed.

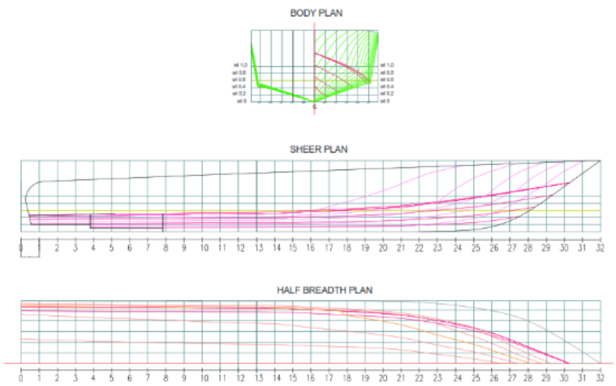

Figure 1. Baseline Hull Geometry of the Patrol Boat

In this study, the independent variables were the chine configuration (single or double) and chine angle (0° and 10°). The dependent variables were total resistance and stability indicators, including *GMt*, *GZmax*, and the angle of maximum *GZ*. Control parameters such as main dimensions, displacement, and service speeds (10 and 15 *knots*) were kept constant throughout all simulations to ensure that the observed differences resulted solely from chine geometry variations.

Hull Variations

Four hull form variations were developed based on differences in chine number and inclination, namely Single Chine 0°, Double Chine 0°, Single Chine 10°, and Double Chine 10°. All variations were derived from the same baseline geometry to ensure that only chine configuration served as the variable parameter affecting performance. The chine was modified along the bilge area of the hull, where its angle and number influence flow separation, pressure distribution, and the magnitude of dynamic lift generated during forward motion.

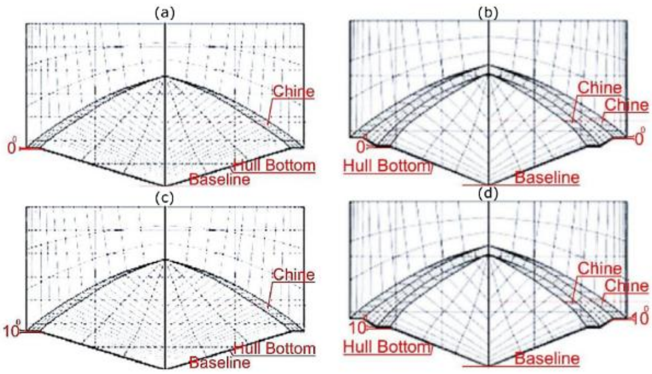

Figure 2. Cross-sectional views of Hull Variations

Computational analysis was performed using Maxsurf software, which provides modules for both resistance and stability evaluation. The Maxsurf Resistance module was used to estimate calm-water resistance through empirical planing hull prediction methods, while the Maxsurf Stability module was employed to assess intact stability according to IMO Resolution A.749(18), Chapter 3. The use of these integrated tools allowed a consistent and comparable evaluation of hydrodynamic and stability parameters within the same design environment.

The simulations were carried out under calm-water conditions at two service speeds of 10 and 15 *knots*, representing typical operational conditions for patrol boats. The input data for resistance analysis included hull geometry, displacement, and speed, while for the stability analysis, the Longitudinal Center of Gravity (LCG) and Vertical Center of Gravity (VCG) were used as input parameters. These values were obtained from preliminary weight and geometric calculations for each hull configuration to ensure accurate simulation results under realistic vessel loading conditions.

The simulations were conducted under calm-water conditions with a seawater density of 1025 kg/m³, which represents typical coastal patrol environments. All analyses were performed assuming negligible wind and wave effects to isolate the influence of hull geometry on hydrodynamic performance. Maxsurf was selected as the primary computational tool due to its efficiency in the early-stage design process, where multiple hull variants can be evaluated quickly with minimal setup time. Nevertheless, it is acknowledged that Maxsurf employs semi-empirical prediction methods that may not fully capture nonlinear flow phenomena or spray formation at high Froude numbers. Therefore, the results of this study are best interpreted as preliminary estimations to support further CFD or experimental validation.

Research Procedure

The research procedure was systematically arranged, beginning with hull modeling, followed by chine variation generation, resistance and stability simulation, and finally, comparative evaluation. The analytical sequence was designed to identify the correlation between chine configuration, hydrodynamic efficiency, and stability performance. The results of resistance and stability were then interpreted to determine the most efficient hull configuration in terms of total drag reduction and compliance with international stability criteria. A schematic representation of the workflow process from modeling to evaluation is presented in Figure 3.

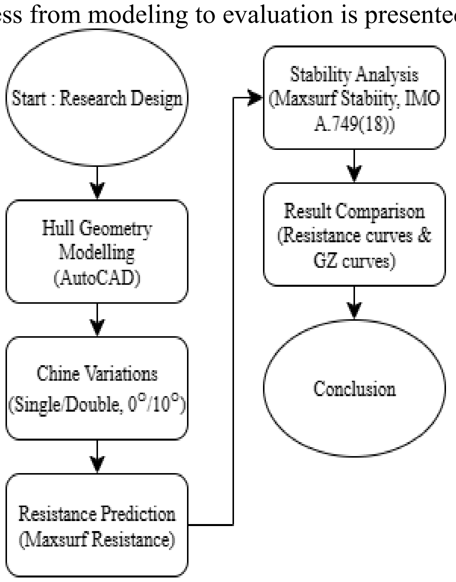

Figure 3. Research Methodology Flowchart

RESULTS AND DISCUSSION

Images Resistance at 10 *Knots*

The resistance prediction at a service speed of 10 knots is presented in Figure 4. Among the four hull variations, the single chine 10° model recorded the lowest resistance of 8145.52 *N*, while the double chine 0° produced the highest resistance of 8336.96 *N*. The single chine 0° and double chine 10° variations showed intermediate values of 8201.11 *N* and 8265.17 *N*, respectively.

These results indicate that increasing the chine angle from 0° to 10° tends to reduce resistance, particularly for the single chine configuration. The effect can be attributed to reduced wetted surface area and improved flow separation, which lower both frictional and wave-making resistance. However, the difference between variations at 10 *knot* remains relatively small (less than 200 *N*), suggesting that chine geometry exerts a more limited influence at lower speeds.

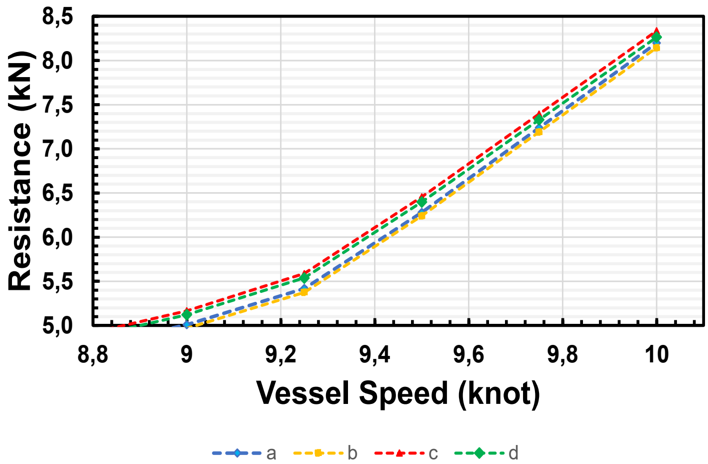

Figure 4. Total resistance of four hull variations at 10 *knots*: (a) Single Chine 0°, (b) Double Chine 0°, (c) Single Chine 10°, and (d) Double Chine 10°

Images Resistance at 15 *Knots*

At a service speed of 15 *knots*, the differences in total resistance became more evident (Figure 5). The double chine 10° hull exhibited the lowest resistance, with a value of 25,156.86 *N*, followed closely by the single chine 10° at 25,227.52 *N*. The double chine 0° recorded 25,358.75 *N*, while the single chine 0° produced the highest resistance of 25,431.54 *N*.

The results at 15 *knots* reinforce the trend observed at 10 *knots*, where hulls with sharper chine angles (10°) generally performed better in minimizing drag. This improvement can be explained by enhanced flow deflection at higher speeds, which reduces wave amplitude and energy dissipation. Although the absolute differences between variations are modest (less than 300 *N*), they represent potential fuel savings during long-term operation, especially at higher service speeds.

These findings are consistent with previous research indicating that sharper chine angles enhance hydrodynamic performance by promoting efficient spray deflection and reducing wetted surface area. Avci (2018) and Hou (2019) reported similar reductions in total drag in high-speed planing craft with increased chine sharpness, while Lotfi and Ashrafizaadeh (2015) demonstrated that geometric refinements in hull surfaces significantly improve flow separation and dynamic lift. The agreement between the present results and those reported in earlier studies reinforces the reliability of Maxsurf-based prediction for preliminary planing hull design evaluation.

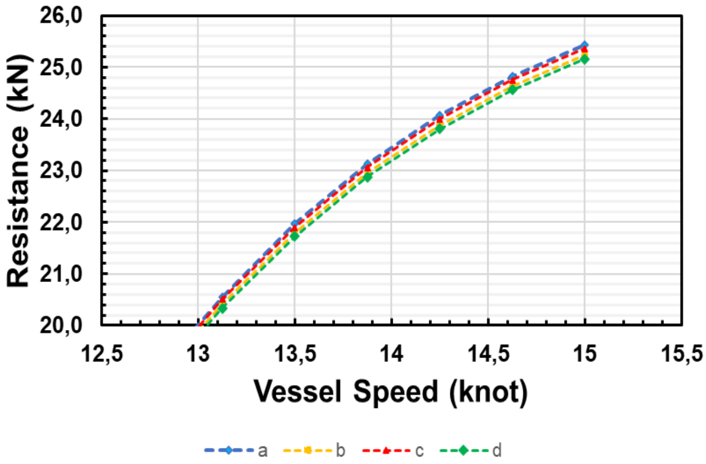

Figure 5. Total resistance of four hull variations at 15 *knots*: (a) Single Chine 0°, (b) Double Chine 0°, (c) Single Chine 10°, and (d) Double Chine 10°

To further clarify the differences between hull types, a comparison was made between the single chine and double chine variations at 15 *knots*, as presented in Table 2. The results indicate that both double chine configurations produced lower resistance values compared to their single chine counterparts. This suggests that, at higher speeds, the double chine hulls demonstrate slightly better hydrodynamic performance by reducing drag. However, the margin of improvement remains relatively small, reflecting the subtle influence of chine configuration on resistance at planing speeds.

Table 2. Comparison of Resistance between Single Chine and Double Chine Variations

No	Speed (knots)	Variations			
		Single Chine 0° (*N*)	Double Chine 0° (*N*)	Single Chine 10° (*N*)	Double Chine 10° (*N*)
1	3	0,287	0,305	0,284	0,300
2	6	1,394	1,439	1,381	1,421
3	9	5,006	5,167	4,967	5,123
4	12	15,980	15,979	15,871	15,847
5	15	25,432	25,359	25,228	25,157

Stability Analysis

The intact stability of all hull variations was evaluated using Maxsurf Stability. The assessment followed the criteria set out in IMO Resolution A.749(18), Chapter 3, which specifies intact stability requirements including initial metacentric height (*GMt*), maximum righting arm (*GZmax*), the angle of maximum *GZ*, and the area under the *GZ* curve. The results are presented in Table 3, while supporting comparisons of specific parameters are illustrated in Figure 6 and Figure 7.

According to the IMO Resolution A.749(18), Chapter 3, the intact stability of small vessels must satisfy several quantitative criteria. These include a minimum metacentric height (GMt) of at least 0.15 m, a maximum righting arm (*GZmax*) not less than 0.2 m occurring at a heel angle between 25° and 35°, and a sufficient area under the *GZ* curve up to a heel of 40°. Compliance with these parameters ensures that the vessel possesses adequate initial and overall stability under normal operational conditions. In this study, these criteria were used as the benchmark to evaluate the stability performance of each hull variation.

Table 3. Stability Parameters of Hull Variations

No	Criteria	Variations			
		Single Chine 0°	Double Chine 0°	Single Chine 10°	Double Chine 10°
1	Area 0 to 30	13,760	14,490	13,731	14,750
2	Area 0 to 40	22,669	23,721	22,621	24,125
3	Area 30 to 40	8,909	9,2301	8,890	9,376
4	Max *GZ* at 30 or greater	1,044	1,064	1,043	1,074
5	Angle of maximum *GZ*	62,7	60,9	62,7	60,000
6	Initial *GMt*	1,87	1,979	1,868	2,015

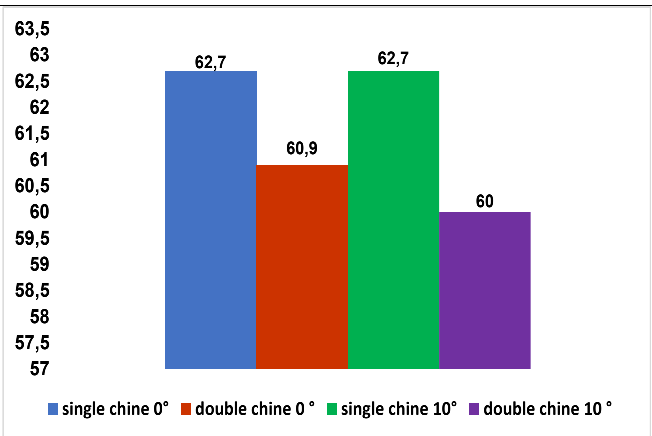

Figure 6. Comparison of Angle of Maximum GZ for Hull Variations

Figure 6 indicates that the angle of maximum *GZ* is highest for the single chine variations (0° and 10°), rather than for the double chine 10° configuration. This means that the single-chine hulls retain their maximum righting arm at a larger heel angle, whereas the double-chine hulls achieve their peak stability at slightly lower heel angles. This indicates that the vessel can sustain higher heel angles before reaching its maximum righting arm, which reflects stronger restoring capability under rough-sea conditions. Conversely, the single chine 0° variation demonstrated the smallest angle of maximum *GZ*, suggesting more limited stability margins.

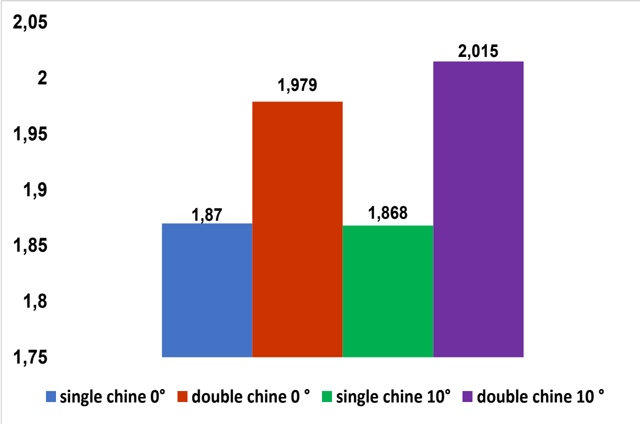

Figure 7. Comparison of Initial GMt for Hull Variations

Figure 7 shows that the double chine 10° hull also achieved the highest initial *GMt*, confirming superior initial stability at small angles of heel. The single chine 0° variation again exhibited the lowest *GMt*, though the value remained above the minimum IMO requirements. The single chine 10° and double chine 0° produced intermediate values, demonstrating that both chine angle and chine number influence the vessel's stability performance.

In summary, the stability analysis demonstrates that the double chine 10° hull provided the best overall performance across all parameters, supported by higher *GMt*, larger maximum *GZ*, and a greater angle of maximum *GZ*. Although all configurations satisfied the minimum criteria of IMO Resolution A.749(18), Chapter 3, the double chine with 10° angle clearly enhanced restoring ability compared to the other variations.

When analyzed together, the resistance and stability results demonstrate that the double chine 10° hull provides the best balance between hydrodynamic efficiency and safety. Although this configuration slightly increases resistance at lower speeds, it offers superior stability at higher speeds and rough-sea conditions. Conversely, the single chine 10° hull is more suitable for calm-water operations where fuel efficiency is prioritized. This synthesis highlights that chine geometry must be selected based on specific operational requirements rather than purely on drag minimization.

CONCLUSION

This study investigated the effect of chine configuration on the hydrodynamic performance of a patrol boat hull through resistance and stability analyses. The results showed that chine geometry has a measurable influence on both parameters. At 10 *knots*, the single chine 10° variation recorded the lowest resistance, while at 15 *knots* the double chine 10° produced the most favorable resistance performance. In general, sharper chine angles contributed to reduced drag, confirming the role of chine geometry in enhancing hydrodynamic efficiency. At 15 knots, the double chine 10° hull reduced total resistance by approximately 1.1% compared to the single chine 0° configuration and achieved a 7.7% higher GMt value, confirming its superior overall performance.

In terms of stability, the double chine 10° hull consistently outperformed the other variations, achieving the highest initial *GMt*, maximum *GZ*, and angle of maximum *GZ*, while still complying with the criteria of IMO Resolution A.749(18), Chapter 3. Overall, the findings suggest that the single chine 10° is recommended for operations prioritizing fuel efficiency in calm waters, whereas the double chine 10° is preferable for missions in rough-sea conditions where greater stability is required.

Nevertheless, this research was limited to numerical analysis using Maxsurf, which provides semi-empirical predictions of hydrodynamic behavior. Future studies are recommended to extend the chine angle variations beyond 10° and to validate the numerical findings through experimental towing tests or high-fidelity CFD simulations. Furthermore, evaluating performance across a broader range of planing speeds and sea-state conditions would contribute to establishing more comprehensive design guidelines for patrol vessels.

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REFERENCES

[1] [IMO], "Code on Intact Stability for All Type of Ships Covered by IMO Instruments Resolution A.749(18)", International Maritime Organization, 1995.

[2] [BKI], "Volume V Rules for Fiberglass Reinforced Plastic Ship", Badan Klasifikasi Indonesia, 2021.

[3] Basir, N. B. A. A., "Analisa Pengaruh Penggunaan Chine Pada Hambatan Kapal Ikan Tipe Katamaran", Jurnal Teknik Perkapalan, Vol. 3, No. 2, 2015.

[4] Prakoso, M. S. E., and Samuel, S., "Analisa Hambatan Total Karena Perubahan Bentuk Chine Pada Kapal Patroli", Jurnal Teknologi, Vol. 14, No. 1, pp. 47–54, 2022.

[5] Windyandari, A. A., "Kajian perilaku ketahanan dan stabilitas utuh kapal patroli yang dilengkapi chine", Jurnal Rekayasa Maritim, 2021.

[6] Widodo, E. S., "Simulasi Penerapan Hull Chine Terhadap Tahanan, Daya Dorong dan Stabilitas Kapal pada PB Suberko-02", Jurnal Teknik Perkapalan, 2017.

[7] Avci, A. B., "An experimental and numerical study of a highspeed planing craft with full-scale validation", Journal of Marine Science and Technology, Vol. 26, No. 5, 2018.

[8] Hou, G. J., "Dynamic response modeling of high-speed planing craft with enforced acceleration", Marine Structures, Vol. 63, pp. 105–117, 2019.

[9] Lotfi, M., and Ashrafizaadeh, R. K. Esfahan, "Numerical investigation of a stepped planing hull in calm water", Ocean Engineering, Vol. 94, pp. 103–110, 2015.

[10] Fathuddin, A., and Samuel, S., "Prediksi hambatan kapal dengan menggunakan metode overset mesh pada kapal planing hull", Rekayasa Hijau: Jurnal Teknologi Ramah Lingkungan, Vol. 4, No. 1, pp. 24–34, 2020.

[11] Febrian, C. E., "Analisa Hambatan dan Gaya Angkat dari Modifikasi Stephull dengan Variasi Sudut pada Kapal Pilot Boat 15 Meter ALU Menggunakan Metode CFD", Jurnal Teknik Perkapalan, Vol. 6, No. 1, 2018.

[12] Pratama, M. A., "Analisa Pengaruh Hidrofoil Dengan Variasi Planing Hull Chine Terhadap Laju Aliran Speedboat", Jurnal Jalasena, Vol. 3, No. 2, pp. 111–118, 2022.

[13] Putra, B. G. P., and S., "Optimasi Hambatan Kapal Terhadap Sudut Kemiringan Bow Kapal Patroli 75 M", Jurnal Jalasena, Vol. 1, No. 2, pp. 77–84, 2020.

[14] Surbakti, A. G., Kamil, A. S., and G. D., "Concept Design Kapal Penumpang Guna Mengurangi Angka Kecelakaan Kapal di Danau Toba", Jurnal Teknologi Maritim, Vol. 6, No. 2, pp. 28–33, 2023.

[15] Cahyo, I. D., "Perbandingan Modifikasi Bentuk Lambung Terhadap Tahanan Kapal Menggunakan Metode Delftship", Jurnal Pengelolaan Laboratorium Pendidikan, Vol. 2, No. 1, pp. 26–34, 2020.

[16] A. Hidayat, H. Inprasetyobudi, and Y. Y. E. Darma, "Design and Modeling of Catamaran Flat Plate Ship with Bottom Glass Concept to Improve Tourism Underwater in Bangsring Banyuwangi," Kapal J. Ilmu Pengetah. dan Teknol. Kelaut., vol. 18, no. 3, pp. 140–150, 2021, doi: 10.14710/kapal. v18i3.38824.

[17] Y. Y. E. Darma, R. H. Pratama, I. S. P. D. Yudha, and A. I. Kusuma, "Impact of Stepped Hull Design on Speed Boat Performance: A CFD Study," Evergreen, 2024, [Online]. Available:https://catalog.lib.kyushuu.ac.jp/opacdetailmd/?lang=0&amode=MD100000&bibid=7236898

[18] Y. Y. Eka Darma, H. Inprasetyobudi, R. E. P. Utomo, G. H. Wibowo, A. Hidayat, and A. D. Saragih, "Motions Analysis Investigation of a 12 Meter Catamaran Tourism Boat on Passenger Comfort Criteria Case Study „MV Garuda Ngelayang,"" Int. J. Mar. Eng. Innov. Res., vol. 8, no. 2, pp. 179–190, 2023, doi: 10.12962/j25481479.v8i2.16581.

[19] Papanikolaou, A., Ship Design Methodologies of Preliminary Design, Springer, London, 2014.

[20] Biddison, M., "Chine System for a Boat Hull", United States Patent, 2003.

[21] Cornelius Sebastian, G., "Perancangan Mesin Kapal Ro-Ro Car & Passenger Ferry 700 GT Tanjung Priok – Tanjung Mas", Doctoral dissertation, Universitas Darma Persada, 2020.