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西南交通大學
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Theoretical investigation into the effect of rail vibration dampers on the dynamical behaviour of a high-speed railway track

Key words: Rail damper; Track dynamics; Dispersion curves; Vibration decay rate

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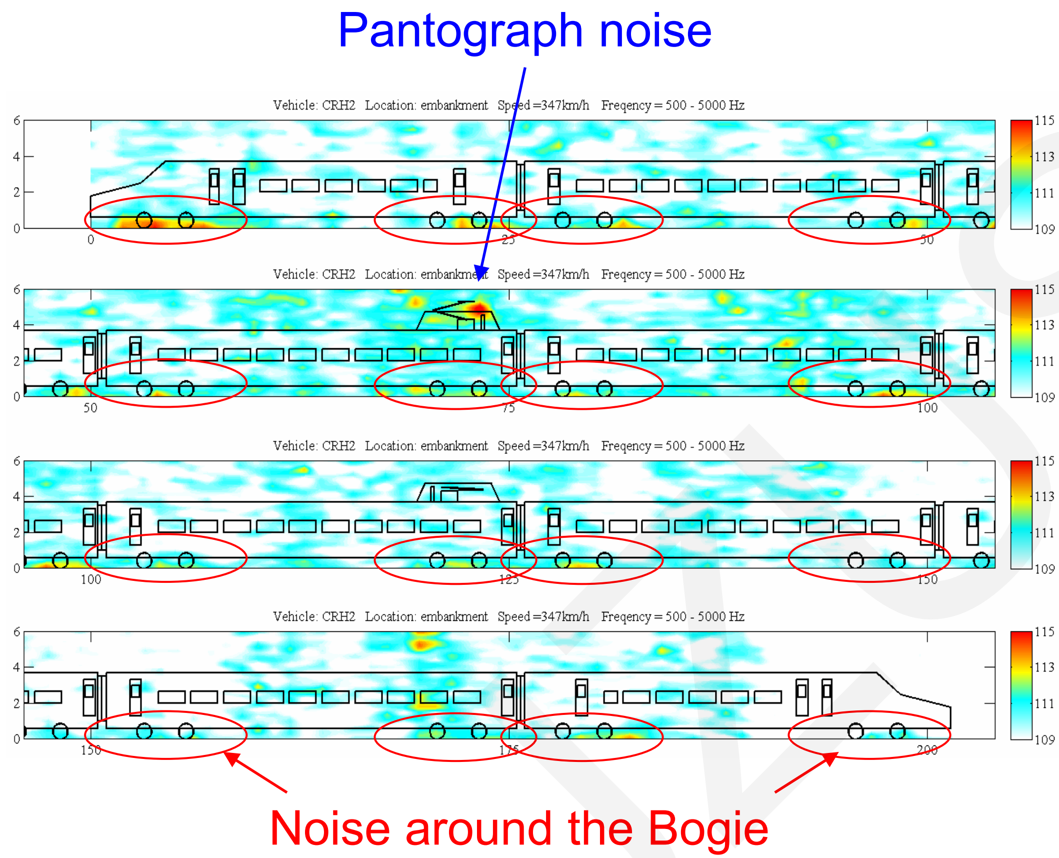
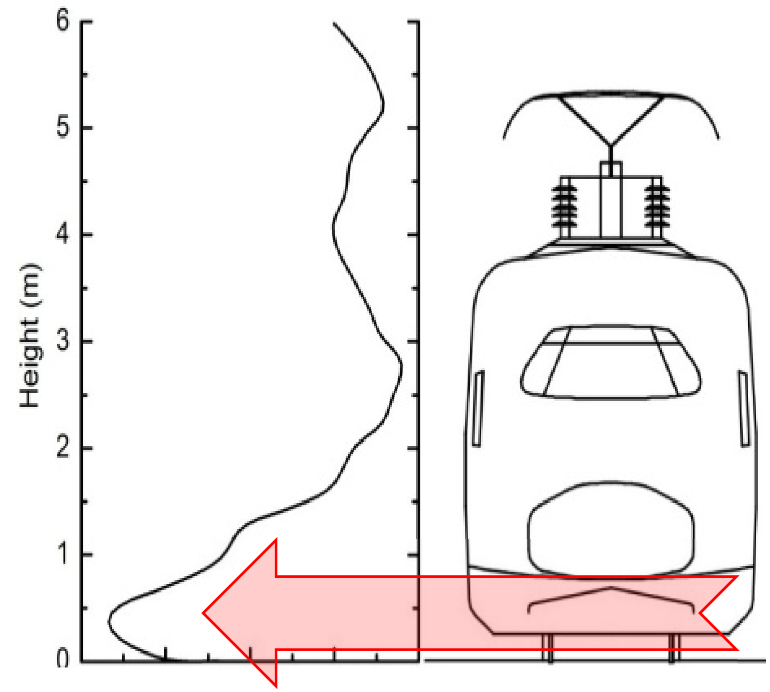
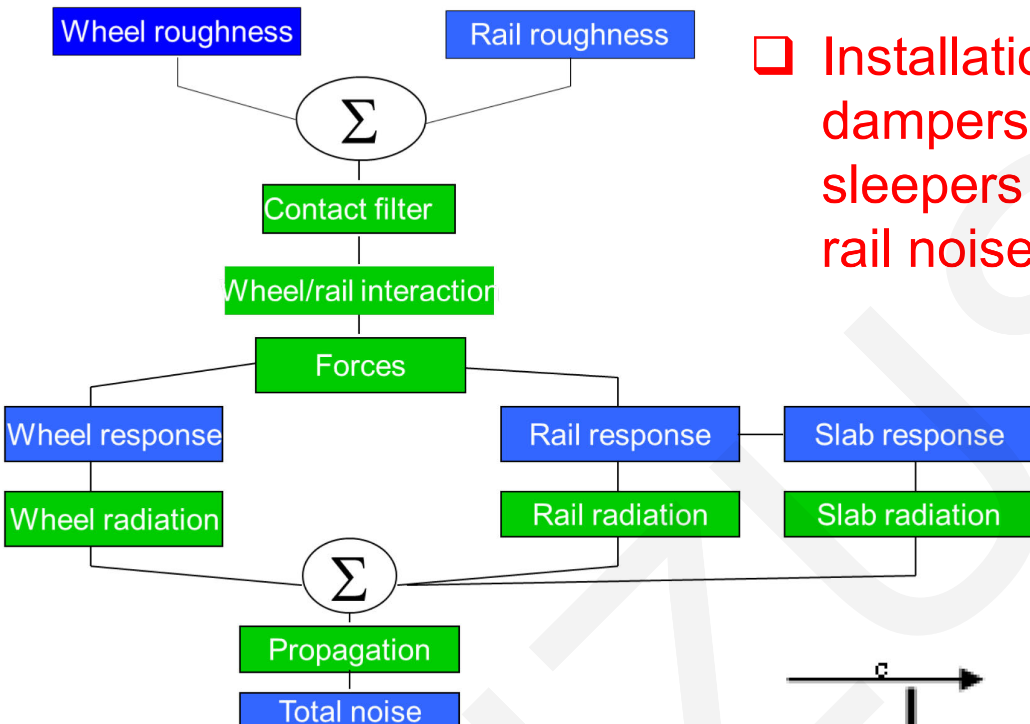
Background and Purpose





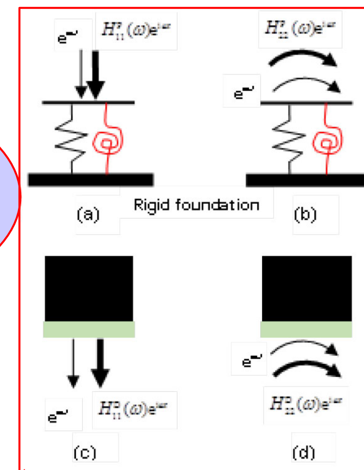
- ❑ Since there are much more bogies than pantographs, control of rolling noise is more pressing.

Background and Purpose



- Installation of rail vibration dampers (rail dampers for short) onto rails between sleepers is one of the measures to control rail noise generation and roughness growth.

Fourier Transform-based Method



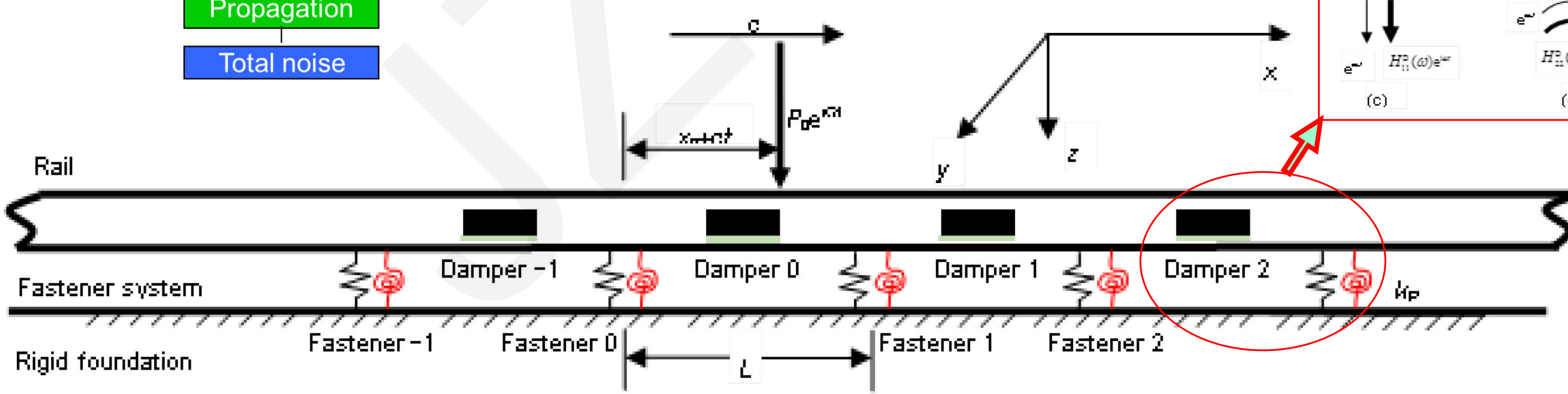


Fig. 3 Model of the track with rail dampers

Dispersion Curves

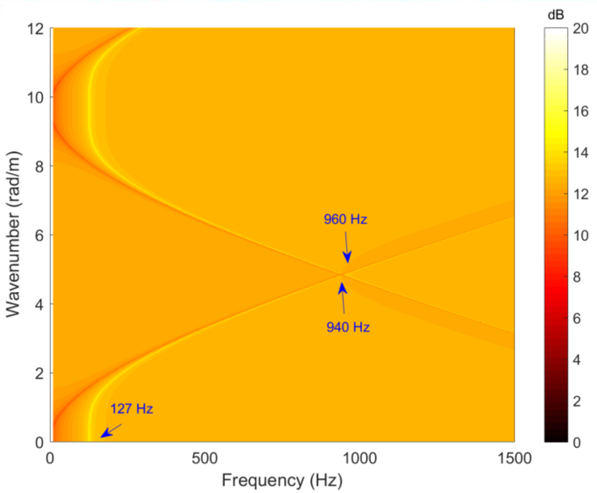


Fig. 5 Dispersion curves of the original track. There are three bounding frequencies: 127 Hz (II, S), 940 Hz (I, S), and 960 Hz (II, A)

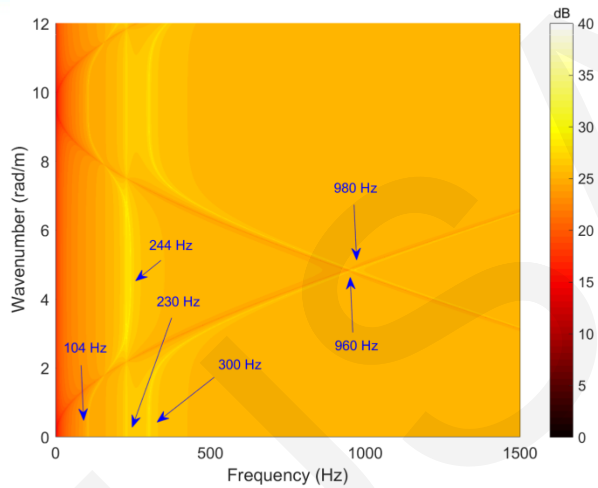


Fig. 6 Dispersion curves of the track with dampers tuned to 250 Hz. Bounding frequencies are 104 Hz (I, S), 244 Hz (II, S), 300 Hz (I, S), 960 Hz (I, A), and 980 Hz (II, S)

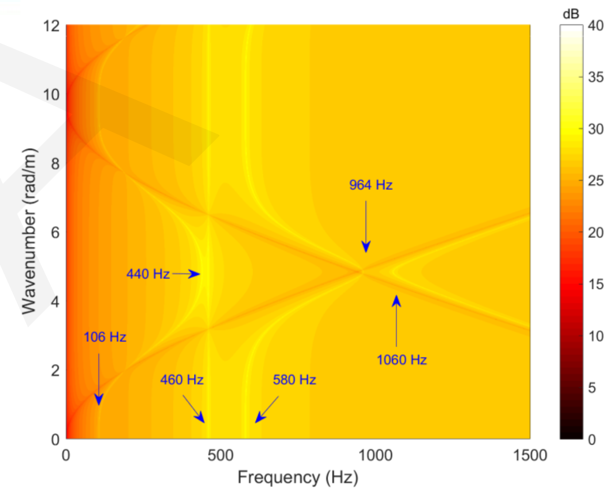


Fig. 7 Dispersion curves of the track with dampers tuned to 500 Hz. Bounding frequencies are 106 Hz (I, S), 440 Hz (II, S), 460 Hz (I, A; II, A), 580 Hz (I, S), 964 Hz (I, A), and 1060 Hz (II, S)

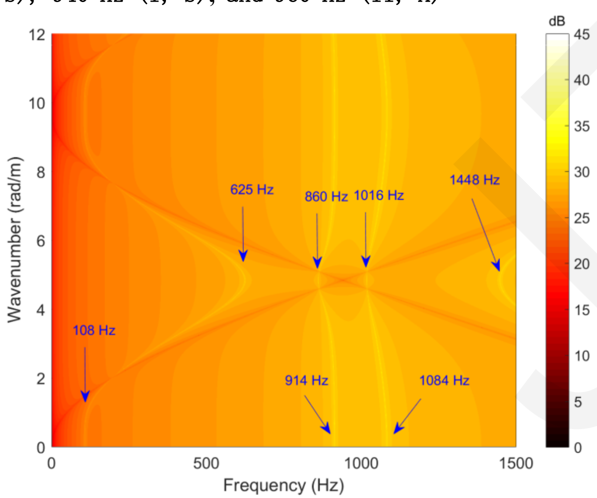


Fig. 8 Dispersion curves of the track with dampers tuned to 1000 Hz. Bounding frequencies are 108 Hz (I, S), 625 Hz (II, S), 860 Hz (I, A), 914 Hz (II, A), 1016 Hz (I, A), 1084 Hz (I, S),

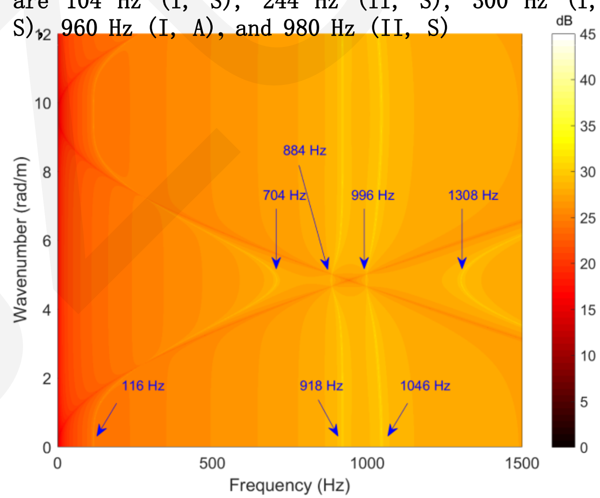


Fig. 22 Dispersion curves of the track with dampers tuned to 1000 Hz but with the mass and stiffness halved (bounding frequencies are 116, 704, 884, 918, 996, 1046, and 1308 Hz)

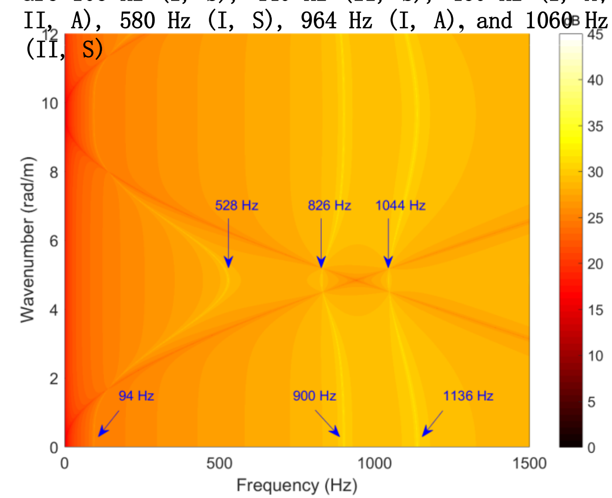
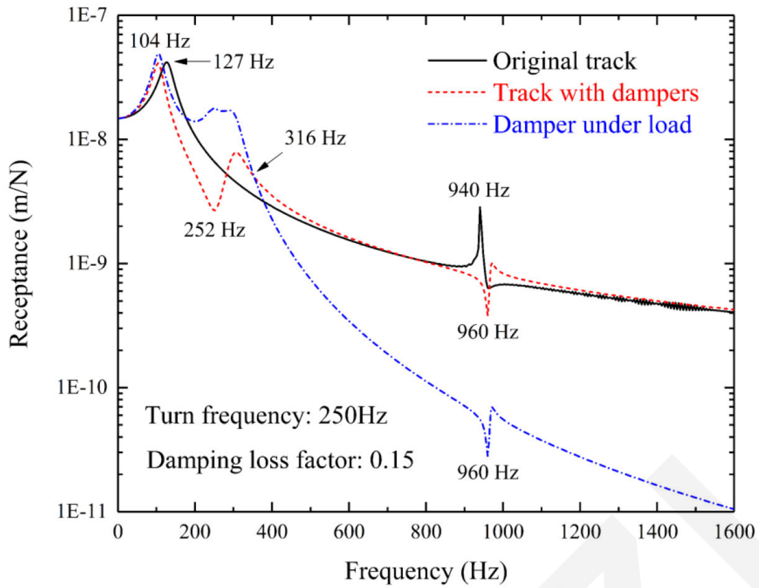
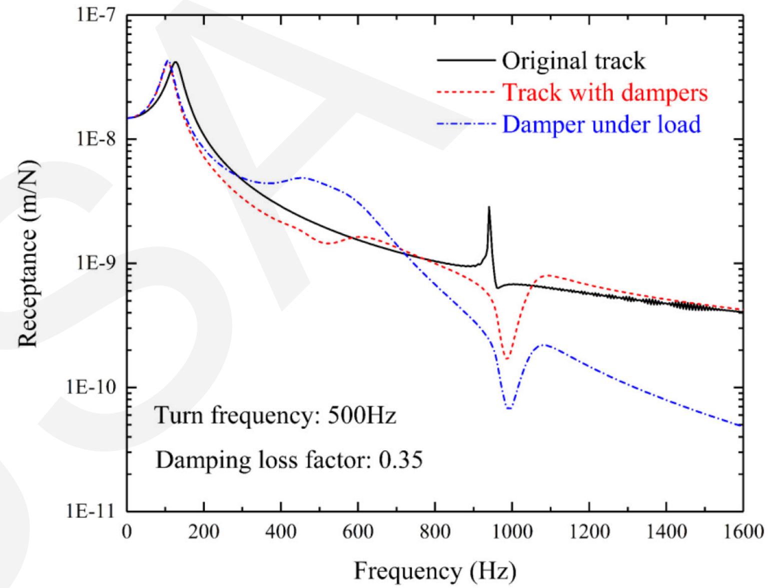


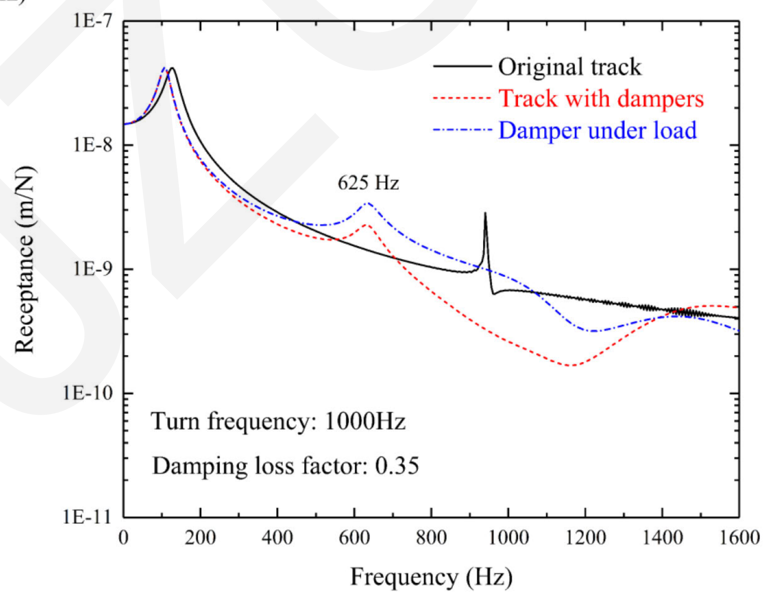
Fig. 23 Dispersion curves of the track with dampers tuned to 1000 Hz but with the mass and stiffness doubled (bounding frequencies are 94, 528, 826, 900, 1044, and 1136 Hz)

Track Responses



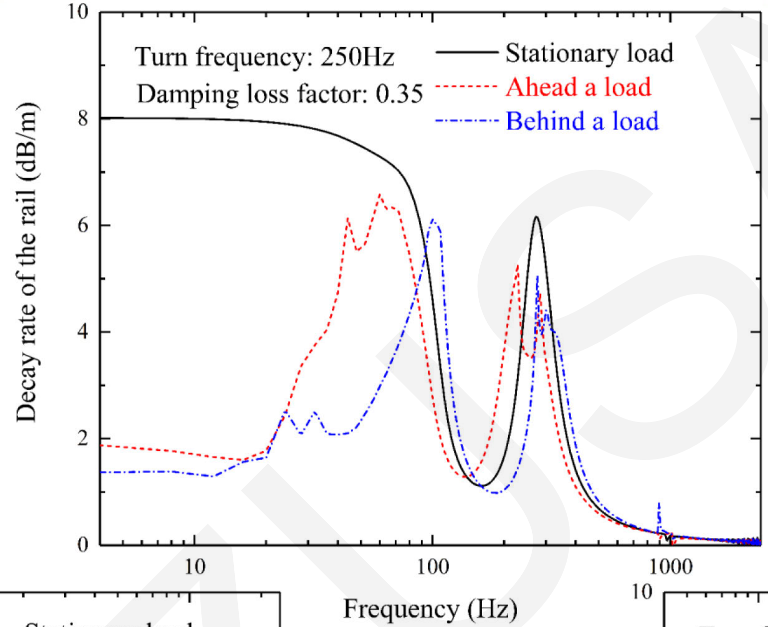


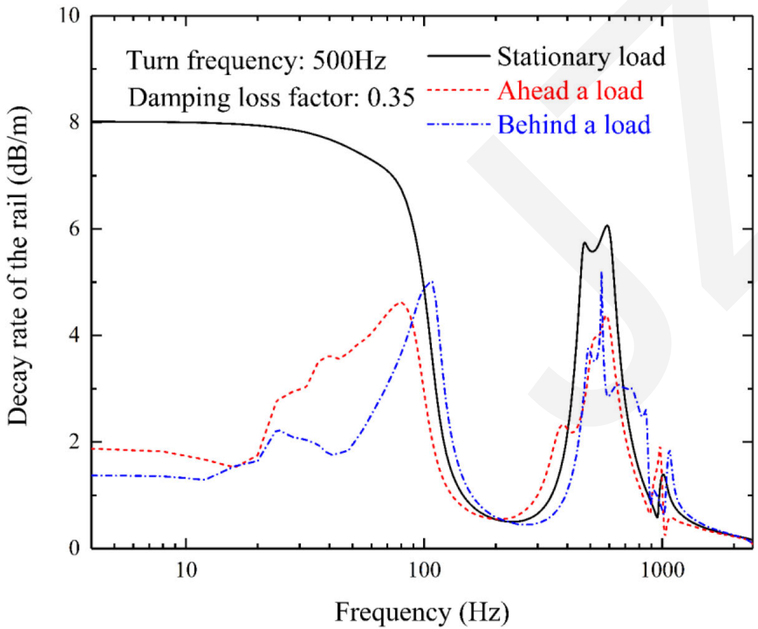
- ❑ Firstly, for frequencies lower than a certain value, the damper vibrates more strongly than the rail, and this value increases with the tuned frequency of the dampers.

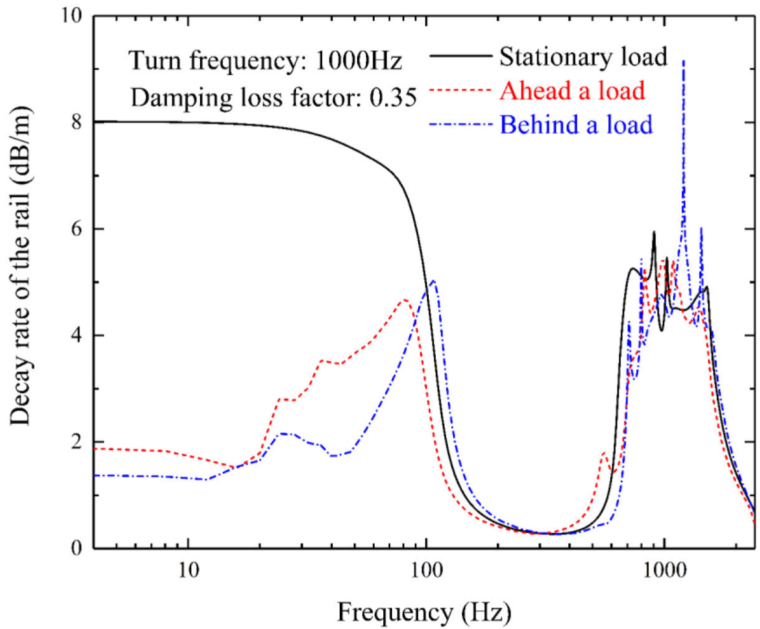


- ❑ Secondly, The dampers, rather than the fasteners, behave like pins to the rail at a frequency just below 1000 Hz.

Vibration Decay Rate

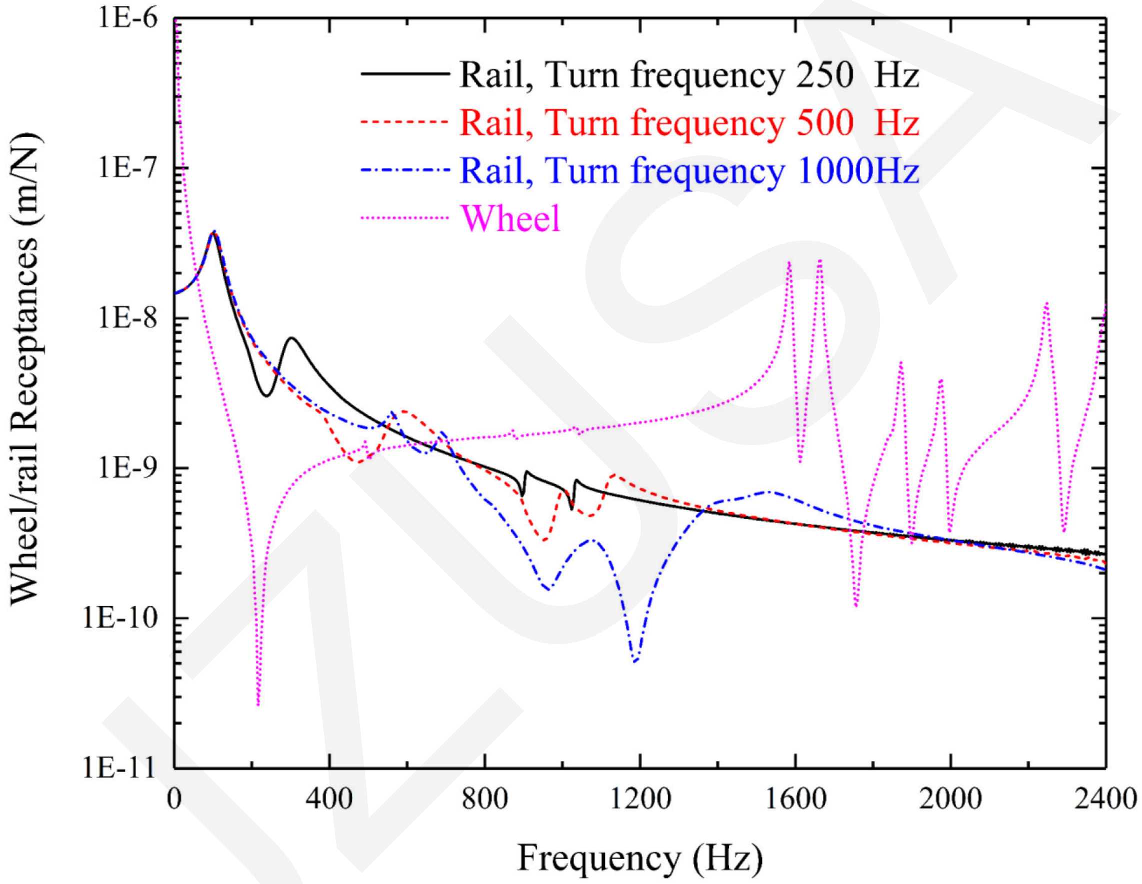






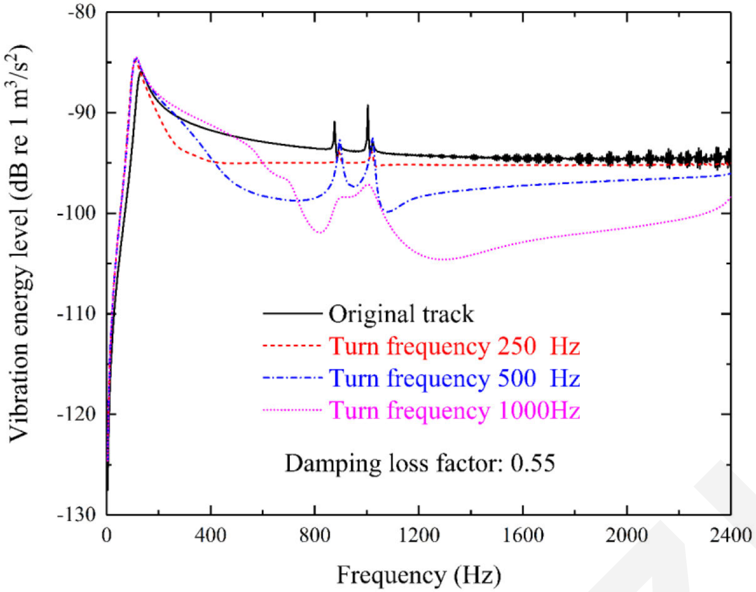
- ❑ The load speed reduces the decay rate of the rail to some extent.

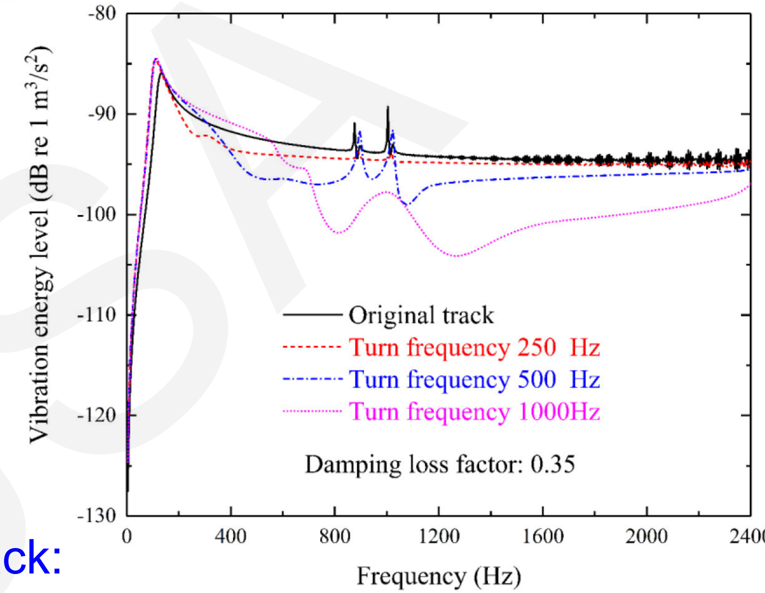
Wheel/rail Receptances

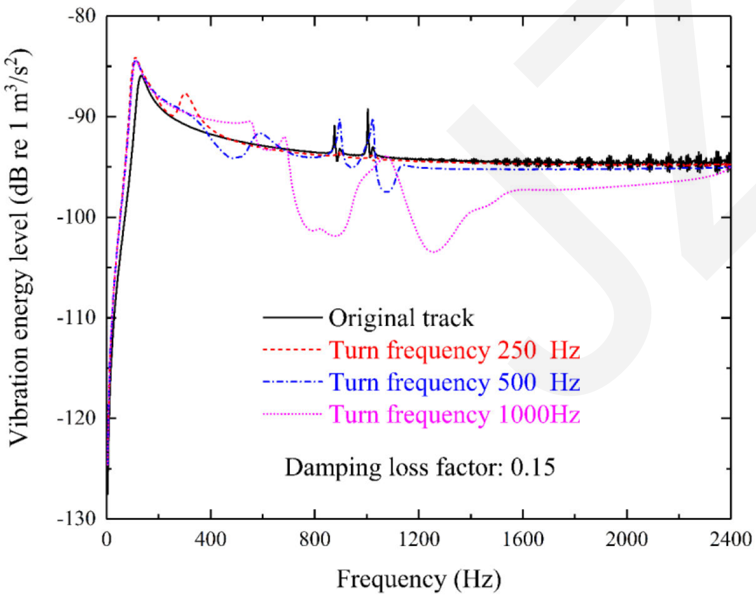


- For most of the frequencies higher than about 700 Hz, the displacement of the wheel is much higher than that of the rail. For a given wheel/rail roughness, the wheel/rail force does not change significantly with rail dampers.

Vibration Energy Level







Original track:

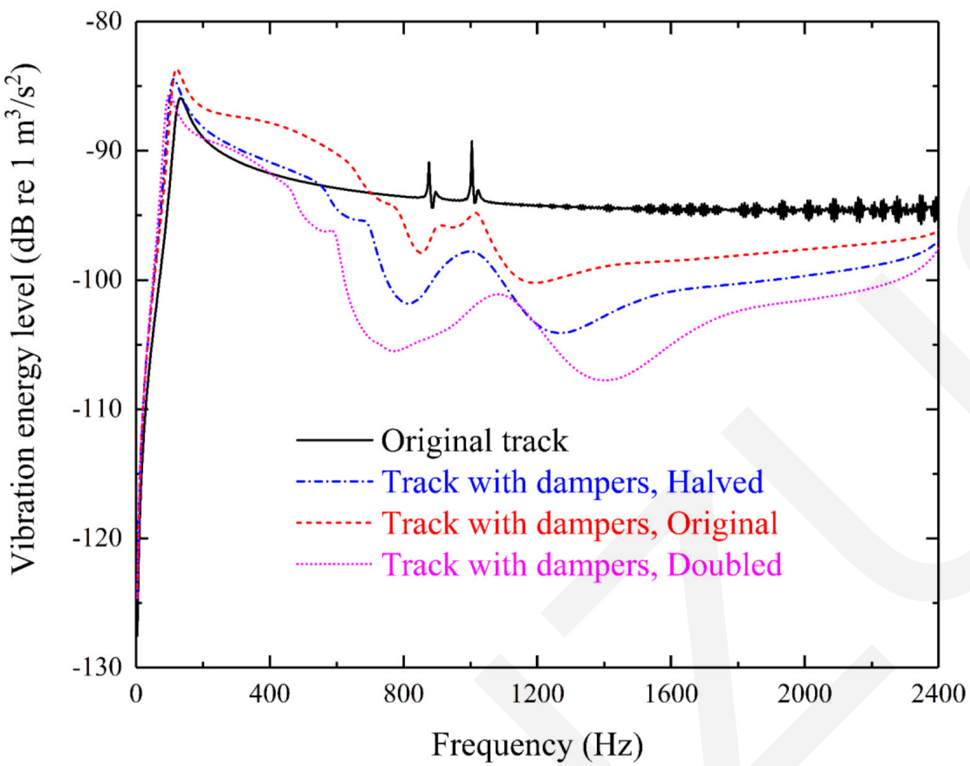
$$E = 10\log_{10}\int_{-20L}^{20L} |\dot{w}(x',0)|^2 \, \mathrm{d}x',$$

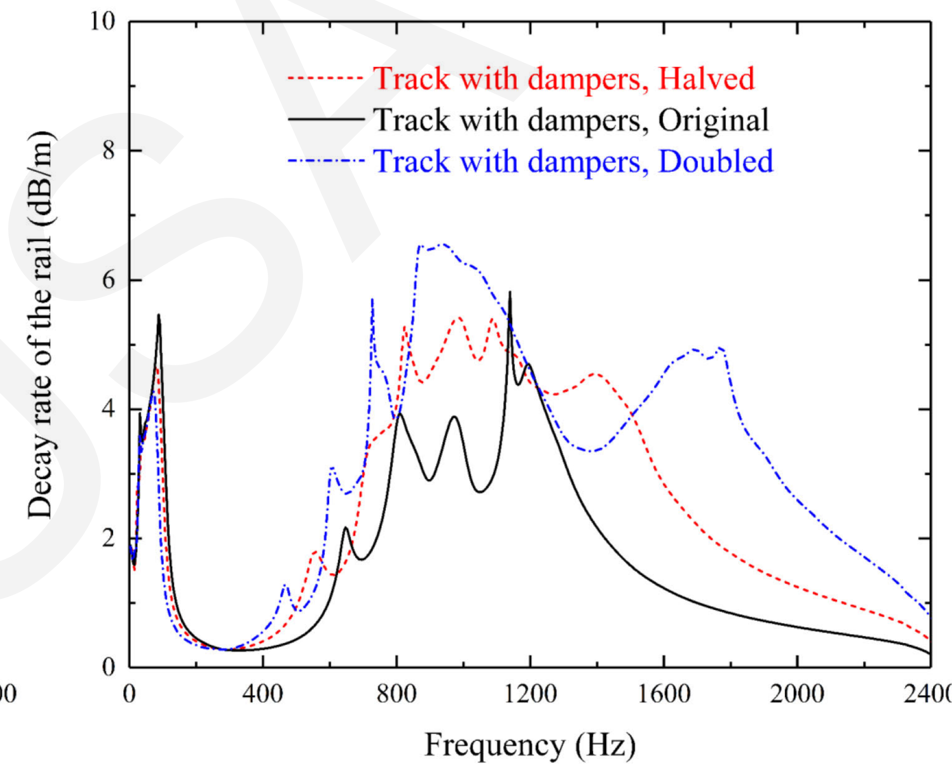
With damper:

$$E = 10\log_{10}\left[\int_{-20L}^{20L} |\dot{w}(x',0)|^2 \, \mathrm{d}x' + L\sum_{j=-20}^{20} |\dot{w}_{\mathrm{D}j}(0)|^2\right],$$

- (1) For frequencies higher than about 700 Hz, all the damper designs can reduce the track vibration energy level to some extent, and dampers tuned to 1000 Hz are much better than the other two damper designs;
- (2) Damping is beneficial in reducing the vibration energy level, however, its effect is not as strong as the tuned frequency;
- (3) To be effective, dampers tuned to a frequency much lower than the pinned-pinned frequency of the original track must have a high damping.

Effect of damper mass





- The frequency range in which the decay rate is higher than a given value is enlarged by increasing the damper mass and stiffness, and this enlargement is mainly achieved from the high frequency side.

- There is still no effect on vibration energy level reduction for low frequencies even when damper mass and stiffness are doubled.

Conclusions

- Physically, installation of rail dampers does not change the period of the track, but adds mass to the track and also creates constraints to the rail at mid-spans. Dynamically, installation of rail dampers introduces new bounding frequencies and stop bands, increasing the total width of stop bands and the vibration decay rate.

- For a given load frequency, the rail vibration decay rate is different between a stationary load and a load moving at high speed, and in general, the decay rate for a moving load is lower than that for a stationary load. This is particularly true for load frequencies less than the first bounding frequency of the original track.

- In terms of the total width of stop bands, the vibration decay rates of the rail and dampers, and the vibration energy level of the track, the damper should be tuned to a frequency close to the pinned-pinned frequency of the original track, and the mass and stiffness of the damper should be as high as possible. For the track considered in this paper, dampers tuned to other lower frequencies (but not too low compared to the pinned-pinned frequency) are also possible, if a high loss factor can be ensured for the dampers.