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AN EXPLICIT INTEGRATION FINITE ELEMENT METHOD FOR IMPACT NOISE GENERATION DUE TO WHEEL FLAT

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Due to the requirements on improvement in passengers' comfort and in living environment standard, the noise problem of railways has attracted more and more attentions. Many studies on railway noise have been carried out since the early 1970s and great progresses have been made during the past 40 years. It has been widely accepted that, at conventional travelling speeds, the generation mechanism of the railway noise is mainly due to wheel and rail interaction [1]. According to different wheel/rail contact forms, the railway noise can be divided into three categories: rolling noise, impact noise and curve squeal noise. The knowledge about impact noise, owing to its complex contact conditions over discontinuities of the rail/wheel surfaces and the possibility of loss of contact, lags far behind that of the other two.

An early comprehensive study on impact noise was published by Vér et al. in 1976 [2], before which the studies focused on test and were largely qualitative. In reviewing the prior work, Remington [3] introduced the models and method of Newton and Clark for contact force calculation [4] into analysis of impact noise to tackle non-linear contact problem, pointing out a new direction for impact noise study. In addition, the geometric discontinuities of the rail and wheel surfaces were replaced with an average roughness spectrum in frequency domain as the excitation inputs for the calculation of impact vibration and noise. By combining time-domain impact force calculation model with frequency-domain rolling noise prediction method, Wu and Thompson in [5] developed a hybrid method for impact noise reproduction, which managed to solve the problem of non-linearity, but due to the simplification of the analytical model, the analysing frequency was limited to 5 kHz. On the basis of this hybrid method, a more complicated numerical finite element (FE) track model was developed in [6] to predict the high frequency response of track system excited by wheel-rail dynamic impact, but the simplification of rigid mass wheel and the non-Hertzian contact still caused deviations especially at high frequency.

Instead of using simplified models of wheel and track, and the assumption of Hertzian or non-Hertzian contact, Yang et al. presented a full finite element wheel-track interaction model to predict the impact noise generated by squat[7]. The wheel, the rail and other track

components are modelled with finite elements in three dimensions, where necessary and appropriate. Realistic contact geometry, including geometric irregularities in the contact surfaces is considered. The integration is performed in the time domain with an explicit central difference scheme. For convergence, the Courant time step condition is enforced, which, together with the detailed modelling of the structural and continuum of the wheel/track system, effectively guarantees that vibration frequency of 10 kHz or higher is reproduced. By making use of the calculated velocities and pressures of the vibrating surfaces, the boundary element method (BEM) based on Helmholtz equation is adopted to transfer the vibration of the railway system into acoustic signal.

As another common type of track discontinuity and exciting source of impact noise, wheel flat is considered with realistic geometry in this paper. The flat is applied to the originally smooth tread of wheel model as shown in Fig. 1. The following improvements are made on the basis of the wheel/rail contact model in [7]: Boundary conditions at rail ends are optimised to reduce the errors introduced by reflections from the artificial boundaries; As another main source of sound emission, sleepers under the wheel rolling region are remodelled with actual geometry and fine mesh; To meet the requirement of high frequency sound prediction by BEM, the mesh of wheel web is further refined. Finally, the track properties and results of vibration and noise are validated respectively by field hammer tests and pass-by tests. The configuration of pass-by measurement can be seen in Fig. 2. Compared to results from previous models, the noise frequency range which could be predicted with desired accuracy is effectively extended.

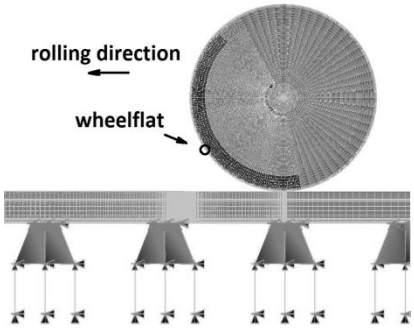

Fig.1 FE Wheel-Rail Interaction Model

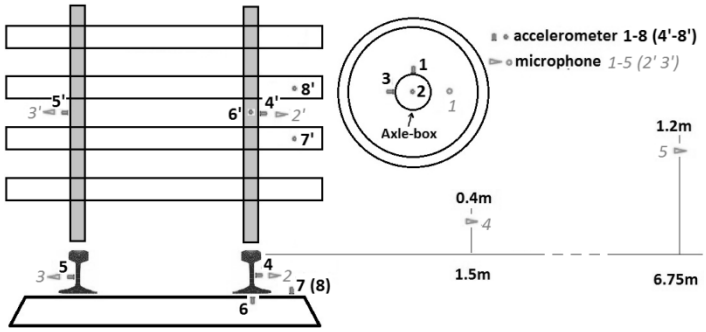

Fig.2 Sensors Distribution of Pass-by Test

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