IMAGINE – RAIL NOISE SOURCES

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1 INTRODUCTION

The European Commission Directive 2002/49/EC relating to the assessment and management of environmental noise states that "Common assessment methods for the determination of L_{den} and L_{night} shall be established by the Commission…" Such common methods are not yet in place, and therefore the first round of noise mapping required by the Directive in 2007 will be carried out either with appropriate national methods, or with EC-recommended interim methods. For railways the interim method is the Dutch national scheme "Reken- en Meetvoorschrift Railverkeerslawaai '96"[1]. In the UK, the national method "Calculation of Railway Noise 1995"[2] (CRN) may be applied in its place, possibly modified to take into account the effects of rail head roughness on rolling noise emission[3].

In order to fulfil the Directive's requirement to produce common assessment methods to supersede the interim or national procedures, the European Commission has provided funding for two research projects. The first, under the 5th Framework Research, Technological Development and Demonstration programme, is the HARMONOISE project. This commenced in 2001 and will be complete in late 2004. It focuses on characterisation of road and rail noise sources and, separately, on the propagation of sound taking into account meteorological conditions. By separating source from propagation, the propagation models can be applied to a range of sources and not just road and rail. The second project, under 6th Framework funding, is IMAGINE. This project commenced late in 2003 and will be complete at the end of 2006. IMAGINE extends the considerations of HARMONOISE to industry and aviation, and is designed to provide guidelines, examples and databases for quick and easy implementation of the harmonised noise computation methods emerging from the two projects.

This paper concentrates on the current activity on railway noise within the IMAGINE project, with reference to the earlier work within HARMONOISE which has formed its foundation.

2 RAILWAY ENVIRONMENTAL NOISE SOURCES

Environmental noise from railways can be subdivided broadly into dominant contributions from traction (engines, fans, gears etc) up to around 50 km/h, rolling (wheel/rail interaction) from around 50 km/h to around 270 km/h, and aerodynamic effects (especially at the current-collecting "pantograph", and from general body-generated turbulence) from around 270 km/h. Figure 1 shows these three regimes. The contributor over the widest speed range is rolling noise. This is a function of the excitation of the wheel and track system by the combined roughness at the wheel/rail interface as the wheel rolls, the vibration response of the various coupled components, and the resultant radiation of sound from these components. It is this source that is of greatest interest in railway noise mapping, although traction noise and aerodynamic noise are still important contributors.

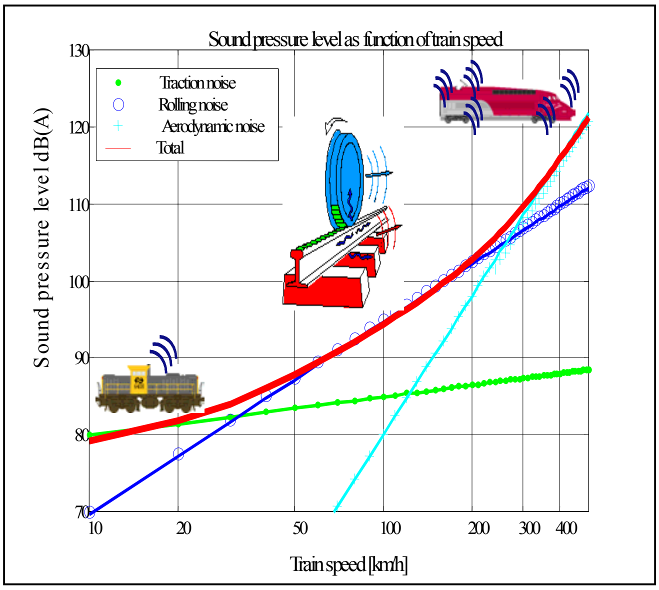

Figure 1. The three regimes of railway environmental noise (source: EC Railway Noise Working Group)

In order to quantify a railway vehicle as an acoustic source for modelling, overall sound power levels and positions (longitudinally and vertically) of the rolling, traction and aerodynamic contributions (see Figure 2) are required as a minimum (although aerodynamic noise is not normally an issue for non- High Speed railways). For more accurate modelling the subdivision of rolling noise into vehicle and track contributions is preferable, as is the directivity and spectral content of the sources.

The Dutch interim railway noise method RMV[1] (also known as SRM) allows for source heights at the railhead and at 0.5m above the rail head for conventional stock, while for High Speed Trains, sources at heights above the railhead of 0.5m, 2.0m, 4.0m and 5.0m are specified. Sources can be specified as Octave Band spectra. The UK method CRN[2] specifies two source locations, at the rail head for rolling noise and 4m above the rail head for the traction noise from diesel locomotives, and considers only A-weighted levels.

The noise emitted by a railway is a function of the system as a whole. Wheel roughness, rail roughness, vehicle parameters, track parameters and track support structures such as sleepers, viaducts and slab tracks all have an influence on rolling noise. Wheel and rail roughness are critical factors. On “smooth” track a wheel with cast iron brakes that bear on its running surface emits rolling noise that is 8-10 dB(A) greater than that from a disc-braked wheel, where the brakes have no contact with the running surface. Composite blocks (resin-based) that bear on the wheel running surface can be as quiet in rolling as disc-braked wheels as they do not roughen the surface in the same manner as cast-iron brakes. Similarly, a rough track, especially one that has a corrugated wear pattern, can lead to rolling noise for a “smooth” wheel that is as much as 20 dB(A) greater than on a track of low roughness.

It is therefore evident from the foregoing that any procedure that is required to model railway noise accurately should consider the contributions from a range of sources and causal factors. However, it is also important that, during the development of the procedure, the level of accuracy in noise prediction vs the degree of refinement in specifying these sources should be considered. It may be the case that the level of accuracy required for strategic noise mapping does not justify source quantification in fine detail.

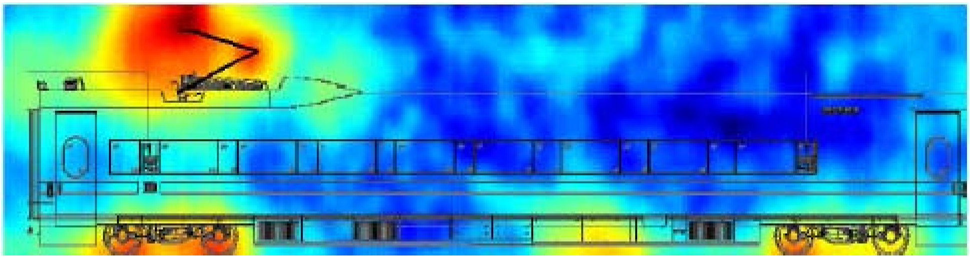

Figure 2. Array measurement of pass-by noise of German ICE3 train at 325 km/h, showing the significance of pantograph aerodynamic noise at higher speeds (Source: Harmonoise State-of-the–Art Report[4])

3 RAILWAY SOURCE TERM ACTIVITY IN HARMONOISE

Within Harmonoise, the Railway Noise Sources work package is led by the French Railways (SNCF), with other partners being SP (Swedish National Testing and Research Institute), Kilde Akustikk (Norway), TNO-TPD (Netherlands), German Railways (DB) and AEA Technology Rail BV (Netherlands). The overall objectives of this work package are to deliver a harmonised source description method for rail traffic related noise sources and to propose a database structure for the harmonised source data. In order to achieve this it was necessary to develop an inventory of existing overall railway noise models and rolling noise models to enable them to be examined and compared, and to cross-refer to the EC 5th Framework Project “STAIRRS” (Strategies and Tools to Assess and Implement noise Reducing measures for Railway Systems) which ran from 2000 – 2003. The work package was also required to consider track parameters in source description, and to develop generic methods for that source description. It was to develop standard approaches to measurement, vehicle categorisation and data storage.

The work package has addressed these objectives in detail and has provided the follow-on activity of IMAGINE with a strong foundation. Notably:

Vehicle categorisation is recommended to be based on rolling noise characteristics, as this tends to be the dominant noise source for a large range of applications. The relevant parameters are therefore:

- Number of wheels per unit length of vehicle
- Type of wheels
- Typical wheel roughness (dependent on braking system)
- Type of track
- Typical track roughness

The source model is recommended to consist of a sub-division into 5 separate source heights (Figure 3):

- At rail head for track contribution to rolling noise
- 0.5m above rail head for wheel contribution to rolling noise (+ possible aerodynamic noise, traction noise from driven axles, auxiliary equipment)
- 2.0m above rail head for traction noise (including fan noise) if present
- 3.0m above rail head for traction noise (including fan noise) if present
- 4.0m above rail head for traction noise and aerodynamic noise

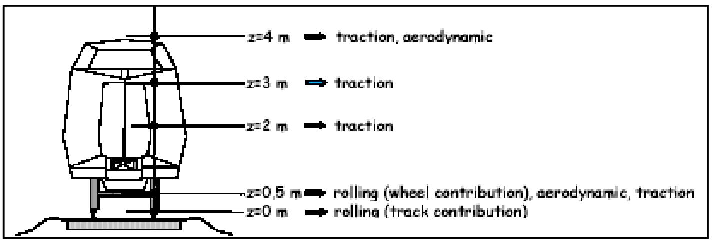

Figure 3. HARMONOISE proposed source distribution[5]

Directivity for most sources is still under discussion, but it is recommended that a dipole horizontal characteristic is assumed for rolling noise.

The parameters required for accurate modelling of rolling noise are:

- Vehicle speed
- Number of wheels per unit length
- Type of wheel (standard, damped, unusual diameters, spoked etc)
- Wheel roughness
- Track type (welded, ballasted, monobloc or bi-bloc sleepers, slab track, joints, curves, bridges etc)
- Track roughness

A preliminary traction noise model has been defined in which the various contributory sources are defined (eg engine exhaust, intake, structure, gearbox, fans, compressors, braking), the importance of operating conditions is highlighted, and advice on the measurement of source data and prediction of wayside noise from that source data is provided.

A key activity of HARMONOISE has been to define the measurement protocol required for a source term database, to enable accurate modelling to be carried out. To this end a comprehensive document has been produced with guidelines for measurement and analysis. These guidelines suggest that the following data has to be gathered to characterise rolling noise:

- Vehicle description and track description using the recommended categorisation procedure
- Pass-by speed
- Operating conditions
- Site information, including meteorological data
- Rail and wheel roughness (to be measured directly if possible, using appropriate precision instrumentation)
- Indirect measurement of wheel/rail roughness (using processes IDR and PBA developed by TNO, requiring track vibration and sound pressure levels at the track side to be measured)
- Methods for separating the contribution to rolling noise sound power level from track and vehicle using techniques that derive transfer functions between, eg total combined roughness at the wheel/rail interface and sound power emission from vehicle and track by measuring pass-by noise and track vibration simultaneously as trains pass (MISO from SNCF, PBA from TNO, VTN from AEA Technology)
- Effective stiffness of the pad between rail and sleeper by measuring the spatial vibration decay rate in the track

A vehicle has been specified (based on knowledge of available technology) that has minimum noise emission (eg small wheels and low-radiation superstructure). Such a vehicle will be useful in calibrating a test site by eliminating (or significantly reducing) one element of the pass-by noise when transfer functions between roughness and pass-by sound, or between track vibration and pass-by sound are being determined.

Guidelines are also provided for traction noise measurement under various modes of operation, and aerodynamic noise measurement including the separation of aerodynamic noise from rolling noise and pantograph aerodynamic noise from aerodynamic noise in the vicinity of the wheels using microphone arrays and barriers (although at an early stage of development). Finally, guidance is provided on the conversion of sound pressure level as measured or derived to sound power level suitable for input to the HARMONOISE propagation model.

HARMONOISE has also produced a proposed database structure that will enable the information gathered by the above techniques to be stored and accessed.

The consultancy LABEIN has carried out rolling noise measurements in Spain, following the proposed protocol as closely as possible. The main conclusions of this exercise were that the protocol is practically feasible, but that it requires specialist staff to set up and carry out, due to its complexity, with associated cost implications for training or hiring-in staff, and acquiring equipment such as roughness measurement systems.

4 THE IMAGINE RAIL NOISE SOURCES WORK PACKAGE

The task of the Rail Noise Sources work package in IMAGINE is to take forward the HARMONOISE recommendations to practical implementation. Its stated objective is to provide default databases for the source description of rail noise for an exemplary sample of the European rail traffic fleet, and to provide guidelines on how to deal with situations deviating from the typical samples. The work package is led by AEA Technology (UK) (with support from Defra), with AEA Technology BV (Netherlands), Kilde Akustikk (Norway), TNO-TPD (Netherlands), BUTE (Hungary), SP (Sweden) and LABEIN (Spain) as partners. Although the HARMONOISE recommendations would ideally be applied exactly as specified, practical implementation will always require a certain amount of revision to the initial set of aspirations. This has influenced the work plan, allowing a certain amount of revision and development of the procedures as activity progresses. The plan is as follows:

- Review the current situation on measurement methods, with the HARMONOISE input as a starting point but also taking into account recent developments such as the ongoing review of the ISO standard for railway noise measurement, pr-EN ISO3095 and the current EU “Technical Specifications for Interoperability”.
- Develop the HARMONOISE techniques further as necessary for efficient data gathering, with revised guidelines for on-site application of the protocol, and an updated specification for an ultra-quiet reference vehicle.
- Validation and improvement as necessary of the HARMONOISE traction noise model using pre-existing measurement data and/or data acquired during the project.
- Acquisition of noise data from in-service trains across a pan-European set of railway locations, including information from accession countries, especially Hungary. Remote long-term monitoring will be carried out where possible to increase the size of the database and hence statistical reliability.
- Creation of a database to house the information thus acquired. This database will only be part-populated within IMAGINE, with the intention of it being robust, user friendly, and live, so that it can be readily added to over time as more information becomes available. The database will then be available to provide source terms for noise maps using either the HARMONOISE/IMAGINE procedures or, potentially, for alternative procedures pending the harmonised method. It will also be of use in determining Action Plans following the noise mapping, and as example data for demonstration purposes and standardisation work.
- Production of guidelines on how to deal with situations deviating from those that are typical. This is required as there are inevitably some situations where the local track characteristics and the nature of the traffic are non-standard and not easy to model simply.

By late summer 2004, the IMAGINE work package has completed its preliminary phase, considering in detail the management and implementation of the various tasks required of it. The HARMONOISE measurement protocol is considered as being a firm basis for the data acquisition programme, which is due to commence in Spring 2005 and to continue throughout the remainder of IMAGINE's life. However, there is a currently a degree of debate within the work package over the level of precision and refinement required for the data. It is accepted that, ideally, the HARMONOISE protocol, which subdivides source data into a number of separate contributions, including a separation of vehicle and track elements of rolling noise, is the correct approach to take for noise mapping with high levels of accuracy. However, it could be the case that the complexity of equipment and analysis required by the full protocol, and the fact that physical access to the track or vehicles will be necessary if accelerometers are to be attached or if wheel or rail roughness is to be measured directly, will limit the amount of data that can be acquired within the project. Rigid application of the protocol could also bar large existing datasets of information from inclusion in the database, although they may be adequate for the purposes of strategic noise mapping where very high precision is not necessarily always required. This issue will be debated and resolved before the commencement of the data-gathering exercise and the implementation of the database.

5 CONCLUSIONS

As part of the European Commission's requirement that common methods are eventually available for noise mapping under Directive 2002/49/EC, the 5th Framework Project HARMONOISE and the 6th Framework Project IMAGINE are developing methods for characterising railway noise source terms.

HARMONOISE has considered the issues involved in detail and has produced a set of recommendations on source description, data gathering and data storage.

IMAGINE will take these recommendations forward to practical implementation, involving the setting up of a European rail noise source database and the acquisition of data within a number of Member States to commence the population of that database.

6 REFERENCES

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3. A.E.J. Hardy and R.R.K. Jones, Rail and wheel roughness – implications for noise mapping based on the Calculation of Railway Noise procedure, www.defra.gov.uk/environment/noise/rail-mapping/index.htm
4. Harmonoise Work Package 1.2 Rail Sources, State of the Art Report, 5 August 2002
5. C. Talotte et al, Railway source models for integration in the new European noise prediction method proposed in HARMONOISE, Inter-Noise 2004