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Study on Reducing Drag on Vehicle Side Mirror Via Shape Tuning

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Abstract

Side mirrors are crucial components of a car that let the driver see behind and to the side of the vehicle to assess the traffic. The increment of frontal area and side mirrors causes the vehicle's aerodynamic drag to rise. The goal of the work is to add several forms of flow manipulators to the side-view mirror of the car. The use of vortex generators (VGs) in the side-view mirrors of a vehicle is examined using computational fluid dynamics (CFD). To enhance the control surfaces and postpone flow separation, vortex generators are employed, which have an impact on the vehicle's drag and lift forces. Understanding the VG influence on the flow processes downstream of the side-view mirror, as well as the impact on drag and lift forces, is the main goal of this work. The side-view mirror's turbulent flow is examined to ascertain the impacts of various VG kinds, geometries, positions, and attack angles.

1. Introduction

Automobile manufacturers consistently innovate to build more efficient automobiles by increasing vehicle aerodynamics. Automobiles today are more streamlined and have less exposed functional parts. The side mirrors of a car are conspicuous protrusions that cannot be easily removed for various reasons. One of them is because side mirrors are crucial for a vehicle as they help the driver to look for another vehicle incoming from both directions. Drag is a force that opposes the movement of an object through the air. Velocity, area, air density, and drag coefficient are its determining elements. The flow separation caused by the side mirror creates a pressure difference, which causes pressure drag. The high pressure of the flow creates a force towards the low-pressure region to the flat mirror behind the side mirror housing.[1] This experiment will study the drag that was generated by the side-view mirror. The simulation will be carried out by creating the side mirror model which is solely based on the actual Mazda 3 2012 side mirror as the base model in SolidWorks and transfer it to ANSYS. The Mazda 3 2012 model will be the vehicle that will be as a reference for the simulation. The data will be carried out by using the data acquisition system DAQ to see the result of the simulation. As already stated, that side mirror was one of the reasons for the increment of drag that affected for moving vehicle. For safety reasons completely getting rid of the side mirror will be impossible as it will also be against Road Safety Regulations in Malaysia. For that reason, this study was initiated to create a shape tuning for side mirrors by using a vortex generator (VG) to create a better flow separation which also will greatly reduce drag on the moving vehicle. A common source of airflow turbulence is the turbulent flow across a car's side-view mirror, which increases drag, aerodynamic noise, and vibration. The purpose of this study is to slightly change the side-view mirror of the car by including various flow manipulators from the original model.

1.3 Drag Force and Flow Separation

In earlier times, high-speed cars were only dependent upon the horsepower of the engine to maintain the performance segment of the vehicle. However, in recent trends, design engineers are adapting the concepts of aerodynamics to enhance the efficiency of the vehicle. [2,3] Aerodynamic drag is the force opposing the forward motion of a moving vehicle. Viscous force is the main contributor to drag at lower velocities. Therefore, skin friction drag is the main source of aerodynamic drag in a vehicle at low velocities.[4] At cruising speeds, pressure drag is the principal cause of drag. Sudden form changes evidence the presence of pressure drag. It is discovered that a vehicle's front pressure drag is higher than its back pressure drag.[5] Thus, reducing the drag is one of the major approaches automotive manufacturers opt for. Shaping the body of the vehicle and the inclusion of various add-on devices contributes to optimization for low drag, which becomes an essential part of the design process.

1.4 Improvement on concept side view mirror

1.4.1 Shape Tuning

Otten [6] conducted a survey and found the average frontal area of a pair of side mirrors consists of 2-3% of the overall frontal area. In running conditions of the vehicle, the side mirror contributes to the drag of the vehicle. The side mirror only contributes to the drag when the velocity is greater than 60 km/h [7]. As for this reason, in order to reduce the drag of the vehicle rather than completely getting rid of the side mirror of the vehicle which is clearly against road safety regulations in Malaysia, these studies suggest that the shape tuning on the side mirror of the vehicle reduces drag on the vehicle.

2. Methodology

After considering all other factors, these projects were conducted based on the flowcharts below. It was compulsory to follow the steps in the flowchart below accordingly in order to gain the desired result throughout this project.

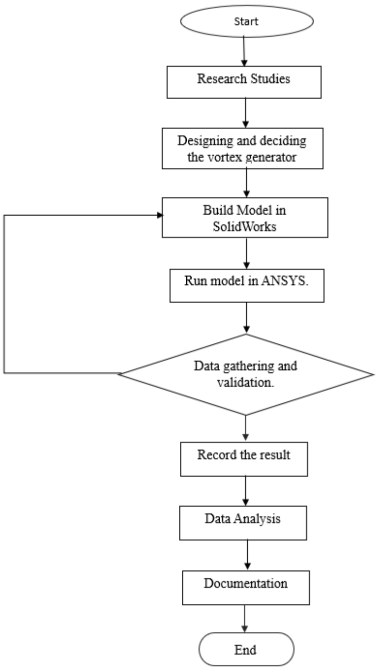


Fig. 1 *Project flowchart*

2.1 Designing and deciding the vortex generator

In this work, there were 3 different prototype designs of VGs. Subsequent changes were made to the baseline model by adding the VGs on the same surfaces but with different quantities and shapes to make sure we got a significant result. For the designing steps of VG on the side mirror [8], there are 3 key parameters: length, height and attack angle.

Table 1 *VG model specification*

Model	Type	Number Of VG's	Length (mm)	Height (mm)	Spacing (mm)	Thickness (mm)	Position (surface)
1	Rectangle	6	10	20	25	3	Top
2	Oval	6	10	20	25	3	Top
3	Square	6	10	15	25	3	Top

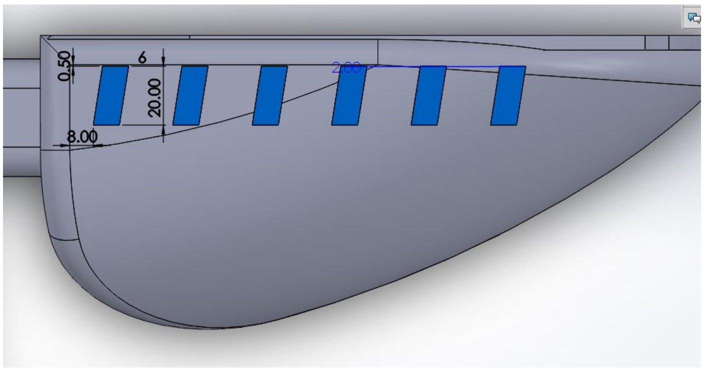
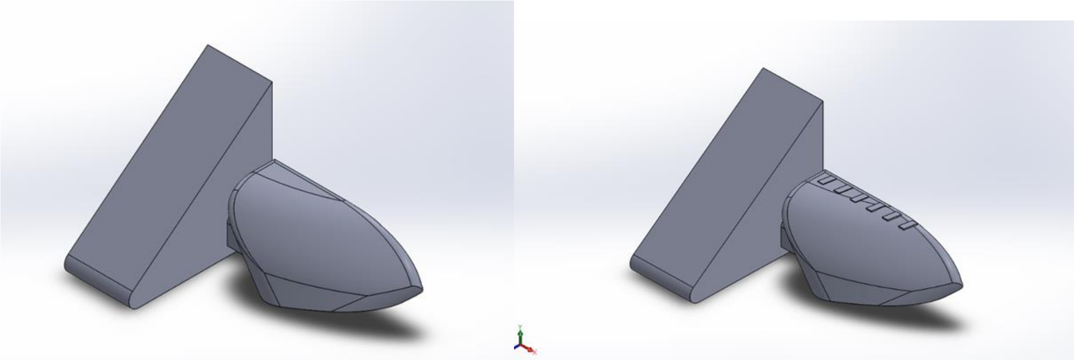


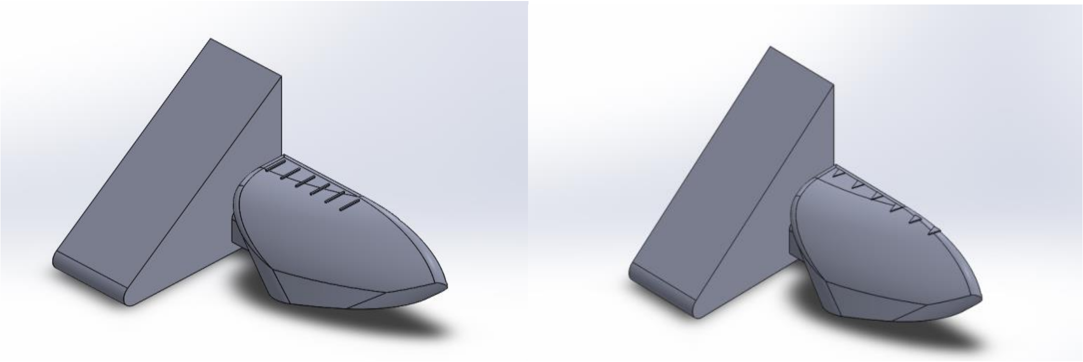
Fig 2 Measurement specification for each vortex

2.2 Modification on vehicle side mirror model in SolidWorks

The specifications of the base model of the side mirror were drawn in SolidWorks based on the Mazda 3 side mirror. As for the vortex, it was added on top of the side mirror model. This approach step was crucial since it would determine whether this proposal would succeed. The purpose of the extra vortex is to determine whether it will lessen the drag force that the side mirrors were generating on the car.



[a] [b]



[c] [d]

Fig. 3 *Description [a] base model; [b] rectangle vortex; [c] oval vortex; [d] triangle vortex*

In contrast to previous research and articles, this study solely examined and shape of VGs on the same surface of the rear-view mirror. All the VGs above will be run in ANSYS and will be compared to the base model on how effective the presence of VGs to reduce drag force.

2.3 Running Model on ANSYS software

The file then was imported into the ANSYS software when the model had been constructed. Importing the model file into the ANSYS software is the first step in the procedure, after which the geometry will be established. The next stage is to mesh the data to improve the accuracy of the output and after that, boundary conditions are set up.

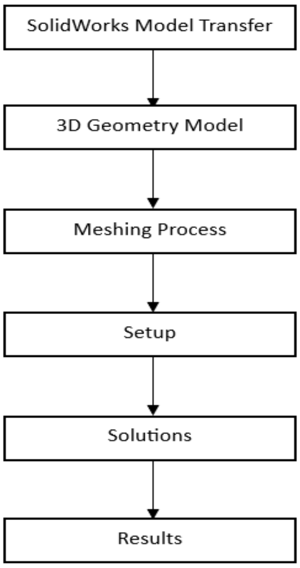


Fig. 4 *Flow on ANSYS simulation*

2.3.1 Meshing Process

The model's meshing process will then be the following stage before the simulation begins. Mesh quality is essential for simulation accuracy. It is important to have a fine mesh element distribution. Automatic unstructured meshing with the 'proximity and curvature' size function will be used in the ambient mesh generation. By setting the meshing parameter to the smaller surface, the meshing accuracy and quality will improve.

Table 2 *Mesh parameter for simulation*

Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	CFD
Solver Preference	Fluent
Element Order	Linear
Element Size	250.0 mm
Export Format	Standard
Export Preview Surface Mesh	No
Sizing	
Use Adaptive Sizing	No
Growth Size	Default (1.2)
Max size	Default (500.0) mm
Mesh Defeaturing	Yes
Defeaturing Size	Default (1.25) mm
Capture Curvature	Yes
Curvature Min Size	Default (2.5 mm)
Quality	
Check Quality Mesh	Yes, Error
Smoothing	High
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Growth Rate	1.2
Statistics	
Elements	24387
Nodes	132054
Mesh Metric	None

2.3.2 Boundary Condition

Table 3 *Other parameters setup*

Parameter	**Description**
Inlet velocity	80km/h
Model	
Viscous	k-epsilon (2eqn)
k-epsilon model	Standard
Near wall treatment	Standard wall function
Material	
Fluid	Air
Solid	Aluminium
Initialization	
Method	Hybrid
Run calculation	
Number of iterations	200

The configuration above was made by a few references [8] and was appropriate and compatible for usage on a side view mirror to measure drag force. The following explanations provide additional details on the boundary conditions:

a) Inlet: The free stream velocity is represented by uniform velocity applied in the z-direction.
b) Outlet: Since a uniform pressure boundary condition exists, the pressure gradient at the outflow is equal to zero. If the space between the outlet and the body of the vehicle is wide enough, the fluid can pass through the outlet without blocking the flow upstream.
c) Side mirror body: The no-slip condition is applied.
d) Wall boundary: For all other sides use no-slip wall boundary.

3. Result and Discussions

By verifying the data, one may increase confidence in the study's conclusions and interpretations by ensuring that it is reliable and appropriate for its intended use. In the context of this study, the result of the drag force that was generated for each type of vortex was successfully recorded. Furthermore, there are 2 more types of data that were recorded which were pressure and turbulence kinetic energy effect on the model surface in which the vortex was placed. Moreover, the flow of streamline through the side mirror, and the graph depicting the impact of turbulence kinetic energy on the surfaces of the side mirror was shown.

3.1 Drag Force

Drag force is the resistance that a moving object experiences due to the air or fluid through which it moves. From the test that had been conducted, the drag generated for each side mirror was different as we can see the drag force generated from the base side mirror (with no vortex) is higher than the modified side mirror (with vortex). Thus, it was reasonable to conclude that the vortex on the top side mirror will positively affect the drag force generated by the side mirror's base model based on the data.

Table 4 *Comparison of Drag Force for each type of vortex*

Type Of Vortex	Drag Force (N)	Drag Force Reduction (%)
Base Model (No Vortex)	16.316	-
Rectangle	15.820	3.04
Oval	15.388	5.7
Triangle	16.059	1.58

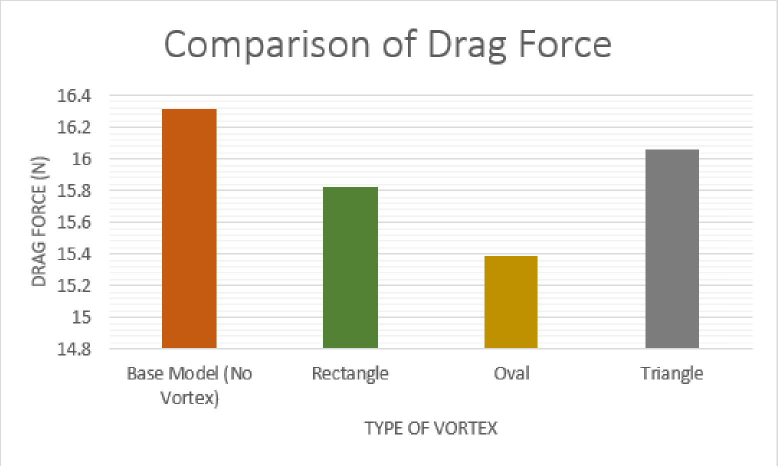


Fig. 7 *Graph trend for each vortex*

The paragraph discusses the impact of various vortex generators (VGs) on drag force reduction in comparison to a baseline model. Table 4 and Fig 7 illustrate the drag force differences between the baseline and models incorporating rectangle, triangle, and oval VGs on the upwind surface. VGs decrease boundary layer height and delay flow separation, notably at speeds above 60 km/h. Oval VGs exhibit the lowest drag force at high speeds, likely due to their capacity to generate stronger vortices compared to triangle and rectangle VGs. Consequently, oval-shaped vortices are considered the most effective, showcasing a 5.7% decrease in drag force, while rectangular and triangular vortices show reductions of 3.04% and 1.58%, respectively. Although the impact of rectangle and triangle vortices on drag force reduction is less significant, their presence disrupts turbulence behind side mirrors, leading to a decrement in drag force compared to the base model.

3.2 Lift Force

The paragraph discusses aerodynamic lift force differences caused by a vehicle's body shape and side mirrors. Positive lift decreases tire grip, while negative lift enhances road grip. Lowering lift force improves vehicle stability, often achieved through downforce. Test results showed varying drag and lift forces between the base and modified side mirrors, with the base mirror generating more lift. Considering this data, it was reasonable to infer that adding a vortex to the top side mirror could potentially reduce the lift force generated by the base model side mirror, aiding in enhancing vehicle stability.

Table 5 *Comparison of Lift Force for each type of vortex*

Type Of Vortex	Lift Force (N)	Lift Force Reduction (%)
Base Model (No Vortex)	4.742	-
Rectangle	3.464	26.95
Oval	3.509	26
Triangle	3.714	21.68

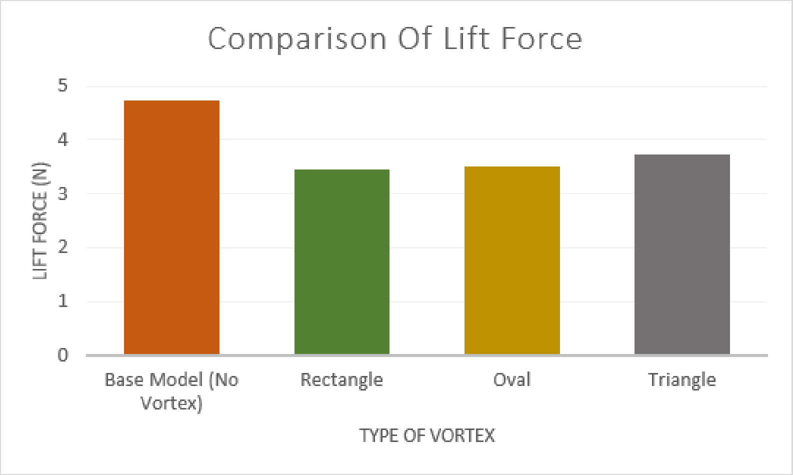
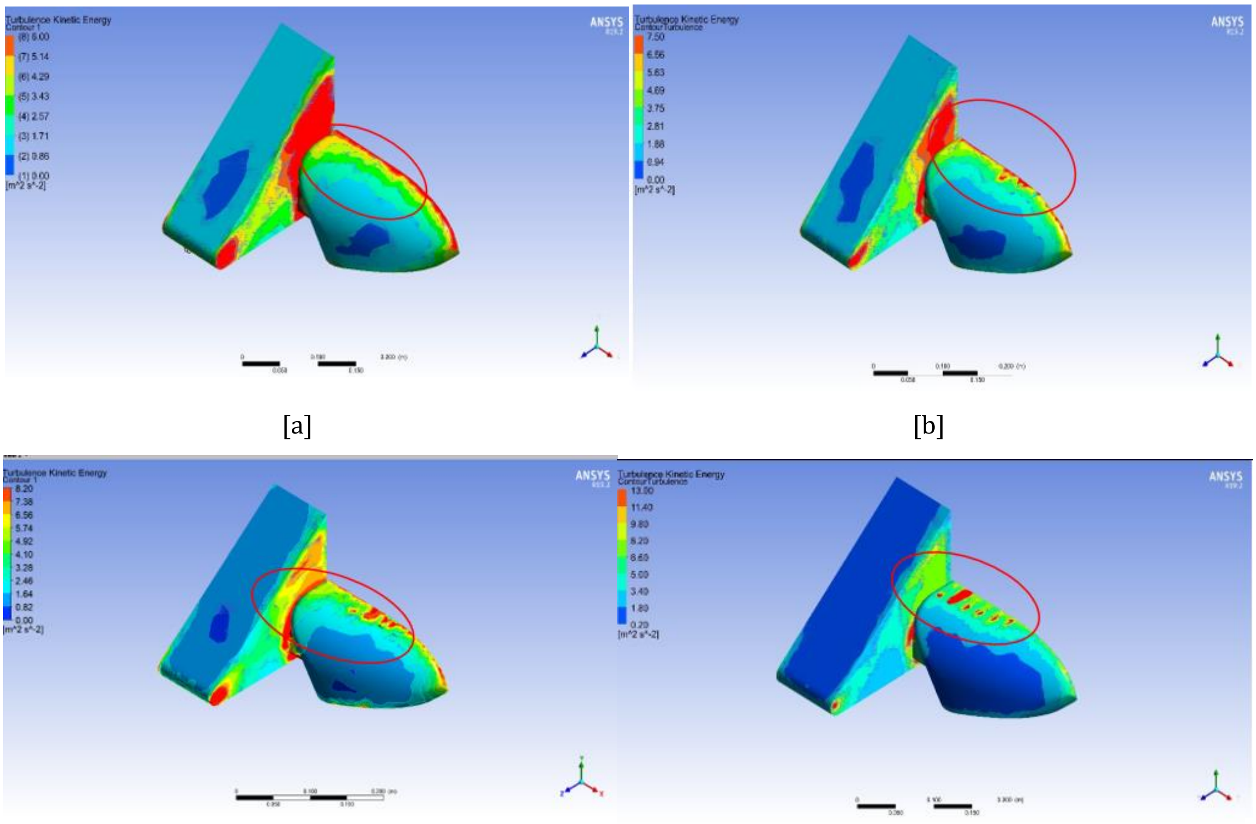


Fig. 8 *Graph trend for each vortex*

Regarding the result, of the two other varieties of vortex utilized in this study, the rectangle-shaped vortex generated the least lift force and was considered the optimum form. Because the rectangular vortex shape reduces lift force by 26.95% when compared to the basic model, it will be chosen as the best form out of all the other shapes. However, if we were to consider the drag force decrement generated out of all vortexes the oval-shaped still could be chosen as the best vortex as the difference value of lift force decrement was not that significant between the rectangle and oval-shaped vortex.

3.3 Turbulence Kinetic Energy Contour Effect on Surface Model



[a] [b]

[c] [d]

Fig. 9 *Figure description (a) Base Model; (b) Triangle vortex; (c) Rectangle Vortex; (d) Oval Vortex*

Figure 9 above presents the findings regarding the impact of turbulence kinetic energy on the door mirror or side view mirror. Both these models were run through a similar velocity setting which was 80 km/h. From turbulence contours, the recirculation zone is visualized behind the side view mirror. The minimum the recirculation zone is, the less turbulence is created, which subsequently leads to minimized drag force. The model with a vortex on top of the side mirror shows the region least impacted by turbulence kinetic energy. On the other hand, the model with no vortex suffers the greatest loss from turbulence kinetic energy. This is due to the fact that a vortex's presence can change the airflow patterns surrounding the side mirror. Reducing the amount of airflow collection on the rear surface area of the mirror is made easier by the vortex located on the upper rearview mirror. Out of all the vortices, the oval-shaped one created the least amount of turbulence, demonstrating the validity of the drag force result that was obtained.

3.4 Turbulence Kinetic Energy for each vortex

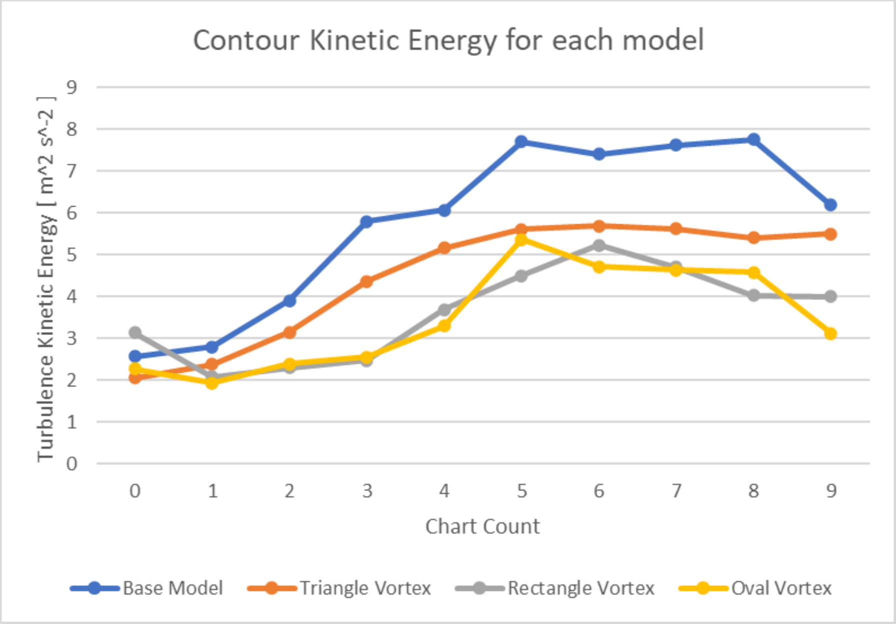


Fig. 10 *Comparison of contour kinetic energy for each vortex with the base model*

The graph in Figure 10 examines turbulent kinetic energy observed in simulations of four side mirror models: the base model, triangle, oval, and rectangle shapes. In the basic model, the highest turbulent kinetic energy, reaching 7.76 m^2s^2, was recorded, indicating greater turbulence. The triangle vortex exhibited peak turbulence of 5.69 m^2s^2, maintaining relatively high levels at 5.51 m^2s^2 by the simulation's end, potentially explaining its lower drag force reduction compared to other vortex shapes. The rectangle vortex displayed peak turbulence of 5.24 m^2s^2, reducing significantly to 4 m^2s^2 by the simulation's conclusion, suggesting its effectiveness in disrupting turbulence and reducing drag force. The oval-shaped vortex peaked at 5.37 m^2s^2 but decreased dramatically to 3.13 m^2s^2 due to energy dissipation, indicating its success in disrupting turbulence and minimizing drag force. Consequently, the oval vortex, with the lowest turbulence kinetic energy among all models, demonstrated the largest reduction in drag force compared to other vortex shapes.

4. Conclusion

In conclusion, the study focuses on the side view mirror which determines the drag force generated by the side mirror. The objective of this study was to study the improvement of aerodynamic drag force from a generic side-view mirror by CFD simulation via ANSYS fluent software. The decrement in drag force of the side mirror that had been installed vortex compared to the base model can be seen after the vortex was added to the side view mirror. CFD analysis of the VG applications on a vehicle side-view mirror was conducted using the standard k-ε turbulence model. Regarding how the tests are being conducted on the side mirror, this simulation was conducted by only using one speed which is 80 km/h. Three types of vortices were implemented on the top surface of the models, which are rectangle, triangle and oval. Based on the simulation result, it can be concluded that the oval shaped vortex produced the least drag force out of the other two vortices. This model experienced lower turbulence kinetic energy, indicating reduced flow disturbances and improved aerodynamics. This happened because the oval-shaped vortex created a minimum recirculation zone, causing the least turbulence was created, which subsequently led to minimized drag. As for the lift force, the rectangle vortex produced the highest reduction result which might considered the best among the vortices, however considering the drag force that was generated, the oval shaped vortex is still chosen as the best vortex out of the three vortices. The oval shaped vortex generated 26% while the rectangle vortex generated 26.95% of reduction. While the rectangle vortex generated a larger amount of reduction, considering only 0.95% of margin the difference might not be that significant. Finally, the results shown in this work indicate that the vortex generator technique is a potential method for reducing drag.

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This guide contains examples of common types of APA Style references. Section numbers indicate where to find the examples in the Publication Manual of the American Psychological Association (7th ed.).

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