15. Similarity Comparative Analysis Results of Towing Tank and Numerical Calculations with Harvald Guldammer Method (Case Study of Propulsion Speed Reduction Pc-43)

By Okol Sri Suharyo

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Comparative Analysis Results of Towing Tank and Numerical Calculations with Harvald Guldammer Method (Case Study of Propulsion Speed Reduction Pc-43)

Arica dwi susanti[1], Ahmadi[2], Okol S Suharyo[3]
[1]*Indonesian Naval Technology College,*
Bumimoro-Morokrembangan, Surabaya 60187, Indonesia

Abstract

The vessel was designed using a steel material with a maximum speed of 27 knots and using engine power by 3 x 1800 HP, T = 1.40 at the empty draught and T = 1.70 at full draught. The speed was decreased in the current conditions by 22 knots at 1.50 meters draught within 1 year after its launching. This paper compared the calculation results of towing tanks and numerical calculations. The results from the manual calculations of power at T = 1.65 meters in 27 knots, the comparison of numerical calculation BHPscr = 4245.04 HP with towing tanks calculations of 4286.40 HP. Thus, the difference in numerical and towing tank results was very little and it could be concluded that it was the same, while the total power engines installed in the vessel (3 x 1800 HP) = 5400 HP (BHP). means a mathematical/theoretical speed of 27 knots can be achieved. Thus, the resistance and power is not one of the causes of speed reduction in Vessel Type PC-43.

Keywords - *Ship Resistance, Power Boats, Patrol Craft, Sea Trial, Towing Tank*

I. INTRODUCTION

Patrol vessel is a type of ship that emphasizes motion to perform its functions. This type of patrol vessels are designed to perform tasks in accordance with basic functions as "LIMITED PATROL VESSEL" which is capable of performing operations either singly or together with similar type of vessels supported by reliable Sewaco and Platform systems (Bertram V. , 2000).The fundamental extra component incurred by a sailing vessel is the induced drag resulting from the lift produced by the keel(s) and rudder(s) when moving at a yaw angle (Anthony F. Molland, 2011).

This paper have any literature to support the research about it, for example paper with title Introduction to Naval Architecture (Tupper E. , 1975). Basic Ship Theory (Tupper K. R., 2001). Practical Ship Design (Watson, 1998). Ship Resistance and Propulsion : Practical Estimation of Ship Propulsive Power (Anthony F. Molland, 2011). Practical Ship Hydrodynamics (Bertram V. , 2000). Ship Design and Contruction (D'arcalengelo, 1969). Resistance Propulsion and Steering of Ship (WPA Van Lamerren, 1984). Resistance and Propulsion of Ships (Harvald, 1992). Hydrodynamic of Ship Propellers (Andersen, 1994). Ship Design for Efficiency and Economy (Bertram H. S., 1998). Design of Propulsion Systems for High-Speed Craft (Bartee, 1975). Amethod of Calculation of Ship Resistance on Calm Water Useful at Preliminary Stages of Ship Design (Zelazny, 2014). An Invertigation Into The Resistance Components of Converting a Traditional Monohull Fishing Vessel Into Catamaran Form (Samuel, 2015). Empirical Prediction of Resistance of Fishing Vessels (Kleppesto, 2015). Designing Constraints in Evaluation of Ship Propulsion Power (Charchalis, 2013). Coefficients of Propeller-hull Interaction in Propulsion System of Inland Waterways Vessels with Stern Tunnels (Tabaczek, 2014). Numerical Investigation of the Influence of Water Depth on Ship Resistance (Premchand, 2015). The Wageningen Propeller Series (Kuiper, 1992). Principles of Naval Architecture Second Revision (Lewis, 1988). Marine Propulsion (Sladky, 1976).

Referring to those problems, the author intends to compare the analysis result of the towing tank and numerical calculation to the speed reduction.This paper would discuss about the speed reached 27 knots at 1.50 meters draft, the speed is decreased in the current conditions by 22 knots at 1.50 meters draft within 1 year after its launching. This could occur because of the draught differences between the sea trial and the operation, or a mismatch between the power efficiency of the machine and the design of the hull (Tao Xing, 2008). The purpose of this study was to compare the results of towing tank analysis and calculations along with method named numerical calculations by Harvald Guldammer to analyze the cause of speed reduction based on the vessel's resistance related to the change of vessel's draught and power engine. The benefit of this study is to develop the knowledge and technology of Indonesian Navy ALUTSISTA.

This Paper is organized as follows. Section 2 review about the basic ship theory. Section 3 gives result and discussion of research. Finally, in section 4 present conclusion this paper.

II. RESEARCH METHODOLOGY

A. *Technical Concept*

In the design of patrol craft that will be used as limited patrol craft, it is expected to have these conditions:

1. High Accuracy, It allows the tactical and technical information to deliver quickly so that decisions can be obtained accurately and rapidly.

2. High Acquacition, This ensures control over the threat better, it requires the sewaco system and platform to be reliable.

3. High Speed, With the speed and agility of the vessel, it allows to conduct amore dynamic and proper limited patrol.

B. *The Primary Size of The Vessel*

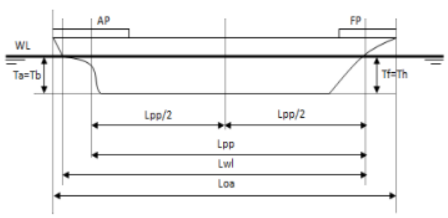

Fig.1. Longitudinal Shape of the Vessel

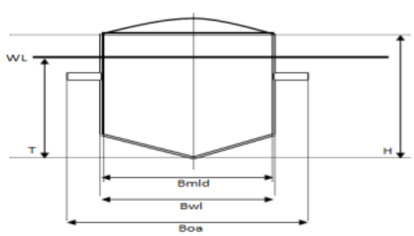

Fig.2. Cross-sectional Shape of the Vessel

1. Vessel Lengthis one of the primary size of the vessel seen from the longitudinal section as shown in Fig.1: Longitudinal Shape of Vessel, with the following explanation: (Tupper K. R., 2001)

- AP (After Perpendicular) is a vertical line that is made through the back of the steering.
- FP (Fore Perpendicular) is a vertical line that is made through the intersection between stem and full load of waterline.
- Lpp (Length between perpendicular) is the length between vertical line of the stern and vertical bow that is measured on full load of waterline.
- Lwl (Length on the water line) is the length from the forwardmost point of the waterline measured in profile to the stern-most point of the waterline.
- Loa (Length Overall) is the extreme length from the start of bow to the end of the stern.

2. Vessel Breadth (B) is one of the primary size of the vessel seen from the cross-sectional as shown in Fig.2: Cross-sectional Shape of The Vessel, with the following explanation: (Tupper K. R., 2001).

- Bmld (Breadth moulded) is the horizontal breadth of the amidships measured in the outside of the framework (excluded the thick shell of the hull).
- Bwl (Breadth at water line) is the maximum beam or breadth in the waterline of the ship measured in the waterline.
- Boa (Breadth over all) is the maximum breadth of the vessel measured from the left side of hull shell to the right side of hull shell, when there is any protrude part of the deck, then the B maximum is that protrude part.

3. The Depth of The Deck (H) is the vertical length from the base line to the lowest deck line measured in the center of the Lpp (Tupper K. R., 2001). Fig.1 : The Longitudinal Shape of The Vessel

4. Draught (T) is a vertical line from the base line to the waterline (Tupper K. R., 2001). Fig.2:Cross-sectional Shape of The Vessel. (Tmax) Maximum Draughtis a maximum depth of the sunken hull measured from the waterline to the lowest part of the ship. When the keel is even, the draught is applied to all of vessel's part. However, when the keel is not even, there are types of draught namely:

- Th = Tf = Draught in the bow that is measured in FP (vertical line of bow)
- Ta = Tb = Draught in the stern that is measured in the AP (vertical line of stern)

C. *The Hull of The Vessel.*

Regarding the correlation with the propulsion system of vessel, the fact that the body of the vessel in the water and air will get resistance force in the form of hydrodynamic and aerodynamic forces is become the main focus in this discussion.

Vessel resistance at some rate is the fluid force which works opposite to the movement of the vessel. That resistance will be equal with fluid force component which work in parallel with the shaft of vessel's motion (Bertram V. , 2000).

Seeing that the ship is engaged in the liquid fluid whose density value is greater than air, it is shown that the increase of the speed and the dimensions of a ship will make the removing energy to produce wave energy increase. This wave will create a friction with the hull with the opposite direction of the vessel and cause opposite force.

Total resistance (RT) on a vessel consists of the componentsor parts of the vesselwhich has the possibility of causing resistance (Holtrop, 1982). Principally, there are two parts of the ship which experienced the resistance, there are sinking part of the vessel and area above the water surface because the air also has inhibitory factor in certain condition. (RT) is used to determine the Efective Horse Power (EHP), which is defined as the power required to actuate a vessel at the speed of (VS) and able to overcome the resistance of (RT) and moreimportantly, (EHP) is used to know the amount of main power engine in order to avoid the surplus power and the unfulfilled power due to the power which can't overcome the vessel resistance. Total resistance (RT) of the vessel consists of different components of resistance caused by an interactive variety of causes. Review of the total resistance is practically needed to deal with this resistance in practice also it can be explained into several main components as follows:

1. Resistance Friction occurs due to the friction between wet surface of the vesseland media path.Friction occurs because all of the fluid has a viscosity value. The resistance components are obtained by integrating the tangential tension throughout the wet surface of the vessel in the direction of motion of the vessel. The components of this resistanceis shown below (Harvald, 1992):

$$Rf = 0{,}5.Cf.\rho.V^2.S \text{ (kN)} \quad (1)$$

Reynold Number (Rn)

$$Rn = Vs.Lwl / \upsilon \quad (2)$$

Coefficient of Friction Resistance (Cf)

$$Cf = 0{,}075 / (\text{Log}10Rn-2)^2 \quad (3)$$

2. Residual Resistance (RR) is the quantity as the result of total resistance reduction of the hull, also known as frictional resistance as the result of the calculation obtained by using a special formula. In general, the maximum part of remain resistance of the vessel is wave making resistance. The formula is shown below (Harvald, 1992):

$$RR = (0{,}5 \text{ x } \rho \text{ x } \Delta^{2/3} \text{ x } V^2) \quad (4)$$

Remain resistance has coefficient value which is obtained from ratio figures of length and volume which are the correlation between Froude number and elongated prismatic coefficient.

$$Fn = V / \sqrt{g.L} \quad (5)$$

3. Viscous Resistanceis component of the resistance related to energy released caused by viscous (Tupper K. R., 2001).

4. Pressure Resistance (PR) is component of resistance which is obtained by integrated the normal tension to all of the vessel's surface according to the direction of the vessel's motion (Tupper K. R., 2001).

5. Viscous Pressure Resistance (RPV) is component of the resistance which is obtained by integrated normal tension caused by viscous and turbulence. This quantity can't be calculated directly except for completely sinking object, in this case is equal to pressure resistance (Tupper K. R., 2001).

6. Wave making Resistance (RW) is component of resistance which is related to energy released to create gravitation wave (Wehausen, 1971)

7. Wave Pattern Resistance (RWP) is component of resistance which is concluded from the calculation of wave elevation far from vessel model, in this case is the subsurface velocity field. It means the fluid momentum can be assumed to relate to wave pattern using linear theory. The resistance is not included to the wave breaking resistance (Wehausen, 1971).

8. Wave Breaking Resistance (WBR) is component of resistance which is related to wave breaking in the vessel's stern (Wehausen, 1971).

9. Spray Resistance is component of the resistance which is related to energy released to create spray (Harvald, 1992).

10. Appendage Resistance is resistance from the shaft boss, shaft bracket and shaft, bilge keel etc. In using physical models, these models are generally equipped with parts and included in the measurement of resistance. Bilge keel is generally not installed. When the parts is not included, the resistance is called bare resistance (Harvald, 1992).

11. Roughness Resistanceis resistance caused by the roughness of the hull surface from corrosion and fouling in the hull (Harvald, 1992).

12. Air Resistance is resistance in the water surface and the superstructure caused by vessel's motion in the air flow (Harvald, 1992).

13. Steering Resistanceis resistance caused by the steering. The motion of the steering is directed to the straightening of the path or vessel maneuver (Harvald, 1992).

D. Displacement

Displacement is the weight of liquid displaced by the hull under the water surface. When the vessel floats in the balance state/motionless then the downward pressure equal to the pressure of the liquid to the hull. Thus the overall weight of the vessel and its contents at that time equal to the weight of liquid displaced by the hull immersed in a liquid in which the vessel is located (Anthony F. Molland, 2011).

Displacement : Lwl x B x T x CB x density of sea water (ton)

E. Volume Displacement

The volume of liquid displaced by the hull under the surfacewater where the ship is located (Anthony F. Molland, 2011).

Volume displacement: LWL x B x T x CB

F. Selection of the Main Engine

In the selection of the main engine, it is necessary to calculate the need of power engine. There are several indicators that need to be sought in order toobtain the desired results, those are effective horse power (EHP), thrust horse power (THP), delivery horse power (DHP), shaft horse power (SHP) dan brake horse power (BHP) (Anthony F. Molland, 2011).

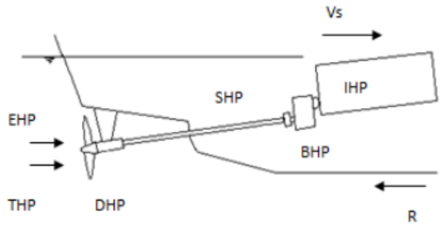

Fig.3. Propulsion System of The Vessel

1. Effective Horse Power (EHP) is power needed to actuate the vessel in water (without) the presence of wave) or to pull the vessel with this equation below (Harvald, 1992):

EHP = RT x Vs (6)

2. Thrust Horse Power (THP) is power distributed by the vessel's propeller without influence of the weather or environment condition (Lewis, 1988).

$$THP = \frac{EHP}{\eta h} \quad (7)$$

$$\eta h = \frac{(1-t)}{(1-w)} \quad (8)$$

$$w = (0.5\ x\ Cb) - 0.005 \quad (9)$$

$$t = k\ x\ w \quad (10)$$

3. Delivery Horse Power (DHP) is power distributed to propeller, with a bracket mechanical adverse and its propeller (Lewis, 1988).

$$DHP = \frac{EHP}{PC} \quad (11)$$

$$PC = \eta H\ x\ \eta rr\ x\ \eta P \quad (12)$$

4. Shaft Horse Power (SHP) is power distributed by the actuator engine (shaft power) (Lewis, 1988).

$$SHP = \frac{DHP}{\eta S \eta B} \quad (13)$$

5. Brake Horse Power (BHP) is used for the brake power or indicated power or power released by by the machine with the influence of the engine load (Lewis, 1988).

$$BHP = \frac{SHP}{\eta G} \quad (14)$$

The BHP above is the power released in normal sailing or SCR or BHP_{SCR} which is 85% of the power released in maximum condition or MCR. The power released in the maximum condition or MCR from the main actuator engine is explained below:

$$BHP_{MCR} = \frac{BHP}{0.85} \quad (15)$$

G. Propeller

The vessel's speed can be achieved due to the power of vessel's propulsion. Currently, the most commonly used is the screw propeller. This propeller changes the engine torque into thrust power that will move the fluid around it. Propeller is generally mounted on a shaft which is located at the stern of the ship. Propeller usually works by rotating and it produces a flow velocity which is shaped like a screw, therefore it is known as Screw Propeller. The screw type of propulsor has been classified into two types: Fixed Pitch Propeller (FPP) and Controllable Pitch Propeller (CPP) (Andersen, 1994).

Screw propeller is the most common form of vessel's actuator. The number of blades in the screw propeller is ranging from three to six blades and the position is protrude from the propeller hub. The propeller's blades is the part that can be merged with a hub or can be removed and mounted on the hub like the type of propulsion system named Controllable picth Propeller. Propeller is generally placed in a low position at the rear of the ship. Propeller must have a designed diameter to accommodate the vessel to avoid air drawing phenomenon and propulsive force produced by propeller when the vessel moves in pitching state by making the propeller sufficiently in sinking condition at a full load or not-full load condition. Screw propeller is divided into two categories: Conventional and Unconventional Propeller (Bartee, 1975).

H. Towing Tanks and Experimental Set-up

In propulsion tests, measurements include towing speed and propeller quantities such as thrust, torque, and rpm (Jeng-Horng Chen, 2006). Normally, open-water tests on the propeller alone are run to aid the analysis process as certain coefficients are necessary for the propeller design. Strictly, open-water tests are not essential for power prediction alone (Joe Longo, 2005). The model propeller is usually a stock propeller (taken from a large selection/stock of propellers) that approximates the actual design propeller. Propulsion tests determine important input parameters for the actual detailed propeller design, e.g. wake fraction and thrust reduction (Mohamad Pauzi Abdul Ghani, 2008). The model tests and experience of a towing tank mainly indicate the potential for improvement; CFD indicates where and how to improve the design (Bertram V., 2000).

Despite the ever increasing importance of numerical methods for ship hydrodynamics, model tests in towing tanks are still seen as an essential part in the design of a ship to predict (or validate) the power requirements in calm water which form a fundamental part of each contract between shipowner andshipyard. Tests are usually performed in towing tanks, where the water is still and themodel is towed by a carriage. (Alternatively, tests can also be performed incirculating tanks, where the model is still and the water moves) (Bertram V. , 2000).

The model size is determined by a number of boundary conditions (Bertram V. , 2000):

- The model should be as large as possible to minimize viscosity scale effects, especially concerning laminar/turbulent flow and flow separation.
- The model should be small enough to avoid strength problems (both internal strength of the model and loads on the test carriage).
- The model should be small enough such that the corresponding test speed can be achieved by the carriage.
- The model should be small enough to avoid noticeable effects of restricted water in the test basin.

The model is towed by weights and wires (Fig. 4). The main towing force comes from the main weight G1. The weight G2 is used for fine tuning (Bertram V. , 2000):

$$R_T = G_1 \pm G_2 \sin\alpha$$

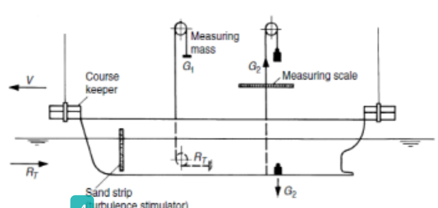

Fig.4. Experimental Set-up For Resistance Test

The sign is positive if the vertical wire moves aft. The angle is determined indirectly by measuring the distance on the length scale. Alternatively, modern experimental techniques also use strain gauges as these do not tend to oscillate as the wire-weight systems. The model test gives the resistance (and power) for towing tank conditions (Bertram V. , 2000):

- (usually) sufficiently deep water
- no seaway
- no wind
- fresh water at room temperature

I. *Method of Research.*

The following is the structure to be designed in this paper:

1. Analysis of vessel resistance towards the draft change of the Indonesia Navy Vessel type PC-43 with theories that support it.

2. Analysis of engine power installed towards the speed of Indonesian Navy Vessel. Methods used in this paper were literature study, field study, model simulation and numerical calculation (Guldhammer, 1974).

III. RESULT AND DISCUSSION

In this part, the authors would like to discuss about resistance and power calculation of the vessel engine. Besides using formulas in the book of resistance and engine power with the help of Excel program on the computer, towing tankwas also used for comparison in order to maintain high accuracy in the results.

A. *The Resistance Calculation of The Vessel with Harvald Guldammer Method*

To calculate the total of resistance of the vessel at draught (1.50 m dan 1.65 m) in the speed of 22, 25 dan 27 knots, primary size of the vessel, lines plans, formulations, table and diagram were used. Input parameter design :

Loa : 43 meters
Lpp : (T 1.50 = 40.13 meters) (T 1.65 = 40.29 meters)
Lwl : (T 1.50 = 41.74 meters) (T 1.65 = 41.90 meters)
B : 7.4 meters
H : 3.4 meters
T : 1.50 and 1.65 meters
Cb : 0.496
ρ of sea water : 1.025 ton/m³

Table 1. The Result of Resistance Calculation of The Vessel with Harvald Guldammer Method

Speed (Knots)	Resistance Draught T:1.50	Resistance Draught T:1.65
22	108.882 kN	126.421 kN
25	127.307 kN	146.611 kN
27	137.437 kN	159.478 kN

B. *Power Calculation of the Vessel*

To calculate the total of vessel resistance at the draught of (1.50 m dan 1.65 m) in the speed of 22, 25 and 27 knots.

Table 2. The Result of Power Calculation of The Vessel

Speed (Knots)	Power Draught T:1.50	Power Draught T:1.65
22	2360.24 HP	2741.94 HP
25	3153.27 HP	3613.46 HP
27	3658.32 HP	4245.04 HP

C. *Calculation with Towing Tank*

To determine the resistance and power effective (EHP) of the vessel, a 43 m model (with scale of 1:30.25 from the actual vessel) of Patrol Craft (PC) had been constructed from fibers glass reinforced plastics (FRP) material coated with paint and resin. The model experiments were tested in 2 laden conditions included 1.65 meters (full load) and 1.50 meters. Measurement data are presented in Table 3.

Table 3: Draught Vessel Model T: 1.50 and Draught T : 1.65

Particular Dimension	Model T:1.50	Model T:1.65
LOA	1.4215 M	1.4215 M

LPP	1.3264 M	1.3319 M
B	0.2446 M	0.2446 M
H	0.1124 M	0.1124 M
T	0.0496 M	0.0545 M
WSA	0.2918 M^2	0.3064 M^2
DISPLACEMENT	6.986 KG	8.226 KG

The vessel model tested before the test showed the model position on the various sides in the form of transom.

Fig.5. Appearance of Vessel from Sideway

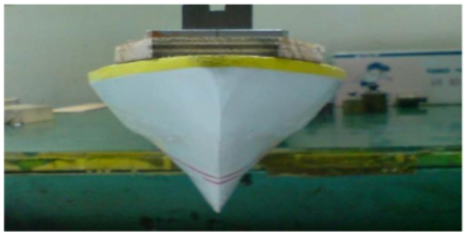

Fig.6. Appearance of Vessel Model from Front-side

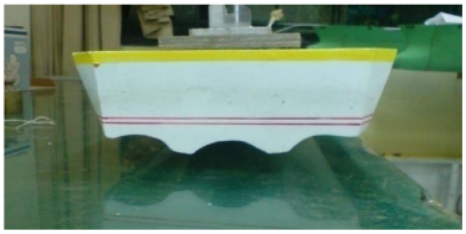

Fig.7. Appearance of Vessel Model from Back-side

1) The Analysis of Model Test Results

Tensile test of the model was performed on 2 kinds of draft which was respectively 0.0545 m and 0.0496 m or on the actual ship with the draft of 1.65 m and 1.50 m. The vessel was pulled at certain speed from 20 knots to 29 knots or 1.90 m/sec to 2.73 m/sec (or Froude 0.53 to 0.76) on the model scale. This was perfomed to determine the characteristics of obstacles and the magnitude of ship propulsion at various speeds. Overall model testing was in moderate and fast ship mode in accordance with existing Froude figures.

The model was tested in a calm waters condition where the end result of power estimation was in the form of BHP (brake horse power) quantity. To know the size of the machine, the measurement results should be corrected by doing a correction of the ship's body efficiency, propeller shaft, propeller, steering, the waters where the vessel will be operated, etc

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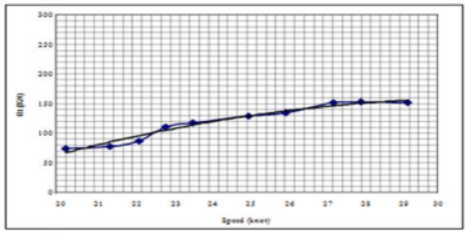

Fig.8. Relationship Between Vessel Speed and Resistance at Draft T : 1.50

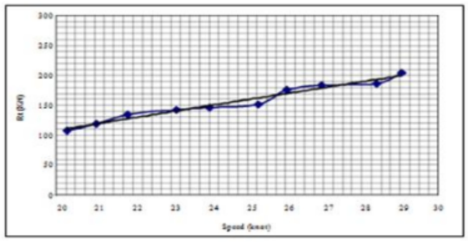

Fig.9. Relationship Between Vessel Speed and Resistance at Draft T : 1.65

Fluctuations in the relationship between speed and the total ship resistance (kN) of the vessel are shown in Fig.8 and Fig.9 Clearly there was an increase in resistance as the speed increases relative regularly in the vessel. This increase was followed by the arising and increasing intensity of wavebreaking that generally occurs in high-speed vessel. Through video viewing model testing, it could be seen that the wave breaking was relatively well wasted to the side of the vessel in the bow. This indicated that the shape of the ship's bow had been good at hydrodinamic.

However, in the stern area of the ship, there was a wake phenomenon or a quite significant wave spin. This was due to the presence of transom stern portions that are immersed in water as the speed of the vessel increases. Consequently, the resistance of the vessel was increased.

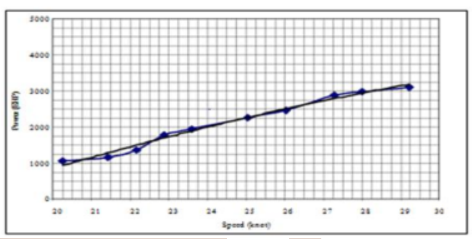

Fig.10. Relationship Between Vessel Speed and Ship EHP at Draft T : 1.50

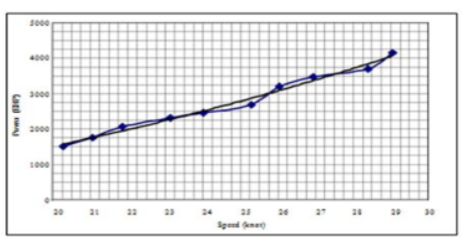

Fig.11. Relationship Between Vessel Speed and Ship EHP at Draft T : 1.65

Fig.10 and Fig.11 showed the relationship between speed (knots) and the magnitude of ship propulsion (BHP). It was clear that there was an increase in BHP as a result of increasing ship speed. At 1.50 meters draft and speed of 25 knots, BHP ship was 3111.49 HP while at 1.65 meters draft and speed of 25 knots, BHP ship 3653.33 HP.

The effective power of the vessel was suspected to be too large from the initial planning due to the formation of wave spin in the stern area as shown in the accompanying video footage. Therefore, the repair of undersea ships in the stern area was believed to minimize total ship resistance

D. Discussion

The comparison between the numeric and towing tank calculation towards the Resistance and Power at draught of T=1.50 and T=1.65 with speed of 22, 25, 27 knots.

Table 4. Comparison Between Numeric and Towing Tank Resistance in Draught T=1.50

Speed (Knots)	Resistance (Numeric)	Resistance (Towing Tank)
22	108.882 kN	111.047 kN
25	127.307 kN	128.647 kN
27	137.437 kN	151.406 kN

Table 5. Comparison Between Numeric and Towing Tank Resistance in Draught T=1.65

Speed (Knots)	Resistance (Numeric)	Resistance (Towing Tank)
22	126.421 kN	134.54 kN
25	146.611 kN	151.72 kN
27	157.478 kN	184.21 kN

Table 6. Comparison Between Numeric and Towing Tank (BHPscr) in Draught T=1.50

Speed (Knots)	Power (Numeric) BHPscr	Power (Towing Tank) BHPscr
22	2360.24 HP	2331.28 HP
25	3153.27 HP	3111.49 HP
27	3658.32 HP	3554.50 HP

Table 7. Comparison Between Numeric and Towing Tank (BHPscr) in Draught T=1.65

Speed (Knots)	Power (Numeric) BHPscr	Power (Towing Tank) BHPscr
22	2741.94 HP	2747.72 HP
25	3613.46 HP	3653.33 HP
27	4245.04 HP	4286.40 HP

IV. CONCLUSION

From the calculation of the draught of T=1.65 meters and V=27 knots, maximum power obtained from the comparative BHPscr numerical calculation results = 4245.04 HP with the calculation of towing tanks 4286.40 HP. Thus, the difference in numerical and towing tank results was very little and could be conclude to be the same. Then, the expected speed (27 knots) could be achieved, while the total power engines installed in the vessel (3 x 1800 HP) =5400 HP (BHP). so that the vessel can be operated as its basic function of "LIMITED PATROL CRAFT" with the adjustment of the speed and the condition of the waters where the vessel is operated.

ACKNOWLEDGEMENTS

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