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Analysis of aerodynamic characteristics of curved crossing based on CFD

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Abstract: In this paper, based on the dynamic mesh technology in computational fluid dynamics (CFD), the transient simulation of the curve crossing process is carried out, and the flow field distribution around the vehicle model and the change trend of lateral force and resistance are obtained. The research shows that the flow field, pressure field and velocity field around the body change with the relative position during the curve passing process. By changing the spacing, the change of the force in the process of vehicle crossing is more significantly observed, that is, with the decrease of the spacing, the change of lateral force and resistance is more unstable, which affects the safety and stability of the vehicle, makes the vehicle deviate from the original path and even causes serious accidents such as yaw and rollover.

1. Introduction

Vehicle cornering, the flow field around the body will be complex changes in the flow field between the vehicle and the vehicle there is mutual interference, but also makes the aerodynamic force changes, affecting the stability of the driver's maneuvering, the flow field of the mutual interference will make the vehicle varying degrees of deviation from the original driving track, a serious impact on the safety of the vehicle driving.[1]

In 1969, the V. Karman Institute in Belgium, in co-operation with the Ford Motor Company in the USA, carried out an experimental exploration of interference phenomena in the aerodynamics of composite vehicles. The experiments revealed significant changes in drag and lateral force coefficients during the relative movement of the scale model. R. J. Corin pointed out through simulation that quasi-static modelling is not suitable for reproducing overtaking scenarios containing the effects of side winds. Toyota Motor Corporation in Japan conducted wind tunnel tests for commercial vehicle overtaking, measured the pressure distribution and observed the airflow layout, but there are still limitations in details [2].Minato and other scholars explored the aerodynamic effects of sedan parade, side-by-side driving and overtaking. Professor Hu Xingjun of Jilin University used dynamic mesh technology to conduct instantaneous CFD simulation of two-vehicle straight-line overtaking and meeting behaviour, revealing the law of aerodynamic sextuple force change with time and vehicle position. Professor Fu Limin of the same university explored in depth the influence of the three-dimensional winding characteristics and aerodynamic performance parameters of the car on driving stability.[3] Professor Gu Zhengqi's team at Hunan University[4] analysed the straight-line rendezvous process of a sedan through CFD simulation, revealing the transient trend of aerodynamic coefficients and the changes of pressure and velocity distribution around the body. The study shows that there are significant airflow interactions and frequent fluctuations of aerodynamic sextant force during the rendezvous. Professor Tang Hongtao's team from Tianjin University of Science and Technology applied dynamic and slip mesh techniques to analyse the aerodynamic characteristics of various overtaking scenarios, pointing out that the lateral forces on the bodywork vary under different conditions, which may affect driving stability. Professor Tang Hongtao's team from Tianjin University of Science and Technology [5] applied the dynamic mesh and slip mesh techniques to analyse the aerodynamic characteristics of different car models under various overtaking scenarios. The conclusions emphasised that the lateral forces on the vehicle body vary under different relative speeds, vehicle sizes and spacing conditions, which may lead to a reduction in driving stability.[6]

Previous studies have focused on transient analyses of aerodynamic characteristics of single-vehicle or plural-vehicle overtaking processes, whereas in reality, cornering is more common, especially on mountainous roads. Accidents occur frequently under such complex working conditions, but there are fewer related studies. In this paper, we focus on the process of corner meeting and analyse its transient aerodynamic characteristics. It focuses on the change of flow field, pressure, velocity and lateral force between two vehicles when the distance between them changes. Through in-depth analysis of the pressure cloud, velocity vector and streamline diagrams, the change rule of the lateral force and the swinging moment of the vehicle in the process of meeting at the curve is investigated. The study aims to provide theoretical support for vehicle design and traffic safety under such complex working conditions.[7]

2. The Basic Control Equation

As this paper combines the practical, linked to the environment of the mountain road, consider the mountain environment factors affect more, especially the existence of a certain side wind influence. In this paper, the maximum speed of the selected vehicle is 20m/s, Mach number is 0.0588, less than 0.4, it can be considered that the wind speed range is incompressible fluid, so the fluid density ρ is a constant, and the applicable mass conservation equation is:

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{1}$$

In the above formula: u, v, w respectively speed x, y, z the component in the direction.

Momentum conservation equation in the direction of x:

$$\frac{\partial}{\partial x_i}\left(u_i u_j\right)=-\frac{\partial p}{\partial x_j}+\frac{\partial}{\partial x_j}\left[\mu_{ef}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)\right]\rho \tag{2}$$

Momentum conservation equation in the direction of y:

$$\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho v u)}{\partial x}+\frac{\partial(\rho v v)}{\partial y}+\frac{\partial(\rho v \omega)}{\partial z}=\frac{\partial}{\partial x}\left(\mu\frac{\partial v}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial v}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial v}{\partial z}\right)-\frac{\partial p}{\partial y}+F_y \tag{3}$$

Momentum conservation equation in the direction of z:

$$\frac{\partial(\rho\omega)}{\partial t}+\frac{\partial(\rho\omega u)}{\partial x}+\frac{\partial(\rho\omega v)}{\partial y}+\frac{\partial(\rho\omega\omega)}{\partial z}=\frac{\partial}{\partial x}\left(\mu\frac{\partial\omega}{\partial x}\right)+\frac{\partial}{\partial y}\left(\mu\frac{\partial\omega}{\partial y}\right)+\frac{\partial}{\partial z}\left(\mu\frac{\partial\omega}{\partial z}\right)-\frac{\partial p}{\partial z}+F_z \tag{4}$$

In the formula between (2) and(4):p is the pressure on the fluid micromeres； u, v, ω respectively velocity vector u *on* x, y,z in the direction formula:$u_i, u_j$is velocity component,$x_i, x_j$is coordinate-axis component,p is the pressure on the fluid micromeres, μ is turbulent viscosity coefficient.

The aerodynamic coefficient is utilized to describe the aerodynamic characteristics of the vehicle. Where (3) is the formula for the drag coefficient. $C_D = \frac{2D}{\rho v_\infty^2 A}$

In the above formula: C_D is drag coefficient, D is the longitudinal aerodynamic resistance of the body (x axial direction), v_∞ is relative air velocity, A is the projected area of the body

3. Numerical Simulation

3.1 Selection of car models and setting of computational domains

The family sedan in this study has body dimensions of 4734 mm in length, 1811 mm in width, 1455 mm in height, 2920 mm in wheelbase and 1465 kg in weight. To simplify the model, the car is considered as a rectangle, with L, W, and H representing the length, width, and height, respectively. The front and rear of the car are treated with rounded corners to ensure the rigor of the study. In order to simulate the wide road conditions in mountainous areas and to consider that the flow field is stabilized only after the vehicle has moved for a certain distance, a larger dimension of the computational domain is set, with the length of 30 L, width of 30 W, and height of 6 H. This setting helps to reduce the influence of the boundaries on the simulation results and to ensure the accuracy and reliability of the study.[8]

3.2 Mesh generation

The triangular unstructured meshing is used to generate meshes with high efficiency, which is advantageous for complex models. The mesh size of the computational domain is 0.6 m, and the mesh of the body is 0.1 m. The mesh around the body is more precise to improve the solving efficiency; the near-wall mesh is finely calculated, and the result is more close to the reality. The grid at the edge of the computational domain is sparse to avoid long computation time and too many grids. Figure 1 shows the grid model of the computational domain, the number of grids generated in this study is about 3×10^5 myriad.[9]

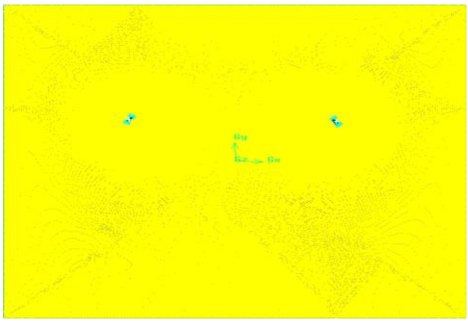


Figure 1: Grid model

3.3 Setting of boundary conditions and initial conditions

In transient simulation, the selection of the computational domain is crucial for computational time and accuracy. The computational domain includes pressure inlet, pressure outlet and wall. Ideal-gas medium and transient solver are used, and Realizable k-β model is chosen for the turbulence model to obtain regularity and acceptable accuracy. The dynamic mesh uses Smoothing and Remeshing, and the Spring Constant Factor is set to 0.05. The trajectory of the model is simulated using the UDF, and the dynamic mesh technique is used to re-divide the mesh with the displacement of the vehicle in order to ensure the quality of the mesh. The momentum equations are solved by SIMPLE algorithm.[10]

3.4 Rendezvous programme design

The research background of this paper is the mountain road meeting, due to the mountainous area external environment affects more factors, this paper aims to study the influence of vehicle spacing on the aerodynamic characteristics of the meeting. Through the study of the aerodynamic characteristics of the two vehicles, as a reminder to remind drivers to drive in a safe and standardised manner. The simulated road is a 180 ° arch turntable road. The right side is CarA, and the vehicle travelling path is an arc with a radius of 50m; the left side is CarB, and the travelling radius is 1.2 times the width of CarA radius, 1 times the width of CarA radius, 0.8 times the width of CarA radius, 0.6 times the width of CarA radius, respectively. The absolute speed of the two cars is constant at 20m/s. The schematic diagram of the meeting is as follows Figure 2:

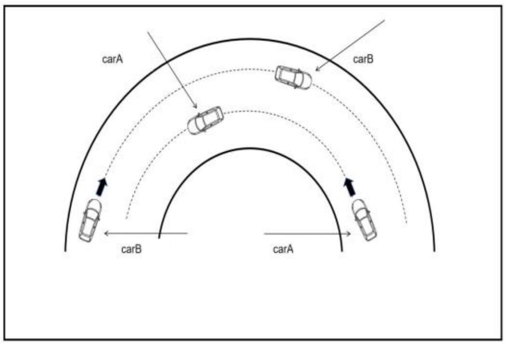
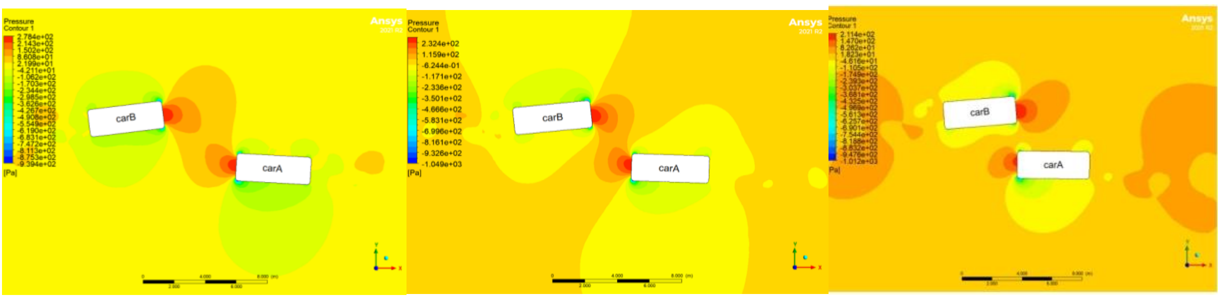


Figure 2: Schematic diagram of driving track

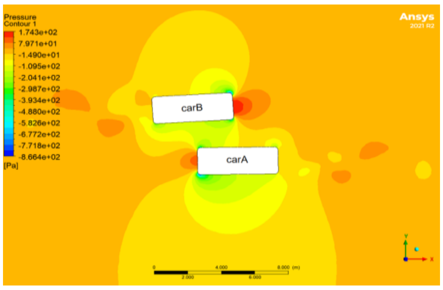
3.5 Analysis of simulation results

The aerodynamic diagram can well respond to the changes in the distribution of aerodynamic forces during the traveling process of a car. In this paper, we focus on the changes of lateral force and drag force on the car during this process. In order to better respond to the change of moment at each position during the meeting process, it is stipulated that the distance of the vehicle along the centerline of the curve is recorded as X, the length of the body is L, and the relative position of the two vehicles is indicated by X/L. The relative distance X is negative before the meeting, and the relative distance X is negative after the meeting. It is also stipulated that the relative distance X is negative before the vehicles meet and positive after the meeting. The lateral force points to the center of the track motion circle as the positive direction.[11]

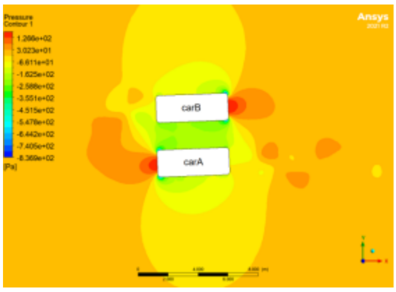
3.5.1 Pressure cloud analysis



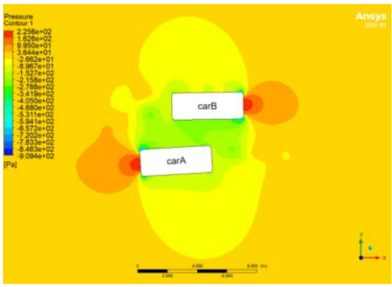
(a)X/L=-1 (b) 4X/L=-0.5 (c)X/L=0



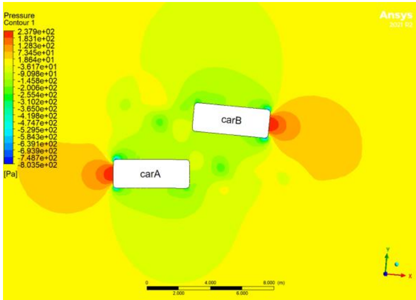
(d)X/L=0.5



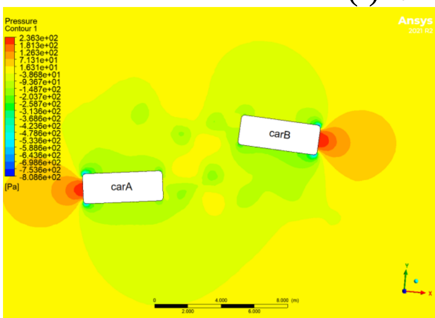
(e)X/L=1



(f)X/L=1.5



(g)X/L=2



(h)X/L=3

Figure 3: Pressure cloud analysis

The simulation results are analyzed using Scheme 1 as an example. The time step of this simulation is 0.0005 s and the number of time steps is 10000. The maximum number of iterations within the time step is 200, and the data is saved every 10 time steps. In order to more closely match the actual to get relatively accurate experimental results, -1 to 3 several meeting process positions are intercepted. This is unit is Pa.[12]

The two vehicles are before the encounter, the mutual interference between the vehicles' external flow fields is weak. The pressure distribution on both sides of the vehicle body is relatively balanced, the pressure difference is small and basically consistent. With the gradual approach of the vehicle, the relative position of the two vehicles at this time is X/L = -1, the flow field at the front of the vehicle to interfere with each other, the pressure distribution at the front of the two vehicles is obvious, and the pressure gradually changes. As shown in Figure 3 (b), at this time the relative position of the two cars for the X / L = -0.5, relative to the previous position, the two cars inside the region of negative pressure area increased significantly, the body at the pressure distribution is obviously unbalanced, the pressure between the two cars from the high-pressure to low-pressure excess, so that the two car body force imbalance, have a tendency to torsion movement. At the same time, the two cars at the front of the high pressure has begun to interfere with each other, with the distance between the two cars close to the two car torsion trend will be due to the front of the high-pressure influence and intensify the torsion, vehicle driving stability slowly reduced.

Two cars just flush, by the CarA front high-pressure area of the influence of CarB inside the body at the pressure increases significantly, the high pressure area is also relatively large relative to the previous position, so that the Car B counterclockwise torsion tendency to increase; the same Car A inside the pressure also increases, the area also increases, the same torsion tendency also increases. Therefore, there is a repulsive effect.[13]

As the positions gradually approach, the overlap area increases. As shown in the current position X/L=0.5, the inner flow field of the two cars interferes obviously, the inner pressure decreases rapidly, and is obviously lower than the outer pressure. the inner pressure of Car A changes from the previous positive pressure area to the negative pressure area, and the pressure difference between the negative pressure area and the outer area decreases, and the tendency to be far away from Car B is obviously weakened, and the mutual repulsion of the two cars is weakened and gradually turns into mutual attraction.

When the two vehicles completely overlap (i.e., X/L=1), the pressure on the inside of the two vehicles is further reduced, due to the encounter, the area of the inside of the body area is continuously compressed, where the airflow velocity is dramatically increased, thus forming a whole negative pressure area. The pressure difference between the two sides also increases further, and the lateral force on the two vehicles increases significantly compared with the previous position.[14]

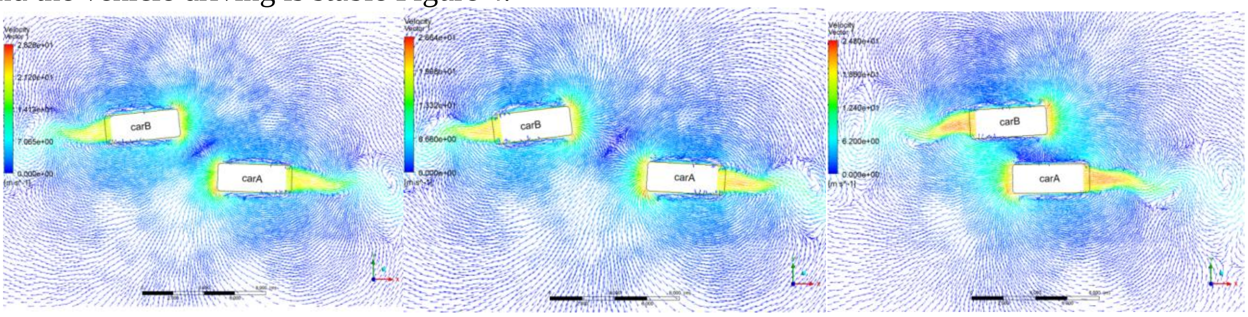
Two cars staggered a certain distance (X / L = 1.5), the two cars continue to interfere with the airflow on the inside, but still in the negative pressure region, the pressure difference between the two sides of the vehicle compared to the previous position has been weakened, the body of the lateral force suffered by the body has been weakened, the mutual attraction of the role of the reduction of the other party by the influence of the tail flow, the two sides of the pressure distribution of the two cars is not balanced.

The two cars are just completely staggered (X/L = 2), the two cars completely into each other's wake region, the two cars inside the pressure has increased, the negative pressure region area has more reduction, and the outside pressure are higher than the inside, so the two cars are still attracted to, but compared with the previous position there is a significant weakening.

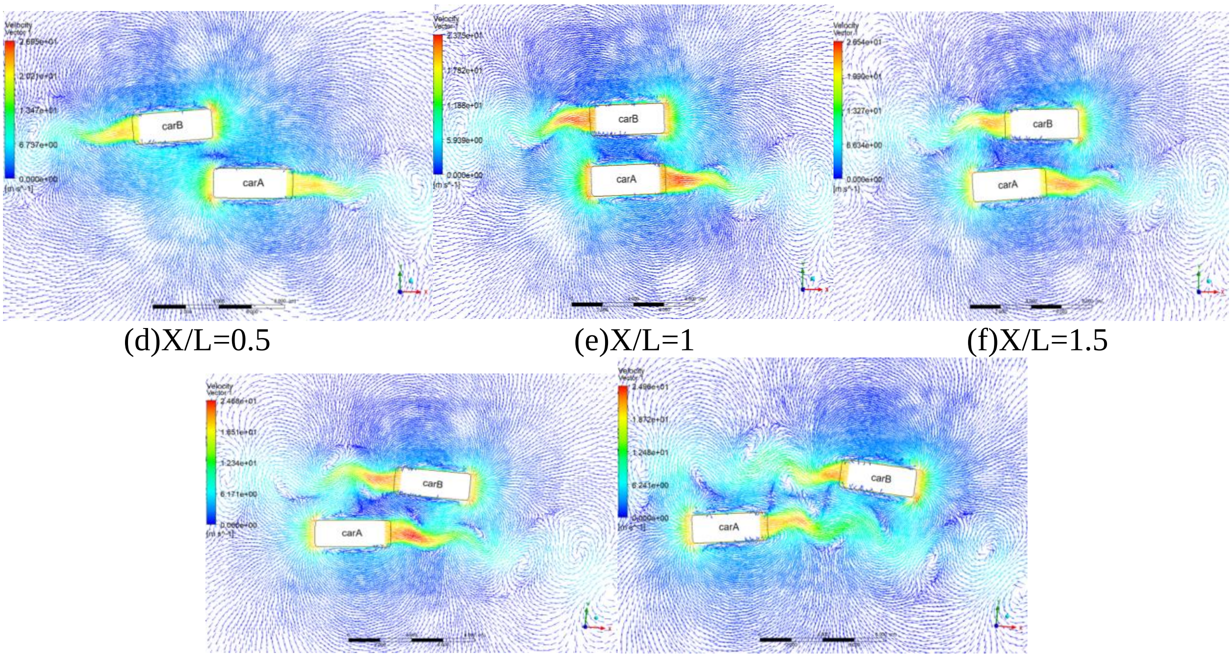
The two cars are completely staggered and the longitudinal distance gradually becomes larger, at this time the two sides of the pressure distribution and the car before the meeting is basically the same, the pressure distribution is balanced, the difference between the two sides of the pressure decreases, the force is gradually balanced, tends to be before the meeting of the state of the car.

3.5.2 Velocity vector map analysis

Vehicles in the driving process, the flow field around the body will change with the airflow movement, the airflow velocity is constantly changing, the flow field distribution is not balanced, resulting in changes in the force around the body. By analyzing the velocity vector diagram around the body, we can understand the change rule of the velocity vector of the body. The velocity vector diagrams at different locations have their own characteristics. Before the rendezvous, the flow field of the two vehicles is relatively independent, the distribution of velocity vectors around the body is balanced, the vector state of the two vehicles is basically consistent, the lateral force is basically zero, and the vehicle driving is stable Figure 4.



(a)X/L=-1　　(b)X/L=-0.5　　(c) X/L=0



(d)X/L=0.5 (e)X/L=1 (f)X/L=1.5

(g)X/L=2 (h)X/L=3

Figure 4: Velocity vector map analysis.

With the shortening of the meeting distance, the position of the two cars is X/L=-0.5, the airflow at the front of the two cars interferes with each other, forming a region of airflow interference with a complex flow direction and lower airflow speed, it is obvious to see that the density of the airflow vector distribution in the middle region increases compared with the previous position, and the low-speed airflow has less influence on the body travelling, so Car A and CarB are still travelling steadily at the present time.

The two cars just start to meet each other (X/L=0), the high-speed airflow in the head of Car A and the low-speed airflow in the inner side of Car B and the inlet airflow impact on each other, the velocity vector distribution is disordered and the density of vector distribution increases, and in the middle, there is still a piece of low-speed zone with complicated flow direction. Local high-speed vectors appear in the outer side of the front end of Car A, and similarly, local high-speed vectors appear in the outer side of the front end of Car B, which is the difference of low-speed vectors in the inner side of the two cars. Both cars have a tendency to move away from each other.

The two cars meet and partially overlap (X/L=0.5), the airflow in the inner side of the two cars interferes, there is a significant increase in the airflow velocity at the back half of the inner body of CarB compared to the previous position, probably due to the local high-speed vector interference at the front of Car A, which partly converges into the inner body of CarB, and the difference in velocity vectors between the two sides of the car body is reduced. At the same time, the area of high-speed vector on the right side of the front of CarB increases significantly compared with the previous position, and the difference in velocity vectors between the two sides of the front of the car is also reduced, so the trend of Car B away from Car A is also a little bit weakened. The wake vortex exists in the wake stream of both cars and keeps moving backward.

The two cars happen to completely overlap (X/L = 1), the body of the inner airflow interfere with each other squeeze, the inner area is constantly compressed to become smaller, the airflow interaction is frequent, the airflow vector density increases, the body on both sides of the vortex generation. The speed increases and is greater than the speed of the airflow on the outside of the body, the airflow flow state difference between the two cars is large, so the two cars are transformed from mutual exclusion to mutual attraction. The local high-speed vector airflow at the body of the two vehicles constantly converge into the other vehicle tail flow, so that the velocity vector at the rear of the two vehicles continues to increase, the tail vortex size also continues to increase and gradually move back, the vehicle driving stability is reduced.

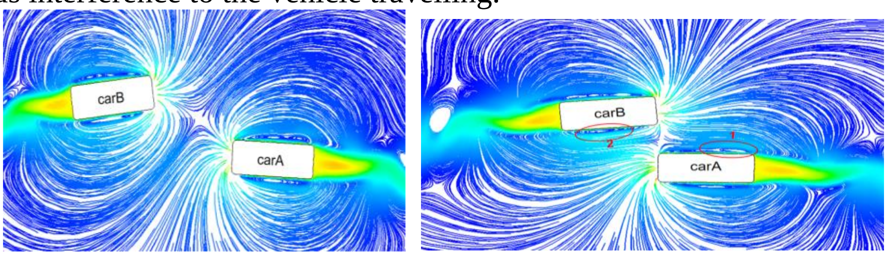
The two cars are gradually staggered and the overlap area decreases (X/L = 1.5). The density of airflow vectors on the inside of the car body decreases, and the velocity vectors on the inside of the car body decreases. The two vehicles gradually enter each other's wake region, affected by the other vehicle's wake region, the local high-speed vector on the right side of Car A's front end converges into CarB's wake, and the high-speed vector area at Car A's front end decreases. Similarly, the area of high-speed vector at the front of Car B is also reduced, and the mutual attraction between the two vehicles is weakened. The vortex size at the rear of the two cars increases and moves backward.

The two vehicles are just completely staggered (X/L=2), the inner airflow flow state of the two vehicles is good and starts to separate, the inner airflow flow area is increasing, and the density of airflow vectors is decreasing. The difference between the two sides of the vehicle airflow flow state becomes smaller, the two cars attract each other tendency is getting weaker and weaker. the right side of the front end of Car B high-speed vector by Car A tail flow, local high-speed vector component into the tail flow, so the right side of the front end of the high-speed vector area decreases, and the Ca rB has a tendency to move away from the Ca rA. Similarly, Car A is also affected by the wake flow of Car B, so the two cars gradually move away from each other.

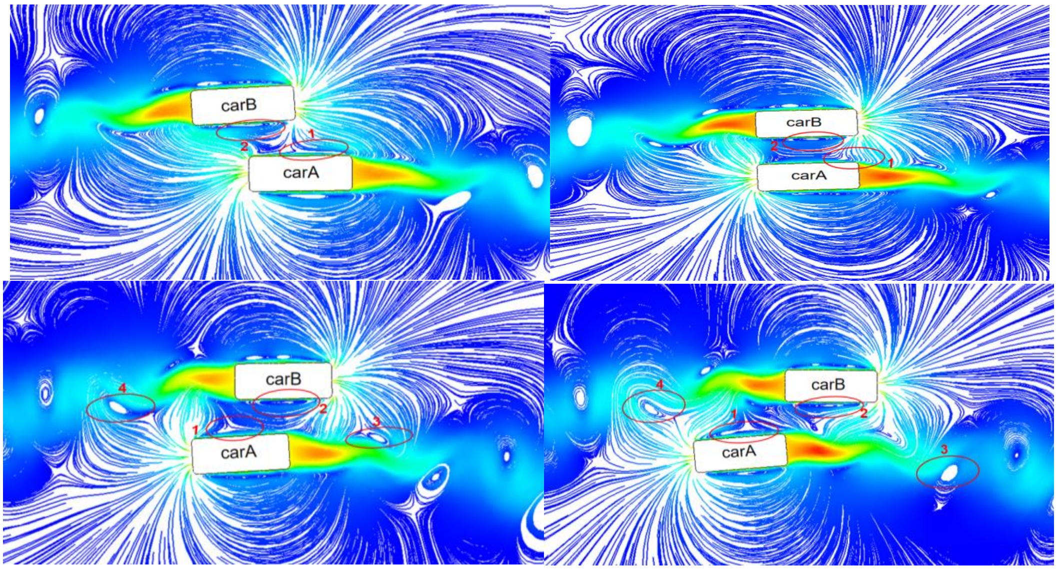
As the longitudinal distance between the two cars is getting farther and farther, the airflow flow state on both sides of the body is gradually stabilised, and the difference in the airflow vector density on both sides of the body is getting smaller and smaller, but compared with the pre-meeting period, there is an obvious difference in the distribution of airflow velocity vectors. The aerodynamic characteristics of the car are restored to the state before the meeting. However, due to the existence of the tail vortex and the size of the tail vortex is expanding and moving backward, there is still a little interference to the airflow on the inside of the two cars' bodies which will last for a period of time, so before the interference of the tail vortex disappears completely, the driver should still pay attention to the stability of the vehicle.

3.5.3 Flow chart analysis

When vehicles meet at a curve, the surrounding airflow is constantly changing due to the proximity of the two vehicles Figure 5, and the airflow between the bodies interferes with each other. Vortices are generated around the vehicle body due to a variety of factors, such as lateral forces and drag. The vortex is accompanied by energy generation and consumption, which leads to constant changes in the force situation of the body, affecting the safety and stability of the vehicle. In the pre-meeting state, the longitudinal distance between the two vehicles is relatively far (X/L=-1), the flow field distribution around the body is relatively stable, and the velocity distribution is balanced. The formation of vortex around the body is accompanied by the generation and consumption of energy, at this time, the vortex around the body has less influence on the stability of the meeting, and does not cause serious interference to the vehicle travelling.



(a)Flow diagram before the meeting process



(b)Flow diagram of the meeting process and end

Figure 5: Flow chart analysis.

There are a pair of bounding vortices on each side of CarA and CarB bodies, and the size and shape of the two vortices and their relative positions to the bodies are basically the same. With the relative distance of the two cars indented (X/L = -0.5), at this time 1 vortex around the streamline density is reduced, 1 vortex size becomes smaller, by the influence of the airflow in the front end of CarB, the center of the vortex gradually began to move backward to the rear of CarA. During the meeting process, the flow field around the body interferes with each other frequently, and the vortex around the body changes actively. 1 vortex experiences size change and shape change, while the generation and disappearance of the vortex is accompanied by the consumption of energy in the surrounding flow field, which makes the lateral force applied to CarA change continuously as well. CarA, CarB meeting process, the vehicle tail vortex has always existed, but with the two cars longitudinal distance continues to decrease, the two cars front airflow continues to converge, the formation of a piece of a larger area of streamline clusters, the vehicle inboard airflow continues to be compressed, the flow density of the flow field continues to increase, 1 vortex 2 vortex between the formation of a relatively confined space, the body force conditions also continue to change In the process of meeting, there is a low-pressure area on the inside of the two vehicles, and the high-speed airflow affects the vortex, causing its shape and position to change continuously. After the completion of the rendezvous, the vortex on the inside of the vehicles is still affected by the wake effect, and the driver needs to pay attention to its influence and make timely adjustments. Research has shown that the change of vortex is important for driving safety. Therefore, understanding the changes of flow field and vortex of vehicles in the process of meeting is crucial for driving safety. At X/L=0, the vortex 1 in the tail of CarA is about to be dislodged, but the vortex sticks to the rear of the car due to the curvature of the tail. As the distance increases and the tail effect strengthens, the pressure at the center of vortex 1 decreases, and the vortex sheds and changes from a bound vortex to a free vortex. Similarly, vortex 2 on the inside of CarB has this condition. At X/L=0.5 to X/L=1, the trailing vortex 1 of CarA is completely dislodged, while the airflow extrusion between the two cars causes the vortex to flatten, increase in pressure and cling to the inner side of CarB. At this point, a low-pressure area is formed on the inside of both cars, and the inner high-velocity airflow flows to the higher-velocity vortex, resulting in vortex deformation.

At X/L=1.5, as the two cars are staggered, the center of vortex 1 moves forward and becomes elliptical due to the influence of airflow from the inside of CarB, and the lateral force on the vehicle changes. The driver needs to adjust his driving state in time to prevent accidents. After the end of the meeting (X/L=2), the vortex is still changing due to the interference of free vortices 3 and 4 at the wake of the two vehicles, which affects the magnitude of the lateral force. Drivers need to pay attention to the influence of the wake effect and adjust their vehicles in time under unfavorable conditions. In summary, the vehicle in the meeting process, the flow field around the body is constantly changing, the flow field changes accompanied by changes in the vortex around the body, thus affecting the safety and stability of the vehicle driving, which in turn brings a lot of unfavorable factors to the driving, so the study of the vortex of the meeting process has a certain significance to the driving safety.

3.5.4 Lateral force analysis

When vehicles meet, the flow fields interfere with each other, resulting in changes in lateral forces on the body. The lateral force is greatest at a particular position. The lateral force directed inward is specified as positive and vice versa. This force perpendicular to the body may cause the vehicle to deflect, deviate from its original path, or even roll over. Therefore, the study of lateral forces during vehicle travel is very important for driving safety and stability. The below figure 6 shows that CarA, CarB in the process of meeting, lateral force coefficient changes in the curve, from the figure can straight look at the whole process of meeting, the lateral force of the two cars are fluctuating at all times. The overall change trend of the lateral force coefficient of the two cars is increasing first and then decreasing. Starting from the position of X/L = -3, the longitudinal distance between the two cars at this time is farther, the airflow interference between the body is almost non-existent, so the lateral force between the two cars has almost no effect, and the two cars travel smoothly. With the shortening of the longitudinal distance between the two cars, the meeting process is further carried out, in the X/L = -1 to X/L = 1 this time, the lateral force coefficient continues to increase, compared to CarA, CarB lateral force coefficient increases in the magnitude of the increase is greater, in a certain time to reach the maximum value, at this time, the longitudinal distance between the two cars continues to shorten, the two cars overlap the overlap area continues to increase until the complete overlap, the two car body airflow inside the body is constantly squeezed, mutual interference effect The airflow on the inner side of the two cars is continuously squeezed, and the mutual interference is continuously strengthened. The lateral force coefficient of both cars reaches the maximum value, and the direction points to the inner side of the car body, and the lateral force coefficient of CarA is increased by 6.61% compared with that of Car B; the lateral force is dramatically increased, and there is a mutual attraction effect between the two cars. In this meeting time, the force between the two cars is unbalanced, the body of the two cars can not travel smoothly, easy to collision or rollover and other traffic accidents, due to pay special attention to the spacing between the two cars, the driver of this unexpected situation due to make timely adjustments, to ensure the safety and stability of driving. Finally, with the end of the process of meeting the two cars, the longitudinal distance between the two cars continues to increase, the interaction between the lateral force between the two cars continues to weaken, and gradually return to the state before the meeting.

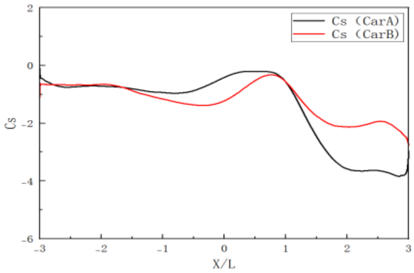


Figure 6: Lateral force diagram

3.5.5 Lateral force analysis at different spacing

Vehicles in the process of meeting traffic, the different spacing between the two vehicles on the vehicle travelling safety, stability, there is also a certain impact.

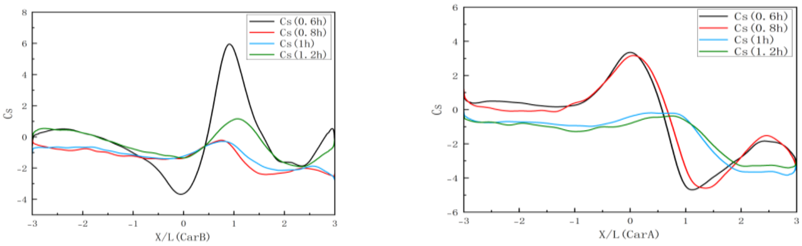


Figure 7: Lateral force distribution of CarA and CarB at different spacing

From the above figure 7, it can be seen that the corresponding lateral force coefficient fluctuates as the spacing between the two cars changes. From the distribution of lateral force coefficients for different spacings, the lateral force coefficient of Car A decreases significantly with the increase of the spacing between the two cars, while the lateral force coefficient of CarB changes in the opposite way. The overall trend is to increase and then decrease and finally level off. From the figure, it can also be clearly seen that with the increase of the spacing, the amplitude of the lateral force change is also significantly reduced, and the extreme value of the lateral force coefficient is also becoming smaller; compared with 1 times the spacing and 1.2 times the spacing, it is obvious to see that 0.6 times the spacing and 0.8 times the spacing, the extreme value of the lateral force coefficient has a significant increase in the extreme value of the extreme value of the point appeared in advance. Compared with 1x vehicle width spacing, the maximum lateral force of CarA increased by 4.34 times, 4.02 times, and -0.33 times for 0.6x vehicle width spacing, 0.8x vehicle width spacing, and 1.2x vehicle width spacing, respectively; while the maximum lateral force of CarB increased by 3.61 times, 0.28 times, and -0.16 times, respectively. The above data show that the spacing between vehicles has a very strong effect on the lateral forces experienced by the meeting vehicles. When the spacing is less than 1x vehicle width spacing (i.e., 0.6x, 0.8x), the maximum lateral force on both Car A and Car B increases significantly; compared to Car B, the lateral force on Car A is more affected by the spacing; especially when the overlapping area between the two vehicles is increasing during the rendezvous, with the shortening of the spacing, the area of the airflow flow between the car bodies is squeezed continuously, and the airflow velocity With the shortening of the distance, the airflow area between the bodies is squeezed, and the airflow velocity increases sharply, which leads to the increase of lateral force, and the body is shaken by the lateral force during the process of meeting, deviating from the original travelling route, and even serious accidents such as rollover will occur, so the driver should control the distance between the two cars in the process of driving, especially during the process of meeting to ensure that the meeting will be completed safely.

3.5.6 Resistance analysis at different spacing

The distribution of drag forces on the two vehicles during the meeting of vehicles at the same spacing is shown in the figure below Figure 8.

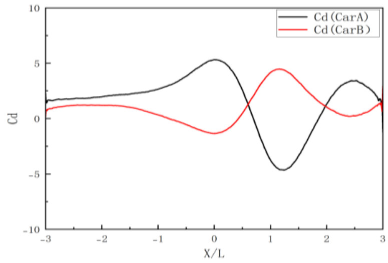


Figure 8: Resistance Chart

From the above figure 9, it can be seen that: Car A, Car B drag coefficient change trend is exactly opposite, respectively, presenting the trend of first rising and then falling and finally tend to stabilise and first falling and then rising and finally tend to stabilise. In the process of meeting (X/L=0 to X/L=1), the area of overlapping parts of the body continues to increase until complete overlap, airflow interference increased, the fluctuation amplitude of the drag coefficient curve increases; at X/L=0, the drag coefficient of Car A obtains the maximum value (the minimum value of the drag coefficient of Car B), at this time, the two car front part of the car began to meet, the two front part of the airflow began to interfere with each other, the drag continues to increase; subject to the high-speed air flow at the front of the car, the drag coefficient increases; the drag coefficient of CarA and CarB is the maximum value. Increase; by the front of the high-speed airflow, the two cars began to exist mutual exclusion trend; in X/L = 1, Car A resistance coefficient to obtain the minimum value (Car B resistance coefficient maximum value), the two cars at this time completely overlap, the body of the inner airflow vector density continues to increase, compared to the resistance, this time, the lateral force plays a dominant role, the two cars have a tendency to attract each other; with the process of the meeting of the car is constantly carried out, the two cars by As the meeting process continues, the resistance of the two cars slowly returns to the state before the meeting.

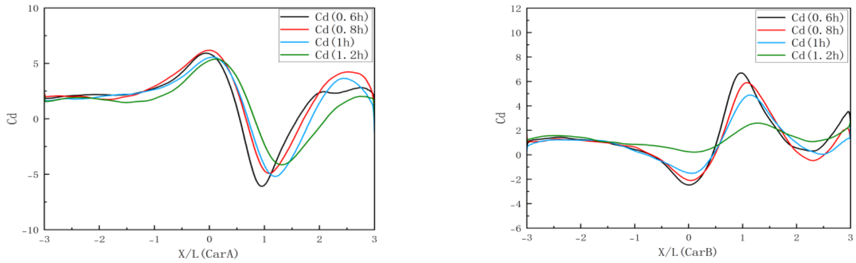


Figure 9: Resistance of Car A, Car B at different spacing

By changing the size of the spacing between the two vehicles, observe the change of the drag coefficient between the two vehicles under different spacing. With the continuous change of the spacing between the two cars, the drag coefficient has been changed to different degrees, and the overall trend is that the drag coefficient tends to flatten out gradually with the increase of the spacing. From the above figure resistance coefficient distribution graph can be clearly seen with the increase of the distance, the extreme value of the resistance coefficient is also becoming smaller, the increase or decrease of the distance can significantly change the area of air flow between the vehicle and the vehicle, thus affecting the change of resistance in the process of vehicle travelling. Through the above figure, it is obvious to observe that, with the decrease of the spacing, the extreme value of the drag coefficient shifts forward significantly, compared with 1 times the spacing, the drag coefficient of CarA in 0.6, 0.8, 1.2 times the spacing increased 0.028 times, 0.177 times, -0.141 times; CarB in 0.6, 0.8, 1.2 times the spacing of the drag coefficient increased 0.135 times, 0.328 times, -0.141 times, -

0.141 times, and -0.135 times, 0.328 times, -0.311 times. It can be seen that within a certain range of spacing, with the increase of spacing, the resistance coefficient is increased by a certain multiple, but beyond a certain range, there is uncertainty between the two. From the above analysis of drag coefficient data changes, it can be seen that, compared with CarA, CarB is more significantly affected by the drag coefficient of the car travelling under the working conditions where the spacing is changed in the process of corner meeting. However, no matter Car A, Ca rB in the process of meeting, with the change of distance, a certain range of lateral force dominant role, and resistance in the whole process of meeting has always existed, which makes the vehicle travelling stability is damaged, and traffic participants with safety hazards.

4. Conclusions

In the case of corner rendezvous, the flow field distribution around the vehicles changes continuously with the rendezvous process. There is no symmetry in the flow field distribution and aerodynamic forces around the two vehicles. With the process of meeting, the lateral force, drag force, and transverse moment around the vehicle body change constantly, which has a certain impact on the safety and stability of vehicle traveling.

In the process of meeting in a curve, the pressure field around the vehicle, the velocity field, with the meeting of the relative position of the car changes constantly, thus affecting the vehicle driving process of lateral force, resistance and other important factors, and the meeting is completed before and after the lateral force, resistance fluctuations are very large, affecting the smooth running of the vehicle.

In the process of meeting in the curve, with the change of meeting distance, lateral force and resistance coefficient also change to different degrees. It can be seen that the general law when the lateral force and drag tend to level off with the increase of the spacing, but there is uncertainty beyond a certain range. From the relative position, at X/L=1 (i.e., the two vehicles just completely overlap), the lateral force on the vehicle reaches the maximum value, the vehicle shakes to a greater extent, and the driver should pay attention to the driving.

In the corner of the meeting is coming to an end, the pressure field around the vehicle, the velocity field within a short period of time is still changing, the reason for this is because at this time the vehicle each other into each other's wake area; by the wake effect of the impact of the vehicle will be completed for a period of time, the vehicle driving safety, stability will be greatly reduced, but also affects the normal operation of the vehicle.

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