Aerodynamics Analysis of UniMAP Automotive Racing Team Formula SAE race car spoiler via simulation: Effect of Spoiler Size

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Abstract. Lift force that occurred on a speeding race car will cause the vehicle to lost its stability, traction and speed. Therefore, a car spoiler is installed on a race car to reduce the lift force, making the vehicle more stable. The present work investigated the impact of spoiler size on the drag force and downforce value on the UniART FSAE race car using simulation software. From the results, a larger spoiler size gives the highest downforce compared to other sizes. The downforce and the area of the spoiler showed a directly proportional relationship. The result of drag force led us to conclude drag force increase if the spoiler is mounted at the rear part of the car, however different sizes of spoiler doesn’t seem to have a big effect on the drag force.

1.0 Introduction

The overall concept behind Formula SAE is that a fictional manufacturing company has contracted a design team to develop a small Formula-style race car. Overall, all the automotive aspects have been considering critically during team designs, builds and tests a prototype based on a series of rules whose purpose is to both ensure onsite event operations and promote clever problem solving [1]. Hence, aerodynamics is one of the crucial factors to be considered. Aerodynamics focuses on the interaction between the motion of airflow and bodies moving through air [2]. The main concerns of automotive aerodynamics are to reduce drag and wind noise, improving vehicle stability and preventing undesired lift forces at high speeds. For a greater aerodynamics result, most racing cars will use rear spoilers to reduce drag and to increase car stability [3]. The form of drag is dependent on the particular area of a wing profile of the spoiler. The changes in air pressure and the velocity of the motion air flowing around the spoiler effectively create the required force to enable traction on the tires to the road. Induced drag or interference drag is a result of vortices that are generated behind the solid object due to the change of the direction of the air around the spoiler [4]. This project will be carried out by demonstrating and evaluating the airflow through the spoiler using ANSYS Fluent workbench. The objective of this research is to find out whether the size of the spoiler can affect the UniART SAE race car performance and analyse changing pattern of the drag force and downforce result based on the size of spoiler impact. The software generated force result approach is used to calculate the drag and downforce being produce from the different sizes.
2. Methodology

2.1 Vehicle generic models and dimensions
Geometry and parameter design for this car body based on FSAE car rule, which must have a wheelbase for at least 1525mm (60 inches). The wheelbase for these body components is 1581.07mm, the height average is 500mm, and the width is 1218.75 mm. The generic model for these body components was designed in 3D view and using a 3D modelling software.

2.2 Spoiler generic models and dimensions
There are three different sizes of the spoiler, where it was distinguished by three different sizes, which is the small spoiler size, the medium spoiler size and the large spoiler size. All dimensions of the spoilers are designed so that it is compatible with the rear part of the car, as shown in Table 1, while the car model is shown in Figure 1.

Table 1: Total area for spoiler small size, spoiler medium size and spoiler large size.

| Parameter     | Spoiler small size | Spoiler medium size | Spoiler large size |
|---------------|--------------------|---------------------|--------------------|
| Length        | 0.885 m            | 0.945 m             | 1.005 m            |
| Width         | 0.156 m            | 0.176 m             | 0.196 m            |
| Total area    | 0.13806 m²         | 0.16632 m²          | 0.19698 m²         |

Figure 1: Car model assembled with spoiler

2.3 Determination of car speed in surrounding channel
Determination of car speed in surrounding channel is evaluated by conducting car speed testing. The purpose of the test is to determine the power of 600 cc engine and suitability of car body weight due to the speed of car produced on the road. In real world testing, it was found that the average car speed is 85 km/h. For the upcoming investigation, the low speed prediction is set equal to 65 km/h and the high speed prediction equal to 105 km/h. The prediction speed was set as the inlet velocity variable in ANSYS Fluent software.

2.4 Simulation process in ANSYS workbench.
The vehicle and spoilers geometry was designed in 3D modelling axis using the CATIA. ANSYS Fluent is the software used for the simulation process. To recreate the actual situation on the
surrounding channel, the speed of the car in this experiment was adjusted in conjunction with the speed resulting from the actual speed of the car on the track during the time trial was performed. During the meshing analysis process carried out to mesh the curve and bends and surfaces, triangular shape surface mesh was used due to its proximity changing on the complex shape. Based on general mesh sizing settings, ANSYS Meshing® identified up to expectation there were partial curvatures around the car body. The meshing was coarse then it was only the initial approximate data by the software. In rule conformity for the purpose to capture accurate information through solver, we needed to improve the mesh properties. The preceding element to operate was changing the mesh sizing parameters into fine quality. It is resulting more accurate meshing compared to the standard setting on the software.

Several Fluent conditions for the car simulation is set up by made the viscous model equal to k epsilon (2eq). The selection of the viscous model was based on the literature review. The accuracy of results was achieved with good stability and minimum computing power requirement. By making material used by the car and spoiler components in the real world as the reference point, the material properties in this research set air particles as fluid flow and glass fibre for the car body condition. Operation pressure at the outlet of surrounding channel is set equal to zero value in purpose to neglect the impact of air from the backward. The inlet velocity is divided into three variables, which is 65km/h, 85 km/h and 105 km/h. Furthermore, with the changing of streamline flow from laminar to turbulent relation from the impact on tested subject geometry, the suitability of turbulent flow has been established equal to the Second-order upwind. Default settings have been set for several parameters to generate the analysis. Figure 2 shows the simulation arrangement using the software.

![Image](image_url)

**Figure 2**: Simulation arrangement
3.0 Result and discussion

3.1 The comparison result of the lift force generates from three different size of spoiler mounting at rear part of car and car without spoiler.

From Figure 3, it shows the distinction between lift force outcomes among four variable parameters. In any condition, the addition of spoiler generated downforce, in which the pressure imbalance is exerted on the spoiler geometry, higher average on the top rather than the bottom surface [5]. Bernoulli’s theory described if the pressure drops along a streamline, the velocity increases and vice versa [6]. Highlighted differences may be located among the outcomes of the car with a spoiler and the car without a spoiler generated positive lift force, where the highest value is 14.72 N at inlet velocity of 105 km/h. The car with the small spoiler indicates a reduction in lift force, however, the lift force is still positive, where the highest value produced is 1.84 N at a 105 km/h. For the medium and large spoiler sizes, the lift force is negative, indicating that there is a downforce exerted on the vehicle. Vehicle spoiler mounted with medium sized spoiler produced the highest downforce of 1.77 N at an inlet velocity 105 km/h. The large size spoiler produced at the highest value compared to other sizes of the spoiler with generated downforce of 19.45 N at the inlet velocity of 105 km/h.

![Figure 3: Lift force comparison of car without spoiler, spoiler small size, spoiler medium size and spoiler large size.](image)

3.2 The comparison between drag force results generates from three different size of spoiler mounting at the rear part of the car and car without spoiler.

Figure 4 shows relationship between the different sizes of the spoiler and the drag force acting on the surface of the car. Significant differences can be categorize between the car without spoiler and car with spoiler, which in the experimental result context proof that car without spoiler, generated more low rate of earnings drag force in average. Car without spoiler producing a maximum drag force 176.44 N on the inlet velocity at 105 km/h. Car with spoiler can be categorize into three parameters, which is small, medium and large spoiler. Car mounting with medium spoiler produces the highest drag force that respectively generates 192.22 N results. Furthermore, its value was followed by a small spoiler size with the resulting drag force equal to 189.37 N. The minimum value of drag force between three variable spoiler size geometry exists when the car was tested with large size spoiler which has resulted in the 182.51 N. Working principle behind drag force related to the force on the opposite
direction of motion that acts on a body moving through air [7]. Hence, in spoiler aerodynamics context and study point can be related to frontal pressure effect with the consequence of the air trying to float across the front of the spoiler. Air particles approach the front geometry of the spoiler components, they begin to compress and simultaneously enhance the pressure in the front of the spoiler [8]. It can be concluded that the drag force increased if the spoiler is mounted to the rear part of the car.

**Figure 4**: Drag force comparison of spoiler small size, spoiler medium size, and spoiler large size

4. Conclusion

The relationship between the lift force and the size of the spoiler was established, that by increasing the size of spoiler, higher value of downforce was generate. Good tire traction and stability of car during cornering was influence by higher value downforce that exerted on the car geometry. With higher the value of downforce, higher probability for gain good tire traction and stability when cornering. For the drag force, by mounting the spoiler at the rear part of the car, the value of drag increased if we compared to the car without spoiler. The variation of drag force between each parameter of size is small because it is only focusing on the frontal impact.

Acknowledgement

The authors would like to thank Universiti Malaysia Perlis for the technical support and facilities provided for this work.

Reference

[1] A. Kourta, P. Gilliéron "Impact of the Automotive Aerodynamic Control on the Economic Issues", Journal of Applied Fluid Mechanics , Vol. 2, No. 2, pp. 69-75, 2009, ISSN 1735-3645

[2] Sumantran, V., & Sovran, G. (1996). Vehicle aerodynamics. Warrendale, PA: Society of Automotive Engineers.

[3] Bonitz, S., Larsson, L., Lofdahl, L., and Broniewicz, A., "Structures of Flow Separation on a Passenger Car," SAE Int. J. Passeng. Cars - Mech. Syst. 8(1):177-185, 2015,
[4] Kyei Minkah, Sandy. "Composite Car Rear Spoiler." Degree Thesis, Arcada University of Applied Sciences (2014)

[5] Anderson, John D. (2004), *Introduction to Flight* (5th ed.), McGraw-Hill, pp. 257–261

[6] Klaus Gersten, E. Krause, H. Jr. Oertel, C. Mayes "Boundary-Layer Theory", Herrmann Schlichting, 8th Edition, Springer 2004

[7] Katz, J. (1995). Race car aerodynamics: Designing for speed. Cambridge, MA, USA: R. Bentley.

[8] Murugan, C. K. B., Ashik, P. N., & Raju, P. CFD Analysis and Optimization of a Car Spoiler. *Journal of Aerodynamics* 48.7 (2013)