Detection of rail corrugation using axle box acceleration measurement and signal processing

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EXTENDED ABSTRACT

1 Introduction

Rail corrugation is a wave type wear that forms longitudinally along the rail with a variety of wavelengths, which often appears in metro lines, urban railways and high-speed railways. The corrugation on the track results in remarkable vibrations, noises that deteriorates the wheel and track qualities. To ensure the safety of the running vehicles and passenger comfort, it is necessary to measure the wavelength and depth of rail corrugation for track maintenance.

Using unexpensive onboard measurement systems, such as axle box accelerometers (ABA), have been developed in the railway industry Bocciolone et al. [1] concluded that the direct fastening tracks showed the best correlation performance between the ABA measurements and rail corrugation levels, when comparing to the ballast and massive tracks. *Ensemble empirical mode decomposition* and *support vector machine* are applied to estimate the wavelength and depth of the corrugation using wheel vibration accelerations [2], which are generated by numerical simulation. Liu et al. [3] developed a methodology to determine the maintenance limit for the rail corrugation with the help of ABA spectrum and the transfer function of rail corrugation to axle box acceleration.

This paper demonstrates that it is possible to detect corrugation based on the ABA measurements and signal processing. The recorded longitudinal and vertical ABA signals of the scaled vehicle and the information about the position and the vertical rail profiles in a scaled track are used. Time-frequency analysis of ABA signals are performed to identify the wavelength of the corrugation along the track.

2 Experimental design

The experiments are carried out on a 1:10 90-m long scaled track and an instrumented scaled vehicle [4] at the University of Seville. The scaled track includes straight sections, transitions and curves. The straight segment, includes 3.6 m corrugation rails. As shown in Fig. 1 (a), the corrugation profile is machined as a periodic profile composed of four different harmonics, with wavelengths 5 mm, 10 mm, 20 mm and 30 mm. The amplitudes associated with corresponding wavelengths are 30 μm, 45 μm, 60 μm, and 75 μm. Figure 1 (b) shows a detail of the corrugated segment machined in the scale track.

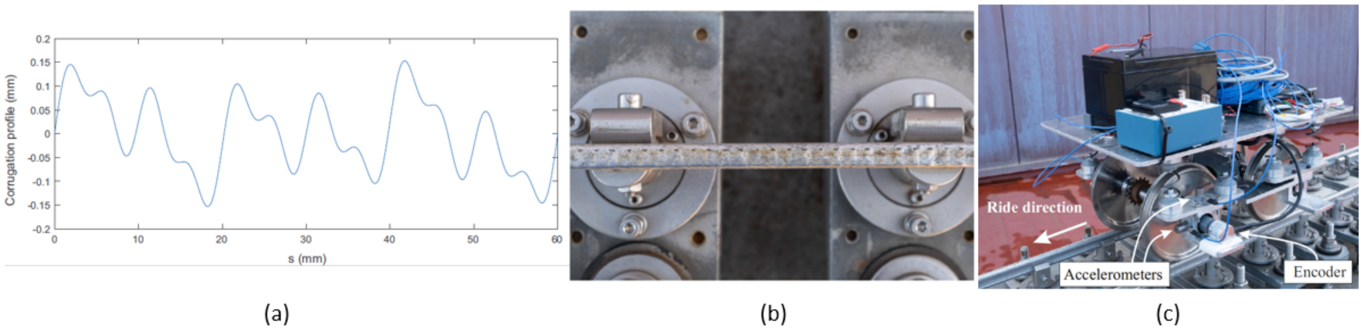
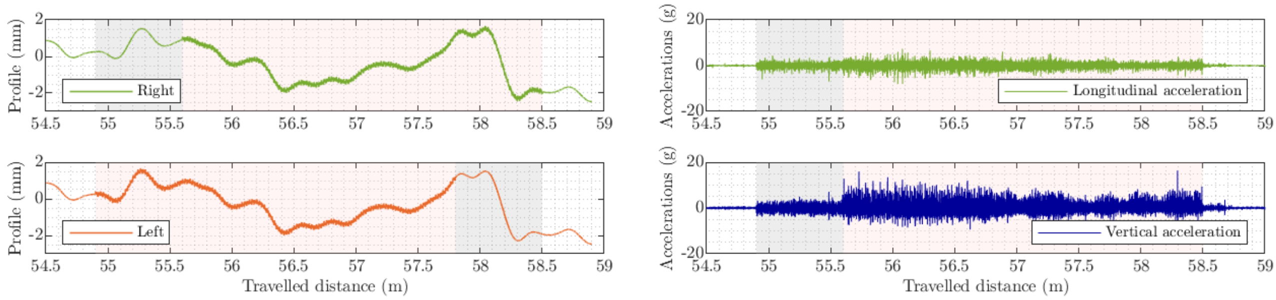


Figure 1: (a) Profile of designed corrugation, (b) Real corrugation in scaled track, (c) Scaled vehicle.

As it can be observed in Fig. 1 (c), the scaled vehicle is a single bogie consisting of two rigid wheelsets, a primary suspension with eight helical springs connecting both wheelsets with the bogie frame. To measure the acceleration in the axle-box, four uniaxial piezoelectric accelerometers have been installed in both axle-boxs in the front wheelset of the vehicle: two of them in each axlebox, in vertical and longitudinal direction. Additionally, one high precision encoder is employed to register rotation of the wheels, from which the distance travelled by the vehicle, s, and its forward velocity, V, can be estimated. All the experimental data are acquired and synchronized by a data acquisition system mounted on the vehicle, using an acquisition rate of 5K Hz.

3 Results

Figure 2 (a) shows the profiles of the left and right rails. The corrugated segment at left rail occupies the track length from $s = 54.9$ m to 57.8 m, wheares the right rail is corrugated from $s = 55.6$ m to 58.5 m. The pink areas show the corrugated segment in both rails. The grey area represent the length of the track in which only one of the rails is corrugated. The white areas represent no corrugation.

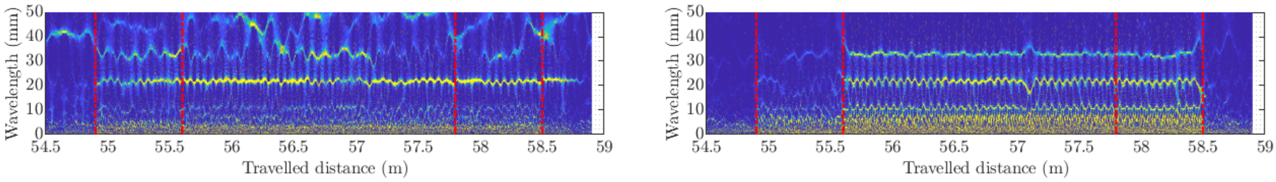


(a) (b)

Figure 2: (a) Vertical profiles at left and right rails, (b) The ABA measurement on the right axle-box with forward velocity $V = 0.5$ m/s in vertical and longitudinal directions

Figure 2 (b) show the space history of the acceleration on the right axle box. The vehicle is running with constant forward velocity $V = 0.5$ m/s. The corrugation on the left rail from $s = 54.9$ m to $s = 55.6$ m in grey areas (see 2 (a)) can be observed in the signals of the right rail in both vertical and longitudinal signals. In the longitudinal ABA, it is easier to observe the vibration differences between the one influenced by the left rail corrugation (grey) and the right one (pink).

To better understand the corrugation-induced vibration characteristic of axle box, the Wavelet Synchorosqueezed Transform (WST) [5] that displays the time domain history of space wavelength is illustrated in Fig. 3. In the vertical ABA, the vibrations that are dominated by the corrugations with wavelengths of 10 mm, 20 mm and 30 mm are stronger than the longitudinal ABA. These dominant wavelengths observed in the figures are determined by using vehicle speed divided by the excited frequency. In addition, the vibration transition between the left corrugation and the right one is better detected by longitudinal ABA.



(a) (b)

Figure 3: The time frequency analysis of the ABA measurements by using Wavelet Synchorosqueezed Transform (WST). (a) Longitudinal direction (b) Vertical direction.

4 Conclusion

In this paper, the wavelength of the corrugation is detected by using the ABA measurement and its time frequency analysis. Compared to longitudinal ABA, the vertical ABA can better detect the vibration wavelengths that are dominated by corrugation. In addition, the transition between the vibrations that are affected by the other rail corrugation and by its own rail corrugation, can only be determined by using the vertical ABA.

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