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TOWARDS THE LOW-NOISE RAILWAY - THE DB NOISE REDUCTION RESEARCH PROGRAMME

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ABSTRACT
The research programme of the Deutsche Bahn AG (DB) is presented which aims for a major leap within the next years towards less railway noise production. In five projects primary noise experience via the ambient air as well as the secondary noise experience via the ground vibrations are tackled from the source to the residents. Beside these investigations, the sound perception and noise assessment is paid attention, too.

1 - INTRODUCTION
In the last few decades, mobility in Europe, based on automobiles for individual traffic and lorries for freight traffic, has grown more and more; yearly growth rates of more than 10% have often been reported by statistics. These growth rates cumulated over the years cannot easily be handled in an environment-friendly way. The European Commission has therefore given distinct political signals to get more passengers and more freight onto the railways. An efficient trans-European transportation network is indispensable to handle this mobility increase.
To empower the environmental friendliness of the railway traffic in Germany, the Deutsche Bahn (DB) is in between of absolving a major research programme concerning noise reduction. The final goal of this ambitious research agenda is to achieve a decline in overall noise production by up to 10 dB(A) compared to 1990 by the year 2005 for DB's business units for freight and passenger traffic as well as the infrastructure division.

2 - NOISE REDUCTION RESEARCH AT DB
The representative "acoustical" situation around a train in motion on a railway line is shown in Figure 1. Train and track both act as the sound sources and the two ways of noise transmission make two lines of research indispensable.
Since in the air only longitudinal waves are possible, the classical rules of acoustics can be used to trace the sound waves from the source to the railway line residents whom they may disturb (see e.g. [1]). The direct noise experienced by these residents can be reduced both by limiting the strength of the sound source and by extending the transmission path of the sound wave by making use of the inflection effect of sound barriers. Also the installation of noise protection windows represents a counter-measure against too high noise exposure.
In the ground, the transmission of energy is possible by longitudinal as well as by transversal waves and different mixed wave structures can be identified apart from these pure wave types. This makes the analysis of the acoustical problem from the source to the residents' ears more complex since transmission of the wave energy through the ground and formation of the secondary sound in the houses involve more parameters and influencing quantities.
To realise this goal, five projects are running within the DB programme "Low Noise Railway". These deal simultaneously with the noise treatment of the trains and the rail/wheel system and include vibration control, the reduction of noise transmission and the assessment of noise perception (fig. 2). External

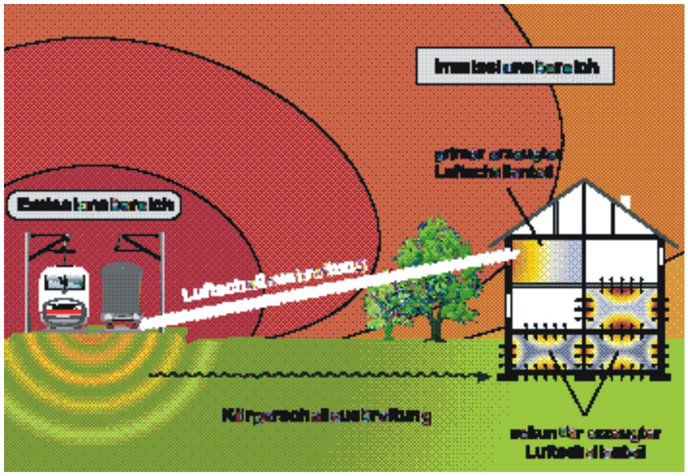

Figure 1: Acoustical situation around a train in motion on a track section.

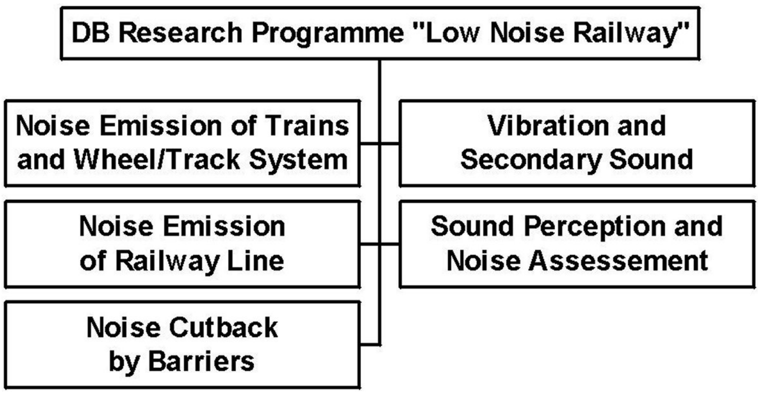

Figure 2: Noise research programme at Deutsche Bahn (DB).

scientific institutions, engineering experts and manufacturers are involved in all of the projects in order to obtain a broad view of the problems stated.
Thus all impacts of rail-bound vehicle noise, from the sources of noise to the residents near the railway line, are being tackled. Overall expenditure per year is approximately 2.5 million Euro which shows the high priority of these noise reduction activities.

2.1 - Noise production of trains and wheel/track system

Since the minimisation of sound radiation directly at the source is the first-choice solution, several work packages deal with the noise emission of the trains and the wheel/track system.
The necessary understanding of the sound sources of high-speed trains was gained within the French-German DEUFRAKO framework in the project K2 "Noise sources of High-Speed guided Transport" [3]. Combined with the acoustical analysis of freight traffic in the EU-funded projects SILENT FREIGHT / SILENT TRACK, the basis was found for the progressive achievement of low-noise traffic in Europe. In the EUROSABOT project, 41 composite materials were investigated concerning their ability to replace the current cast-iron blocks on the existing European freight wagon fleet and thus to reduce freight traffic noise.
Railway coaches and wagons are equipped with 4 or 8 wheels and the discs of these wheels are excited by wheel/rail interaction and dominate overall sound radiation. Since this high "loudspeaker" area per unit train length cannot be reduced because of axle load limitations, silent railway wheels – both for block and disk brake operation – will play an important role in the future to meet the goal of a low-noise railway system.
The basic studies concerning the optimum shape with respect to the acoustic requirements have already been performed (Figure 3). Now, wheel manufacturers, wheel and brake engineers and material experts are involved in the workgroup to clarify the questions of the casting process, brake safety and life cycle costs.

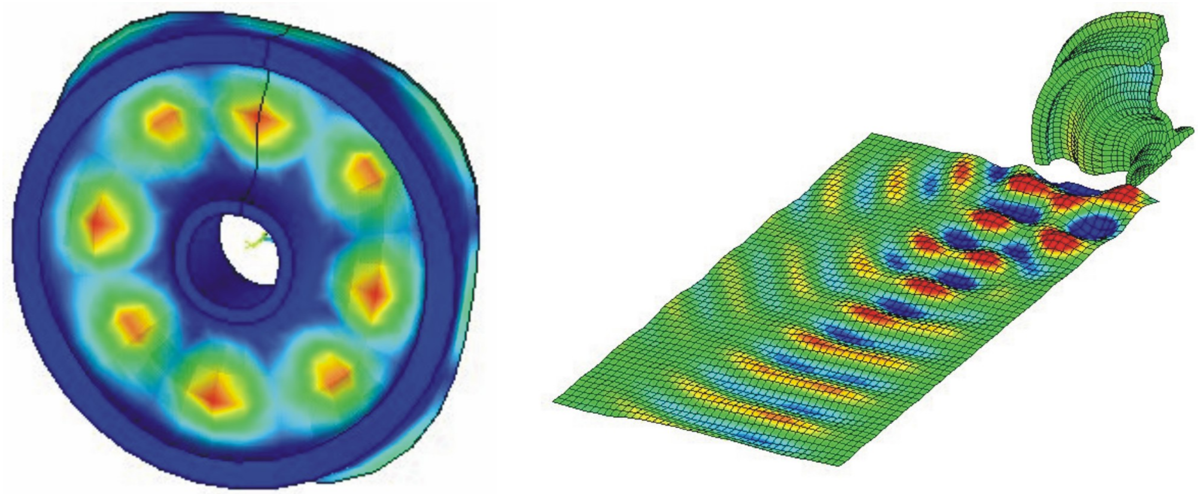

Figure 3: Numerical simulation of the sound radiation of railway wheels with different shapes.

Work on rail corrugations which cause rail noise and also excite the wheels is currently focussed on the analysis of a huge data set concerning these corrugations and on tracing the growth rate of the corrugations on track sections with different grinding procedures.

2.2 - Noise production from railway line

In the last few years, DB has implemented the acoustical concept of the "Specially Monitored Track (SMT)" (in German: "Besonders überwachtes Gleis (BÜG)"). The SMT concept is based on the periodic acoustic monitoring of the relevant track section by means of a test coach specialised for sound measuring. Should noise production be beyond a certain limit, grinding of the track section will remove the tiny periodic rail corrugations which excite the train wheels and lead to sound radiation from the wheels and the rail itself. Figure 4 shows a representative example of the sound pressure level before and after grinding the rails.

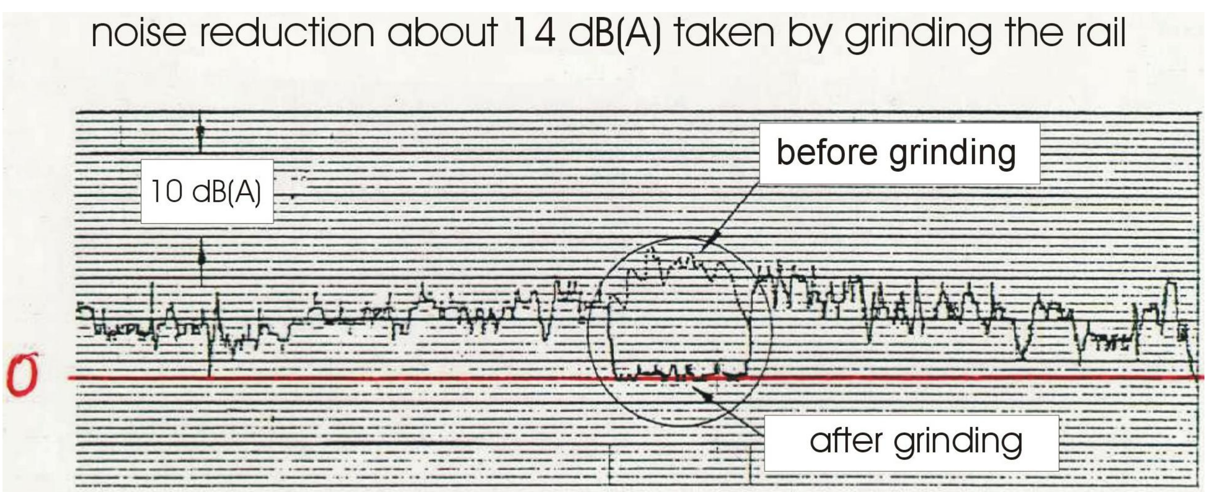

Figure 4: Noise emission from railway line before and after local grinding.

The Federal Railway Office (EBA) officially confirmed SMT as a noise reduction system with effectively -3 dB(A) for ballasted tracks and slab tracks.
Further development of SMT and related techniques is towards a mobile measuring device for rail surface roughness to perform in-situ quality control directly after grinding and towards an application of SMT to slab tracks equipped with a sound absorbing layer.
To complete these activities, an automatic system for sound diagnosis will be developed to measure the sound production of the different train fleets at a given track location over a longer time period to gain a better insight into the scatter in the noise emission within a fleet and its impact on the line emission.

2.3 - Noise reduction by means of sound barriers

In relation to rolling noise, the typical screening effect of a 2 m high sound barrier is average 10 dB(A). At up to 1 million EURO/km, the installation of sound barriers is costly and to justify these substantial investment costs the effectiveness of the noise protection installations must be as high as possible. Barriers with 3 or 4 m height will be an exception since they impair the residents. Furthermore, train passengers can no longer enjoy the outside landscape through the coach windows and travelling by train becomes less of a pleasure.

Another means to increasing the effectiveness of the sound barriers is a better understanding of the inflection properties followed by systematic optimisation of the construction of the wall. Since the inflection effect is dominated by the structure of wall edge, the numerical simulation of several detailed configurations will provide an initial selection of the configurations for later full-scale testing (Figure 5).

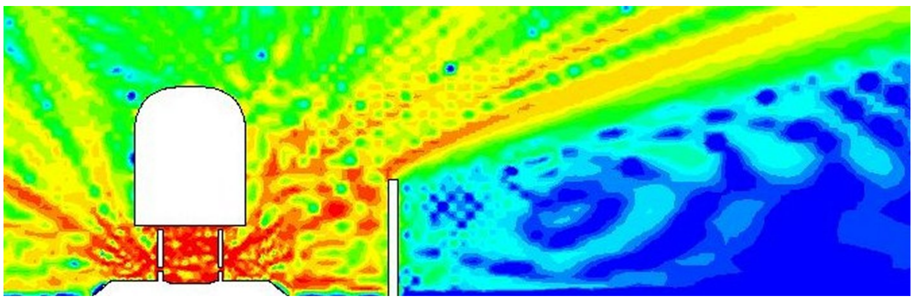

Figure 5: Simulation of sound cutback effect by barriers with varying inflection properties.

These investigations are being completed by the quantification of the damping effect of the ground and meteorology in between the sound source and the residents to optimise the overall noise protection. The results will also enter the sections related to noise protection in the environmental protection laws in Germany.

2.4 - Sound perception and noise assessment

The description of a certain sound experience as annoying "noise" is a very individual judgement and can by no means be considered in terms of physical quantities alone. The question of when sound is qualified as noise is therefore a very basic one and it is investigated parallel to the above-mentioned activities taking physiological and psychological aspects into account.

In several European countries, there is a "bonus" approach towards railway-created noise. This is based on consideration of the fact that, for a given hourly passing according to sound pressure level, railway noise is to some extent less annoying than noise created by private car and lorry traffic because of the dissimilar sound-production characteristics. In Germany and Austria, this allowance is -5 dB(A) [2], while, for example, in France it is -3 dB(A). To allow for a better understanding of this phenomenon and to support the legislative authorities, the assessment of noise quality is investigated in detail. The focus is on the noise effect of high-speed trains and of conventional passenger and freight trains. Additionally, studies concerning sleeping residents being woken up and the acoustic disturbance inside rooms are continuing.

The avoidance of the wheel squeal to be heard from freight wagons on very small-radius track curves is a distinct goal. Up to now, the occurrence of this noise component in freight-train formation facilities could only be reduced by costly sound barriers; research is now to be performed into avoiding the noise at the source.

To increase passenger comfort on the train, investigations into the noise effects and sound absorption inside the coach are also underway. The aim is to set criteria for effects such as the slope of the sound spectrum on the traveller's feeling of well-being and subsequently to allow for an adequate sound design of the coaches. As part of this study, Figure 6 shows the measured decay of the sound pressure level versus the distance from the source in the open air and within an ICE passenger coach.

2.5 - Vibrations and secondary sound

Train movement on the track not only causes direct audible sound via transmission through the air but also sets off vibrations which are transmitted through the soil. Away from the railway line, these vibrations may reach a building thus creating both vibrations in the structure itself and also so-called secondary sound due to the periodic excitation of the floor in the building.

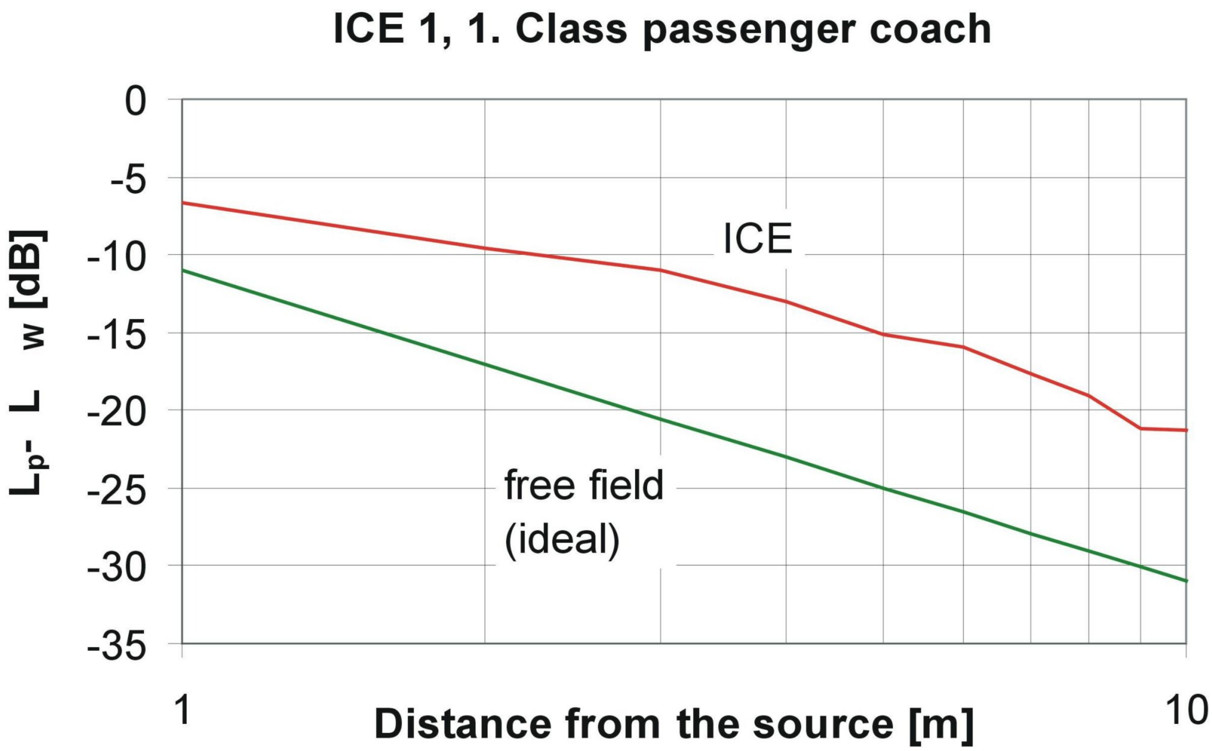

Figure 6: Measured SPL versus distance from the source (open air and ICE coach).

Current legal specifications for tolerable vibration limits are not very satisfactory. In combination with the difficulty of forecasting, this results in some uncertainty concerning the vibration values to be aimed for during the planning phase of construction projects for various new railway lines or for upgrading existing lines. More or less reasonable error margins are taken into account to be "on the safe side" concerning later complaints by residents.
To overcome this uncertainty, the validation and application of numerical simulation models for vibrations is essential. The scope is wide-ranged in the sense that, from the train/track interaction through the transmission to the formation of the secondary sound in the house near the railway line, the simulation should give a reliable forecast. Also the effect of vibration protection walls buried in the ground has to be calculated with precision. Beside the physical modelling, the input information such as the material data of the ground is essential for the success of the simulation.
As an example, Figure 7 shows such an approach based on a complex spring-damper modelling of a track section creating ground vibrations during train passage.
The definition of suitable vibration limit values for residents is, of course, also vital to allow for more confidence in the planning procedures. Here, laboratory investigations with volunteers exposed to vibrations of the "railway-induced type" are underway and will form a data basis concerning the perception of, for example, the average and peak values and their spectral composition.
In addition, reduction of vibrations at the source is being investigated by the analysis of the possible development of a low-vibration bogie for future freight wagons.

3 - CONCLUSIONS

DB is undertaking a major noise reduction research programme to answer the public demand for low-noise railway traffic in future. All aspects of the creation, the transmission and the perception of noise are being tackled in several projects by various workgroups launched with DB experts along with acoustic professionals from other European railway undertakings and external institutions.

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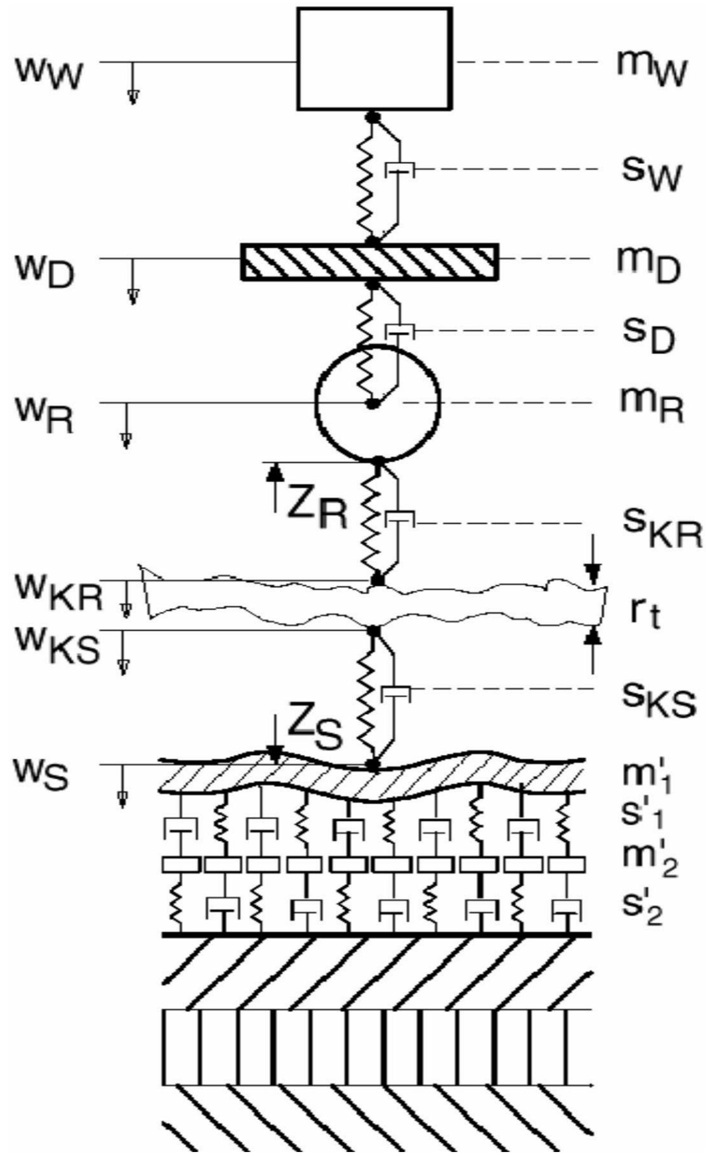

Figure 7: Physical model of a track section creating ground vibrations during train passage.

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