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Investigation of Different Windshield Designs for Aerodynamic Drag Force in Motorcycle

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Abstract

This research investigates the aerodynamic performance of different windshield designs for the Honda CB500X motorcycle at 140 km/h, focusing on drag force, drag coefficient, and pressure distribution. Three aftermarket windshields and one original equipment manufacturer (OEM) windshield were developed in SolidWorks and simulated using computational fluid dynamics (CFD) in ANSYS Fluent. The OEM windshield outperformed the aftermarket designs in terms of aerodynamic efficiency, with a lower drag force (735.65991 N) and drag coefficient (0.3951). However, a pressure distribution study found that aftermarket windshields provided better deflection of airflow, resulting in less direct wind effect on the rider, potentially improving rider comfort and safety. These findings highlight the trade-off between aerodynamic efficiency and rider comfort in windshield design.

1. Introduction

Motorcycles are popular modes of transportation in many countries, including Malaysia, where they are the most common vehicle on the road. From 2008 to 2017, Malaysia saw a considerable increase in registered vehicles: a 70% rise in cars and a 55% increase in motorcycles, compared to a 16% increase in population [1]. Malaysia ranked seventh in the world with 8.4 million registered motorcycles, following Indonesia, Thailand, and Taiwan [2].

The modest size of motorcycles allows for maneuverability and ease of travel. However, riders frequently experience discomfort and safety difficulties due to exposure to environment and aerodynamic forces. Windshields have been a typical accessory that improves rider comfort and safety by enhancing aerodynamics [3]. The primary function of a windshield in motorcycle design has been to manage airflow, which substantially impacts stability and comfort. Smaller windshields diverted airflow, while larger ones offered more thorough protection. However, poor aerodynamic design could increase drag force and turbulence, reducing the riding experience [4].

When a vehicle moves on a level road, it encounters resistance forces, specifically rolling resistance and aerodynamic drag. Both have a greater influence as the vehicle speeds up. The aerodynamic drag coefficient has been critical in determining the drag force experienced by the vehicle [5]. This resistance not only affected the smoothness and safety of the ride but also had significant impacts on fuel efficiency, noise reduction, and other factors [6].

The automobile industry has been extremely concerned with lowering fuel consumption to save energy and protect the environment [7]. Better aerodynamic performance, achieved by reducing drag through careful design, enables vehicles to maintain speed while using less energy. Reduced aerodynamic drag coefficients allow vehicles to travel further on a single tank of petrol. This improves fuel economy, which is crucial for reducing fuel use and operational costs. More efficient fuel use leads to lower carbon dioxide (CO_2) emissions, meaning vehicles have less of an environmental impact since they require less petrol to cover the same distance.

The problem statement for this study focused on how aerodynamic drag and turbulence caused by different windshield designs affect riders' stability, comfort, and safety, particularly on touring motorcycles. This study aimed to identify the optimal windshield arrangement for optimizing aerodynamic performance, reducing fuel consumption, and improving overall rider enjoyment. The study was expected to contribute to the theoretical understanding of motorcycle aerodynamics and provide practical applications benefiting both manufacturers and riders.

2. Method

The methodology of this research is systematically designed to explore the relationship between motorcycle windshield designs and their aerodynamic effects. Below is a detailed description of the procedures, complemented by a flowchart for better visualization.

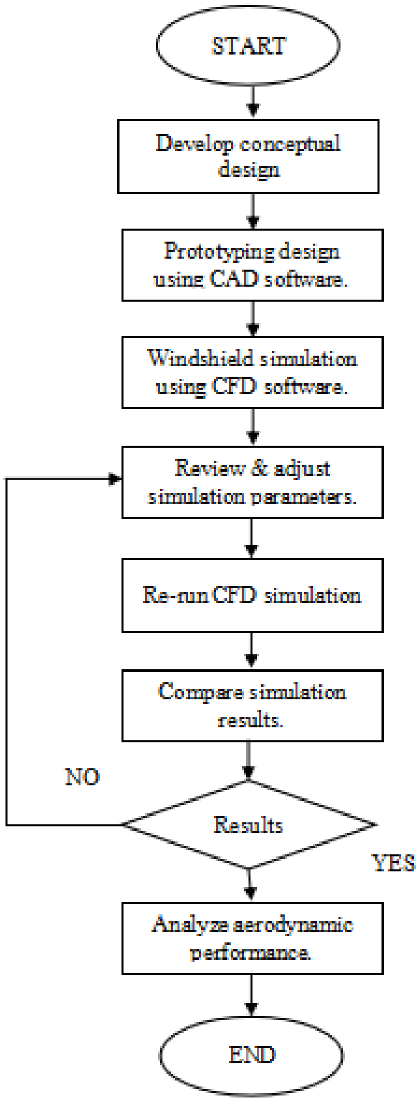


Fig. 1 *Research flowchart*

2.1 Selection Motorcycle Model

Choosing a representative touring motorcycle model is critical for ensuring that the study's findings apply to a diverse variety of motorcycles. The selection is based on the MotoWorld website's top ten motorcycles recommended for beginners, with the focus being on models with engine capacities ranging from 500cc to 700cc.

This project will undertake a thorough investigation of the Honda CB500X's conceptual design, aerodynamics, and windshield alternatives, providing valuable insights for riders looking to upgrade in the category of larger motorcycles for beginners. The CB500X is an ideal candidate for this research because of its adventure motorcycle features, manageable engine size, and the dependability of a well-established brand.

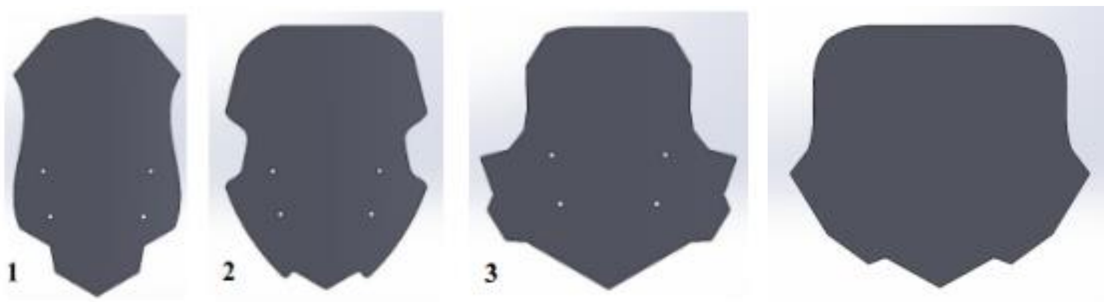
Fig. 2 *Honda CB500X motorcycle mode*

2.2 Windshield Design

This study used SolidWorks to generate three aftermarket windshield designs and one OEM (Original Equipment Manufacturer) windshield design for the Honda CB500X. These designs were created at a 1:1 scale to guarantee that the simulations were accurate and realistic. These designs will be imported into ANSYS Fluent, where computational fluid dynamics (CFD) simulations will be run to assess and evaluate the aerodynamic performance of each windshield configuration.

Table 1 *Dimension windshield design*

Type Windshield	Dimension (mm)		
	Length, L	Height, H	Thickness, H
Aftermarket windshield 1	317	525	4
Aftermarket windshield 2	375	490	4
Aftermarket windshield 3	449.43	460	4
OEM windshield	345	305	4



(a) **(b)**

Fig. 3 *Windshield (a) Aftermarket design; (b) OEM design*

2.3 Simulation Setup

The 3D models of the three aftermarket windshield designs, as well as the OEM windshield design for the Honda CB500X, were imported into ANSYS Fluent for Computational Fluid Dynamics (CFD). The simulation setup included setting the computational domain to simulate real-world riding conditions, then creating a high-quality mesh to represent the flow characteristics surrounding the motorcycle and its windshield.

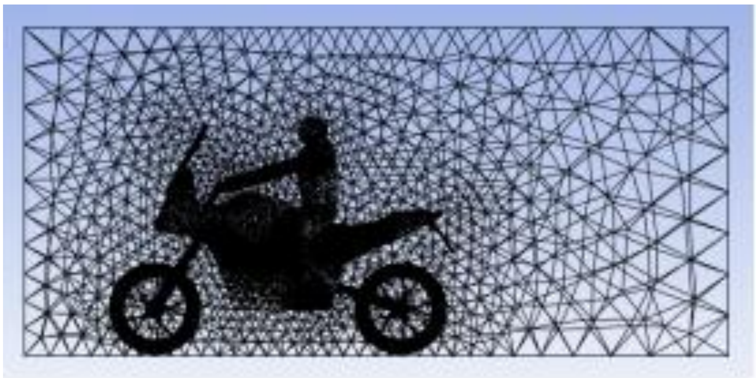


Fig. 4 *Mesh geometry of wind tunnel*

The appropriate boundary conditions were then used to replicate wind speed, direction, and other important variables. After the setup was completed, CFD simulations were done to evaluate the aerodynamic performance of each windshield design. This included computing key parameters like drag force, coefficient drag force, pressure distribution, and velocity vectors.

Table 2 *Operating condition in Ansys Fluent*

Aftermarket and OEM design model	
Units	km/h
Viscous model	k-epsilon (2 equation)
Materials	air
Velocity magnitude (km/h)	140
Reference value (Area)	2.01
Solver setting	
Scheme	SIMPLE
Gradient	Least Squares Cell Based
Pressure	Second Order
Momentum	Second Order Upwind
Turbulent Kinetic Energy	Second Order Upwind
Turbulent Dissipation Rate	Second Order Upwind

3. Result & Discussion

This section displays the results of the CFD simulations performed using ANSYS Fluent on the three aftermarket windshield designs and the OEM windshield design for the Honda CB500X. The findings show drag force, coefficient of drag, streamline visualization, and pressure distribution. Each characteristic gives information on the aerodynamic performance of the various windshield designs.

3.1 Drag Force

The drag force encountered by the motorcycle has been obtained for each windshield design. Drag force is a significant factor because it directly affects the motorcycle's fuel efficiency and stability. The results were shown in Fig.5. All three aftermarket designs show significantly higher drag forces, with Aftermarket design 2 having the highest drag force at 897.5608 N. Among the designs, the OEM design windshield had the lowest drag force, indicating improved aerodynamic performance.

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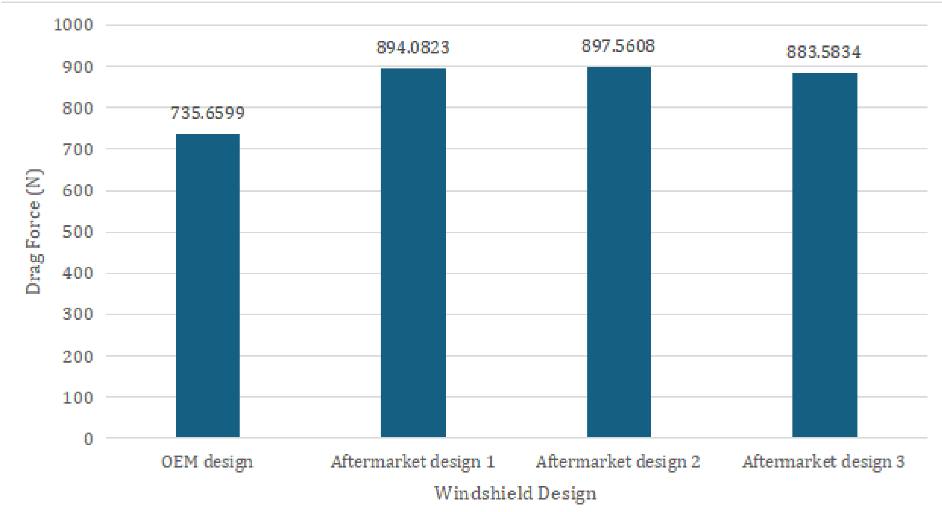


Fig.5 *Graph of drag force (N) against windshield design*

Aftermarket designs show much higher drag forces than OEM design windshield due to less optimized shapes and sizes. A larger windshield can increase frontal area and consequently drag, whilst a smaller one may not efficiently streamline the airflow around the rider, resulting in increased turbulence. This emphasizes the significance of challenging aerodynamic design and testing when developing motorcycle windshields to ensure rider comfort and fuel efficiency.

3.2 Coefficient of Drag

The coefficient of drag (Cd) is a dimensionless number that represents the drag per unit area of the windshield. Fig.6 displays the computed Cd values for each design. All three aftermarket designs have greater drag coefficients, with Aftermarket design 2 having the highest (0.4821). The results also showed that OEM design windshield had the lowest Cd value, which indicated its better aerodynamic performance.

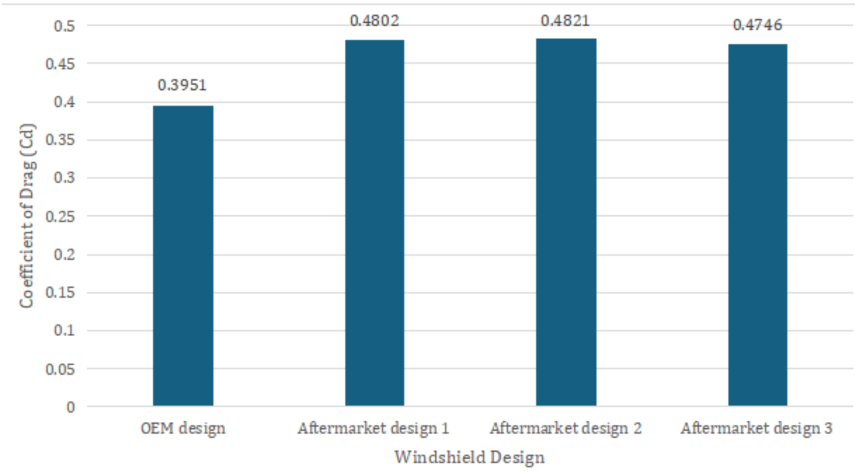


Fig.6 *Graph of Coefficient of Drag (Cd) against Windshield Design*

The data show that the OEM windshield design has better aerodynamic performance, as indicated by the reduced drag force and coefficient of drag when compared to the aftermarket designs. This improved performance is most likely due to the OEM design's optimized shape, size, edge treatment, and integration with the motorcycle's overall design. While aftermarket designs provide different benefits, they may not be as aerodynamically efficient as OEM designs, resulting in higher drag forces and coefficients of drag. As a result, for riders seeking improved fuel efficiency and stability, the OEM windshield appears to be the best option.

3.3 Streamline Visualization

Streamline visualizations provide insights on the airflow patterns around the motorcycle and windshield. Fig.7 demonstrates the streamlining patterns for windshield design. The streamline that shows the smoothest airflow with little turbulence around the rider will boost comfort and stability.

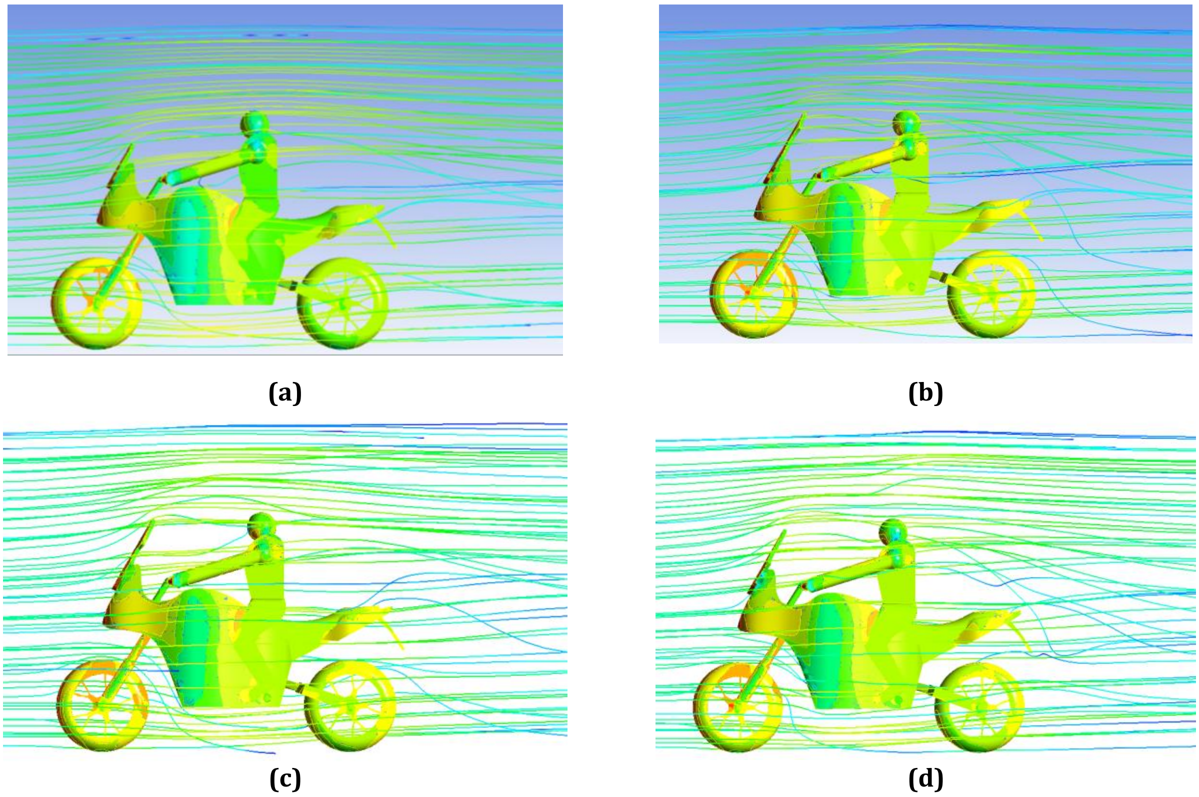


Fig.7 *Streamline motorcycle windshield (a) OEM design (b) Aftermarket design 1 (c) Aftermarket design 2 (d) Aftermarket design 3*

The OEM design windshield optimized aerodynamic shape and better fit result in smoother airflow and less turbulence, as seen in the streamline visualization Fig.7 (a). These characteristics help to lessen drag force and the coefficient of drag (Cd). In contrast, aftermarket design windshields in Fig.7 (b)(c)(d) produce more turbulence due to less optimized forms, resulting in higher drag forces and Cd values. Turbulence can be identified by the appearance of chaotic streamlines that swirl or diverge significantly from the surface. This explains the aerodynamic differences between OEM and aftermarket windshield designs.

3.4 Pressure Distribution

The pressure distribution around the motorcycle and rider for both OEM and aftermarket design windshields was investigated to better understand their aerodynamic impact. The results are shown in the figures below, which highlight differences in pressure fields.

The pressure distribution for the OEM design windshield in Fig.8 reveals that the highest-pressure zones are focused in the frontal area of the windshield and the motorcycle. The red and orange spots represent high pressure zones, which are generally limited to the bottom portion of the windshield and the front of the motorcycle. The increased pressure zones immediately hit the rider's face and shoulders. This implies that the airflow is not completely deflected, resulting in some wind resistance for the rider.

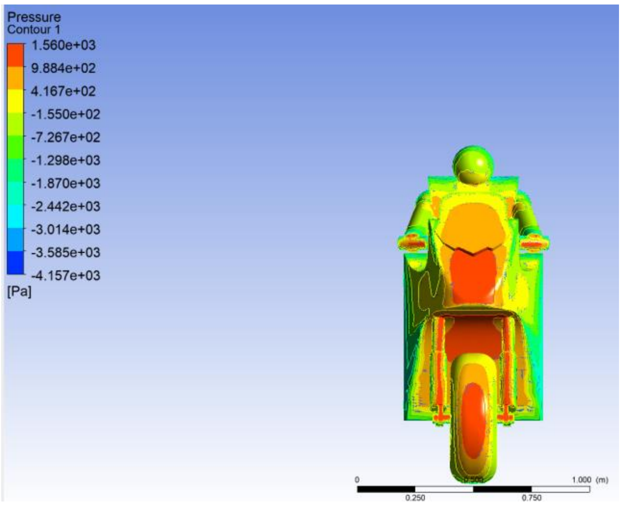
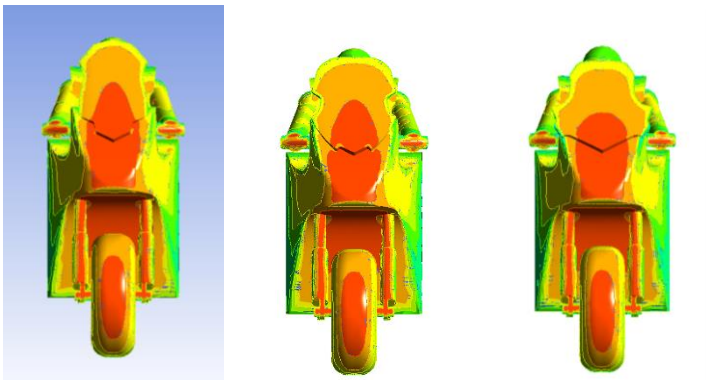


Fig.8 *Pressure distribution OEM design windshield*



(a) **(b)** **(c)**

Fig.9 *Pressure distribution (a) Aftermarket design 1 (b) Aftermarket design 2 (c) Aftermarket design 3*

In Fig.9, the pressure distribution for the aftermarket design windshields also displays high-pressure zones in the frontal area. However, the high-pressure zones are more widespread, extending further up the windshield and around the sides. This means that the aftermarket design windshields provide a larger frontal area, which encounters more air resistance. Despite that, the aftermarket design windshields deflect airflow more effectively, resulting in a higher-pressure zone at the frontal area of windshields but not directly hitting the rider.

4. Conclusion

The study used CFD simulations to analyze the aerodynamic characteristics of several windshield designs for the Honda CB500X at 140 km/h. The OEM design windshield proved to be the most aerodynamic efficient, having the lowest drag force and coefficient. Despite this, aftermarket design windshields, although producing larger drag forces, were shown to be more successful in deflecting airflow away from the rider, and lowering wind pressure on the rider's body. This deflection considerably improves rider comfort and decreases strain on extended rides.

In conclusion, while OEM windshields have higher aerodynamic efficiency, aftermarket windshields provide considerable benefits in terms of rider comfort and safety. This study emphasizes the need to design motorcycle windshields that consider both aerodynamic performance and rider comfort. Future work could include experimental validation of these CFD results, as well as further investigation of optimized designs that strike a balance between these two key elements.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to this manuscript as follows. ***Study conception and design:*** *Muhammad Farid Ghazali, Mohammad Fahmi Abdul Ghafir.* ***Data collection:*** *Muhammad Farid Ghazali.* ***Analysis and interpretation of results:*** *Muhammad Farid Ghazali.* ***Manuscript preparation:*** *Muhammad Farid Ghazali, Mohammad Fahmi Abdul Ghafir. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] N. Z. Ubaidillah, "A study of car demand and its interdependency in Sarawak," vol. 21, no. 3, pp. 997–1011, 2020.
[2] N. Z. B. Ubaidillah, "Determinants of Car and Motorcycle Ownership and Use in Sarawak," 2019, [Online]. Available: http://etheses.whiterose.ac.uk/26409/
[3] M. I. N. Ma'arof, G. T. Chala, and E. T. K. Yang, "An investigation on motorcycle windshield designs for enhanced aerodynamic feature," *Int. J. Mech. Eng. Technol.*, vol. 9, no. 9, pp. 106–113, 2018.
[4] K. Underland, "Motorcycle aerodynamics," 2017. [Online]. Available: https://conservancy.umn.edu/handle/11299/209014
[5] S. Vignesh, V. S. Gangad, V. Jishnu, Maheswarreddy, A. Krishna, and Y. S. Mukkamala, "Windshield angle and Hood inclination optimization for drag reduction in cars," *Procedia Manuf.*, vol. 30, pp. 685–692, 2019, doi: 10.1016/j.promfg.2019.02.062.
[6] F. Ferdaus, N. Raghukiran, Vijaykumar, and Karthikeyan, "Aerodynamic Performance Improvement by Streamlining The Front Fairing of a Racing Vehicle," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1128, no. 1, p. 012007, 2021, doi: 10.1088/1757-899x/1128/1/012007.
[7] M. Elrawemi and İ. Ibrahim Aburawey, "The effect of front and rear windshield angles on the aerodynamic drag force of a simplified car model," *Int. J. Energy Appl. Technol.*, vol. 6, no. 3, pp. 83–88, 2019, doi: 10.31593/ijeat.610436.