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Research on Influence of Rail Fastener Failure on Vertical Interaction between Wheel and Rail

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Abstract. In this paper, the reasons for the failure of the fastener, the performance characteristics of the fastener and the importance of the fastener system to the stability of the track are briefly introduced. Based on the effect of the fastener failure on the wheel and rail, a vehicle track vertical coupled vibration analysis model is established, from the vertical interaction force of the wheel rail, the vehicle subsystem and the vertical interaction of the track. In order to ensure the stability, reliability and safety of railway transportation, the influence of different modes of fastener failure on the dynamic characteristics of wheel rail system under different conditions is carried out under different conditions.

Keywords: Rail transit, wheel track, fastener failure, vibration analysis, dynamic characteristics.

1. Introduction

Regardless of rail transit such as high-speed rail or subway, fasteners that connect rails and sleepers to form rails play an important role in ensuring the stability and reliability of rails, and have an important impact on the safety of railway transportation. The static mechanics research and public works experience show that: the occurrence of inflation and cracking of track slabs may cause the failure of the fastener system and the local irregularity of the track[1]. These two secondary diseases may have a greater impact on the dynamic response of the wheel-rail system. In severe cases, traffic safety may be affected. Dynamic irregularities such as fastener failures will change the interaction between wheels and rails, have a significant impact on the vertical interaction of wheel and rail, and require timely treatment and remediation to ensure the safe and smooth operation of high-speed trains. For this reason, based on the theory of wheel-rail system dynamics, the finite element method is used to analyze the impact of track plate expansion cracking on the dynamic response of the wheel-rail system[3].Therefore based on the dynamics theory of wheel rail system, the influence of the expansion cracking of the rail plate on the dynamic response of the wheel rail system is analyzed by the finite element method[4].[1]

2. Vertical Coupled Vibration Model of Vehicle-rail System

This paper combines the secondary diseases caused by the fastener failure and the line driving conditions, and uses the vehicle track system coupling dynamics method to study the dynamic properties of the local irregularities and track structures caused by the fasteners after the failure cracking. Based on the coupled dynamics of vehicle-ballast less track based on vehicle dynamics and ballast less track dynamics, and using the wheel-rail relationship as the link, the high-speed train and ballast less track are regarded as an interactive large-scale system and applied to computer numerical simulation[9]. Methods The dynamic performance, safety and comfort of the track structure under the condition of certain speed were analyzed to provide the theoretical basis for the study of the effect of fastener failure on the safety of the train. Establish the vertical coupling dynamics model of the vehicle-orbit structure shown in Fig. 1current designations.

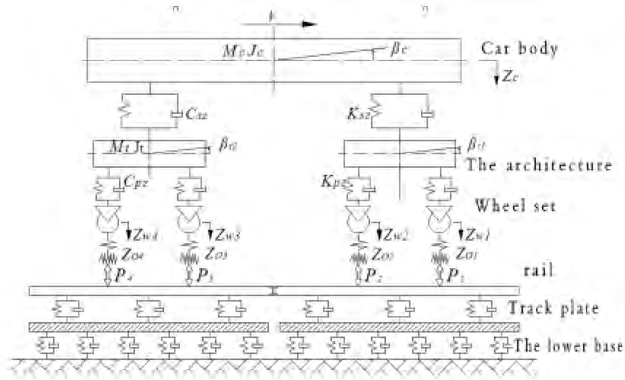


Fig. 1 Vertical coupled vibration mechanical analysis model of vehicle-track structure

The role of fasteners between rails and sleepers is to elastically support or dampen the damping. The effect of the subgrade on the track is simplified as a spring and a damper[7]. The stiffness of the track bed is divided into two parts, that is, the equivalent stiffness of the track bed is multiplied by 2 and set separately.

System kinetic energy: $$T = \frac{1}{2}\sum_{i=1}^{N}\left[M_s Z_{si}^2\right] + \frac{1}{2}M_{bb}\sum_{i=1}^{2N} Z_{bbi}^2$$

System potential energy: $$U = \frac{1}{2}\sum_{i=1}^{N} k_r(z_{si} - z_{ri})^2 + \frac{1}{2}\sum_{i=1}^{N} k_s(z_{si} - z_{bbi})^2 + \frac{1}{2}\sum_{i=1}^{N}\left[k_b z_{bbi}^{\ 2}\right]$$

In the formula, above and below the masses of the track beds, the stiffness KS above the masses is equal to the equivalent stiffness Kb below the masses.

3. The Response of Fasteners to The Vertical Interaction Between Wheel and Rail

3.1 Wheel-rail Vertical Interaction Force.

Because the body has its own vibration (natural) frequency, when the train is running at a certain speed, it will make the train resonance line is not smooth. According to the wavelength range, irregularities can be classified as short-wavelength, medium-wavelength, and long-wave irregularities[5]. Irregularities with a wavelength of 30-120m are referred to as long-wave irregularities. The track irregularity is an external turbulence to the train system and is the main source of the vibration of the train system. Wheel-rail interaction, when the locomotive and rolling stock is running on the railway line, is subject to vibration due to the effect of line irregularity; the gravity and other loads generated during the operation of the locomotive and rolling vehicle act on the rail through the wheel, causing elastic deformation and orbital subsidence of the rail which intensified the irregularity of the line. The vertical vibration of the rolling stock caused by the vertical track irregularity generates vertical action force between the wheels and rails[2].

(1) When the long wave irregularity is not considered, there is a comparison of the time course curve of the vertical interaction between the wheel and the rail.

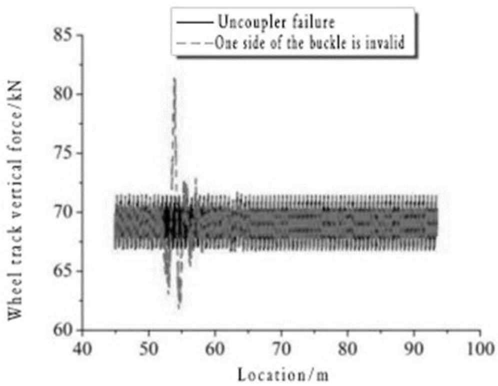


Fig. 2 Comparison of the vertical force of the wheel-rail with or without fasteners (not consider long-wave irregularities)

As can be seen from Fig. 2, when considering the fastener failure, when the high-speed train passes through the fastener failure area, the wheel first takes off load, then impacts, and then repeats the process of load shedding and shock, mainly with one shock and two minus[6]. Load peak. Compared with the failure of fasteners, the impact coefficient increases more than the deducting rate.

(2) Consider the comparison of the time-history curves of the vertical interaction between wheel and rail when the fastener is in failure.

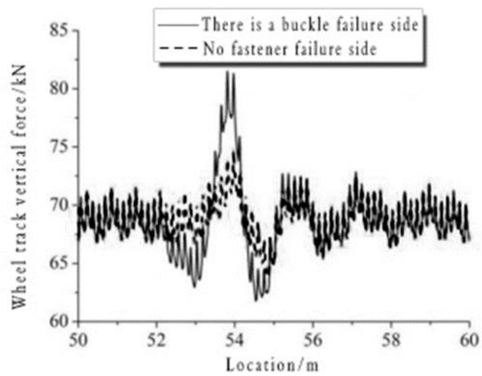


Fig. 3 Comparison of the vertical interaction forces on both sides of rails on one side with fasteners failure

It can be seen from Fig. 3 that when the high-speed train passes through the simulation area, the trend of the wheel-rail force-time curve of fasteners with and without fasteners is basically the same, but the amplitudes are quite different[2]. The maximum values are 81.52 KN and 74.67 KN, respectively. They are 61.77 KN and 63.89 KN, respectively.

(3) The left and right rails also take into account the vertical interaction of the wheels and rails when fasteners fail.

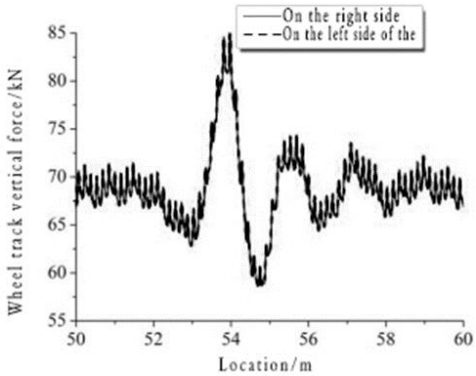


Fig. 4 Both sides of the vertical interaction of the wheel and rail when the fasteners fail

It can be seen from Fig. 4 that when the fasteners fail to be symmetrically arranged, the interaction curves of the wheel-rail interactions on both sides are exactly the same, with the maximum and minimum values being 85.0 KN and 58.63 KN, respectively.

From the above analysis, it can be seen that the failure of fasteners changes the vertical interaction between wheels and rails, and has a certain influence on the vertical interaction between wheels and rails.

3.2 Vehicle Subsystem Dynamic Response.

Irrespective of the long-wave irregularity, there is a comparison of time-history curves of vertical vibration acceleration of the vehicle body when local irregularities are caused by expansion cracking.

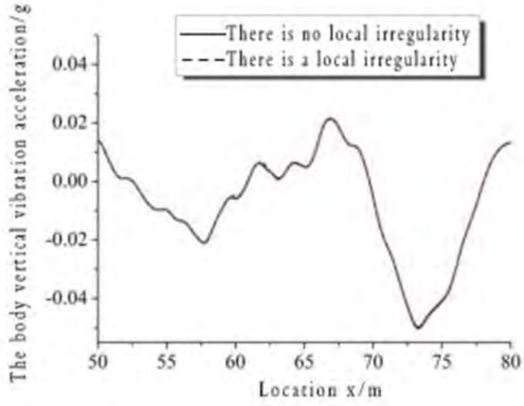
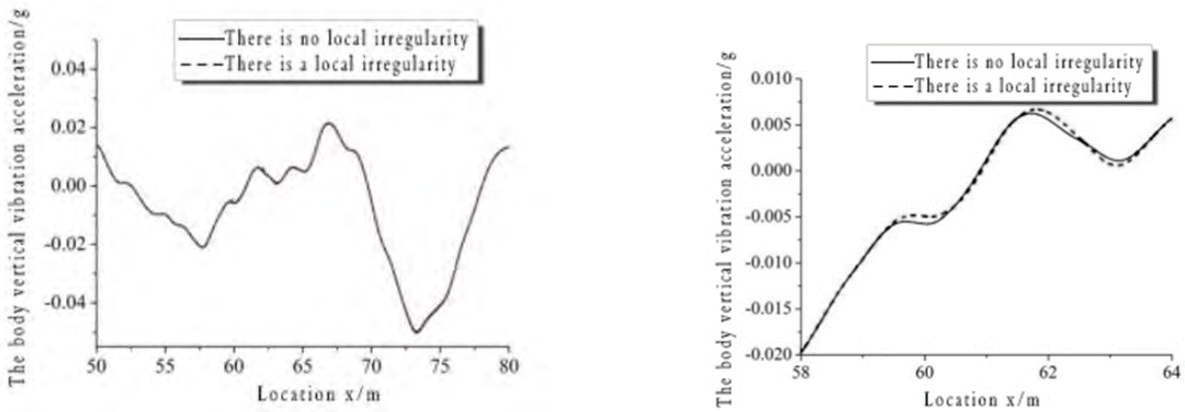


Fig. 5 Comparison of the time history curve of vertical vibration of the car body with or without local irregularity (not consider long wave irregularities)

As can be seen from Fig. 5, when considering only partial irregularities, the vertical acceleration of the vehicle body is an iterative process that increases first and then decreases when the high-speed train passes through the partial irregularities caused by expansion cracking. The main positive and negative peaks there are two, respectively, when considering local irregularities, the maximum positive and negative accelerations are 0.0007g and 0.00073g, respectively.

Fig. 5 is a comparison of the time history curve of vertical vibration acceleration of the vehicle body when there is local irregularity due to the presence or absence of expansion cracks when long-wave irregularities are considered.



(a) Consider long wave irregularities (b) Local magnification

Fig. 6 Comparison of the time history curve of vertical vibration acceleration of the vehicle with or without local irregularity (taking into account the long-wave irregularity)

It can be seen from Fig. 6 that when long-wave irregularities and local irregularities are taken into account at the same time, when the high-speed train passes through the partial irregularities caused by expansion cracking, the vertical acceleration of the vehicle body does not differ substantially from the overall point of view. Look, local unevenness has certain influence on the vertical vibration acceleration of the vehicle, but at this time, the amplitude is still relatively small, which is not obvious yet[3]. Fig. 3-5 considers whether the long-wave smoothness or not, and the local irregularities caused by expansion cracking have an incremental effect on the vertical acceleration of the vehicle body. It can be seen from the figure that, considering the long-wave irregularity, the increase is basically the same. The rules affecting the vertical interaction of wheels and rails are consistent.

3.3 Analysis Results

Through the above analysis of the fastener failure on the vertical interaction of the wheel and rail, there are the following results:

The failure of fasteners changes the interaction between wheels and rails. When a high-speed train passes through this area, the vertical interaction force between wheels and rails changes abruptly. This is a process in which the shock is repeated after the first load shedding. Considering long-wave irregularities, the increments of vertical vibration accelerations of various parts of the vehicle subsystem are basically the same.

4. Conclusion

Through the above analysis, we can see that the dynamic failure of the fasteners and other changes, changing the wheel-rail interaction, has a significant impact on the vertical interaction of the wheel and rail. It needs to be handled and rectified in a timely manner to ensure the safe and smooth operation of high-speed trains[9].

Fasteners are the main components that provide elasticity in the high-speed railway track structure system. Failure of the fasteners will affect the dynamic response of the track structure, accelerate deterioration of the track state, and endanger the safety of train operation in severe cases. Historical accident data shows that fastener failure is a risk factor that cannot be ignored.

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