Assessment of the efficiency of railway wheel dampers using laboratory methods within the STARDAMP project

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Introduction

During the past decade, several national and European projects have been conducted in the aim of understanding railway noise sources and developing mitigation measures.
Yet, the step from R&D of damping devices to their regular application remains challenging. One reason is the lack of standardized measurement methodologies to assess the effectiveness of rail and wheel dampers. The definition of such methodologies is the main purpose of STARDAMP. A general description of the project is presented in a parallel paper [1].
This paper deals with the proposal for a wheel absorber measurement protocol combining finite element calculations, experimental modal analysis and analytical calculations using TWINS (Track-Wheel Interaction Noise Software) [2]. Within STARDAMP, a software tool based on TWINS has been developed with the aim of providing a tool to a larger public, including non experts. The procedure described here also applies when using this software instead of TWINS.

Wheels and absorbers tested in STARDAMP

Altogether, four different wheels have been used in the STARDAMP project. The wheel considered here has especially been designed by GHH-VALDUNES for the project to be compatible with different kinds of absorbers. The absorbers used are the GHH-VALDUNES VLN ring absorber and the GHH-VALDUNES plate absorber.
The ring absorber is a relatively light device, clamped to the inner wheel rim. It adds damping to the wheel through dry friction. The plate absorber is made of an elastic layer between two metal sheets. Due to varying lengths of the different blades and the high damping introduced by shearing of the elastic layer, this absorber is also effective over a wide frequency range. Note, however, that neither of these absorbers has been tuned to the wheel. Indeed, the aim of the project is not to optimize wheel absorbers but to define characterisation methods.

Wheel noise calculation procedure

The presented methodology is based on TWINS calculations [2]. This software implements an analytical description of wheel-rail interaction, rail response, rail radiation and wheel radiation. The wheel response is not directly calculated in TWINS but by the use of an externally calculated modal basis (using a Finite Element model). Input to TWINS consists in a reduced number of modal displacements on wheel tread and web, largely sufficient for the calculation of wheel-rail interaction and wheel radiation. Modal damping varies very little from one bare wheel to another; default values (depending on the number of nodal diameters) are used. After definition of all track parameters (such as rail and sleeper type, rail pad stiffness and others), TWINS calculates the sound power radiated from each component (wheel, rail and sleeper) for a unit roughness excitation. These results are finally weighted by a given wheel and rail roughness spectrum as well as a contact filter that depends on the static wheel load; the speed of the train determines the corresponding excitation frequencies. For wheels with damping devices, the procedure is very similar. Indeed, the FE results of the bare wheel can still be used because most absorbers have only a small effect on mode shapes. Modal frequencies and damping coefficients are measured by means of an Experimental Modal Analysis (EMA). The TWINS input file is then updated with these data and calculations are performed as described above.

Results

Wheel dampers act through the additional modal damping applied to the wheel. The effect can be clearly seen on the wheel receptances. Figure 1 compares receptances of the bare wheel and those obtained with mounted ring or plate absorbers. The reduction at the main receptance peaks is roughly between a factor 10 and 100. As the bare wheel receptance does not reflect the damping when rolling, however, this is not the gain that will be obtained for the wheel response. Indeed, Figure 2 shows that the gain on the vertical displacement of the wheel at the wheel-rail contact point reduces to a factor 3 to 10.

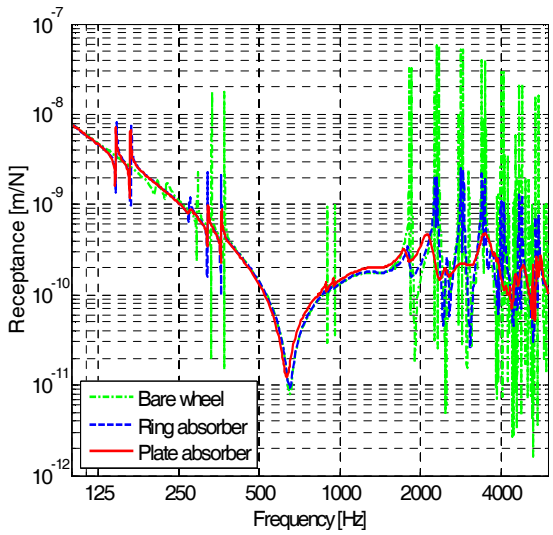

Figure 1 : Receptances of bare wheel, wheel with ring absorber and wheel with plate absorber

Figure 3 and Figure 4 indicate the acoustic powers of wheel, rail and sleeper, for the bare wheel and the wheel equipped with plate absorbers. With 9.8 dB(A) reduction in wheel

power, the absorber is seen to be very efficient. The much simpler ring absorber is found to reduce the wheel noise by 6.3 dB(A). Because of the predominance of the rail, however, the overall reduction achieved with both systems is close: 1.7 dB(A) and 1.5 dB(A) respectively. The additional benefit of the plate absorber would therefore only be audible on a quieter track (for example with stiffer rail pads or rail absorbers). These results clearly show that a total noise reduction produced by a given wheel absorber can only be

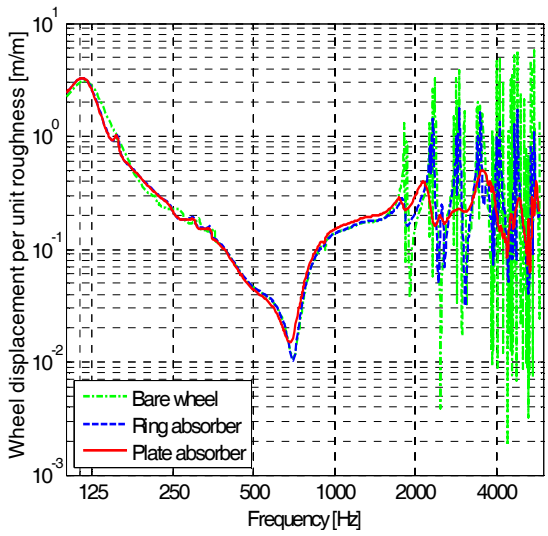

Figure 2 : Wheel response per unit roughness for bare wheel, wheel with ring absorber and wheel with plate absorber

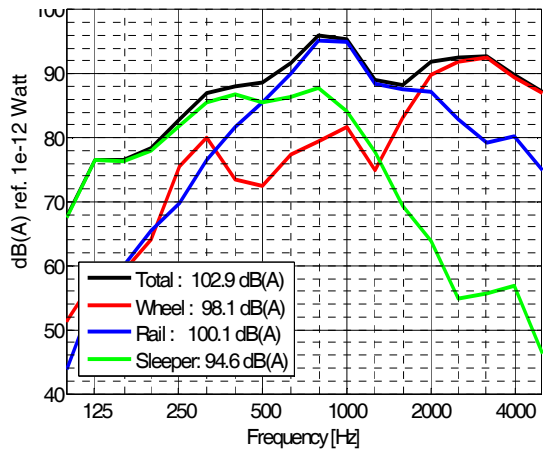

Figure 3: TWINS calculated sound powers for wheel, rail and sleeper; bare LK 900 wheel

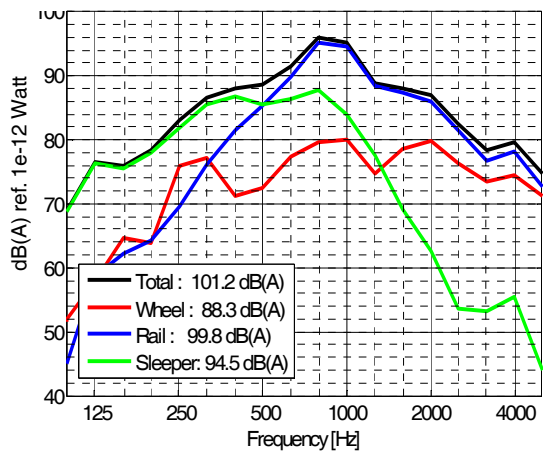

Figure 4 : TWINS calculated sound powers for wheel, rail and sleeper; LK 900 wheel with plate absorber

given for one specific track. Another parameter that highly influences the performance of any wheel absorber is the roughness of wheel and rail. The results presented above have been obtained by the use of TSI+ rail roughness and a typical roughness spectrum measured on a disc braked wheel for a speed of 100 km/h. A typical tread braked wheel roughness spectrum for example is characterised by significantly higher levels in the mid-frequency range. The predominance of the rail will then be even clearer and the relative benefit of a wheel damper lower.

Comparison with other methods

The presented method for the assessment of wheel damper efficiencies is one of three techniques that are tested within STARDAMP. One alternative method, developed by GHH-VALDUNES, consists in measuring vibro-acoustic transfer functions between a force excitation of the wheel and its sound radiation in a reverberant room. As this excitation is not representative for rolling conditions, a post-processing with a model similar to TWINS is necessary. Wheel acoustic power is measured directly here, which represents a considerable advantage when assessing wheel absorbers that are liable to radiate sound themselves. This is in fact the case for the GHH-VALDUNES plate absorber.

Conclusion

The STARDAMP project aims at qualifying methods that permit the assessment of wheel and rail damper efficiencies. For wheel dampers, the "Experimental Modal Analysis + TWINS" method is a promising candidate that is applicable for all devices that mainly modify the modal damping of the wheel without affecting too much mode shapes or radiation. In these cases, the method has the big advantage of calculating wheel and rail power separately, which is important for a correct prediction of total noise reduction. Wheel and rail roughness are part of the input data and therefore numerically controlled. This is very important because any sound power reduction that is obtained with an unknown roughness spectrum is of little significance.
The comparison with alternative laboratory methods is currently in progress. These are especially interesting for the assessment of the plate absorber.

Acknowledgments

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