Effect of Bogie’s Quadrangular Height Difference on the Operation Safety of a Railway Passenger Coach

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Abstract: In order to study the influence of quadrangular height difference of the bogie on the operation safety of a 25T railway passenger coach, a multi-rigid-body dynamical model is built. In numerical simulations, the quadrangular height difference of a twisted type, a pitch type and a roll type are investigated, respectively. It shows that the quadrangular height difference has a negative effect on the operation safety, namely the derailment coefficient and the wheel unloading rate. It is found that the twist type affects most, followed by the roll type and the pitch type in turn. When the quadrangular height difference increases, the derailment coefficient and the wheel unloading rate increase. When the quadrangular height difference reaches up to 12 mm, the vehicle can be operated safely at 160 km/h on tangent track and at 90 km/h on a curve with a radius of 500 m as well as passing through a twisted track at a quite low speed.

1. Introduction

Safety problem is an eternal problem in railway transportation. Bogie is an important security component of railway vehicles, which needs to transform vehicles’ traction and bear all kinds of impulsive loads during the operation process of railway vehicles. The bogie of 25T passenger cars is a CW-200k series bogie, which is a welded structure composed of beams, carlings, side beams and all kinds of lifting sockets. During the welding process, the internal stress will cause the welding deformation and then form a quadrangular height difference [1-2]. By improving the welding sequence and craft, it can help to reduce the quadrangular height difference effectively [3]. It is known that the wheel wear evolution and related vehicle dynamics of a railway vehicle with an operating distance of around can be numerically predicted and measured through a long-term experimental test, the vehicle dynamics change a lot with the wheel wear [4]. While there exists little research on the influence of bogie’s quadrangular height difference on the operation safety of the vehicle, which occurs often during the assembling of a vehicle.

Therefore, this paper takes a 25T railway passenger coach as an example, a multi-rigid-body dynamical model is built, the quadrangular height difference of bogies is divided into three types, which are twist type, pitch type and roll type, and the influence of different types of quadrangular height difference on the operation safety of vehicle are analyzed comparatively. The derailment coefficient and wheel unloading rate are evaluated.
2. The quadrangular height difference
The basic feature of the ideally standard bogie (intangible deviation) is that the four angle heights on the left and right sides of the rear and front axle stands are equal. If the height on the left side of the front axle stand is not equal to the other three heights, the quadrangular height difference is called twisted type. If the heights on the left and right sides of the front axle stand are not equal to those of the rear axle stand, the quadrangular height difference is called pitch type. If the heights on the left side of the front and rear axle stands are not equal to those on the right side of the front and rear axle stands, the quadrangular height difference is called roll type. Take the quadrangular height difference in Figure 1 as an example to present a simulation analysis on the bogie.

Figure 1. Schematic diagram of different types of quadrangular height difference

3. The dynamical model of vehicle
The dynamical model of a 25T passenger car is established, where the nonlinear wheel-rail contact geometrical relationship, the wheel-rail interaction force and the suspension parameter are considered. The car body, bogie and wheelset all have 6 degrees of freedom corresponding to the movements along the three shifting directions (longitudinal, lateral and vertical) and the rotations around these axes (rolling, pitching and yawing). The tumble (axle box) has one degree of freedom corresponding to the pitch movement. Therefore, the vehicle system has 50 degrees of freedom in total.

The dynamical equation of the vehicle system is:

\[ M\ddot{x} + C\dot{x} + Kx = P(\dot{x}, \ddot{x}, x) + Te \]  

4. Influence of the quadrangular height difference on the operation safety
The vehicle operation safety is an evaluation of vehicle operation security. Currently, the evaluation index used widely is the derailment coefficient, the wheel unloading rate and so on. The derailment coefficient is evaluated according to the UIC518 standard and the wheel unloading rate is evaluated according to the GB/T5599-1985 standard.

The quadrangular height difference of a twisted type, a pitch type and a roll type are considered separately, and the calculated height deviations are 0 mm, 4 mm, 8 mm and 12 mm respectively. The vehicles run on a straight line, a curved line and a twisted line at different speeds, where the track’s random irregular excitation is considered. The wheel-rail force in each condition is extracted and the corresponding operation safety index can be obtained according to the relevant standards.

4.1 Twisted type
In the operating condition on a straight line, where the vehicle operates at a speed of 80km/h-160km/h, the influence of the twisted quadrangular height difference on the vehicle operation safety is showed in Figure 2. It can be seen that the higher the speed is, the greater the influence of the twisted quadrangular height difference on the derailment coefficient is, and the greater the influence of the quadrangular height difference is, the larger the derailment coefficient is. However, the influence will
be smaller and the derailment coefficient is less than 0.8; the wheel unloading rate increases with the
twisted quadrangular height difference, which is less than 0.6.

In Figure 3, it shows the influence of the twisted quadrangular height difference on the vehicle
operation safety, when the vehicle operates on a curved line with a radius of 500m. It can be seen that
with the increase of the quadrangular height difference, the derailment coefficient and the wheel
unloading rate will increase, where the derailment coefficient is less than 0.8 and the wheel unloading
rate is less than 0.6.

The calculation result in the operating condition on a twisted line is shown in Figure 4. From
Figure 4, with the increase of the quadrangular height difference, the derailment coefficient and the
wheel unloading rate will increase, where the derailment coefficient is less than 1.2 (Note: under the
operating condition on a twisted line, the limit of the derailment coefficient is 1.2) and the wheel
unloading rate is less than 0.6.
4.2 Pitch type

In the operating condition on a straight line, the vehicle operates at a speed of 80 – 160 km/h, the influence of the quadrangular height difference of pitch type on the vehicle operation safety is showed in Figure.5. From Figure.5, the quadrangular height difference of pitch type has little effect on the derailment coefficient and the wheel unloading rate.

Figure.6 shows the operating condition on a curved line with a radius of 500 m. It can be seen that the quadrangular height difference of pitch type has little effect on the derailment coefficient and the wheel unloading rate.

The calculation result in the operating condition on a twisted line is shown in Figure.7. From Figure.7, with the increase of the quadrangular height difference, the derailment coefficient will increase, where the derailment coefficient is less than 1.2 (Note: in the operating condition on a twisted line, the limit of the derailment coefficient is 1.2), and the quadrangular height difference of pitch type has little effect on the wheel unloading rate.

![Figure 5. Pitch type on a straight track](image1)

![Figure 6. Pitch type on a curved track](image2)

![Figure 7. Pitch type on a twisted track](image3)
4.3 Roll type
In the operating condition on a straight line, where the vehicle operates at a speed of 80 – 160 km/h, the influence of the roll type quadrangular height difference on the vehicle operation safety is shown in Figure.8. From Figure.8, the higher the speed is, the greater the influence of the roll type quadrangular height difference on the derailment coefficient is, and the greater the influence of the quadrangular height difference is, the larger the derailment coefficient is, but the influence will be smaller and the derailment coefficient is less than 0.8; the wheel unloading rate increases with the twisted quadrangular height difference, which is less than 0.6.

Figure.9 is in the operating condition on a curve with a radius of 500 m, which shows the influence of the roll type quadrangular height difference on the vehicle operation safety. From this figure, with the increase of the quadrangular height difference, the derailment coefficient and the wheel unloading rate will increase, where the derailment coefficient is less than 0.8 and the wheel unloading rate is less than 0.6.

The calculation result in the operating condition on a twisted track is shown in Figure.10. From Figure.10, with the increase of the quadrangular height difference, the derailment coefficient and the wheel unloading rate will increase, where the derailment coefficient is less than 1.2 (Note: in the operating condition on a twisted line, the limit of the derailment coefficient is 1.2) and the wheel unloading rate is less than 0.6.

![Figure 8. Roll type on a straight track](image8)

![Figure 9. Roll type on a curved track](image9)
5. Conclusions
The quadrangular height difference has a negative effect on the operation safety of a 25T railway passenger coach. The twisted quadrangular height difference is the severest one, followed by the roll type, and the pitch type in turn. With the increase of the quadrangular height difference, the derailment coefficient and the wheel unloading rate increase. When the bogie quadrangular height difference reaches 12 mm, the vehicle can be operated safely at 160 km/h on a straight track and at 90 km/h on a curved track with a radius of 500 m as well as passing through a twisted track at a quite low speed.

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