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A Numerical Study About the Flow Around Motorbike with Different Types of Fairing When Travel Through Crosswind

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Abstract: Riding a motorbike possess to a dangerous situation because of its stability and balance. Crosswind has a significant impact on riding since, with a strong gust, it can easily drive the motorbike off the road or into another lane or traffic. A numerical study has been conducted to investigate the aerodynamic loads of the drag, side, and lift coefficient and to analyze the flow pattern occurs of the motorbike with different types of fairing when travel under various angle of crosswind that was set ranging 0◦, 15˚, 30˚, 60˚ to 90˚. Two models of Yamaha YZF M1 with different types of fairing were designed using SolidWorks 2020 and then simulated using Ansys CFX with 25m/s as the velocity for main and crosswind inlet. The aerodynamic loads coefficient was calculated for each model and the streamlines flow were analyzed. The aerodynamic loads coefficient was found increases as the yaw angle increases. Half fairing model was found to have higher aerodynamic coefficient compared to fully fairing model since half fairing model was not aerodynamic shape.

Keywords: Motorbike, crosswind, Ansys CFX, flow pattern

1. Introduction

In Malaysia, 5.8 million out of 7 million households own a motorbike which make roughly about 13 million motorbikes in the country [1-6]. There are many types of motorbikes such as cruiser, sport, touring, standard, dual-purpose, and dirt bike. On top of that, motorbike also comes with different types of fairings especially the superbike type. The fairings can be divided into three types which are fully fairing, half fairing and no fairing or known as naked. The aerodynamics shape matter on a motorbike because of the turbulence. Turbulence could be danger to the rider because pockets of turbulent air disrupt an object in motion, the air molecules that in contact with the object create a friction that pushes against it.

The turbulence also happens not only when slicing the air but also from a crosswind. Crosswinds which one of natural phenomenon also influence the stability of the motorbike and rider due to the increases of aerodynamic forces. Moreover, these forces also include rolling, pitching, side forces and yawing moments with addition to the normal aerodynamic drag and lift forces [6]. Crosswinds in general is a strong wind that blows across the direction that vehicles travelling or perpendicular to the vehicle and makes it harder for them to keep moving steadily forward [7]. This study aims to investigate the aerodynamic loads of the drag, side, and lift coefficient and to analyze the flow pattern occurs of the motorbike with different types of fairing when travel under various angle of crosswind. The velocity was set to 25 m/s for both crosswind speed and motorbike's speed. The curvy object on the motorbike resembles as a rider and this study focused on two types of fairing which are fully fairing and half fairing. The angle of crosswinds chosen was 15˚,30˚,60˚, and 90˚ as the comparison to the past studies [7-9]. The additional 0˚ as the baseline of this study.

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Riding a motorbike is already possessing to a dangerous situation because of its stability and balance. That circumstance has an impact on the technical state of motorbikes in various weather situations. This can impact on the motorbikes aerodynamic. Crosswind interaction affects both the frontal aerodynamic drag, as well as side drag and the aerodynamic lift [7-8]. This research is conducted to analyze the flow around motorbike with different types of fairing and aerodynamic forces by using various yaw angle of crosswinds.

The study of how air interacts with moving bodies is known as aerodynamics. This is the study of forces and how they cause objects to move through the air. It is possible to calculate the forces and moments acting on an item by understanding the airflow around it. Its primary objectives are to reduce drag and wind noise, reduce noise pollution, and eliminate unwanted lifting forces and other sources of high-speed aerodynamic instability.

2. Methods

A flowchart was made to ease the journey of obtained the anticipated results and to ensure that the project was following the plan. Figure 1 illustrated the whole process in order to obtain the results.

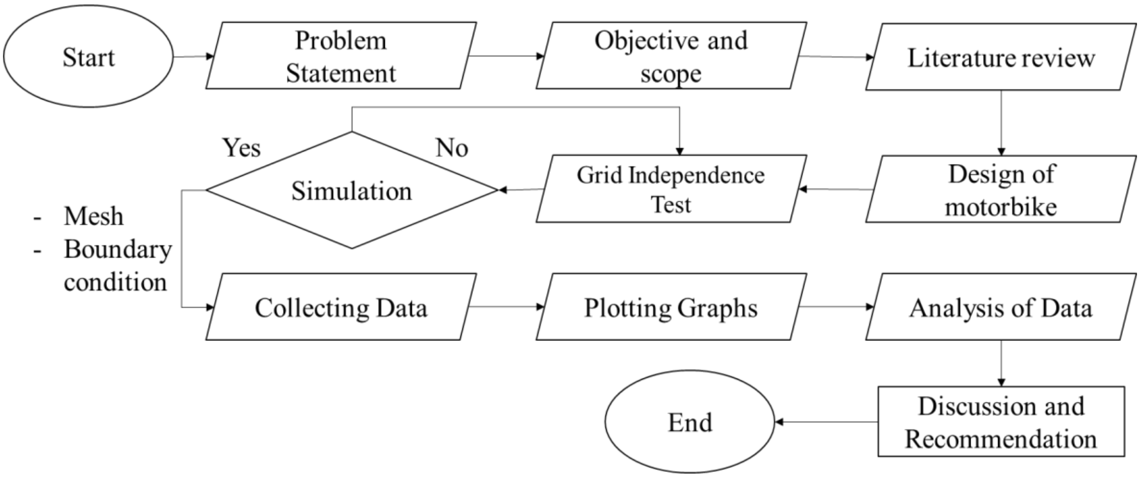


Fig. 1 - Project flowchart

2.1 Geometrical Modelling

The analysis of motorbike is based on simplified model of YAMAHA YZF M1 designed using SolidWorks software. The dimension of the motorbike based on the real model provided by Yamaha [10-12] The model were designed with two different types of fairing which are fully fairing and half fairing. The flow structures around both models, its drag coefficient, side coefficient, and lift coefficient when various angle of crosswind are analyzed and calculated.

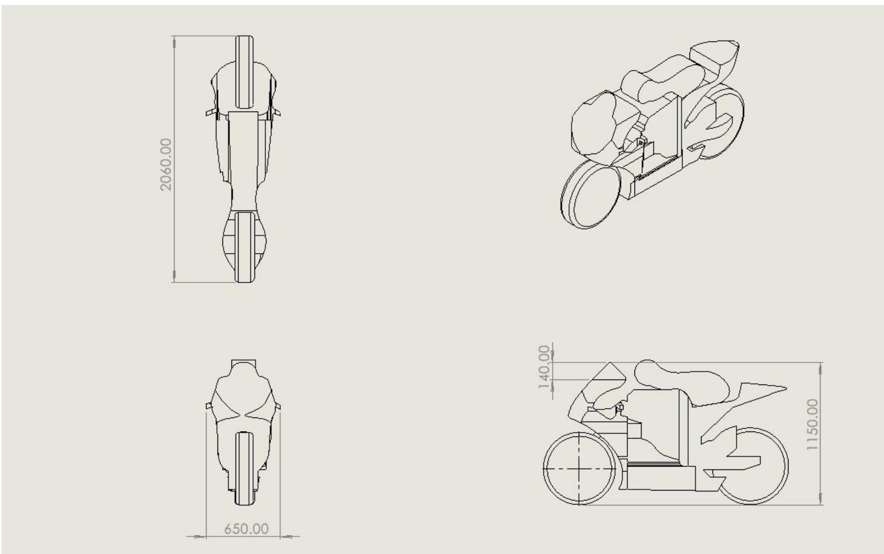


Fig. 2 - Orthographic view of Yamaha YZF M1 model

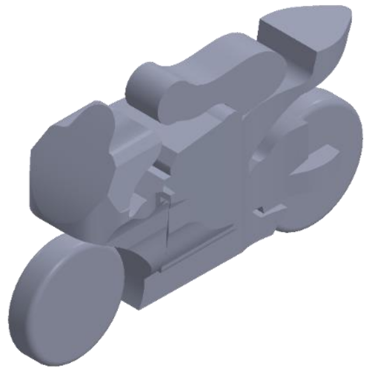


Fig. 3 - Simplified model of Yamaha YZF M1 (fully fairing)

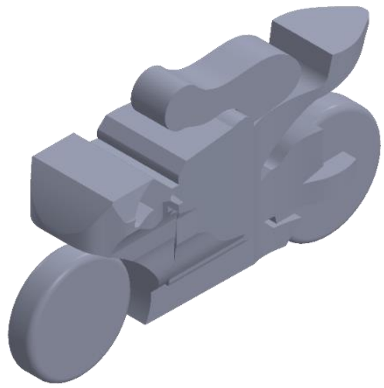


Fig. 4 - Simplified model of Yamaha YZF M1 (half fairing)

2.2 Simulation

Before running a simulation, meshing process is one of the crucial steps in CFD simulation. The results accuracy is depending on the size and quality of mesh. As the mesh gets finer, the results will be more accurate, but it takes a longer time to complete a simulation. An enclosure was built to represents as wind tunnel. The meshing is of the model is done in ANSYS software.

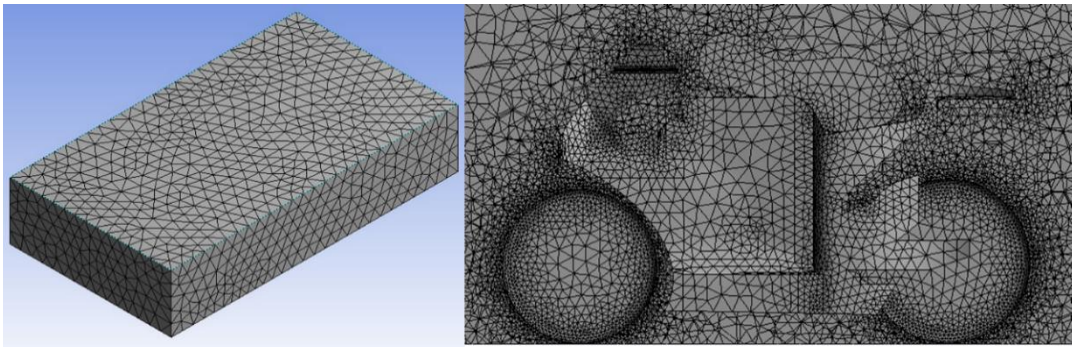


Fig. 5 - Model meshing in ANSYS

The boundary conditions that need to be set before simulation are tabulated in the table below. Table 1 shows the boundary conditions before running the simulation.

Table 1 - Boundary conditions

Type of Boundary	Flow Characteristic	Parameter
Inlet	Flow Regime	Subsonic
	Mass and Momentum	Cartesian Velocity Components
	U	-4.3000e+01 m/s
	V	-0.0000e+00 m/s
	W	-2.5000e+ m/s
	Turbulence	Medium Intensity and Eddy Viscosity Ratio
Outlet	Flow Regime	Subsonic
	Mass and Momentum	Average Static Pressure
	Pressure Profile Blend	5.0000e-02
	Relative Pressure	0.0000e+00 Pa
	Pressure Averaging	Average Over Whole Outlet
Wall	Mass And Momentum	No Slip Wall
	Wall Roughness	Smooth Wall
Motor	Mass And Momentum	No Slip Wall
	Wall Roughness	Smooth Wall

2.3 Equations

The aerodynamic loads obtained from the simulation will be calculated. The formula for drag, lift, and side coefficient are shown below:

$$Cd = \frac{Fd}{0.5\ pV^2A} \tag{1}$$

$$Cs = \frac{Sd}{0.5pV^2A} \tag{2}$$

$$Cl = \frac{Ld}{0.5pV^2A} \tag{3}$$

The calculated coefficients than will be plotted in graph for both models to determine types of fairing that has more aerodynamic coefficients.

3. Results and Discussion

The focus of this chapter was to present and discuss the obtained results from the simulation by plotting the graph and analyze the flow structures around both models.

3.1 Grid Independent Test

Figure 6 displays the velocity distributions for the 25 m/s at 0° crosswind as the baseline simulation with various numbers of elements was to determine the suitable elements number that going be used for this simulation. According to the grid independence test, the velocity distribution does not significantly change between 320 K and 500 K elements number.

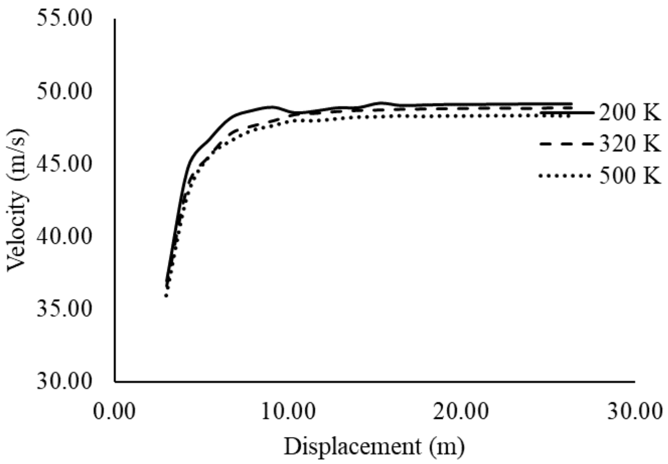


Fig. 6 - Velocity distribution at outlet boundary

3.2 Aerodynamic Loads Coefficient

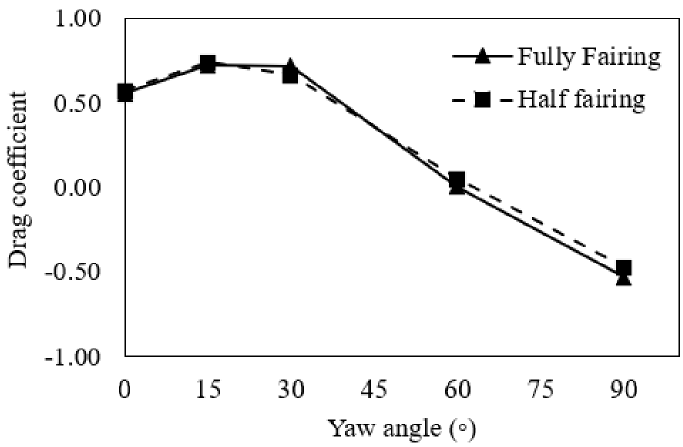


Fig. 7 - Drag coefficient with various yaw angle of crosswind

Figure 7 shows the aerodynamic loads coefficients of both models with different types of fairing for various and yaw angle. Figure 6, from 0º to 15º, the value of drag coefficient (*Cd) is* slightly different for both types of fairing. As can be seen, the value of *Cd decreasing as the yaw angle increasing*. In terms of fairing, the half fairing obtained higher *Cd compared to fully fairing except at Ψ = 30* º where fully fairing has higher fairing than half fairing.

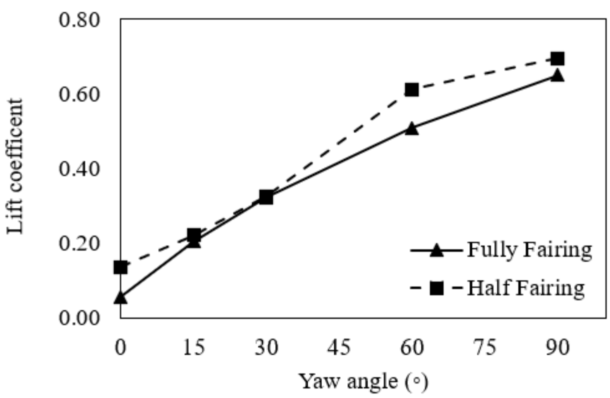


Fig. 8 - Lift coefficient with various yaw angle of crosswind

Figure 8 depicts the motorbikes' lift force coefficients, (*Cl*) for both types of fairing. As the yaw angle increased, the

Cl value gradually increased for both types of models. At *Ψ* = 30º, the *Cl value* for both fairings show almost identical value as it has no different shape of fairing. However, as the yaw angle increase, the half fairing shows a significant value at *Ψ* = 60º and decrease when the *Ψ* = 90º. This shows that, the shape of fairing plays a role when getting hit by crosswind.

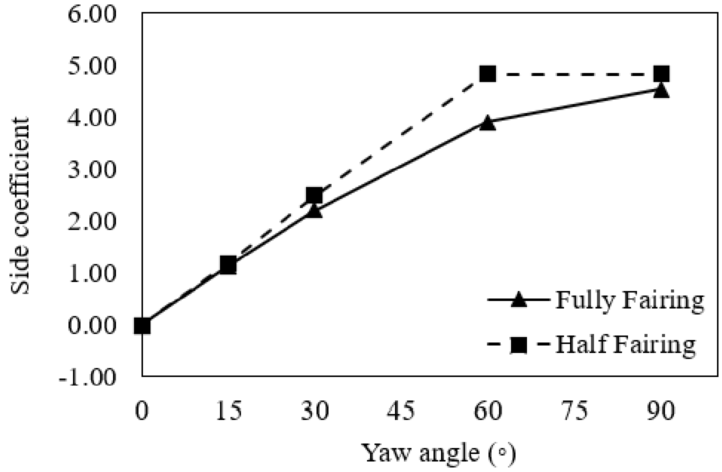


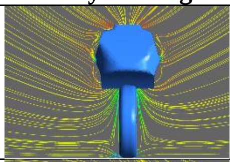
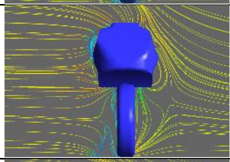
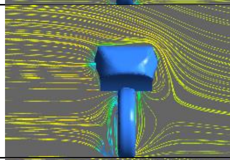
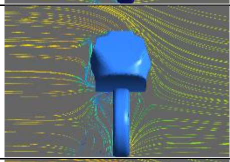
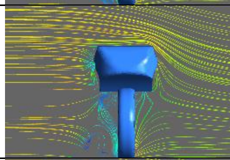
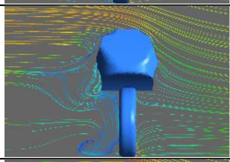
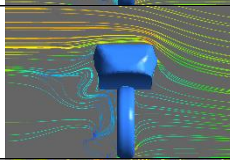
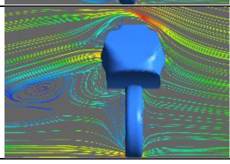
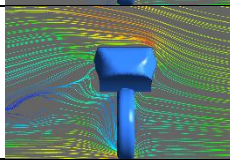
Fig. 9 - Lift coefficient with various yaw angle of crosswind

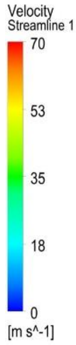
Figure 8 shows the side force coefficients (*Cs*) of the of both models with different types of fairing for various and yaw angle. As can be seen, the value of *Cs* increasing as the yaw angle increasing due to the contact area of the motorbike and wind loads on the windward side. From *Ψ* = 0º to 60º, the value of *Cs* increasing drastically then level when *Ψ* = 90º. At this point, it can see that half fairing model obtained higher *Cs* compared to fully fairing model. Hence, shows that half fairing reduces the aerodynamic performance.

3.3 Streamlines

Table 2 shows the flow structures displayed as streamlines on a plane for both models from the front view. The plane was set on the fairing to see the difference formed of streamlines for both models. The numbers of streamlines were set to 150 lines for both models. The streamlines produced has minor different of flow structures for both models. The streamlines difference can be seen by the forming of recirculation region. The significant recirculation can be identified at *Ψ* = 30◦,60◦, and 90◦ for both types of fairing. It can justify that, as the yaw angle increases, the recirculation region formed become clearer.

Table 2 - Streamlines surfaces for both motorbike model (front view)

Yaw angle (◦)	Fully Fairing	Half Fairing
0		
15		
30		
60		
90		

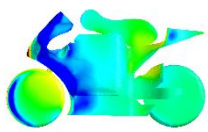
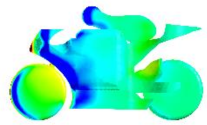
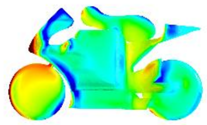
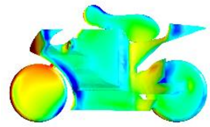
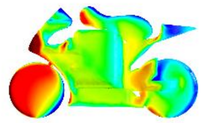
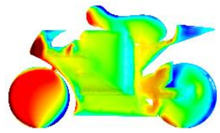
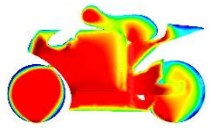


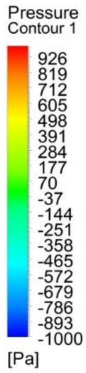
3.4 Pressure Contour

Table 3 depicted the pressure contours on the wall motor in provide valuable insights into the impact of crosswind conditions on the performance of different types of motorbikes. By analyzing the pressure distribution on the side view of the motorbikes, it is possible to determine which parts of the models receive high and low pressure. At yaw angles ranging from $\Psi = 30^{\circ}$ to 90°, the high-pressure areas on the models gradually shift from the front to the side of the models. This is due to the specific angle of the crosswind, which affects the distribution of pressure on the motorbikes. As the yaw angle increases, the high-pressure area moves from the front to the side of the models, leading to a decrease in the drag force and an increase in the lift and side forces. This shift in pressure distribution is a result of the interaction between the crosswind and the shape of the motorbikes. The specific angle of the crosswind affects the distribution of pressure, causing the high-pressure area to move from the front to the side of the models. This, in turn, leads to changes in the lift and side forces, which are critical to the performance and stability of the motorbikes.

Furthermore, the analysis of pressure contours on the side view of the motorbikes also highlights the importance of fairing in enhancing the performance of the models. The different types of fairing have a significant impact on the distribution of pressure on the models, and this can have a major influence on the performance of the motorbikes under various crosswind conditions. In conclusion, the pressure contours on the wall motor in Table 3 provide valuable information about the impact of crosswind conditions on the performance of motorbikes. By analyzing the pressure distribution on the side view of the models, it is possible to determine which parts of the motorbikes receive high and low pressure, and how the specific angle of the crosswind affects the distribution of pressure. This information can be used to optimize the design of motorbikes and improve their performance under various crosswind conditions.

Table 3 - Pressure contour on motorbike model

Yaw angle (◦)	Fully Fairing	Half Fairing
0		
15		
30		
60		
90		



4. Conclusion

The study's main goals, which were to examine the aerodynamic loads on the motorcycle's drag, side, and lift coefficients and to analyses the flow pattern that results from various fairing types when travelling in various crosswind conditions, were successfully accomplished through the use of computational fluid dynamics (CFD) analysis.

Initial changes in crosswind yaw angles (Ψ) have a major impact on aerodynamic loads. The quantitative data charts that are shown serve as proof of this. The formation of a recirculation region and increased pressure are both caused by higher crosswind angles, according to qualitative data affecting streamline surfaces and pressure. Half-fairing motorcycles frequently have a higher aerodynamic coefficient than fully fairing motorcycles in terms of fairing types.

Since the crosswind angle in real-world scenarios is limitless, it is advised that crosswind variations be made in order to provide a more accurate study of various crosswind conditions. It is important to take wind gusts into account as well. The study's scope can be widened in order to implement these suggestions. Although putting these new suggestions into practice may be more challenging, they have the potential to advance our current understanding, particularly in the flow around motorcycles.

Acknowledgement

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