The STARDAMP method: Generation of input data through laboratory measurements

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Introduction

Within the Franco-German research project, STARDAMP, software has been developed that allows the quantification of the efficiency of acoustic rail and wheel dampers, reducing the need for costly field tests on real track. A general description of the project has been presented at DAGA 2012 [1]; the software has been discussed in more detail in [2] and wheel modelling aspects are addressed in [3]. Laboratory tests can provide most of the needed input data concerning both wheel and rail dampers. The scope of this contribution is on measurement procedures to determine rail damper performance from measurements on a 'free' damped rail.

The noise radiated by the rail is usually the dominant source of rolling noise between 0.5 and 2 kHz and often in terms of overall level. The rail dynamic behaviour can be described by its decay rate (DR). From an acoustic point of view, high DRs are desirable in order to minimise the length of radiating rail. This can partly be achieved through stiff rail pads that assure coupling with the sleepers up to relatively high frequencies. However, soft rail pads are often preferred in order to protect the infrastructure from high dynamic loads. Rail dampers represent a possibility to increase track DRs while using soft rail pads.

Several designs of damper are now commercially available. Generally, these dampers are bolted or clipped on to the rail between sleepers and work on the principle of tuned mass dampers. Overall noise level reductions of 2 to 5 dB(A) can typically be found in comparative measurements of dampers installed within a track [4]. Indeed, the effectiveness of rail dampers depends to a large extent on the (initial) dynamic behaviour of the track. Currently, there are no standardized procedures to measure the effectiveness of these dampers without the need for their installation in a track. A procedure is proposed here, that is based on laboratory measurements on a piece of rail equipped with dampers and DR measurements on the real track (without dampers). Two methods are proposed to measure the damper performance (DRs): (i) for long rails, by integrating DRs derived from FRF's measured at intervals along the rail; and (ii) for short rails, at low frequency from the modal properties of the rail, and at high frequencies directly from point and transfer responses functions (FRFs) at either end of the rail.

Long rail method

The long rail method is based on DR measurements according to standard EN 15461:2008 [5]. However, the length of rail analysed is reduced to 32 m (length of the test track used). Measurements were made of the DRs of the undamped track, the damped track and the damped 'freely supported' rail. For the damped conditions, Schrey&Veit dampers were bolted on at mid span along the full length of the rail. For the damped 'free-rail' condition, the rail was unclipped and supported on sections of hydraulic hose resulting in a bounce mode of the rail at ≈15 Hz. A grid was marked up from a reference point 10 sleeper spans (5.96 m) from the rail end. Measurements were made at ¼-sleeper intervals from this point up to the 16th sleeper span, then at mid-span positions 17, 18, 20, 22, 26, 30, 34, 38, 42 and 46. An instrumented hammer with hard tip was used to excite the rail at each of the measurement points in turn. The response was measured with an accelerometer mounted at the reference point.

DRs in each ⅓ octave band up to 5 kHz were calculated in dB/m from the point frequency response function (FRF) at the reference point, $A(x_0)$, and the transfer FRFs, $A(x_n)$, between the reference position and the other points on the measurement grid, x_n, using:

$$DR = 4.343 \Bigg/ \sum_{x=0}^{x_{\max}} \frac{\left|A(x_n)\right|^2}{\left|A(x_0)\right|^2} \Delta x_n \qquad \text{[dB/m]} \qquad \textbf{(1)}$$

Damped track DRs are found by summing the DRs of the undamped track and the DRs of the unclipped damped rail. For validation of the method, these have been compared to the directly measured damped track DR.

Short rail method

A "laboratory method" for rail damper testing requires the tests to be carried out on a shorter piece of rail. This also permits a better control of temperature which highly affects the damper behaviour. With the short rail method, dampers are installed symmetrically over the whole length of a 6 m rail at a centre-to-centre spacing representative of the intended track installation. The rail should be 'freely suspended' at either end. Miniature accelerometers are rigidly attached as close as possible to either end of the rail (5 mm), attached either at the centre of the rail head for vertical measurements or on the side of the rail head for lateral measurements. For both lateral and vertical measurements, a point FRF at one end and a transfer FRF to the other end is measured. The rail temperature should be controlled between 18 and 25°C during the tests. Further measurements are recommended at temperatures encompassing the in-situ temperature range. It is also recommended to measure more than one sample of rail fitted with a given type of rail damper in order to check variability.

Where decay rates are high (i.e. at frequencies above ~300 Hz), the DR is determined in each ⅓ octave band as the decibel difference of the transfer FRF to the point FRF divided by the rail length. With low DRs, the % error in the DR for a given dB error in the FRFs is large and therefore in practice the lower threshold for reliable measurements using this method is found to be ~1.0 dB/m. Where decay rates are lower than this (i.e. at lower frequencies), DRs can be derived from the modal properties of the rail. A description of this 'modal method' and further details of the long rail method can be found in [6] and [7].

Long rail results

Measured vertical DRs for the undamped track, the damped 'freely supported' rail and the damped track are shown in Figure 1. For the undamped track, at low frequencies, there is high attenuation because of the stiffness of the foundation. Above around 500 Hz, waves begin to propagate freely in the rail and the DR decreases, before increasing again to a peak at around 5 kHz, caused by a flapping mode of the rail foot. This broad dip in the vertical DR coincides with a peak in the noise spectrum. The damped 'free' rail DR shows that the dampers introduced high DRs in the region of the trough in the undamped track DRs. Damped track DRs have been predicted by summing the damped 'free' rail DR with those of the undamped track. These show reasonable agreement with the directly measured DRs at most frequencies. Inaccuracies in the predicted DRs are believed to be caused by end effects of the finite length of rail as well as temperature differences during measurements. An identical analysis of lateral DRs has been performed, exhibiting an even better fit between predicted and directly measured DRs. These are not reported in detail here.

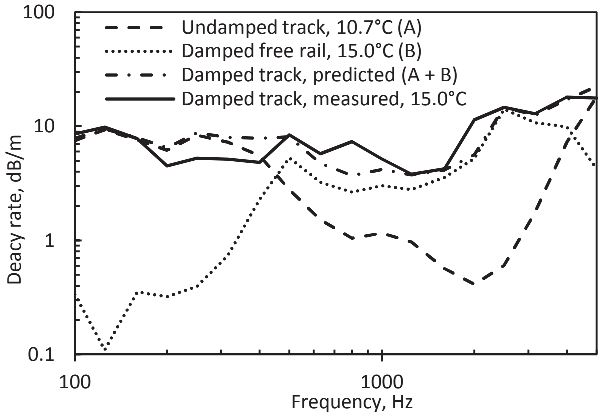

Figure 1: Vertical decay rates measured on the 32 m test track.

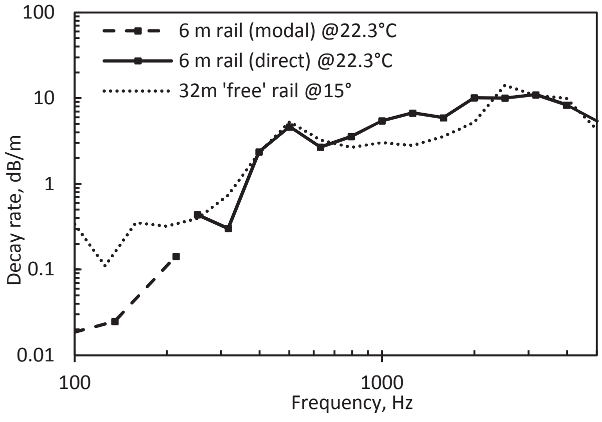

Figure 2: Vertical decay rates measured on the 6 m rail compared to the 'freely supported' damped 32 m rail.

Short rail results

Vertical DRs calculated according to the short-rail method are given in Figure 2 in comparison to the long rail results. The two methods show reasonable agreement between 300 Hz and 5 kHz. The modal method for determining decay rates on the 'short' 6 m rail was restricted to low frequencies (< 300 Hz) and resulted in much lower rates than those measured on the 'long' 32 m rail. As the damper decay rates are relatively low below 400 Hz and tend to have little influence on overall track decay rates, the direct short-rail method, yielding plausible measurements down to 300 Hz, may be sufficient for many applications. Lateral DRs showing similar results are not reported in detail here.

Conclusions

A combined experimental-numerical procedure for determining rail damper effectiveness without the need to mount them on the track has been proposed within the STARDAMP project. It consists of measuring the DRs of a short section of freely supported rail equipped with dampers and the DRs of the real track where the dampers are intended to be fitted. The DRs are then used as inputs in rolling noise prediction software which compares noise generation, with and without rail dampers. Reasonable predictions of the damped track DRs of a test track have been obtained using a 32 m free rail as well as a 6 m free rail.

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