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Original Paper

Racing Car Design Based on Stabilizer Wings

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Abstract
We know that Formula 1 is the most common vehicle to use stabilizers. Therefore, we designed a Formula 1 race car with controllable front and rear wings. Through 3D modeling and partial aerodynamic analysis, the design consisted of the chassis, hull, and stabilizers. The design was 3D printed using ABS plastic. The controllable stabilizers demonstrate the importance of stabilizers in racing. Stabilizers are not just for racing; they can also be widely used in everyday life, improving driver safety.
Keywords
Formula 1, Downforce, 3D printing, Aerodynamics

1. Introduction

With the continuous advancement of science and technology, mechanical performance, particularly the speed and handling characteristics of automobiles, has significantly improved. Improving vehicle stability and safety at high speeds has become a key research topic in vehicle engineering and aerodynamics. Because the aerodynamic effects on vehicles at high speeds are significantly enhanced, even subtle aerodynamic changes can have a significant impact on handling and stability. Therefore, simply increasing engine power is no longer sufficient to meet the demand for performance optimization. To this end, researchers have developed various aerodynamic components, including aero foils, to improve vehicle handling, increase cornering downforce, and enhance overall stability.

In principle, aero foils are designed to mount an inverted wing structure to the vehicle body, creating a pressure differential between the upper and lower surfaces of the airfoil, generating downforce directed toward the ground. The concept was first proposed by French engineer Paul Jaray in 1909. In 1956, Formula 1 engineer Michael May first experimented with a rear wing on a Porsche 550 Spyder at the Swiss Grand Prix to increase downforce. By 1968, stabilizer fins had become widely used in Formula 1 racing cars and have become a crucial component of modern racing aerodynamic design.

Based on aerodynamic principles, this study constructed a Formula 1 racing car model with adjustable front and rear wings. The model design adheres to the 2026 Formula 1 technical regulations published by the International Automobile Federation (FIA). An active control system dynamically adjusts the front and rear wings to open and close, allowing for the study of aerodynamic characteristics at different angles of attack. The car's overall streamlined design minimizes the effects of air resistance on speed. Airflow visualization was performed in a virtual wind tunnel environment to observe airflow paths and downforce distribution.

In addition, the model incorporates a ground effect floor design based on the new 2026 regulations to prevent stalling due to insufficient grip when the stabilizer fins are deployed. The model was constructed using 3D printing technology, with the stabilizer fins in both open and closed states as the analysis basis. Experimental data on downforce, airflow direction, and speed were compared to explore the effects of the adjustable stabilizer fins on the vehicle's aerodynamic performance.

2. Theoretical Analysis

2.1 Lift Force

Lift is the vertical upward force generated by a fluid (such as air) acting on the surface of an object. This force usually acts on the wings of an aircraft to help it take off. The magnitude of lift is closely related to the air flow speed, the shape of the wing, and the angle of attack. The basic formula for calculating lift is:

$$L = \frac{1}{2}\rho v^2 S C_L$$

The formula of lift force

Where L is the lift, ρ is the air density, v is the air velocity, S is the wing area and C_L is the lift coefficient.

However, in the aerodynamics of a racing car, stabilizers act in opposition to lift. Their purpose is to generate a downward force, known as downforce. Downforce is calculated in the same way as lift, except that it is directed toward the ground. By adjusting the angle of attack of the stabilizer, the amount of downforce can be adjusted, thereby affecting the vehicle's grip and stability. Specifically, by adjusting the angle of attack or the airfoil design, the downforce coefficient (C_D) which can be altered to optimize the vehicle’s performance on the track.

The drag coefficient indicates the magnitude of aerodynamic resistance. A larger angle of attack increases the C_D, thereby reducing the drag coefficient of the vehicle.

In wing design, if the requirements for the wing are high, the lift-to-drag ratio is used. Of course, if you want to achieve high aerodynamic effects, the designed stabilizer must be as large as possible. Of course, it cannot reach the stall angle. When the angle of attack exceeds a certain value, the airflow on the wing will be destroyed.

$$\frac{|C_L|}{C_D}$$

The formula of coefficient of downforce

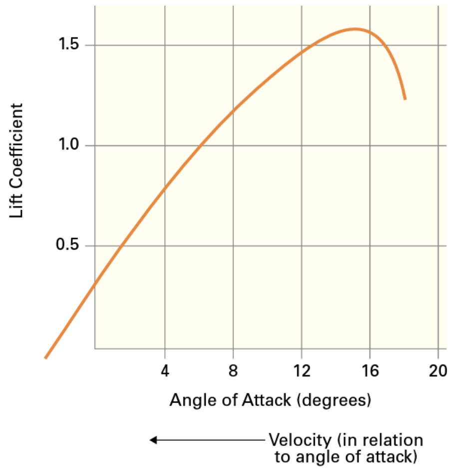

Figure 1. Relationship between Lift Coefficient and Angle of Attack

2.1 Turn System

The above article explains the functions and calculation formulas of racing stabilizing wings. Steering can be categorized as either oversteer or understeer.

Oversteer, commonly known as drifting, occurs when the actual steering angle entering a corner is greater than the front wheels' turning angle, causing the rear wheels to slide outward. When a vehicle's actual turning radius is smaller than expected, it drifts, a phenomenon known as oversteer. This typically occurs in rear-wheel drive vehicles

2.1.1 Understeer and Oversteer

Understeer occurs when a vehicle requires more steering angle to maintain its desired trajectory. This occurs when the front tires' slip angle with the ground builds faster than the rear tires. For example, when entering a corner, the actual turning radius is larger than expected, resulting in a feeling of pushing forward. This often occurs in front-wheel drive vehicles or in Formula 1 cars entering long, high-speed corners.

Oversteer and understeer are characterized by an unequal distribution of grip between the front and rear tires. It's impossible for a car to experience both at the same time. Of course, I can't just write about steering for no reason, because steering is inherently connected to aerodynamics.

In Formula 1, the front and rear wings generate downforce for the tires. However, if the front wing is affected by dirty air ahead or the front wing angle is not set correctly, the front wheels will lack downforce, resulting in understeer. Conversely, if the rear wing provides insufficient downforce or the rear diffuser, which uses ground effect, is inefficient, the rear wheels will lose grip and oversteer.

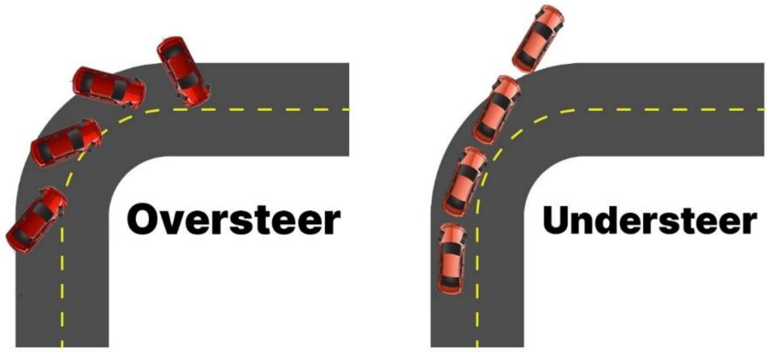

Figure 2. Definition of Oversteer and Understeer

3. Aerodynamic Design and Analysis

3.1 The Influence of the Angle of Attack of the Stabilizer

Because the upper surface of the stabilizer is curved and the lower surface is relatively straight, Bernoulli's principle shows that the airflow velocity over the upper surface is higher than the lower surface, so the pressure generated by the lower surface is higher, resulting in a downward force known as downforce.

Different angles of attack represent different inclination angles of the stabilizer, which determines the amount of downforce. A larger angle of attack generates greater downforce, but at the expense of tail speed. Conversely, a smaller angle of attack increases tail speed at the expense of cornering grip.

The main design parameters of the stabilizer are the lift coefficient, which determines the amount of downforce per unit area and per unit dynamic pressure of the stabilizer. As mentioned above, increasing the angle of attack increases the lift coefficient, which improves cornering stability but also increases the car's drag. In my research, the common range of lift coefficients is -0.5 to 3.0.

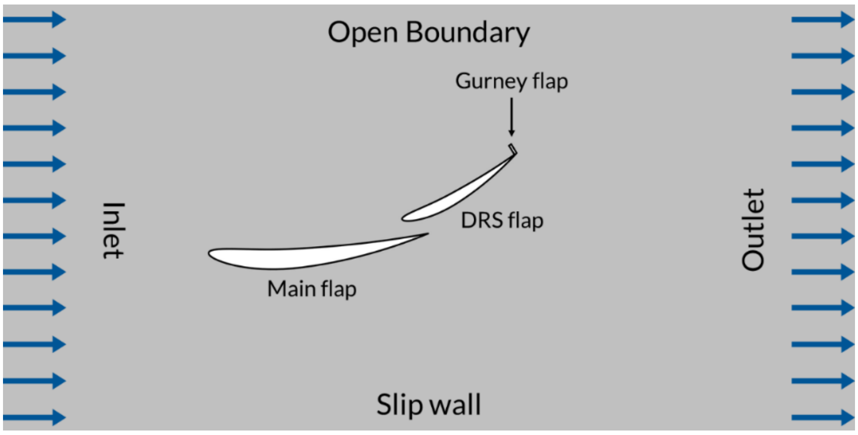

Figure 3. The Definition of the Back Wing

3.2 Stability and Aerodynamic Balance

Beyond simply pursuing high downforce, design also requires consideration of front-to-rear downforce distribution to ensure stability and avoid oversteer or understeer. The aerodynamic efficiency of the airfoil impacts the performance of the car. High efficiency generates more downforce with less drag. However, excessive angles of attack can cause flow separation, leading to reduced efficiency and even a loss of downforce.

Figure 4. Aerodynamics

4. Engineering Implementation and Experimental Method

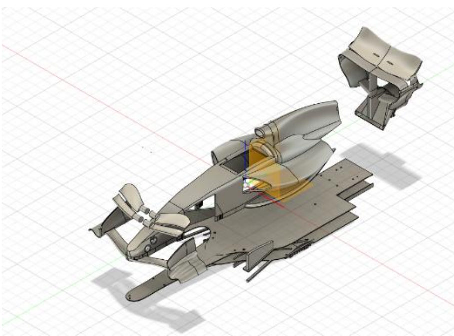

Figure 5. The Models of My Project

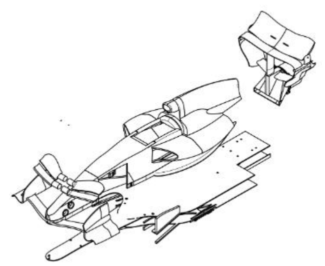

Figure 6. The Models of My Project

To verify the role of adjustable stabilizers in the aerodynamic performance of a racing car, this study used Autodesk Fusion 360 software for 3D modeling and structural design. The design strictly adhered to the Formula 1 2026 Technical Regulations published by the FIA to ensure the rationality and engineering feasibility of the model's proportions, aerodynamic device layout, and overall geometric features.

The vehicle model consists of three main components: the floor, the body, and the adjustable front and rear stabilizers. The floor utilizes a two-layer composite structure, a "1+1" approach: a 3D-printed floor is added beneath the alloy floor to enhance structural strength and optimize the ground-effect airflow path. This structure improves the airflow velocity distribution under the floor, thereby enhancing overall downforce efficiency.

Open cooling vents are used in the sidepod area to improve thermal management of the electric motor and battery unit. This design not only enhances system heat dissipation but also ensures stable operation of the control module and power unit under high load conditions.

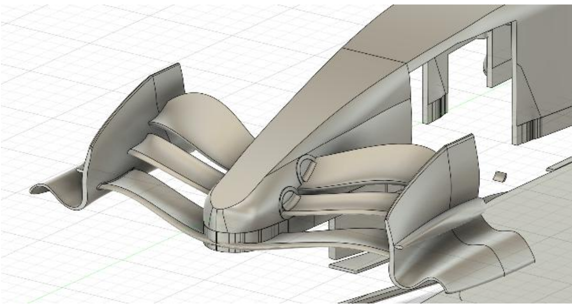

Figure 7. Stable Wings while is Less Downforce Statement

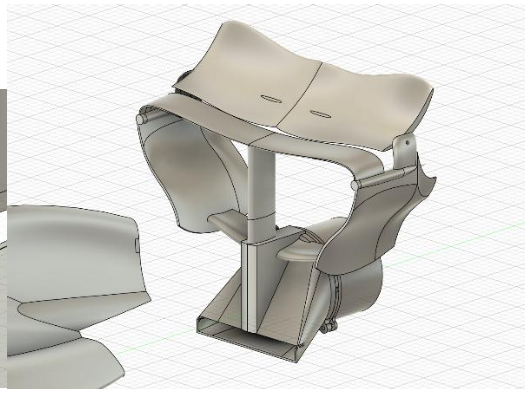

Figure 8. Stable Wings while is Less Downforce Statement

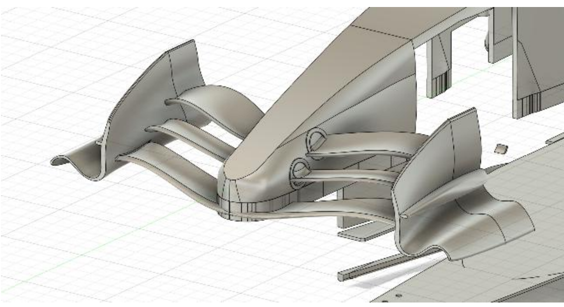

Figure 9. Stable Wings while is Higher Downforce Statement

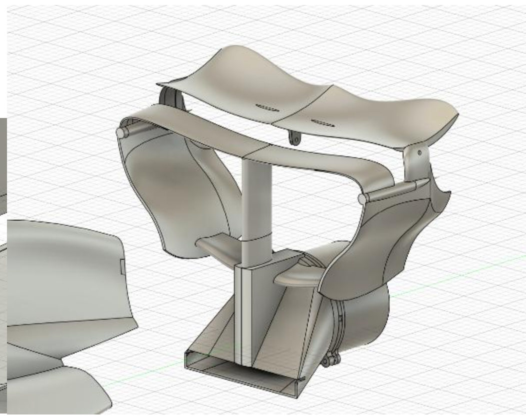

Figure 10. Stable Wings while is Higher Downforce Statement

4.1 Control Department

This is the flow chart of my control part, which mainly consists of servos, circuits, and motors. The following figure is an example of the button composition.

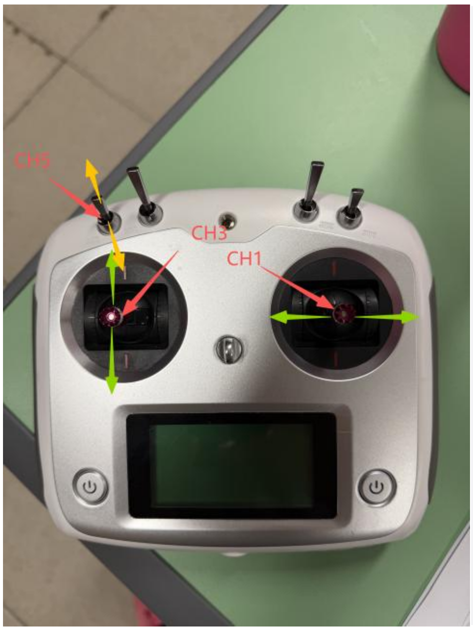

Figure 11. Control Department

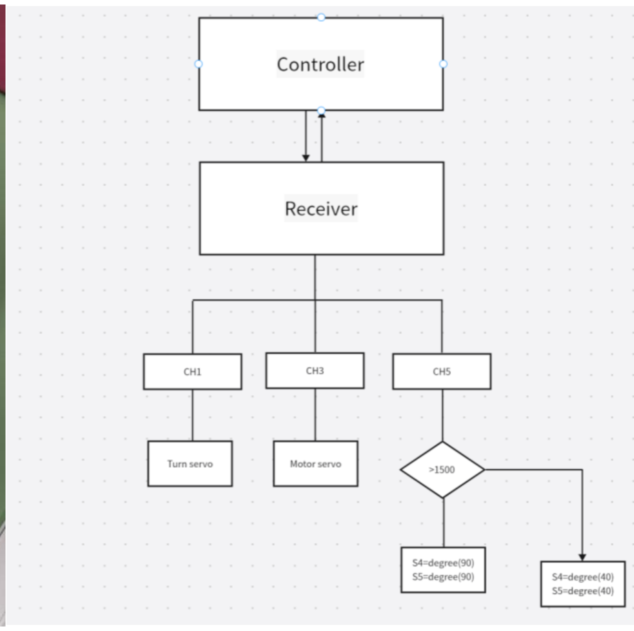

Figure 12. Control Department

By using signals sent from the controller and received by the receiver, three values—CH1, CH4, and CH5—are extracted from the controller's PPM signal sequence. These three values represent different meanings: CH1 is connected to the steering signal, CH4 to the powertrain signal, and CH5 to the active air system signal. Different signals control different units.

5. Conclusion

Figure 13. My Project in Reality

5.1 Experimental Results Analysis

Through testing of 3D-printed models and active control systems, this study quantitatively and qualitatively analyzed the aerodynamic performance of adjustable stabilizers at different angles of attack. The experimental results show that varying the angle of attack of the front and rear wings significantly affects the aerodynamic characteristics of the race car.

When the front and rear wings are closed (low angle of attack mode), the vehicle exhibits reduced aerodynamic drag and significantly increases top speed, but grip is significantly insufficient during high-speed cornering, making understeer more likely. In contrast, when the front and rear wings are open (high angle of attack mode), downforce is significantly increased, tire grip is significantly improved, and the vehicle exhibits enhanced stability in medium- and high-speed corners.

In straight-line acceleration tests, the model achieved an average speed of 9.46 m/s over a 100-meter test distance. The low-drag mode achieved a greater distance than the high-drag mode at the same time, primarily due to increased aerodynamic drag. However, in cornering simulation tests, the open mode enabled the vehicle to complete cornering at higher speeds, and lateral acceleration was significantly improved, as shown by time comparison. These results confirm the significant effectiveness of adjustable stabilizers in improving cornering stability.

Due to limited conditions, this project did not have the opportunity to conduct air simulation tests and deeper calculations. I've also identified many shortcomings of this project. For example, the compromised vehicle length ratio between the front and rear axles prevented the car from being used in existing facilities for simulated airflow experiments. Furthermore, the wiring and wiring were not properly routed and tied. Limited technology prevented the front of the car from achieving a complete 1:1 replica of a real Formula 1 car. I will definitely improve these aspects in my future studies and, if I have the opportunity, research related projects.

References

Gao Zhengyang, Meng Xiangye, Zhang Zhixiang, et al. (2025). Design and Verification of FSEC Racing Transmission System. *Automotive Practical Technology*, *50*(24), 1-6.

Xiao Zhipeng, Tao Lanlan, Chen Shuai, et al. (2022). Experimental study on the flow field inside a stable wing four inclined blade Rushton combined propeller kettle. *Chemical Machinery*, *49*(05), 756-763.