

Analysis of Fin Stabilizer Effects on 100 GT Fishing Vessel Resistance Using Computational Fluid Dynamics

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KEYWORDS

*Cfd ;
Fin Stabilizer ;
Fishing Vessel ;
Flow Pattern ;
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ABSTRACT – Fishing vessels require good hydrodynamic efficiency to limit propulsion power and energy consumption. Adding a fin stabilizer can modify the flow pattern, pressure distribution, wetted area, and consequently the total resistance; however, studies specifically addressing its resistance effect on a 100 GT fishing vessel remain limited. This study compares the flow characteristics and ship resistance before and after fin-stabilizer installation using Computational Fluid Dynamics (CFD). The hull geometry was developed from a 25 GT fishing-vessel dataset through a scaling approach, producing a working model with an LOA of 42 m, LWL of 40.2 m, beam of 8.3 m, depth of 3.2 m, and draft of 2.3 m. Simulations were performed at 10 knots using the RANS equations, the SST k-omega turbulence model, and a Volume of Fluid approach for the air-water interface. Total resistance decreased from 9425.965 N for the bare hull to 9134.796 N with the fin, corresponding to a 3.089% reduction. Flow visualization also indicated local changes around the fin and in the pressure field. The analyzed configuration therefore reduced resistance under the simulated operating condition.

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INTRODUCTION

Hydrodynamic efficiency is an important aspect in ship operations because the resistance acting on the hull is directly related to propulsion power requirements and fuel consumption. On high-speed and planing vessels, changes in resistance components, trim, and flow conditions around the hull can have a marked effect on propulsion performance and operating efficiency [5], [16], [17], [19]. Previous experimental and numerical studies have demonstrated that modification of the hull geometry and stern appendages can alter the hydrodynamic characteristics of a vessel, including resistance, trim, sinkage, and flow behavior [1], [3], [5], [7].

One approach that has been widely studied is the use of hydrodynamic appendages. Although most references used in this research discuss interceptors and stern flaps, these studies provide relevant hydrodynamic principles regarding the interaction between appendages and the surrounding flow. The installation of an appendage can modify pressure distribution, wetted surface characteristics, wave patterns, and local flow fields, consequently affecting the total resistance of the vessel [1], [2], [5], [14]. Song et al. reported that interceptors and stern flaps installed on a deep-vee ship can reduce resistance, running trim, and sinkage, with the magnitude of the hydrodynamic improvement depending on the operating condition and appendage configuration [1]. Seok et al. further demonstrated that the installation of an interceptor changes the stern-bottom pressure distribution as a result of flow blockage, which subsequently influences the running attitude of the vessel [2].

The effectiveness of an appendage is determined not only by its presence but also by its geometric parameters and installation conditions. Mansoori et al. showed that interceptor height should be selected with consideration of the boundary-layer characteristics near the transom, since inappropriate sizing may reduce the expected hydrodynamic benefit and adversely affect the vessel's trim [3]. Numerical and experimental investigations of interceptor-flap combinations have also shown that the hydrodynamic performance depends on the configuration, height, and flap angle, with certain combinations providing improvements in resistance and trim compared with a single interceptor [4], [6], [7], [9], [15]. Putra and Suzuki confirmed that the geometric characteristics and angle of attack of an interceptor influence the pressure distribution, hydrodynamic forces, and resistance of a high-speed vessel [8]. Similar numerical investigations have demonstrated that interceptor layout and blade height can significantly influence the resistance and hydrodynamic behavior of planing hulls

[14], [18]. These findings indicate that the interaction between an appendage and the local flow field needs to be evaluated specifically for each vessel geometry and operating condition.

Computational Fluid Dynamics (CFD) has been widely applied to evaluate the hydrodynamic performance of planing and high-speed vessels because it provides detailed information regarding hydrodynamic forces, pressure distribution, velocity fields, and free-surface behavior. CFD-based investigations have been applied to evaluate the effects of interceptors, stern flaps, and other appendages on planing hulls [7], [13], [16], [17], [19]. RANS-based numerical methods have also been employed to predict the resistance and flow characteristics of planing hulls and to investigate the influence of hull and appendage configurations [13], [16], [17]. In addition, CFD studies have demonstrated good potential for evaluating variations in hull and appendage configurations prior to experimental testing [19], [20]. Nevertheless, numerical validation and mesh-independence or numerical-independence studies remain important to ensure the reliability of CFD predictions [16], [17], [19].

Several studies have investigated interceptors, stern flaps, and their combinations on planing craft, deep-vee ships, and high-speed vessels [1]-[9], [14], [15], [18]. Other studies have also investigated hull-form modifications, including stepped and reverse-V configurations, to improve the resistance characteristics of planing hulls [12]. These studies establish that relatively small modifications to the hull or stern region can produce measurable changes in the hydrodynamic behavior of a vessel. However, most of the existing studies focus on interceptors, stern flaps, or planing-hull modifications, while limited attention has been given to the influence of side fin stabilizers on the resistance characteristics of fishing vessels. In particular, the hydrodynamic effect of fin stabilizers on a 100 GT fishing vessel operating at a specified speed has not been directly addressed in the aforementioned studies.

The installation of fin stabilizers introduces an additional hydrodynamic surface that may modify the local pressure distribution and flow pattern around the hull. At the same time, the additional wetted area and induced local vortical structures may contribute to changes in resistance. Similar hydrodynamic interactions have been observed in studies of other hull appendages, where changes in local flow and pressure fields influence the overall resistance and running attitude of the vessel [1], [5], [14], [16]. Therefore, the influence of stabilizer fins on resistance needs to be evaluated for the specific hull geometry, fin configuration, and operating condition of the vessel rather than being directly inferred from studies of interceptors or stern flaps.

This research aims to analyze the effect of installing fin stabilizers on the resistance of a 100 GT fishing vessel using the Computational Fluid Dynamics (CFD) method. The analysis focuses on two aspects, namely comparing the flow patterns before and after the installation of stabilizer fins and comparing the total resistance values between the two configurations. The numerical approach is intended to provide an initial assessment of the hydrodynamic influence of the fin configuration before further development is carried out in terms of vessel stability, structural strength, and experimental testing. The results are expected to provide an initial hydrodynamic basis for assessing the feasibility of fin stabilizers as an appendage configuration for improving the overall performance of a 100 GT fishing vessel.

METHODS

Objects of Geometry Research and Development

The initial research data used a 25 GT fishing boat geometry because complete 100 GT fishing boat data was not available at the design stage. The initial approach was carried out with a geometric scale based on volume ratios, namely from an initial volume of around 50.36 m³ to a target of around 400 m³, resulting in a linear scale factor of around 1.995. The geometry was then developed into a working model of a 100 GT fishing boat. The main model sizes used in the simulation are in Table 1.

Table 1. Principal dimensions of the 100 GT fishing vessel model

Parameters	Symbol	Value
Length overall	LOA	42.0 m
Length waterline	LWL	40.2 m
Width	B	8.3 m
Height	H	3.2 m
Draft	T	2.3 m
Simulation speed	V	10 knots (5.14 m/s)

The dimensional ratio of the development results remains to be checked against the general characteristics of fishing vessels as model validation. The simulation was carried out at one speed condition, namely 10 knots, so the results of this study represent these operating conditions.

Design and Integration of Fin Stabilizers

The fin stabilizer is designed as a fixed appendage on the side of the hull. The dimensions used are an area of around 5 m² for each fin, a span of 2.5 m, and a chord of 2.0 m, so the geometric aspect ratio is around 1.25. The fin is placed approximately 18 m from the bow and 0.8 m from the baseline. Based on the design body plan, the fins are installed at an angle of approximately 5° to the local reference direction. This placement is a preliminary design because stability performance data and actuator characteristics are not part of the research.

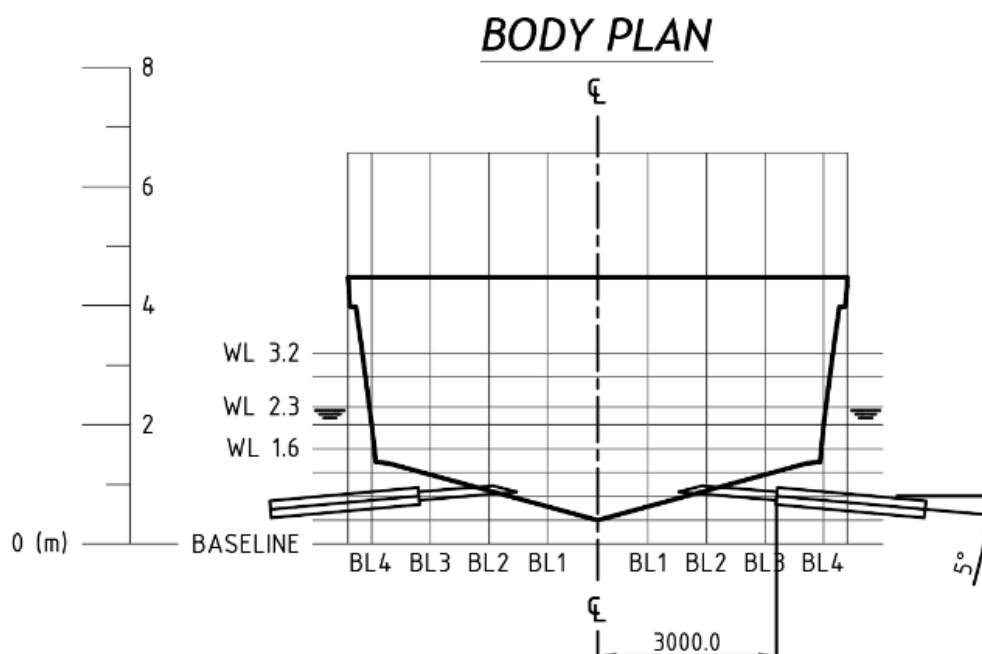


Figure 1. Position and installation angle of the fin stabilizer on the body plan

The fin model is then integrated with the hull and checked so that there are no gaps or overlapping geometries that could cause errors in the meshing process. The analysis only compares the conditions of the bare hull and hull with fin stabilizer; the effects of roll movement as well as the fin control system are not modeled.

CFD Simulation Setup

Numerical simulations were carried out using ANSYS Fluent under a valid institutional license provided by the National Research and Innovation Agency (BRIN), Indonesia, with the RANS formulation for turbulent flow. The k- ω SST turbulence model is used because it can combine the characteristics of k- ω near the walls and k- ϵ in the outer region and has been used in ship hydrodynamic studies to handle flows with strong pressure gradients [5], [7]. The water-air free surface is modeled using the VOF approach, which is commonly used to capture the two-phase interface in ship resistance simulations [3], [5], [7], [9], [12].

The computational domain is formed based on a LOA of 42 m. The inlet distance is set at 1.5L or 63 m in front of the model, the outlet is 3L or 126 m behind the model, the side domain is 1.5L or 63 m, and the top and bottom distance is around 1L or 42 m. The mesh is created in an unstructured manner by local compaction around the hull, fins and free surfaces. The domain and mesh configuration are shown in Figure 2.

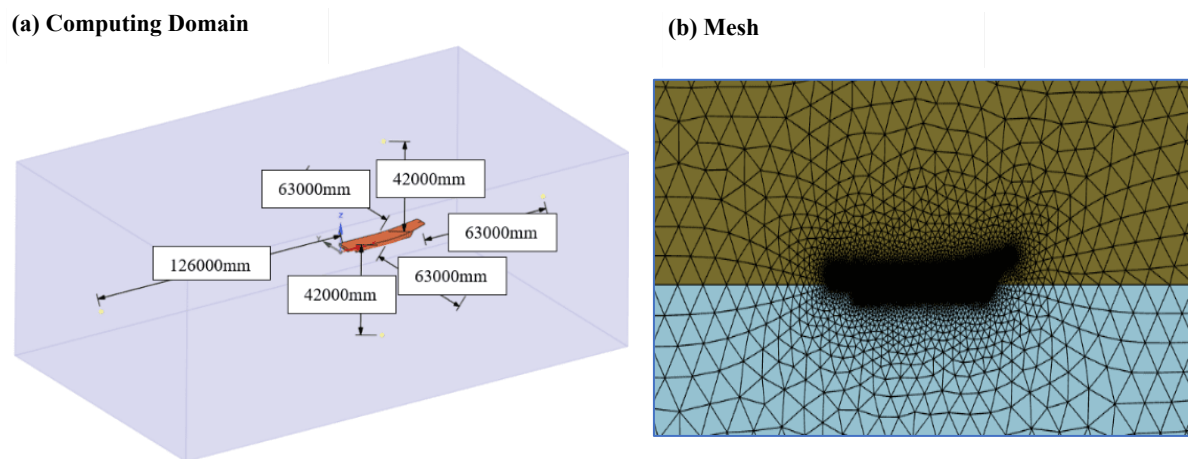


Figure 2. Computational Domain and Mesh Compaction Around the Hull

The main boundary conditions consist of an inlet velocity of 5.14 m/s, outlet pressure of 0 Pa, wall no-slip on the hull and fin, and symmetry/slip on the side boundaries which do not represent a solid surface. The water and air phases are defined in the VOF domain. Calculations are carried out steadily until the residual decreases and the resistance force value shows a stable trend. The target residual criteria used are 10^{-4} for continuity, momentum, k , and ω , with resistance force stability as an additional check.

Prisoner Evaluation

Total resistance is obtained from the integration of force components on the surface of the hull and appendage in the direction of the ship's axis of motion. The percentage change in resistance is calculated for bare hull conditions using the equation:

$$\Delta R = \frac{RT_{Fin} - RT_{bare}}{RT_{bare}} \times 100\% \quad (1)$$

In addition to force values, free surface contour results and pressure distribution are used to qualitatively assess changes in flow patterns. Since the study did not divide the resistance into viscous and wave components separately, the resistance reduction was limited to the flow and pressure fields.

Dimensionless Operating Parameters

To place the simulation conditions in a hydrodynamic context, the Froude number is calculated using the waterline length (LWL) as the characteristic length. With $V = 5.144$ m/s, $LWL = 40.2$ m, and gravitational acceleration of 9.81 m/s², Fn is obtained around 0.259. This value is lower than the Froude range in most previous interceptor and stern flap studies, for example Fr 0.334–0.584 on deep-vee ships [1] and Fr 0.29–1.74 on planing hulls [6].

$$Fn = V / \sqrt{gLWL} = 5.144 / \sqrt{9.81 \times 40.2} \approx 0.259 \quad (2)$$

The difference in operating points is important in determining the results. The amount of reduction in resistance in this study was not used as a direct validation of the percentage of planing vessels, but rather as a comparison of the influence of the appendage. Several studies show that the appendage's response changes to speed, position, size and geometric orientation [1], [3], [6], [8].

RESULTS AND DISCUSSION

Mesh Quality and Numerical Convergence

The numerical stability and mesh quality were evaluated prior to assessing the hydrodynamic performance of the bare-hull and fin-stabilizer configurations. The computational mesh was generated using an unstructured approach with local mesh refinement applied around the hull, fin stabilizers, and free-surface region. Inflation layers were introduced adjacent to the hull and fin surfaces to provide adequate resolution of the boundary layer

and accurately capture the near-wall flow characteristics. A finer mesh concentration was applied around the fin-stabilizer region because the presence of the appendage can generate local pressure variations, flow separation, and vortex structures. Additional refinement was also applied near the free-surface region to improve the resolution of the water-air interface. Mesh configuration used in the present study is illustrated in Figure 3.

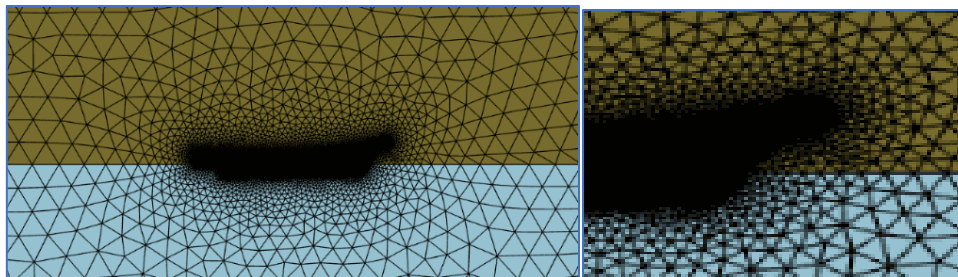


Figure 3. Computational Mesh and Local Mesh Refinement Around the Hull

The quality of the computational mesh was assessed using the skewness mesh quality metric. The skewness values were evaluated separately for the model, air, and water regions to assess the geometric quality of the generated computational cells. As presented in Table 2, the average skewness values for the no-fin configuration were 0.038, 0.032, and 0.041 for the model, air, and water regions, respectively. For the fin configuration, the corresponding average skewness values were 0.039, 0.032, and 0.04. Based on the skewness mesh metric spectrum shown in Figure 4, all obtained values fall within the “Excellent” category.

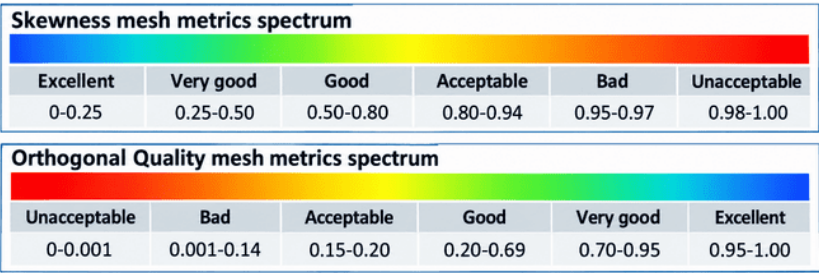


Figure 4. Skewness and Orthogonal quality mesh metrics spectrums [11].

Table 2. Convergence based on Skewness Mesh Metric Spectrums

Simulation	Average Sqewness (Model)	Average Sqewness (Air)	Average Sqewness (Water)	Category
No Fin	0.03776168	0.031601486	0.040798142	Excellent
Fin	0.03897561	0.032045970	0.041459626	Excellent

The results indicate that both computational configurations have a satisfactory mesh quality in the model, air, and water regions. The slightly higher average skewness observed in the fin configuration remains within the excellent quality range, indicating that the addition of the fin stabilizers does not result in a significant deterioration of the overall mesh quality. The local mesh refinement around the hull and fin regions provides a sufficiently resolved computational domain for the subsequent hydrodynamic analysis.

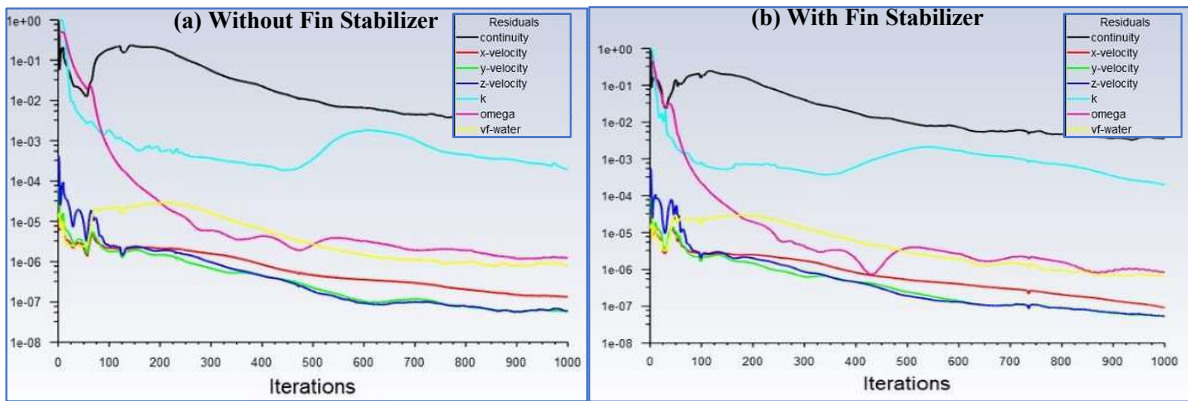


Figure 5. Residual Convergence History : (a) without fins and (b) with fin stabilizer

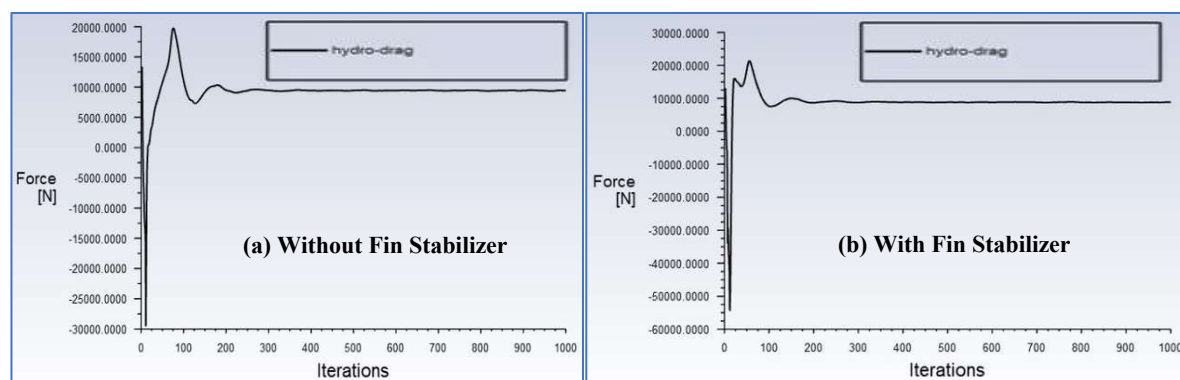


Figure 6. Force Convelgence History : (a) without fin and (b) with fin stabilizer

The numerical convergence of the simulations was evaluated based on the residual histories and the hydrodynamic force response. Figure 5 presents the residual convergence histories for the bare-hull and fin-stabilizer configurations. For both configurations, the residuals generally decrease during the iterative process and subsequently approach relatively stable levels. The continuity residual shows a gradual reduction with some fluctuations, while the momentum and turbulence-related residuals decrease more substantially as the solution progresses. The volume-fraction residual also exhibits fluctuations, which are associated with the VOF-based multiphase formulation used to capture the air-water free-surface interface. The overall residual trends indicate that the numerical solutions progressively approach a stable iterative state.

In addition to the residual monitoring, the longitudinal hydrodynamic force was monitored throughout the simulation. Figure 6 shows the force convergence histories for the bare-hull and fin-stabilizer configurations. Both simulations exhibit relatively large force variations during the initial iterations, followed by a progressive reduction in the magnitude of the fluctuations. After the initial transient stage, the force histories become relatively stable and fluctuate around a nearly constant mean value. This behavior indicates that the calculated hydrodynamic force has reached a stable condition for both configurations. The resistance values obtained from the stable portion of the force histories were subsequently used for the comparison between the bare-hull and fin-stabilizer configurations.

Comparison of Ship Resistance

The total resistance obtained at a speed of 10 knots is presented in Table 3. The total resistance is decomposed into viscous resistance (R_V) and pressure-related resistance (R_{PW}) as :

$$R_T = R_V + R_{PW}$$

Table 3. Comparison of total resistance from simulation results

Configuration	R_V (N)	R_{PW} (N)	R_T (N)	ΔR_T (N)	ΔR_T (%)
Bare hull	6098.731	3327.234	9425.965	-	-
With stabilizer fins	6117.384	3017.412	9134.796	-291.169	-3.089

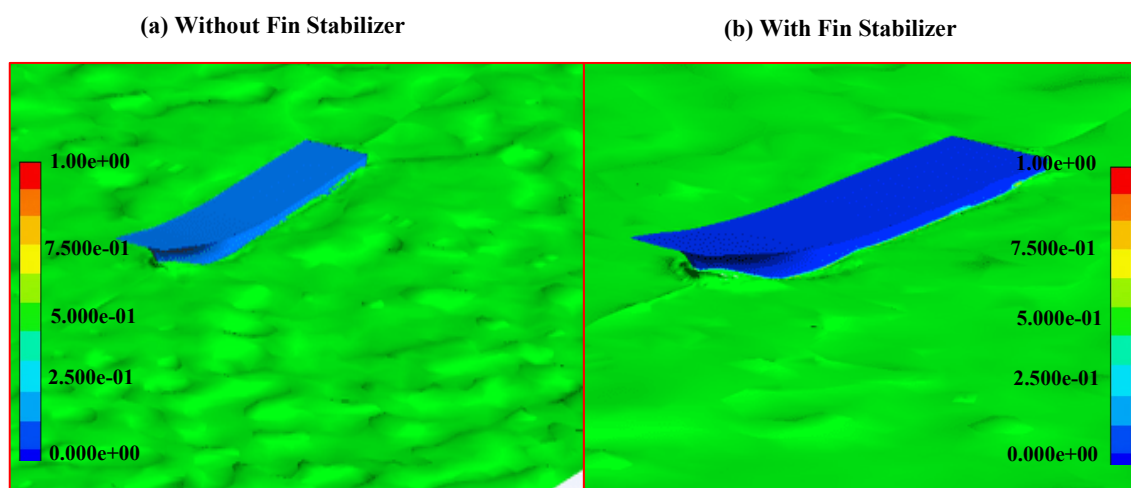
The bare-hull configuration produces a total resistance of 9425.965 N, while the configuration with stabilizer fins produces 9134.796 N, corresponding to a reduction of 291.169 N or 3.089%.

The viscous resistance shows only a small increase from 6098.731 N for the bare hull to 6117.384 N with the stabilizer fins, corresponding to an increase of 0.306%. In contrast, the pressure-related resistance decreases from 3327.234 N to 3017.412 N, representing a reduction of 9.315%. The larger reduction in pressure-related resistance compared with the increase in viscous resistance results in a net reduction in total resistance.

Changes in Flow Patterns and Free Surfaces

Comparison of the volume fraction contours in Figure 4 shows that fin installation modifies flow locally around the hull sides and the area after the fin. This change is a result of the interaction between the incoming

flow and the fin surface which increases the wet area as well as hydrodynamic forces and local vortex structures. Previous research on interceptors shows that appendages can form high pressure areas and modify the flow around the hull [2,3], while stern flaps can change wake and wave patterns thereby affecting resistance [5]. Although the fin mechanism is different from that of the interceptor and stern flap, the principle of changes in the flow field due to appendage remains relevant for qualitative interpretation.



Pressure Distribution

The pressure contour in the longitudinal plane using the same color scale is shown in Figure 5. After the fin is installed, local disturbances can be seen in the area around the appendage position, while the pressure pattern along the bottom of the hull continues to follow the transition from the higher-pressure area below the waterline to the lower pressure area around the free surface. These local changes indicate that the fin modifies the pressure field and flow direction, so that the force distribution on the surface of the vessel also changes.

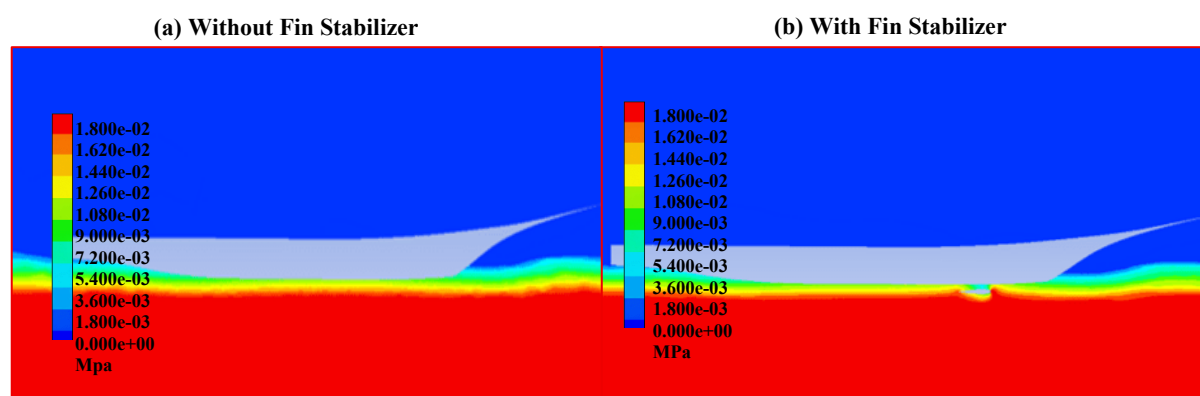


Figure 8. Pressure contours in longitudinal cross section: (a) without fin and (b) with fin stabilizer

Physically, adding fins can have two opposite effects. First, the wet surface area and vortex formation at the fin tip have the potential to increase viscous resistance. Second, changes in pressure and flow patterns around the hull can decrease other parts of the total resistance. In this simulation, the reduction in resistance is 3.089%, so changes in pressure and flow distribution are thought to be more dominant than the additional local fin drag at 10 knots. This statement is an interpretation of the total force and contour results.

Volume Fraction Distribution on the Gastric Surface

The three-dimensional visualization in Figure 6 clarifies the changes in the water and air interface previously observed from the free surface view. In a bare hull, the volume fraction transition zone follows the contour of the hull side without any additional geometric disturbance. Once the fin stabilizer is installed, there is a local change in the transition line around the fin position and in the flow behind it. These changes indicate that the fin

interacts directly with the flow layer on the hull side and produces local redistribution before flow again develops towards the stern.

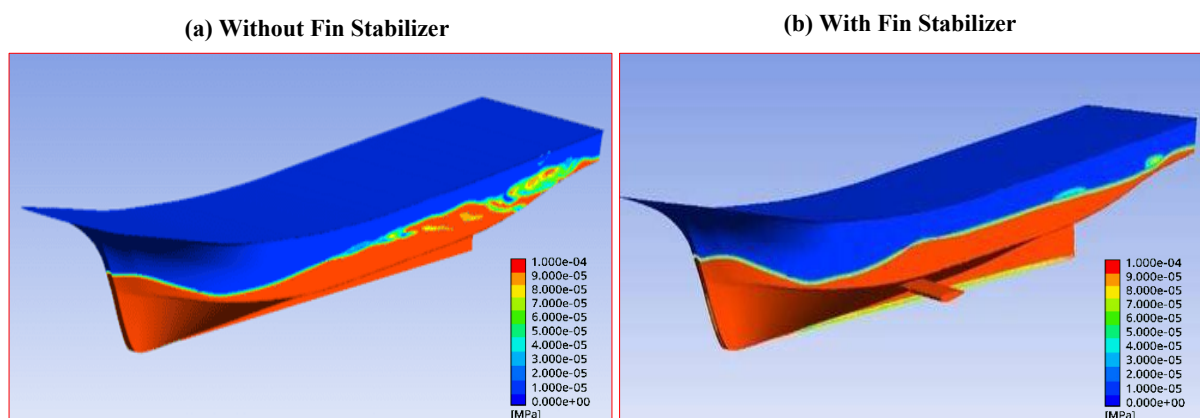


Figure 9. Volume fraction distribution on the hull surface: (a) without fin and (b) with fin stabilizer

Interpretation of these contours must be carried out qualitatively because the research data does not provide numerical extraction of wave height, wet surface area, or wave energy. Nevertheless, the changing pattern around the fin is consistent with the concept that appendage can modify the wake and pressure distribution through changes in local flow momentum. In stern appendage research, changes in wake and wave patterns were also shown to be part of the resistance reduction mechanism [5].

Surface Pressure Distribution and Synthesis of Resistance Mechanisms

The three-dimensional pressure contour in Figure 7 shows that the addition of the fin creates a local pressure zone in the area where the appendage meets the flow. The most obvious differences occur around the bottom of the fin and the adjacent bottom of the hull, while the pressure pattern in parts of the hull far from the appendage maintains relatively the same trend. This condition supports the results in Figure 5 that the changes due to the fin are mainly local but are sufficient to change the resultant longitudinal force that is integrated over the entire surface.

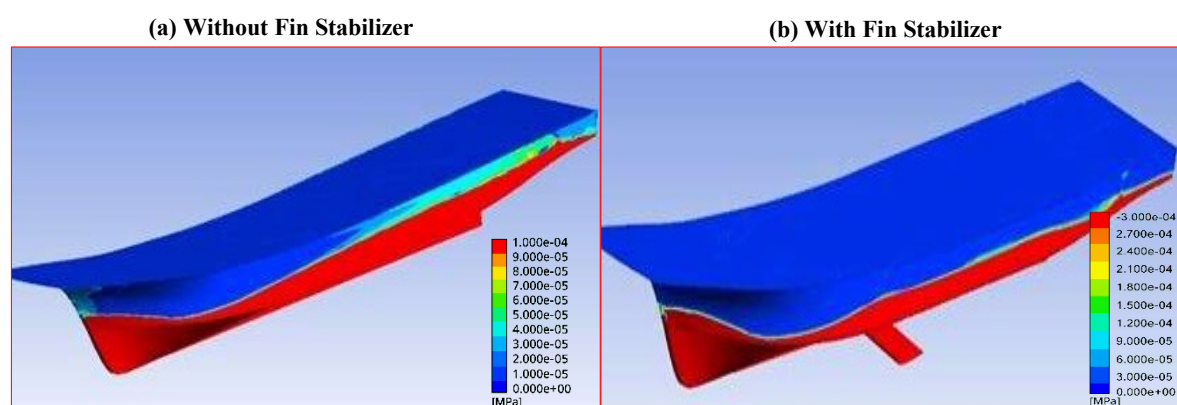


Figure 10. Pressure distribution on the hull surface: (a) without fin and (b) with fin stabilizer

The total mechanism that produces a resistance reduction of 3.089% cannot be separated quantitatively from the total force monitor alone. Fins add wetted surface area and potentially increase skin-friction and vortex-induced drag, but at the same time change the pressure field and flow direction on the hull sides. In the 10-knot condition analyzed, the resultant of both simulations due to this effect produces a lower total resistance.

Comparison with Previous Research and Numerical Reliability

To assess the position of the research results against the state of the art, Table 3 explains several appendage results from previous research that used different configurations and operating ranges.

Table 3. Comparison of research results with several studies

Source	Configuration/Object	Condition	Resistance Change
Present study	Stabilizer fin; 100 GT fishing vessel	10 knots; $Fn \approx 0.259$	Decreased by 3.089%
Song et al. [1]	Interceptor/stern flap; deep-Vee ship	Fr 0.334–0.584	Decrease of approximately 3–9%
Samuel et al. [6]	Integrated interceptor-stern flap; planing hull	Fr 0.29–1.74	5° configuration: 2–17%, average 6.5%
Samuel et al. [9]	Interceptor flap; planing hull	Up to Fr 1.45	Up to 33.3% for certain configurations
Rosmani et al. [10]	Stern flap; planing hull	Various flap angles	Average of 5.05–6.27%

The value of 3.089% in this study is at the bottom of the range of resistance reductions that have been carried out in several appendage studies. However, the trend still shows that additional geometric changes are not always synonymous with increased resistance. Song et al. showed a reduction of about 3–9% in deep-vee ships [1], while Samuel et al. reported that an integrated interceptor-stern flap with an angle of 5° could provide a 2–17% reduction in hull planing [6]. At the same time, previous research also shows that appendages can lose effectiveness or even increase drag under certain conditions, so that optimization of geometry and operating points is still necessary [3], [6], [8].

From the numerical side, the decreasing residuals and the stability of the force monitor indicate iterative convergence but are not enough to quantify the discretization uncertainty. Mansoori et al. used the Grid Convergence Index to assess the influence of grid spacing and time-step [3], while integrated interceptor-stern flap studies also performed mesh independence checks before selecting the number of grids [6]. Therefore, the current results can be used as an initial indication of fin influence, but the level of certainty will be stronger if equipped with at least three mesh levels, y^+ evaluation, as well as GCI estimates or other equivalent grid verification methods.

Research Limitations and Development Implications

There are several limitations that limit the results. The geometry of the 100 GT fishing vessel was developed from 25 GT vessel data using a primary vessel size approach, so that the hydrostatic characteristics and volume distribution of the target vessel were not derived from a directly validated 100 GT design. In addition, the simulation was only carried out at a speed of 10 knots and used a steady solution, so that the curve of resistance to speed, transient response of the free surface, as well as changes due to wave conditions could not yet be evaluated.

The main function of a fin stabilizer is to generate a hydrodynamic moment for roll-motion control, whereas the present study focuses on its effect on flow characteristics and resistance. Although the addition of the fins increases the wetted surface area and introduces additional local viscous and vortex effects, the resistance-component analysis indicates that the increase in viscous resistance is relatively small compared with the reduction in pressure-related resistance. Consequently, the observed 3.089% reduction in total resistance should be interpreted specifically as the resistance response of the fixed-body configuration at 10 knots and should not be taken as a direct measure of the overall stabilization performance. Further studies should incorporate free sinkage and trim, roll or seakeeping analysis, variations in fin angle and area, multiple operating speeds, and experimental or sea-trial validation.

CONCLUSION

Based on CFD simulations, installing fin stabilizers on a 100 GT fishing boat model changes the flow pattern, free surface volume fraction, and pressure distribution locally around the appendage. At a speed of 10 knots ($Fn \approx 0.26$), the total bare hull resistance of 9425.97 N decreases to 9134.80 N after the fins are installed, resulting in a net decrease of 291.17 N or 3.09%. Three-dimensional contours show that changes are mainly concentrated around the bottom of the fin and flow after appendage, while the global pattern of the hull remains similar. These results show that the analyzed fin configuration does not increase the total resistance at the simulation operating point but provides a reduction in resistance that is on the lower order of magnitude compared to several appendage studies on higher speed vessels. Further validation through grid independence

studies, speed variations, roll motion modeling, as well as experimental testing is required before the fin configuration is recommended for design implementation.

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