Location Analysis Of Patrol Boat Fin Stabilizer Based On Numerical Method

Wawan Kusdiana1,a, Semin2, I Made Ariana3, Cahya Kusuma4,a Baharudin Ali5

1,2,3,aDepartment of Marine Engineering, FTK, Kampus ITS, Sukolilo, Surabaya
4Sekolah Tinggi Teknologi Angkatan Laut, Surabaya
4Lembaga Hidrodinamika Indonesia, Badan Riset dan Inovasi Nasional, Sukolilo, Surabaya

wkusdiana2744@gmail.com, seminis@gmail.com, ariana_made@its.ac.id, cahya_kusuma11@yahoo.co.id, baharuddin.ali@brin.go.id

Abstract. The fin stabilizer is located on the hull of the ship, one left and one right, which is connected to the fin stabilizer control room as a tool to respond to excessive ship rolling in both directions. In this study, we will analyze the ship resistance due to the addition of a fin stabilizer type Naca 0013 on patrol boats with variations in angles of 0°, 5°, 10°, 15° with speed variations of 25 - 30 knots. Calculation of ship resistance using Maxsurf modeler software and Numeca fine marine. In the early stages of validating the model that has been tested on a towing tank with a patrol boat design made using the Maxsurf modeler and Numeca fine marine. Validation results with a maximum error of 2.38% maxsurf software and 2% Numeca software. There was an increase in resistance due to the fin being installed at an angle of 0° by 0.56% - 1.22%, at an angle of 5° by 2.26% - 3.75%, at an angle of 10° by 6.48% - 9.49%, at an angle of 15° by 13.92% - 18.79 % of the total drag of the ship.

1. INTRODUCTION

Ship movements at sea basically have three translational motion (surge, sway, and heave) and three rotational motion (roll, pitch, and yaw), which can affect the stability of the ship when sailing due to influences from inside and from outside and to overcome this with the ability of ship motion as one of the crucial aspects related to shipping movement in response to the influence of external forces acting on the ship[1]. In improving the quality of maneuvering on ships, the use of an anti-roll system on ships is able to affect the response of rolling motion on ships. One of the anti-roll systems is the fin stabilizer. There are several ways to increase stability and reduce appendages resistance ship by varying the slope angle and fin-type from NACA 0012 and NACA 0018.[2] as well as controlling the tilt angle with a control system with several methods such as the Sugeno-Takagi fuzzy logic method[3], Adaptive Fuzzy [1][4] and MATLAB LMI [5] model predictive control [6], PID control system with RBF neural network [7], software package ANSYS AQWA [8].

Based on Global Marine Technology Trends, GMTT 2030 on Energy Management, various studies have been conducted to save energy from fossils either by seeking alternative energy[9] reduce exhaust
emissions[10], reduce ship drag such as optimization of bulbous bow and axe bow[11], and increase propeller efficiency[12] and fin stabilizer [13].

Research based on the location of placement and ratio of fins was carried out on NACA 0018 fins mounted on the bow of the ship to find the effect of fin action at various angles of attack and get the best resistance by using a model test in the towing tank and compared with computer simulations from the simulation results to get the lowest resistance at an angle of 5° [2].

![Figure 1. Mesh model with a 5° fin angle](image1)

**Figure 1.** Mesh model with a 5° fin angle

![Figure 2. Hull resistance without fins, with fins at d=0 degree and d=+/−15 degree](image2)

**Figure 2.** Hull resistance without fins, with fins at d=0 degree and d=+/−15 degree [14].

Research on ships without fins and using fins with an angle of attack ± 15° has a significant effect on the total resistance of the boat as shown in Figure 2 shows the ship resistance based on simulation data and towing tanks where the simulation results show good agreement with experimental data, the difference in ship resistance is lower than 2% when the fin is not deflected (d=0 degrees), while when the fin is deflected by d=+/−15 degrees, the drag increases by about 17.5% compared to when the angle of attack is 0[14].

Ship stability is one that is very important for the comfort and safety of the crew, especially on warships equipped with weapons so that in firing weapons, the results are better. One of the ship's anti-roll tools is the Fin stabilizer which is installed on the right and left hulls of the boat, but the addition of a fin stabilizer can provide additional ship resistance. Further analysis of ship resistance by using models in towing tanks and using simulation software. This study uses Numeca fine marine simulation software with patrol boat objects with the following data:

- Design speed: 25 - 30 [knots]
- LOA: 59.5 [meters]
- Length on Waterline: 54 [meters]
- LBP: 53.71 [meters]
- Length: 7.23 [meters]
- Displacement: 467 [Ton]
- Draft: 2.57 [meters]
- Temperature: 30°C
- Viscosity: 1025 kg/m³
2. Research Methods

In a comparative method study, the authors compare the results of the modeling of ship resistance on the patrol ship model before installing the fins on the towing tank with the results of the Numeca fine marine simulation with a maximum error of 3%. Next will make a simulation of the patrol boat after the fin is installed to find out the addition of ship resistance with variations in ship speed 25 – 30 knots with variations in the angle of attack of the stabilizer fin 0°, 5°, 10°, 15° in the Parasolid "x_t" format. The schematic of the modeling process is as follows.

2.1. The design process and 3D models

The simulation process in CFD software starts from making a hull model designed from Maxsurf Modeler based on the lines plan and test model on the towing tank, then exported to the IGES program to change the ship model into a solid form. The ship model consisting of surfaces is made into a tight closed-form to become a solid object. The following solid model is made with Rhinoceros; besides that, Rhinoceros is used to change the shape of the surface so that it can be moved in the Parasolid "x_t" format. The schematic of the modeling process is as follows:

![Diagram of modeling process](image)

**Figure 3.** Numeca Fine marine Testing Process scheme

2.2. Selection of Number of Grids (Meshing) and Simulation Model

A grid is defined as a collection of elements that combine to form a specific shape. The determination of the number of grids used in ship modeling affects the level of accuracy of the model. The smaller the size of the grid used, the more the number of grids used, and it will take a long time to perform the simulation. The small grid size will affect the level of smoothness of each part of the hull. The use of a grid size that is too large will also affect the shape of the hull that will be produced to reduce the results obtained, so it is necessary to carry out a process to get the optimum number of grids. The number of grids used in ship modeling with Numeca Software is determined based on modeling experiments with various variations in the number of grids which are then optimized to obtain the optimum number of grids. The optimum number of grids is the number of grids used does not affect the magnitude of the results accepted.

2.3. Model Verification and Validation

The verification and validation of the model aim to check whether the developed model has presented the expected conditions; besides that, it is also a comparison between the needs of the tested model and the patrol boat design that was made using a maxsurf modeler with Numeca software in accordance with a maximum error of 3%. Then proceed with making the geometry of the selected fin-type using data according to the NACA standard and combined with a ship model that has been validated using the Rhinoceros software and Numeca Software for research to analyze the effect of adding fins to ship resistance.

3. Analysis and discussion

3.1. Model Verification and Validation

From the results of model tests and simulations, it is found that the comparison of ship resistance between the model conditions that have been tested and the patrol boat design made using the Maxsurf modeler with a maximum error of 2.38% and the Numeca fine marine software with a maximum error of 2%. Model verification and validation include model unit test, resistance test,
parameter test. Test the resistance when using Numeca with a half body condition so that the resistance value is multiplied by 2. For example, when the speed is 27 knots, the resistance data obtained by the Numeca software is 150,577 kN, so the actual resistance is 2 x 150,577 kN = 301,154 kN. Based on the data in table 1, with a maximum error of 2.0, it can be continued to the next stage by adding fin Naca 0013.

![Image](image.png)

**Figure 4.** Resistance test results using the Numeca software at 27 Knots

| Vs (knot) | R (kN) | R (kN) | Error (%) | R (kN) | Error (%) |
|-----------|--------|--------|-----------|--------|-----------|
| 25        | 283    | 283.1  | 0.04%     | 279.156 | 1.4%      |
| 26        | 294    | 290.8  | 1.09%     | 288.144 | 2.0%      |
| 27        | 306    | 303.4  | 0.85%     | 301.154 | 1.6%      |
| 28        | 320    | 317.4  | 0.81%     | 313.630 | 2.0%      |
| 29        | 333    | 336.1  | 0.93%     | 327.662 | 1.6%      |
| 30        | 344    | 352.2  | 2.38%     | 339.026 | 1.4%      |

### 3.2. Model simulation with fin stabilizer

After creating a validated ship model, then proceed with making the geometry of the selected fin-type using data according to NACA standards and combining it with a validated ship model using Rhinoceros and Numeca Software. Selection of fin stabilizer with a model according to Naca foil to be tested for locations below the waterline, at coordinates X = 24 m, y = 0 m, and Z = 1 m with variations in ship speed from 25 – 30 knots with variations in the angle of attack of Fin stabilizer 0°, 5°, 10°, 15°.
From Figure 6 at a speed of 25 knots with a fin attack angle of 0°, the ship's resistance is 140.358 kN, in half body simulation conditions so that the actual resistance is 2 x 140.358 kN = 280.716 kN, from these results to determine the amount of resistance caused by the addition of the fin. It can be obtained by reducing the data before there is a fin at the same speed so that we get 280.716 kN – 279.156 kN = 1.56 kN or 0.56% of the total ship resistance. The complete simulation result data is shown in table 2.

| Speed knot | The angle of attack (kN) |
|------------|-------------------------|
|            | 0°                      |
| 25         | 280.716                 |
| 26         | 290.082                 |
| 27         | 303.958                 |
| 28         | 315.634                 |
| 29         | 331.664                 |
| 30         | 343.138                 |
|            | 5°                      |
| 25         | 285.474                 |
| 26         | 295.356                 |
| 27         | 310.718                 |
| 28         | 322.834                 |
| 29         | 339.552                 |
| 30         | 351.734                 |
|            | 10°                     |
| 25         | 297.254                 |
| 26         | 307.884                 |
| 27         | 324.868                 |
| 28         | 338.546                 |
| 29         | 356.050                 |
| 30         | 371.194                 |
|            | 15°                     |
| 25         | 318.006                 |
| 26         | 331.290                 |
| 27         | 350.052                 |
| 28         | 365.502                 |
| 29         | 386.844                 |
| 30         | 402.742                 |
Table 3. Fin Resistance

| Speed knot | Angle of attack | 0°   | 5°   | 10°  | 15°  |
|------------|-----------------|------|------|------|------|
| 25         | 0.56%           | 2.26%| 6.48%| 13.92%|
| 26         | 0.67%           | 2.50%| 6.85%| 14.97%|
| 27         | 0.93%           | 3.18%| 7.87%| 16.24%|
| 28         | 0.64%           | 2.93%| 7.94%| 16.54%|
| 29         | 1.22%           | 3.63%| 8.66%| 18.06%|
| 30         | 1.21%           | 3.75%| 9.49%| 18.79%|

Figure 7. Fin resistance at a speed of 25 - 30 knots with variations in the angle of attack

Based on the simulation results from Numeca Marine software in table 3, data obtained at the shipping speed from 25 knots - 30 knots at an angle of 0° an increase in resistance of 0.56% - 1.21% of the total resistance of the ship, at an angle of 5° an additional resistance of 2.26% - 3.75% of the total resistance of the boat, at an angle of 10° there is an increase in resistance of 6.48% - 9.49% of the total resistance of the ship, at an angle of 15° there is an increase in resistance of 13.92% - 18.79% of the total resistance of the boat. The higher the speed of the ship and the angle of the stabilizer fin, the more the additional resistance of the boat increases.

4. Conclusion

A fin stabilizer is one of the anti-roll systems that can affect the excessive rolling response of the ship in both directions. Installation of fins, in addition to having a positive impact, can have a negative effect on the form of an increase in ship resistance. In foil naca type 0013 at a ship speed of 25 knots - 30 knots, the data on the rise in ship resistance is obtained as follows: at an angle of 0°, there is an increase in resistance of 0.56% - 1.21%, at an angle of 5° there is an increase in ship resistance of 2.26% - 3.75%, at an angle of 0°, angle of 10° an increase in resistance of 6.48% - 9.49%, at an angle of 15° an increase in resistance of 13.92% - 18.79% of the total resistance boat. From the results of this study, when compared with research from Della Rosa, it is almost the same wherein his research mentions the fin
stabilizer with an angle of attack of 0° there is an increase in ship resistance of less than 2% and at an angle of attack of 15° by 17.5% of the total ship resistance.

Implementation of the use of fin stabilizer and variations in the angle of attack depending on the size of the external force caused by sea waves and the control of the angle of the fin stabilizer has been integrated with the control system so that the use of the fin stabilizer is more effective. At the next research stage, research can be carried out by varying the type of foil and fin shape to get the best ship resistance and anti-roll

5. References

[1] M. A. M et al., "Feasibility Study on Application Active Skeg as Anti Rolling on Fast Ship with Model Test Method," pp. 85–93, 2015.

[2] A. Pengaruh, V. Bentuk, and D. O. Turbin, “Jurnal teknik perkapalan,” vol. 5, no. 2, pp. 421–430, 2017.

[3] C. M. Chang, W. J. Chang, C. C. Ku, and F. L. Hsu, "Passive fuzzy control for lift feedback fin stabilizer systems of a ship via multiplicative noise based on a fuzzy model," J. Mar. Sci. Technol., vol. 26, no. 2, pp. 159–165, 2018, doi: 10.6119/JMST.2018.04_(2).0002.

[4] R. Bai, "Adaptive Fuzzy Output-Feedback Method Applied to Fin Control for Time-Delay Ship Roll Stabilization," Math. Probl. Eng., vol. 2014, pp. 1–6, 2014, doi: 10.1155/2014/791932.

[5] B. R. R. Ram, S. Surendran, and S. K. Lee, "Computer and experimental simulations on the fin effect on ship resistance," Ships Offshore Struct., vol. 10, no. 2, pp. 122–131, 2015, doi: 10.1080/17445302.2014.918308.

[6] T. Perez and G. C. Goodwin, "Constrained predictive control of ship fin stabilizers to prevent dynamic stall," Control Eng. Pract., vol. 16, no. 4, pp. 482–494, 2008, doi: 10.1016/j.conengprac.2006.02.016.

[7] M. Sun, T. Luan, and L. Liang, "RBF neural network compensation-based adaptive control for lift-feedback system of ship fin stabilizers to improve anti-rolling effect," Ocean Eng., vol. 163, no. 52, pp. 307–321, 2018, doi: 10.1016/j.oceaneng.2018.06.011.

[8] B. Rajesh Reguram, S. Surendran, and S. K. Lee, "Application of fin system to reduce pitch motion," Int. J. Nav. Archit. Ocean Eng., vol. 8, no. 4, pp. 409–421, 2016, doi: 10.1016/j.ijnaoe.2016.05.004.

[9] F. M. Felayati, Semin, B. Cahyono, and R. A. Bakar, "Investigation of the effect of natural gas injection timing on dual-fuel engine emissions using split injection strategies," Int. Rev. Mech. Eng., vol. 13, no. 11, pp. 645–654, 2019, doi: 10.15866/ireme.v13i11.16980.

[10] M. B. Zaman, D. T. Rahmatullah, Semin, and F. M. Felayati, "Effect of natural gas injection pulse width to diesel dual fuel performance," AIP Conf. Proc., vol. 2187, no. December 2019, doi: 10.1063/1.5138278.

[11] K. K. Yang and Y. Kim, "Numerical analysis of added resistance on blunt ships with different bow shapes in short waves," J. Mar. Sci. Technol., vol. 22, no. 2, pp. 245–258, 2017, doi: 10.1007/s00773-016-0407-9.

[12] M. Indiaryanto and I. M. Ariana, “Kajian Numerik Pengembangan Symmetrical Blade Propeller Untuk Kapal Patroli 60m dengan Menggunakan Teori Lifting Line,” R.E.M. (Rekayasa Energi Manufaktur) J., vol. 2, no. 1, p. 7, 2017, doi: 10.21070/r.e.m.v2i1.778.

[13] B. R. R. Ram, S. Surendran, and S. K. Lee, "Computer and experimental simulations on the fin effect on ship resistance," Ships Offshore Struct., vol. 10, no. 2, pp. 122–131, 2015, doi: 10.1080/17445302.2014.918308.

[14] S. Della Rosa, S. Maceri, I. M. Viola, and S. Bartesaghi, "Design and optimization of a fin stabilizer using CFD codes and optimization algorithms," 16th Int. Conf. Sh. Shipp. Res., 2009.