BRAINS for improved rail vehicle acoustics

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Summary

BRAINS (Bombardier RAIlways Noise Software) is an acoustic prediction software for interior and exterior noise from railway vehicles. The tool was developed in-house by Bombardier to fulfil the specific needs of noise control management and noise predictions in the rolling stock industry.

Essentially, BRAINS forms an efficient administrative framework in which several computational modules are integrated. It is created in the Matlab environment but can also run as a compiled executable. It has a graphical interface and several features to facilitate modelling of different train types and the import of source, transmission and absorption spectra.

BRAINS by default performs the calculations in 1/3-octave band spectra. It interacts with the Bombardier acoustics material database. The modelling is based on a hybrid-approach using the most appropriate method for each class of acoustic problem ranging from analytical, statistical and empirical formulations based on experimental data, to pre-calculated values for standard cases from other more specialized simulation packages, such as Twins, Odeon, Sysnoise, Simpack, Nastran/Patran and AutoSEA2.

The software has been validated on several vehicles and is primarily used in the bid phase of a new vehicle project within a framework of processes in acoustics and vibration to assure compliance to customer requirements at justifiable cost.

During the order phase of a vehicle project more detailed predictions, e.g. using Statistical Energy Analysis (SEA) are done [1] [2].

Exterior Acoustic Prediction

This type of calculation is based on analytical laws of point source radiation including an advanced ground reflection model taking into account complex-valued frequency dependent ground impedance. General point sources are described by their sound power spectra. Wheel/rail sources are described by sound power and decay spectra. The rail sound power is spread out along the rail based on the decay rate. A 50/50 combination of monopole and dipole character is assumed for the wheel/rail sources. A large database of Twins-calculated spectra has been incorporated into BRAINS for easy access. Rail and wheel roughness spectra can be read from a standard library or be user-specified. For roof-mounted sources the diffraction effect of the roof-wall edge is considered as well as the effect of side skirts [3].

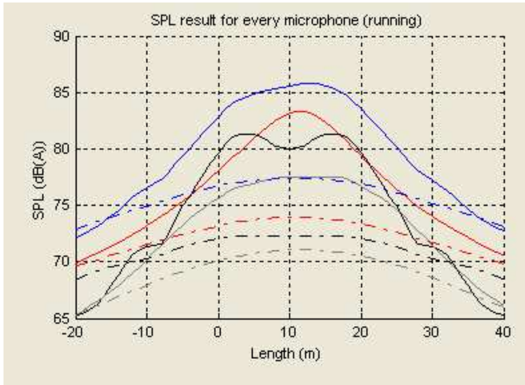

Figure 1: Source ranking during pass-by.

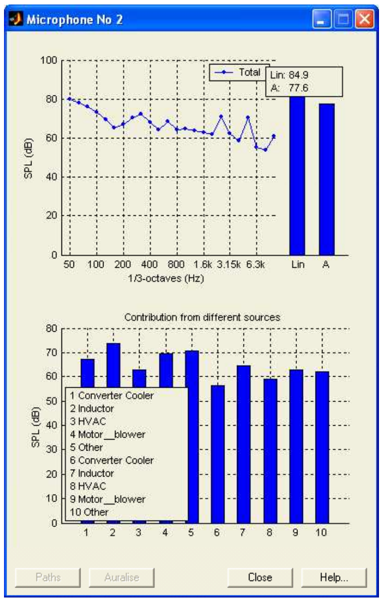

Figure 2: Calculation of source contribution at microphone position at standstill.

Wayside sound pressure time histories at standard or user-specified microphone positions are calculated (s. Figure 3 and Figure 4) and also the following quantities: LpA,eq,TP, LpAmax and TEL. A ranking of source contribution is made as shown in Figure 1 and Figure 2.

Interior Acoustic Prediction

The basic hybrid approach in BRAINS is used for interior acoustics. The detailed calculations can be carried out in the most appropriate software for each class of problem, i.e. finite or boundary element methods, statistical analysis, analytical expressions, ray-tracing, MBS. All calculated values are carefully validated and tuned with experimental data to assure an appropriate quality. Values and transfer functions for standard cases are hence pre-calculated and can be imported as such to BRAINS. This approach also assures

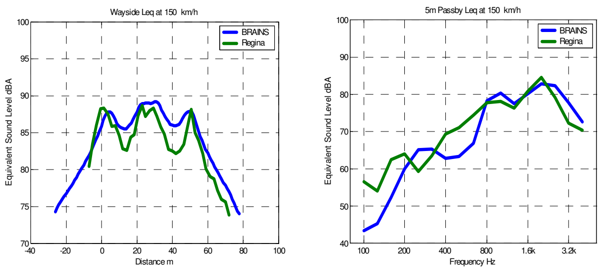

Figure 3: Example from comparison between Brains and measurement for exterior passby noise at 7.5m distance for an electrical multiple unit at speed 150 km/h. (a) time history, (b) spectral composition of peak value.

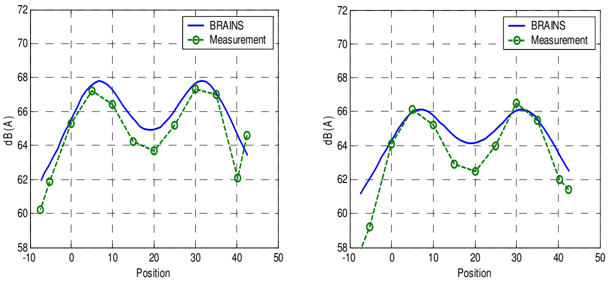

Figure 4: Example from comparison between Brains and measurement for exterior standstill SPL at different microphone heights 1.2m and 3.5m

that results can be achieved very quickly without repeating and depending on time consuming numerical calculations.

For interior noise the fundamental calculations are based on a classical source-transmission-receiver model. The core of the calculation is a SEA formulation of the energy balance of interior cavities [4]. Air-borne sources may be located outside or inside the corridor. In case of interior sources, the source power is directly injected into the cavity without transmission functions. For some classes of sources, e.g. cooling fans and traction motors, acoustic installation effects are considered [5].

Interior partitions between cavities, which affect the coupling loss factor CLF between them, can be modelled. These partitions can either be partly or fully covering the vehicle cross-section.

For the air-borne noise transmission into the cavities, surfaces are covered with 2D plate elements characterized by transmission loss spectra. The transmission loss spectra can either be imported from a database or derived by a special module inside Brains, enabling the modelling of TL spectra for many different configurations including sophisticated orthotropic double walls with acoustic short cuts [6].

For structure-borne noise a semi-empirical approach is used which is gradually being refined with new results based on testing [7] and simulations from FE/SEA as well as parametric MBS approaches for the bogie at lower frequencies.

The sound field outside the (floor/wall/roof) surfaces depends on the type of operation. For the sound field around a train running in free field analytical expressions are used, which were calibrated to full scale measurements. For tunnel operation pre-calculated level differences from ray tracing methods, which were calibrated to full scale tests, are applied. The set of these pre-calculated functions is gradually extended for different types of tunnels having different track design and cross-sections.

The final results, which are interior sound pressure level of course, but also sound level distribution below and around the train and transmitted sound power per surface, can be visualized indicating the weakest points for a certain configuration as depicted in Figure 6. For each interior cavity the contribution from different sources and the transmission trough adjacent elements and cavities is given.

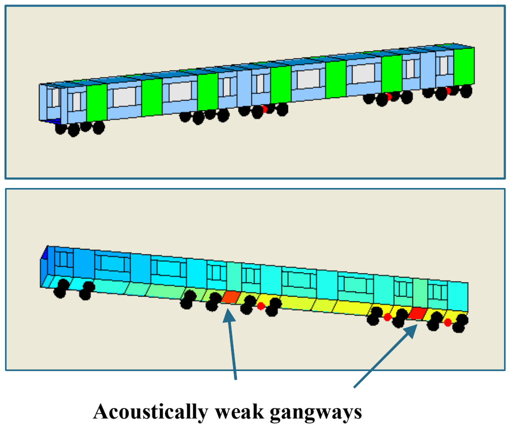

Figure 6: Transmitted sound power per unit area.

Conclusions

BRAINS, applied within a process for acoustics and vibration engineering, together with other tools and experience gives Bombardier an efficient and quick method at hand, which provides the capability to run parametric studies and find weight and cost optimised solutions.

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