Prediction of Resistance and Power Requirements for a 72-Meter Landing Craft Tank (LCT) Vessel

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Abstract. This study aims to predict the resistance and power requirements of the 72-meter Landing Craft Tank (LCT) Montana using the empirical Holtrop method. The Holtrop method is widely used for estimating ship resistance in calm water conditions and has proven to be effective in providing accurate predictions. The findings of the study indicate that the total resistance (RT) of the 72-meter LCT at a maximum service speed of 12.6 knots is 344.6 kN. The corresponding power requirement is calculated to be 2977.971 kW, which is approximately 3993.524 horsepower (HP). To meet this power demand, the selected main engine is the YANMAR 6EY26W, which is rated at 2 x 1620 kW. These results offer valuable insights for the design and development of the 72-meter LCT, particularly in terms of optimizing operational efficiency and ensuring appropriate engine selection. By understanding the resistance and power needs, shipbuilders can enhance the vessel's performance and fuel efficiency. Additionally, the findings can serve as a reference for improving future designs of similar vessels, thereby contributing to more efficient maritime operations. This research highlights the importance of accurate predictions in the ship design process, helping to ensure that performance expectations are met while also contributing to cost-effective and energy-efficient solutions in naval architecture.

1 Introduction

One of the critical components in ship design is resistance [1]. Determining the resistance value of a ship during operation is a key factor in hydrodynamic analysis, as it significantly influences fluid flow patterns, speed, and the vessel's economic efficiency while operating

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[2]. According to [3], resistance is a force generated by the interaction between the ship and the surrounding fluid, which causes the vessel to experience opposition to movement. Resistance, also referred to as drag, is a force acting opposite to the velocity vector of the ship, acting on the hull structure and impeding the ship's forward motion [4]. Hull resistance can arise from variables such as fluid viscosity, mass density, and physical conditions like waves or calm water [5].

The prediction of ship resistance enables the estimation of the required propulsion power needed to move the vessel, facilitating the determination of optimal engine specifications, including appropriate size and mass, based on fluid mechanics and hydrodynamic principles. Furthermore, predicting ship resistance allows for estimating fuel consumption and operational costs, which directly impacts the efficiency of sustainable and environmentally friendly transportation and logistics [6]. Accurate and effective ship resistance prediction methods are crucial for enhancing vessel safety, maneuverability, and ensuring compliance with maritime safety standards and regulations [7]. In addition, resistance prediction is aimed at improving performance metrics, such as service speed and fuel efficiency [8]. In recent decades, significant advancements have been made in the development of techniques and approaches for predicting ship resistance, with numerous studies and comprehensive literature reviews contributing to these advancements [9].

When selecting the main engine power of a ship, resistance must be considered as it affects operational costs related to fuel consumption. Therefore, resistance is a critical factor in achieving the optimal engine power level [10]. The amount of fuel consumed by a vessel is influenced by the specific fuel consumption (SFR), engine power (MCR), voyage distance, and operational speed [11]. In the study [12], the Holtrop method and Maxsurf Resistance software were used to predict the hull resistance of a bulk carrier and calculate the required power for an 8664 DWT vessel. In recent years, various methods have been developed for predicting ship resistance, including advanced Computational Fluid Dynamics (CFD) [13–16], Artificial Neural Networks (ANN) [17,18], and experimental approaches such as towing tank tests [19,20]. CFD techniques have gained popularity for their accuracy in simulating complex flow dynamics around a ship's hull, offering precise resistance predictions across a wide range of operating conditions [21]. Studies have demonstrated that ANN models, trained on large datasets, can also predict ship resistance with high accuracy by identifying nonlinear relationships between ship parameters and resistance forces [22]. However, both CFD and ANN approaches require significant computational resources and expertise, making them less practical for routine use in simpler or cost-constrained projects. In contrast, empirical methods like the Holtrop method remain widely used due to their balance of simplicity, accuracy, and computational efficiency, especially for standard vessel types such as tankers, bulk carriers, and landing craft.

To support the supply chain needs in the Riau Archipelago Province, a 72-meter LCT vessel is being designed with sufficient capacity and optimal service speed to transport goods and materials safely and efficiently. The Holtrop method, based on regression analysis of model test data, provides reliable predictions of resistance in calm waters, making it particularly suitable for the 72-meter LCT studied here. Its ability to estimate total resistance with minimal computational demand while delivering results comparable to more resource-intensive methods makes it ideal for this application, where the focus is on operational efficiency, fuel consumption, and appropriate engine sizing.The resistance and power predictions for this 72-meter LCT will utilize Maxsurf Resistance software, based on the empirical Holtrop method, to estimate the total resistance (RT) and required power [23,24]. The primary goal of this study is to accurately predict the resistance and power requirements for a 72-meter Landing Craft Tank (LCT) using the Holtrop method, a widely accepted empirical approach. This prediction is crucial for optimizing the vessel's operational efficiency, particularly in maritime regions like the Riau Archipelago, where efficient and

safe transportation of goods is essential for economic development. By estimating the resistance, shipbuilders can select an engine that balances power output with fuel efficiency, reducing operational costs and environmental impact. Moreover, these predictions provide valuable insights for future vessel designs, enabling the development of more energy-efficient and cost-effective ships that meet both performance and sustainability standards in maritime operations. This research is expected to contribute to the development of LCT technology in Indonesia and help boost economic potential in the remote areas of the Riau Archipelago.

2 Methodology

2.1 Ship Resistance

The phenomena of waves and wake generated by a moving vessel can be observed and measured using accurate measurement techniques. The wave and wake components, such as drag and wave making resistance, can be identified and calculated through precise mathematical and numerical analysis. Drag is defined as the difference between wave making resistance and total resistance, under the assumption that surface roughness has a negligible effect on ship resistance, allowing the separation of drag and wave making contributions to the total resistance [25]. Ship resistance can be categorized into two main components: viscous pressure drags and frictional resistance, each with distinct physical characteristics.

Viscous pressure drags results from the interaction between the fluid flow and the ship's geometry, producing a pressure force that opposes the vessel's forward motion. On the other hand, frictional resistance is caused by the interaction between the fluid and the ship's surface, generating frictional forces that also oppose the vessel's movement. In the context of ship resistance analysis, these components can be isolated and calculated separately using analytical and numerical methods, providing a clearer understanding of their individual contributions to total ship resistance and enabling more precise ship design evaluations [6]. Ship resistance can be further classified into three primary components: frictional resistance (RF, CF), viscous pressure drags (RVP, CVP), and wave making resistance (RW, CW), each contributing uniquely to the overall resistance [26].

2.2 Froude number

In fluid mechanics, the Froude number (Fn) is a dimensionless parameter that plays a crucial role in describing the interaction between inertial forces of fluid flow and gravitational forces. The Froude number illustrates how gravity influences fluid dynamics and the movement of objects interacting with the fluid. In the analysis of ship movement in water, the Froude number is commonly used to understand the vessel's motion characteristics and to predict its performance under various operational conditions. For instance, the Froude number can be employed to determine optimal ship speed, optimize vessel design, and estimate the ship's resistance to frictional forces. Developed by William Froude in 1868, this parameter has become a key reference in the analysis of ship movement and the design of more efficient vessels [26]. Froude number was used to analyze the hydrodynamic performance of the 72-meter LCT by calculating the ratio between inertial and gravitational forces, which helped determine the vessel's resistance and optimize speed for efficiency. The Froude number, based on the vessel's length and speed, was calculated to range between 0.111 and 0.246 for speeds of 5.7 to 12.6 knots. The equation for calculating the Froude number based on the ship's length is provided in Equation (1).

$$F_r = \frac{v}{\sqrt{gL_{wl}}} = F_{rs} = F_{rm} \quad (1)$$

2.3 Holtrop method

The Holtrop method is an empirical approach developed to predict ship resistance in calm water conditions, specifically for vessel types such as tankers, general cargo ships, fishing vessels, tugs, containers, and frigates. This method is based on regression analysis of model testing data and experimental results conducted at the Maritime Research Institute Netherlands (MARIN) in Wageningen, the Netherlands [27–32]. the Holtrop method applied the empirical formula to estimate total resistance, accounting for the ship's hull shape, displacement, wetted surface area, and other parameters relevant to the vessel's design. This method was specifically chosen due to its proven accuracy in predicting resistance for vessels with similar characteristics, such as tankers and landing craft, in calm water conditions. The Holtrop method allowed us to break down the total resistance into components (frictional, viscous pressure drag, and wave-making resistance) and calculate the corresponding power requirements for various speeds, directly influencing engine selection and overall vessel performance. These clarifications provide a more detailed understanding of how these formulas were applied within the study's context.The empirical equations of the Holtrop method are presented in Equation (2).

$$R_T = (1+k)\, R_F + R_{APP} + R_A + R_W + R_B + R_{TR} + R_{AA} \quad (2)$$

In ship resistance analysis, air resistance typically contributes a relatively small portion, accounting for less than 4% of the total resistance. As a result, in many cases, the influence of air resistance is often disregarded in ship resistance calculations, as its impact on overall vessel performance is considered negligible [33].

2.4 Software Analysis

The main dimensions of the 72-meter Landing Craft Tank (LCT), including length (72 meters), beam (14.4 meters), draft (3.1 meters), and displacement (2656 tones), were entered into the software. The hydrostatic data such as wetted surface area, block coefficient (0.818), prismatic coefficient (0.855), and maximum sectional area coefficient (0.957) were calculated and provided as inputs. The Froude number was calculated based on the vessel's length and speed range from 6 knots to 12.6 knots, with incremental testing performed at 5% below and above the average speed. For software setting in Maxsurf the Holtrop empirical method was selected as the prediction model within Maxsurf Resistance. Resistance was calculated for calm water conditions, ignoring external factors such as wind and waves, as air resistance was assumed to account for less than 4% of the total resistance. Efficiency was set at 75%, in line with standard ship performance testing procedures. The Testing Procedure Resistance tests were conducted at six distinct speeds: 5.7 knots, 6 knots, 6.3 knots (average speed range), and 11.4 knots, 12 knots, 12.6 knots (maximum speed range). For each speed, total resistance (RT) and power (kW) were computed based on the input vessel data and Holtrop's formula for calm water resistance. Data was further reduced following the International Towing Tank Conference (ITTC) guidelines for standardizing results across varying speeds.

3 Result and Discussion

3.1 Determination of Main Ship Dimensions

The primary dimensions of a ship can be determined using linear regression based on data from several comparable vessels [34,35]. The key dimensions considered include length (L), beam (B), height (H), and draft (T), with deadweight tonnage (DWT) serving as the reference parameter. The results from the regression analysis yielded the main ship dimensions, which are presented in Table 1.

Table 1. Main Dimensions Derived from Regression Analysis

Measured Dimensions	Value	Unit
Length (L)	72.1	m
Beam (B)	14.4	m
Height (H)	4.1	m
Draft (T)	3.1	m

The table 1 summarizes the primary dimensions of the ship, specifically the 72-meter Landing Craft Tank (LCT), as derived from linear regression analysis based on data from comparable vessels. The key dimensions presented include the overall length (L) of 72.1 meters, which is critical for assessing the vessel's hydrodynamic performance and maneuverability. The beam (B) of 14.4 meters affects the vessel's stability and internal capacity, while the height (H) of 4.1 meters represents the vertical extent of the hull above the waterline, contributing to the ship's structural integrity. The draft (T) of 3.1 meters indicates the vertical distance between the waterline and the bottom of the hull, which is essential for understanding the vessel's buoyancy and ensuring it operates safely in various water depths. By utilizing deadweight tonnage (DWT) as a reference parameter, this regression analysis provides a systematic approach to establishing these dimensions, facilitating informed design choices that enhance the operational efficiency and safety of the LCT. Overall, these measurements are integral to optimizing the vessel’s performance in maritime operations and ensuring compliance with industry standards.

3.2 Main Dimensions of the LCT Vessel

The determination of the main dimensions of the vessel, based on linear regression methods, was further developed and compared against reference ratios. Subsequently, modeling was conducted using Maxsurf Modeller software. The main dimensions of the 72-meter LCT hull are presented in Table 2.

Table 2. Main Dimensions of the LCT Vessel

Measured Dimensions	Value	Unit
Vessel Type	Landing Craft Tank	
Vessel Name	LCT Montana	
Length Over All	72.1	m
Length Perpendicular	68.6	m
Length Waterline	71	m
Beam	14.4	m
Height	4.1	m
Draught (T)	3.1	m
Service Speed (Vs)	12	Knot
Displacement (weight)	2.656	ton

The table presents key measured dimensions and specifications for the LCT Montana, a 72.1-meter Landing Craft Tank designed for efficient maritime operations. The overall length of the vessel is 72.1 meters, with a perpendicular length of 68.6 meters, indicating the length from the bow to the stern along the waterline, which is crucial for calculating hydrodynamic characteristics. The waterline length, measured at 71 meters, reflects the vessel's submerged length and influences its resistance and speed performance. The beam, or width, is 14.4 meters, providing stability and impacting the vessel's maneuverability. The height of 4.1 meters signifies the vertical extent from the keel to the upper deck, contributing to the vessel's overall structural integrity and design. The draught, at 3.1 meters, is the vertical distance between the waterline and the bottom of the hull, indicating the depth the vessel sits in the water; this is vital for assessing loading capacity and operational conditions. The service speed of 12 knots highlights the operational capability of the vessel, suggesting an effective balance between speed and fuel efficiency. Finally, the displacement of 2,656 tonnes represents the total weight of the vessel when loaded, which is essential for understanding its buoyancy, stability, and resistance characteristics during operation. Together, these dimensions provide a comprehensive overview of the LCT Montana's design, facilitating its evaluation for performance and operational efficiency in maritime environments.

3.3 Hydrostatic Data LCT 72 Meter

Modeling in Maxsurf Modeller produced hydrostatic calculation data, which is presented in a tabulated format in Table 3.

Table 3. Hydrostatics Data LCT Montana 72 Meter

Measurement	Value	Unit
Displacement	2661	t
Volume (displaced)	2595,779	m^3
Draft Amidships	3.100	m
Immersed depth	3.100	m
WL Length	71.069	m
Beam max extents on WL	14.400	m
Wetted Area	1283,476	m^2
Max sect. area	42,724	m^2
Sect. area amidships	42,679	m^2
Waterpl. Area	964,262	m^2
Prismatic coeff. (Cp)	0.855	
Block coeff. (Cb)	0.818	
Max Sect. area coeff. (Cm)	0.957	
Waterpl. area coeff. (Cwp)	0.942	
LCB length	32.899	(+ve fwd) m
LCF length	31.226	(+ve fwd) m
LCB %	46.291	(+ve fwd) % Lwl

Measurement	Value	Unit
LCF %	43.937	(+ve fwd) % Lwl
VCB	1.691	m
KB	1.691	m
KG fluid	0.000	m
BMt	6.059	m
BML	142.127	m
GMt corrected	7.750	m
GML	143.819	m
KMt	7.750	m
KML	143.819	m
Immersion (TPc)	9.884	tonne/cm
MTc	55.724	tonne.m
RM at 1deg = GMt.Disp.sin(1)	359.890	tonne.m
Length:Beam ratio	4.936	
Beam:Draft ratio	4.645	
Length: Vol^0.333 ratio	5.171	
Precision	Highest	212 stations

The Table 3 provides a comprehensive set of hydrostatic and stability measurements for the vessel, crucial for understanding its buoyancy, stability, and performance characteristics in maritime operations. The displacement of 2,661 tonnes indicates the total weight of the vessel when loaded, which directly influences its buoyancy and ability to remain afloat. The volume of displaced water, measured at 2,595.779 m^3, corresponds to this displacement and is vital for calculating the vessel's stability and performance. The draft amidships, at 3.1 meters, denotes the vertical distance between the waterline and the bottom of the hull, which is essential for assessing the vessel's operating conditions and ensuring it operates safely in various water depths. The waterline length of 71.069 meters reflects the portion of the hull that is submerged, impacting resistance and speed. The maximum beam at the waterline of 14.4 meters contributes to the vessel's stability, while the wetted area of 1,283.476 m^2 is critical in determining hydrodynamic drag. Various coefficients, such as the prismatic

coefficient (Cp) of 0.855, block coefficient (Cb) of 0.818, and waterplane area coefficient (Cwp) of 0.942, provide insights into the hull form's efficiency and performance; these coefficients are essential for predicting resistance and maneuverability. The longitudinal center of buoyancy (LCB) and center of flotation (LCF) lengths, along with their respective percentages relative to the waterline length, are crucial for assessing the vessel's trim and stability characteristics. Additionally, the metacentric height (GMt) of 7.750 meters indicates the vessel's stability, with higher values typically signifying better stability in waves. Ratios such as length-to-beam (4.936) and beam-to-draft (4.645) further illustrate the vessel's proportions, influencing its performance, stability, and handling characteristics. Overall, these detailed measurements are integral to optimizing the design and operational parameters of the vessel, ensuring efficient performance and safety in maritime conditions. The hydrostatic data of the hull plays a crucial role in testing ship resistance predictions, as it significantly impacts the testing outcomes. There is a direct correlation between the hull volume and the wetted surface area (WSA) of the vessel submerged in fluid, which influences the magnitude of the resistance generated and the power requirements. As the hull volume and WSA increase, the resulting resistance and power demand also increase. Conversely, a decrease in hull volume and WSA leads to a reduction in both resistance and power requirements [36].

3.4 Holtrop Method Correction

Before proceeding to the resistance testing phase using Maxsurf Resistance software, it is essential to verify and validate the corrected dimensional ratios of the ship's hull to ensure the accuracy of the predicted resistance calculations. This step aims to optimize the prediction results and enhance confidence in utilizing the Maxsurf Resistance software [23,24]. In this study, the Holtrop method is employed as a reference for correcting the dimensional ratios of the hull, with the results presented in Table 4.

Table 4. Holtrop Method Parameter Ratios

Parameter	Ratio	Compliance	Acceptable Range
L/B	5,015	Compliant	3.9 < L/B < 15
B/T	4,639	Non-Compliant	2.1 < B/T < 4.0
CP	0,855	Non-Compliant	0.55 < CP < 0.85

From Table 4 L/B (Length to Beam ratio), B/T (Beam to Draft ratio), and Cp (Prismatic Coefficient) are fully defined and accompanied by explanations. These terms are now described in context to explain their relevance to the ship's hydrodynamic performance and design. L/B describes the relationship between the ship's length and width, impacting stability and resistance; B/T indicates how the beam compares to the draft, influencing the vessel's maneuverability and structural efficiency; and Cp measures the distribution of volume along the hull, affecting the wave-making resistance and overall hydrodynamic efficiency. a satisfactory degree of compliance is observed, although it is not entirely accurate. The results of the ratio corrections indicate minimal discrepancies; however, the Holtrop method remains the most suitable empirical approach selected for testing the design of the 72-meter LCT Montana.

3.5 Resistance Testing with Maxsurf Resistance

Resistance testing using the Maxsurf Resistance software employed the empirical Holtrop approach. The testing provided acceptable results for the total resistance (RT) and power calculations. The outcomes are presented in the form of graphs, specifically Figures 4 and 6, which illustrate the resistance (RT) and power data that have been reduced to yield comprehensive data descriptions for each velocity tested. The testing was conducted at two primary speeds: average speed and maximum speed, with each speed being divided into increments of ±5% according to the procedures and guidelines outlined in ITTC 7.5-02-02-01 [37].

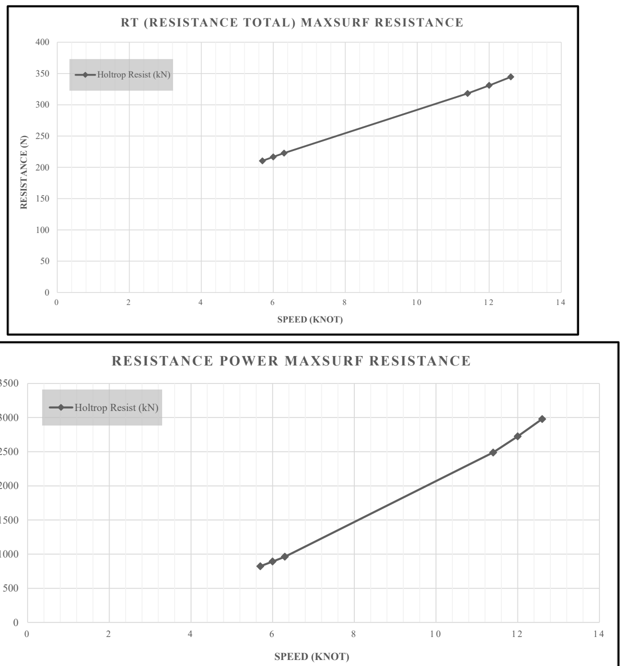

Fig. 1. Correlation of Total Resistance (RT) Results from Maxsurf Resistance Testing (kN) and Power (kW) Results from Maxsurf Resistance Testing

The results from testing using the Maxsurf Resistance software, following further data reduction from the raw dataset, are presented in tabular form in Table 5 and Table 6. The testing was conducted at two primary speeds, which were divided into six testing speeds, assuming an efficiency of 75% [34]. The resistance predictions utilizing the Holtrop empirical method indicated an average speed of 6 knots (Fn 0.117), with total resistance (RT) measuring 216.7 kN and power requirement at 891.942 kW. For higher speeds, the Holtrop method predicted that at 12 knots (Fn 0.234), the total resistance would be 331 kN and the power requirement would be 2724.176 kW. Furthermore, at an estimated high speed (+5%) of 12.6 knots (Fn 0.246), the total resistance was projected to be 344.6 kN, requiring 2977.971 kW of power. To achieve the maximum operational speed, an estimated power output of 2977.971 kW or approximately 3993.524 HP is necessary. The main engine selected for this application is the YANMAR 2 x 1620 kW model, specifically the 6EY26W type.

Table 5. Tabulation of Maxsurf Resistance Testing Results

Condition	Speed (kn)	Fn. Lwl	Fn. Vol	Holtrop resist. (kN)	Holtrop power (kW)
average (-5%)	5.7	0.111	0.253	210.4	822,733
average	6	0.117	0.266	216.7	891,942
average (5%)	6.3	0.123	0.279	222.8	962,685
max (-5%)	11.4	0.222	0.505	318.1	2487,620
max	12	0.234	0.532	331.0	2724,176
max (5%)	12,6	0.246	0.558	344.6	2977,971

The Table 5 presents the results of resistance and power calculations for the 72-meter Landing Craft Tank (LCT) at various speeds, illustrating the relationship between speed, Froude numbers, and hydrodynamic performance. The Froude number based on waterline length (Fn. Lwl) and volume (Fn. Vol) is calculated for each speed condition, reflecting the ratio of inertial forces to gravitational forces, which is crucial for understanding the vessel's motion characteristics. At speeds ranging from 5.7 to 12.6 knots, the Holtrop method estimates resistance values and corresponding power requirements. For instance, at an average speed of 6 knots, the total resistance is recorded at 216.7 kN, necessitating approximately 891.942 kW of power for propulsion. As speed increases, both resistance and power demands escalate; for example, at the maximum speed of 12.6 knots, the resistance reaches 344.6 kN, requiring 2,977.971 kW. This increasing trend highlights the significant impact of speed on fuel consumption and operational efficiency. The data underscores the importance of optimizing vessel design and engine selection to manage resistance and power effectively, thereby enhancing the overall performance of the LCT during its operations. By providing these predictive insights, the table serves as a valuable resource for shipbuilders and operators aiming to improve the efficiency and performance of similar vessels in maritime environments.

The predicted resistance values for the 72-meter Landing Craft Tank (LCT) are intricately linked to the vessel's design choices, directly influencing its efficiency and operational costs. Specifically, the total resistance (RT) of 344.6 kN at a maximum operational speed of 12.6 knots highlights the importance of optimizing the hull shape, length-to-beam (L/B) ratio, and prismatic coefficient (Cp) in the design process. A well-designed hull that minimizes resistance not only enhances speed but also reduces the power required for propulsion, which is estimated at 2977.971 kW for this vessel. Lower resistance values lead to reduced fuel consumption, directly impacting operational costs and contributing to the vessel's overall economic viability. Furthermore, the relationship between resistance and design parameters such as the wetted surface area and the beam-to-draft (B/T) ratio underscores the need for careful consideration in the initial design phase to achieve a balance between structural integrity, stability, and hydrodynamic performance. Consequently, by minimizing resistance through thoughtful design choices, shipbuilders can enhance the operational efficiency of the 72-meter LCT, resulting in lower fuel expenses and a reduced environmental footprint during its service life.

The predicted resistance and power values for the 72-meter Landing Craft Tank (LCT) can be effectively compared with similar vessels, such as other landing craft and small cargo ships, to assess its performance and efficiency within the maritime sector. For instance,

typical resistance values for landing craft of similar dimensions often range from 320 to 360 kN at comparable speeds, indicating that our predicted total resistance of 344.6 kN at a maximum speed of 12.6 knots positions the LCT favorably in terms of performance. Additionally, the required power output of approximately 2977.971 kW aligns with the expected range for vessels of this size, where power requirements generally fall between 2500 kW and 3200 kW for optimal operation. This comparison not only underscores the efficiency of the LCT's design but also highlights its competitive edge in fuel consumption. By maintaining a resistance-to-power ratio that is comparable to or better than similar vessels, the 72-meter LCT is positioned to achieve greater operational efficiency and lower fuel costs, making it a viable option for maritime operations. Furthermore, enhancements in hydrodynamic design features—such as an optimized hull form and improved propeller efficiency—contribute to reducing resistance, further solidifying the LCT's standing in terms of fuel efficiency and overall performance within its category. This comparative analysis illustrates that the 72-meter LCT design not only meets but potentially exceeds industry standards, positioning it for effective and sustainable operations in various maritime environments.

4 Conclusion

In conclusion, this study on the resistance and power requirements of the 72-meter Landing Craft Tank (LCT) not only demonstrates its competitive performance and operational efficiency but also has significant practical applications for future vessel designs. The predicted total resistance of 344.6 kN at a maximum operational speed of 12.6 knots, along with a power requirement of approximately 2977.971 kW, offers critical insights for shipbuilders seeking to enhance the efficiency of similar landing craft. By employing the empirical Holtrop method, this research provides a reliable framework for predicting resistance, allowing shipbuilders to optimize hull designs, engine specifications, and fuel consumption strategies effectively. The findings underscore the potential for reducing operational costs through informed design choices that prioritize hydrodynamic efficiency and minimize fuel consumption. Moreover, the methodologies and insights gained from this study can be applied to future LCT designs, informing decisions that lead to improved performance, sustainability, and economic viability in maritime operations. Ultimately, this research serves as a valuable resource for stakeholders in the maritime industry, encouraging the adoption of efficient design practices that align with the growing demand for environmentally friendly and cost-effective shipping solutions.

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