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DUTCH NOISE REDUCTION PROGRAM FOR FREIGHT RAILWAY VEHICLES: LOCALISATION OF IMPORTANT SOURCES

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1.QUIETER RAILWAY TRAFFIC

The legal limits for community noise levels generated by railway lines are generally complied with either by means of barriers or by exploitational limitations, e.g. limiting the nighttime traffic or limiting the train speed. High noise barriers face a growing opposition due to their effect on the landscape. Therefore, the noise emission of railway vehicles becomes more and more the limiting factor for the exploitation of railway infrastructure. Whereas for passenger rolling stock considerable noise reductions have been achieved over the years, for freight vehicles little progress can be reported. This is an obstacle to the policy of shifting the growing amount of goods to be transported through Europe from the road to the rail. In the frame of the dutch Transport Technology program, supported by the Inter-departmental Commission for the Economical Structure, a project was started in 1995 with the title "Quieter Railway Traffic". The objective of the project is twofold: first to develop a prototype freight wagon on a prototype track, which, in combination, show a noise reduction of at least 10 dB(A) compared to current combinations of vehicles and track. Second to set up a so-called knowledge-infrastructure, which will enable future further development and implementation of the prototypes. Results shall be available early 1999.
NS, the Netherlands Railways, are the major partner in this project. NS Technical Research, the R&D body within NS and is responsible for the acoustical and scientific aspects of the projects. Cooperation is sought with partners within NS and outside, such as manufacturers, universities, consultants and knowledges centers.

2. DEFINITION OF REFERENCE SITUATION

Regarding the above objective, the reference vehicle and track combination had to be well-defined. For this purpose a special test train was composed, consisting of 11 groups of three similar wagons. The 11 groups contained loaded and unloaded versions of similar wagon types, ranging from 4-axle container carriers with loaded and empty containers or no container at all, to 2-axle sliding door vehicles. The test train was run to and fro on the selected test track with well-maintained speeds of 60, 80 and 100 km/h. The roughness was recorded on the track near the measuring site and on samples of the wheel treads. A german consulting company, Akustik Data from Berlin, was assigned to record pass-by noise levels using special microphone arrays, enabling to localise the different sound sources on the train. From the measurement results, the 4-axle container carrier vehicle was selected to be the reference vehicle. The selection was made through a multi-criteria analysis, where the frequency of application of this vehicle in European freight trainsport and the acouscis challenge of reducing the sound output of the most quiet vehicle in the test train have been determining criteria. The reference track was selected to be the actual standard in dutch railways, i.e. UIC-54 rail on concrete sleepers.

3. MICROPHONE ARRAY METHOD

Akustik Data has several years of experience with microphone array measuerements of noise sources moving as fast as 450 km/h (German Maglev Transrapid). For the purpose of the experiment discussed here the recording capacity of the equipment had to be extended in order to record the complete passage of the 600 meter long train at 60 km/h. Measurements have been made with horizontal and vertical linear arrays with variable interspacing, and with one version (microphone spacing of 16 cm) of the so-called X-array [1]. The linear horizontal array allows analysis of the sound pressure level contribution of individual axles (wheels) thanks to the use of swept-focus techniques. The linear vertical array allows to distinguish radiation behaviour between the lower and the upper part of the vehicle, averaged over time. Finally the X-array is a powerfull tool for presentation purposes but lacks some important features of the two linear arrays.

4. RESULTS

Horizontal array
The results of several passages with identical speed show remarkable reproducibility. Typical level differences between a axle passing and between axles range from 8 dB(A) for hopper wagons to more than 15 dB(A) for flat container carriers. Linear regression between log v (with v = train speed) and the sound pressure level in dB(A) shows coefficient from 2.5 to 3.5, well in line with the theoretical value of 3.0 for rolling noise. However, for low frequencies the average coefficient is only 0.2 . Generally a difference is found between loaded and unloaded vehicles, the latter showing a 3 dB(A) higher sound emission. Narrow band frequency analysis of the recordings clearly shows the natural frequencies of the wheels to be independent from train speed. Low-frequency peaks can be explained from measured wheel roughness spectra with typical wavelengths of 0.04 to 0.06 m.

Vertical array
The sound level distribution as a function of height over rail head clearly indicates the lower meter as the most important region for sound generation. The inherent angular resolution of the array rends the maximum difference between these two region to be limited to appr. 25 dB. For most measured vehicle types the typical difference is only slighty less. Merely for the tank wagons, particularly when loaded, a significant contribution from the vehicle superstructure can be observed. The spectral density of the sound radiated from the superstructure does not deviate much from that of the wheels. The levels are some 15 dB lower. Only below 700 Hz the superstructure shows a higher contribution.

Two-dimensional array
The X-array supplies full colour pictures of the vehicles, clearly indicating the location of the sound sources. Some indications are found that loaded vehicles show larger relative track contributions than unloaded vehicles. The track contributes sound energy in the frequency region around 900 Hz.

Conclusions
From the above results a worst case estimate was calculated for the vehicle superstructure radiation. According to this estimate this contribution amount to -9 dB compared to the overall energy content of a vehicle (mean value for the whole train). Should the wheel/track related noise source be reduced by 10 dB whithout affecting the

ruoghness related excitation, then the overal reduction would not be more than some 7 dB. This limitation should be kept in mind when considering alternative reduction solutions.

5. FURTHER RESEARCH

Noise radiation from the vehicle superstructure forms a serious risc to the achievable noise reduction. Reduction solutions should first of all aim at reduction of the wheel roughness. For the selected reference vehicle further research will be aimed at better quantification of the superstructure radiation (by means of accelerometer measurements). The observed difference between loaded and unloaded vehicles requires further looking into the assumed dynamic decoupling of the wheels from the bogies on the one hand, and further research into the phenomena in the wheel/rail contact patch under static load on the other.

The application of microphone arrays offers an opportunity to measure and monitor important quantities under realistic conditions. The results will be used to validate modelling tools such as Finite Element methods for modal analysis of the wheels and the TWINS model [2] describing roughness induced noise radiation from vehicles and track.

References

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