Railway noise statistics by monitoring stations – input for Dutch prediction method RMR and track access charging

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Abstract

The infrastructure management organisation ProRail has installed five noise monitoring stations on the railway network in the Netherlands for the purpose of monitoring the progress of the Dutch Noise Innovation Programme. These monitoring stations record noise spectra and rail vibration spectra of train pass-bys. A weather station is integrated to allow the exclusion of data recorded during windy and rainy periods. As the stations are also capable of identifying trains that are equipped with tags. This creates a unique possibility for statistical analysis of the noise of such trains.

A statistical data analysis programme has been conducted by Railway Noise Knowledge Centre of ProRail. In this programme, the performance of silent test trains has been monitored. These passenger and freight test trains have been equipped with LL braking blocks, which are expected to keep the running surface of the wheel smooth. The monitoring stations provide information on the long-term performance of these trains in terms of noise reduction.

The analysis programme also involves an evaluation of the source parameters of the Dutch railway noise prediction method (RMR). These source parameters which depend on the type of rolling stock have been derived and established in the mid 1990s. It has been established that the average noise emission level of most train types is still close to the RMR values; however, for some train types a significant lower noise emission level has been measured. This will lead to adjustment of source parameters in RMR, which enables a more efficient use of noise abatement resources in the future.

Furthermore, the potential usability of the noise monitoring in noise-based railway access charging is considered. For this purpose, the reliability and accuracy of individual pass-by measurements is assessed. Special attention is paid to the measurement uncertainty caused by local track properties, which, of course, should be eliminated before imposing a fine on noisy trains.

1. Introduction

1.1. Noise monitoring and source recognition

Noise monitoring is common practice in the assessment of industrial and aircraft noise sources. For such applications that generally aim at long-term L_{den}-assessment a large range of reasonably priced stand-alone equipment is available. Spurious noise events (related to other sources than the ones under investigation) are eliminated automatically or manually during post-processing. This can be done if the sound characteristics of the source are known in sufficient detail (temporal and spectral behaviour) and if video systems are used.

Noise monitoring is a much more complex task if the noise events and sources need to be classified into (sub)types. In the case of trains the principle of axle pattern recognition is often used to classify the type of rolling stock [1, 2]. The principle is based on the fact that the distance between successive axles is characteristic for each type of train, although this method is inadequate for the monitoring goals set by the Noise Innovation Programme.

1.2. Noise Innovation Programme and project goals

Within the railway part of the national Noise Innovation Programme [3], retrofit solutions are applied to trains with cast-iron braking blocks. In order to study the long-time noise effects caused by the new braking blocks, monitoring stations have been developed that are capable of identifying the pilot trains and measuring their respective noise levels. Apart from this task the stations are also used to check the average and spread of the noise emission of regular trains and compare these to the values that are incorporated in the Dutch railway noise prediction method (RMR, [4]). The third goal for monitoring is to assess the usability of the stations for noise-based access charging.

2. The monitoring stations

2.1. Design goals and specifications

The design properties of the monitoring stations have been described elsewhere [5], and will only briefly be repeated here. Five noise monitoring stations have been designed and built in conformity with Procedure A of the *Reken- en Meetvoorschrift Geluidhinder*, a national regulation for calculation and measurement of railway noise[1]. This basically means that the monitoring stations meet the requirements for the measurement environment, track condition, microphone position, rail roughness and weather conditions.

Each station consists of a stand-alone computer, two microphones and accelerometers (one per track), a weather station and a data transmission modem (GSM). The monitoring stations make use of the Radio Frequency Identification (RFID) tags for train recognition. Most Dutch trains are equipped with these tags for maintenance purposes [6]. This allows for the statistical analysis of the pass-by noise of individual trains.

2.2. Measurement parameters

The following data are generated automatically after each train pass-by:

- Pass-by time and date;
- Noise: A-weighted noise level + octave spectrum 63 Hz – 8 kHz (microphone position at 7,5 m from the centre of each track, 1,2 m above the rail head);
- Acceleration level of the rail + octave spectrum 31,5 Hz – 8 kHz, (accelerometer position underneath the rail foot, measuring in vertical direction);
- Pass-by duration from buffer to buffer[2], speed at the front and speed at the tail;
- Number of vehicles, their tag identification numbers and rolling stock type;
- Wind direction and speed, precipitation, air temperature.

[1] This regulation has become part of the European interim computation method for railway noise [4].
[2] The buffer position is read from a look-up table with all tagged trains types and combined with rail peak vibrations of the first and last axle, giving the time window for the noise analysis and also the pass-by time.

Besides train-related data, each station produces status and quality information to facilitate maintenance and control. The measured data and status information is transmitted each night to a central database which can be accessed through an internet application [7].

In order to acquire reliable data from the unmanned stations, extensive quality checking is required. This is done by automated rail vibration measurements, pass-by time checking and daily microphone calibration. Invalid data due to bad weather conditions and non-constant speed are excluded manually before further analysis.

The rail roughness is measured manually once a year. Depending on the analysis task, the noise levels are adjusted for rail roughness differences.

The measurement stations have been developed in 2004, and installed and tested over 2005. Full operation has started in April 2006. The monitoring stations are located on the main lines in the railway network (near Utrecht, Amsterdam, Rotterdam and Eindhoven). Both tracks of each line are Dutch standard ballasted track: 54E1 rail profiles on concrete sleepers (NS90) with stiff pads (FC9). As the project has only national objectives, the sites have not been tested against TSI requirements. Nevertheless, only one of the sites has TSI+ roughness and, although decay rates have not been determined, it is known from sites with similar track systems that the vertical decay rates can be out of TSI+ range between 400 and 630 Hz [8]. With lateral decay rates there is usually no problem.

2.3. System performance

The performance of the stations is monitored by means of key performance indicators. The most meaningful indicator, *availability*, counts the number of days that a station is fully operational. The average availability of the five stations lies between 15% and 60%. This rather poor performance is mainly due to problems related to the accelerometers, which frustrate the triggering of the measurements (e.g. deterioration of mechanical contact). Unfortunately, the repair times for accelerometer failures are long due to safety regulations, as track closure is required. Other failures, that occur incidentally, are related to instable hardware components like the modem, temperature control, weather station, back-up battery (UPS) and hard disk. The repair of failures has in some cases been postponed or prioritised because of the needs of the analysis programme.

3. Monitoring individual trains

This section describes the results of monitoring an individual test train in normal service. The cast-iron braking blocks of three test coaches of type “ICR” have been replaced by composite braking blocks (LL type) as a part of the Noise Innovation Programme. ICR trains use disc brakes for low braking power and, additionally, cast-iron blocks for high braking power. The trains that include these test coaches also include regular ICR coaches with cast-iron blocks. They run on several lines and will sometimes pass a monitoring station.

Figure 1 shows the development of the pass-by noise level of the middle coach of the three coaches with LL blocks, starting from the moment of reprofiling and retrofitting[3]. Each circle represents one pass-by at a speed between 120 and 135 km/h. The measurements are all taken from the same site. The rail roughness of that site lies between the ISO3095 limit and the TSI+ limit.

[3] With respect to measurement accuracy, only three silent coaches is not preferable, but it is an operational condition that we have to face and which may lead to a small overestimation of the noise levels of the middle coach.

The graph shows a gradual increase of the noise emission during the first two months (mileage 40.000 km) and then the noise emission stabilises. This period is about 4 times as long as with standard cast-iron blocks after reprofiling.

Because of the monitoring stations it is now known that LL blocks may require a much longer period before representative noise levels are measured than for instance cast-iron blocks. This information is important for type testing programmes and also for measurements that feed the noise prediction method.

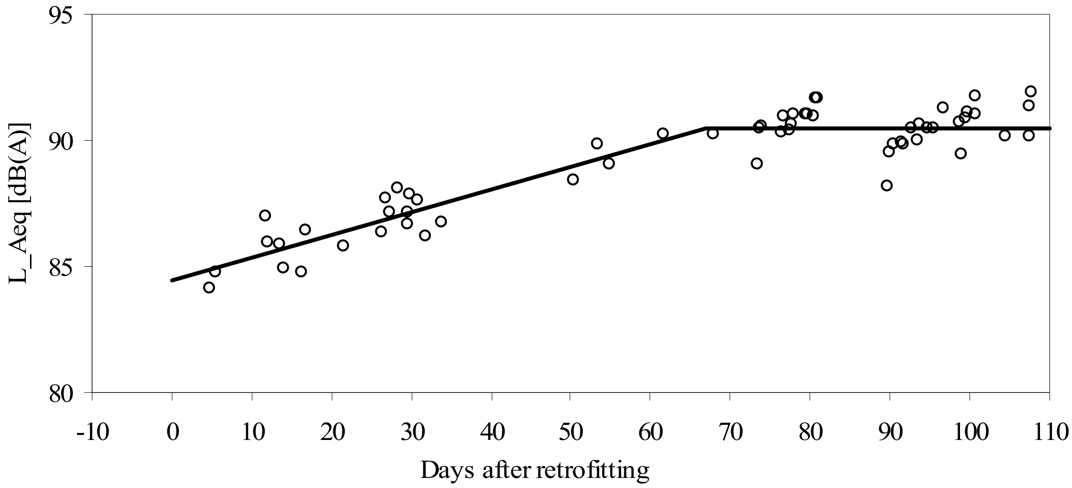

Fig. 1. Development of A-weighted equivalent sound pressure level L_{Aeq} after retrofitting and reprofiling for LL block equipped wagons.

4. Checking the source parameters of the noise prediction model

4.1. Train categories

At present eleven categories of trains exist in the Netherlands on the basis of their noise emission. Each category has a fixed set of source parameters for rolling noise and, if applicable, braking noise, traction noise and aerodynamic noise. The parameters were originally determined in the early 1980s and updated and extended in the mid 1990s [9]. More than 80 train pass-bys for each category were used to derive the parameters. Although there has been no particular reason to doubt the values of the parameters, it is considered that the noise monitoring stations offer a good possibility to check these parameters and to update them, if necessary. Under the Noise Abatement Act (*Wet geluidhinder*), an update of these parameters would affect the required intensity of noise reduction measures in future construction plans for houses and railways.

4.2. Results

A dataset of 10.000 pass-bys has been analysed. Most of these are from the first half of May 2006 from three monitoring stations. The measured rolling noise of fifteen sub-types of rolling stock out of six categories has been compared with the theoretical values. The results for the main train types are given in Table 1. Fortunately none of the examined trains have become noisier over the last decade**.** On the contrary, three types of trains turned out to be quieter than expected. Also, for two types of trains a steeper slope was found for the noise emission level as a function of train speed. These trains are about 3 dB less noisy at a speed of 80 km/h, but still show good agreement at maximum speeds of the conventional network (130-140 km/h). All measurements have been adjusted for rail roughness differences in conformity with the national method (see reference [10], equation (1)).

Table 1. Comparison of the old and new noise measurement.

cat.	name	decade	type, brakes[a]	# meas.	match with results of 1995	
					at 80 km/h	at 130 km/h
1	Mat64	60s	EMU, b1	1600	within 1 dB	
2	ICR	80s	coach, b2	1500	within 1 dB	
	ICM3	70-80s	EMU, b2	1400	within 1 dB	
3	SGM	70s	EMU, b3	450	now 3 dB less	within 1 dB
4	freight	any	all types, b1	600	within 1 dB	–
8	DDM2	80s	EMU, b3	850	within 1 dB	
	ICM4	90s	EMU, b3	700	now 3 dB less	within 1 dB
	IRM	90s	EMU, b3	900	now 2 dB less[b]	
9	TGV-PBA	90s	EMU, b3	70	now 4 dB less[c]	
	ICE-3M	90s	EMU, b3	70	now 4 dB less[d]	

[a] b1 = cast-iron blocks, b2 = disc brakes + additional cast-iron blocks, b3= no cast-iron blocks (i.e. disc, K-blocks or magnetic)
[b] IRM was already slightly quieter than category 8 in 1995.
[c] Category 9 has been based on high speed measurements of a older TGV type (Atlantique) in France.
[d] ICE has been assigned in 2006 to the same category as TGV-PBA.

4.3. Conclusion

The monitoring stations can be used to assess the source parameters of the national noise prediction method. Monitoring stations can provide a larger statistical basis than manned measurements. Monitoring stations can also be used to determine the category of newly introduced rolling stock. They form an independent source of information which is much more relevant to noise prediction than the usual noise type testing report that is based on fresh new trains.

It is believed that significant changes of the actual noise emission will not occur on the time scale of one year. Therefore, the source parameters need only be checked every two or three years.

5. Usability for noise-based track access charging

Railway operators have to pay for the use of the railway infrastructure for their services. ProRail aims to reflect the weight of trains and the scarcity of rail capacity in the access charges. One of the environmental factors of scarcity is the noise emission. It is considered that noise-based access charges would stimulate silent rolling stock (new of retrofit). In principle noise monitoring stations could play a role in the administration of noise emission. A few principal requirements must be met:

- Reliability of the measurements must be high. This has been evaluated through analysis of repeatability and comparison with manned measurements. It appears that the unmanned stations perform as well as manned measurements.
- Accuracy of the judgement (which noise charge?) must be high. The overall accuracy is limited due to differences between measurement locations that cannot (yet) be compensated for. Even after compensation for rail roughness, one individual train yields a standard deviation between around 1,4 dB(A) between different, but highly similar sites.
- Sufficient stations must be installed over the railway network. In the Netherlands, approximately 40 monitoring locations are needed for full coverage [6].

A matter of concern for access charging is the poor up-time of the stations (less than 60%). Also, the question if noise measurements are useful for access charging depends on the method of charging. If the charge is related to the actual noise emission of a train, then noise measurements are useful. If the charge is related to the number of silent vehicles in a train, then noise measurements are not sufficiently discriminating. This will be problematic for mixed freight trains of which some vehicles may be retrofitted while others are not. In that case a tag reader would suffice in order to identify and count the number of silent vehicles; noise measurements would not be required then.

6. Conclusions

The noise measurement stations have proved to be excellent tools to study railway noise emission. Especially, the train identification feature creates unique research possibilities.

The monitoring stations provide reliable information about the performance of silent pilot trains. Because of the monitoring stations it is now known that LL blocks may require a much longer period before representative noise levels are measured than for instance cast-iron blocks.

The monitoring stations allow for regular updates of source parameters for the noise prediction method. It turned out that most of the noise values of the prediction model were still valid after ten years. The stations can also be used for track access charging, however it will be difficult to measure accurate noise levels if silent vehicles are sandwiched between noisy vehicles within the same train.

Acknowledgements

The Noise Innovation Programme (*Innovatieprogramma Geluid*) develops measures to tackle traffic noise at the source, to make Dutch railways and highways quieter. Rather than inventing new technologies, this programme uses available knowledge from earlier (European) research projects and prototypes from industrial research projects and puts them into practice. The programme includes the development and data analysis of the noise measurement stations and is initiated and sponsored by the Ministries of Transport and Environmental Affairs.

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