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Aerodynamic Performance of 160km Box Car

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ABSTRACT

In order to increase the efficiency of rail transportation, the velocity of box car is increased to 160km/h. Therefore, significant changes of aerodynamic performance of boxcar are generated. The purpose of this study is to evaluate the effect of velocity increasing of box car when it runs on different high embankment under cross wind. The results of the study show that the pressure distribution on boxcar surface changed with train speed, which lead to a sharply increasing of aerodynamic forces and rolling moment of boxcar. These effects might give rise to a more dangerous vehicle operation, and should be taken into account in the design of vehicle.

1.INTRODUCTION

The aerodynamic performance of boxcar is the worst due to its shape according to previous studies include full-scale train tests, tunnel experiments and numerical simulations (Raghunathan 2002; LIANG Xi-feng 2006; Khier 2000; Baker 2004; Suzuki 2003). To improve the rail transportation capacity in China, government decided to increase the velocity of boxcar from 120km/h to 160km/h, which will cause a significant aerodynamic performance change to the boxcar. Considering most of the Chinese railroads pass through gale regions and lots of embankments exist along the railway, this study is aim to evaluate the effect brought by train velocity increasing, which is subjected to cross wind action and runs on embankment.

2.NUMERICAL MODELS, MESH AND SETUP

2.1 Numerical models

Full scale boxcar is chosen as the numerical model, which consist of one locomotive and three boxcars, every car in the model was defined respectively as locomotive, boxcar1, boxcar2, boxcar3.The structures of the windows, doors and bogies are simplified along the train’s surface, shown in Fig. 1(a). Train is running on

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embankment with different height h, which is 3m, 5m and 8m, respectively, Fig. 1(b).

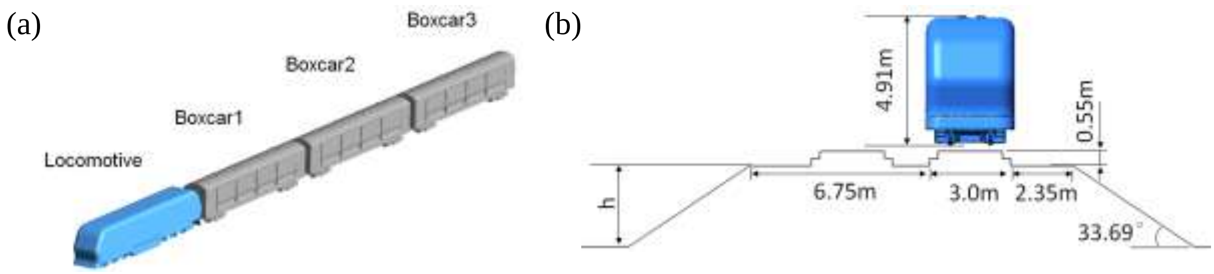

Fig. 1 Models used in numerical simulations: (a) Train model; (b) Embankment model.

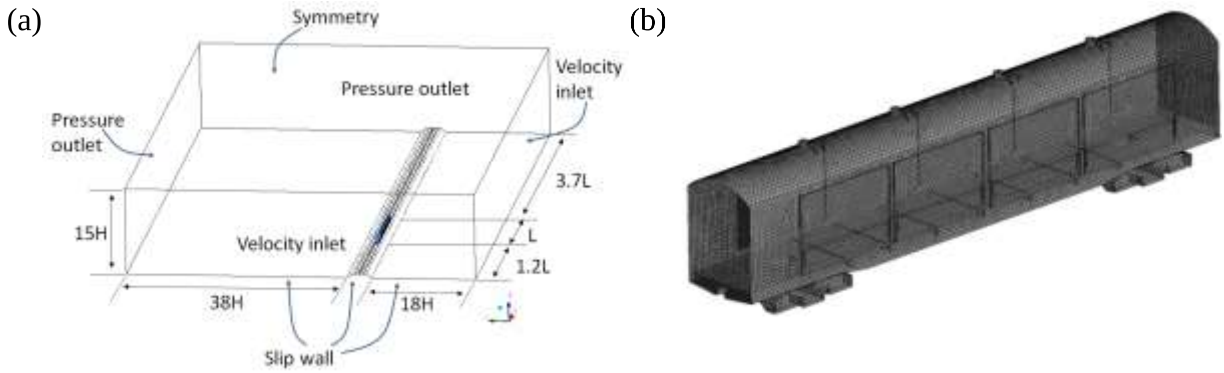

Fig. 2 Domain and mesh grid: (a) Domain size and boundary conditions; (b) Mesh grid on boxcar surface.

2.2 Computational domain and mesh

To avoid the wake flow of trains impacting the export section, the domain length should be defined to make the downstream boundary away from the train as far as possible, and the domain width should be chosen to avoid yielding the phenomenon of blocking effects(FINNEMORE 2002).

Fig. 2 (a) shows the computational domain. H and L present the height and length of train, 4.91m and 84.3m, respectively. Surfaces of the train were set as no-slip wall, the top surface of the domain were set as symmetry and the ground surfaces were set as slip boundary to reflect their relative motion to trains.

The entire calculation domain was scattered about unstructured grids, where triangular grids were for material surfaces and tetrahedral grids were for volume. The number of tetrahedral elements of the whole simulated model was about 3.7×106. Fig. 2(b) displays the body grids of a boxcar.

2.3 Setup and computational conditions

In current work, the k-ε two equations turbulent model is adopted to solve the flow field around the train. This method has been widely applied to simulations of the aerodynamic performance of trains(TIAN Hong-qi 2015; REZVANI 2014; LIU Tang-hong

2013). For numerical simulations, SIMPLEC algorithm is used for the coupling of pressure-velocity field (semi-implicit method for pressure-linked equations-consistent), and QUICK formulation is employed for the discretization of the Navier-Stokes equations.

3.RESULTS

In this work, under the cross wind speed of 35 m/s and different height of embankments, drag forces, lift forces and lateral forces of the train with different running velocity, 120km/h and 160km/h, are simulated. The locomotive usually follows numbers of boxcars, and most of boxcars have a similar condition except for the first and last one. As a consequence, the boxcar2 in Fig.1 (a) is the only one that will be analysed.

3.1Pressure and velocity distribution

It is possible to observe that the pressure distribution on the side surface of boxcar2 is asymmetrical, as Fig. 3 shows. Windward side and part area of the front of the vehicle is covered with obvious positive pressure, while top of boxcar is experiencing negative pressure due to flow separation. As the train is running, the maximum pressure position appeared in front of windward side surface. At the front of top surface, flow separation is occurred and thus the negative pressure is larger than that in the rest area.

With the height of embankment increases, the separation over the vehicle become harder and larger negative pressure is generated on the top of the vehicle. When the velocity of train increased from 120km/h to 160km/h, shown in Fig. 3, the positive pressure of the front windward area is larger, meanwhile, the protuberance(凸起物) on side surface of boxcar experience a larger pressure which can be easy found in the Fig. 3. The increased velocity also causes the bigger separation area over the vehicle and larger absolute value of negative pressure is generated.

Fig. 4 shows a comparison of speed contour lines around cross section of the boxcar2 under different height of embankment and running velocities. We can reach that the airflow around the vehicle is changing with the height of embankment, and separation over the train body can be observed. The speed of airflow over and below the vehicle increased both with the height embankment and the velocity of train.

3.2 Aerodynamic force results

The data reported in Fig.5 confirm the indisputable effect of the velocity and embankment on a train's aerodynamic behaviour. It can be seen that the drag, lift, lateral forces of boxcar2 are significant increased when the train running at a higher speed, and the absolute value of rolling moment also obviously increased. At the cross wind speed of 35 m/s, aerodynamic performances of train are affected by the height of embankment, which is agree with results in reference(Zhou Dan 2007). In particular, the difference of aerodynamic performances at different train speed is increasing with the height of embankment. This can be explained as the flow modification induced by the embankment, which lead to a obvious higher speed of airflow over the top of train and flow separation become more serious, as in Fig.4. For the 8m-high embankment, when the velocity of train increased from 120km/h to 160km/h, the drag, lift, lateral forces and rolling moment increased 67.9%, 15.6%, 12.6%, 15.8%, respectively.

Fig. 3 Pressure contours of boxcar2 : (a) 120km/h; (b) 160km/h

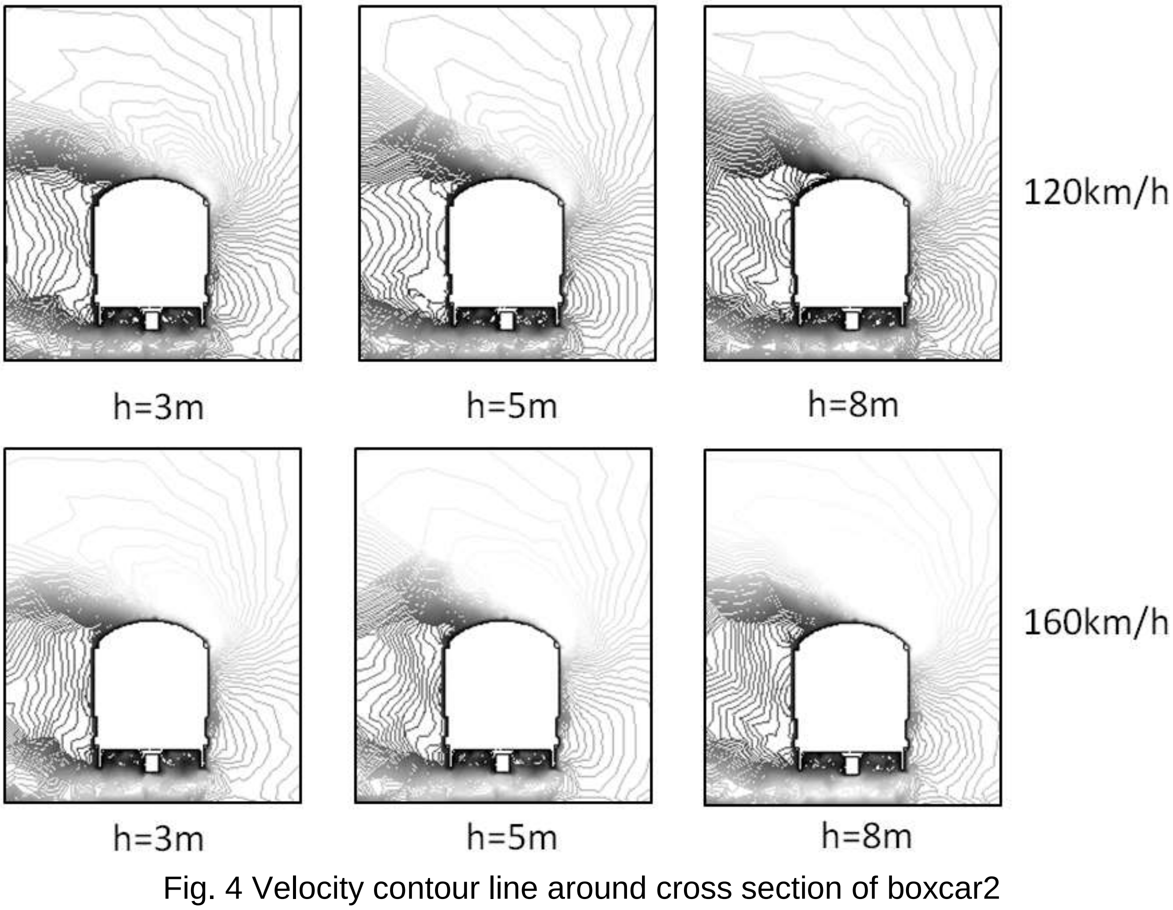

Fig. 4 Velocity contour line around cross section of boxcar2

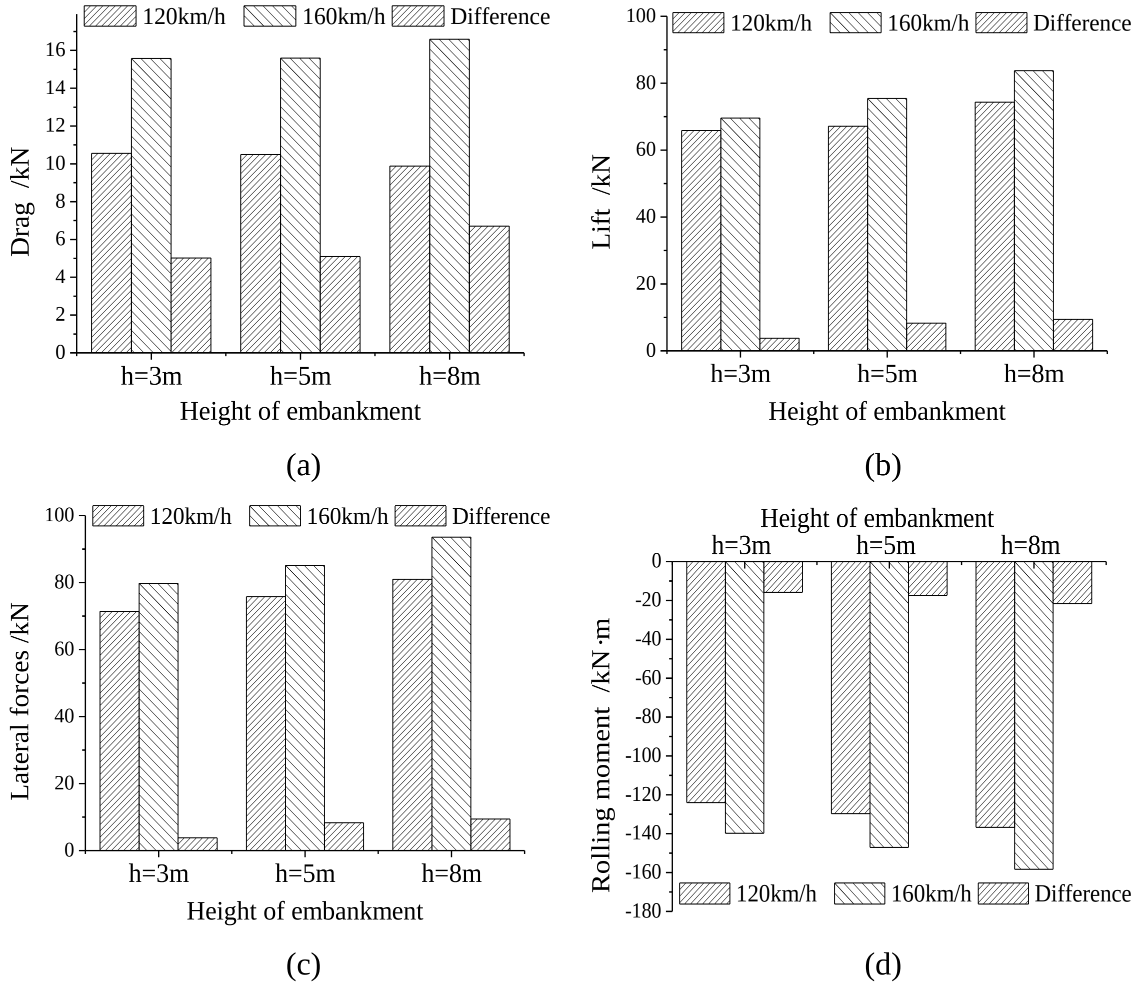

Fig.5 Aerodynamic forces and rolling moment with different velocity for boxcar2: (a) Drag force; (b) Lift force; (c)Lateral force; (d) Rolling moment.

4. CONCLUSIONS

In this study, under the 35m/s cross wind speed condition, the aerodynamic performances of boxcar running on different height embankment with the velocity of 120km/h and 160km/h are investigated using CFD.

With a higher running speed, the boxcar experiences a larger positive pressure and absolute value of negative pressure. Higher embankment contributed to the faster airflow over the top of vehicle body.

Drag, lift and lateral forces of boxcar2 are significant increased after the train accelerated to 160km/h, and thus the absolute value of rolling moment also obviously increased. The differences of aerodynamic performance of boxcar, at 120km/h and 160km/h, are increased with the height of embankment increased. For the 8m height embankment, the drag, lift, lateral forces and rolling moment increased 67.9%, 15.6%, 12.6%, 15.8%, respectively.

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