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Analysis of the variability of wheel-rail rolling noise caused by different track structures

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Abstract

In this paper, the finite element models of normal monolithic bed track (NMBT), steel spring floating slab track (SSFST) and longitudinal sleeper track (LST) are established. The dynamic characteristics of the three rail structures are studied by analysing and comparing the rail admittance characteristics and track slab admittance characteristics, and the accuracy of the models is verified combined with the dynamic test results of track structures. Then, in order to analyse and compare the sound radiation characteristics of different tracks, the corresponding models are established based on the boundary element method. Finally, for the purpose of calculating the wheel-rail rolling noise corresponding to different tracks, a wheel-rail interaction model was developed to analyse the corresponding wheel-rail forces per unit roughness. Meanwhile, wheel-rail roughness tests were carried out to find out the wheel-rail rolling noise of different tracks under actual roughness, and the reasonableness of the model was verified with the actual test results. The results show that, compared to NMBT, the laying of both SSFST and LST will increase wheel-rail rolling noise. Below 80Hz, the wheel-rail rolling noise of SSFST is the largest; while above 80Hz, the LST has the highest noise.

Keywords: wheel-rail rolling noise, normal monolithic bed track, steel spring floating slab track, longitudinal sleeper track.

1 Introduction

Underground lines are often laid in sections with various types of track structure to ensure a combination of construction economy and vibration and noise isolation performance. At present, due to the increased emphasis on vibration isolation in urban rail transit, the use of vibration damping track has become the mainstream vibration damping measure for urban rail damping engineering. However, the main function of using vibration damping track is to attenuate the vibration transmitted to the surrounding foundation when the metro is running, ignoring its vibration and noise impact on the vehicle-track system. A large number of field tests have shown [1-3] that the track structure is an important factor leading to abnormal vibration and noise of the vehicle, and the track structure type and parameters have significant variability for the vehicle noise. The rolling noise is the most important source of contribution to vehicle noise [4].

NMBT has a simple structure and is the preferred type of slab track structure for many cities building rail transportation. The vibration isolation effect of SSFST is the best among vibration damping tracks, which is suitable for metro lines with high requirements for vibration isolation of buildings [5]. SSFST balances the dynamic load caused by wheel-rail interaction by mass inertia of the floating plate, and can reduce its own inherent frequency by adjusting the mass of the floating plate and the stiffness of the vibration isolator, thus achieving excellent vibration isolation effect. LST is also one of the common types of vibration damping track, which provides excellent vibration and noise reduction by lifting the longitudinal sleeper for continuous support in the longitudinal direction and using vibration damping material to link the longitudinal sleeper with the track slab.

At present, there is a lack of detailed research on the influence of different track structures on wheel-rail rolling noise. This paper systematically integrates the dynamic characteristics of the track structure and the theory of wheel-rail rolling noise to explain the reasons for differences in the influence of track structure on wheel-rail rolling noise from mechanism.

2 Methods

During the field test, the admittance characteristics of rails with different rail structures and wheel were obtained by hammer pulse method, and the wheel roughness and rail roughness were tested by direct method, on which the combined wheel-rail roughness was calculated.

The finite element method is used to establish the dynamic analysis models of the track structure and wheel, and to calculate the vertical, lateral and cross admittance of the track and the radial, axial and cross admittance of the wheels respectively.

Based on the boundary element method, the boundary element mesh models of different track structures are established. The vibration data of surface nodes calculated by the finite element model are mapped to the corresponding nodes of the boundary element model, and the sound radiation results of different track structures under vertical and lateral unit force excitation are calculated. Similarly, the boundary element model of the wheel is established and its sound radiation is calculated.

Combined with the wheel-rail interaction force, the actual combined wheel-rail roughness after contact filtering, and the sound radiation power under unit force, the wheel-rail radiation noise under the actual roughness excitation is finally calculated.

3 Results

Figure 1(a) shows the results of the rail roughness test of three rail structures and the wheel roughness test, and the combined wheel-rail roughness after contact filtering is calculated on this basis as shown in Figure 1(b). Figure 2 shows the calculated results of rail admittance, wheel admittance and contact admittance for the three rail structures.

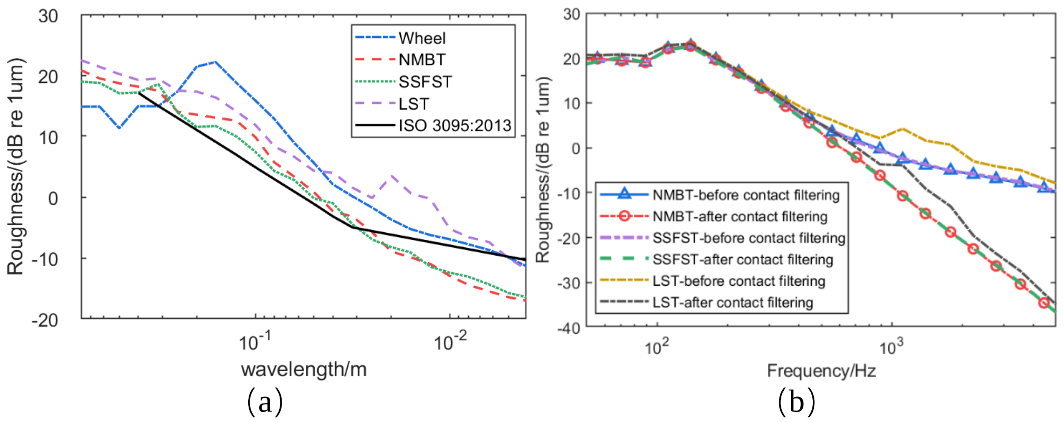

Figure 1: (a) Rail wheel roughness (b) Combined wheel-rail roughness after contact filtering.

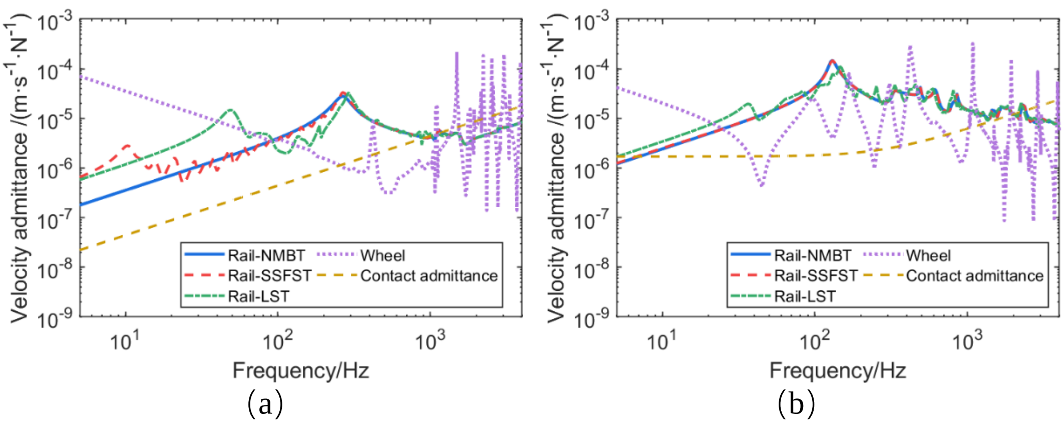

Figure 2: Rail admittance, wheel admittance and contact admittance (a)Vertical direction (b) Lateral direction.

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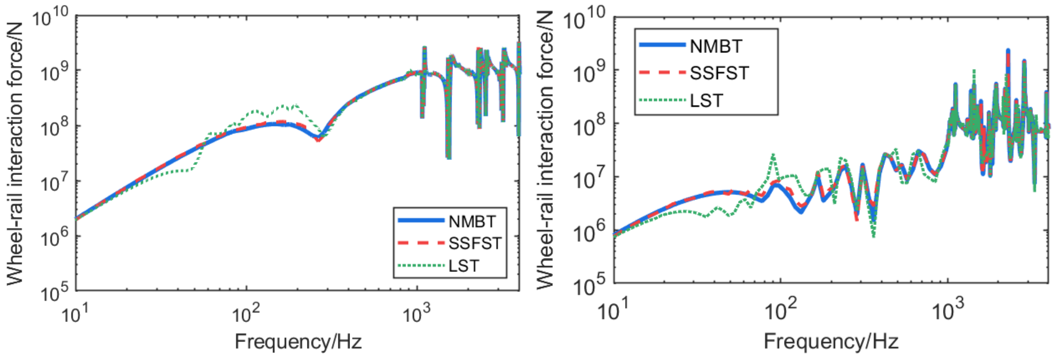
As is shown in Figure 3, the vertical wheel-rail force is almost the same for NMBT and SSFST, and the valley value exists at 260Hz; valley value exists at 50Hz and 290Hz for LST. The lateral wheel-rail force of NMBT and SSFST both have a valley at 130Hz and LST has a valley at 145Hz.



(a) (b)

Figure 3: Wheel-rail interaction force at unit roughness (a)Vertical direction (b)Lateral direction

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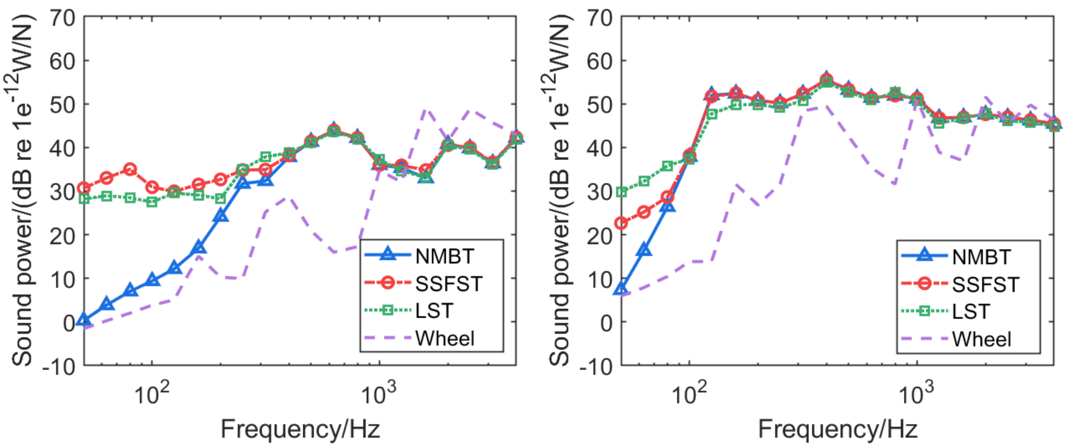
The comparison of the track structure radiated noise under the action of unit force is shown in the Figure 4. The main noise peaks of three track structures both appear at 630 Hz. At lateral unit forces the differences between the three track structures are not significant.



(a) (b)

Figure 4: Wheel-rail rolling noise under unit force (a) Vertical direction (b) Lateral direction.

As Figure 5 shown, when the railway vehicle is running at 80km/h, the wheel-rail rolling noise of NMBT, SSFST and LST are 106.8dB, 108.2dB and 109.9dB respectively. Below 80Hz, the wheel-rail rolling noise of SSFST is the largest; above 80Hz, the noise of LST is the largest; below 315Hz, the noise of SSFST is larger than NMBT, and the main source of noise contribution is caused by track vertical vibration, and the noise in other frequency band is similar. The wheel-rail rolling noise of NMBT and SSFST has a peak at 160Hz, mainly caused by the radiated noise of track vibration caused by lateral force; LST has a peak at 200Hz, the track under vertical excitation is the major contribution source. The wheel-rail rolling noise of three track structures both has a peak at 630Hz, with the main contribution coming from vertical vibration noise of the track.

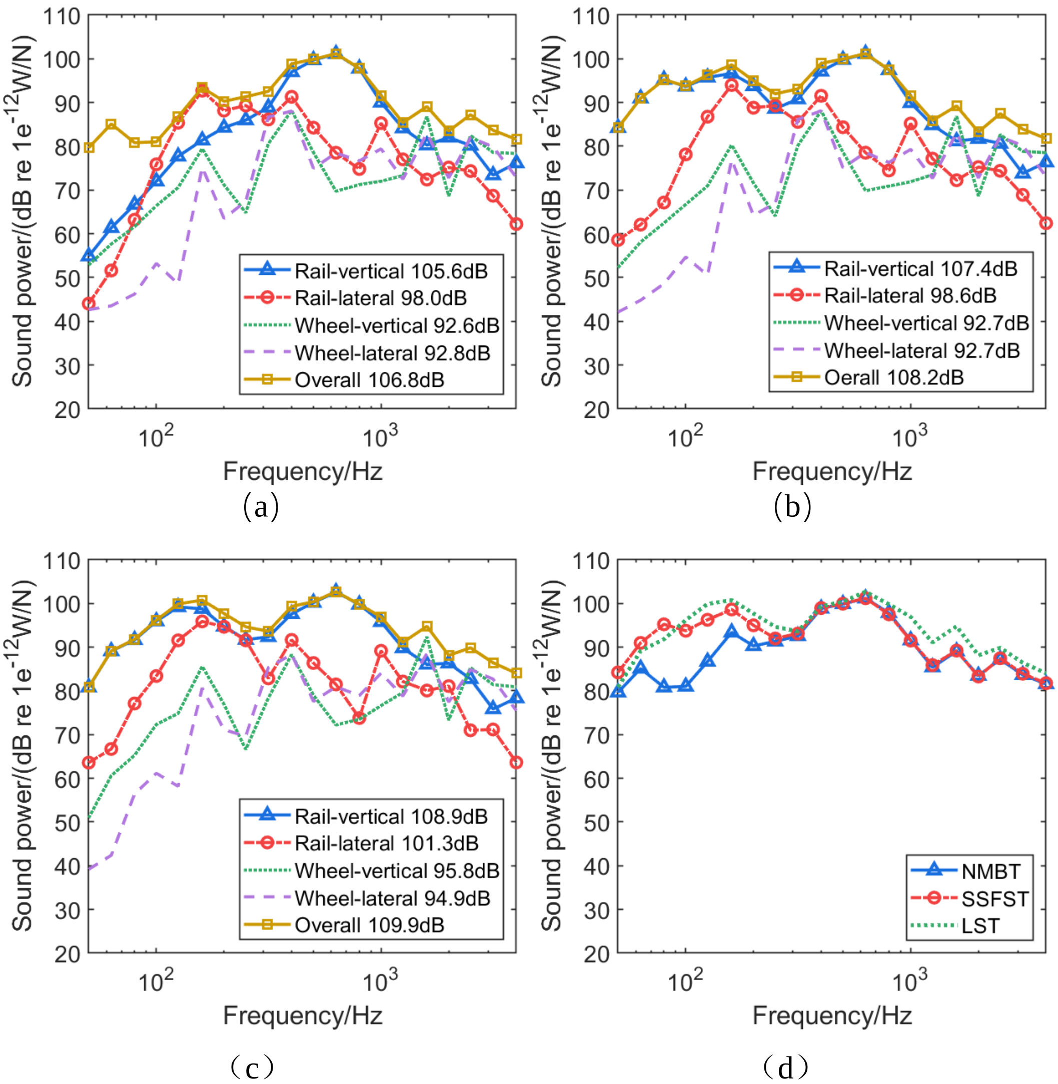


Figure 5:Wheel-rail rolling noise under actual roughness excitation (a) NMBT (b) SSFST (c) LST (d) Comparison.

4 Conclusions and Contributions

In this paper, three different types of slab track structures, namely normal monolithic bed track, steel spring floating slab track and longitudinal sleeper track, are researched, and their structural finite element models and boundary element sound radiation models are established respectively. Research is carried out on the dynamic characteristics of the track structure and the wheel-rail rolling noise in both lateral and vertical directions. In terms of wheel-rail rolling noise, LST has the highest noise, followed by SSFST, and NMBT is the lowest. It can be seen that the way of laying vibration damping track has a negative impact on wheel-rail rolling noise, although it alleviates the vibration noise to the external environment. In the future, in the design of vibration damping track, in addition to considering its damping of the external environment, it is necessary to further consider its impact on the noise inside the vehicle.

References

[1] Xia F., Wang A.B., " Effect of vibration-damping track structure on vibration and noise in subway cars", Noise and Vibration Control, 039(003), 103-106,2019.

[2] Sun K., Ge J.M., " Analysis of the effect of vibration isolated roadbed on the noise of railway vehicles", Noise and Vibration Control, 37(5), 5,2017.

[3] Tian J.H., Li B., Jian L., "Characterization of the influence of different roadbeds on the interior noise in railway vehicles", Noise and Vibration Control, 35(6), 5,2015.

[4] Liu J.H., Lian S.L., "Urban railway vibration and noise", Journal of Traffic and Transportation Engineering, 2(1), 5,2002.

[5] J.T Nelson, "Recent developments in ground-borne noise and vibration control. Journal of Sound & Vibration", 193(1), 367-376,1996.