Study on safety and compatibility of controllability and stability test and square for large bus

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Abstract. The simulation model of the large bus was verified by real vehicle test, and simulation test of GB/T6323-2014 was carried out, and the safety and compatibility of the test and square were analyzed. The results show that the controllability and stability test can be completed in the square, but part of the test can only in the diagonal region. The lateral acceleration should be controlled within 0.6g for safety.

Introduction

At present, the test method has been developed for controllability and stability at home and abroad. From the beginning of the last century, the United States Automobile Engineering Association (SAE)[1], the Japanese Automobile Industry Association (JASO)[2-7]and the international standard organization ISO[8-16], have been developed and implemented a series of standards for vehicle controllability and stability. China from its national conditions, with reference to foreign standards, from the last century 80's began to develop and improve the relevant test standards [17-21]. At present, there are many test methods for controllability and stability, mainly including step test, angle pulse test, sine input test, returnability test, pylon course slalom test, lane change test and steady circle test.

GB/T6323-2014 is the main basis for vehicle controllability and stability test, and the following simulation test is based on the standard. A square of 330m*330m has been built, safety and compatibility of controllability and stability test and the square for large bus is studied.

Establishment and validation for simulation model

A simulation model was established with two axis (Tour Bus 5.5T/10T). The model parameters are shown in Table 1.

Table 1. Parameters of simulation model

Physical meaning	Value
Length*Width*Height[mm]	9380*2500*3500
Wheelbase L[mm]	4500
Tread B[mm]	2020/1800
Sprung mass M/ kg	8120
Distance from centroid to front axle L_1[mm]	3238.2
Centroid height h/[mm]	1200
Rotary inertia around X axis I_{xx}[kg/m^2]	9825.2
Rotary inertia around Y axis I_{yy}[kg/m^2]	39300.8
Rotary inertia around Z axis I_{zz}[kg/m^2]	39300.8

As shown in Table 2, the simulation test was carried out and compared with the real vehicle test. The steady-state steering test was carried out at the speed of 30km/h and turning radius of 20m.

From Table 2 we can see that the relative error between roll angle and lateral acceleration is not more than 1%, which proves the scientific and accuracy of the model. The speed control of real vehicle test is not stable, which influences on the relative error.

Table 2. Comparison of simulation with real vehicle test

Steady-state steering	Real vehicle	Simulation	Relative error
Roll angel d [*deg]*	2.150	2.144	0.28%
Lateral acceleration $a_y[g]$	0.353	0.350	0.85%

Simulation and analysis

Steady static circular test of closed loop. The vehicle accelerates from 0 to 100km/h with 50s. The radius is 30m. At the time of 26s, vehicle speed reaches 50km/h, and left rear tire is off the ground with the lateral acceleration of 0.6g, as shown in Fig. 1. The velocity of real vehicle test should not be higher than 50km/h, and the lateral acceleration should not be beyond 0.6g. As shown in Fig. 2, the test field should not be less than 65m*65m.

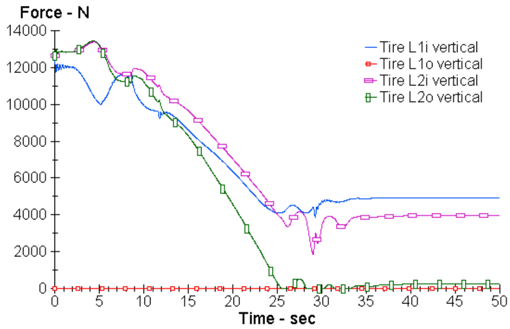


Fig. 1 Vertical forces of left tires of steady static circular test of closed loop

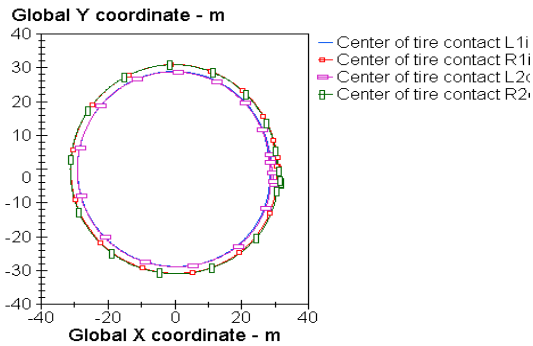


Fig.2 Center of tire contact of steady static circular test of closed loop

Steady static circular test of open loop. The vehicle accelerates from 0 to 90km/h with 100s. The radius is 30m, and steering wheel angle is 218.2°. At the time of 61s, vehicle speed reaches 55km/h, and left rear tire is off the ground, as shown in figure 1. The velocity of real vehicle test should not be higher than 55km/h. As shown in Fig. 3, the test field should not be less than 75m*75m.

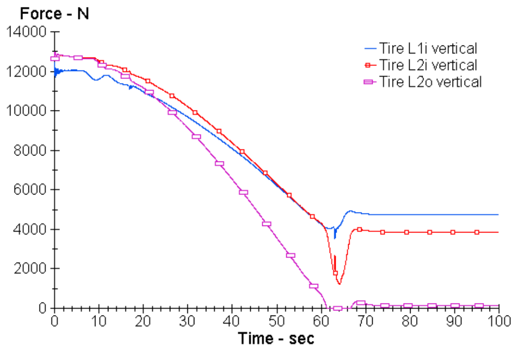


Fig. 3 Vertical forces of left tires of steady static circular test of open loop

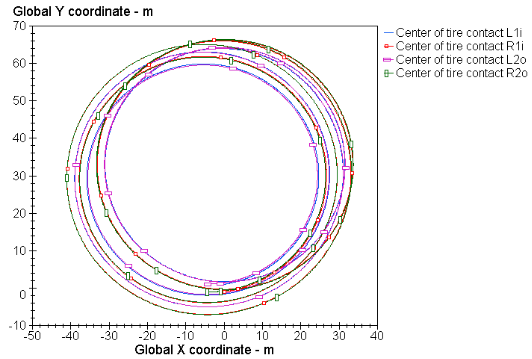
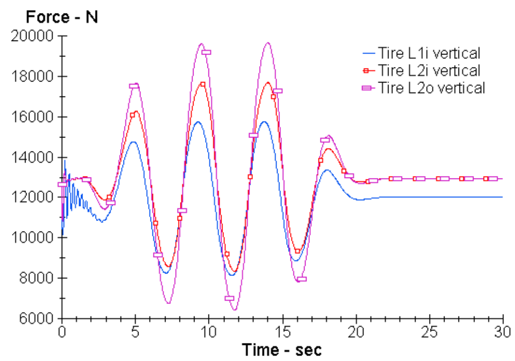


Fig.4 Center of tire contact of steady static circular test of open loop

Pylon course slalom test. The speed is set to 80km/h. As shown in Fig. 5, both sides of tire vertical forces were not zero, indicating no rollover risk. As shown in Fig. 6, the test field should not less than 350m*4m without the accelerating and braking distance, only the square diagonal meets it.

Steering transient response test (Steering wheel angle step input). The steering wheel angle are respectively 28.5°, 37.5°, 47.25°, 56.25°and 66° with the lateral acceleration of 1.0m/s2, 1.5m/s2, 2.0m/s2, 2.5m/s2, 3.0m/s2. Set the simulation speed 80km/h and steering wheel 28.5° and 66 ° respectively. As shown in Fig. 7 and Fig. 8, test field should not be less than 140m *25m. Test is safe with the lateral acceleration less than 3.0m/s2.



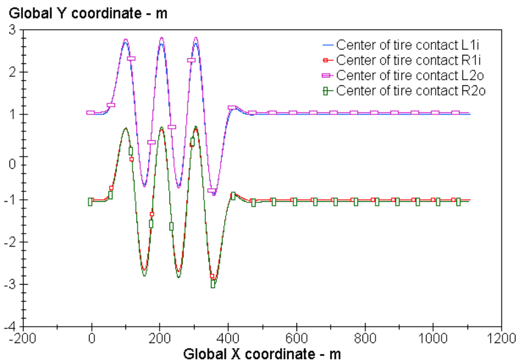
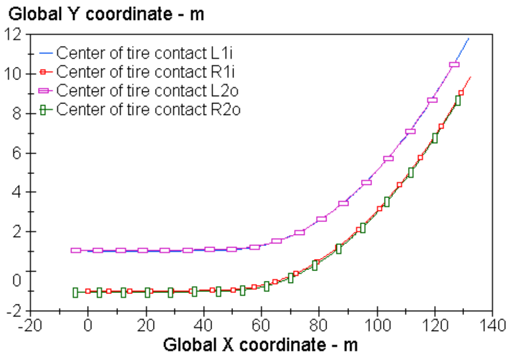


Fig. 5 Vertical forces of left tires of pylon course slalom test

Fig.6 Center of tire contact of pylon course slalom test



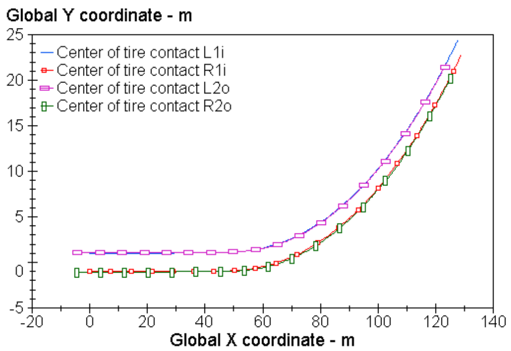
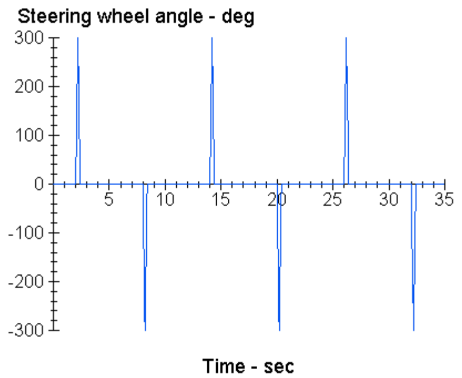


Fig.7 Center of tire contact of steering wheel angle step input with 28.5°

Fig.8 Center of tire contact of steering wheel angle step input with 66°

Steering transient response test (steering wheel angle pulse input). Test speed is 80km/h, and steering wheel angle is 300°, and the period is 0.4s.The maximum lateral acceleration reaches 4m/s2, which meets the standard requirements. Turn the steering wheel right and left three times respectively, and the time interval of each input must not be less than 5s, as shown in Fig. 9. As shown in Fig. 10, the two consecutive trials needs at least 500m*45m, so pulse test can only be carried out 1 cycle at a time.



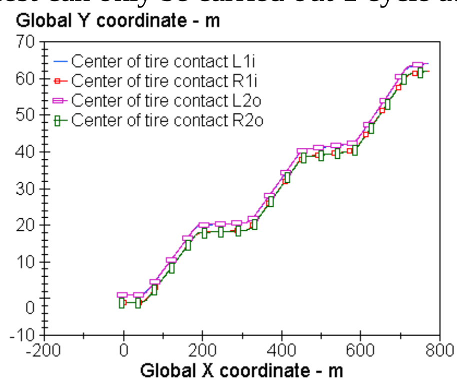
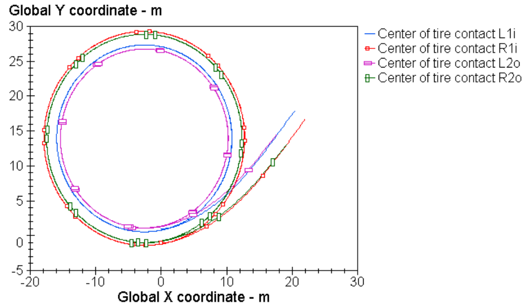


Fig.9 Steering wheel angle of pulse input

Fig.10 Center of tire contact of of pulse input

Returnability test with low speed. The radius is 15m; the lateral acceleration reaches 4m/s2; the vehicle speed is 27km/h; the steering wheel angle is 481.3□. Record vehicle movement process of release 4s at least. Fig. 11 shows that the field can only be 50m*35m. Vehicle is rollover at the speed of 40km/h in this test.

Returnability test with high speed. The speed is set to 80. According to the lateral acceleration of 2.0m/s2, the steering wheel angle is 47.25□. Fig. 12 shows that the area is at least 120m*20m.



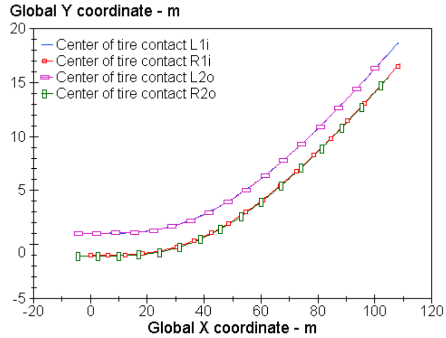


Fig.11 Center of tire contact of returnability test with low speed

Fig.12 Center of tire contact of returnability test with high speed

Steering efforts test. The velocity is 10km/h. This test is relatively safe with low speed. As shown in Fig. 13, the test space is about 60m*25m, which is related with the vehicle parameters such as wheelbase and angle of lock.

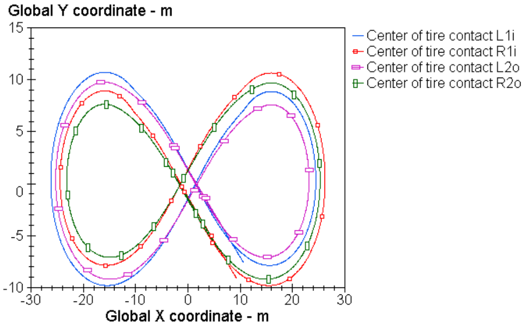
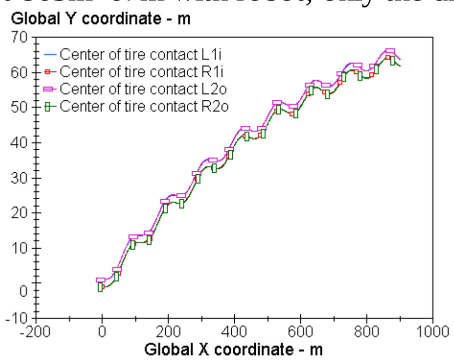


Fig.13 Center of tire contact of steering efforts test

Steering wheel center position test. The test speed is 80 km/h and the lateral acceleration peak is not more than 4 m/s2. The test should be at least 40s with manual input, to ensure that at least 8 input cycles. Data records should be above 1s after the end of the experiment. Therefore, at least 41s of the test should be carried out. Fig. 14 shows that the space is at least 865m*67m. The built square cannot meet the requirements, and a series of short data are combined for testing analysis with at least 20 cycles of data. The test is carried out at least 20s with robot, in order to ensure that at least 4 cycles is obtained, plus 1s after the end of the test, so the tests were carried 21s. Fig. 15 shows that the space is at least 865m*67m with robot, only the diagonal of built square meets the requirement.



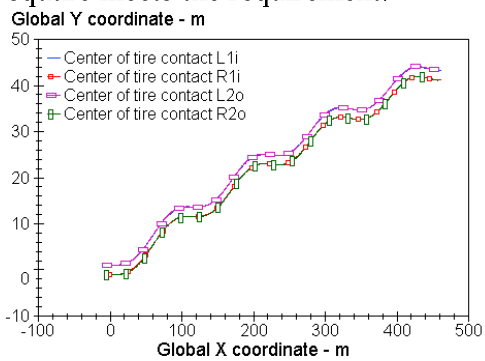


Fig.14 Center of tire contact of steering wheel center position test with manpower

Fig.15 Center of tire contact of steering wheel center position test with robot

Conclusions

In order to avoid vehicle rollover, the lateral acceleration of vehicle should be less than 0.6g controlling the steering angle and frequency and vehicle velocity. The controllability and stability test of GB/T6323-2014 can be completed in the built square, but some tests can only be done in the diagonal region, so the square utilization is not high.

Acknowledgements

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