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| **Project G** | **Noise and vibration model developments and improvements** |
| Part of | **Research Challenge 3, NOISE-LESS TRACK** |
| Project timing | Started June 2015 |
| More information from | Professor David Thompson |
| Project partners | Pandrol track systems<br>DB Systemtechnik<br>Sicut Enterprises Ltd |
| Associated projects | EU project In2Rail, H2020-MG-2014: Grant agreement 635900<br>WP3, Deliverable 3.2: T2F wrote section 5 on curve squeal noise and contributed to Chapter 6 on impact noise at crossings |

**Project aims**

Theoretical models for both rolling noise and ground-borne vibration are required to support the development of a low-noise, low-vibration track. Current models require further development to allow them to take account of the expected mitigation measures. This project aims to establish the fundamental basis and principles for the design of a low-noise, low-vibration track by

1. extending models of rolling noise to improve the sound radiation estimates
2. implementing poro-elastic models to account for absorptive materials including ballast
3. developing and extending models for ground-borne vibration
4. developing new hybrid models of impact noise combining vehicle dynamics and acoustic models
5. using the improved models to study potential design options for reduced noise and vibration.

**Progress to date**

**Project aim 1.** The state-of-the-art model TWINS has been enhanced to improve the calculation of noise radiation from the rail and sleeper in the presence of the ground, and the influence of ballast absorption [G12, G13, G14]. These results have been validated by laboratory measurements on a $^1/_5$ scale rig (Fig.G1) using the $^1/_5$ scale ballast developed for Project A. The improved model allows a better evaluation of differences between the noise from slab and ballasted track. A new track vibration model has also been developed that considers deformation of the rail cross section as well as the discrete supports, which previous noise models generally neglect. Excellent agreement with field measurements has been found.

*Fig.G1: Scale model*

**Project aim 2.** A modelling method to allow for the effect of porous absorbing materials has been implemented in existing in-house 2.5D Finite / Boundary Element software. The formulation includes vibration of the frame (allowing for sound radiation) as well as the acoustic properties of the air in the pores (i.e. its absorptive properties). This has applications to (i) ballast absorption and vibration, where the challenge is to represent a surface that is both absorbing and vibrating (something that cannot be achieved in a conventional boundary element formulation); and (ii) absorptive treatments for slab track.

**Project aim 3**. Ground vibration models are usually based on the assumption that the roughness on the two rails is identical. Analysis of measured roughness data has shown that, for wavelengths less than about 5 m, the two rails are largely uncorrelated. The effect of this on ground vibration has been investigated using an updated model that includes rotation of the sleeper and the wheelset as well as vertical vibration [G15]. Semi-analytical ground vibration models, developed in EPSRC project MOTIV, are being extended to include coupling between ground and buildings for simple cases (Fig.G2). A study of critical velocities using a 3D FE track/ground model included an assessment of the effect of ground non-linearities [G16, G17].

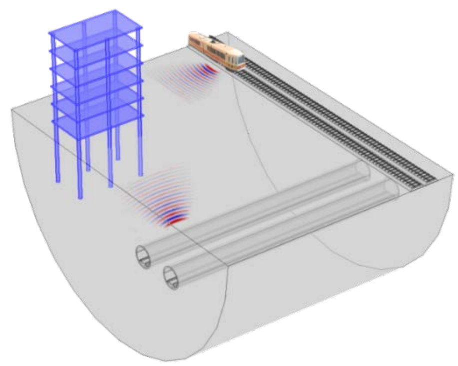

*Fig.G2: Schematic view of cases available in MOTIV software.*

**Project aim 4.** A hybrid time / frequency domain model for ground vibration has been developed [G18]. Predictions of impact noise from switches have been generated, based on a combination of time domain vehicle dynamics models and frequency domain models for noise. Results have been compared with field measurements at Lorelei, Germany (In2Rail).

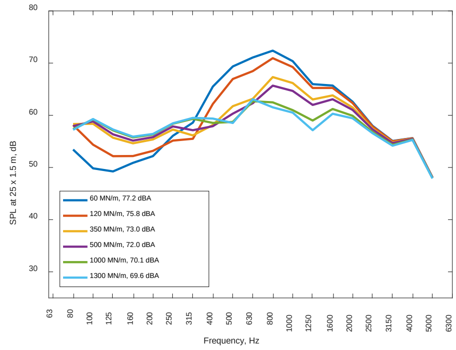


*Fig.G3: Effect of rail pad stiffness on rolling noise.*

**Project aim 5.** Preliminary parametric studies have been carried out to assess design options for reducing noise and vibration, including changes to rail pad stiffness and the use of noise barriers or rail shields. Softer rail pads generally reduce vibration but increase noise (Fig.G3).

**Planned further work** (Programme objectives in brackets)

- Laboratory measurements of the dynamic stiffness of track components (3.2)
- Development and testing of hybrid models for noise and vibration from switches, and validation against field measurements (3.1, 3.3, 3.4)
- Additional parametric studies to include USPs, rail dampers, rail shields, slab track absorptive treatments, low barriers, plastic sleepers and different fastener designs (3.3)
- Laboratory tests at $^{1}/_{5}$ scale to verify the performance of optimized designs (3.3)
- Use of data to optimise track system performance (1A.4)
- Incorporation of results into integrated performance and maintenance models (3.6).

**Journal papers**


[G12] X. Zhang, G. Squicciarini, D.J. Thompson, 2016. Sound radiation of a railway rail in close proximity to the ground. *Journal of Sound and Vibration* **326**, 111-124. doi:10.1016/j.jsv.2015.10.006

[G13] X. Zhang, D.J. Thompson, G. Squicciarini, 2016. Sound radiation from railway sleepers. *Journal of Sound and Vibration* **369**, 178-194. doi:10.1016/j.jsv.2016.01.018

[G14] X. Zhang, D.J. Thompson, H. Jeong, G. Squicciarini, 2017. The effects of ballast on the sound radiation from railway track. *Journal of Sound and Vibration* **399**, 137-150. doi:10.1016/j.jsv.2017.02.009

[G15] E. Ntotsios, D.J. Thompson, M.F.M. Hussein, 2017. The effect of track load correlation on ground-borne vibration from railways, *Journal of Sound and Vibration* **402**, 142-163. doi:10.1016/j.jsv.2017.05.006

[G16] J.Y. Shih, D.J. Thompson, A. Zervos, 2016. The effect of boundary conditions, model size and damping models in the finite element modelling of a moving load on a track/ground system. *Soil Dynamics and Earthquake Engineering* **89**, *12-27. doi:10.1016/j.soildyn.2016.07.004*

[G17] J.Y. Shih, D.J. Thompson, A. Zervos, 2017. The influence of soil nonlinear properties on the track/ground vibration induced by trains running on soft ground. *Transportation Geotechnics* ***11**, 1-16. doi:10.1016/j.trgeo.2017.03.001*

[G18] S.G. Koroma, D.J. Thompson, M.F.M. Hussein, E. Ntotsios, 2017. A mixed space-time and wavenumber-frequency domain procedure for modelling ground vibration from surface railway tracks. *Journal of Sound and Vibration* **400**, 508-532. doi:10.1016/j.jsv.2017.04.015


**Related publications**