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A novel model for determining the amplitude-wavelength limits of track irregularities accompanied by a reliability assessment in railway vehicle-track dynamics

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ABSTRACT

The loads on a vehicle and the vibrations transmitted to track infrastructures due to the operation of rolling stocks are mainly determined by the irregularities of the track profile. Hence, it is rather important to ascertain the limits of track irregularities, including amplitudes and wavelengths, to guarantee the dynamic performance of running vehicles and guiding tracks. Furthermore, the operation and management levels as well as irregularity status for different railways are highly dissimilar. Therefore, it is a necessary to conduct a reliability assessment for a specific railway line. In the present work, a large amount of measured track irregularities are concentrated as a group form of the track irregularity power spectrum density. A track irregularity inversion model is presented to obtain realistic representations of track profile deformations with information regarding amplitudes, wavelengths and probabilities. Then, the methodologies for determining the limits of track irregularities and achieving a reliability assessment are presented by introducing the probability density evolution method and development of a Wavelet-Wigner-Hough method. Using the vehicle-track interaction model, numerical studies for confirming the limits of track irregularities and evaluating the reliability of the dynamic performance of the vehicle can be conducted to provide valuable suggestions. This paper offers new possibilities for studying the limit amplitudes, characteristic wavelengths of track irregularities as well as corresponding reliabilities when a railway vehicle runs under different track geometric conditions.

1. Introduction

Track irregularities are commonly viewed as the most essential element in aggravating wheel-rail interactions, reducing the maintenance cycle and life of railway tracks, deteriorating riding comfort and threatening traffic safety, and they are therefore very important in railway dynamics. Hence, researchers have attached much attention to the supervision of the track geometric status. To characterize the status of track irregularities, the irregularity amplitude is mainly used as the controlling factor [1–3], but without taking the influence of the wavelengths of the irregularities into account. However, the characteristic wavelengths have a dramatic impact on the interactions between railway vehicles and tracks, especially when the irregularity amplitudes are at the boundary conditions.

Normally, it is possible to ascertain the limit irregularities of tracks using dynamic simulations and measurements. However, the track irregularity levels are closely linked to the levels of railway usage. Therefore, railway workers hope to be informed of the

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reliability regarding running safety, ride comfort and quality of maintenance for a specific railway line when the irregularities actually reach the track deformation limits.

Previous work involving track irregularities mainly analyzed the vehicle-track dynamic interactions against different types of track irregularities, such as squat-like cracks [4] and random irregularities [5,6]. Yu et al. [7] employed the number theory method (NTM) and probability density evolution method (PDEM) to identify the random vibration characteristics of a train-bridge system excited by rail irregularities. Generally, the management of track irregularities is regarded to be dependent on the irregularity amplitudes at certain chords or wavelength ranges in different countries around the world. However, the principles and methodologies used for setting the irregularity limit values are currently rarely reported. Tian et al. [8] utilized the track irregularity power spectrum density (PSD) as the input of the vehicle-track coupled system and presented a method for estimating the track irregularity limits without an in-depth study of the characteristic wavelengths corresponding to the limit values.

In the current paper, a comparatively perfect approach for obtaining the amplitude-wavelength limits of track irregularities and reliabilities of a vehicle-track dynamic system is presented using the methodologies of dynamics and time-frequency analysis. The modelling framework is constructed using the following components:

(1) the three-dimensional (3-D) time-domain vehicle-track interaction model enables the study of the dynamic responses of a vehicle-track system excited by random (or definitive) track irregularities.

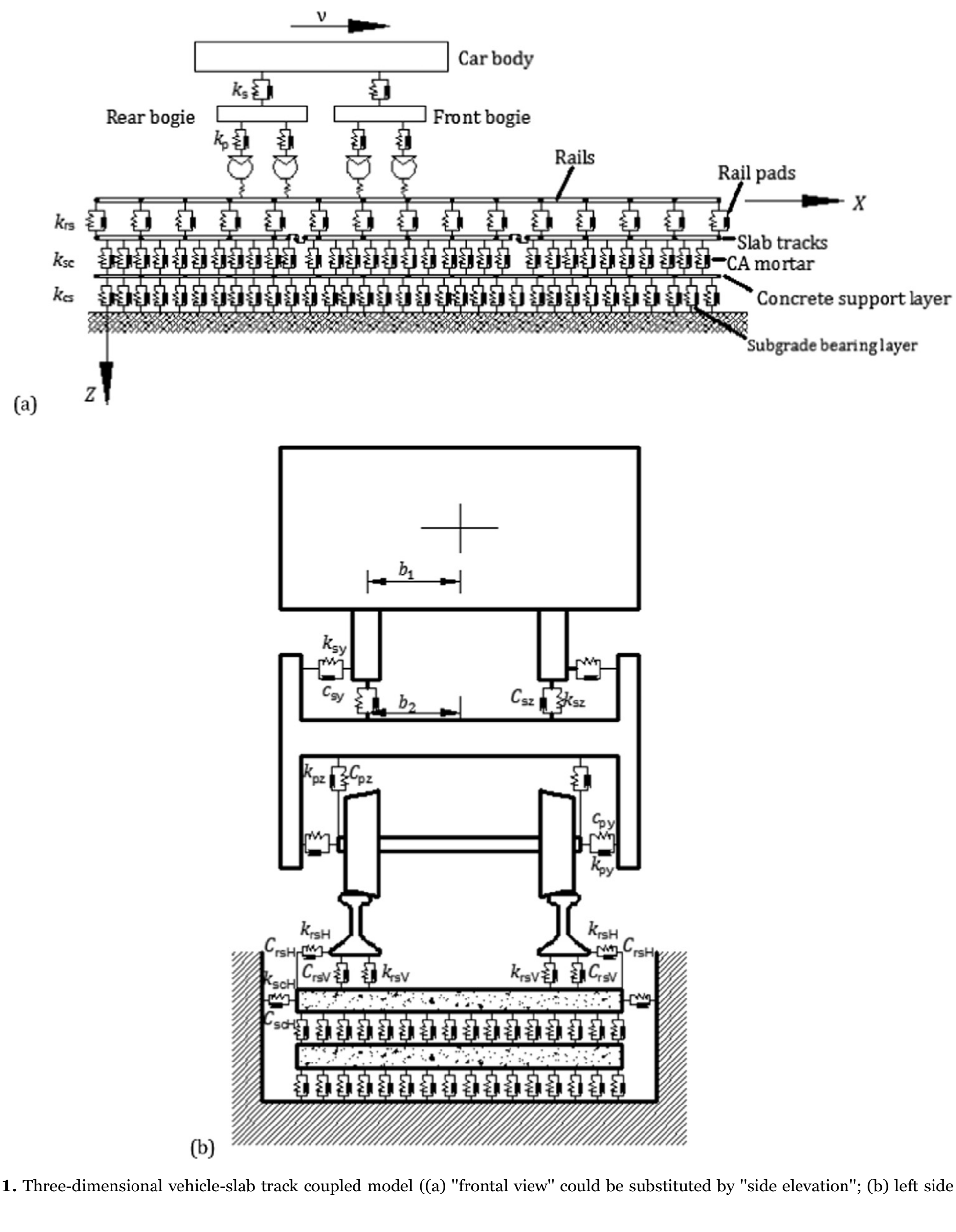

Fig. 1. Three-dimensional vehicle-slab track coupled model ((a) "frontal view" could be substituted by "side elevation"; (b) left side view).