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# *Aerodynamic Characteristics Analysis of Curve Overtaking Based on CFD*

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***Keywords:*** Road curve; overtake; difference in pressure; center of presssue; vortex

***Abstract:*** In this paper, numerical simulation of the overtaking process in a curve is carried out based on Computational Fluid Dynamics (CFD) and dynamic mesh technology, and the flow field distribution data between the main overtaking vehicle and the overtaken vehicle at different speeds are statistically analyzed. The study shows that: during the overtaking process in a bend, pressure and flow field changes of different degrees occurred between the two vehicles. As the relative position between the vehicles changes, the higher the speed of the main overtaking vehicle, the more drastic the aerodynamic force changes between the two vehicles; the fluctuation range of the change curve of the lateral force coefficient of the overtaken vehicle is larger, and the lateral force also appears to have a larger extreme value. The overtaking vehicle caused a forward shift of the overtaken vehicle's centre of pressure in relation to its centre of mass. This induced an increase in lateral force and swinging moment, rendering the vehicle more unstable and prone to rollover and skidding, severely compromising driving stability.

## 1. Introduction

When driving at high speeds, overtaking often occurs. When a car overtakes other vehicles, the flow field around the two cars will interfere with each other, causing changes in the aerodynamic force of the body, which can easily affect the handling stability and safety of passengers[1]. When the vehicle is in a bend, the most influential aerodynamic characteristics are the lateral force and roll moment. The biggest difference between overtaking on a bend and overtaking on a straight path is the presence of centrifugal force. If the speed is too fast, there may be a risk of slipping or overturning[1].

When driving on curved roads, people often have too much confidence in their driving skills, which can easily lead to traffic accidents. This behavior not only affects traffic order, but may also pose a threat to the lives of passengers. Therefore, it is necessary to conduct research and analysis on it. Wang Baoyu[2] et al. used overlapping grid technology to study the instantaneous aerodynamic characteristics of the DrivAer model during cornering. The results showed that the peak aerodynamic force increased with the increase of speed and showed a linear change overall; It will also increase as the distance between passing vehicles decreases, showing an overall non-linear change. Kang Ning, Zheng Hao, and others[3] conducted relevant simulation calculations on the trend of aerodynamic characteristics around the body of a car when it exceeds another vehicle at different speeds[4]. The calculation results show that at different speeds, the trend of the lateral force coefficient being overtaken is similar, but the peak value and position of the lateral force coefficient are related to the overtaking speed. Gu Zhengqi[4-5] et al. used dynamic grid technology and sliding interface technology to numerically simulate the external flow field during the overtaking process of two cars. They obtained the transient changes in resistance and lateral force of the two cars, analyzed the changes in pressure and velocity fields, and completed the analysis of transient aerodynamic characteristics during the overtaking process of cars and trucks. Liu Lining[6] et al. used dynamic grid and sliding grid techniques to compare the constant speed and acceleration of a truck overtaking another truck, respectively. The results indicate that the main overtaking acceleration has little effect on the vehicle itself, but has a significant impact on the aerodynamic characteristics of the overtaken vehicle. The resistance, lateral force, and yaw moment coefficients of overtaking all increase with the increase of the main overtaking acceleration, seriously affecting the stability of overtaking driving. Tang Hongtao and Tong Daoxian[7] simulated the transient overtaking process of right turning vehicles and straight driving vehicles, and found that as the speed of straight driving vehicles increased, their lateral force and yaw moment both increased, while the lateral force of right turning vehicles first increased and then decreased; As the turning radius of a right turning vehicle increases, the lateral force of both vehicles and the yaw moment of a straight vehicle decrease linearly, while the yaw moment of a right turning vehicle increases linearly. For research on different vehicle models, PARK[8] et al. selected 14 relative positions when the DrivAer model overtook a truck and studied the changes in the flow field around the overtaking body. Obtained the relative positions of the maximum aerodynamic resistance and maximum yaw moment acting on overtaking vehicles; And it was clarified that the most sensitive aerodynamic characteristic parameter during overtaking is the yaw moment coefficient. Jun Liu and Zhengqi Gu[9] et al.used SST turbulence models and overlapping grid techniques to analyze the interaction of the flow field between cars and buses when overtaking under the influence of lateral spacing and crosswind. Research has shown that in the process of overtaking, especially in situations with low lateral spacing or strong crosswinds, bidirectional coupling analysis of overtaking should be considered.

In summary, based on the publicly available literature both domestically and internationally, there is very limited information on flow field analysis during overtaking on bends. Therefore, this article simulated the overtaking situation of vehicles on the roundabout highway, explored the transient characteristics of the flow field around the two vehicles during the overtaking process, and analyzed the impact of different vehicle speeds on the flow field changes between the two vehicles and the changes in the body vortex shape during the overtaking process. The changes in the pressure center and center of mass position relationship between the two vehicles were also statistically analyzed.

## 2. Numerical simulation

### 2.1 Turbulence model

In this analysis, considering the rationality of the simulation, when selecting the speed, due to the fact that vehicles on the road, even when traveling at high speeds against the wind, have a speed much lower than one-third of the speed of sound, fluid mechanics believes that this fluid can be regarded as an incompressible gas[10].Therefore, the turbulence model is selected as the standard for $k$- $\varepsilon$ Models, these two equation models involve the calculation of turbulent kinetic energy and dissipation rate. The turbulence model equation is shown below (considering custom source terms).

Standard k-εThe turbulent kinetic energy and dissipation rate transport equation of the model:

$$\frac{\partial(\rho k)}{\partial t}+\frac{\partial(\rho k u_i)}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_i}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k \tag{1}$$

$$\frac{\partial(\rho \varepsilon)}{\partial t}+\frac{\partial(\rho \varepsilon u_i)}{\partial x_i}=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_i}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right]+C_{1\varepsilon}\frac{\varepsilon}{k}(G_k+G_{3\varepsilon}G_b)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}+S_\varepsilon \tag{2}$$

In equations (1) - (2): $\mu_i$ is the turbulent viscosity; $G_k$ is the turbulent kinetic energy generation term caused by the average velocity gradient; $G_b$ is the turbulent kinetic energy generation term caused by buoyancy effects; $Y_M$ is the effect of compressible turbulent pulsation expansion on the total dissipation rate; $C_{1\varepsilon}, C_{2\varepsilon}, C_{3\varepsilon}$ is an empirical constant; $\sigma_k, \sigma_\varepsilon$ are turbulent kinetic energy k and turbulent energy dissipation rate, respectively ε Corresponding Prandtl number; $S_k, S_\varepsilon$ represents a user-defined source item.

Using aerodynamic coefficients to describe the aerodynamic characteristics of a car. Equation (4) is the formula for calculating the lateral force coefficient[1].

$$C_s=\frac{2S}{\rho v_\infty^2 A} \tag{3}$$

In formula (3): $C_S$ is the lateral force coefficient, S is the lateral aerodynamic resistance of the vehicle body (y-axis direction), $v_\infty$ is the relative velocity of the synthesized airflow, and A is the frontal projection area of the vehicle.

## 2.2 Computational Domain and Model

This study used a certain SUV model, with the original dimensions of 5060mm in length, 2004mm in width, and 1779mm in height. The car has a mass of approximately 2.1 tons and a projected area of approximately 2.7 $m^2$. This study used a certain SUV model, with the original dimensions of 5060mm in length, 2004mm in width, and 1779mm in height. The weight of the car is about 2.1 tons, with a projected area of about 2.7 square meters and simplified according to the original dimensions. The car accessories such as door handles, rearview mirrors, and wipers are ignored, and the tips around the car body are smoothed. The length of the car body is represented by L, the width is represented by W, and the height is represented by H. At the same time, it is stipulated that the calculation domain size is 30L in length, 30L in width, and 6H in height. The calculation domain is shown in the figure 1.

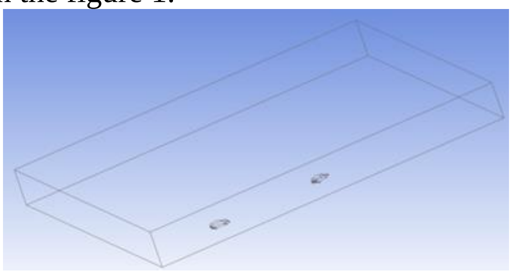


Figure 1: Computational area of the model

## 2.3 Grid processing

This article uses tetrahedral unstructured mesh partitioning. The body grid size is set to 0.1m, and the computational domain grid size is set to 0.8m. The grid around the car should be denser, and the grid size away from the car body should be larger, in order to quickly stabilize the fluid around the car body before driving. While ensuring accurate calculations, it can also reduce the running time of the computer and reduce the workload of subsequent processing. The grid model is shown in Figure 2, with approximately 5.5 $\times 10^4$.

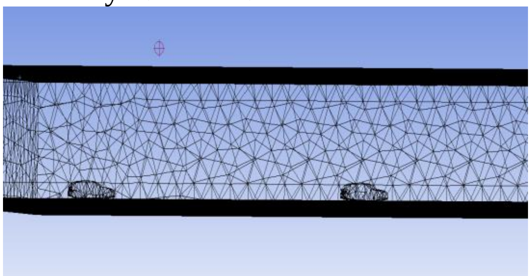


Figure 2: Enlarged Side View of Grid Model

## 2.4 Setting of boundary conditions

The left boundary of the calculation domain is the pressure inlet, and the right boundary is the pressure outlet. The two car bodies have walls. The two car turbulence model uses the standard k-epsilon model[11]. The SIMPLE algorithm is selected as the iteration method. The spatial discretization adopts a second-order upwind difference scheme.

## 3. Overtaking plan on bends

To study the overtaking behavior of vehicles on the roundabout road and simulate the overtaking process under this special situation. To remind passengers to drive safely. Both vehicles are required to drive on a circular bend with a radius of 50m, with car A as the main overtaking vehicle and car B as the overtaking vehicle. According to the traffic rules of the roundabout and the actual driving route of vehicles close to the roundabout, the two vehicles are not driving on concentric curves and there is no possibility of collision. The cross-sectional plan of the overtaking process is shown in the figure 3.

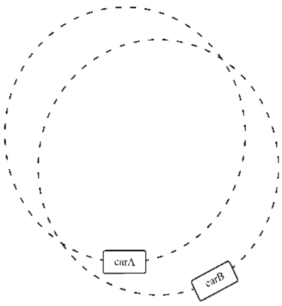



Figure 3: Schematic diagram of overtaking section

The overtaking plan is shown in Table 1:

Table 1: Overtaking Plan

| Programme | car A speed of a motor vehicle($m\ s^{-1}$) | car B speed of a motor vehicle ($m\ s^{-1}$) | Radius (m) |
|---|---|---|---|
| 1 | 22 | 15 | 50 |
| 2 | 20 | 15 | 50 |
| 3 | 18 | 15 | 50 |

To ensure driving safety, equation (4) takes into account the maximum safe speed when the car does not roll over[12].

$$V_r \leq \sqrt{\frac{gRl}{2h_g}} \tag{4}$$

In the formula: $v_r$ is the uniform circular motion speed of the car; R is the size of the circular motion radius; L is the distance between the left and right wheels; $h_g$ is the height of the car's center of mass; Gravitational acceleration g. According to this case study, the maximum speed is found to be around 22m/s, which meets the requirement of being less than or equal to the maximum safe speed for rollover.

## 4. Calculation results and analysis

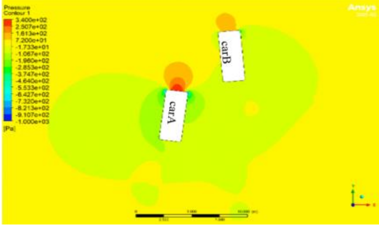
This article only specifically analyzes the changes in the lateral force coefficient and pressure center of the two vehicles during the overtaking process. In order to facilitate the description of the overtaking positions and analyze the flow field of the transient process. The distance of the vehicle along the centerline of the curve is denoted as X, and the length of the vehicle body is denoted as L. X/L represents the relative position of the two vehicles. The lateral force pointing in the opposite direction of the curvature of the bend is positive.

### 4.1 Pressure cloud map analysis

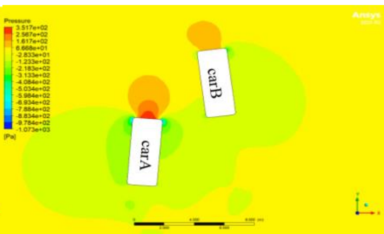
Taking Scheme 1 as an example, analyze the simulation results with a time step of 0.0005s and 16000 steps, and save the data every 5 time steps. In order to accurately analyze the changes in the external flow field during the overtaking process, positions -1.5 to 4 of the overtaking process were selected. The legend unit is $P_a$.

Before the overtaking process, the flow fields of the two cars have not yet interfered with each other. The pressure difference distribution on both sides of the vehicle is basically balanced, and the pressure on both sides is basically equal.

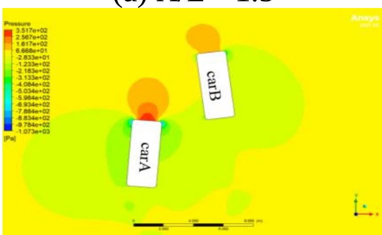
At the beginning of car A overtaking, unlike before overtaking at X/L=-1 (X/L=-1.5) in Figure 4 (b), the pressure distribution on both sides of the car body has begun to lose symmetry, and the flow field on the left side of car B has been significantly affected by the flow field of car A, causing the forces on both sides of the car to become unbalanced.



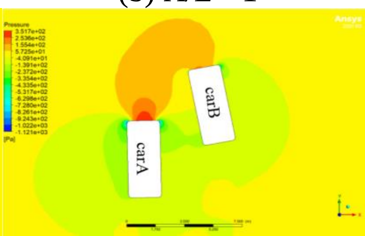
(a) X/*L*=-1.5



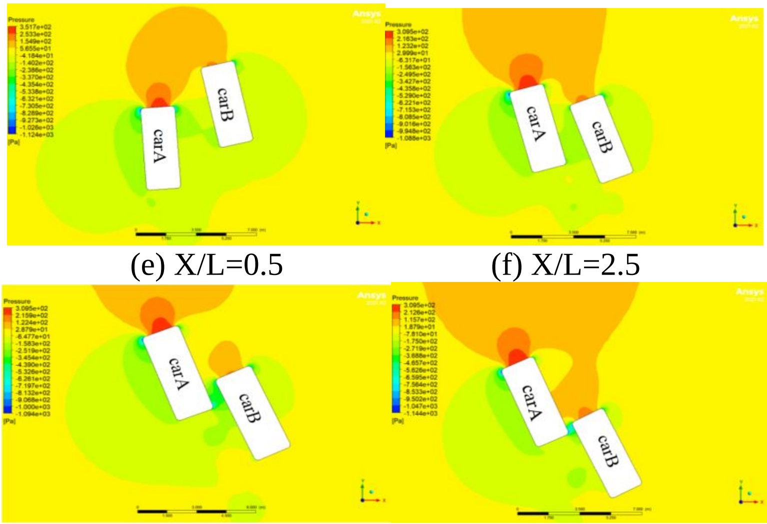
(b) X/*L*=-1



(c) X/L=-0.5



(d)X/L=0




(e) X/L=0.5 (f) X/L=2.5

(g) X/L=3.5 (h) X/L=4

Figure 4: Pressure nephogram at different overtaking positions

When car A is at the X/L=-0.5 position in Figure 4 (c), the two cars further approach, and the interference of car A on the flow field of car B is further enhanced. The airflow from the front of the car on the right side of car A affects the left side of car B, and the pressure on the left side of car B is significantly greater than that on the right side, indicating a tendency to slide to the right.

When car A is at position 4 (d), the pressure on the left side of car A is basically not affected, but as the two cars intersect, the negative pressure area on the right side of car A is more obvious compared to the previous position, and the area also increases. The imbalance of forces on both sides intensifies, and the pressure areas at the front of the two cars begin to interfere with each other.

When car A is at the X/L=0.5 position in Figure 4 (e), there is not much change in the pressure distribution compared to the previous position. However, as the distance from the main overtaking to catch up with car B becomes closer, the positive pressure area on the left side of car B decreases due to the influence of the flow field on the right side of car A, and the trend of car B turning to the right becomes more severe. Until the X/L=1.5 position, the front ends of the two cars were almost level, and the positive pressure on the left side of car B completely disappeared. The negative pressure on the inside of the two cars increased, indicating a possibility of mutual attraction.

As shown in Figure 4 (f), X/L=2.5, car A continues to surpass car B, similar to the situation where the left front of car B existed before. There is a partial positive pressure area on the right front of car A, which intensifies the trend of car A's front sliding to the left. This trend continues until the X/L=3.5 position in Figure 4 (g), where the positive pressure area on the right side of the car A body continues to increase, which is not conducive to the safe driving of the car A.

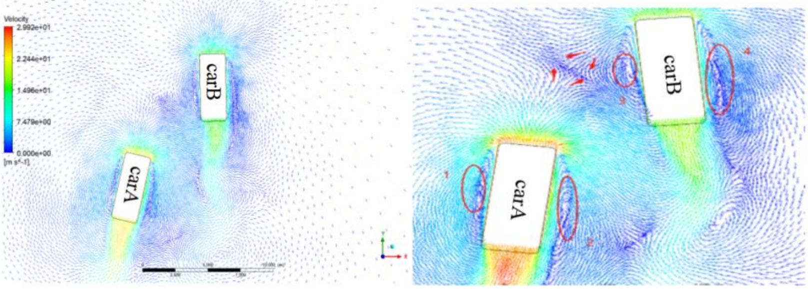
Moreover, when X/L=4 in Figure 4 (h), due to the proximity of car B, the right side of the car body of car A is interfered by the positive pressure of the car B front, and there is also positive pressure in the right side of the car body of car A itself[9]. There will be a certain pressure difference resistance between these two parts of the pressure, which makes the right side of the car A body unstable and affects driving stability. In addition, the flow fields at the front and rear of the car B car interact with each other, and the overlapping area is in a negative pressure state[10]. The rear of the car A car tends to move towards the front of the car B car, increasing the danger of driving the two cars. As the distance between the two cars increases, the mutual influence of the flow field weakens, and the force on the body gradually returns to the state before overtaking.

## 4.2 Analysis of velocity vector diagram

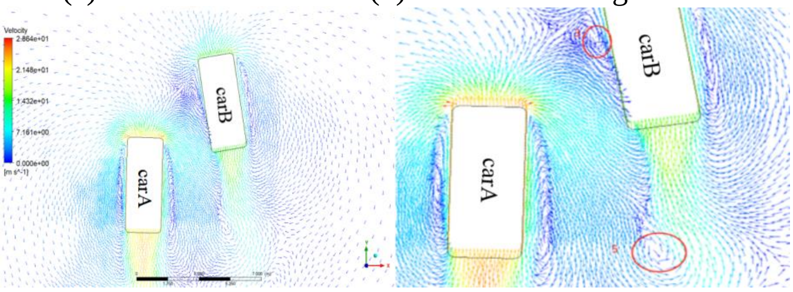
Analyze the velocity vector diagram from the previous case, with the unit in m/s.

Before overtaking, there are a pair of bound vortices on both sides of car A and car B, with their positions basically symmetrical and sizes basically equal. Both cars are in equilibrium.

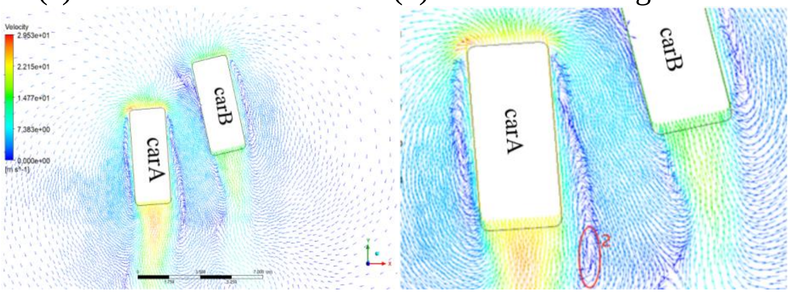
The figure shows the velocity vector at Figure 5 (a) X/L=-1.5. At this point, the airflow from the front of car A is about to interfere with the rear of car B, and the airflow velocity in the interference area increases, forming a negative pressure zone. In addition, compared to before overtaking, the airflow vector density on both sides of car B increases, and there are two airflow streams on the left side that collide with each other, reducing the airflow velocity on the left side, resulting in an imbalance of airflow vectors on both sides, making car B tend to turn clockwise.



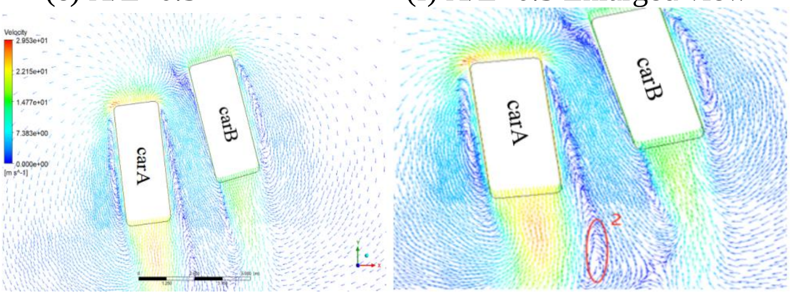

(a) X/L=-1.5 (b) X/L=-1.5 Enlarged view



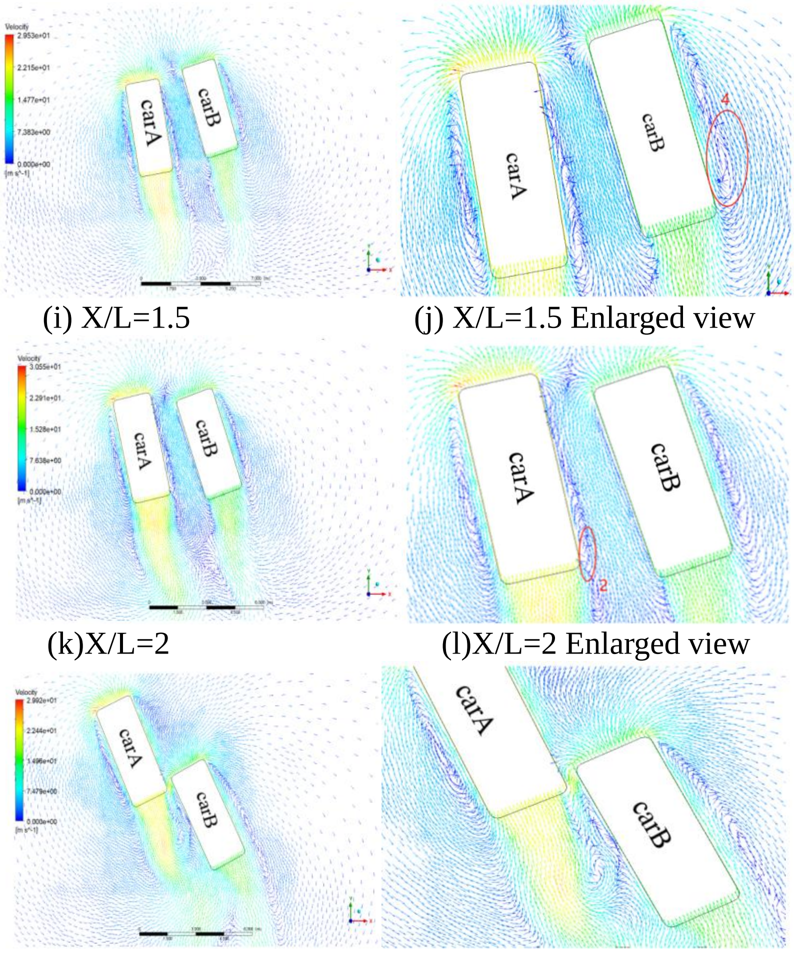

(c) X/L=-0.5 (d) X/L=-0.5 Enlarged view




(e) X/L=0.5 (f) X/L=0.5 Enlarged view




(g) X/L=1 (h) X/L=1 Enlarged view



(i) X/L=1.5 (j) X/L=1.5 Enlarged view

(k)X/L=2 (l)X/L=2 Enlarged view

(m) X/L=4 (n) X/L=4 Enlarged view

Figure 5: Vectorgraph of different overtaking positions

When X/L=-0.5 in Figure 5 (c), due to the influence of the flow field at the front of car A on the left side of car B, the third vortex on the left side of car B are pushed by the airflow from car A's front, forming an elliptical shape. The vortices on both sides of car B are significantly asymmetric, and the force on the car body is unbalanced. The airflow from the front of the car A car is pushed to both sides of the body, with some of the airflow merging with the car B wake. Due to the interaction between the airflow, a 5-vortex with a high velocity vector is formed at the car B wake and continues to move towards the rear of the car[11]. The formation and variation of the wake vortex consume energy in the flow field, leading to a decrease in vehicle driving stability.

Until X/L=0.5 as shown in Figure5 (e), as the two cars approach in distance, the airflow inside the two cars compresses the two vortices on the right side of car A, causing the vortex shape to become flat and the vortex center to shift backwards, resulting in significant differences in the air flow state of the car A body and unstable driving. And there is a high-speed vector area on the left rear side of the car B body, forming a partial low-pressure area. At this point, the lateral force on the car B body reaches its maximum, which seriously affects the driving stability of the car B.

As shown in the velocity vector diagram at Figure 5 (g) X/L=1, car A is about to level with the front of car B. Compared to the velocity vector on the right side, the velocity vector on the left side of car A differs the most at this moment, and the center of the second vortex on the right side continues to move backward, causing the vortices on both sides to become significantly asymmetric. Coincidentally, the lateral force on the body of car A reaches its maximum, which has a significant impact on the driver's operation. At the same time, due to the impact of the airflow from the front of car A on the left side of car B,the third vortex on the left side of car B disappear, and the flow field on both sides is unstable, resulting in significant changes in the force on car B. The right side velocity vector density of car B decreases relative to the previous position, which affects the driving safety of car B at this time.

At the next position in Figure 5 (i), when X/L=1.5, the front ends of the two cars are basically level. As the area of the inner area decreases, the vector density of the inner airflow of the two cars increases, and the speed also accelerates, both of which are higher than the outer airflow velocities of each other. The two cars have a tendency to attract each other. For car A, the difference in airflow speed on both sides is small, and the force on the car body is reduced[12]. On the contrary, the size of the fourth vortex on the right side of car B decreases, and there is a significant difference in the airflow state on both sides. The force state of the car body is more unstable, and the driving difficulty of car B at this position is greater than that of car A.

At X/L=2 in Figure5 (k), the front of car A overtakes the front of car B, and the airflow on the left side of car B flows between the two cars. Part of it merges with the car A wake, while the other part merges into its own wake. The density of velocity vectors on the right side of car B decreases, and the distribution of velocity vectors on both sides is unbalanced, resulting in the lateral force coefficient of car B reaching its extreme value at that position. At the same time, due to the influence of the airflow in the overlapping area on the inner side, the energy of the Second vortex on the right rear body of the car A is continuously dissipated outward, the strength of the vortex center decreases, and the vortex structure is no longer stable, which can easily lead to a decrease in vehicle driving stability.

Before the overtaking process ends, at X/L=4 in Figure 5 (m), when the rear of car A is about to exceed the front of car B, the car A wake has a significant impact on the left side of car B. The vortex of car A and the airflow in the front of car B cause turbulence in the airflow on the left side of car B, and there is a significant difference in airflow speed between the left side and the right side, which affects the stability of subsequent driving after being overtaken.

As the distance between the two vehicles increases, the interference in the flow field between the two vehicles gradually weakens, and finally each vehicle returns to a single vehicle driving state.

### 4.3 Lateral force analysis

When overtaking on a bend, the flow fields between vehicles interfere with each other, causing changes in lateral forces. In special positions, significant fluctuations in lateral forces can pose adverse factors to vehicle stability and driving safety. The lateral forces mentioned in the article are all forces perpendicular to the vehicle body. The positive direction of lateral force is defined as pointing from the left side of the vehicle to the right, and the negative direction is defined as pointing from the right side of the vehicle to the left.

As shown in Figure 6, the lateral force coefficient of the main overtaking car car A fluctuates continuously, with the overall direction pointing towards the inner side of the vehicle. The lateral force coefficient shows an overall trend of increasing first and then decreasing. Its lateral force first increases continuously from X/L=-4, and as the two cars intersect during the overtaking process, the overlapping area increases and the mutual interference effect increases[13]. Finally, it reaches its peak at X/L=1, which is the position where the main overtaking car head is about to be parallel to the overtaking car head. At this position, the airflow inside the front of the two cars collides with each other, and the direction of the lateral force points towards the inside of the car body, indicating a trend of mutual repulsion between the two cars. This position may cause car A to deviate from the normal driving trajectory while driving, which has a negative impact on driving. Afterwards, the lateral force gradually decreases to X/L=2, and the subsequent lateral force also decreases and tends to stabilize.

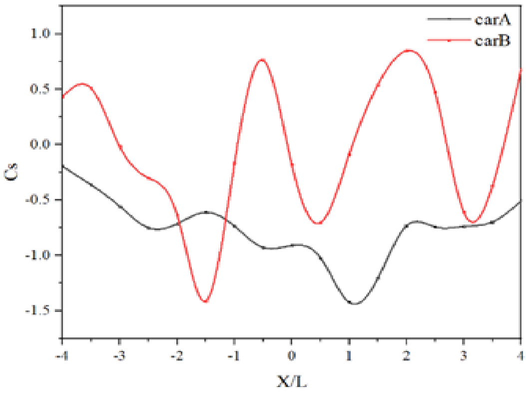
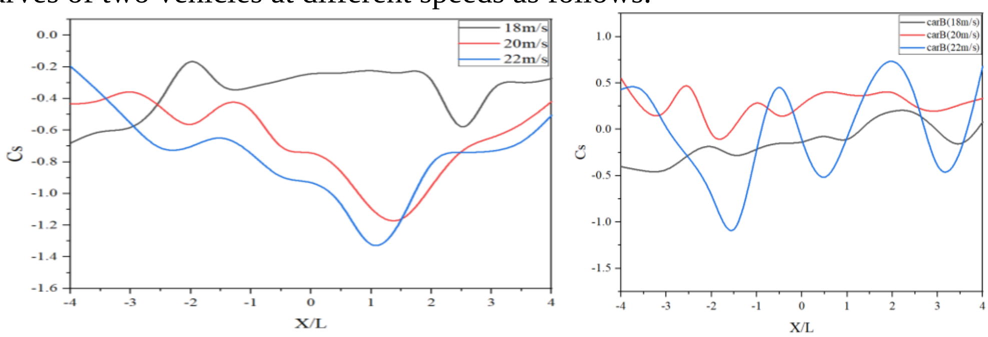



Figure 6: Distribution of lateral force coefficients

Due to the fast speed of car A and the influence of overtaking, the lateral force of car B changes significantly, showing a trend similar to a sine curve. From the graph, it can be seen that the overtaking exhibits lateral force peaks in different directions at X/L=-1.5, -0.5, 0.5, and other positions. Moreover, there is a change in the direction of lateral force within the range of X/L=-1.5 to X/L=-0.5. At the front of the main overtaking car car A, which is approximately at the same level as the rear of car B, the lateral force reaches the first peak and is also the largest among the peaks, indicating that this position has the greatest interference and impact on the body compared to other positions, which is extremely unfavorable for smooth driving. Subsequently, the lateral force of car B gradually decreases to zero and increases in the opposite direction to the second peak at X/L=-0.5, with the direction of the lateral force pointing towards the outside of the vehicle. Within the range of X/L=-1.5 to X/L=3, the direction constantly changes and the lateral force fluctuates frequently, resulting in a decrease in the driving stability of car B and a significant increase in the danger of overtaking.

Special overtaking positions can cause unstable lateral forces on the overtaking and overtaken vehicle, which greatly affects ride safety and vehicle stability. This section analyzes the lateral force variation curves of two vehicles at different speeds as follows.




a) car A b) car B

Figure 7: Lateral force curves at different vehicle speeds

According to Figure 7, it can be seen that at different speeds of car A. As the speed increases, the amplitude of the lateral force change in car A increases, and the extreme value of the lateral force also increases. Compared with Case 1 (18m/s), in the other two cases, the extreme point of the lateral force reaches its maximum earlier due to the increase in speed, which is manifested as the relative position of the intersection of the two vehicles becoming unstable earlier during the overtaking process. In addition, as shown in Figure 7, when comparing Case 2 and Case 3 with Case 1, at a speed of 20m/s, the maximum lateral force of car A increased by about 48.4%, and the lateral force of car B increased by 54.4%; At a speed of 22m/s, the lateral force of car A increased by approximately 87.7%, while the lateral force of car B increased by 134.77%.

According to the above experimental data, it can be seen that during the process of overtaking on curves, the change in vehicle speed has the most significant impact on the overtaken car B. And during the overtaking process, the lateral forces of both cars increase with the change of speed, and the aerodynamic forces in the two workshops become very active, making driving more unstable. When the distance between the two cars is too close at a certain moment, the body airflow affects the force state of the body and is prone to collision. The driving safety of passengers cannot be guaranteed.

### 4.4 Wind pressure center data analysis

The wind pressure center is the equivalent point of action for the aerodynamic force of a car's airflow, and the relative position change between the wind pressure center and the center of mass affects the driving stability of the car [13]. Taking Scheme 1 as an example, a positive value in the figure represents the forward displacement of the wind pressure center relative to the center of mass, while a negative value represents the backward displacement. The figure 8 is a comparative analysis of the changes in wind pressure center during the overtaking process.

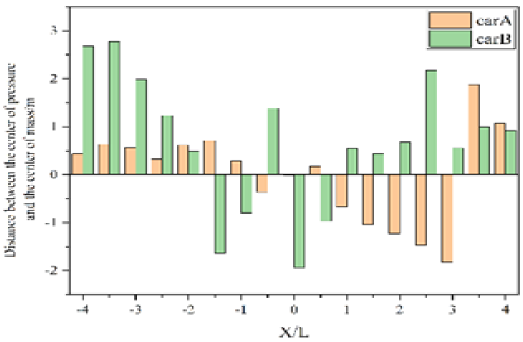



Figure 8: Pressure center variation during overtaking process

During the overtaking process, the lateral force acts on the pressure center, and the distance between the pressure center and the center of mass will generate a lateral moment. Overall, the pressure center offset and fluctuation fluctuation of car B vary significantly compared to car A. Before X/L=-1 and after X/L=3.5, the pressure center of the main overtaking is always in front of the center of mass, and the lateral force and yaw moment of the car A increase, which tends to exacerbate lateral driving and disrupt the driving stability of the car A. When X/L=0, the wind pressure center position and center of mass position of car A basically coincide, and the lateral force induced yaw moment is basically zero, which can maintain the normal and stable driving of the vehicle. During the process from X/L=1 to X/L=3, the pressure center of car A is located behind the center of mass, which helps to reduce biased driving and improve safety and stability. But if the center of the wind pressure moves back significantly, it will cause the lateral force to increase in the opposite direction, so driving must pay attention to driving safety.

During this process, due to the aerodynamic interference caused by car A gradually approaching car B, the overall displacement is large, and the basic pressure center is located before the center of mass, forcing car B to be subjected to greater force, posing a certain threat to the driving safety of car B. At X/L=-1.5 to X/L=0.5, the offset of car B is basically negative, that is, the pressure center moves backward. However, at X/L=-0.5, the wind pressure center moves forward, and the position change of the wind pressure center brings certain interference and danger to car B driving next to the main overtaking.

## 5. Conclusion

(1) If overtaking occurs on the roundabout road, the flow field between two vehicles is no longer similar to that of a single vehicle. When multiple vehicles are driving, the aerodynamic force and flow field no longer have symmetry, and the pressure and flow field distribution become more variable; At the same time, the presence of bends can also create centripetal forces on vehicles, which places higher demands on drivers and can lead to traffic accidents in extreme cases.

(2) As the main overtaking speed increases, the airflow and pressure changes in the two workshops become more complex. When the car A speed is 22m/s, unlike the trend of lateral force coefficient changes in Scheme 2 and Scheme 3, the lateral force coefficient change curve of car B fluctuates more, and there are also larger extreme values of lateral force, which greatly affects the driving stability of the overtaken (car B).

(3) When two cars are driving, the relative position between the pressure center and the center of mass determines the effect of aerodynamic force on the car. The force on the vehicle changes, which affects the stability of driving. Due to the overtaking behavior of car A, the pressure center of car B's body moves forward for a longer period of time, causing inconvenience to the vehicle's driving and steering, disrupting driving comfort, and even posing a serious threat to the safety of passengers.

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