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Eccentric Load on Vehicle Dynamics Performance based on Refinement Modeling

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Abstract

The finite element models of the load-bearing structure and the curb state of the metro vehicle body were established respectively, and the effects of different elements, mesh sizes and five curb car body modeling methods on the modal calculation results of the car body were studied. The vehicle system dynamics model is established by polycondensation of the finite element model, and the influence of the eccentric load of the vehicle body on the vehicle dynamic performance index is calculated and analyzed. The results show that: 25mm quadrilateral element mesh is used to divide the finite element model of the car body, which can meet the needs of the car body for modal calculation; the mass point-equipment frame-hanging method is used to simulate the frame-type box structure of the under-vehicle equipment with a skeleton, which can increase the rigidity of the connection between the equipment and the chassis, thereby increasing the modal frequency of the vehicle body. Compared with the lateral eccentric load, the longitudinal direction has a greater impact on the lateral and vertical running stability. After the longitudinal eccentric load occurs, the vertical stability index of the load-reducing end bogie will increase, resulting in poor running stability.

Keywords: subway vehicle, finite element model, modal analysis, eccentric load, vehicle dynamics

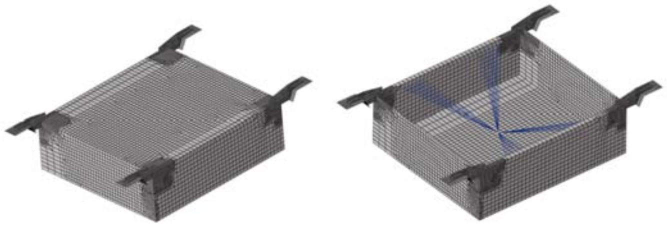
1 Introduction

Computational modal analysis is an important basis for rail vehicle dynamics and structural design [1-2]. The accuracy of the modal analysis depends on the finite element model modeling method. J Lu [3] uses two different element types solid45 and solid63 to establish a finite element model of a typical part of an aluminum alloy subway car body, compares the static and dynamic calculation results of the two models under the same boundary conditions and loads. Mao-ru, CHI [4] studied the influence of eccentric load on vehicle stability, and found that with the increase of eccentric load, the stability of the vehicle gradually deteriorated, and longitudinal eccentric load will cause a large gap in the stability of the front and rear . XIA, Zhanghui et al. [5] established a refined rigid-flexible coupling dynamic model of high-speed EMUs including car body elasticity and under chassis equipment, studied the influence and mechanism of under chassis equipment eccentricity on the vibration performance of the vehicle. The vibration of the six-direction degrees of freedom of the under-chassis equipment is coupled, resulting in a large change in the rigid body mode and frequency of each order, and the vibration reduction effect of the equipment under the vehicle is reduced the running stability of the vehicle is deteriorated. At present, there are few reports on the influence of vehicle eccentric load on vehicle dynamic performance based on refined modelling.

2 Methods

Taking the subway vehicle body as the research object, this paper studies the influence of triangular and quadrilateral elements, different mesh sizes, and the modeling method of the vehicle body on the modal calculation results, provides a basis for the modal refinement research of rail vehicles. The element size is set to 15mm, 25mm, 35mm, and 45mm for four groups.

After the finite element model of the vehicle body load-bearing structure is established, it is necessary to establish a finite element model of the complete structure, that is, add auxiliary equipment on the basis of the vehicle body load-bearing structure. The loading method of these equipment will also affect the overall stiffness and mass matrix of the structure, and then affects the modal calculation results of the car body. To this end, this paper proposes the following five vehicle body model modeling methods in the curb state to explore the influence of different methods on the modal calculation results of the vehicle body, including: equivalent density method, mass point method, mass point-hanging method, cube-hanging method, mass point-equipment frame-hanging method. Figure 1 and Figure 2 shows the model and installation diagram of the equipment under the vehicle in the mass point-equipment frame-hanging method.



(a) Equipment shape. (b) Equipment hides the upper panel.

Figure 1: Under chassis equipment model.

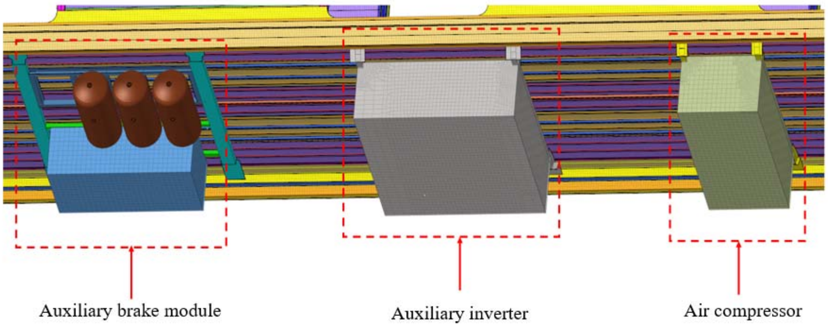


Figure 2: Installation of equipment under the vehicle.

Based on the finite element model, polycondensation is performed to establish the vehicle system dynamics model, and the influence of the eccentric load of the vehicle body on the vehicle dynamic performance indicators is analyzed. Calculate and analyze the influence of eccentric vehicle body load on vehicle critical speed, axle lateral force, derailment coefficient, wheel load reduction rate and running stability index. It provides a theoretical basis for the vehicle body eccentric load control and the formulation of related specifications.

3 Results

The modal analysis frequency comparison of different methods is shown in Figure 3. It can be seen from the results that the modal frequency of each order of the finite element model of the vehicle body established by the cube - hanging method and the mass point - equipment frame - hanging method has been greatly changed compared with the other methods.

Taking the first-order vertical bending mode as an example, the equivalent density method, the mass point method, and the mass point - hanging method are used for modelling, and the modal frequencies are basically the same. The modal frequency obtained by the mass point - equipment frame - hanging method is higher than the other four methods, indicating that this method will increase the vertical stiffness of the car body. Taking the first-order diamond mode shape as an example, the equivalent density method and the mass point method are used for modeling, and the obtained modal frequencies are basically the same. The modal frequency results obtained by the suspension method are higher than those obtained by the equivalent density method and the mass point method, indicating that the suspension method will increase the lateral stiffness of the vehicle body underframe. In general, the mass point

- equipment frame - hanging method simulates the frame-type box structure with the skeleton of the under-chassis equipment. Improved and closer to real vehicle conditions.

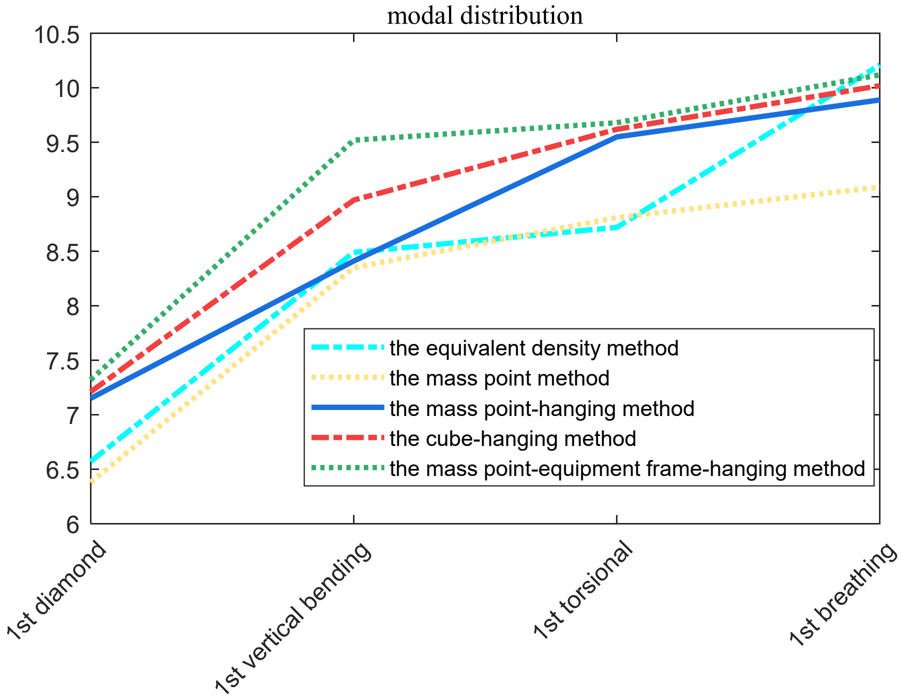


Figure 3: Modal distribution.

The lateral eccentric load has little effect on the critical speed, while the longitudinal eccentric load, the longitudinal and transverse eccentric loads in the same direction, and the two reverse eccentric loads all have an impact on the critical speed. The lateral eccentric load of the car body will slightly affect the lateral force of the axle; the longitudinal eccentric load of the car body and the lateral eccentric load have a great influence on the derailment coefficient. , and as the center of gravity moves horizontally to the right, the derailment coefficient gradually increases; with the increase of the longitudinal eccentric load and lateral eccentric load of the car body, the wheel load reduction rate generally tends to increase gradually.

4 Conclusions and Contributions

Using triangular and quadrilateral elements, dividing the finite element model of the vehicle has little effect on the modal calculation results. It is recommended to use quadrilateral elements for modeling; using four groups of 15mm, 25mm, 35mm, and 45mm to divide the finite element model of the vehicle with different mesh sizes. The modal frequency shows a trend of increasing first and then decreasing. To comprehensively balance the fineness of the model, the amount of modeling and the calculation efficiency, it is recommended to use a 25mm mesh size to divide the finite element model, which can meet the needs of modal analysis. Equivalent density method and mass point method are used for modeling, ignoring the influence of equipment position and mass distribution; using cube-hanging method for modeling, which increases the difficulty of modeling and ignores the influence of equipment eccentricity; adopts mass point-equipment frame-Suspension method modeling, considering the position of the center of gravity of the equipment, and simulating the frame-type box structure with the skeleton of the equipment under the vehicle, which can increase the rigidity of the connection between the equipment and the underframe of the vehicle body, thereby increasing the modal frequency of the vehicle body , which is closer to the real vehicle situation.

The lateral eccentric load has little effect on the critical speed in the range of [-0.15m, 0.15m], while the longitudinal eccentric load has an effect on the critical speed, and the critical speed gradually increases as the center of gravity of the vehicle moves forward. Longitudinal eccentric load has a greater impact on the modal frequency of the vehicle body, which in turn has a greater impact on the lateral and vertical running stability of the vehicle.

Acknowledgements

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