IOP Conf. Series: Materials Science and Engineering **324** (2018) 012071 doi:10.1088/1757-899X/324/1/012071

Analysis of Flexible Car Body of Straddle Monorail Vehicle

Zhong Yuanmu

CRRC QINGDAO SIFANG CO.,LTD., 88 jinhong east road, Qingdao, Shandong, 201804, China

zhongyuanmu@cqsf.com

Abstract. Based on the finite element model of straddle monorail vehicle, a rigid-flexible coupling dynamic model considering vehicle body's flexibility is established. The influence of vertical stiffness and vertical damping of the running wheel on the modal parameters of the car body is analyzed. The effect of flexible car body on modal parameters and vehicle ride quality is also studied. The results show that when the vertical stiffness of running wheel is less than 1 MN / m, the car body bounce and pitch frequency increase with the increasing of the vertical stiffness of the running wheel, when the running wheel vertical stiffness is 1MN / m or more, car body bounce and pitch frequency remained unchanged; When the vertical stiffness of the running wheel is below 1.8 MN / m, the vehicle body bounce and pitch damping ratio increase with the increasing of the vertical stiffness of the running wheel; When the running wheel vertical stiffness is 1.8MN / m or more, the car body bounce and pitch damping ratio remained unchanged; The running wheel vertical damping on the car body bounce and pitch frequency has no effect; Car body bounce and pitch damping ratio increase with the increasing of the vertical damping of the running wheel. The flexibility of the car body has no effect on the modal parameters of the car, which will improve the vehicle ride quality index.

1. Introduction

The straddle-type monorail vehicle is welcomed by all countries in the world because of its large capacity, safety, quickness, low noise, low pollution, less land occupation and adaptation to the large ramp. Ren Lihui[1] established a straddle-type monorail vehicle dynamics model, compiled a graphical simulation program, and the response characteristics of the straddle-type monorail vehicle passing through the curve and the joint of the track beam are simulated. Du zixue[2] analyzed the impact on vehicle passing performance by changing the vertical stiffness of running wheel. Urban rail vehicle body lightweight design led to lower car body stiffness, the problems caused by the flexible vibration of the car body can not be ignored. Therefore, thinking of the car body as an elastomer is closer to reality. Zhou Jinsong[3] adopted the modal superposition method to regard the flexible car body as the Euler beam to study the impact of vehicle body flexibility on vehicle ride quality, and installed in the car body dynamic vibration absorber to inhibit the car body flexible vibration. Based on the finite element analysis and multi-body dynamics simulation, a rigid-flexible coupled dynamic model of straddle-type vehicle with body flexibility is established in this paper. The influence of the flexible car body on the modal parameters of the car body and the power spectrum of the acceleration response is studied and analyzed, and its influence on the ride quality of the vehicle is analyzed.

2. Modelling

In this paper, combined with finite element analysis and multi-body dynamics simulation, a rigid-flexible coupled dynamic model of straddle monorail vehicle is established as shown in Fig.1. Flexible car body file contains the structure of the model and modal information.

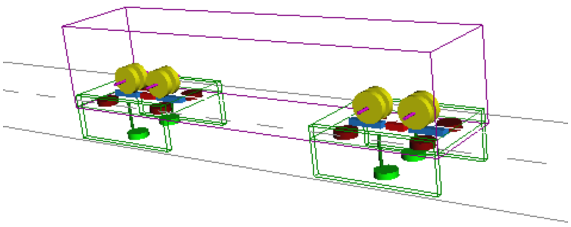

Figure 1. Rigid-flexible Coupling Dynamics Simulation Model

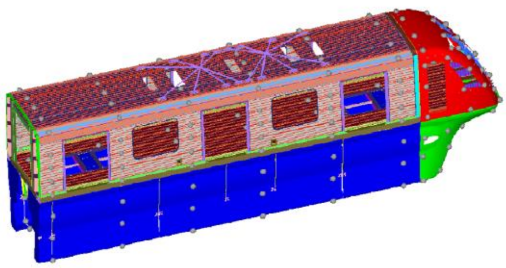

Figure 2. Car body Finite Element Model with Node Set

In the finite element model, a set of points that can describe the contour of the car body is established as shown in Fig.2. Then, the flexible car body file is imported into the established rigid car body model to replace the initial car body, and the relevant parameters are modified to obtain the complete rigid-flexible coupling model. The analysis of the coupling between rigid car body and flexible car body is helpful for further study on the influence of structure flexibility on vehicle dynamic performance.

3. Modal parameter analysis

Table 1 shows the comparison of the modal parameters of rigid car body and rigid-flexible car body of straddle monorail vehicle. As can be seen from the table, under the original parameters, the rigid car body and rigid-flexible coupling car body modal parameters has a little difference. But basically the same. The bounce frequency of the vehicle body is about 1Hz, damping ratio is about 18%; Pitch frequency is about 1.5Hz, damping ratio is about 23%. Modal parameters in a reasonable range.

Table 1. Modal parameters of the vehicle

Mode	Rigid car body		Rigid and flexible coupling car body	
	Natural frequency Hz	Damping ratio %	Natural frequency Hz	Damping ratio %
Car body bounce	1.149	18.1	1.150	17.8
Car body pitch	1.602	23.3	1.607	23.2
Frame bounce	3.328	16.5	3.368	16.6
Frame pitch	3.196	11.3	3.198	11.3
Car body yaw	1.234	8.3	1.207	7.9
Car body lower sway	1.283	16.3	1.276	15.8

3.1. The influence of the running wheel vertical stiffness on the modal parameters

By changing the vertical stiffness of the running wheel, the car body modal parameters can be calculated. Fig.3 shows the results of the frequency of the car body bounce and pitch. With all other parameters remaining the same, when the vertical stiffness of running wheel is less than 1 MN / m, the car body bounce and pitch frequency increase with the increasing of the vertical stiffness of the running wheel, when the running wheel vertical stiffness is 1MN / m or more, car body bounce and pitch frequency remained unchanged. Fig.4 shows the results of the damping ratio of the car body bounce and pitch. When the vertical stiffness of the running wheel is below 1.8 MN / m, the vehicle body bounce and pitch damping ratio increase with the increasing of the vertical rigidity of the running wheel; When the running wheel vertical stiffness is 1.8MN / m or more, the car body bounce and pitch damping remained unchanged.

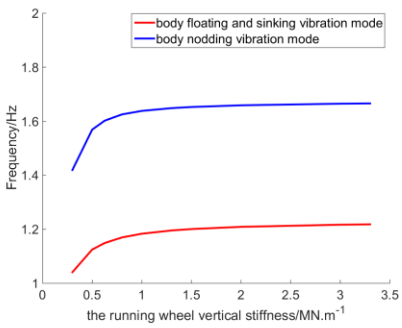

Figure 3. Modal Frequency of Car Body

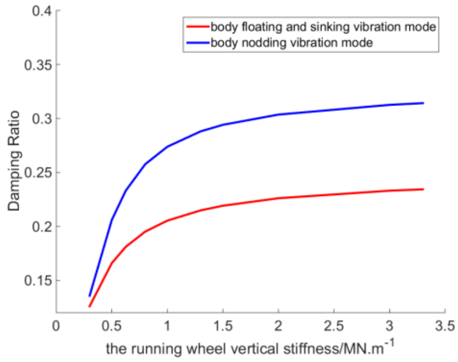

Figure 4. Modal damping Ratio of Car Body

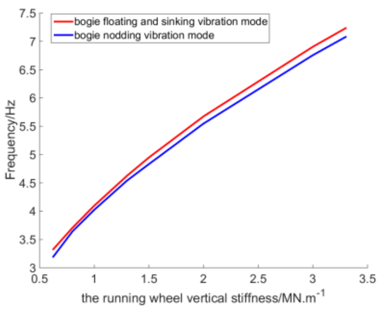

Figure 5. Modal Frequency of bogie

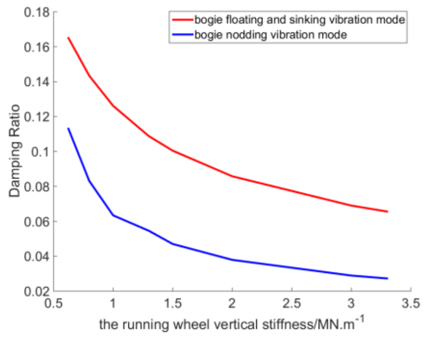

Figure 6. Modal damping Ratio of bogie

Fig.5 shows the results of the frequency of the bogie bounce and pitch. Bogie bounce and pitch frequency increase with the increasing of the vertical damping of the running wheel. The growth trend is almost linear. Fig.6 shows the results of the damping ratio of the bogie bounce and pitch. The bogie pitch and bounce frequency decrease with the increasing of the damping coefficient of the running wheel.

3.2. The influence of the running wheel vertical damping on the modal parameters

The vertical damping of the running wheel also has a certain impact on the modal parameters of the vehicle. Fig.7 shows the results of the frequency of the body bounce and pitch. The running wheel vertical damping on the car body bounce and pitch frequency has no effect. Fig.8 shows the results of the damping ratio of the car body bounce and pitch. Car body bounce and pitch damping ratio increase with the increasing of the vertical damping of the running wheel. The growth trend is almost linear.

IOP Conf. Series: Materials Science and Engineering **324** (2018) 012071 doi:10.1088/1757-899X/324/1/012071

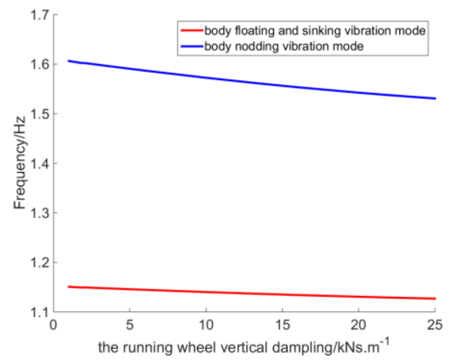

Figure 7. Modal Frequency of Car Body

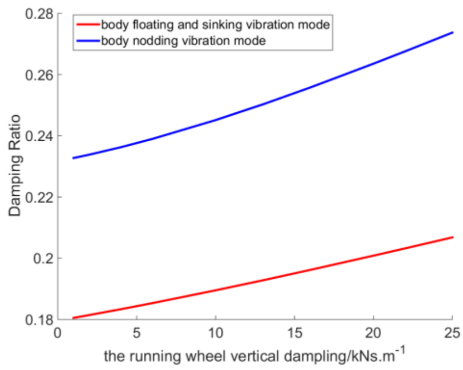

Figure 8. Modal damping Ratio of Car Body

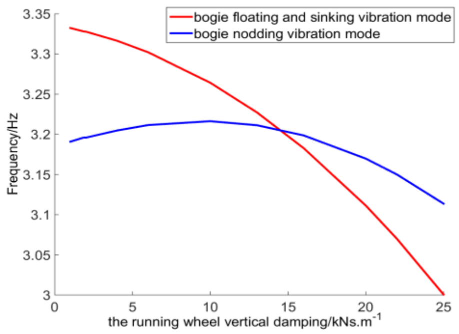

Figure 9. Modal Frequency of bogie

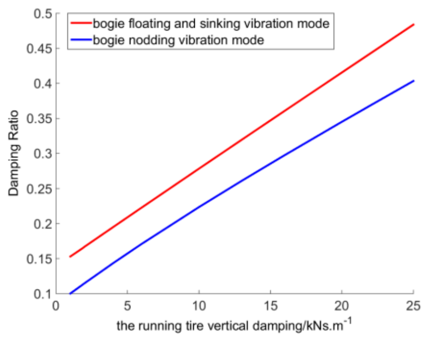

Figure 10. Modal damping Ratio of bogie

Fig.9 shows the results of the frequency of the bogie bounce and pitch. The bogie pitch and bounce frequency decrease with the increasing of the damping coefficient of the running wheel. When the vertical damping coefficient of the running wheel reaches 14 kNs/m, the frequency of the bogie bounce and pitch is equal to 3.2Hz. Fig.10 shows the results of the damping ratio of the bogie bounce and pitch. Bogie bounce and pitch damping ratio increase with the increasing of the vertical damping of the running wheel. The growth trend is almost linear.

4. Vehicle running quality analysis

Based on the rigid car body dynamics model and the rigid-flexible coupling dynamics model of the straddle monorail vehicle established above. The effects of different operating speeds on the ride quality of rigid car body and flexible car body are calculated respectively. Fig.11-13 shows the ride quality of rigid car body and flexible car body as a function of speed. We can see from the figure, rigid car body and flexible car body ride quality trend is about the same. And flexible car body quality index is slightly higher than rigid car body. In the 65-80km/h speed range, rigid car body and flexible car body quality index no more than 2.2. Passenger ride comfort will not be affected at this time.

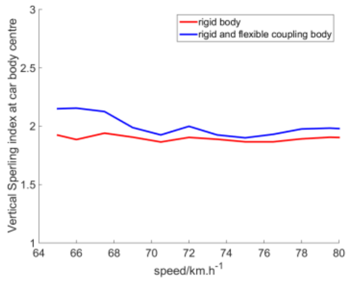

Figure 11. Ride quality at front of the car body

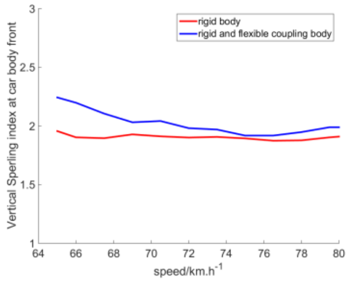

Figure 12. Ride quality at center of the car body

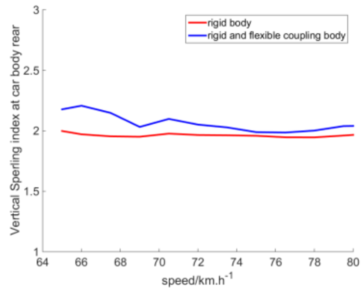

Figure 13. Ride quality at rear of the car body

5. Conclusion

Based on the finite element model of straddle monorail vehicle, a rigid-flexible coupling dynamic model considering vehicle car body's flexibility is established. When the vertical stiffness of running wheel is less than 1 MN/m, the vertical stiffness of the running wheel has a great influence on the modal parameters of the car body, and the car body bounce and pitch frequency increase with the increasing of the vertical stiffness of the running wheel. when the running wheel vertical stiffness is 1MN/m or more, car body bounce and pitch frequency remained unchanged; When the vertical stiffness of the running wheel is below 1.8 MN / m, the vertical stiffness of the running wheel has a great influence on the damping ratio of the car body, and the vehicle body bounce and pitch damping ratio increase with the increasing of the vertical rigidity of the running wheel. When the running wheel vertical stiffness is 1.8MN / m or more, the car body bounce and pitch damping ratio remained unchanged. The running wheel vertical damping on the car body bounce and pitch frequency has no effect; Car body bounce and pitch damping ratio increase with the increasing of the vertical damping of the running wheel. The flexibility of the car body has no effect on the modal parameters of the car, which will improve the vehicle ride quality index. In the 65-80km / h speed range, rigid car body and flexible car body quality index no more than 2.2. Passenger ride comfort will not be affected at this time.

References

[1] Ren L, Zhou J, Shen G. Dynamics Model and Simulation Study of a Straddle Type Monorail Car 2004 *China Railway Science*. 25(5), 26-32.
[2] Ren L, Zhou J, Shen G, Liu S. Hunting Stability of Straddle-type Monorail Car Based on Equation Eigenvalue 2003 *Journal of Tongji University*. 31(4): 469-472.
[3] Du Z, Zuo C. Impact of Running Wheel's Vertical Stiffness on Curve Negotiation Performance of Straddle-type Monorail Vehicle 2013 *Electric Drive For Locomotives*. (03), 40-42.
[4] Gong D, Zhou J, Sun W. Influence of under-chassis-suspended equipment on high-speed EMU trains and the design of suspension parameters 2016 *Proceedings of the Institution of Mechanical Engineers Part F Journal of Rail & Rapid Transit*. 230(8).
[5] Wang F, Zhou J, Ren L. Analysis on track spectrum density for dynamic simulations of high-speed vehicles 2002 *Journal of the China Railway Society*. 24(5), 21-27.