Wave: Jurnal Ilmiah Teknologi Maritim
(Journal of Maritime Technology)

Vol. 18, No. 1, Juni 2024: page: 23-31
p - ISSN: 1978-886X
e - ISSN: 2614-641X

The Effect of Bow Flare Angle Variation on Speed Boat Resistance

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Article Info

Article history:

Received May 21, 2024
Revised July 2, 2024
Accepted August 9, 2024

Keywords:

Bow Flare Angle
Speed Boat
Hydrodynamic Resistance
Speed Variaton
Energy Efficiency

ABSTRACT

Today's ship design industry needs innovation, especially in speed boat design, to improve efficiency and stability. The study aims to analyze the influence of the variation of the bow flare angle on the obstacles on the speed boat. Through numerical simulations using Maxsurf Resistance software and Savitsky Pre-Planing, Savitsky Planing, and Holtrop calculation methods, the study analyzed variations in bow flare angles of 25º, 30º, and 35º at speeds of 17, 19, and 21 knots. The simulation results showed that the 35º bow flare angle gives the lowest impediment of 34 kN and requires a power of 367,163 kW at a speed of 21 knots, making it a more efficient choice compared to the 25º and 30º angles, which yield the highest impedance of 34.2 kN and requires 369,739 kW power. This analysis confirms that a larger bow flare angle can reduce barriers and improve energy efficiency, which is important for the design and operation of speed boats. These results show that choosing the right bow flare angle can improve ship speed efficiency by reducing obstacles and fuel consumption. The results of this research are expected to be beneficial to the designers and operators of speedboats in achieving optimal performance.

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INTRODUCTION

Nowadays, the ship design industry needs innovation in maritime transport, especially ships, to sustain the existence of marine states worldwide (Fathuddiin et al., 2020). The bow flare angle is a part of the design that affects the impediment and stability of the speed boat. The angle of inclination on the body plan of the ship is measured from the cut of the middle line against the loaded line with the vessel's deck (Setiawan et al., 2022).

Speed boats are a category of fast ships with a higher speed for rescue and inspection/investigation activities in coastal waters, rivers, lakes and transport modes of crossing (Siswanto, 2009). Along with the growing demand for fast and stable boat speeds, understanding how variations in bow flare angles can affect boat speed performance becomes vital. These variations can have a significant impact on hydrodynamic barriers on speed boats.

A ship's barrier is a fluid style that opposes its movement and is influenced by various factors such as size, speed, the coefficient of the shape of the vessel's armour, heavy displacement, volume displacement, and the size of the wet surface of the ship (Laamena & Taihutu, 2021). In this study, the Savitsky and Holtrop equation methods are used to calculate the obstacles on a speedboat. The results are compared to the calculations using the software Maxsurf Resistance. The study (Setiawan et al., 2022) entitled "Effects of Bow Flare Angle Variation on the Movement of the Bulk Carrier 44000 DWT", which varied the bow flare angles 10º, 15º, 20º, 25º, and 30º, discusses the influence of the bow flare angle on the heave, pitch, and possible wetness deck and bottom slamming responses on the bulk carrier 44000, DWT. The calculations were made using Maxsurf and Ansys Aqwa software.

The main focus of this research is on speed boats with monohull belly types. Although speed boats have many variations, previous research has not specifically shown the influence of bow flare angle variation on the boat's speed barriers.

Therefore, this study aims to obtain the characteristics of boats with bow flare angle variations to get the smallest total obstacle that meets IMO standards and provide a more in-depth description of the "Effect of Bow Flare Angle Variation on Speed Boat Resistance." Hopefully, the results of this research can be useful and help address the development of more hydrodynamically effective speedboat designs, improving safety aspects in the world of water transport.

METHOD

Research Methods

This research was conducted using numerical and analytical simulations. Maxsurf software was used to collect empirical data on the hydrodynamic resistance of speedboats with varying bow flare angles. Further data analysis was performed to identify trends and relationships between the studied variables.

Maxsurf is a software to create a ship model (Laamena & Taihutu, 2021) (Rachman et al., 2020). Maxsurf software is used to generate line plans in a 3D form. Maxsurf has several software programs, including Hydromax, Hull Speed, Seakeeper, Workshop, and Span. (Laamena & Taihutu, 2021).

Research Flow Diagram

The method in Figure 1 shows the flow diagram used to compile this study.

Literature studies

This stage involved a comprehensive literature review to understand the basic theory and related research on bow flare angles and hydrodynamic barriers on speedboats. The literature study helped formulate initial hypotheses and identify variables that need to be observed.

Computing Modeling/Ship Design

Considering the influence of the variation of the bow flare angle on ship movement, speedboats with the primary dimensions listed in Table 1 were utilized. Based on these dimensions, the ship's hull was modelled using the Maxsurf Modeler Software, illustrated in Figure 3. This formed the fundamental framework of the current research.

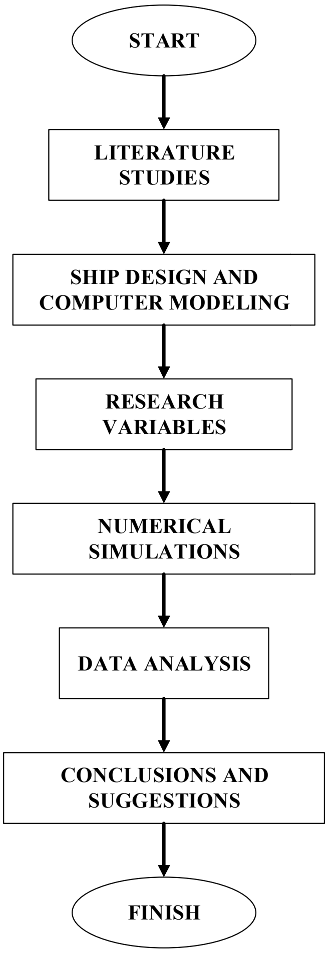


Figure 1. Research flow diagram

Maxsurf Modeler is a software application designed for creating 3D ship design models and conducting their analysis (Liddin & Pranatal, 2023). It allows users to visualize 3D models incorporating input data for various surface designs, facilitating easy image viewing. The modelling capabilities of Maxsurf Modeler also enable the creation of diverse hull shapes and variations, supported by integrated hydrostatic calculations within the ship design process. This feature simplifies experimentation with hull forms and exploration of structural parameters (Kurinawan &Pranatal, 2024).

Table 1. Main size of the ship
(Syarifuddin et al., 2021)

Item	Unit
Total Length (LoA)	20.00
Initial Line Length (Lwl)	19.28
Length Between Straight Lines (Lpp)	19.28
Width (B)	5.50
Height (D)	2.10
Terms (T)	1.00
Total Length (LoA)	20.00

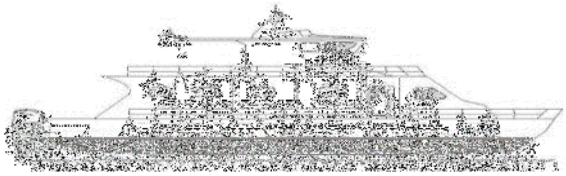


Figure 2. Reference design of the speed boat(Syarifuddin et al., 2021)

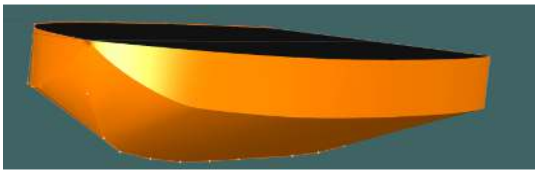
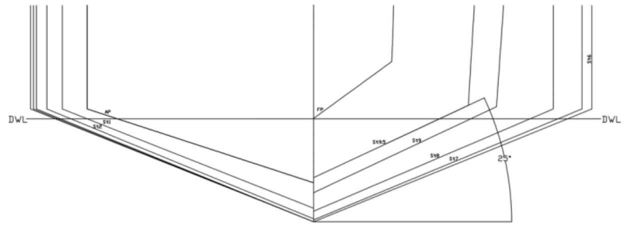


Figure 3. Modeling of the ship's structure

Research Variables

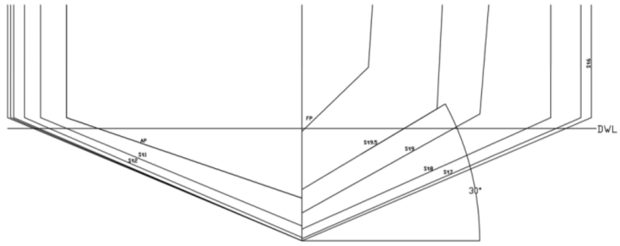
The free variables in this study are variations in the bow flare angle and the speed of the boat. The variations of the bow flare angle studied are 25º, 30º, and 35º, as modelled in Figures 4, 5, and 6.

In this study, the speed measurement method can be employed in accordance with applicable maritime standards to determine the speed of the boat, as depicted in Figure 2. The reference vessel for this study is a type III speed boat (rescue boat) designed to achieve a speed of 21 knots (Syarifuddin et al., 2021). Therefore, the variations in speed for the speed boat were 17 knots, 19 knots and 21 knots.



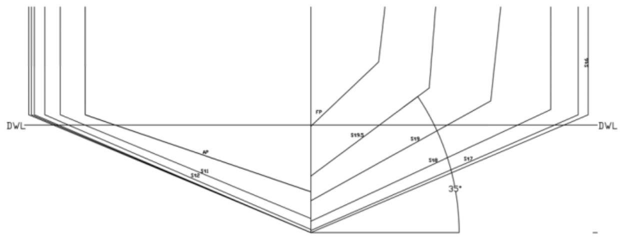
Angle 25º

Figure 4. Bow flare modeling angle 25º



Angle 30º

Figure 5. Bow flare modeling angle 30º



Angle 35º

Figure 6. Bow flare modeling angle 35º

The variable under investigation in this study is the flow barrier on the speed boat. The barriers to be examined are the hydrodynamic barriers generated by the variation of the bow flare angle of the speed boat. These barriers can arise from frictional resistance and wave-making resistance caused by the movement of the speed boat over the water surface.

Numeric Simulation

In this phase, numerical simulation was conducted using Maxsurf Resistance software to vary the bow flare angle on the speed boat model. The resulting data encompassed hydrodynamic barriers and pressure distribution. Maxsurf Resistance offers a method for predicting a ship's resistance. Predictions from Maxsurf Resistance can be automatically read and measured to obtain the necessary parameters, or these parameters can be entered manually (Rachman et al., 2020).

Several methods are available to predict ship resistance. For this study, the Savitsky pre-planning, Savitsky planning, and Holtrop methods were employed (Pranatal, 2020). (Mercier & Savitsky, 1973). In 1973, this method was used to conduct barrier calculations, performing a regression analysis of calm water resistance across seven series of transform-stern hulls comprising 118 hull forms. The Holtrop method was also utilized in the research to ensure that the model accurately represents the original (Pangestu et al., 2021).

Data Analysis

The data obtained from the simulation was analyzed to identify the relationship between the variation in the bow flare angle and the speedboat's hydrodynamic barriers. Statistical analysis was used to test the result's significance and determine the significant outcome.

The data obtained from the numerical simulation was analyzed using descriptive statistical methods and regression analysis. The correlation between the bow flare angle and the hydrodynamic barrier on the speed boat was evaluated. Additionally, a sensitivity analysis was performed to determine the extent to which changes in the bow flare angle affect the boat's speed performance.

RESULTS AND DISCUSSION

After the simulation process using the Maxsurf Resistance software was completed, several analysis results were obtained, including graphs in Figures 7 to 9. Figures 7 to 9 show

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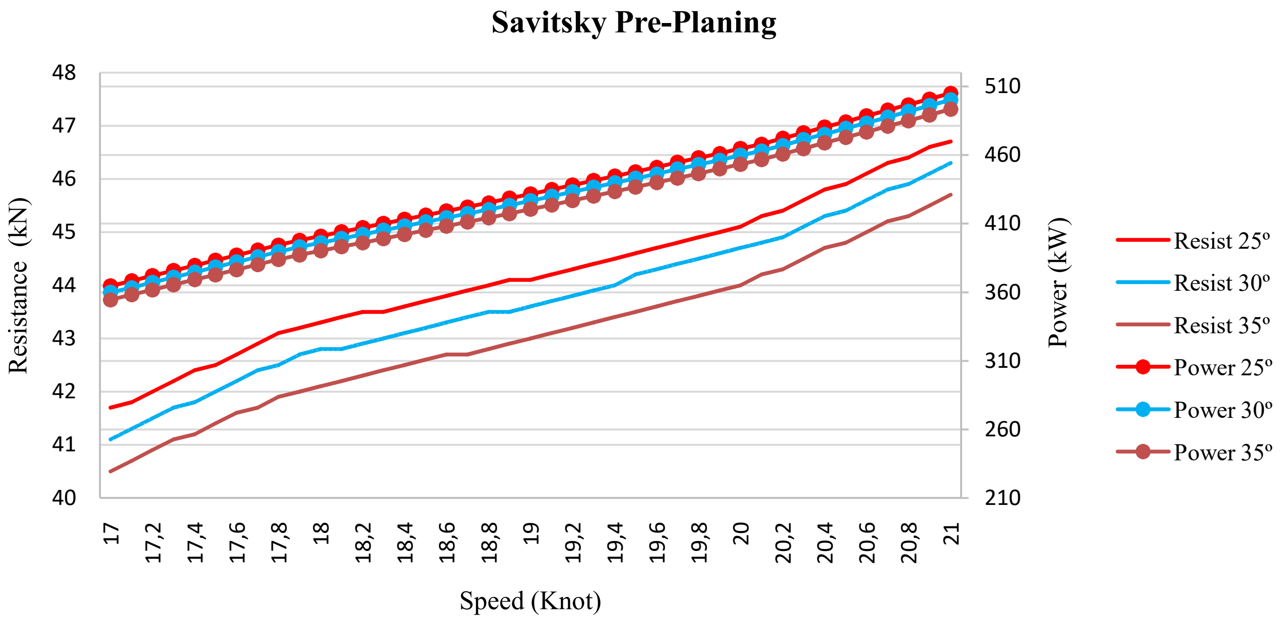

Figure 7. Savitsky pre-planing method simulation outcome diagram

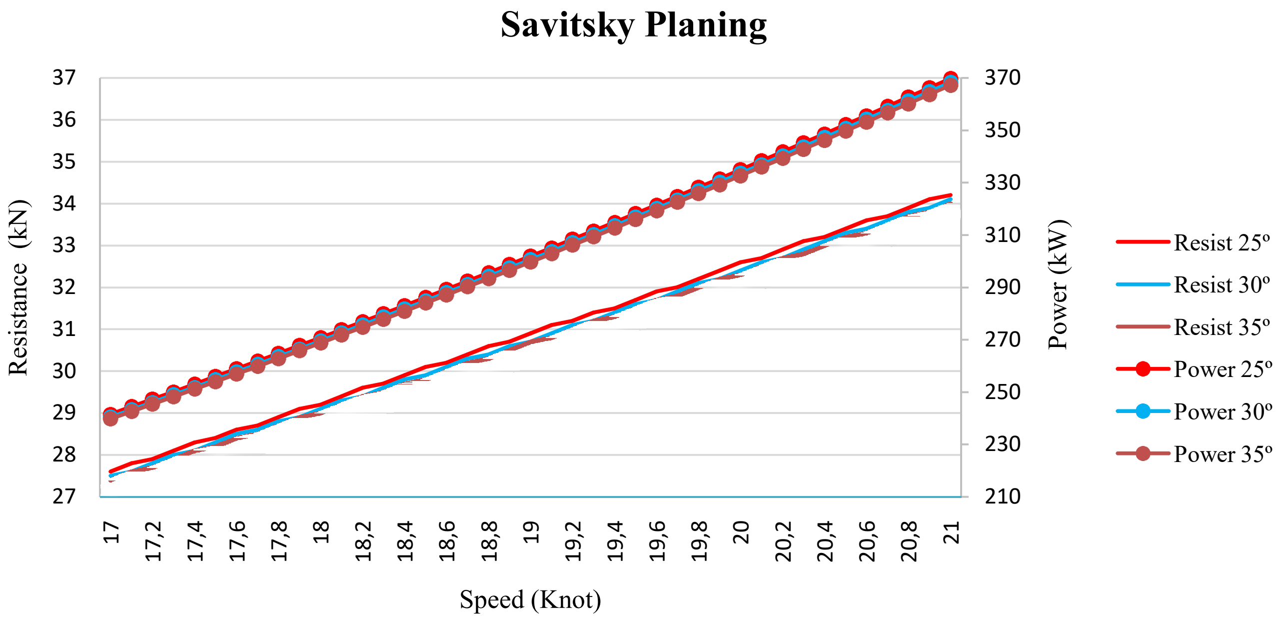

Figure 8. Diagram of simulation results of Savitsky planing method

graphs of the barrier values and power using three methods: Savitsky Pre-Planning, Savitsky Planning, and Holtrop. The diagrams illustrate the differences and similarities between the methods used, providing a clearer picture of the hydrodynamic performance of ships at different speeds. The Savitsky Pre-Planing method analyzes the ship's performance at moderate speeds before reaching full planning conditions. The results of the simulation, varying the bow flare angle on a speed boat using Maxsurf Resistance software, show variations in obstacle values and power requirements at speeds between 17 and 21 knots.

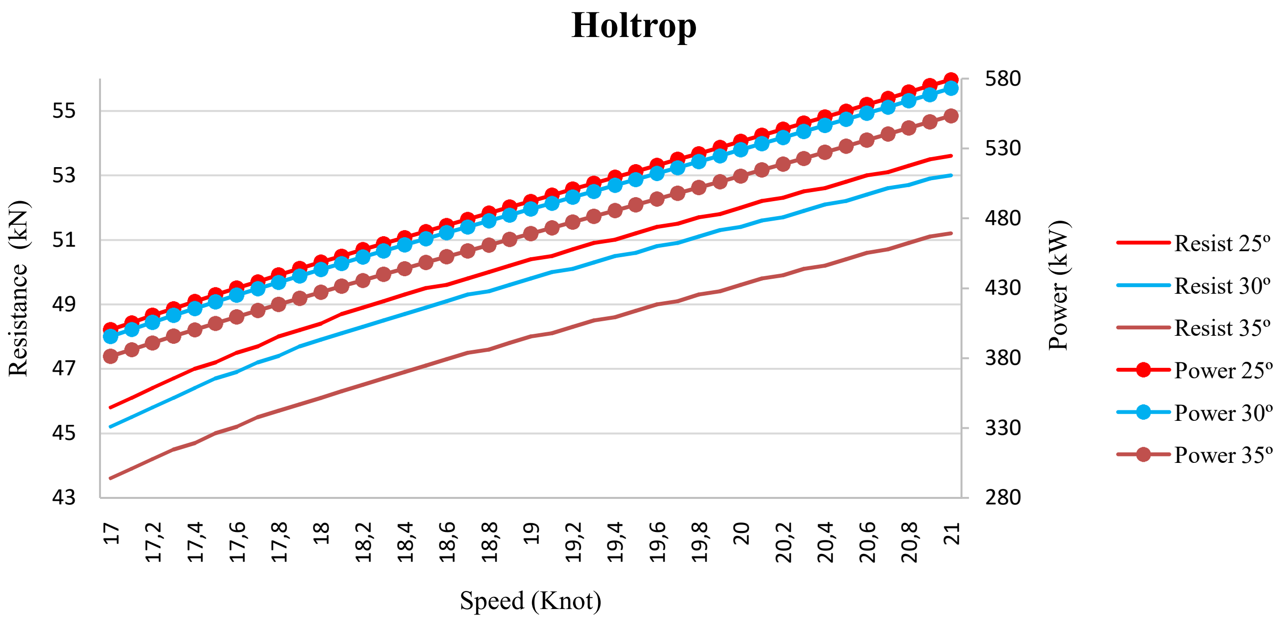

Figure 9. Holtrop method simulation outcome diagram

The angle of the bow flare significantly influences the hydrodynamic pressure and waves generated by the vessel. The simulation results indicate that a 35° bow flare angle produces the smallest barrier value of 45.7 kN at a speed of 21 knots, requiring only 493.232 kW of power. This suggests that a larger bow flare angle can minimize the resulting barrier, implying better energy efficiency at that speed.

Meanwhile, a 25° bow flare angle gives the greatest barrier value of 46.7 kN at a speed of 21 knots, requiring 505,046 kW of power. This suggests that a smaller bow flare angle tends to produce a larger barrier, thus requiring power to reach the same speed. The difference in barrier and power values between the 25° and 35° bow flare angles highlights the importance of choosing an optimal bow flat angle to improve boat speed performance and efficiency.

In the context of speed boat design, these results provide important insights into how variations in the bow flare angle affect the obstacles and power requirements. Using the optimal bow flare angle can reduce fuel consumption and increase the speed of the ship without adding to the engine load. Therefore, choosing the optimum bow Flare angle is a critical factor in the design and operation of speed boats to ensure efficient and economical performance.

Overall, this study confirms that the Savitsky Pre-Planing method is highly useful for analyzing the influence of bow flare angles on speed boat performance.

The Savitsky planning method is used to analyze the ship's performance when it reaches a speed high enough to enter the planning mode, where most of the vessel's body is above the water's surface. This method also shows that the difference in obstacles between the two bow flare angles is not very significant. The 35° bow flare angle shows the lowest obstacle value of 34 kN and requires a power of 367,163 kW, indicating its potential to reduce water resistance effectively.

On the other hand, although the 25° bow flare angle shows a slightly higher barrier value of 34.2 kN and requires a power of 369,739 kW, this difference suggests that a 25° bow flare angle requires somewhat more power for equivalent speed. In a design context, choosing a 35º bow flare angle can offer advantages in fuel efficiency and overall performance, highlighting the importance of considering the trade-off between aerodynamic resistance and engine power requirements.

The Holtrop method is one of the methods used to analyze the ship's resistance under various speed and hull design conditions. In this method, the difference between barrier and power values is more pronounced. The 35º bow flare angle results in the smallest resistance of 51.2 kN, requiring 553.458 kW of power, whereas the 25º angle exhibits the greatest resistance of 53.6 kN, with a power requirement of 579.369 kW.

This difference suggests that a 25º bow flare angle requires more resistance and power than a 35º angle, indicating that a larger angle could be a more efficient choice for speedboats operating at speeds of 17 to 21 knots.

Overall, the results of this simulation highlight the significant role of the bow flare angle in boat speed performance, particularly concerning resistance and power requirement. Larger angles, such as 35º, generally increase resistance and demand more power, whereas shallower angles, like 25º, can enhance efficiency by reducing resistance and power consumption.

CONCLUSION

Based on the results of numerical simulations with variable bow flare angles using three different simulation methods, it can be concluded that:

The 35º bow flare angle yields the lowest impediment value and the least power requirement among the three methods, with values of 34 kN and 367,163 kW, respectively. This suggests that the 35º flare bow angle is a more efficient choice for speed boat designs that aim to minimize impediment and power consumption at speeds of 17 to 21 knots.

The 30º bow flare angle, used as the benchmark in the previous ship design, produced obstacles and power values of 34.1 kN and 368.271 kW, respectively. This suggests that the 30º flare bow angle is ideal for speed boat designs aiming to minimize obstacles and power consumption at speeds of 17 to 21 knots.

The 25º bow flare angle produces the highest barrier values and the greatest power requirement among the three methods, with values of 34.2 kN and 369.739 kW. This suggests that the 25º flare bow angle is not ideal for speed boat designs aiming to minimize barrier and power consumption at speeds of 17 to 21 knots.

Overall, the results of this simulation show that the selection of the bow flare angle on a speed boat has a direct impact on the resulting obstacles and the power requirements of the engine to reach the desired speed. It is worth noting that the simulation results only show a general picture, and the actual values may vary depending on other factors such as stomach geometry, mass distribution, and sea conditions. Therefore, it is important to perform a more detailed simulation and consider different factors before determining the optimal bow flare angle for the speed design of the boat.

ACKNOWLEDGEMENTS

A sincere thank you to both my parents and the teacher's father/mother. Support, affection, and guidance have been a source of strength throughout this research process. Without his support and sacrifice, I wouldn't have been able to have reached this far. Thanks also to the M20 class A1 friends who have always been there for me, both in love and sorrow. Together in the classroom, discussions and the pleasant moments we shared have made this academic journey more meaningful.

Remember, thanks to my friend's Assistant Laboratory of Mechanical Engineering, who has provided technical support and guidance throughout this research process. Collaboration with you has enriched my experience. Finally, to the friends of HIMAMEGMA, thank you for your friendship and solidarity. The warmth of our organization has become a place where I can share experiences and learn together. Thank you to everyone who has contributed and supported me through this research journey. I hope we continue to help each other and maintain this good relationship. Thank you for everything.

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Vol. 18, No. 1, Juni 2024: page: 23-31
p - ISSN: 1978-886X
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