Application of European Noise Legislation in Rolling Stock Projects

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Summary

In the EU there is special legislation for railway vehicles regarding highest permissible noise levels. This legislation is specified in the NOI TSI (Technical Specification of Interoperability NOIse) and is mandatory for vehicles to be allowed to run on the railway network in Europe. The NOI TSI has now been applied in vehicle projects both within and outside of Europe for more than a decade and the experience from this wide application is described for a number of countries. Experiences from applying a so-called simplified method replacing some of the on-track test with comparative assessments in relation to measured results for a reference vehicle configuration, is described and shown to be very beneficial for a recent European vehicle project. Appropriate track quality is also a challenge to assure, e.g. on the UK network. In an outlook to the future, results of research activities from the FP7 project Acoutrain, supporting virtual testing, are presented as well as coming European research project for railway noise within Horizon 2020.

1. Introduction

The development of new legislation and standards has an important impact on the design of new rolling stock. Since January 2015, a new full revision of the NOI TSI (Technical Specification of Interoperability NOIse) is in force, merging the requirements for conventional rail and high-speed rolling stock and defining new limit levels [1]

The so-called simplified method is a very important change that was fully introduced in the limited revision of the NOI TSI in 2011 [2]. This method can limit the extensive testing associated with approval of a new vehicle according to this legislation. In the long term, the ambition is to partially replace physical TSI testing by so-called virtual testing, in which calculated results are used as a decision basis.

In addition, the application of the TSI is becoming more widespread as customer contractual requirements also from other parts of the world. In e.g. Asia and Australia customers are increasingly referring to the NOI TSI. Additionally, although the NOI TSI does not apply to vehicles such as metros or those circulating on functionally separated networks, these now often explicitly refer to the NOI TSI in the technical specification.

For the future, the link between the research needs for noise and vibration and the new European Programme for Rail R&D, Shift2Rail, is important. An outline of research strategies in Shift2Rail covering development of more efficient source separation, as well as improved simulation methods and low noise design of vehicles, is included in the last part of this paper.

2. Application of NOI TSI in Germany and outside of Europe

For DB (Deutsche Bahn) high-speed projects in Germany, application of the testing and certification process according to TSI HS RST

2002 [3] was made right after it became legally binding. Later on, EC certificates were granted also according to TSI HS RST 2008 [4]. When NOI TSI 2005 for conventional rail [5] came into force, various vehicle projects, such as EMU and DMU families, as well as electric and diesel locomotives were tested and certified from 2006 to 2011 according to this procedure. Thereafter, certification was done according to NOI TSI 2011 limited revision [2].

Figure 1. TSI testing of a locomotive on a mainline railway

NOI TSI measurement campaigns can be carried out on the test ring of Wildenrath, but also on many standard mainline tracks in Germany, which fulfill reference track requirements, as illustratedin Figure 1. The relative simplicity of accessing these tracks has made them a competitive alternative from a time and cost point of view.

Regarding so-called 'Type examination', it is stated for all TSIs since 2002 that**..** *A type may cover several versions of the subsystem provided that the differences between the versions do not affect the provisions of the TSI.* This, together with a so-called list of noise relevant characteristics and constituents according to RFU-RST-027 [8] allows for the certification of different versions of a type, e.g. a vehicle family, based on measurements of only one variant of the family. With the limited revision of the NOI TSI 2011 the term 'simplified evaluation' was coined and the method further detailed to be more widely applicable.

Although intended for rolling stock in international service within the European Union, an increased reference to the NOI TSI is observed for bids and project in other regions. This is noticed for regional and high speed trains as well as for metro and commuter applications.

Some of the reasons are that the NOI TSI:

- Specifies challenging noise limits, taking into account the balance of environmental needs and technical feasibility of low-noise rail vehicles.
- Defines the conditions under which the measurement is valid. This includes a description of the acceptable test environment and of the track characteristics influencing the rolling noise.
- Provides a rigorous process for demonstrating the fulfillment of the requirements, including the determination of the infrastructure related parameters responsible for noise generation.

This combination of balanced noise limits, defined track characteristics and methods for demonstrating compliance has led to the NOI TSI being used out of its intended geographical scope. This is observed for example in Australia, for regional train tenders and for the latest Turkish high-speed trains tender. It is also common that train manufacturers and buyers agree on the application of the TSI during the course of a vehicle development project. Even the People's Republic of China to a large extent refers to the NOI TSI when specifying noise limits for high-speed trains.

In the latest revision of the testing standards EN ISO 3095 for exterior noise [6] and EN ISO 3381 for interior noise (currently in draft), the minimal possible horizontal and vertical decay rates of the track are now specified, so that the differences between TSI and EN ISO test conditions tend to disappear.

3. Application of NOI TSI simplified method in France

Certification according to NOI TSI for an EMU double deck family product was recently carried out in France. This particular vehicle family consists of five different configurations as shown in Figure 2. In that context, the main challenge was to minimize TSI track testing to reduce cost and to comply with the project time frame.

The simplified evaluation method introduced by the 2011 NOI TSI revision [2] and completed by the ERA application guide [7] was used to assess the noise compliance of the entire family product.

Figure 2. Vehicle family product

The 2011 NOI TSI states: "*it is permitted to substitute some or all of the tests by a simplified evaluation. The simplified evaluation consists of acoustically comparing the unit under assessment to an existing type (further referred to as the reference type) with documented noise characteristics…*" The text introduces the notion of "reference type" defined by type testing and allows "acoustical comparison" of other units with that "reference". The ERA application guide [7] defines some practical cases in which assessment of a family of vehicles is described: "*A family of vehicles is defined as a group of vehicles which are largely based on the same design (e.g. multiple units with a minimum number of vehicles which can be increased by adding vehicles identical to one of the existing in the minimum configuration). In such case it is sufficient to select for each basic parameter the vehicle with the highest noise emission level for the assessment according to NOI TSI. If such vehicle is TSI compliant, it can be assumed that the other vehicles in the same family comply as well without further tests.*"

One condition defined by TSI is that the "reference type" shall be "comparable", meaning that dynamic type testing shall be measured on a test track compliant with the TSI quality criteria. ERA application guide [7] adds that "*the unit under assessment and the reference type are comparable in terms of design, operation and acoustic behavior*" which is clearly fulfilled in our case, shown in Figure 2.

Following the simplified evaluation procedure, a noise compliance strategy was defined as illustrated in Figure 3, and agreed with the NoBo.

An assessment was made by for each operating mode (stationary noise, starting noise, pass-by noise at 2 speeds, cab noise), calculating which train set arrangement had the highest TSI noise levels. These worst cases defined the "reference types" which were measured by type testing according to TSI.

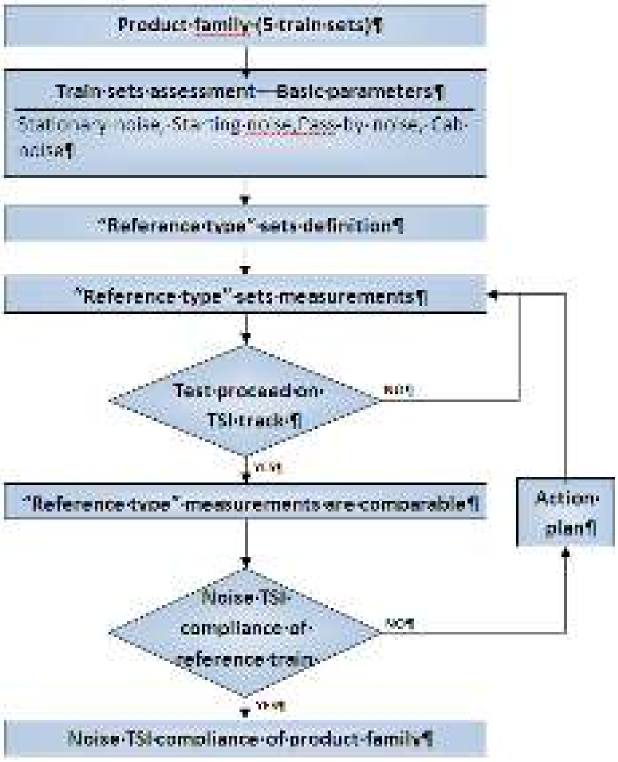

Figure3. Noise assessment strategy

Assessments were done by acoustic simulations (with clear description of the calculation process and assumptions used) and documented by rolling stock noise characteristics analysis (description of noise relevant systems according to RFU-RST-027 [8]).

Noise type tests were then carried out only on "reference type" train sets according to TSI conditions. In this manner, only five type tests were carried out to cover the full TSI scope, for which potentially up to 50 tests would be needed without using the simplified method (5 train sets x 5 operating conditions x 2 power supplies).
NOI TSI compliance of the whole product family was then demonstrated by evaluation of noise levels of each individual train set configuration based on the "reference type" measurements. In the previous edition of the NOI TSI from 2011, the simplified evaluation method could only be used if the calculated noise level did *not exceed the reference case*. This has been changed in the 2014 NOI TSI edition and the simplified method can now be used to demonstrate that the calculated noise level does *not exceed the limit value*.

4. Application of NOI TSI in UK

Since the first edition of the NOI TSI a key challenge in the UK has been to find suitable track conditions where pass-by compliance can be demonstrated.

Historically, amongst railway Acousticians, it was thought that UK track roughness was poorer than that that of mainland Europe. Therefore the requirement to make tests on reference track would disadvantage the UK, as sites on the infrastructure were not readily available and no dedicated test track exists.

In the limited scope revision of the TSI in 2011 [2] this problem was acknowledged and the requirement to test on reference track was removed as long as limit levels were not exceeded. However, as rolling noise is so significant for pass-by then the challenge still remains to locate sites where track conditions are as close to those defined in the TSI as possible.

The TSI defines a reference track in terms of rail roughness and decay rate. The combined roughness of the rail head and wheel determines the level of excitation in the system. The decay rate defines how vibration in the rail decays with distance. Both of these factors strongly influence the amount of rolling noise generated.

Sites that offer the correct track conditions and environment have proven very difficult to find. This is further complicated by the need to have both AC and DC test sites, to cover the range of trains running in the UK.

Electrical Multiple Unit and Diesel Multiple Unit performance has therefore been tested on a mix of infrastructure and test track sites including the South Eastern Main line (SEML) (DC), London Tilbury & Southend line (AC), West Coast Mainline (WCML) (AC), Velim test track, Czech Republic and Old Dalby test track, UK (DMU only).

Old Dalby is a test track only suitable for testing DMU’s and it was clear that the track roughness level and rail decay rate were in excess of the TSI limits. So it was only possible to undertake investigative tests at this location.

Grinding was considered for Old Dalby to reduce rail roughness but the grinders used on the rails leave a finish that requires a considerable vehicle tonnage to pass to achieve an acceptable roughness level. The Old Dalby test track would not see this level of traffic.

A linear grinder was brought in to grind the track for tests on the SEML. However, roughness levels at the time of tests were still in excess of the TSI limit. A special linear grinder capable of producing a TSI compliant roughness level would therefore be required for tests on the Old Dalby test track, which would be prohibitively expensive.

Rail dampers were fitted to the track at Old Dalby in order to improve the rail decay rate. These appeared to have an impact, but a great difference was seen by having two different companies assess the track decay performance. In any case, roughness of the rail was such that pass-by noise was still non-compliant.

BT has undertaken its own surveys, to identify suitable locations on the infrastructure. However, once sites have been found, there is no guarantee that the track will remain in a suitable condition within the required timeframe for the test program.

On UK infrastructure, tests are often only possible at night and there are severe time constraints as tests must be planned around operational traffic. This limits possibilities for repeating runs or investigative measurements. The assessment of track roughness and decay rate requires access which is difficult to obtain in the specified TSI timeframe. On one occasion this meant that pass-by tests had to be repeated.

Measurements of track roughness at the WCML site have shown that the roughness levels are below the TSI limit in many 1/3 octave bands. However, the decay rate is not compliant, resulting in a ‘non-comparable’ test result. This is due to soft track pads which cannot be changed.

Despite the challenges, Bombardier has worked with NoBos to ensure the homologation of all the UK products tested to date. The challenges that have had to be overcome have resulted in a body of knowledge that enables successful testing of future products and has been fed into the UK and UNIFE mirror group for the TSI revisions.

5. Virtual certification and Acoutrain

In view of the technical and logistic challenges and costs associated with TSI testing, the ACOUTRAIN FP7 R&D project aims at developing procedures and calculation tools to simplify the TSI Noise test procedures, see http://www.acoutrain.eu/. The main task is to define a framework for introducing virtual certification with a reliable simulation approach. In addition, dedicated work has been carried out to clarify applications of the simplified method [9], as discussed above for use in France and Germany.

Virtual Testing (VT) within a certification process means that the physical tests required are partially, or completely, replaced by numerical simulations, see Figure 4.

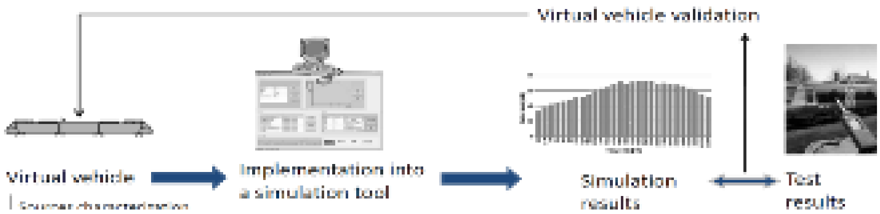

Figure 4. Virtual testing scheme, with validation and verification steps. From reference [10].

If virtual TSI testing should be an alternative to real tests then: (i) limit values, predefined operational and environmental conditions and receiver positions of the two procedures should be identical and (ii) the output results should be equivalently reliable. The choice of test procedure should not affect vehicle acceptance.

The VT concept is based on the use of a Virtual Vehicle in a dedicated simulation tool. This virtual vehicle acoustically represents the real vehicle as a set of noise sources and is the basis for simulation of TSI noise levels at stationary or pass-by.

After being defined, the virtual vehicle has to be validated, i.e. it has to be proven that it correctly represents the real vehicle. The validation process is described in [11] with proposals for evaluation criteria. The VT process is judged to be as reliable as real testing when the same level of uncertainty can be achieved. At present, assessment of uncertainty is still an issue which requires further work, also for standard TSI testing.

Different virtual testing schemes have been defined: *Full Virtual Testing, Extension of Approval (EoA) and a Hybrid Approach*. The most relevant approach depends on availability of inputs and existing models. The key difference between the EoA and the Hybrid Approach schemes is that the EoA approach requires a validated virtual vehicle for a similar vehicle. The concept of acoustic similarity between two vehicles is defined in [11] where also a decision model is proposed.

The VT process has been developed with special focus on real life applicability. The different procedures that make up the VT process should provide clear results so that a NoBo easily can review them.

The procedure and methodology was evaluated by comparing results from simulations with track-side measurements for a regional train. Two different simulation tools were applied: the ACOUTRAIN tool and SITARE. [10][11].

The pass-by noise calculations show a good agreement with measurements, see Figure 5. Results are shown for two microphone positions, 10 m apart, and for two different measured track decay rates (TDR), see reference [10]. The spread in TDR can partly be attributed to different ambient temperatures at the time of measurements. Accordingly, there is a certain spread in both calculated and measured results. For the calculation results, averaged wheel and rail roughness measurements were applied.

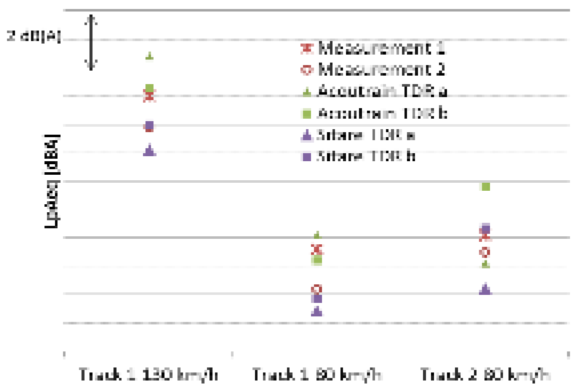

Figure 5. Measured pass-by noise levels at two microphone positions and corresponding levels calculated with two different track decay rates.

6. Future research in the Shift2Rail project

The Shift2Rail Joint Undertaking (S2R JU) is a new public-private partnership in the rail sector, providing a platform for cooperation that will drive innovation in the years to come. The S2R JU will pursue research and innovation activities in support of the achievement of the Single European Railway Area and improve the attractiveness and competitiveness of the European rail system [12].

Activities will be organised around five key “Innovation Programmes”: 1) Cost-efficient and reliable trains, including high speed and high-capacity trains; 2) Advanced traffic management & control systems; 3) Cost-efficient and reliable high capacity infrastructure; 4) IT Solutions for Attractive Railway Services; 5) Technologies for Sustainable & Attractive European Freight.

The Founding Members of the Joint Undertaking are the European Union plus eight representatives of the rail industry, including rolling stock and rail equipment manufacturers Alstom, Ansaldo STS, Bombardier, Construcciones y Auxiliar de Ferrocarriles (CAF), Siemens and Thales, as well as infrastructure managers Network Rail and Trafikverket.

Additional members will be selected through open calls and as associate members. The aim is to ensure that railway operators and other important public and private stakeholders in the rail sector, as well as research organisations, SMEs and actors from outside the sector, are fully represented.

At vehicle level, a number of Technical Demonstrators will be developed: Traction, Running gear, Carbody, Brakes, Doors and technologies related to Freight traffic. On the infrastructure side another set of demonstrators are developed; Switches, Crossings, Bridges and General Track with a medium and long term perspective.

The research on methods for noise reduction will be embedded in the development of each Technical Demonstrator. The most important systems for the rolling stock are the Traction and Running gears. For traction systems both tonal electromagnetic noise, important for the starting noise, and cooling noise will be treated. For running gears, external way-side noise as well as structure borne noise transmission to the interior compartments affecting the passenger comfort will be addressed.

A so-called Cross Cutting activity on noise will also be included. Targets will be set for each sub system both on vehicle and infrastructure level, to enable the desired overall noise reduction of 3 to 10 dBA to be achieved. Targets will depend on the combination of infrastructure and rolling stock and on the particular running conditions. The development work in this part includes refined prediction methods, source characterisation and ranking as well as source separation at a system level.

Conclusions and outlook

The European legislation on rolling stock noise has gained a wide application during the last decade, not only in Europe but also on other continents. It is expected to be further developed in the future to an even more efficient legislation by, e.g. including new methods for separation of noise sources on vehicle versus track and to replace testing by gradually introducing more simulations and virtual testing.

Acknowledgement

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