Monitoring the Tube: rail roughness derivation from axle vibration

CSIC Cambridge Centre for Smart Infrastructure & Construction

Introduction

Noise and vibration is a major concern for railway operators as it can disturb nearby homes and buildings. One cause is roughness and corrugation on the rail's rolling surface (Fig. 1), which worsens over time. Currently, railways are manually inspected, but it is more efficient to use sensors on in-service trains (e.g. passenger trains) to monitor rail roughness.

Fig. 1. Severe rail corrugation

Aim

To monitor the condition of a rail network using sensors fitted to the axle boxes of passenger trains.

- Accelerometers measure the wheels' vertical acceleration as they ride over the roughness on the rail (Fig. 3).
- The acceleration signal needs to be processed to derive rail roughness and separate it from wheel roughness.

Signal processing

Existing: Calculate RMS of signal over 50 m sections of track

New: Calculate PSD spectra of signal at each track section → Estimate track stiffness and damping → Separate wheel and rail roughness → Calculate rail roughness spectrum

Problem: ABA varies not only with rail roughness but also with weather conditions that affect track stiffness.

West Midlands Metro

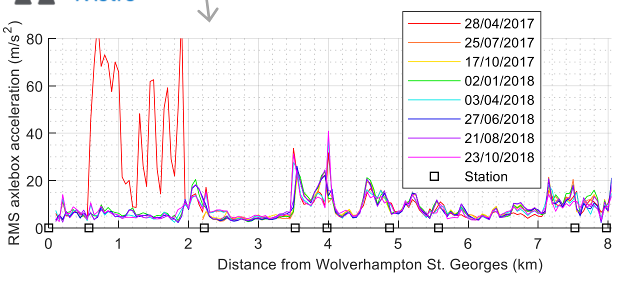

Fig. 2. RMS axle-box acceleration measured over 18 months on the West Midlands Metro tram network
(track section at 0.5-2 km was replaced after 28/04/2017)

Deriving rail roughness

To derive roughness from axle-box acceleration (ABA), we need to know the dynamic properties of the train and track (Fig. 3).

- Track stiffness is the least known and most varying. It can be extracted from ABA by curve-fitting the roughness–ABA transfer function to its resonance peak in the spectrum of ABA (Fig. 4).
- Wheel roughness is separated from rail roughness by comb-filtering ABA.

The new processing is tested to derive rail roughness from ABA measured on the London Underground. This is compared in Fig. 5 against rail roughness measured using a CAT trolley, showing good accuracy at most wavelengths.

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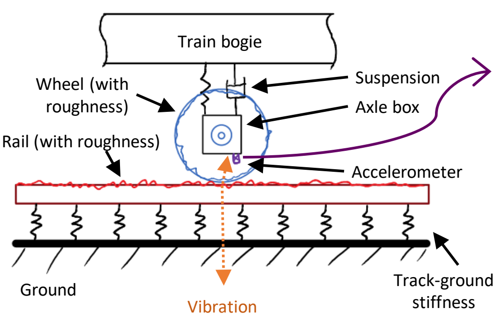


Fig. 3. Physical model of track and vehicle with axlebox accelerometer

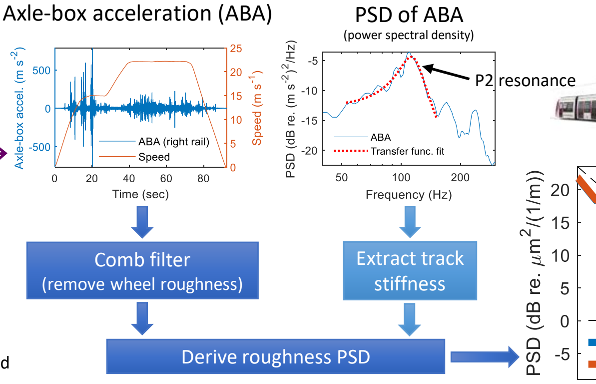
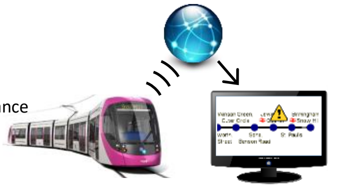


Fig. 4. Separating wheel and rail roughness, and identifying track stiffness



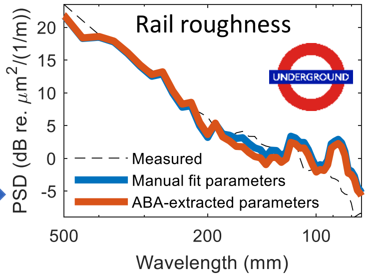


Fig. 5. PSDs of rail roughness

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