Research on the Aerodynamic Characteristics of Vehicle Passing out Tunnel

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Abstract. Taking bus driving out of the tunnel as the research background, study the aerodynamic characteristics of the vehicle when the vehicles subjected the sudden change wind load. Numerical wind tunnel model is established. Respectively analysis the vehicle's aerodynamic change rule of three-component coefficients in the process of vehicle driving out tunnel at different speed under wind load and without wind load. The results show the vehicle's aerodynamic force increases suddenly when the vehicle run out of the tunnel. The suddenly increasing pressure on vehicle is very adverse impact on the driver's operation and driving safety.

1. Introduction

In the process of vehicle driving, the vehicle will subject the function together which composite of wind action generated by vehicle running and natural wind action. The value of vehicle subjected is not only related with the vehicle’s shape and size but also infected by the natural wind field around vehicle and the spatial location of vehicle. The synthesis of wind load vehicle subjected in the process of running, is not affect the vehicle running safety but also the running comfort characteristics. In particularly, the sudden change wind load vehicle subjected in the process of driving, will have such an important influence on the driver's operation that will threat the vehicle running safety. The existing research on the aerodynamic characteristics of vehicle are most study the aerodynamic force coefficients of vehicle based on the model of one vehicle running on the vacant road, then to study the running safety and comfort characteristics of vehicle. This article establishes the moving meshing numerical wind tunnel to study the aerodynamic characteristics of vehicle under the sudden change wind action based on the model of vehicle passing out a tunnel.

2. Calculation model

2.1. Model of vehicle and tunnel

Establish the numerical wind tunnel model to study the variation rule of aerodynamic force and use the moving grid technology to simulate the vehicle running. In the numerical wind tunnel model, the bus, tunnel and road border are established respectively. Set the different velocity of vehicle running and different lateral wind speed to study the change rule of aerodynamic characteristics while vehicle passing out a tunnel. The established numerical wind tunnel model is as Fig.1.
The fluid analysis software FLUID is applied to establish the three-dimension numerical wind tunnel with the consideration of clogging effect. When meshing the wind tunnel model, the encryption grid around vehicle are adopted. In the numerical wind tunnel, set the lateral boundary as the velocity inlet and pressure outlet, set the up and down boundary as the symmetry boundary. In the moving grid calculation, simulate the turbulence indirectly with Reynolds average method. In the process of solving the momentum equations, transient pulse is expressed in the homogenization equation through the assumed model.

2.2. Aerodynamic coefficients

The six-component of the aerodynamic forces are generated while vehicle under the wind load action, which are lateral force, vertical lift force, resistance force, overturning moment, torque moment, and pitching moment. Usually, express aerodynamic force as the dimensionless six-components coefficient. Where, the three-component force coefficient which mainly affect the vehicle running safety are defined as bellow.

\[
C_x = \frac{F_x}{\frac{1}{2} \rho V^2 HL} \quad C_y = \frac{F_y}{\frac{1}{2} \rho V^2 BL} \quad C_{Mz} = \frac{M_z}{\frac{1}{2} \rho V^2 B^2 L}
\]

where, \(C_x, C_y, \) and \(C_{Mz}\) respective is lateral coefficient, lift coefficient and overturning moment coefficient, besides that \(\rho\) is the air density and \(V\) is the synthesis of positive wind generated by vehicle traveling and the natural wind. Moreover, \(H, B, L\) respectively represents the height, width and length of vehicle.

3. Aerodynamic characteristics changes of vehicle without cross wind load

First, study the aerodynamic force change rule of vehicle when a vehicle is passing out of the tunnel without lateral wind load action. Set up numerical simulation time step 0.05s to transient analysis aerodynamic characteristics of vehicle when the vehicle running out of the tunnel at speed of 80 km/h. The variations of the vehicle's three-component aerodynamic coefficients are shown in figure 2.
The overturning moment of the vehicle, lift force, lateral force coefficients are approximately 0 in the process of vehicle passing out tunnel without wind loads action. The vehicle aerodynamic coefficients small random variation shows that, vehicles are only subjected the front wind load which generate by the vehicle running in the process of free driving without wind load action. The wind load situation makes the wind pressure on the car body of front surface are large and the both sides of the surface pressure are small. So, the value 0 of vehicle's overturning moment coefficients, lateral force coefficients are accord with the actual, which at the same time also shows right feasibility of numerical simulation when the vehicle passing out tunnel.

4. Aerodynamic force characteristics variation of vehicle passing out tunnel under the wind loads

To study change rule of vehicle aerodynamic force while a vehicle is passing out of the tunnel under the action of lateral wind, set up the time step 0.05s, the speed of vehicle running out of the tunnel at 80 km/h and 100 km/h, the influenced lateral wind function speed 8 m/s and 15 m/s, to numerical simulation transient analysis and respectively study the characteristics of flow field and the vehicle body of wind pressure while vehicle driving in the tunnel, vehicle driving at tunnel exit and vehicle passing out of tunnel completely. While vehicles driving at 80 km/h speed at the same time under the wind action by the speed of 15 m/s, the change rule of the aerodynamic force coefficient of vehicle passing out of the tunnel and vehicle completely out of the tunnel are shown as followings.
While vehicles are driving in tunnel, overturning moment coefficient and lateral force coefficient of vehicle is about 0, which is in accordance with the actual also explains the correctness of the simulation program. The aerodynamic coefficient of vehicle began to increase when the vehicle running away from tunnel exit about 5m and the aerodynamic coefficient increased to maximum stable until vehicles running out of the tunnel about 15m. Aerodynamic coefficient of vehicle increasing process amount to the total mileage is 20 m.

5. Conclusions
While vehicle travels at different speeds, the three-component aerodynamic coefficient difference of vehicle is smaller, which show the Reynolds number effect of vehicle is not obvious. While vehicle travels out of tunnel at a speed of 80 km/h, three-component of the aerodynamic force coefficients of vehicle increases quickly within 0.9 s, which also suggests that aerodynamic force of vehicle increases suddenly when the vehicle running out of the tunnel. This suddenly increase of aerodynamic force is negative influence on the driver's operation and traffic safety.

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