Estimation of Vibration Power Flow to and Sound Radiation from a Railway Concrete Viaduct Due to Vehicle/Track Interaction

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Summary

The structure-born noise from a railway concrete viaduct due to vehicle passage is predicted via analysis of vehicle-track interaction, vibration power flow into and sound radiation from the structure. The dominant component of the structure-born noise from a concrete viaduct is below 100 Hz, which is associated with the vehicle's unsprung mass oscillating on the track stiffness, and irrelevant to train speed. Use of soft rail pad/fastener can effectively reduce the structure-born noise via reducing the dynamic force transmission to the viaduct, and thus, the vibration power flow. A reduction of 15 dB (A) in sound power radiated from a concrete viaduct can be achieved by replacing 60 MN/m pad with 6 MN/m rail fastener.

1 Introduction

Concrete viaduct structure is widely used for the elevated lines in Shanghai Metro Light Rail System. Although its construction is easier and costs less than the underground tunnel, the sound radiated from the viaduct structure during train passage causes environmental noise problem. The predominant component of radiation from a concrete viaduct is usually below 100 Hz, and can propagate over long distance. As the size of a concrete viaduct is large, the sound radiation from the structure is difficult to control except by reducing its vibration energy level, e.g. using soft rail pad/fastener to decrease the dynamic force transmission from the wheel/rail interface to the structure.

In this work, the vehicle-track dynamic interaction due to a relative displacement excitation is simulated using a slab track and a simplified vehicle model. The force in the rail pad is calculated and used as the excitation to the viaduct structure. The mobility matrix of the viaduct structure is determined using the finite element
software ANSYS. The vibration power flow injected into the structure caused by roughness excitation is calculated, provided the viaduct is composed of concrete plates, and the distribution of vibration energy among the plates is determined according to their mobility or thickness. The radiation ratio is calculated for each plate of the viaduct using the method described by Xie, et al.[1]. The sound power radiated is predicted from the viaduct structure. Using the model and the methodology developed, the effects of soft rail pad/fastener are estimated on reduction of the structure-born noise from a concrete viaduct.

2 Vehicle-Track Interaction and Excitation to Viaduct

Considering a slab track laid on a viaduct, the rail is modelled as an Euler beam on an elastic foundation. In the audible frequency range, as the vibration displacement is much smaller than the deformation of medium-soft (≤200MN/m) rail pad, the concrete viaduct can be simplified to a rigid foundation in the track model. To calculate the wheel-rail interaction force, an eighth of vehicle is employed to interact with the track, see Fig. 1.

The wheel-track interaction force due to a relative displacement excitation is calculated using the following formula

$$ F_c = -\frac{R}{\alpha_v + \alpha_c + \alpha_t}, \quad (2.1) $$

where $R$ is the combined roughness spectrum on the wheel and rail tread, $\alpha_v$ is the receptance of vehicle, $\alpha_c$ is the contact receptance, which is inverse of the linearised contact stiffness, $1/k_H$ and $\alpha_t$ is the track receptance.

The force in the rail pad is calculated and regarded as the excitation to the viaduct structure, and can be determined according to the pad stiffness and rail displacement due to the roughness excitation.

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Fig. 1. Track model on viaduct