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MEASURES FOR RAILWAY ROLLING NOISE ABATEMENT AND THE REGULATORY BACKGROUND

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Abstract: *Rolling noise is one of the major obstacles for public acceptance of railway traffic. Generally, railway traffic has an environmentally friendly reputation however often the expected noise hinders the construction of new lines or the increase of traffic or speed on existing lines. As a result the abatement of railway noise has been of particular political interest for a number of years. The construction of noise barriers provides significant additional investment costs. In the following document a brief historical background is given, leading into the noise specifications on European level (Noise-TSI). Prior to the Noise-TSI, there were already some national laws regulating railway noise emission. For pass-by noise these regulations demanded the measurement of pass-by noise on a good normal operational track. After the development of the first High-Speed TSI, a measurement campaign was undertaken to assess roughness and dynamic behaviour of typical high-speed tracks in Europe (NOEMIE). It resulted in limit curves for rail roughness and vibration decay rates for the rail of the test track. Due to these new regulations and growing customer demands, industry has developed a series of solutions to enhance the noise emission of the railway system. This paper will outline possible measures and previous successes in this area. As a result of the recent increased theoretical understanding of rolling noise formation, the discussions about further noise reductions have reached an educated level. After two TSI-Noise revisions it is clear that further attempts to decrease limit values go hand in hand with a refinement of the measurement procedure of noise certification.*

Key words: railway rolling noise pass-by certification Europe TSI measures

1. INTRODUCTION

Can you think of something worse than living in a house adjacent to a railway track where 300 trains pass per day, and another 200 per night? Where up to 110 dB(A) of sound pressure could be measured. This is the reality for the people in the Rhine valley [1]. There are villages where the number of houses exceeds the population. Generally, the construction of noise barriers has become a common standard when new lines are built. Fig. 1 shows the effect of a one-sided noise barrier on flat terrain. However, it is sometimes either not possible to build them, or the geographical situation reduces their effectiveness. The average costs for a 1 km two-sided noise barrier in Europe is around 3.6 M € (Capital costs + Maintenance costs + Removal costs) [2]. With the release of the European Environmental Noise Directive 2002/49/EC [3], hot spots will now be detected and measures shall be taken throughout Europe.

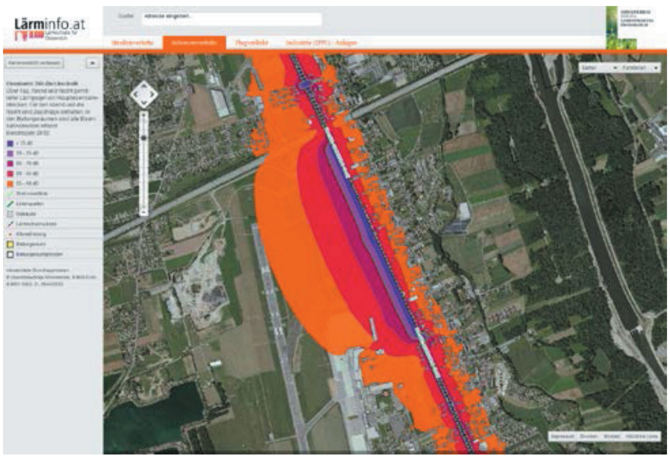

Fig.1. Effect of a one-sided noise barrier on flat terrain (http://www.laerminfo.at/)

2. DIFFERENT TYPES OF RAILWAY NOISE

We distinguish between different types of railway noise through a number of factors including the vehicle type,

speed and vehicle operation modes distinct components which will dominate the exterior noise.
Rolling noise dominates exterior pass-by noise over a wide range of speeds, radiated by both the rails and wheels and also by the sleepers at low frequencies. Stationary noise refers to noise radiation in a situation where the vehicle is ready to drive at the station. Commencing in 2015 the intermittent noise sources from air compressors and blow off valves, which are currently excluded, will be included in the stationary noise test [4]. Starting noise covers the acceleration phase from stand-still. Breaking noise and squealing in narrow curves are a well known phenomenon but are rather difficult to assess since these noise events are unstable and are highly dependent on environmental conditions. As an example for this the heating of a rail is shown to enable squealing assessment (fig 2). As a result, the latter has not yet been included in European noise legislation.

Fig.2. Heating up rails for squealing measurments

3. THEORETICAL BACKGROUND ROLLING NOISE

The theoretical understanding of rolling noise has its roots dating back to the 1970s in investigations of Remington. The later work of David Thompson [5] lead to the development of TWINS (Track Wheel Interaction Noise Software) coordinated by ERRI, the former European Rail Research Institute. The main inputs into the phenomenon of rolling noise are the rail and wheel roughness, rail and wheel dynamics (fig. 3, 4 and 5) as well as contact filter between rail and wheel, and the speed.

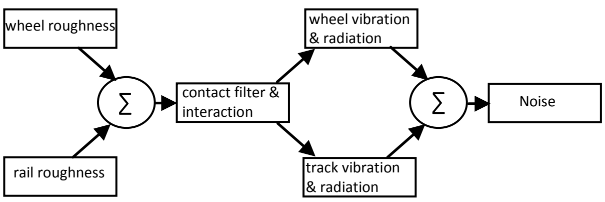

Fig.3. Model of rolling noise formation

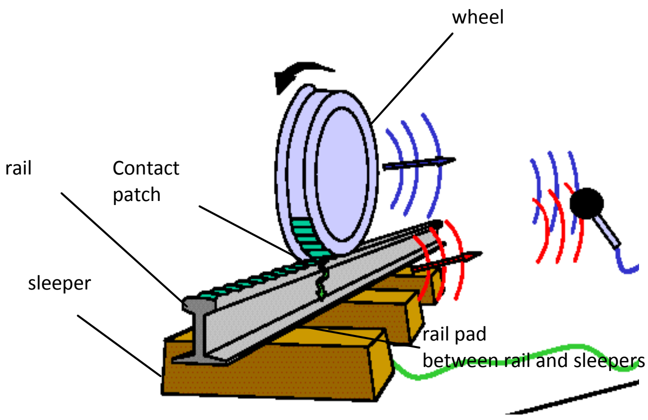

Fig.4. Illustration of rolling noise generation

Since the contact patch between rail and wheel is about 1 cm in length, roughness is understood to be unevenness with wavelengths from 1cm up to about 50cm. This contact patch works as contact filter by attenuating short wavelength excitations. The size of this contact filter and the typical spectrum of rail/wheel roughness lead to the rule of thumb that the pass-by noise raises with 30*log10 of speed.

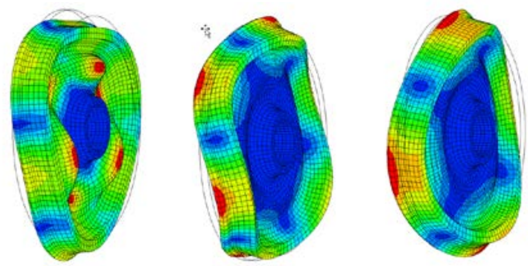

Fig.5. Wheel modes R3, 1L3 and 0L2

For the wheel vibration and noise radiation it is known that Rn and 1Ln mode classes count for rolling noise where 0Ln (n>1) modes count for squealing noise.

4. NATIONAL LAWS

Before the first TSI was implemented there were some national laws limiting railway noise. Most of these laws limited noise reception though only a few (AT, FI, IT) limited noise emission [6]. However, with the introduction of the TSI, national laws should not provide an obstacle to the introduction of a TSI compliant train into service.

5. DEVELOPMENT OF NOISE TSI

In order to ease borderless High-Speed-Rail traffic throughout Europe the first TSI for rolling stock (Technical Specifications for Interoperability) developed was the High-Speed TSI in 2002 [7]. Dedicated High-Speed lines (High-Speed TEN) were defined, and vehicles had to comply with the High-Speed TSI to get permission to run on those tracks. As a result, noise emission from those trains was covered and limited under this TSI. The acoustic properties of the test track were defined as follows: "A track type is used with design parameters ensuring minimum sound radiation from the track. These include: monoblock concrete sleepers in ballast and railpads with a static pad stiffness of at least 500 kN/mm at 60 kN preload". The railhead roughness was limited over a wavelength from 0.005m to 0.2m in one third octave bands by Lrough≤[4-6log(1m/λ)] in dB.

Shortly after the NOEMIE project (Noise emission Measurements for high speed interoperability in Europe) was launched by AEIF within the scope of the revision process of the High-speed TSI steered by the European Commission following the letter of DG TREN on March 27th 2002. In this letter, “the great uncertainty about measurement methods and track specifications as well as the lack of measurement data giving a clear picture of the noise emissions from the existing train fleet” was emphasised. In this study several track sites in Europe were tested for rail head roughness and track decay rates (fig. 6-8). Track decay is the amount an induced vertical or lateral vibration in a rail cross section declines along the rail. The results of this study lead to a new definition of the acoustic properties of the test track. In order to not jeopardise the availability of test tracks, it was decided to define more lenient conditions. As such a spectral maximum condition for roughness and a spectral minimal condition for track decay rates were derived from the envelope curves of the measured data.

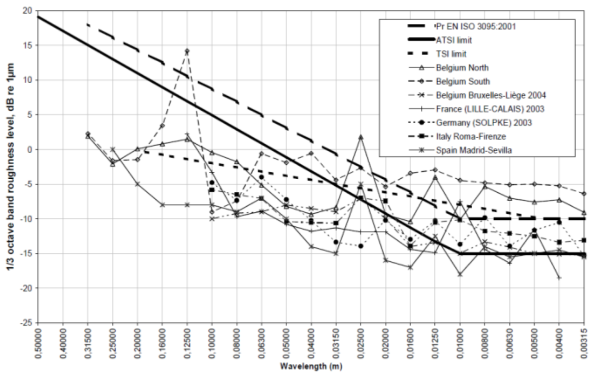

Fig.6. Measured rail roughness in the NOEMIE project

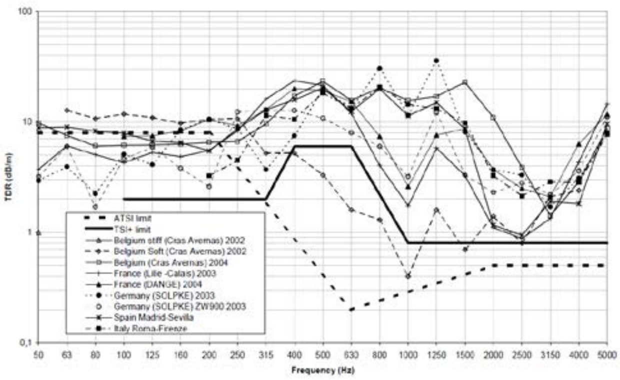

Fig.7. Measured vertical track decay rates in the NOEMIE project

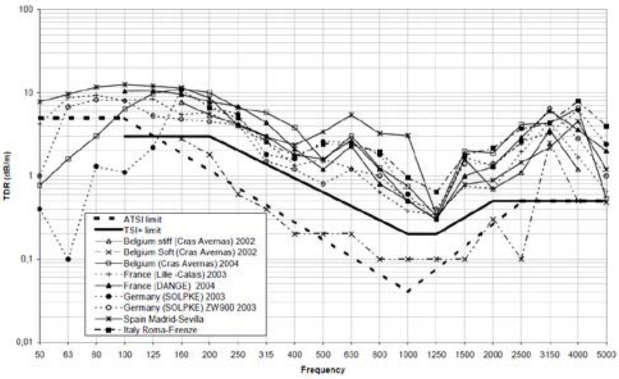

Fig.8. Measured lateral track decay rates in the NOEMIE project

It was said that acoustic tests performed on such test tracks are "comparable" among each other. This new test track definition was first applied in the TSI-Noise for the conventional rail system [8] in 2006. In contrast to the High-Speed TSI, the TSI-Noise was a Commission Decision exclusively dealing with noise certification. Additionally, in 2008 the revised High-Speed TSI [9] included this new test track definition. In 2009-2010 a limited revision of the TSI Noise [10] for conventional rail was made to simplify the certification process through allowing calculations instead of measurements and allowing measurements from pass-by-noise on a track which does not fulfil the acoustic requirements. The latter was necessary because even a single small spectral violation of the limit curves of the track definition made the whole test invalid. Hence, even if the train complied with the noise limits on a track of lower quality, the standard demanded that you repeat the entire measurement.

Coexisting national laws remain in place since the TSI is only applicable for the TEN (Trans-European-Network) rail network. In case of disruptions, trains need to also go onto off-TEN tracks; hence in many cases a pure TSI certification is not yet sufficient.

In 2011 a full revision of the Noise TSI started with the goal to combine the noise sections of the high speed TSI and the Noise-TSI for conventional rail. In addition the revision aims to lower the limit values and to expand the scope of the TSI to the complete rail network, hence rendering national laws obsolete. The publication of this new TSI is expected to be completed in 2015. The definition of the measurement track remained the same.

6. NOISE ABATEMENT

The highest priority for rail noise abatement has been a retrofit solution of wagons with cast iron brake blocks with composite brake blocks. Currently a vast majority of wagons are equipped with cast iron brake blocks which are known to lead to very high wheel roughness and consequently to a very high acoustic excitation. With this particular retrofit a noise reduction of about 10 dB can be achieved. The Noise-TSI only effects new vehicles, hence new wagons are equipped with composite brake blocks, but the boost for retrofitting of the existing fleet still remains a political solution. On the opposite side of the rail/wheel-contact, acoustic rail grinding is also efficient in the same manner. During acoustic grinding the grinding stones move along the rail direction and lead to a rather smooth rail head surface. Wheel shape optimisation aims to increase wheel stiffness and reduce axial vibration when excited in radial direction. From experience the range between best and worst wheel is about 6dB in wheel noise. This means that when compared to rail noise under standard conditions the worst wheel was 3 dB louder than the rail and the best wheel was 3 dB quieter than the rail. Further reductions are possible when useing dampers on wheel and rail. Hence reducing their acoustic vibration. For over 10 years such systems have been applied on ICE-trains as well as on metros and trams (fig. 9, 10). These systems are also known as "noise absorbers".

Fig.9. Examples of ICE wheel dampers

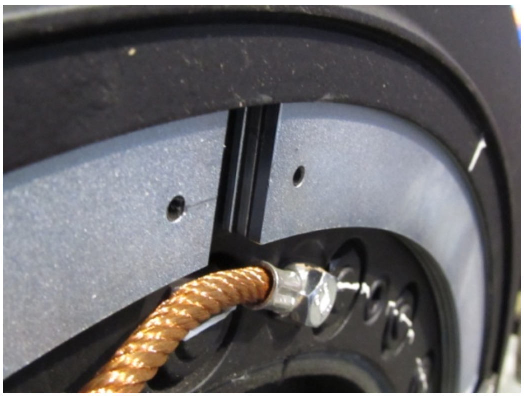

Fig.10. Examples of tramway wheel dampers

With dampers, wheel rolling noise can be further reduced by around 4 dB depending on the type of absorber; In addition wheel squealing noise can also be substantially reduced. Since squealing is largely dependent on environmental conditions and the actual contact situation between rail and wheel, the reduction here is more a statistical phenomenon. From experience squealing can be reduced by up to 100%, hence result in the disappearance of squealing leading to a noise level reduction of up to 15 dB.

The reduction of rail noise by means of dampers is dependent on how well the rail was already damped through rail pads, sleepers and ballast. Already the NOEMIE report demonstrated that the tightening of rail fasteners can raise the track decay rates by a factor of three, thus reducing rail noise radiation. A special case is the slab track. Here the railpads are rather soft and measures may need a special design. Slab tracks are used for high-speed lines as well as in metro systems.

We should always keep in mind that we have to deal with two noise sources in both the wheel and the rail. Hence, measures applied on only one noise source can have a vanishing effect on total noise. Therefore it is always a good idea to not only look at total levels, but also on the noise spectra since rail and wheel appear in different parts of the spectrum.

7. FURTHER DEVELOPMENT

Naturally reducing limit values in order to enhance noise situation is of major interest. Some countries within Europe work under additional regulations beyond TSI to reduce the noise impact on their citizens. In the Netherlands, Noise Production Ceilings for main railway sections have been introduced [11], in Germany an action plan to halve railway noise by 2020 [12] is under way, and both of them as well as Switzerland, have adopted noise dependent track access charges [13]. Noise dependent track access charges should speed up the retrofitting of cast iron brake blocks. In the UK, track access charges for Noise were planed but until now have been postponed. On the other hand, pressure by reducing TSI limits is being made; in the latest revision reductions of up to 5 dB were defined. However, plans for substantial reductions in pass-by noise were found not to be practical in the current situation. The primary reason for this is that the current test track definition is strongly linked to the current pass-by noise limits. In other words, if significantly lower limit values are defined, significantly better measurement tracks would be required because the current track definition allows for too much track noise. Although, theoretically, the choice of test track is up to the supplier, will it be possible to find an appropriate track throughout Europe to ensure a successful certification even if the train is highly tuned to low noise design? At the moment: No. A point of disscussion was also if the test track should represent a normal -good- operational track in Europe (wherever we find that) or if it should be a special low-noise track which might be installed in some hot spots? However, due to the split of track and rolling stock operators, it is becoming increasingly complicated to find an appropriate test track, even under the current definition. Another complication is that the test track definition is often called the "reference track". Even among experts the expression

"reference track" awakened the imagination that the limit curves for roughness and track decay rates are reference lines. But a test track which is only on the limit curve of the test track definition would be far too noisy and no train running on such a track would comply with the current TSI. In order to avoid such situations or misunderstandings the current question stands: How to enhance the pass-by measurement?
The goal is to find a new assessment method

- Which is better than the current one without the demand of being perfect or exact
- Which is not more expensive than the current one
- Where silent vehicle design can be assessed
- Where the assessed values can give a better basis for track access charges
- Where new limit values can exclude acoustically bad wheel designs
- Where the new method avoids "grinding competition" for certification
- Where the new method could allow more flexibility for the choice of test tracks.

One possibility would be to allow tests on any track and to convert the measurement results to a reference track, currently such a conversion is not available. However, any calculation conducted after a measurement increases the uncertainty of the result, thus some experts demand to keep a clean measurement. Another thought is to maintain the role of the TSI as a tool for interoperability, where no modifications of TSI limit values would be necessary. This discussion will continue until the next revision.

8. CONCLUSION

The introduction of Noise Limits in the TSI was a valuable step towards a silent railway traffic. Generally, modern trains have now a high acoustic quality. Noise prediction and the specification of components became an integral part of system engineering. As a further step, the last revision will additionally reduce the annoyance of overnight parking trains. Of course it is clear that after the big step through the wagon brake block retrofit smaller steps towards lower noise emission will follow. Undersleeperpads will allow for higher stiffnesses of railpads and so enable to go for higher track decay rates. Wheel dampers will become more popular especially for squealing noise. Electric breaking with the engines will replace step-by-step brake blocks so braking noise will vanish where the design of the system allows it.

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