DESIGNING HIGH-SPEED RAILWAY SYSTEMS: NOISE CHALLENGES

P-E Gautier & L Guccia

SNCF Research, Paris, France

Facing increasing demand for higher speed and lower environmental disturbances, the design of high speed railway systems must meet stronger and stronger requirements in terms of noise emission.

Improving the efficiency of noise barriers, which does not limit the emission of noise really at source proved insufficient towards the need for noise reduction. Requirements mentioned above can only be met through a combined reduction both at source, which implies reducing all sources of noise, and in the vicinity of the track, by means of noise barriers.

After a review of legal constraints, leading to the order of magnitude of the reductions of noise to be targeted, the potentials of every field of action will be assessed.

1 - LEGAL LIMITATIONS

Environmental problems are becoming a stronger concern in Europe, particularly since high speed railway lines projects were planned. Accordingly, in several countries, legal limitations in terms of noise perceived by the people living in the neighbourhood of infrastructure were driven. It was recognised in most European countries, that an acceptable and practically operational indicator for annoyance was the contribution of the railway infrastructure expressed in terms of a L_{Aeq} over a 24 h or day or night-time period.

It was also recognised that, to be considered equally annoying to road traffic, railway contributions could be 5 dB(A) higher in terms of L_{Aeq} than road traffic contributions. This was called a railways "bonus", somehow inadequately since it suggested that railways might have been favoured in this process. Anyhow, most of European countries officially agreed in this need for a correction of the L_{Aeq} to set an indicator of railway annoyance coherent with an assessment of global annoyance for all ground borne transportation infrastructures.

The following table summarises the limits driven by various states in Europe.

COUNTRY	SWITZER-LAND	GERMANY	NETHER-LANDS	FRANCE PROJECT	ITALY	AUSTRIA
Corrective factor "bonus" (dB(A)	5	5	7	5 ?	?	5
Legal limits L_{Aeq} (dB(A) 06 AM - 10 PM 10 PM - 06 AM	55 to 60 45 to 50	59 49	57 * 47 *	60 ? 55 ?	65 55	60 50
Effective) day limits) night	63 to 68 53 to 58	67 57	60 50	60 ** 55 **	?	68 58

* day : 07 AM - 11 PM, night : 11 PM - 07 AM
** specific to TGV

These limits are rather stringent when the L_{Aeq} over the period [6 AM - 22 PM] created at 100 m distance of a high speed line, where trains run at 300 km/h during this period are calculated :

$$L_{Aeq}\ [6\ AM - 22\ PM] = 68\ dB(A)$$

This means that, to satisfy the above legal requirements, either barriers are needed, noise must be reduced at source.

In the most demanding situations, both measures are needed, and their capabilities must be assessed and verified in practice with an accuracy going down to 1 dB(A).

The potential of both challenges will be assessed in the following.

2 - THE EFFICIENCY OF NOISE BARRIERS

The calculation of the efficiency of noise barriers used to be carried out in a practical way using MAEKAWA theory. It appeared that, to take into account various results obtained with different types of barriers (Insertion Loss ranging from 4 to over 10 dB(A) for high speed applications), specific calculations had to be taken into account.

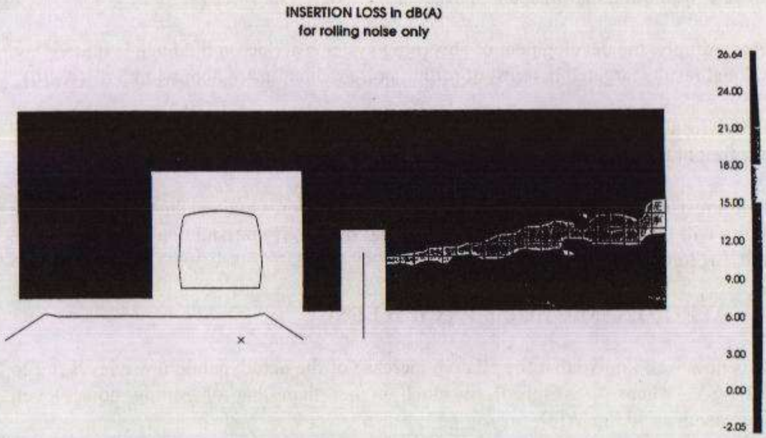
At first, potential reflection of noise over the body of the train had to be taken into account in any case. This was successfully implemented in environmental prediction codes such as MITHRAFER, developed and validated by SNCF [1].

Moreover, a better understanding of the behaviour of the barriers in railway applications was to be undertaken prior to their acoustic optimisation.

An European BRITE-EURAM project "EUROECRAN" was then started, associating some European railways along with barrier manufacturers, aiming at an improvement in the barrier efficiency of 3 dB(A) in terms of Insertion Loss.

To this end, boundary element calculation was assessed against ray tracing methods.

The former being well suited to the assessment of the effect of variations in shape of the barrier, or in the implementation of absorptive material was developed at SNCF. An example of result is given below.



3 - REDUCING ROLLING NOISE : DEVELOPING OPTIMISED SOLUTIONS

Significant progress in reducing rolling noise (up to 10 dB(A) was obtained in the years 1970- 1980's by suppressing shoe brakes that created surface defects on the wheels, and replacing them by disk brakes. Similarly programs are under development in France and Germany aiming at ribbing similar defects on the rail by appropriate grinding.

The reason for this efficiency is that rolling noise comes from the excitation, by surface defects of some micrometers of amplitude with wavelength ranging from several millimetres to 30 cm, of wheel and rail. This model, suggested by REMINGTON, was successfully and quantitatively implemented in the TWINS calculation model, developed at ERRI [2].

The TWINS model, qualified for rolling noise predictions at conventional speeds [3] was also validated for high speed trains up to 350 km/h [4]. Rolling noise can be predicted within 1 - 2 dB(A) over all the involved 3rd octave bands (800 Hz - 5 000 Hz). The reduction measures mentioned above aimed at suppressing the micro defects on the wheels and rails. Once this is achieved, further reduction can be obtained by minimising the responses of the wheels (along its vibration modes) and rails (propagating waves).

An important output of TWINS validation was that, thanks to understanding the relative balance between wheel and rail contributions in rolling noise, the efficiency of solutions for noise reduction devices acting either on wheel or rail could be assessed in terms of global system response. Indeed, it was verified that a 5 dB(A) reduction in terms of wheel emission actually obtained through optimised design of the wheel shape [5] entailed only a lower reduction in global rolling noise, due to the track contribution that was not altered.

Accordingly, the development of absorbing systems acting on the track is under way. Global results targeted in terms of rolling noise reduction are about 4 to 5 dB(A) [6].

These results look achievable, since similar noise reductions, were recently obtained for freight traffic [7].

One must not forget, though, that the noise reduction obtained in terms of rolling noise will be partly rubbed in terms of global results, if no reduction of aerodynamic noise is looked for.

4 - AERODYNAMIC NOISE : A CHALLENGE

It is now well known that the relative increase of the aerodynamic noise level (60 to 80 log V, where V is speed), is much higher than that of rolling noise level, increasing as 30 log V [8].

The speed for which aerodynamics noise becomes prominent depends on the relative contribution between rolling and aerodynamic noises, which in turn depends on the train. For TGV, aerodynamic noise contribution was found to be equal to the rolling noise contribution at the speed of 350 km/h [8]. This was confirmed by the "German-French co-operation on noise of guided transport" [9] , and within this latter work, through acoustic antenna measurements, a mapping of main noise sources on ICE and TGV was obtained. Going deeper into acoustic antenna techniques, it appears however, that quantitative values for noise sources obtained so far should be carefully discussed, as the results could be biased by the directivity of sources or non-stationary effects-. This is the subject of present investigations described in [10].

Nevertheless, a comprehensive research program including aerodynamic calculations, wind tunnel tests of potential solutions to reduce aerodynamic noise, to select the best candidates to practical applications was undertaken, which will provide practical assessment of the reductions achievable for aerodynamic noise.

5 - CONCLUSION

The challenges in designing high speed railways systems is twofold :

- meeting the requirements of a more and more stringent regulation,
- anticipating the technical progress achievable on both the rolling stock and infrastructure, either at source or in the noise barriers installed along the track.

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