Influence of different angle of spoiler fin at specific position on vehicle aerodynamics

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Abstract:The significance of Aerodynamic Research on automobile is not only to improve the high-speed driving stability and crosswind stability, but also to reduce vehicle fuel consumption. As an additional device, the rear spoiler has shown a good effect in the external components of the automobile, so the reasonable design and assembly of the rear spoiler is particularly important. The rear spoiler with proper height can effectively reduce the air drag coefficient and lift coefficient. This paper mainly uses the software ICEM, Fluent and Post in ANSYS to analyze the influence of different angles of the specific spoiler on the aerodynamic performance of the vehicle. In the software experiment, I adjusted the spoiler angle and car speed and I found that in a certain range, the downforce generated by the spoiler is proportional to the angle between the spoiler and the ground.

Keywords:Automotive Engineering, computational fluid dynamics, aerodynamics

1 Introduction

Before that, there has been a lot of research on the car spoiler. Many mature research results have been widely used in the field of automotive engineering. Fu Limin (2010) states that the results of previous studies have shown that the medium pressure differential resistance in pneumatic resistance of cars accounts for 85% of the total resistance, and the pressure differential resistance, in turn, has a close relationship with the wake structure of cars.[1] So I think the research on the spoiler is very important and has a wide application prospect. Among them, I found that the clear relationship between spoiler angle and downforce is not given in many data. I'm going to use the experiment to explore this relationship and find the best angle of the spoiler. In my experiment, I will use the given car and spoiler model to simulate. The car model and selected spoiler model is shown in Figure 1. The model is a closed entity. Because there are a lot of small features on the surface of automobile, it is a big obstacle to mesh. Therefore, it is necessary to simplify the model and transform the surface into a plane as far as possible. Then, a cuboid is set up as the calculation domain, and half of it can be taken for calculation due to its symmetry.

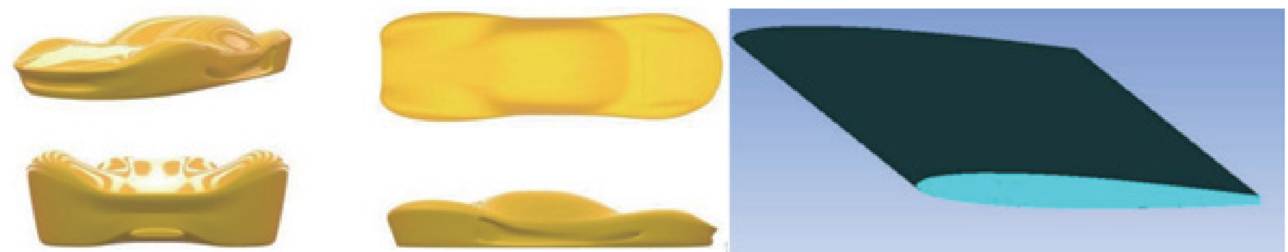


Figure 1 (Selected model)

Based on the experiment documents given, I can determine the spoiler shape relative to the car and the spoiler. As shown in Figure 2, the spoiler should be installed at position 17 with coordinates (- 70, 0, 70) relative to the origin.

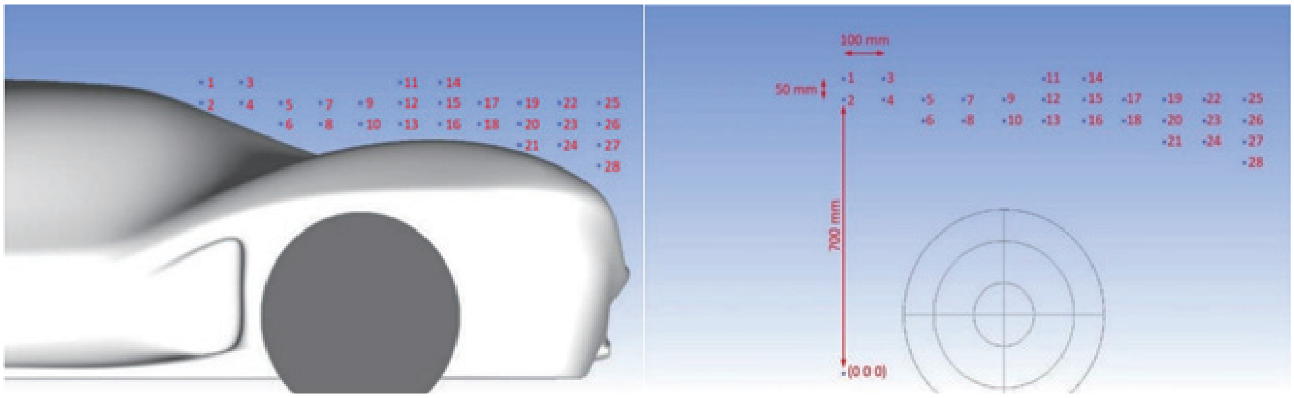


Figure 2 (relative position of spoiler and vehicle)

2 Methodology

2.1 Mesh building

First, I download the STL files of the given car and spoiler and import them into ICEM. Through ICEM, my installation files require that the angle of the spoiler and the relative position of the spoiler and the car be adjusted. Note that this process needs to be repeated five times to get a grid of different spoiler angles, which are 30 degrees, 25 degrees, 20 degrees, 15 degrees and 10 degrees.

Through ICEM's measurement program, I measured the maximum size of the vehicle model is 340X140X85. According to this data, I built a cuboid with the calculation domain size of 2000x800x800 and the initial point of (800, 0, - 6), as shown in Figure 5. In the computational domain, I created a body named air, which stands for air. After that, I will name the faces of the computational domain separately, so that the boundary can be set later. Then draw the curve of the junction of the solid, I can start the mesh setup.

The first is the global mesh setup. After trying, I set Max element to 80 and min size limit to 0.4 (figure 5). The second step is to set prism meshing parameters, Initial height 0.9, Height ratio 1.15, Number of layers 5 (figure 5). The third step is to perform part mesh setup (figure 6). After creating two density area, I started to compute the mesh. The mesh quality under the condition of 30 degrees and 30 m / s of completed mesh is shown in Figure 7.

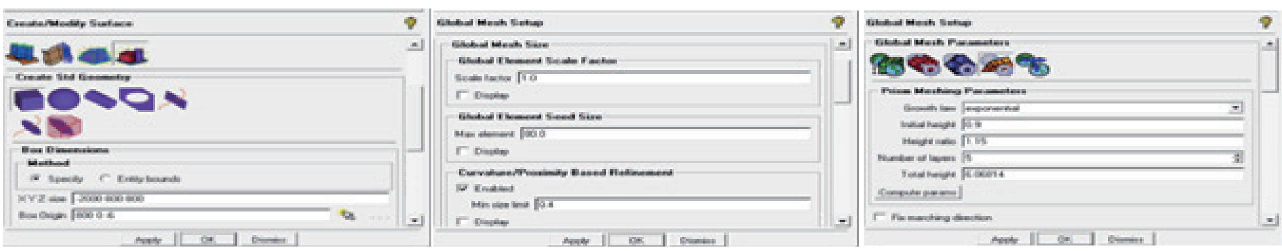
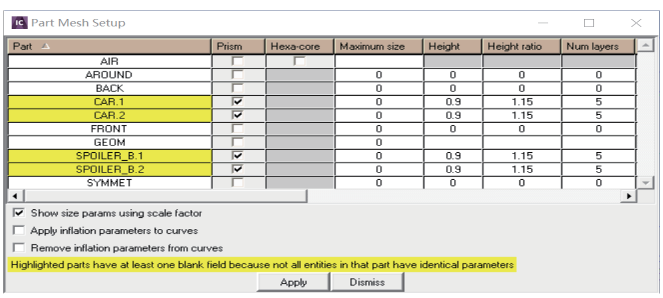


Figure 3（Setting）


Part Mesh Setup

Part	Prism	Hexa-core	Maximum size	Height	Height ratio	Num layers
AIR	☐	☐				
AROUND	☐		0	0	0	0
BACK	☐		0	0	0	0
CAR.1	☑		0	0.9	1.15	5
CAR.2	☑		0	0.9	1.15	5
FRONT	☐		0	0	0	0
GEOM	☐		0			
SPOILER_B.1	☑		0	0.9	1.15	5
SPOILER_B.2	☑		0	0.9	1.15	5
SYMMET	☐		0	0	0	0

☑ Show size params using scale factor
☐ Apply inflation parameters to curves
☐ Remove inflation parameters from curves
Highlighted parts have at least one blank field because not all entities in that part have identical parameters
Apply Dismiss

Figure 4 (Part mesh setting)

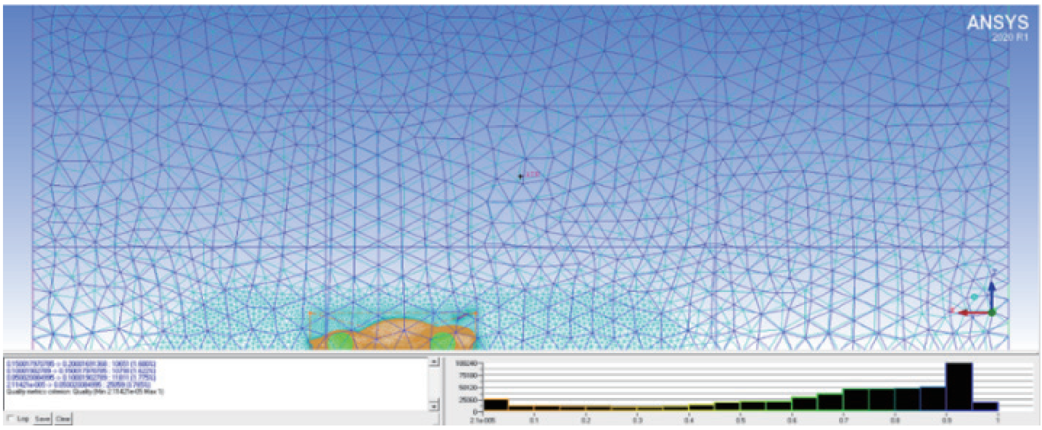


Figure 5 (Mesh quality)

In addition, in order to prove the effect of the spoiler on the car, I also set up a control group with only the car model and no spoiler model.

2.2 Fluent computing

$$\frac{\partial \boldsymbol{u}}{\partial t} + (\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = -\nabla p + \frac{1}{Re}\nabla^2 \boldsymbol{u}$$

$$\nabla \cdot \boldsymbol{u} = 0$$

$$\nabla = \{\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\}^T \qquad \nabla^2 = \{\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\} \qquad \boldsymbol{u} = \{u, v, w\}^T$$

Import the mesh to fluent for calculation. 3D solver is used to solve the problem, and SSK k-omega equation model is selected as turbulence model. Given the boundary conditions, the inlet velocity is u = 30m / s, u = 40m / s, u = 50M / s, u = 60m / s, u = 65m / s. Select intensity and visibility ratio in the inlet boundary setup. Set the visibility ratio to the default value of 10%. The three-dimensional incompressible Navier Stokes equations commonly used in engineering are used here.

"Where: u, N, w-x, y, z direction component: p-pressure: re Reynolds number, re = H / V: u-average velocity of channel flow, h-distance from channel center line to wall surface: y-coefficient of motion viscosity." [2]

The residual calculation is performed for five times, and the curve reports of the stress on the car body and spoiler in Z direction are generated respectively. After the calculation, 25 CAS and data files were exported in turn. The residual curve and the overall force curve of the car under the condition of 30 degrees and 30 m / s. (Figure 7)

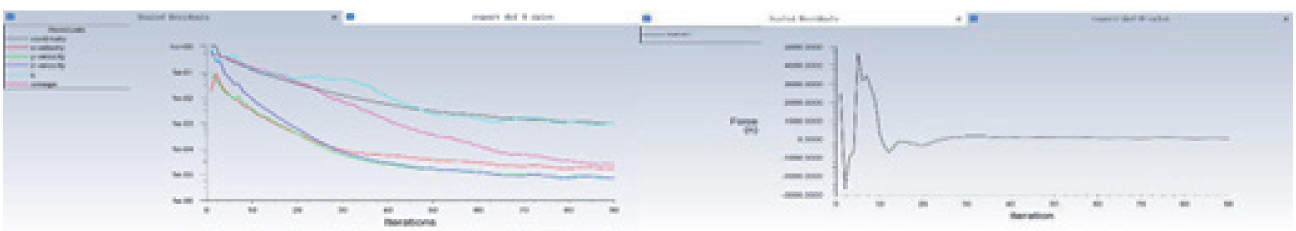


Figure 6 (Residual curve and overall force curve)

3 Results and discussion

3.1 results

By outputting the results, I get the data. By calculating these data, I get the model rise force.

Rise Force (N)

Speed / Degree	30M/S	40M/S	50M/S	60M/S	70M/S
30 Degrees	69.34286	133.839	219.5943	281.1406	403.1017
40 Degrees	97.07742	156.3547	252.3375	362.3021	445.6705
50 Degrees	117.6753	179.9498	264.9781	306.7306	476.1981
60 Degrees	118.1872	170.8535	241.6082	449.3911	525.6961
65 Degrees	134.1327	247.6101	391.0025	566.6053	655.4968
No Spoiler	174.6341	285.9204	518.6639	735.2431	906.6973

By comparing the rising forces of different angles at the same speed, the following curve can be obtained.

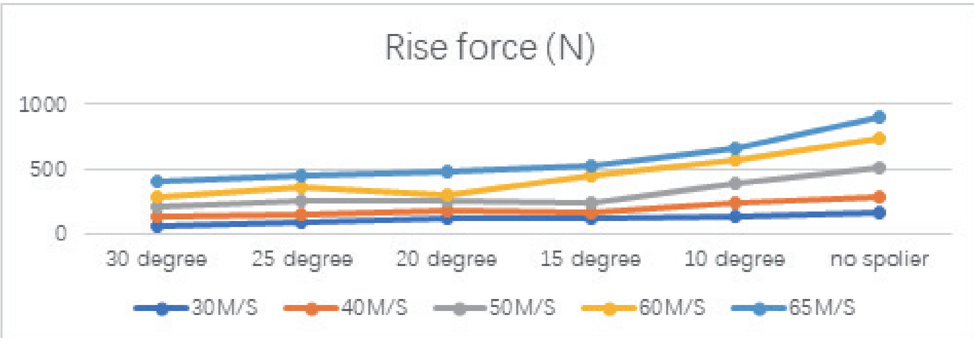


Figure 7

It can be seen from this picture that in the range of 0 to 30 degrees, with the increase of the spoiler angle, the downforce of the car increases. The downforce of the spoiler is proportional to the speed of the car. In addition, the installation of the spoiler will provide additional downforce to the car.

I also measured the resistance of the car in the X direction and got the following curve.

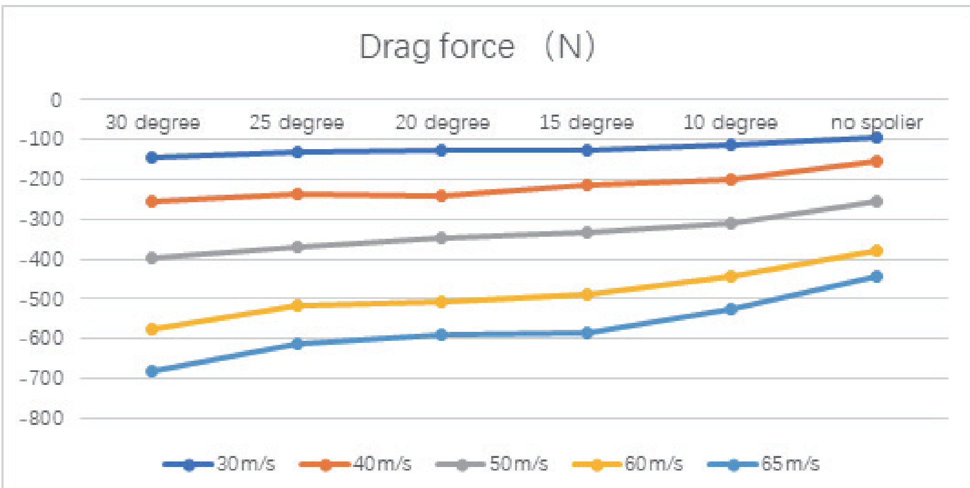


Figure 8

It can be seen from this picture that in the range of 0 to 30 degrees, with the increase of spoiler angle, the resistance in X direction increases. The resistance of the car in the X direction is proportional to the speed of the car. In addition, the installation of the spoiler will provide additional resistance to the car.

4 Conclusions

It is clear that at the same speed, the rising force increases with the decrease of the spoiler angle in the range of 0 to 30 degrees. In addition, the lifting force of the model without spoiler is much greater than that of the model with spoiler under the same condition. This means that under the same conditions, in the range of 0 to 30 degrees, the downforce of the car is proportional to the spoiler angle. Therefore, the best angle of the spoiler to increase the downforce is 30 degrees. However, we can also conclude that while providing the maximum downforce, the 30degree spoiler also causes the maximum resistance in the X direction. Therefore, whether the 30degree spoiler can provide the best effect when the car is running still needs further test.

References

[1] Fu Limin. (2010) Automotive design and aerodynamics [M]. Beijing: China Machine Press.

[2] Lu Changgeng and Shao Shan. (2001) Compact finite difference and Fourier spectral methods for three-dimensional incompressible NS equations, Journal of Hohai University, 29(4), pp44-49.