

# Impact Analysis of Trim Tab Inclination Angles Variation to Propulsion Power Requirement of 6 Meter's Speed Boat

Amiadji<sup>1</sup>, Achmad Baidowi<sup>2</sup>, Aufal Nanda Oktova<sup>3</sup>

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**Abstract**—determining the ship's propulsion power requirements is one of the most crucial things in ship design which is related to the ship's resistance. One of the causes of the high value of a ship's resistance is excessive trim of the ship. Therefore it needs a mechanism to overcome this, it can be by applying trim tabs. The trim tab is a small surface mounted on the ship's transom that can be adjusted according to the conditions of the ship. By adjusting the angle of the trim tab to be larger, it can increase the lift force and torque moment at the stern of the ship which can reduce the trim of the ship. Based on the boat's characteristics, referring to the guide from Bennet Marine, the appropriate trim tab's geometry for this boat is a trim tab with a span width of 18" (46 cm) and a chord length of 9" (23 cm). After selecting the trim tab geometry, then analyzing the resistance and trim of the ship using the CFD method. Through CFD simulation, trim tab with an angle of 15° can reduce the value of the ship's resistance to 17.25% and for the trim can be reduced to 46.72%. Then after the ship's propulsion power requirements calculation, it is shown that the trim tab with an angle of 15°, a reduction of 11.56% is obtained from 78.854 kW to 69.741 kW.

**Keywords**—CFD, Propulsion Power, Ship Resistance, Trim, Trim Tab.

## I. INTRODUCTION

Ship resistance is one of the important factors in ship planning. By study of Deddy Chrismanto and Berlian Arswendo (2014) that the total resistance of the ship can affect the total required engine power [1]. Frictional resistance is one of the main components of the largest ship resistance ranging from 60% - 70%. With a significant reduction in frictional resistance, it can reduce fuel consumption [2].

One of the causes of the increase in the value of frictional resistance is due to excessive trim at the stern of the ship. In addition, variations in trim can cause instability in the form of porpoising on fast boats [3].

Referring to research by Maria Margareta Z.B. (2016) discusses the effect of the trim tab angle on a 60 meter fast patrol boat using the CFD approach. It was found that the installation of trim tabs can reduce the turbulence that occurs at the stern of the ship. In addition, with the installation of trim tabs on the transom of the ship, it causes torsional moments and lift forces [4].

Therefore, it's necessary a system that is installed on the ship that functions to minimize the occurrence of excessive trim and porpoising especially at high speed operation. One method to overcome this is by installing trim tabs which are the most widely used devices both in

the planning hull and also can be applied to aircraft wings [3].

The installation of the trim tab on a 6-meter speed boat expected will reduce the ship's resistance and excessive trim values and can reduce the required propulsion power of the ship.

## II. METHOD

In this study, the method that will be used is the simulation method. In particular, this research will focus on the comparison of ship resistance, trim, and ship propulsion required on speed boats before and after trim tab installation. For a detailed explanation, it will be explained below :

### A. Identification of Problems

Identification, problem formulation, and research objectives are carried out first so that research can be directed. The topic in this study is about the impact of the trim tab angle on the propulsion power requirement of a 6 meter speed boat. Simulation of ship resistance and trim speed boat 6 meters using the CFD method. Then from the resistance of the ship, the required ship propulsion power is calculated using the approximate formula.

### B. Data Collection

To support the research, it takes some data that contains the main data of the ship including:

- 3D Model
- General Arrangement
- Construction Profile

### C. Weight Calculation

The weight of the ship is calculated by the post post method and is divided into several parts including the hull, superstructure, construction, equipment and deadweight of the ship. The calculation of the weight of the ship can be seen in the following table.

Amiadji, Departmen of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia. E-mail : [amiadji@its.ac.id](mailto:amiadji@its.ac.id)

Achmad Baidowi, Departmen of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia. E-mail : [ahmadbai@gmail.com](mailto:ahmadbai@gmail.com)

Aufal Nanda Oktova, Departmen of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia. E-mail : [aufaloktova0610@gmail.com](mailto:aufaloktova0610@gmail.com)

TABLE 1.  
 WEIGHT CALCULATION

No	Item	Weight	LCG	VCG	TCG
		(kg)	(m)	(m)	(m)
1	HULL	380.57	2.02	0.34	0.00
2	SUPERSTRUCTURE	249.32	2.44	0.61	0.00
3	CONSTRUCTION	97.29	3.32	1.27	0.00
4	FO TANK	245.00	1.75	0.15	0.00
5	EQUIPMENT AND OUTFITTING	288.08	0.93	0.57	0.00
6	PAX	810	2.202	0.676	0.00
7	LUGGAGE	90	2.202	0.676	0.00
TOTAL		2160.268	2.028	0.563	0.00

**D. Model Validation**

To get high accuracy between simulation and real data, a validation process is carried out. In this study, validation was carried out by comparing the vessel resistance and trim on each different number of cells. This process showed good results with a percent error of not more than 2.46%

**E. Trim Tab Addition**

Before the CFD simulation, the trim tab was added to the ship's hull. The trim tab is installed on the transom of the ship and is installed according to the shape of the transom of the ship. To determine the geometry of the trim tab size, use parameters including ship length and main engine configuration. After obtaining the geometry trim tab, the next step is to vary the angle which will be used in the simulation process. Trim tabs are varied at angles of 5°, 10° and 15°.

**F. CFD Simulation**

Simulation using CFD NUMECA FINE MARINE software is carried out by simulating 4 ship models (1 bare hull model and 3 variations of trim tab angle model)

with 3 speed variations including 15 knots, 17 knots, and 19 knots. So the total simulation is 12 times.

As shown in Figure 1, in the hull meshing process, the thing that needs to be considered is to add a refinement box in the form of a sector made around the ship. This is because in the case study of speed boats, occurred extreme pitching and porpoising movements. Therefore, it is necessary to add a refinement box to prevent negative volume errors during the running process. In addition, another thing that needs to be considered in the meshing process is the addition of the number of refinements in the trim tab area to obtain meshing details in that area.

In this study, the solver process was carried out using an unsteady time configuration on 2 fluid media including air and seawater with a temperature of 19°C. Therefore, the point to consider is the input inertia matrix on the body motion parameter. Then in the boundary condition parameters, all surfaces on the ship are defined as solid wall functions except for the surface deck defined as slip.

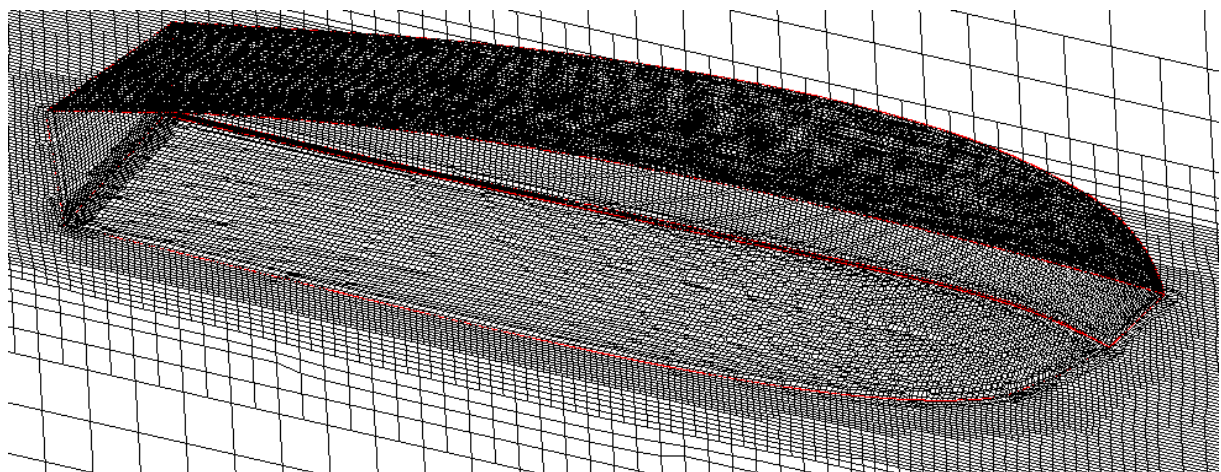


Figure. 1. Meshed Half Body.

**G. Ship Propulsion Power Calculation**

The last step is the calculation of the propulsion power required for the speed boat. Calculations are carried out using an approximation formula based on

references from Sv.Aa. Harvard (1983) [5], J. S. Carlton (2012) [6] and Edward V. Lewis (1988) [7] with the following steps :

- Effective Horse Power

- $EHP = R_t \times V_s$  (1)
- Wake Friction  
 $w = (0.5 \times c_b) - 0.05$  (2)
- Thrust Deduction Factor  
 $t = k \times w$  (3)
- Speed of Advance  
 $V_a = (1-w) \times V_s$  (4)
- Hull Efficiency  
 $\eta_h = (1-t) / (1-w)$  (5)
- Propulsive Coefficient  
 $P_c = \eta_h \times \eta_{rr} \times \eta_o$  (6)
- Thrust Horse Power  
 $THP = EHP / \eta_h$  (7)
- Delivered Horse Power  
 $DHP = EHP / P_c$  (8)

- Shaft Horse Power  
 $SHP = DHP / \eta_{s\eta b}$  (9)
- Brake Horse Power (SCR)  
 $BHP_{scr} = SHP / \eta_g$  (10)
- Brake Horse Power (MCR)  
 $BHP_{mcr} = BHP_{scr} / 0.85$  (11)

### III. RESULTS AND DISCUSSION

#### A. Trim Tab Geometry Addition

In the selection of this trim tab, it is determined by several parameters including the length of the ship, the configuration of the main engine, and the availability of space in the ship's transom. Based on the guide, the trim tab is obtained with a span width of 18" (46 cm) and a chord length of 9" (23 cm). Then proceed with modeling along with variations in angles by referring to trim tab installation instructions as shown in Figure 2.

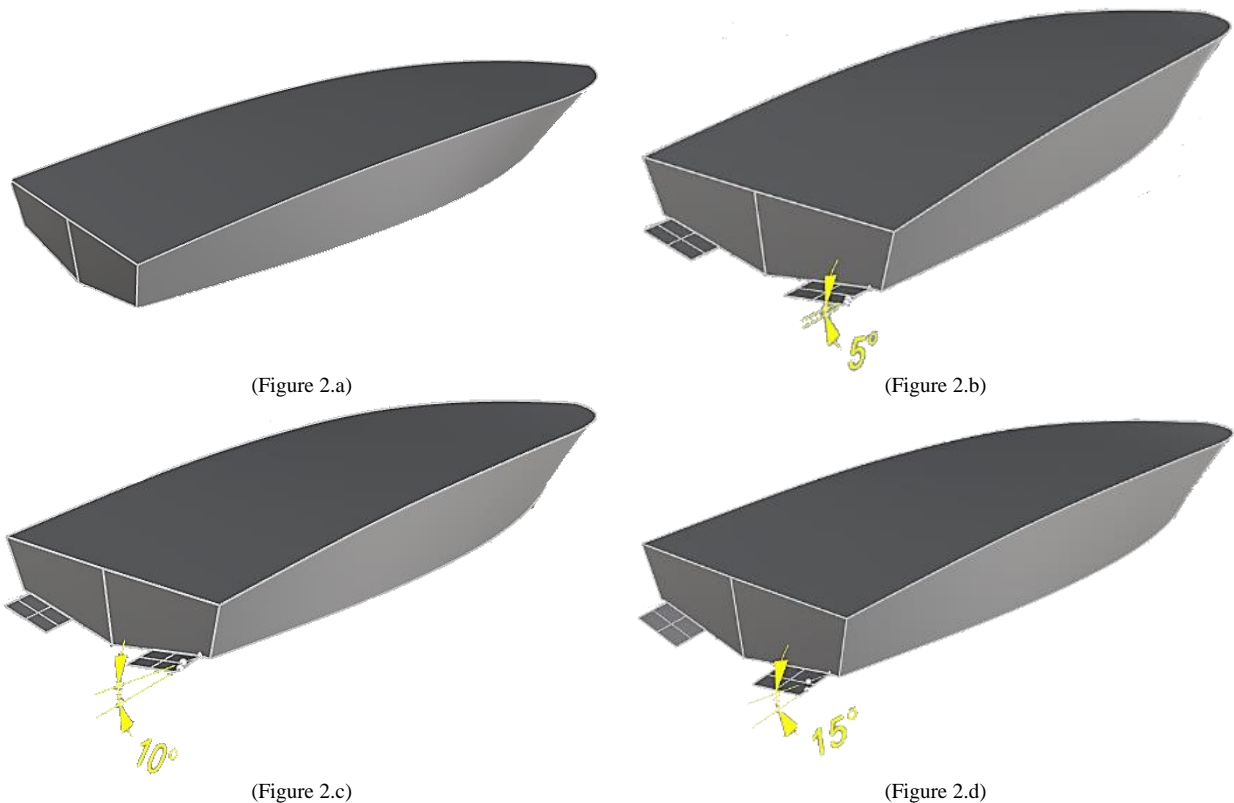


Figure 2. (a) Bare Hull (b) Trim Tab 5° (c) Trim Tab 10° (d) Trim Tab 15°

#### B. Simulation Result

The discussion on the results of the CFD simulation will be explained in several parameters including ship resistance, trim, wave elevation, hydrodynamic pressure, and relative velocity which will be reviewed based on variations in the model made.

##### 1. Ship Resistance

In the discussion of the results of the first CFD simulation, it is to compare the results of the ship's resistance before and after the installation of the trim tab and its slope variations. From the simulation results, it is

found that the higher the speed of the ship, the smaller the resistance value. This is because the object discussed in this study is a ship with planning hull characteristics. Where the hull can lift on the surface of the water when the ship is moving at high speed.

Based on the simulation results in Table 2 and Figure 3, it was found that in all variations of the trim tab angle, both 5°, 10°, and 15°, it showed a significant reduction in the total ship resistance value. At Fn 1.006; ship resistance is reduced by 17.25%. Then at Fn 1.140; the ship resistance was reduced by 11.98% and at the

condition of Fn 1.274; ship resistance was reduced by 11.56%. From the discussion, it was found that the superior ship model based on the value of the ship's resistance is the ship model with a trim tab angle of 15°.

TABLE 2.  
 SHIP RESISTANCE SIMULASTION RESULT

Model	Fn	Ship Resistance (kN)	Reduction (kN)	%
Bare Hull	1.006	3.872	0.000	0.00%
	1.140	3.588	0.000	0.00%
	1.274	3.444	0.000	0.00%
Trim Tab 5 deg	1.006	3.562	0.310	8.01%
	1.140	3.334	0.254	7.08%
	1.274	3.170	0.274	7.96%
Trim Tab 10 deg	1.006	3.368	0.504	13.02%
	1.140	3.220	0.368	10.26%
	1.274	3.064	0.380	11.03%
Trim Tab 15 deg	1.006	3.204	0.668	17.25%
	1.140	3.158	0.430	11.98%
	1.274	3.046	0.398	11.56%

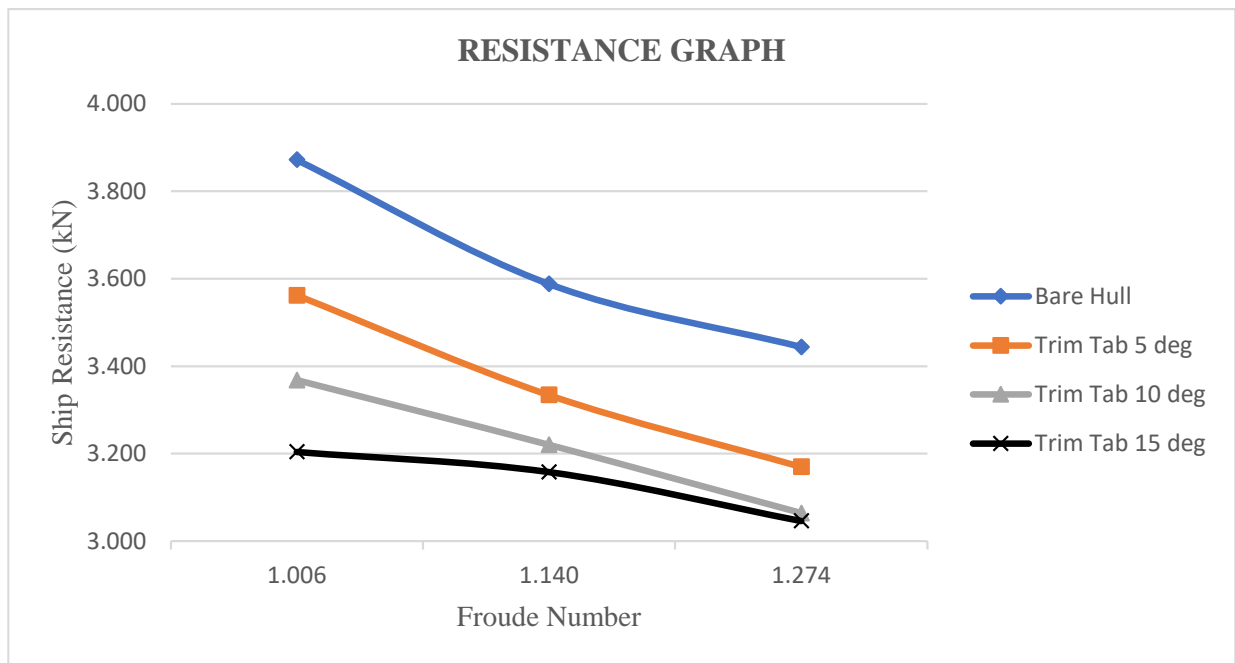


Figure. 3. Ship Resistance Graph.

## 2. Trim Angle

The trim angle of the ship is measured with respect to the center of gravity of the ship. Based on the simulation results in Table 3 and Figure 4, it was found that after installing the trim tab and the angle of inclination, it showed a significant reduction in the trim value of the ship. In the condition of Fn 1.006, the trim value of the

ship has changed by 46.72%. Then in the condition of Fn 1,140, the trim value of the ship has changed by 40.53%, and finally in the condition of Fn 1,274, the trim value of the ship has changed by 42.73%. From the analysis based on the following ship trim values, it was found that the best trim angle reduction occurred at 15° trim tab conditions.

TABLE 3.  
 TRIM ANGLE SIMULATION RESULT

Model	Fn	Trim (deg)	Reduction (deg)	%
Bare Hull	1.006	8.976	0.000	0.00%
	1.140	8.013	0.000	0.00%
	1.274	7.526	0.000	0.00%
Trim Tab 5 deg	1.006	7.589	1.387	15.45%
	1.140	7.048	0.965	12.04%
	1.274	6.284	1.242	16.50%
Trim Tab 10 deg	1.006	6.314	2.662	29.66%
	1.140	5.916	2.097	26.17%
	1.274	5.439	2.087	27.73%
Trim Tab 15 deg	1.006	4.782	4.194	46.72%
	1.140	4.765	3.248	40.53%
	1.274	4.310	3.216	42.73%

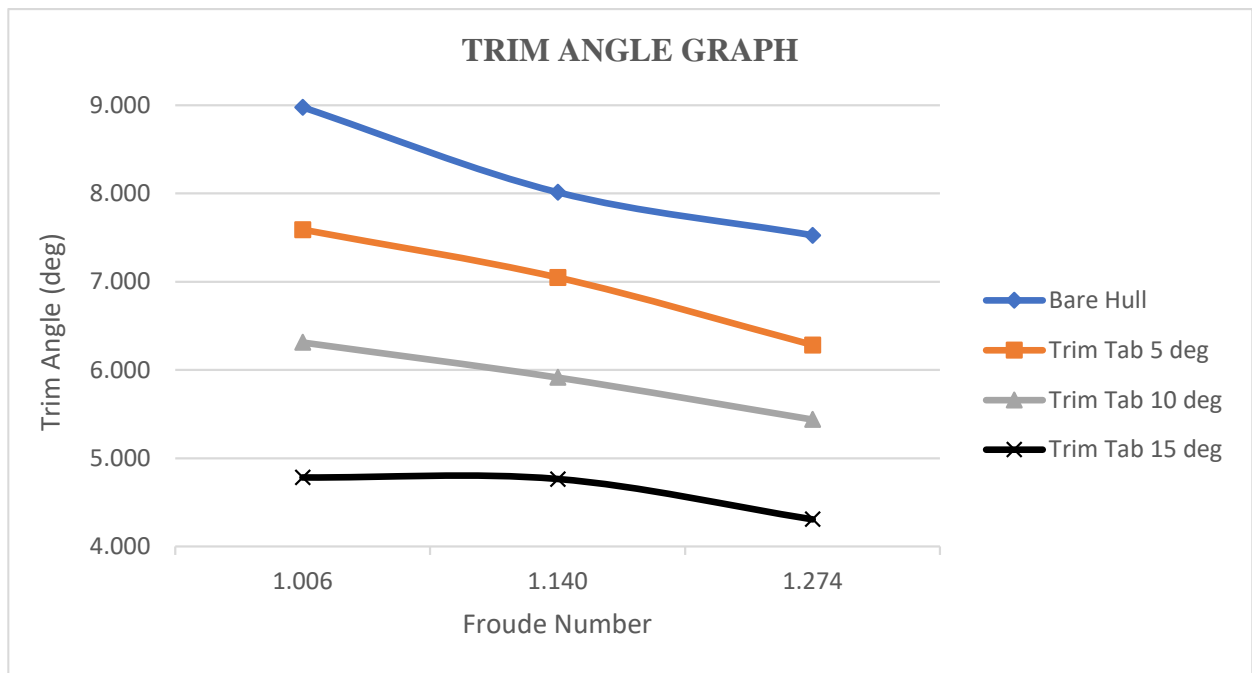


Figure 4. Trim Angle Simulation Result.

### 3. Wave Elevation

As it is known that one of the coefficients of the ship's resistance is the result of the formation of waves due to the movement of the ship. Therefore, by identifying the wave pattern generated by the ship, it can be seen the effect of adding a trim tab to the ship's resistance.

Based on the simulation results at a speed of 15 knots or Fn 1.006 in Figure 5, it was found that in the bare hull condition, the wave pattern at the stern of the ship tends to be irregular with a height of 0.85 m. In contrast to the

5° trim tab condition, the wave pattern looks straighter and the maximum wave height is reduced to no more than 0.7 m. Then on the trim tab 10°, the waveform tends to be the same as the previous condition, but the resulting wave height can be reduced to 0.65 m. Furthermore, in the 15° trim tab condition, the stern of the ship is mostly dominated by blue and light blue which indicates the low waves generated in the range of 0.2 to 0.3 m.

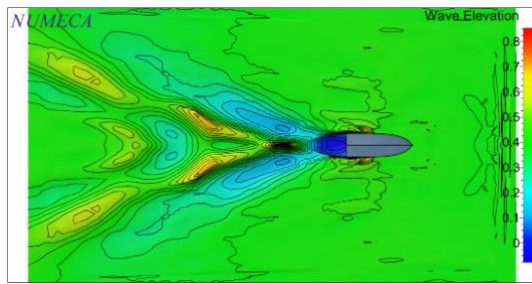


Figure (5.a)

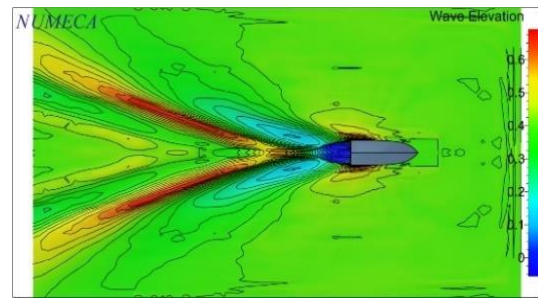


Figure (5.b)

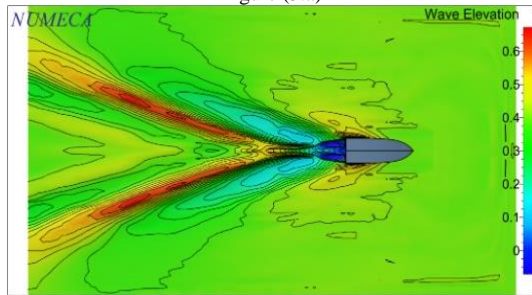


Figure (5.c)

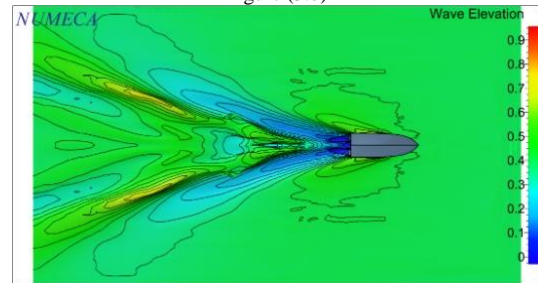


Figure (5.d)

**Figure 5.** Wave Elevation at Fn 1.006 (a) Bare Hull (b) Trim Tab 5° (c) Trim Tab 10° (d) Trim Tab 15°.

And for the simulation results at speed of 19 knots or Fn 1.274 in Figure 6, it is found that in the bare hull, the waves that appear at the stern of the ship are very high reaching  $> 0.7$  m and the wave movement tends to widen compared to the condition after the addition of the trim tab. The addition of trim tabs at the stern of the ship and the angle of inclination can affect the wave pattern of the ship for the better. From these values, it can be said that the greater the angle of the trim tab can reduce the

maximum wave height that occurs at the stern of the ship. In the 5° and 10 trim tab conditions, the maximum wave height that arises at the stern of the ship is still above 0.7 m, but on the 15° trim tab condition, there is a reduction in the maximum wave height that is generated, which is 0.675 m. From this discussion, it can be seen that the best wave height reduction is in the trim tab 15° condition.

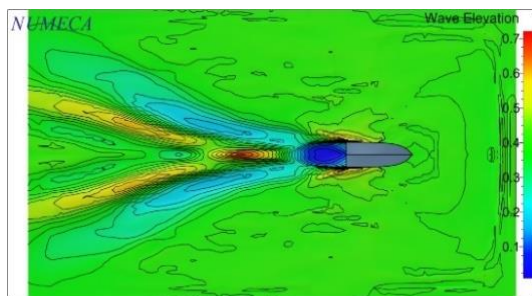


Figure (6.a)

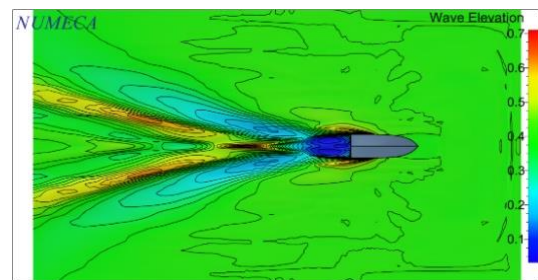


Figure (6.b)

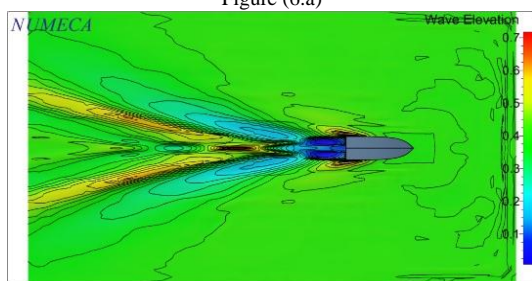


Figure (6.c)

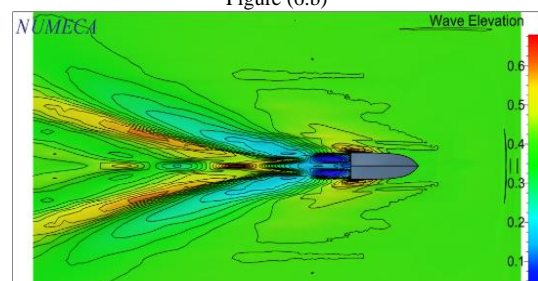


Figure (6.d)

**Figure 6.** Wave Elevation at Fn 1,274 (a) Bare Hull (b) Trim Tab 5° (c) Trim Tab 10° (d) Trim Tab 15°.

#### 4. Hydrodynamic Pressure

With the addition of trim tabs, it can cause an increase in pressure on the stern of the ship, especially in the area of adding trim tabs [6]. This can be proven by obtaining the hydrodynamic pressure value from the ship simulation results.

Based on the simulation at a speed of 15 knots or Fn 1.006 in Figure 7, it is show that in the bare hull

condition, the high pressure distribution is dominated by the hull section of the ship with the highest pressure reaching  $>4000$  Pa. Not much different from the previous condition, in the 5° trim tab the highest pressure is still dominated by the hull, while the trim tab area is dominated by yellow with a pressure value of around 2000 Pa.

While in the condition of the trim tab  $10^\circ$ , the red color on the hull faded slightly and there was an increase in pressure in the trim tab area which indicated the presence of high pressure on the trim tab with a maximum pressure reaching  $>5000$  Pa. Then in the condition of the

trim tab  $15^\circ$ , it was shown that the red area on the hull did not dominate much and shifted to focus on the trim tab area and there was a fairly high pressure increase up to  $>7500$  Pa.

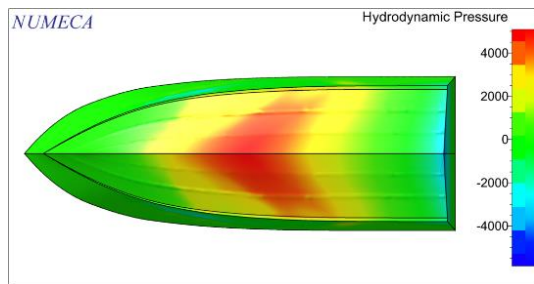


Figure (7.a)

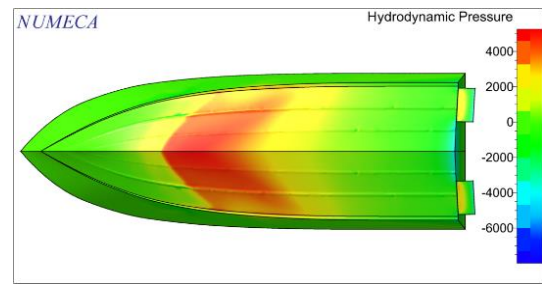


Figure (7.b)

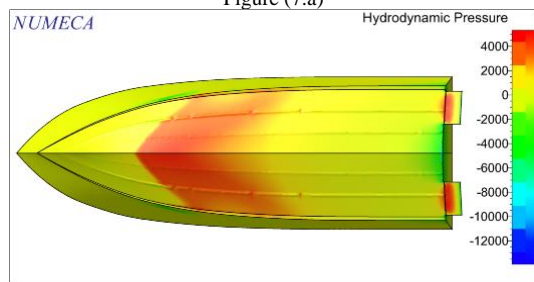


Figure (7.c)

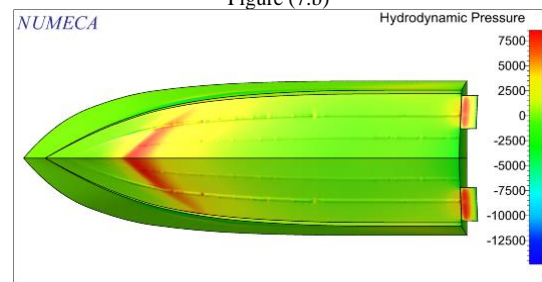


Figure (7.d)

**Figure 7.** Hydrodynamic Pressure at Fn 1.006 (a) Bare Hull (b) Trim Tab  $5^\circ$  (c) Trim Tab  $10^\circ$  (d) Trim Tab  $15^\circ$ .

And based on the simulation results at a speed of 19 knots or Fn 1.274 in Figure 8, it was found that in the bare hull condition, the pressure focused on the hull with a value of  $>4000$  Pa. Likewise in the condition of the  $5^\circ$  trim tab, a large increase in the value of the pressure that arises in the trim tab area reaches 6000 Pa while on the hull it can reach 8000 Pa. The highest pressure is still

focused on the hull which is due to this condition the angle formed is still relatively small.

While in the condition of the  $10^\circ$  trim tab, there is a red color in the trim tab area which indicates an increase in pressure which reaches 7500 Pa. Likewise, the greater the angle of the trim tab, which is at an angle of  $15^\circ$ , the pressure is focused on the trim tab area and there is a significant increase in pressure reaching 10000 Pa. With the vortex causes a lift force on the ship so as to minimize the occurrence of excessive stern trim and

### 5. Relative Velocity

The working principle of the trim tab is based on the

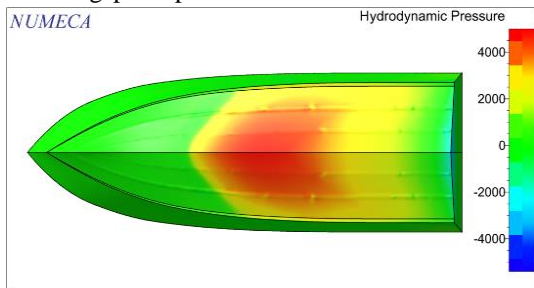


Figure (8.a)

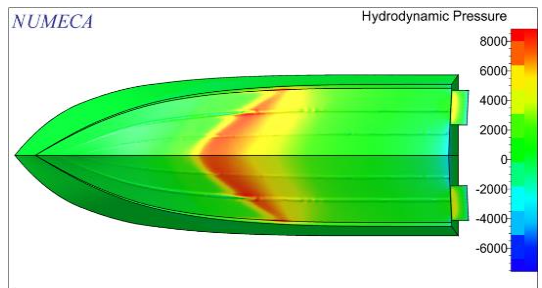


Figure (8.b)

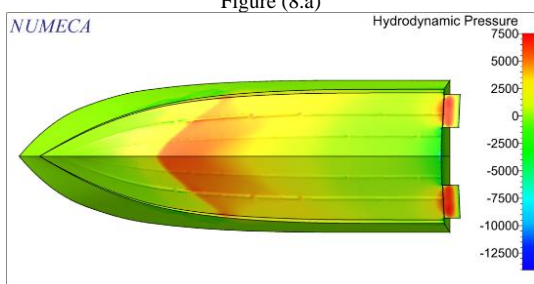


Figure (8.c)

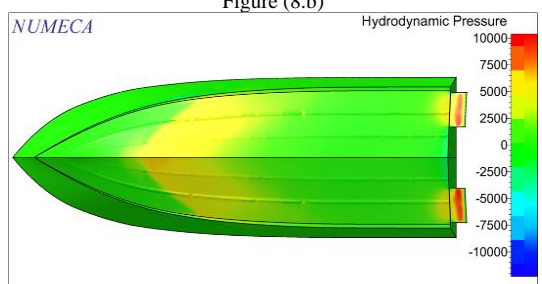


Figure (8.d)

**Figure 8.** Hydrodynamic Pressure at Fn 1.274 (a) Bare Hull (b) Trim Tab  $5^\circ$  (c) Trim Tab  $10^\circ$  (d) Trim Tab  $15^\circ$ .

eddy / fluid vortex that is formed in the area around the trim tab. The fluid vortex is caused by the trim tab blocking the flow of water at the bottom of the ship.

reduce the value of the ship's resistance.

Based on the simulation at a speed of 15 knots or Fn 1.006 in Figure 9, it was found that in the bare hull the

flow velocity around the stern of the ship tends to be constant, identified from the green color that is evenly distributed from the hull to the ship's stern. While in the condition of the 5° trim tab, there is a blue but not dominating color that appears around the trim tab area. This indicates a reduction in the flow velocity that appears in the area.

In contrast to the previous condition, in the 10° trim tab condition, the green color is slightly faded, and more and more vectors are light blue. This indicates that there are more areas where the flow velocity decreases. Further changes are shown in the condition of the 15° trim tab, the blue color increasingly dominates the trim tab area which indicates more and more areas around the trim tab are run into a decrease in flow velocity.

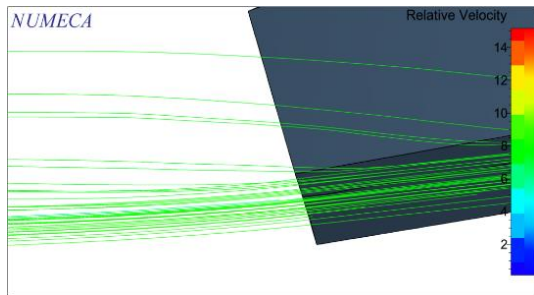


Figure (9.a)

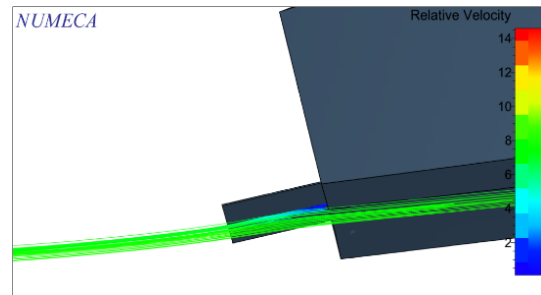


Figure (9.b)

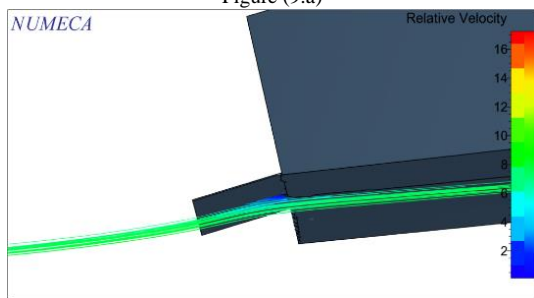


Figure (9.c)

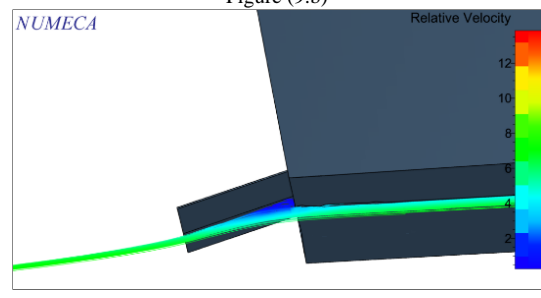


Figure (9.d)

**Figure 9.** Relative Velocity at Fn 1.006 (a) Bare Hull (b) Trim Tab 5° (c) Trim Tab 10° (d) Trim Tab 15°.

And at a speed of 19 knots or Fn 1.274 in Figure 10, it is found that in the bare hull, at the stern of the ship there is no bulge and the flow velocity tends to be constant, shown in green. In contrast to the condition of the 5-degree trim tab, the light blue and dark blue colors

appear when there is a flow velocity right in front of the trim tab. Then in the 10-degree and 15-degree trim tab conditions, the blue color begins to dominate in the trim tab area, where the flow velocity is reduced to a lower level until it approaches 0.

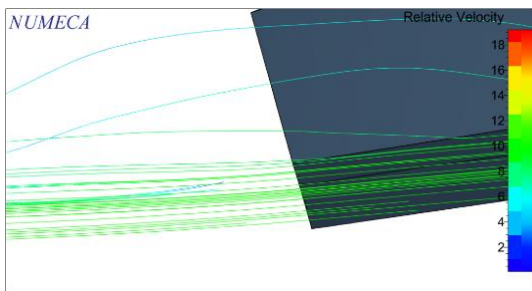


Figure (10.a)

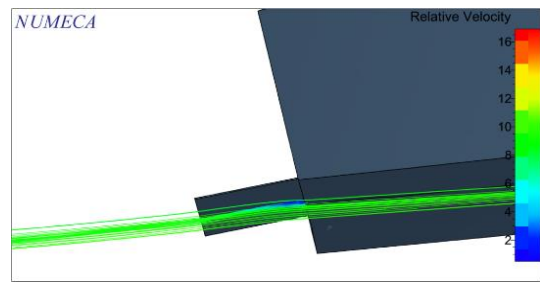


Figure (10.b)

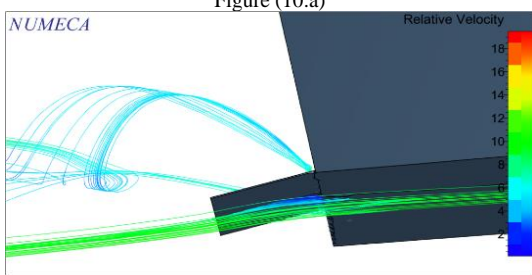


Figure (10.c)

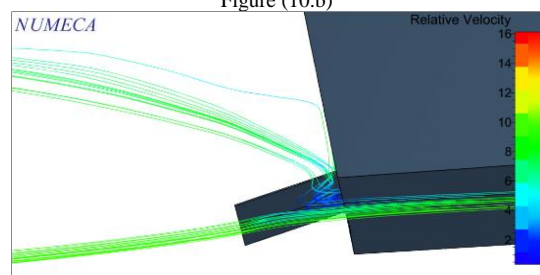


Figure (10.d)

**Figure 10.** Relative Velocity at Fn 1.274 (a) Bare Hull (b) Trim Tab 5° (c) Trim Tab 10° (d) Trim Tab 15°.

The blue color that appears around the trim tab area can be said to be an eddy or fluid vortex which work to generate lift at the stern of the ship. In the condition of

the trim tab 10 degrees and 15 degrees also shows the air flow that expands to the side of the ship and kicks up,



this is due to the large angle of the trim tab and consequently the high speed of the ship.

C. Propulsion Power Requirement

As explained in the previous sub-chapter that the higher the speed, the smaller the ship's resistance gain. However, in calculating the ship's propulsion power requirements, it becomes even greater. This is because the calculation of power requirements consists the parameters of ship resistance and ship speed.

Based on Table 4 and Figure 11, it was found that after the trim tab was installed, the propulsion power

requirement of the ship could be reduced. In the condition of Fn 1.006, the ship's propulsion power was reduced to 57.915 kW with a reduction of 17.25%. Then at the condition of Fn 1.140, the propulsion power of the ship was reduced to 64.695 kW with a reduction of 11.98%. And at 1.274 Fn condition, the ship's propulsion power has been reduced to 69.741 kW with a reduction of 11.56%. From the discussion, it was found that based on the propulsion power requirement, the largest reduction in any speed variations that occur on the ship with a trim tab angle of 15°.

TABLE 4.  
SHIP PROPULSION POWER REQUIREMENT

Fn	BHP <sub>MCR</sub> (kW)				Reduction (%)		
	Bare Hull	Trim Tab 5 deg	Trim Tab 10 deg	Trim Tab 15 deg	Trim Tab 5 deg	Trim Tab 10 deg	Trim Tab 15 deg
1.006	69.990	64.386	60.879	57.915	8.01%	13.02%	17.25%
1.140	73.504	68.300	65.965	64.695	7.08%	10.26%	11.98%
1.274	78.854	72.580	70.154	69.741	7.96%	11.03%	11.56%

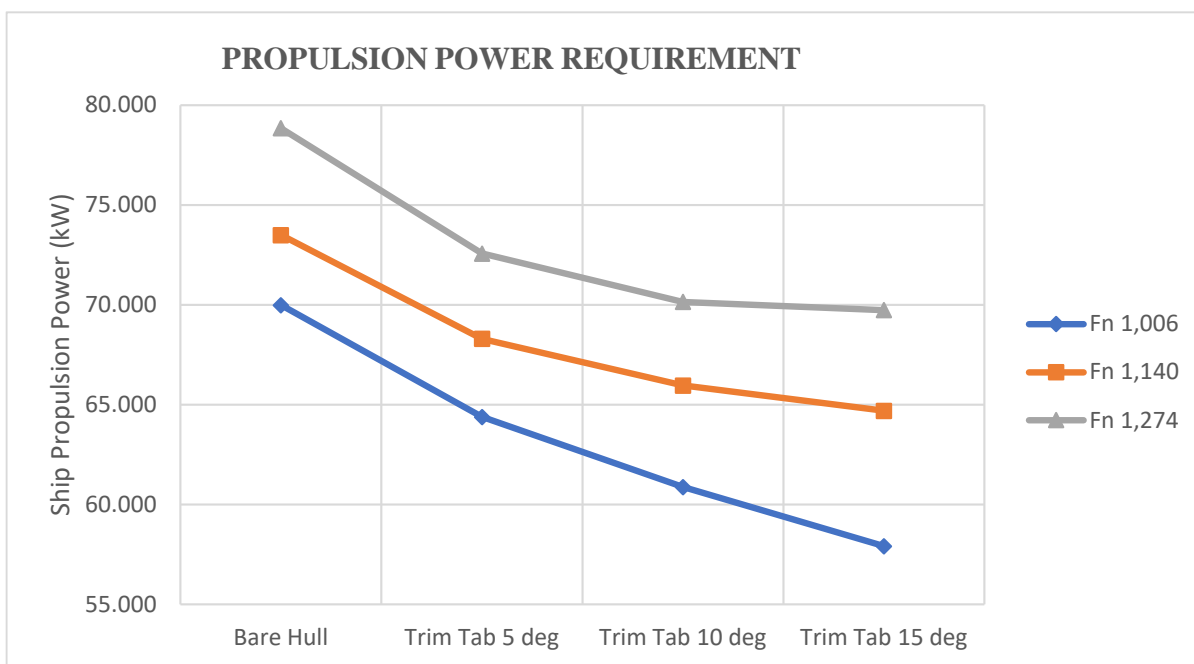


Figure 11. Ship Propulsion Power Requirement Graph

IV. CONCLUSION

Based on the results of the analysis and simulations that have been carried out on a 6 meter speed boat regarding the impact of the trim tab installation and its angle variations, the following conclusions can be drawn as follow :

1. Based on the characteristics of the speed boat with a length of 6 meters and a single outboard engine configuration, the appropriate geometry is obtained which is a trim tab with a span width of 18” (46 cm) and a chord length of 9” (23 cm) and is installed at the stern of the ship.
2. After installing the trim tab with a size of 46 cm x 23 cm on a 6 meter speed boat, it was found that there was an effect on the value of the resistance and trim of the ship. In general, the biggest change

- occurred in the condition of the 15° trim tab on all speed variations. It is proven by the reduction of ship resistance up to 17.25% with a reduction from 3.872 kN to 3.204 kN which occurs at a speed of 15 knots. While the trim value of the ship, obtained a reduction of up to 46.72% with a reduction from 8.976° to 4.782° which also occurred at a speed of 15 knots.
3. After installing the trim tab with a size of 46 cm x 23 cm on a 6 meter speed boat, it was found that there was a reduction in the propulsion power requirement of the ship. It can be concluded that the greater the angle of inclination of the trim tab, the smaller the required propulsion power of the ship. With details on the bare hull condition of 78.854 kW, at 5° trim tab angle of 72.580 kW, then on the trim tab 10° condition of 70.154 kW, and at 15° trim

tab angle of 69.741 kW with the largest reduction reaching 11.56%.

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