Effect of CA mortar disengagement on Dynamic characteristics of Slab Ballastless Track on Subgrade

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Abstract. According to the improved model of the vehicle-ballastless slab track-subgrade coupling system, the effects of cement asphalt mortar (CA) disengagement on dynamic characteristics of vehicle and track are analysed. The results show that when the CA mortar longitudinal disengagement length exceeds 0.65m and the horizontal disengagement degree exceeds 0.5, the maximum and minimum of wheel-rail force, the maximum of the displacement of track system change obviously with the increase of CA mortar disengagement length. The effect of CA mortar disengagement on track system is larger than the vehicle system. The CA mortar disengagement should be repaired timely.

1. Introduction

Ballastless tracks have been extensively laid nationwide due to its outstanding characteristics, such as good smoothness, good stability, long service life, good durability and low maintenance associated costs [1]. As an important part of China Railway Track System II-type (CRTSII) slab ballastless track, CA mortar plays the role of support and adjustment, bearing and force transmission, vibration isolation and shock absorption. In the actual operation process, due to the nature of the CA mortar material, the influence of the natural environment, the warpage of the track plate caused by the temperature gradient and the frequent train loading, the separation occurred in the local area of the contact surface between the track slab and the CA mortar layer. When the adhesion is completely lost, the damage phenomenon is called CA mortar disengagement.

At present, the research on CA mortar at home and abroad mainly focuses on the damage form of CA mortar and the cause of CA mortar disengagement and its material properties. As the foundation stiffness of subgrade is less than that of bridge and tunnel, the track deformation on subgrade is relatively larger under the same train loading. Studies on the influences of CA mortar disengagement on the dynamic characteristics of ballastless track on subgrade are few. Wang et al. [2] analyzed the effects of different CA mortar disengagement lengths on dynamic responses of vehicle-track system and suggested that the CA mortar disengagement should be repaired when the length exceeds 1.95m. Li et al. [3] established a vehicle-track-bridge model and analyzed the dynamic responses of the coupled system. The results show that when the CA mortar disengagement length exceeds 0.8m, the dynamic irregularity

of track caused by disengagement plays a leading role in wheel-rail interaction and various dynamic responses are obviously intensified. Therefore, the effects of CA disengagement on dynamic characteristics of ballastless slab track on subgrade are studied in this paper.

2. Model

2.1. Improved model of vehicle-ballastless slab track-subgrade coupling system

Shi et al. [4] proposed an improved model of the vehicle-ballastless slab track-subgrade coupling system, which includes vehicle model, improved track model and the coupling model.

As shown in Figure 1, the track system is modelled here as a beam continually supported on a triple-layer spring-damper system, which represent rail pads, CA mortars and subgrade, respectively. According to dividing the CA mortal model equally into several units, the improved track model can simulate the CA mortar disengagement with arbitrary longitudinal length. The vertical coupling relationship adopts the Hertzian nonlinear elastic contact model.
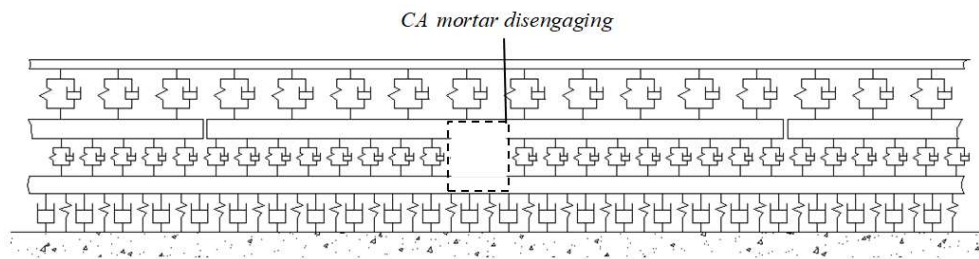
Figure 1. Improved track model.

In this paper, The China Railways High-speed 2 (CRH2) emu trailer and the high-speed line with China Railway Track System II-type (CRTS II) track slab are adopted, with their property values referenced to Zhai [5]. The simulated length is the length of 16 track slabs, i.e., 104m.

### 2.2. Different conditions of CA mortar disengagement

The condition of CA mortar disengagement can be simulated as a loss in stiffness by changing the coefficients of elastic spring and damper which represent CA mortar in corresponding areas [6]. The CA mortar disengagement is set on the 8th track slab and its form is shown in Figure 2. The direction along the rail is the longitudinal direction, while the direction which is vertical to the rail is the horizontal direction. The supporting force of CA mortar on the track slab can be expressed as:

$$F = \left(1 - b_0 / b\right) \cdot k_s \cdot \left(z_{\mathrm{r}} - z_{\mathrm{s}}\right) + \left(1 - b_0 / b\right) \cdot c_s \cdot \left(\dot{z}_{\mathrm{r}} - \dot{z}_{\mathrm{s}}\right) \tag{1}$$

Where z_{r} and z_{s} are displacement of rail and track slab, respectively; k_s and c_s are the stiffness and damping coefficients of CA mortar; b_0 is the overall track slab width; b is the CA mortar disengagement width. Therefore, the CA mortar horizontal disengagement degree is represented with d, which can be expressed as:

$$d = 1 - b_0 / b \tag{2}$$

With $d = 0 \sim 1$.

(a) Front view   (b) lateral view
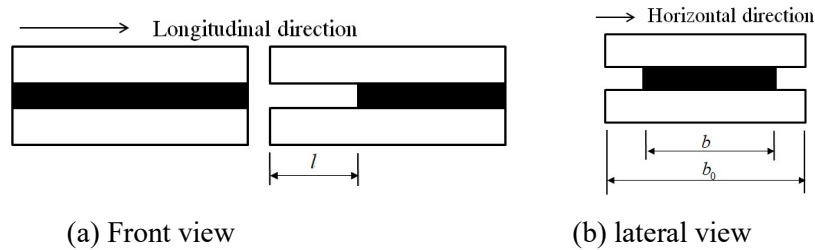
Figure 2. Schematic diagram of the CA mortar disengagement areas.

3. Effect of CA mortar disengagement on Dynamic characteristics of Slab Ballastless Track on Subgrade

3.1. Comparative analysis with or without disengagement

In order to obtain the comparative analysis with or without disengagement, a simulation under the condition of l=1.3m&d=1 and l=0m are carried out.

Figure 3 shows the wheelset acceleration and rail acceleration in the time domain and frequency domain. It can be seen that under the condition of disengagement longitudinal length l=1.3m, the magnitude value of the wheelset acceleration in the time domain becomes higher in the disengagement section. There are much difference in the power spectrum in the range of 1Hz~100Hz. The change of the rail acceleration is not obvious due to its high frequency in the time domain. The increase will result in the interaction between the vehicle and the track strengthened, so that the disengagement area is further expanded.
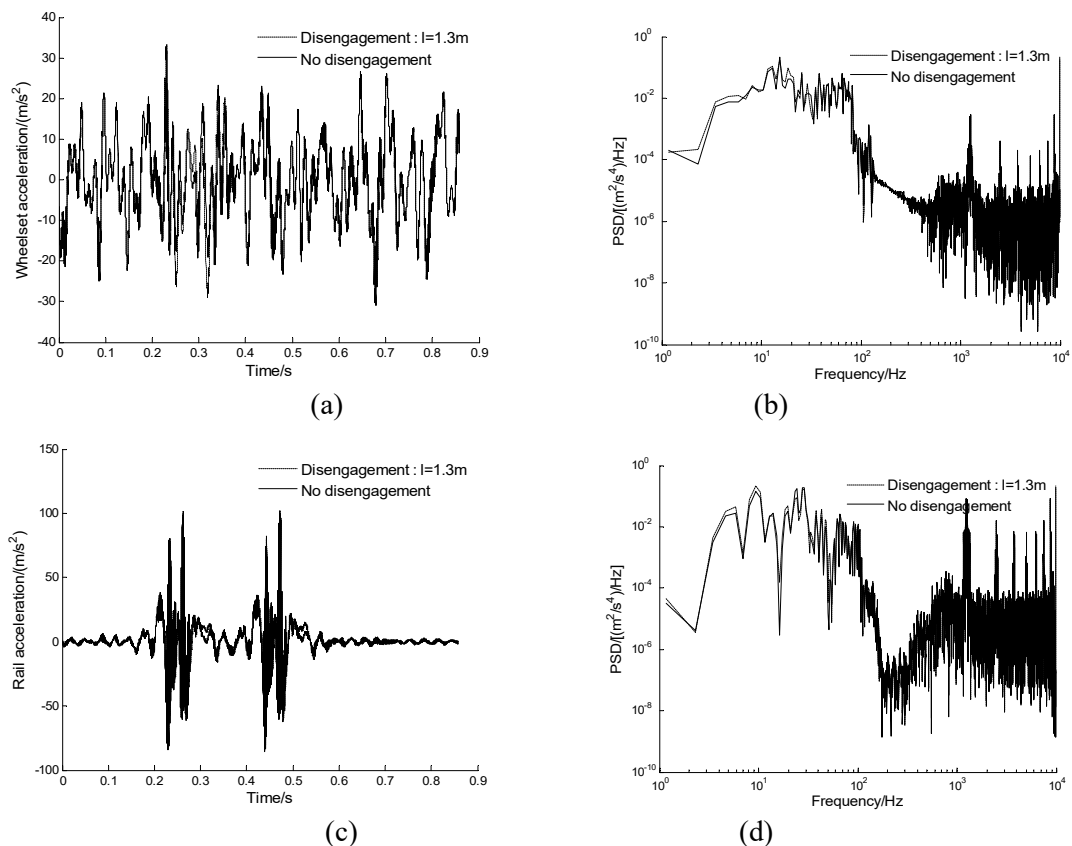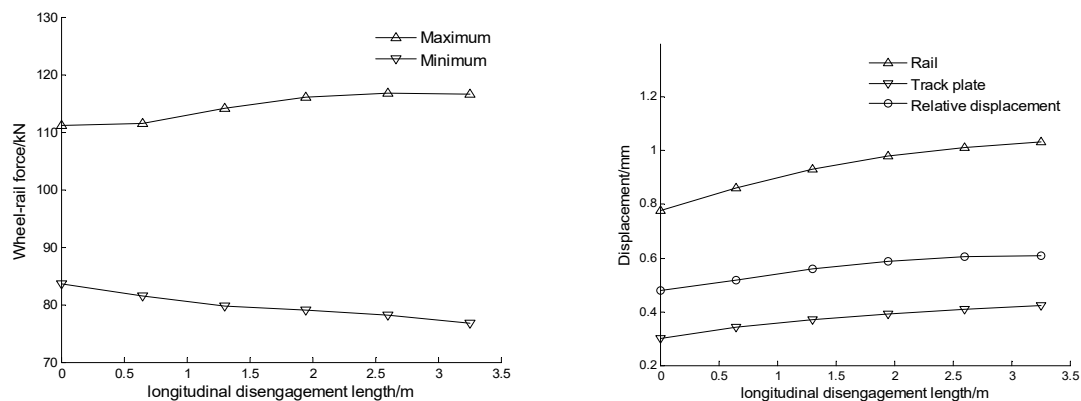

Figure 3. Dynamic responses with or without disengagement.

3.2. Effect of CA mortar longitudinal disengagement length

In order to analyze the influence of the longitudinal disengagement length of the CA mortar on the dynamic responses of the coupled system, a simulation analysis with various l (0.65 m, 1.3 m, 1.95 m, 2.6 m and 3.25m) under the condition of d=1 was carried out.

Figure 4 shows the relationship between the maximum and minimum values of the wheel-rail force, the displacement of the rail and the track plate and the longitudinal length of the disengagement. From Figure 4(a), it can be seen that when the longitudinal length of the CA mortar disengagement does not exceed 0.65m, the variation of the wheel-rail force is small. When the longitudinal length exceeds 0.65m, the maximum value of the wheel-rail force increases with the increase of the longitudinal length of the CA mortar disengagement, and the minimum of that decreases significantly with the increase of the longitudinal length. When the disengagement length is 3.25m, The maximum and minimum value of wheel-rail force is 116.6376kN and 79.8042kN, 4.87% higher and 4.56% lower than no disengagement. From Figure 4(b), it can be seen that the displacement maximum of the track structure increase as the disengagement length increases. When the disengagement length is 3.25m, the displacement of rail, track slab and the relative displacement is 33.26%, 41.93% and 27.82% higher than no disengagement, respectively.
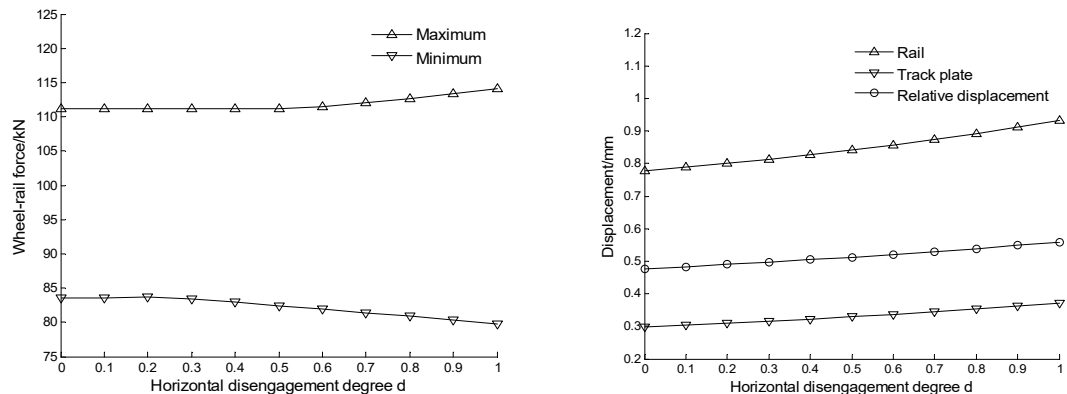

(a) Maximum and minimum of wheel-rail force (b) Displacement maximum of track structure

Figure 4. Influence of longitudinal disengagement length of CA mortar.

3.3. Effect of CA mortar horizontal disengagement length

In order to analyze the influence of the horizontal disengagement length of the CA mortar on the dynamic responses of the coupled system, a simulation analysis with various d (0~1) under the condition of l=1.3m was carried out.

Figure 5 shows the influence of horizontal disengagement degree of CA mortar on the wheel-rail force, the displacement of the rail and the track plate and their relative displacement. It can be seen from Figure 5(a) that when the horizontal disengagement degree is less than 0.5, the maximum and the minimum of the wheel-rail force hardly change. However, if the horizontal disengagement degree continues increase, they become bigger and smaller, respectively. When the horizontal disengagement degree is 1, the maximum value is 114.169kN, 2.65% higher than no disengagement, while the minimum value is 79.8042kN, 4.56% lower than no disengagement. It can be seen from Figure 5(b) that the displacement maximum of the track structure increase slowly as d increases. When the horizontal disengagement degree is 1, the displacement of rail, track slab and the relative displacement is 19.98%, 24.46% and 17.18% higher than no disengagement, respectively.

(a) Maximum and minimum of wheel-rail force (b) Displacement maximum of track structure

Figure 5. Influence of horizontal disengagement length of CA mortar.

4. Conclusion

The CA mortar disengagement is one of the main damage types in slab ballastless track. Based on the theory of vehicle-track coupling dynamics, a vertical coupling model for a vehicle-CRTS II slab ballastless track-subgrade system was established, and the CA disengagement on dynamic characteristics of the coupled system are analyzed. The results show that when the CA mortar longitudinal disengagement length exceeds 0.65m and the horizontal disengagement degree exceeds 0.5, the maximum and minimum of wheel-rail force, the displacement of track system change obviously with the increase of CA mortar disengagement length. The effect of CA mortar disengagement on track system is larger than the vehicle system. Therefore, the CA mortar disengagement detection is necessary to ensure the safety of vehicle operations and make a timely rail line maintenance plan.

References

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