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# ANALYSIS OF RESISTANCE ON FISHING VESSELS ON FISHERIES PORT, KARANGANTU SERANG

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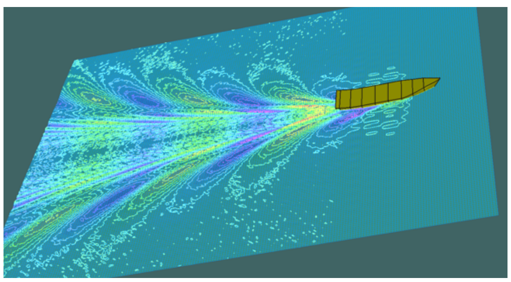
**Graphical abstract**



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## Abstract

Karangantu Port, located in Banten Province, plays a strategic role in supporting capture fisheries activities. However, fishing vessels operating in this port often face hydrodynamic resistance issues that affect operational efficiency. This study aims to analyze the influence of vessel speed and draft on the total resistance experienced by fishing boats. A 3D hull model was developed using SolidWorks and simulated using Maxsurf. Speed variations ranged from 5 to 12 knots, with four draft levels tested: 0.5 m, 0.7 m, 0.9 m, and 1.1 m. The results show that total resistance increases significantly with speed, particularly due to the dominance of wave-making resistance at speeds above 8 knots. Deeper drafts also lead to higher frictional resistance, caused by the increased wetted surface area. The optimal operational speed for maintaining fuel efficiency is in the range of 6 to 9 knots, with a balanced draft setting to ensure vessel stability without excessive resistance. These findings are expected to contribute to more efficient design and operation of fishing vessels at Karangantu Port.

*Keywords:* Boat generated wave; wave height; wave angle

## Abstrak

Pelabuhan Karangantu di Provinsi Banten memiliki peran strategis dalam mendukung aktivitas perikanan tangkap. Namun, kapal-kapal nelayan di pelabuhan ini sering menghadapi hambatan hidrodinamika yang berdampak pada efisiensi operasi. Penelitian ini bertujuan menganalisis pengaruh kecepatan dan draft terhadap hambatan total kapal nelayan. Model lambung kapal dirancang dalam 3D menggunakan SolidWorks, kemudian disimulasikan di Maxsurf. Variasi kecepatan antara 5 hingga 12 knot diuji bersama empat nilai draft: 0,5 m, 0,7 m, 0,9 m, dan 1,1 m. Hasil menunjukkan hambatan total meningkat signifikan seiring bertambahnya kecepatan, terutama karena dominasi hambatan gelombang di atas 8 knot. Draft yang lebih dalam turut meningkatkan hambatan gesekan akibat bertambahnya luas permukaan basah kapal. Kecepatan optimal kapal untuk efisiensi operasional berada pada kisaran 6–9 knot, dengan pengaturan draft seimbang untuk menjaga stabilitas tanpa menambah hambatan berlebihan. Hasil studi ini diharapkan menjadi masukan dalam perancangan dan pengoperasian kapal nelayan yang lebih efisien di Pelabuhan Karangantu.

*Kata kunci*: Ship Resistance, Speed, Draft, Holtrop Method, Maxsurf

## 1.0 INTRODUCTION

**Karangantu Port**, located in Banten Province, is one of the key fishing ports supporting fishery activities along the western coast of Java Island. The existence of this port has a significant impact on the economic sustainability of the local fishing communities. However, in practice, fishing vessels operating at this port still face various technical challenges, one of which is hydrodynamic resistance, which affects fuel consumption and sailing efficiency.

According to the International Convention for the Safety of Life at Sea (SOLAS), 1974, Chapter I, Regulation 2, "*A fishing vessel means a vessel used for catching fish, whales, seals, walrus, or other living resources of the sea*", which implies that fishing vessels used for harvesting marine resources must be equipped with proper safety equipment [1]. Fishing vessels are defined as ships, boats, or other floating devices used for fish capture, fishery support operations, aquaculture, fish transportation, fish processing, fisheries training, and research or exploration purposes [2]. The operational efficiency of fishing vessels highly depends on their hydrodynamic performance, which is significantly influenced by the resistance encountered during navigation.

Ship resistance is one of the important factors that must be considered in the design and operation of ships, especially for small vessels such as fishing boats. Ship resistance is defined as the force that acts in the opposite direction to the movement of the ship at a certain speed. The magnitude of this resistance force is highly influenced by the ship's speed and the shape of the hull [3].

The total resistance experienced by a ship consists of several components, namely frictional resistance, wave-making resistance, pressure resistance, and other additional resistances. The magnitude of this total resistance is strongly influenced by various factors, including the shape of the hull, the speed of the vessel, and the draft of the ship [4].

Draft can be defined as the measured depth of the ship's submersion in the water, measured from the bottom of the keel to the surface of the water in which the ship is floating [5]. The greater the draft value, the larger the area of the hull that comes into contact with the water, thereby increasing the frictional resistance [6].

Furthermore, draft is closely related to the principle of buoyancy, which is explained by Archimedes' Law. According to Calloni et al., Archimedes' Law is a principle that states that any object submerged in a liquid or fluid, whether partially or entirely, will experience an upward force known as the buoyant force [7].

In the analysis of ship design and performance, one of the important parameters is the block coefficient. This coefficient represents the ratio between the actual volume of the ship's hull and the volume of an imaginary rectangular block that encloses it. The value of the block coefficient provides an indication of the shape of the vessel [8].

Ships with a high block coefficient generally have a fuller form and tend to generate greater wave-making resistance, while ships with a low block coefficient have a slenderer shape and are more efficient in cutting through the water [9].

## 2.0 METHODOLOGY

In order to obtain relevant data and support the completeness of this research, the author applied several data collection methods as described below:

1. Literature Study
   This method was carried out by collecting various references from scientific journals, books, technical documents, and reliable online sources related to ship design, ship resistance theory, the working principles of simulation software (SolidWorks, Rhinoceros, and Maxsurf), as well as the technical parameters used in resistance analysis.
2. Field Observation
   Field observations were conducted directly on-site with the aim of performing detailed measurements of the hull dimensions of fishing vessels. The measurement data obtained from the field were used as the basis for the 3D remodelling process of the vessel. This observation also aimed to ensure that the model used corresponds to the actual conditions in the field.
3. 3D Modelling
   The modelling process began with the reconstruction of the hull shape using SolidWorks software based on measurement data obtained from the field. The model file from SolidWorks was then converted and further refined in Rhinoceros 8 to improve the surface accuracy. After that, the final model was imported into Maxsurf to be used for the ship resistance simulation process.
4. Simulation
   The completed 3D model was imported into Maxsurf Resistance to conduct resistance simulations. Parameters such as speed and draft were varied to observe their influence on the total resistance generated. The simulation was carried out with a marine environment configuration adjusted to the operating conditions of fishing vessels at Karangantu Port.
5. Data Processing and Analysis
   The data obtained from the Maxsurf simulation results were then processed and analyzed numerically. The analysis results are presented in the form of graphs and tables to facilitate interpretation. From this data, conclusions were drawn regarding the relationship between speed, draft, and the total resistance of the vessel, as well as determining the optimal speed range for the operational efficiency of fishing vessels.

Based on the results of observational measurements of the fishing vessel used, Table 1 were obtained and subsequently utilized for the reconstruction of the 3D model.

**Tabel 1.** Main Vessel Specifications

| Specification | Measurement |
|---|---|
| Length | 11,07 m |
| Beam (Width) | 3,17 m |
| Height | 1,95 m |
| Gross Tonnage | 6 GT |

In this study, simulations were conducted by varying both the vessel's speed and draft to observe their effects on the ship resistance values. The speed variations used in the simulation ranged from 5 knots to 12 knots. Meanwhile, the draft variations applied were 0.5 m, 0.7 m, 0.9 m, and 1.1 m. The selection of these draft variations aimed to examine how changes in the hull's submersion depth influence the magnitude of resistance encountered by the vessel.

## 3.0 RESULTS AND DISCUSSION

The initial modeling of the fishing vessel was carried out in SolidWorks using the lofting method between sketches placed on separate planes (Figure 1), in order to form a smooth hull curve from the stern to the bow. A total of 13 planes (Plane1–Plane13) were created as references for the vessel's cross-sections, with each sketch (Sketch1, Sketch2, Sketch11, Sketch25) representing the shape of the cross-section at specific points along the vessel. The Loft feature (Loft10–Loft18) was used to connect these cross-sections into a continuous hull surface.

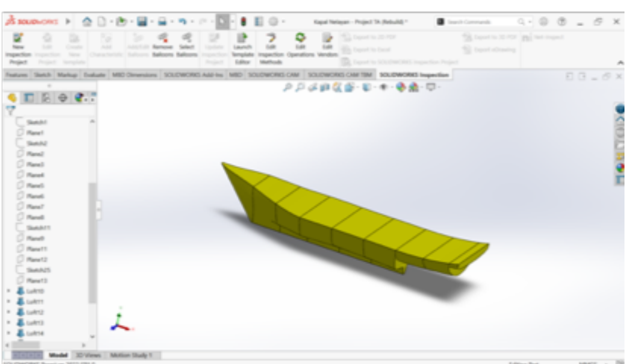

**Figure 1.** 3D SolidWorks model of the fishing vessel hull

This method is effective in producing a 3D geometric form that closely resembles the actual shape of the fishing vessel, based on field documentation at Karangantu Port. The loft surface technique was chosen because it is more suitable for forming complex geometries such as ship hulls, compared to other methods like extrude or revolve.

After the modeling process was completed, the file was saved in .sldprt format and then exported to IGES (.iges) format to preserve surface integrity when opened in Rhinoceros 8. In Rhinoceros, the model was re-examined before being saved as a .3dm file, which was later used as input for further analysis in Maxsurf.

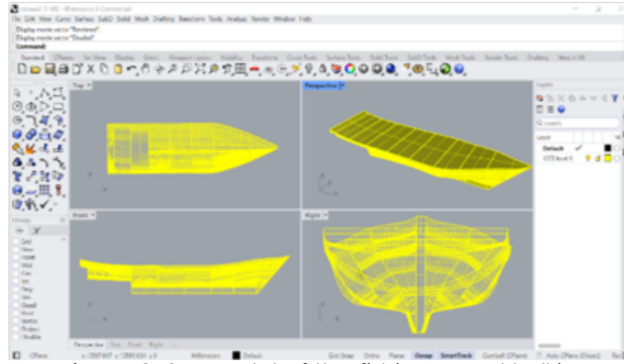

**Figure 2.** 3D Model of the fishing vessel hull in Rhinoceros 8

After the conversion is completed, Maxsurf Modeler is able to import files in .3dm format, followed by the configuration of the frame of reference, zero-point, vessel draft, and other related settings.

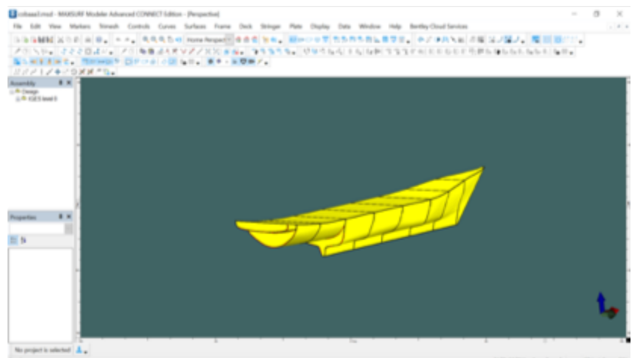

**Figure 3.** 3D Model of the Fishing Vessel Hull in Maxsurf

The following is the hydrostatic data generated from the process using Maxsurf Modeler.

**Tabel 2.** Ship Hydrostatic Data

| Measurement | Draft 0,5 | Draft 0,7 | Draft 0,9 | Draft 1,1 |
|---|---|---|---|---|
| Block Coeff. (Cb) | 0,227 | 0,280 | 0,326 | 0,386 |
| Draft Amidships | 0,500 | 0,700 | 0,900 | 1,100 |
| Volume (displaced) | 1,751 | 4,225 | 7,849 | 12,263 |

After the ship model is imported into Maxsurf Modeler, resistance analysis is carried out using Maxsurf Resistance. This module estimates the vessel's total resistance using empirical methods, such as the Holtrop method, to determine the force that must be overcome when the vessel moves at a certain speed. Data from Maxsurf Modeler is imported, followed by the input of parameters such as displacement, length at waterline (LWL), design speed, and hull form coefficients for simulation purposes.

Based on the simulated draft variations, the load of the fishing vessel is calculated using Archimedes' principle and the block coefficient, in which the vessel's weight is considered equivalent to the weight of seawater displaced by the submerged hull. The formula used is:

$$\Delta = \rho LBTC_b$$

$$\Delta = 1025(7.104)(2.159)(0.5)(0.227) = 1784.33 \text{ kg}$$

The vessel's weight for each draft variation was calculated using the same method, and the differences between each draft level were then analyzed to determine the magnitude of the additional load that occurs as the draft increases.

**Tabel 3.** Vessel weight based on draft

| Draft (m) | L (m) | B (m) | Cb | Vessel Weight (kg) | Weight (ton) |
|---|---|---|---|---|---|
| 0,5 | 7,104 | 2,159 | 0,227 | 1784.331 | 1,784331 |
| 0,7 | 8,463 | 2,579 | 0,280 | 4384.859 | 4,384859 |
| 0,9 | 9,750 | 2,766 | 0,326 | 8110.372 | 8,110372 |
| 1,1 | 9,930 | 2,908 | 0,386 | 12567.460 | 12,56746 |

The data show that as the draft increases, the vessel's weight (displacement) also increases, and the increase is not linear but rather becomes progressively steeper. This is due to the hull shape, which widens toward the top, resulting in a significantly larger volume of displaced water. Each draft level was then analyzed at various speeds in Maxsurf to observe its impact on the vessel's performance.

**Tabel 4.** Vessel Weight Differences

| From Draft (m) | To Draft (m) | Weight Difference (kg) | Weight Difference (ton) |
|---|---|---|---|
| 0,5 | 0,7 | 2600,528 | 2,600528 |
| 0,7 | 0,9 | 3725,513 | 3,725513 |
| 0,9 | 1,1 | 4457,088 | 4,457088 |

The resistance calculation results can be accessed through the Results menu, available in both data and graphical formats. The graph displays the relationship between speed (5–12 knots) and total resistance, as well as a comparison between engine power and vessel speed. The simulation results in Maxsurf Resistance illustrate the dynamics of the fishing vessel's movement during sailing, along with the wave patterns formed around it.

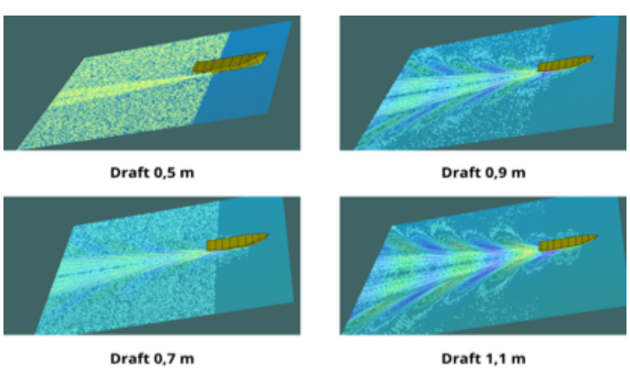


**Figure 4**. Calculate Free Surface Interface

The simulation results from Maxsurf Resistance present graphs illustrating the relationship between speed (5–12 knots) and total resistance, as well as the comparison between engine power and vessel speed, as shown below.

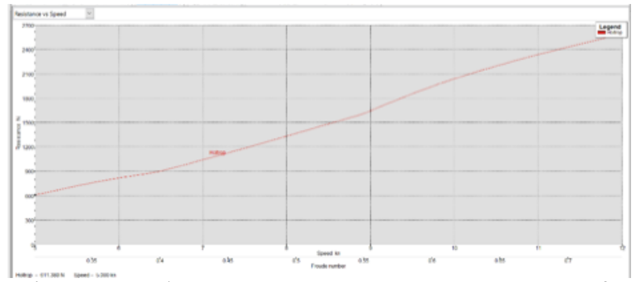

**Figure 5**. Resistance vs. Speed Graph at 0.5 m Draft

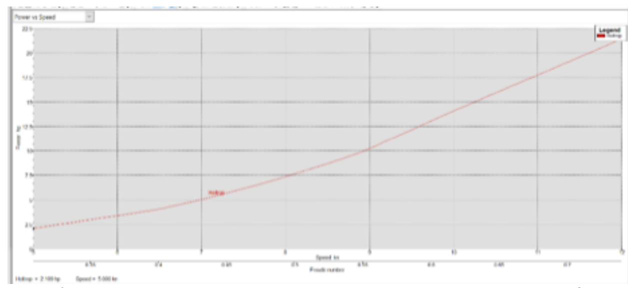

**Figure 6**. Power vs. Speed Graph at 0.5 m Draft

In the first graph (Resistance vs Speed), it is observed that the total resistance of the vessel increases with higher speeds. Within the speed range of 5 to 6 knots, the increase in resistance remains relatively gradual, indicating the dominance of viscous resistance. However, from 7 to 9 knots, the resistance begins to rise more sharply due to the increasing influence of wave-making resistance, and at speeds between 10 and 12 knots, a significant surge in total resistance is evident.

Similarly, the second graph (Power vs Speed) displays an exponential trend, where the required power increases rapidly with speed. A noticeable rise in power begins around 6 to 8 knots, followed by a steep escalation between 9 and 12 knots. This pattern is not only evident at a draft of 0.5 meters, as shown in the graph, but is also consistently observed at other drafts such as 0.7, 0.9, and 1.1 meters. This indicates that although the absolute values of resistance and power vary with draft, the overall relationship between speed, resistance, and required power remains consistent. These findings are essential for determining an efficient operational speed and for designing a propulsion system that aligns with the hydrodynamic characteristics of the vessel.

**Tabel 5.** Comparison of Holtrop resistance values

| Speed (knot) | Newton | | | |
|---|---|---|---|---|
| | Draft 0.5 | Draft 0.7 | Draft 0.9 | Draft 1.1 |
| 5 | 611.39 | 1735.97 | 3597.55 | 5541.24 |
| 6 | 815.3 | 1894.66 | 3817.8 | 6046.09 |
| 7 | 1040.2 | 2145.99 | 4122.04 | 6565.4 |
| 8 | 1329.82 | 2501.59 | 4643.33 | 7351.05 |

| Speed (knot) | Newton | | | |
|---|---|---|---|---|
| | Draft 0.5 | Draft 0.7 | Draft 0.9 | Draft 1.1 |
| 9 | 1646.58 | 2876.7 | 5125.51 | 8133.25 |
| 10 | 2038.04 | 3274.16 | 5634.9 | 8932.38 |
| 11 | 2337.72 | 3636.65 | 6177.77 | 9825.1 |
| 12 | 2589.36 | 3961.96 | 6684.81 | 10700.5 |

**Tabel 6.** Comparison of Holtrop Power Values

| Speed (knot) | Horsepower | | | |
|---|---|---|---|---|
| | Draft 0.5 | Draft 0.7 | Draft 0.9 | Draft 1.1 |
| 5 | 2.108931 | 5.988078 | 12.4094 | 19.11399 |
| 6 | 3.3755 | 7.843288 | 15.80389 | 25.02753 |
| 7 | 5.024849 | 10.36536 | 19.90819 | 31.70878 |
| 8 | 7.340137 | 13.80739 | 25.62791 | 40.57274 |
| 9 | 10.22486 | 17.86197 | 31.82407 | 50.50038 |
| 10 | 14.06162 | 22.58984 | 38.87653 | 61.62689 |
| 11 | 17.74134 | 27.59881 | 46.88342 | 74.56371 |
| 12 | 21.43623 | 32.79938 | 55.34062 | 88.58495 |

Based on the previous analysis and data, there are two main factors that influence the total resistance (RT) of fishing vessels: speed and draft. Resistance increases significantly with rising speed, following a non-linear pattern that closely aligns with a quadratic relationship, consistent with the theory of frictional resistance and wave resistance. Resistance can increase more than ninefold as speed increases, thus requiring considerably higher power and fuel consumption. Therefore, it is advisable for vessels to operate at economical speeds, especially in shallow waters such as those in Karangantu.

In addition, as the draft increases, the wetted surface area (S) also increases, leading to greater frictional resistance. Draft also affects the flow behavior around the hull, and in shallow water conditions, it can trigger the shallow water effect, which increases wave resistance even when the speed remains constant.

The calculation of a vessel's total resistance aims to determine the forces acting against the vessel's movement during operation in water. This resistance consists of frictional resistance (Rf), caused by the friction between the hull and the water, and wave-making resistance (Rw), resulting from wave formation as the vessel moves. Both components together form the total resistance (Rt), which is influenced by the vessel's speed and hull shape.

Based on the obtained Rt values, further analysis can be conducted to determine other resistance components such as Rf, Rw, frictional coefficient (Cf), total resistance coefficient (Ct), and the Reynolds number at various speeds. These calculations serve as the basis for evaluating the hydrodynamic performance of the fishing vessel. The data required to calculate Ct, Cf, Rf, and Rw at one of the draft conditions (0,5 m) with a speed of 5 knots as the calculation scheme are as follows, Length at Waterline (LWL)= 7,1 m, Draft= 0,5 m, Wetted Surface Area (S)= 14.412 m², Seawater Density (ρ)= 1025 kg/m³, and Kinematic Viscosity (v)= 1e-6 m²/s.

1. Speed Conversion

$$V = 5(0.5144) = 2.527\ \text{m/s}$$

2. Bilangan Reynolds (Re)

$$R_e = \frac{2.527(7.1)}{1 \text{ x } 10^{-6}} = \frac{18.263}{1 \text{ x } 10^{-6}} = 18.263 \text{ x } 10^{6}$$

3. Frictional Coefficient (Cf) - ITTC 1957

$$\text{CF} = \frac{0.075}{(\log_{10}(R_e) - 2)^2} = \frac{0.075}{(\log_{10}(18.263 \text{ x } 10^6) - 2)^2}$$
$$= \frac{0.075}{(7.261 - 2)^2} = 0.002709$$

4. Frictional Resistance (Rf)

$$\text{RF} = 0.5(1025)(2.5722)^2(14.412)(0.002709)$$
$$= 132.39\text{N}$$

5. Wave-Making Resistance (Rw)

$$\text{Rw} = 611.39 - 132.39 = 479.00\text{N}$$

6. Total Resistance Coefficient (Ct)

$$\text{Ct} = \frac{611.39}{0.5(1025)(2.5722)^2(14.412)} = 0.002331$$

Subsequently, calculations were carried out at various draft and speed levels to obtain the resistance values corresponding to each increment of these parameters, serving as the basis for a more in-depth analysis. The results of the calculations are presented in Table 7-10.

**Tabel 7.** Calculation Results at 0,5 m Draft

| Speed (knot) | Speed (m/s) | Re (×10⁶) | Cf (ITTC 1957) | Rf (N) | Rt (N) | Rw (N) | Ct |
|---|---|---|---|---|---|---|---|
| 5 | 2.572 | 18.26262 | 0.002709 | 132.39 | 611.39 | 479 | 0.002331 |
| 6 | 3.087 | 21.915144 | 0.002629 | 185.03 | 815.3 | 630.27 | 0.002308 |
| 7 | 3.601 | 25.567668 | 0.002565 | 245.65 | 1040.2 | 794.55 | 0.002273 |
| 8 | 4.116 | 29.220192 | 0.002511 | 314.08 | 1329.82 | 1015.74 | 0.002262 |
| 9 | 4.63 | 32.872716 | 0.002464 | 390.17 | 1646.58 | 1256.41 | 0.002234 |
| 10 | 5.144 | 36.52524 | 0.002424 | 473.8 | 2038.04 | 1564.24 | 0.002222 |
| 11 | 5.659 | 40.177764 | 0.002388 | 564.86 | 2337.72 | 1772.86 | 0.002043 |
| 12 | 6.173 | 43.830288 | 0.002356 | 663.25 | 2589.36 | 1926.11 | 0.001961 |

**Tabel 8.** Calculation Results at 0,7 m Draft

| Speed (knot) | Speed (m/s) | Re ($\times 10^6$) | Cf (ITTC 1957) | Rf (N) | Rt (N) | Rw (N) | Ct |
|---|---|---|---|---|---|---|---|
| 5 | 2.572 | 17.20869 | 0.0026326 | 184.9 | 1735.97 | 1551.07 | 0.024703 |
| 6 | 3.0866 | 20.644092 | 0.002554 | 258.5 | 1894.66 | 1636.16 | 0.018721 |
| 7 | 3.6011 | 24.079494 | 0.002495 | 345.4 | 2145.99 | 1800.59 | 0.015578 |
| 8 | 4.1155 | 27.514896 | 0.0024428 | 444.9 | 2501.59 | 2056.69 | 0.013903 |
| 9 | 4.6299 | 30.950297 | 0.0023966 | 555.4 | 2876.7 | 2321.3 | 0.012633 |
| 10 | 5.1444 | 34.385699 | 0.0023548 | 675.7 | 3274.16 | 2598.46 | 0.011646 |
| 11 | 5.6588 | 37.821101 | 0.002316 | 804.1 | 3636.65 | 2832.55 | 0.010691 |
| 12 | 6.1733 | 41.256503 | 0.0022805 | 938.9 | 3961.96 | 3023.06 | 0.009786 |

**Tabel 9.** Calculation Results at 0,9 m Draft

| Speed (knot) | Speed (m/s) | Re ($\times 10^6$) | Cf (ITTC 1957) | Rf (N) | Rt (N) | Rw (N) | Ct |
|---|---|---|---|---|---|---|---|
| 5 | 2.5722 | 25.07895 | 0.002573 | 247.43 | 3597.55 | 3350.12 | 0.037411 |
| 6 | 3.0866 | 30.09435 | 0.002499 | 346.04 | 3817.8 | 3471.76 | 0.027571 |
| 7 | 3.6011 | 35.11073 | 0.002439 | 459.71 | 4122.04 | 3662.33 | 0.02187 |
| 8 | 4.1155 | 40.12613 | 0.002389 | 588.11 | 4643.33 | 4055.22 | 0.018862 |
| 9 | 4.6299 | 45.14153 | 0.002346 | 730.92 | 5125.51 | 4394.59 | 0.016451 |
| 10 | 5.1444 | 50.1579 | 0.002308 | 887.78 | 5634.9 | 4747.12 | 0.014649 |
| 11 | 5.6588 | 55.1733 | 0.002275 | 1058.84 | 6177.77 | 5118.93 | 0.013273 |
| 12 | 6.1733 | 60.18968 | 0.002245 | 1243.52 | 6684.81 | 5441.29 | 0.012069 |

**Tabel 10.** Calculation Results at 1,1 m Draft

| Speed (knot) | Speed (m/s) | Re ($\times10^6$) | Cf (ITTC 1957) | Rf (N) | Rt (N) | Rw (N) | Ct |
|---|---|---|---|---|---|---|---|
| 5 | 2.5722 | 25.541946 | 0.0025654 | 296.91088 | 14253.3 | 13956.3891 | 0.12315 |
| 6 | 3.0866 | 30.649938 | 0.0024916 | 415.2515 | 18663 | 18247.7785 | 0.11198 |
| 7 | 3.6011 | 35.758923 | 0.0024319 | 551.6764 | 23645.2 | 23093.5636 | 0.10423 |
| 8 | 4.1155 | 40.866915 | 0.0023819 | 705.72754 | 30255.1 | 29549.3625 | 0.10211 |
| 9 | 4.6299 | 45.974907 | 0.0023391 | 877.10765 | 37658.1 | 36781.0224 | 0.10043 |
| 10 | 5.1444 | 51.083892 | 0.0023017 | 1065.5857 | 45955.2 | 44889.5843 | 0.099265 |
| 11 | 5.6588 | 56.191884 | 0.0022686 | 1270.8046 | 55602.2 | 54331.3554 | 0.09926 |
| 12 | 6.1733 | 61.300869 | 0.0022392 | 1492.7473 | 66057.8 | 64565.0527 | 0.099088 |

Frictional resistance (Rf) increases proportionally with the square of speed, while wave-making resistance (Rw) rises sharply at speeds above 7–8 knots. At lower speeds, Rf is the dominant component; at higher speeds, Rw becomes dominant and leads to greater energy demands. A larger draft increases the wetted surface area and thus the resistance, although it also contributes positively to vessel stability.

The best efficiency is achieved at speeds ranging from 6 to 9 knots, with the draft adjusted according to the vessel's load. Therefore, managing speed, cargo load, and trim is essential to optimizing sailing efficiency.

## 4.0 CONCLUSION

Based on the data and analysis results, it can be concluded that vessel speed has a significant impact on total resistance (RT). Resistance increases drastically with higher speeds, following a non-linear pattern. Frictional resistance (Rf) increases proportionally to the square of the speed ($\propto V^2$), while wave-making resistance (Rw) rises more steeply, especially at speeds above 7–8 knots. At lower speeds (5–7 knots), Rf is the dominant component, whereas at speeds above 8 knots, Rw becomes dominant and significantly increases energy demand.

The optimal operating speed for fishing vessels lies between 6 and 9 knots, striking a balance between time efficiency and fuel consumption. In addition, the vessel's draft also affects the magnitude of resistance. A larger draft increases the wetted surface area, thereby raising frictional resistance, and disrupts the water flow more significantly, resulting in higher Rw values. While a greater draft enhances vessel stability when loaded, an excessively large draft contributes to an overall increase in total resistance.

Maximum efficiency is achieved at speeds of 6–9 knots with a draft that corresponds to the vessel's load. Therefore, careful management of draft, load distribution, and trim is essential to support optimal sailing efficiency.

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