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The Effect of Adding Diffuser by Experimental

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Abstract – *The purpose of this project is to improve the aerodynamics coefficient of Proton Persona by adding diffuser onto it. It is done by determining each of the drag coefficient of the model, by experimental method using Low Speed Wind Tunnel. All the relevant data are collected through the literature reviews from books and journals. First, the basic thing in aerodynamic is studied. Then, the theory of the diffuser need to be understand. Diffuser can work to reduce drag and increase downforce of the vehicle. There are things that need to be concerned when studies aerodynamics. They were air flow and vehicle shape which we regard as aerodynamics factor that will determine aerodynamic of the vehicle. Fundamental of air flow and vehicle shape is reviewed includes the relationship between air speed with pressure, the boundary layer, Reynolds number, drag, lift drag and shape optimization. Wind tunnel is also closely studied before the experiment is conduct. In methodology, model specification and experiment procedure is explained, together with considered assumptions. Five selected speed were been tasted during the experiment to determine the Drag Coefficient (CD) value. The relevant graphs are then plotted and discussed. Then, the diffuser angle with the minimum CD will be chosen to calculate the drag reduction percentage.*

Keywords: Drag Coefficient, Diffuser Angle, Wind Tunnel, Reynold Number

1.0 INTRODUCTION

Aerodynamics plays a very important role to the vehicles such as cars, airplanes, and helicopters. Throughout time, there have been many types of design that have been done to increase the efficiency of the aerodynamics of the vehicle. This is because it has a direct influence such as car performance, fuel consumption, stability, and etc. For example, the scientists and engineers been working really hard to decrease the drag coefficient in order to improve the shape of the vehicle as well as the efficiency and the performance of the car. There are at least 4 stages of improvement of the aerodynamics of the car that has been done up until now. Most of the stages are mainly focused on the improvement of the shape of the vehicle. However, apart from the aerodynamic shape of the car, there are also another factor that can contribute to the increasing of the aerodynamics efficiency of the vehicle. One of the factor that can contribute to the increasing of the aerodynamics efficiency is the rear end diffuser. It is one of the most important aerodynamics add on devices. Many research [1, 2, 3, 4, and 5] has proven that large downforce can be generated by diffuser systems.

The study is to determine the drag coefficient of the Proton Persona by using 1:15 scaled-car model in the wind tunnel. The Proton Persona scaled model car was built with 3^o, 6^o, and 9^o of

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diffuser angle. The model will be tested at 5 different speeds which is 10 ms^{-1}, 15 ms^{-1}, 20ms^{-1}, 25 ms^{-1}, and 28 ms^{-1}. Data compared between the added diffuser models with non-added diffuser model. The total aerodynamic drag coefficients are first increasing then decreasing with increasing diffuser angle. There is an appropriate diffuser angle at which the total aerodynamic drag coefficient has a minimum value.

2.0 METHODOLOGY

Four models with different angle of diffuser are fabricated with scale 1:15 from the original dimension. Reference dimension taken from the Protonedar website. Figure 1 shows the basic dimension of Proton Persona.

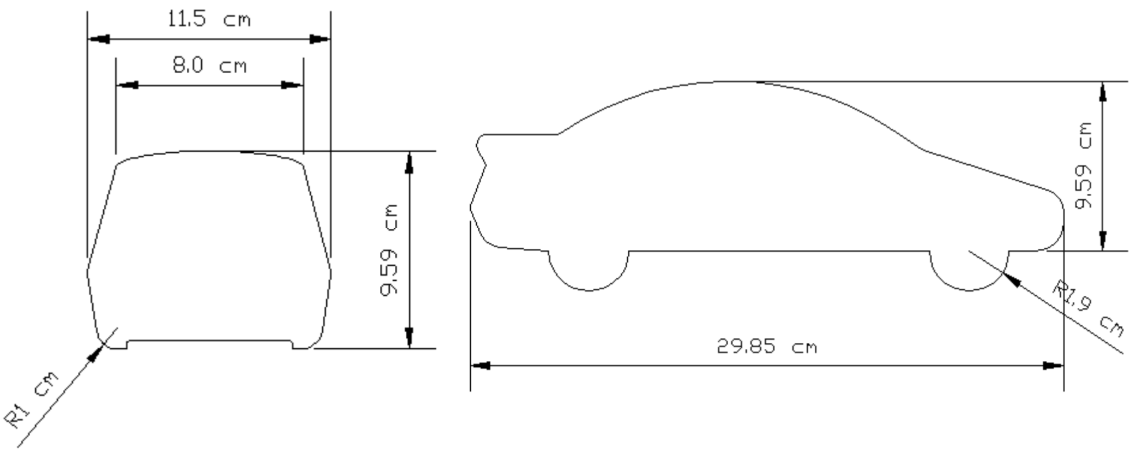

Figure 1: Front and side view dimension

Experiment done using fabricated model with several diffuser angle of 3°, 6°, and 9° as shown in figure 2. The test been done using Plint & Partners Ltd. subsonic wind. There are six components of force and moment acting on a wind tunnel model. These six components are known by those skilled in the art as lift force, drag force, side force, pitching moment, yawing moment, and rolling moment. By determining the magnitude of these components acting on a scale model in a wind tunnel, certain design parameters can be obtained which will apply to the full scale aircraft. Only drag force been considered during the experiment in order to obtain the drag coefficient.

The dynamic pressure and drag force was recorded at 10 ms^{-1}, 15 ms^{-1}, 20 ms^{-1}, 25 ms^{-1}, and 28ms^{-1} for all diffuser angle 3°, 6°, and 9°. The drag coefficient will be calculated using equation below. In Figure 3.1, the graph paper show the frontal area of the model is 0.01064 m^2. The air density, ρ, and dynamic viscosity, μ, taken from the experiment area at 27°C and at atmospheric pressure.

The air density, ρ, is 1.17 kg/m3 and the dynamic viscosity, μ, is 1.983 x 10-5 kg/ms.

$$c_d = \frac{F_d}{\frac{1}{2}\rho v^2 A} \tag{1}$$

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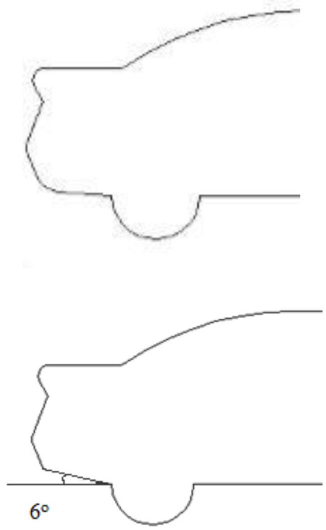

Figure 2: Diffuser angle for experiment

where;

F_D : The axial force or drag force which obtained from six component balance
p : Density of air
v : Velocity of air flow during testing (10 ms^{-1}, 15 ms^{-1}, 20 ms^{-1}, 25 ms^{-1} & 28 ms^{-1})
A : Frontal area of the scaled model

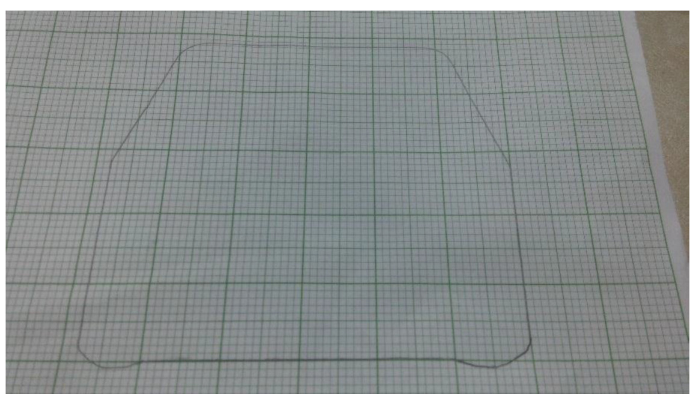

Figure 3: Frontal Area of Scaled Proton Persona Model

3.0 RESULTS AND DISCUSSION

The model of the scale 1:15 Proton Persona had been placed in the test section with ground clearance of 0.022 m from the floor of the wind tunnel section. The temperature of the laboratory is at 30°C with the density of air at 1.17 kg/m3. There were four model car with 4 different angles were tested. Results obtained is tabulated at Table shows below. Each table shows the five different of wind speeds which are at 10, 15, 20, 25 and 28 m/s. 28 m/s is the limit of the wind speed that the wind tunnel can sustain.

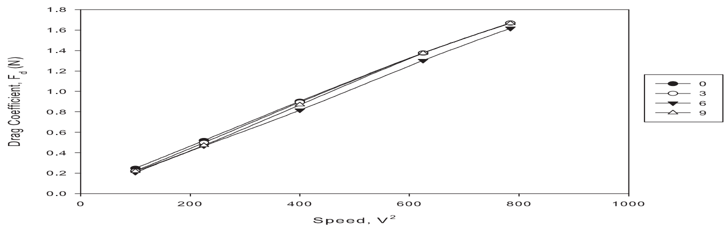

Figure 4: Frontal Area of Scaled Proton Persona Mode

From Fig. 4, it shows that the drag force is directly proportional to the square of speed. The increase of square speed will increase the drag force. It is called the aerodynamic drag. Referring to the air drag equation (1), the drag force will increase as the square of speed, density of the medium, frontal area and the drag coefficient increases. It is the same as logic, that the faster the car is drove, the stronger the resistance it gets. For example, an object that is stationary with respect to the fluid will certainly not experience any drag force. Start moving and a resistive force will arise. Get moving faster and surely the resistive force will be greater.

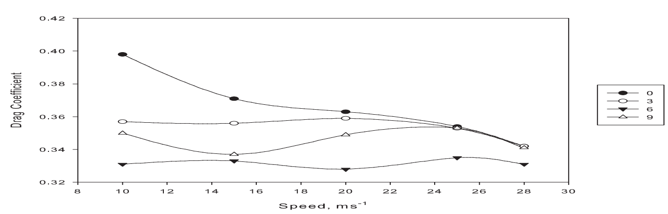

Figure 5: Frontal Area of Scaled Proton Persona Mode

Figure 5 shows the drag coefficient at corresponding speed. It is divided into four case. From the graph, we can see that the drag coefficient of case one is decreasing whereas the drag

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coefficient for the other three cases show more constant value throughout the speed. At 10 ms-1, the highest drag coefficient is from the case one, 0.398, followed by case two, 0.357, case four, 0.350, and lastly case three, 0.331. During 15 ms-1 to 28 ms-1 the value of drag coefficient for all the cases show more constant values throughout the speed. What can be deduced from this graph is that the diffuser can somehow make the drag coefficient more constant and maintain at smaller range throughout the speed. Some error may occur during the running of experiment. Uniform air flow is hard to achieve due to changing of dynamic pressure at lower speed. Hence, it is affecting the drag force and the drag coefficient. That also explain why the values of drag coefficient at 10 ms-1 for case one is too high among the rest.

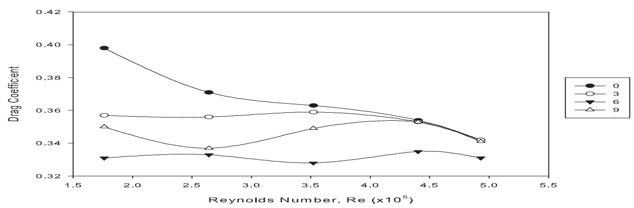

Figure 6: Frontal Area of Scaled Proton Persona Mode

Figure 6 shows the drag coefficient versus Reynolds number. There is similarity between the graphs in figure 6 (drag coefficient versus Reynolds number and the graphs in figure 5 (drag coefficient CD versus speed). Based from the equation of the Reynolds Number:

$$R_e = \frac{\rho v L}{\mu}$$

It can be seen from the formula that Reynolds Number depend on the velocity as the travelled length of the fluid, dynamic and kinematic viscosity is constant throughout the velocity. Hence, that explains why the graph for figure 6 is similar to the graph for figure 5.

4.0 CONCLUSSION

From the experiment using the subsonic wind tunnel with four models, results shows that by increasing the diffuser angle will improved the drag coefficient. Eventhough the data shows an increase in drag coefficient at 9°, the drag coefficient is still better than 0° angle. Table 1 shows the drag coefficient for all tested samples.

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Table 1: Total Drag Coefficient for Various Diffuser Angle of the Model.

Diffuser Angle	C_D
0 °	0.366
3 °	0.353
6 °	0.332
9 °	0.346

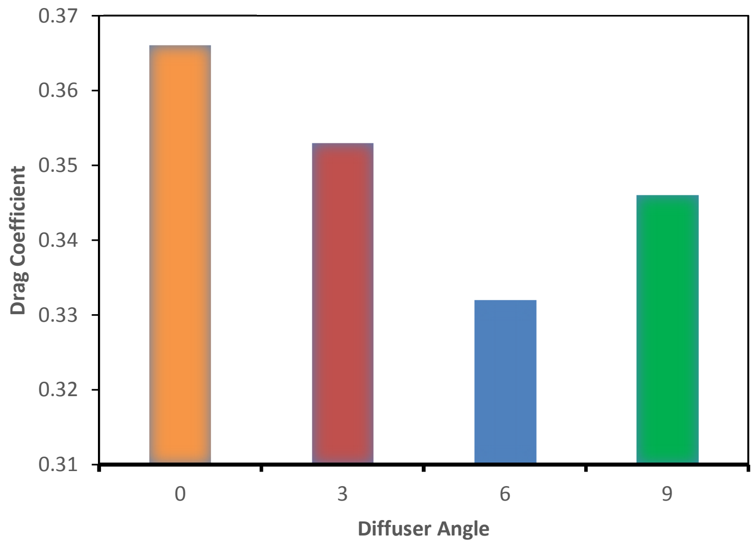

Figure 7: Drag Coefficient for Diffuser Angles

From Fig. 7, it observed that the increase of diffuser angle has an influence on wake and the underbody flow behind the rear wheels. The lowest drag coefficient recorded for diffuser angle of 6° and the highest recorded at 0°. The result concluded that by increasing the diffuser angle can help to reduce the drag coefficient, however the drag coefficient is performing well before start to increase again at 9°.

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