# Based on Previous Research to Improve the Rear Wing of the Car

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Abstract: Previous studies have found that drag and down force generated by Formula cars' rear wings, as well as the whole car's aerodynamics can be changed with different speeds, different Angles of Attack, different types of rear wings, and different install locations. This study filtered and organized those articles. After using principles and logical assumptions to analyze. This study also studied how the rear wing shape of a Formula car can change its downforce and drag; beyond that, the first part of the suggestion on how to modify the rear wing shape was given. Furthermore, the second part of the suggestion was given after combined with real race speed. Lastly, based on the different impacts on the aerodynamic characteristics, a suggestion on how to improve the shape and install location of the rear wing to make the best downforce and drag ratio on Model Drela AG03, makes the driving experience and aerodynamic characteristics better.

## 1 INTRODUCTION

Formula 1, one of the top sports in the world, has the most development in car performance. Car engineers consider most on how to make their cars go fastest when designing those machines. Studies across the globe have shown that race car speed isn't heavily relied on the engine, but on its grip. When the tangential force applied on tires and ground goes beyond a certain limit, the tire will lose its grip and eventually spin. (Wang, Zhang, and Zhou, 2021) This is because driving force, steering force, and brake force in conventional race cars is made in the friction force within the tire and the ground. Nowadays, the best way to increase downforce and grip without adding extra weight is to use the rear wing's aerodynamic design. (Zhang, Li, and Qiu, 2021） Countless studies about the whole race car have shown that while the car weight brings 20% of its grip, the rear wing can generate 80%. (Zhu, and Yu, 2020) Downforce directly shows how much the rear wing can provide grip; meanwhile, drag shows how much the rear wing shape can change the car driving experience. Therefore, finding the balance between those two figures is the key to making and designing an excellent race car.

Rear wing shapes have a direct and significant impact on downforce and drag. It can improve handling and stability by scientific design and modification while reducing the impact on drag as little as possible. This research will summarize factors that affect by rear wing and different rear wing choices and designs based on rear wing shape design and research on previous studies; Furthermore, this research combined and modified the rear wing design. This research can make new and more choices for single-rear wing race cars, make contributions for better handling and stability, and as fast as it can.

## 2 THEORETICAL BASIS

Racing cars are usually subjected to lateral, longitudinal, and vertical resistance during driving. Installing a racing spoiler can reduce resistance on the racing car and increase downforce (Wang, and Xia, 2021). According to Bernoulli's equation, it can get: (Zhang, Jiang, and Gong, 2022). When the upper surface speed of the racing spoiler is less than that of the lower surface, the air pressure difference will be generated, so as to generate downforce under pressure.

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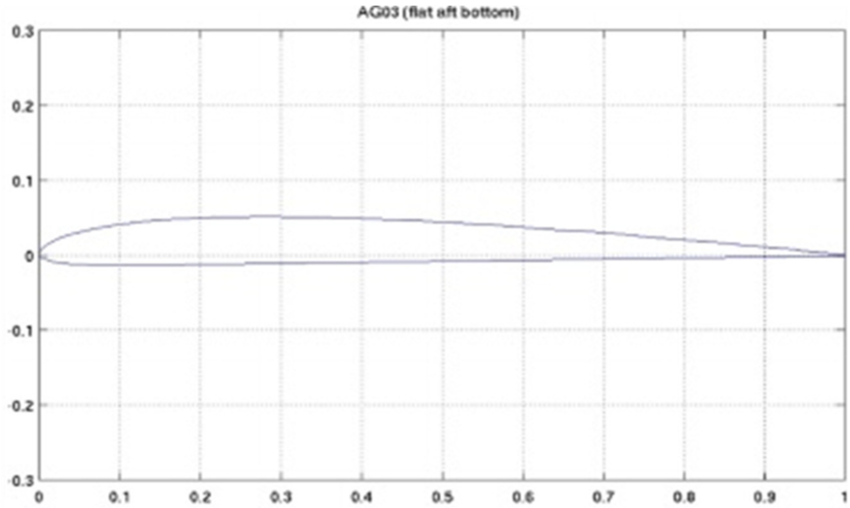


Figure 1: Drela AG03 model diagram.

R The studied racing spoiler in this research is a single racing spoiler. Among the foreign researchers, Riebeek investigated the effect of spoiler and car body interaction on the general shape of two closed-wheel racing cars in his research. Later, they combined 3D computer simulation techniques with wind tunnel testing during the aerodynamic development of closed-wheel racing cars (1994)(Kieffer, Moujaes, and Armbya, 2006), conducted experimental and computational studies of ground effects on two-dimensional spoilers(Mather, Papadakis, and Heron, 1998), and experimented and tested a variety of spoiler configurations in Wichita State University's Beech Memorial low-speed wind tunnel. According to Zhidong Guo's spoiler research on the Drela AG series in 2023, speed, spoiler type, and elevation have an impact on the downforce and resistance of the racing spoiler. When conducting experiments on different spoilers, under the condition that speed and elevation were determined, the resistance and down force were generated by different types of spoilers. The results showed that Drela AG03 has the highest ratio of downforce and resistance in figure 1, so it was considered to have the best aerodynamic performance. Therefore, Drela AG03 was taken as the basis of this design and was upgraded and improved.

# 3 RESULTS

In the process of studying the influence of speed on the downforce and resistance of a racing spoiler, it was found that the higher the speed, the higher the maximum and minimum pressure on the spoiler, and the higher the resistance and downforce caused by the spoiler(Guo, 2022). It was also found that the ratio of the spoiler resistance and downforce was the best when the speed was 60m/s. In the process of studying the influence of the angle of attack on spoiler resistance and downforce, it was found that the greater the spoiler angle of attract, the greater the resistance, but the downforce showed a Z-shape distribution and reached the peak at 20°. In addition, under different driving speeds, the angle-XY pressure image obtained by changing the angle of attack of the racing car was the same, that is, when the angle of attack was about 20°, the ratio of downforce and resistance was the largest, and the racing car could obtain the best driving experience at this time. Therefore, it is concluded that the optimal operating parameters of the spoiler during the driving process should be: Drela AG03(flat spoiler bottom) spoiler, driving speed: 60m/s, and angle of attack: about 20°.

However, for the general FI racing cars, in reality, the cornering speed is at least 300km/h, about 83.33m/s. To achieve the best downforce and resistance of the racing spoiler, and the best stability of the car, it is necessary to make certain adjustments to the spoiler. According to the simulation data, when the speed, when the speed is 83.33m/s, the downforce is smaller than the resistance, so it is necessary to improve the spoiler to make the ratio of downforce and resistance close to 11.03. According to the research, the spoiler angle of attack was changed at the speed of 80m/s, it was found that the ratio of downforce and resistance at 20°was the largest, so the front part of the spoiler can be appropriately raised to form an angle difference of nearly 20°with the back part.

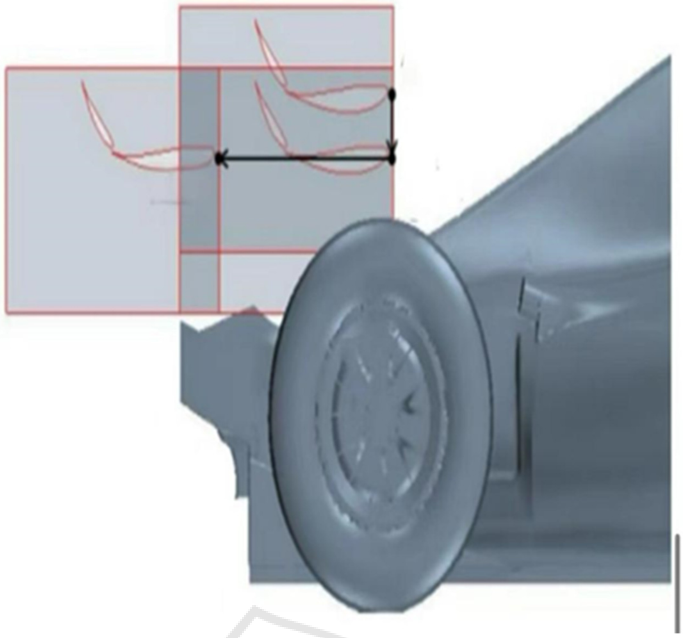

Figure 2: Different positions of the spoiler.

Figure 3: Spoiler design diagram.

In the study of the interaction between the spoiler and the aerodynamic characteristics of the car body, Zhang Yingchao et al. conducted a simulation test of the influence of the spoiler on the overall aerodynamic characteristics of the car body at three different typical installed positions of the spoiler in the Figure. The top one of Figure 2 is position 1, below it, is position 2, and the far left one is position 3. (Yan, Du, and Hu, 2019). It was found that when the spoiler was installed in position 3, relatively far away from the car body, although the downforce of the spoiler was reduced more than that of the single tail and positions 1 and 2, and the lift-resistance ratio was also poor, the life force of the spoiler was improved compared with positions 1 and 2; the downforce of the diffuser and the bottom plate was greatly increased; finally, the overall downforce and life-resistance ratio were relatively optimal.(Katz, and Dykstra, 1994) The optimal operation of the racing cars can be enhanced based on the experiment verification, the overall analysis of the forces of the specific steering mechanism of the racing cars, and the racking track conditions.

On the basis of the above analysis and organization, the following better-improved single racing spoiler was designed, as shown in Figure 3.

The spoiler installation position is position 3 mentioned above, which is the position 10 cm down and 10 cm back of the normal position for the spoiler installation of normal Fi racing cars.

## 4 DISCUSSION

For better handling performance when the car goes through a corner at high speed, according to the Bernoulli equation, the improved rear wing of the car in this study can provide better stability within the optimal range of the ratio of rear wing resistance to downforce, and has almost no impact on the speed of the car. The improvement of this study mainly lies in enlarging the height difference between the front and back parts of the tail fins, and even eliminating the elevation adjustment device of the tail fins, which can further the lightweight of the car and provide new ideas for the future lightweight research of the car. This study can also provide a new idea for the study of the rear wing position of the car. It is not necessary to follow the rules and adopt the position this research have always used. The aerodynamic characteristics of multiple positions can be tested to make the aerodynamic performance of the car more excellent and make the car faster.

# 5 CONCLUSIONS

This study first researched the impact of the rear wing shape on the downforce and drag with the existing race car aerodynamics theory. Based on that, the Authors gave the first part of how to modify the rear wing; then combined with real-life speed factor to give the second part of the modification. Lastly, after examining the different changes of aerodynamic characteristics in different positions of the rear wing, the final suggestion of rear wing shape and install location was given, position 3, which is 10 centimeters down and 10 centimeters back from the normal F1 car's rear wing installed.This research is aimed to improve on part of single rear wing in race car, and expanded on more, like the design of car body, engine, tires and so on. Hopefully, futuristic studies can have more improvements on more factors. By focusing on these elements, researchers push the boundaries of what is possible in race car engineering.

# AUTHORS CONTRIBUTION

All the authors contributed equally and their names were listed in alphabetical order.

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