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AN INVESTIGATION ON MOTORCYCLE WINDSHIELD DESIGNS FOR ENHANCED AERODYNAMIC FEATURE

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ABSTRACT

A motorcycle windshield protects motorcyclist from wind and external environment from making direct contact to the upper body extremities while riding. The windblast that has direct contact with the motorcyclist is considered to be a laminar flow. However, in the event of poor streamlining, the windshield would trap the turbulence instead and creates a higher dynamic pressure which affects its overall aerodynamic functionality. This study was aimed at investigating the different designs of windshield to minimize dynamic pressure to signify good aerodynamics characteristics. ANSYS-Fluent workbench was used to simulate the flow and optimize the streamline. It was observed that windshield with slot had lower performance compared to the design without slot due to the air passage through the slot that would subsequently alter the streamline and make the turbulence wake and output dynamic pressure to be higher. Consequently, the design with a smaller surface area would perform better due to less stagnation points.

Keywords: Windscreen, laminar and turbulent flow, streamline, pressure drag, slot.

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1. INTRODUCTION

It is evidenced by the Jabatan Pengangkutan Jalan Malaysia (JPJ) and the Malaysian Automotive Association that the amount of motorcycle registration is increasing in recent years [1, 2]. Within the Asian region, Indonesia is noted as the biggest consumer with about 6.2 million motorcycles and scooters being sold in 2016 [3]. Motorcycles have many preferences in comparison to other registered road vehicles, especially in the city. As the demand for motorcycle is high in recent years, manufacturers such as Yamaha, Kawasaki, Suzuki and the likes, are producing motorcycles in various engine capacities and designs. These various designs represent their own unique characteristic attracting different types of consumers. It is not uncommon for motorcycle owners to make modifications on their respective motorcycles to better suit their preference [4]. Furthermore, in viewing to the current trend since 2012, manufacturers are even encouraging their customers to modify their motorcycles by providing a huge list of OEM after-market parts e.g. Triumph on their Bonneville lineup and Kawasaki with respect to their latest Vulcan 650 model. Aside from attaining sheer performance, the most generic modifications made onto the motorcycle is generally with respect to motorcycling comfort [5-7]. The motorcycle windscreen or commonly known as windshield protects the motorcyclist from the wind i.e. windblast and external environment (e.g. dirt and debris) from making direct contact to their upper body extremities (especially the head and upper torso region) while riding. Aside from aesthetics and cosmetic changes, this main function of the windshield is to affect the air flow during motorcycling; and this was the function of critical interest in this study i.e. aerodynamics prowess.

With respect to aerodynamics, the windshield facilitates in either channeling the air flow away from the motorcyclist (e.g. small windscreen that redirects the flow) or totally protecting the motorcyclist (e.g. big windscreen that shields the motorcyclist completely). The wind that has direct contact with the rider is considered as laminar air flow. In the event of poor streamlining, the windshield would trap the turbulence instead and creates a higher pressure. This in return will result in the chain effects of increasing drag force, turbulent wake zone and reverse flow. In short, undesirable for motorcycling due to poor aerodynamics. Henceforth, at best, the windshield is capable in either maintaining a streamlining air flow or break the turbulence flow [8].

According to the research and result of wave breaker turbulence as a mechanism for sediment suspension by Mocke et al., the essential of the wave breaker turbulence for silt suspension is plainly settled [9]. The investigation has showed that silt particles are suspended softened the waves up surf zone. The suspended silt is measured by a few requests of extent statures. The higher the heights over the bed, with suspended silt outside the surf-zone, frequently confined to the constrained wave limit. With this technique, the flow is able to be reduced and minimized [10]. The laminar air flow facing straight by the rider would also have chances to minimize those defects.

Ivan et al. [11] developed an equation showing the discrepancy between the volume of flux in turbulent and laminar flow at a same incremental of pressure gradient. The study used a fixed bulk-Re number and looked for the lowest bound for friction drag to control schemes that utilization surface blowing and suction with zero net volume flux expansion. They have showed that the sustained drag below the laminar Poiseuille flow case is impractical by using a crossflow approach. There is criteria to accomplishing sub-laminar drag and utilize to the control strategy and the limitation of Reynolds numbers. The uniform control of flow over the channel was utilized by Fukagatar et al. [12]. The study proved that the sustained drag below the laminar Poiseuille flow case is unrealistic. Through the experiment, lessening the turbulence level in the flows driven by a steady energy source can prompt significant increases of the velocity. The reduction of the turbulence flow intensity and consequently an increase in the mean wind speed was due to suspension of particles in the flow.

The setup of a windshield height should come up to the tip of the rider nose when the rider sits upright on the saddle to have a slip stream impact. Slot is the short gap between the slat and the leading edge. Increasing the angle of attack reduces the turbulence due to eddy. By moving the wing up or down to control the angle of attack and impact the wings generate lift force. Besides, putting it upward would increase the lift while decreasing the airspeed. Laminar breaker would minimize the physical fatigue with respect to the upper extremities. It would reduce the stagnation point and smoothen the air [13, 14]. The study made led to the chain effects on drag force, turbulent wake zone and reverse flow [15]. During the ride, a smooth and streamlined laminar flow is created when the motorcyclist's head is angled downward. However, when the motorcyclist is seated upright, this creates direct air blast. The impact of laminar flow includes various physical and psychological issues such as headache, back pain and mental fatigue. Moreover, it most critically affects the aerodynamics characteristics due to the increase of drag force, turbulent wake zone and reverse flow. The objective of this study was, therefore, to investigate the performance of several motorcycle windshield designs. Data comparison was also made to evaluate the overall performance of these windshields with respect to the average outlet velocity and the pressure output, which provides a solid quantitative data in term of the most aerodynamically functional windshield.

2. MATERIALS AND METHODS

In this study, four windshield models for a type Z motorcycle which has the capacity to cruise at 150-180km/h were tested. Figure 1 shows the four design models investigated. The Model X is the design currently available in the market (see Figure 1a). Another version of the Model X is equipped with a slot (see Figure 1b). This Model X with slot is yet to be available in the market during this study, though, reported to be made available in the future. The slots were qualitatively noted by the vendor to give a better aerodynamics performance in comparison to the initial Model X design. To prove that the theory of streamline is important on a windshield design, Model Y was generated and tested (see Figure 1c). The design of Model Y was inspired by the Model X design. The Model Y was further modified with oval shape slot to investigate its performances (see Figure 1d). SolidWorks was used to represent the different designs, whilst, ANSYS-Fluent workbench was used to simulate the flow and investigate the effects from the different designs. In addition, the original size was also created and simulated using ANSYS-Fluent workbench.

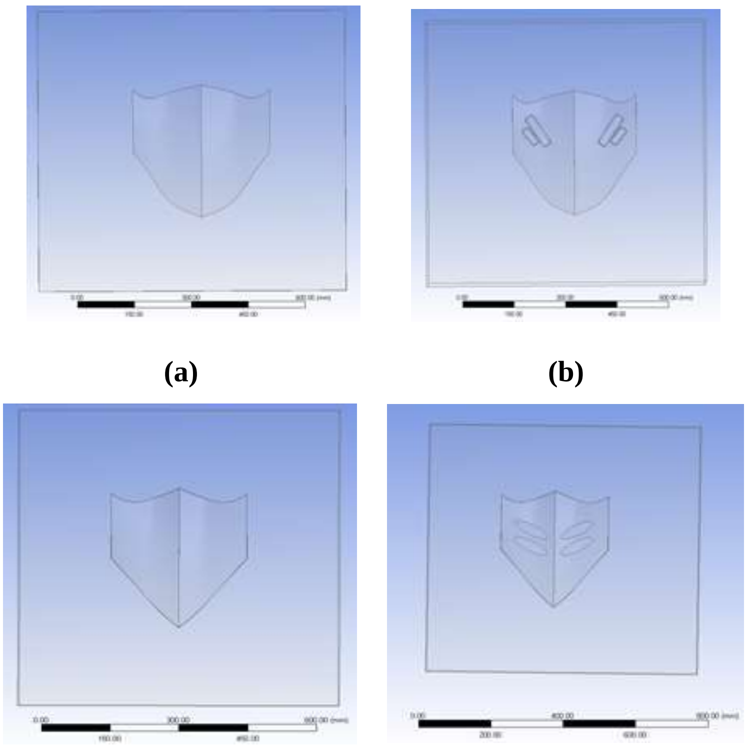
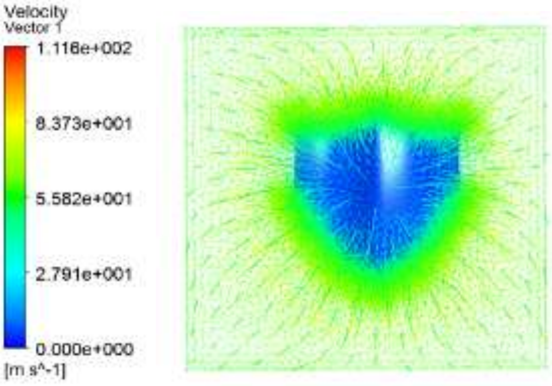
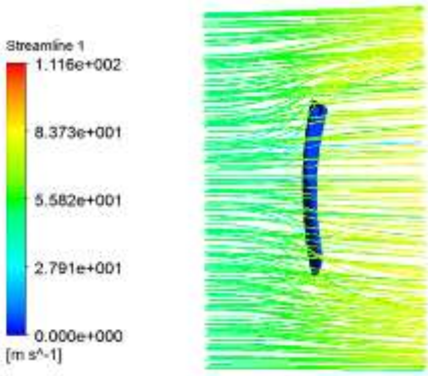


Figure 1 Motorcycles windshield: (a) Model X (market design), b) Model X with slot (future market design), c) Model Y (new design), and d) Model Y with slots (new design)

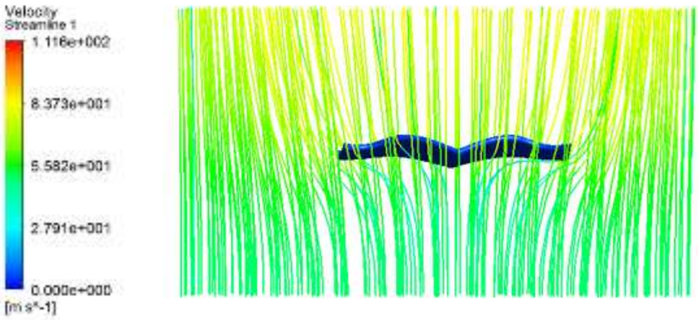
3. RESULTS AND DISCUSSION

Model X represents the generic market design; however, due to the poor streamlining, the windshield traps the turbulence and creates a higher pressure. Figure 2 shows the velocity profiles for the model X. The average outlet velocity was 53.40 m/s and the pressure output was -5.05Pa due to the streamline and turbulence wake. The windshield created high kinetic energy in wake reverse flow pressure. Additionally, the particles have a districted size streaming either above or below the stagnation point.





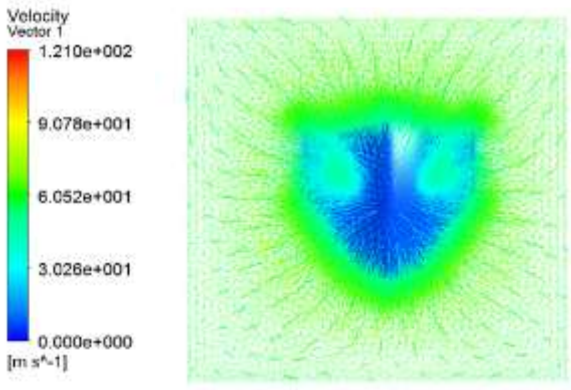
a) **b)**

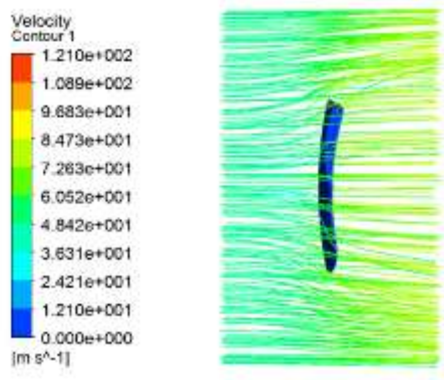


c)

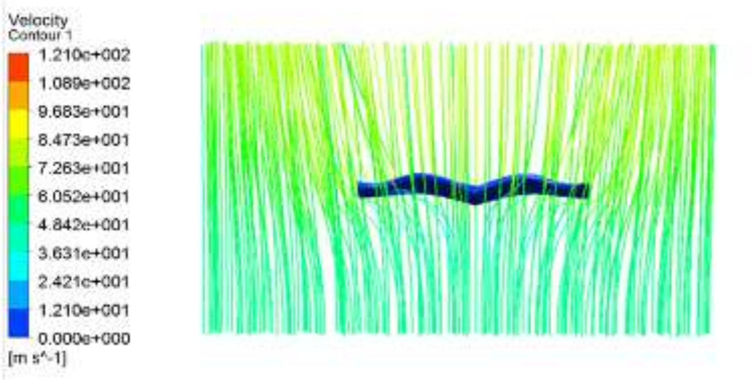
Figure 2 Velocity profile of Model X: a) Front view, b) side view and c) top view

Figure 3 shows velocity profile for the model X with slot. The average outlet velocity was 53.87m/s and the pressure outlet was -7.47Pa. The design was created because the slot is believed to assist in a smooth flow of air enhancing a better streamline based on the principle of slot and slat in aerodynamics. Yet, it was observed that the slots actually resulted in making the streamlining much harder to be achieved. Moreover, turbulence wake would be created, thus, leading to the increase in drag force.





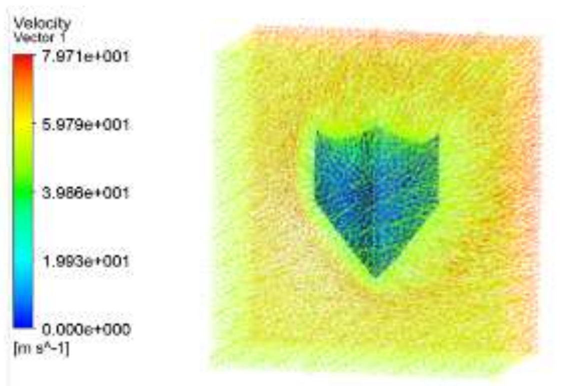
(a) **(b)**

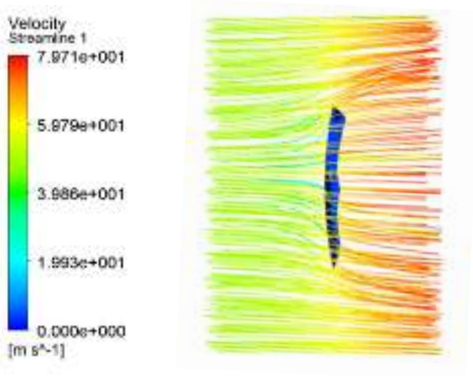


(c)

Figure 3 Velocity profile of Model X with slot: a) front view, b) side view, and c) top view.

Figure 4 shows velocity contours for Model Y. The average outlet velocity was 52.81m/s and the pressure output was -3.9Pa. This might be due to the much better air flow streamlining and the minimization of turbulence wake. The windshield creates high kinetic energy in wake reverse flow pressure. Additionally, the particles have a districted size they stream either above or below the stagnation point streamline. Model Y without slots obtains the lowest output pressure because the surface area and the output velocity were the lowest compared to the Model X. This leads to a chain effects with the drag force, turbulent wake zone and reverse flow to be lowered or decreased simultaneously. The smaller surface area would lessen the stagnant point and minimizes the effects from the air with respect to frontal pressure.



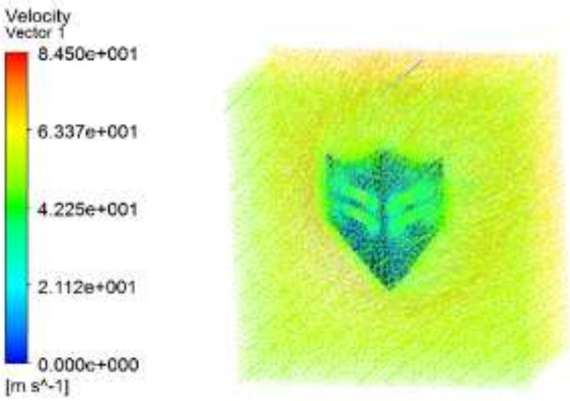


a) **b)**

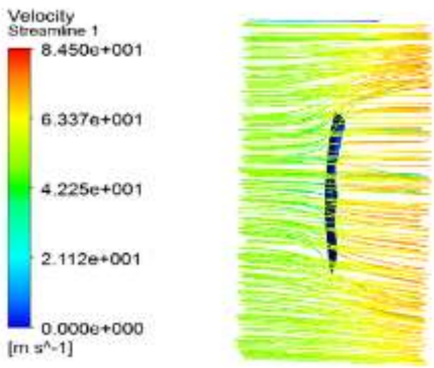
c)

Figure 4 Velocity contour of Model Y: a) Front view, b) side view and c) top view

Figure 5 shows velocity contours for Model Y with slot. The average output velocity is 53.75m/s and the pressure outlet is -12.46Pa. The design was created as the slot was believed to assist in a smooth flow of air enhancing a better streamline according to the principle of slot and slat in aerodynamics. However, it was found that the presence of slot in the windshield would disrupt the air flow, thus, making streamlining much harder to be achieved. Hence, negatively affecting the aerodynamics characteristics. Moreover, Model Y with slots showed an almost identical output velocity, nevertheless, the addition of the slots actually created a higher pressure (the highest for all designs tested). This implies poor flow streamlining and an increase in drag force.



a)



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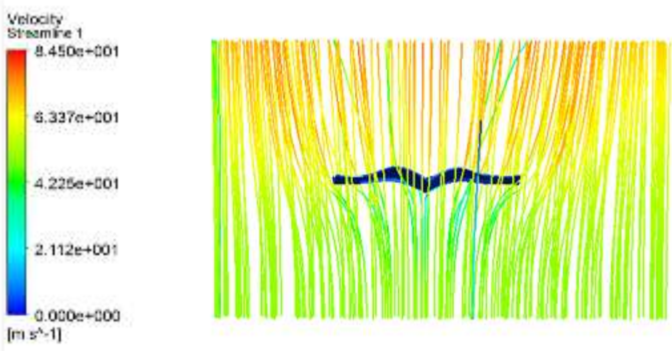

c)

Figure 5 Velocity streamline for Model Y with slots: a) Front view, b) side view and c) top view

The drag force is directly proportional to the dynamic air pressure. In return, the dynamic air pressure is directly proportional to outlet air velocity. By having the capacity to minimize the outlet pressure, it implies that the air flow is streamlined i.e. no turbulence is trapped as the streamlined air exits the windshield. This results in the decrement of drag force, turbulent wake zone (the amount of drag is proportional to the size of the wake) and reverse flow. These are essential in making the task to cut through air that much easier. In short, the overall aerodynamics superiority of the windshield in this study was gauged based on the capacity to achieve low readings for outlet air velocity.

Table 1 shows velocity and pressure values of the four windshield designs. In general, the windshield with slot has lesser performance compared to the design without slot due to the air passage through the slot that subsequently affects the streamline and increases the drag force, turbulent wake zone and reverses flow. Therefore, the output pressure of the design with slot is higher than that of the design without slot. With respect to the results, this study has provided the quantitative evidence that the qualitative assumption that the slots could actually improve the aerodynamics prowess of the windshield is actually inaccurate. Even so, unless the design of the slots could actually minimize the trapping of turbulence and actually aids in air flow streamlining, only then it could be said otherwise. Consequently, it was found that the design with a smaller surface area would perform better as the stagnation point becomes lesser. Yet, the decrement in the overall surface area may result in the increase in the direct exposure of the motorcyclist to the air flow during motorcycling. Hence, highlighting the only limitation of this study, which is, the motorcyclist's upper body extremities (e.g. head and torso) was not modeled and included in the simulation. This study was specifically conducted in investigating the outlet pressure and velocity readings with respect to the windshield's shape, surface area and the existence/non-existence of slots as the only parameters.

Table 1 Comparison of performances among the windshields

	Model X	**Model X with slot**	**Model Y**	**Model Y with slot**
Inlet Velocity	50m/s	50m/s	50m/s	50m/s
Outlet Velocity	53.40m/s	53.87m/s	52.81m/s	53.7462m/s
Outlet Pressure	-5.05Pa	-7.47 Pa	-3.9 Pa	-12.46 Pa
Total Area	218 623.4mm^2	212 438.45mm^2	159 171mm^2	142 675mm^2
Thickness	3mm	3mm	3mm	3mm

4. CONCLUSION

This paper investigated the effects of different designs of windshields of motorcycles. Four different designs were created and simulated using ANSYS-Fluent workbench. It was observed that the output pressures and average outlet velocity of the Model X were -5.05Pa and 53.4032m/s, respectively. On the other hand, the output pressure and average outlet velocity for model X with the additional rectangular slot were -7.47Pa and 53.879m/s, respectively. The output pressures and average outlet velocity of the Model Y were -3.9Pa and 52.81m/s, respectively. On the other hand, the output pressure and average outlet velocity for model Y with slots were -12.46Pa and 53.746m/s, respectively. It can be understood that the design without slot is much better in reducing drag force, reverse flow and wake turbulence, thus, improving the streamline. Nevertheless, for future study, since slots is theorized to improve air flow with reference to the principle of slot and slat in aerodynamics, it is recommended to investigate in various slots angles in determining whether it could actually improve air flow streamlining for windshield. Furthermore, since this study did not include the motorcyclist's upper body extremities as one of the parameter in investigating the overall streamlining, it is proposed that this variable is also taken into consideration in gauging the performance of the windshield for future studies.

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