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Evaluation of wheel dampers on an intercity train

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Abstract

Pass-by noise from high-speed trains is one important area that has to be handled in all new train projects. For the new line between Oslo and the Gardemoen Airport which opened in 1998, very stringent requirements were set out regarding external noise. To reach the target it was decided that the train should be equipped with wheel dampers. Two different types of wheel dampers were used on the train; a ring damper was mounted on the wheels of the driven bogies, whilst plate dampers divided into tuned absorber fins were mounted on the wheels of the trailer bogies.

During the type testing of the Airport Express Train, additional measurements were performed in order to evaluate the acoustic effect of the plate wheel dampers. Two test series were performed with the same train set; first with the train in standard configuration and secondly with the wheel dampers removed from the second and third bogie. The external noise was measured at 5 and 25 m distance from the centre of the track at speeds ranging from 80 to 200 km/h. The third-octave filtered time histories were analyzed to calculate the effect of the wheel dampers. As expected, there was a significant reduction of 4–6 dB at frequencies above 2000 Hz, but there was also a reduction of 2 dB for frequencies as low as 800 Hz. This reduction was also found in the parts of the time histories when the rail should be dominating. This implies that the wheel dampers also reduce the rail noise. The total rolling noise reduction for the trailer bogie was 3 dB at 200 km/h and 1 dB at 80 km/h. From comparison with TWINS-calculated sound power levels it was estimated that the wheel noise would be reduced by 5 dB and the rail noise would be reduced by 1 dB at 200 km/h.

1. Introduction

External pass-by noise was one major concern when the new Airport Express Train line between Oslo and Gardermoen Airport was planned. The train sets have a maximum speed of

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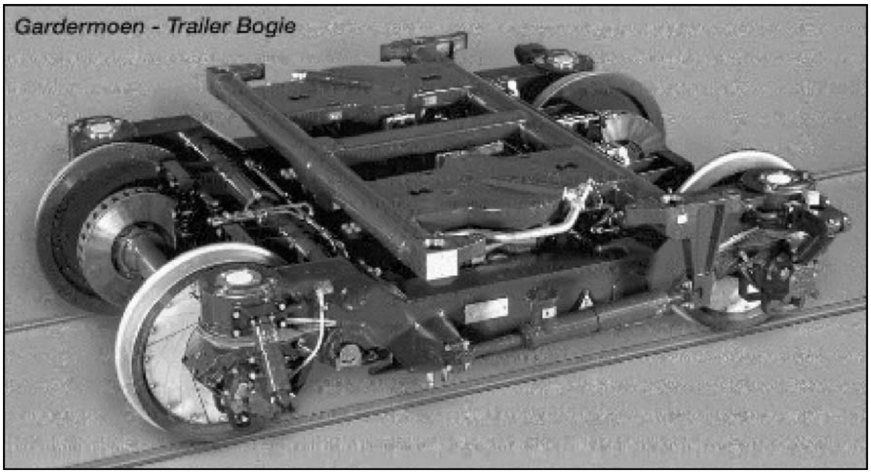

Fig. 1. Gardermoen trailer bogie with plate wheel dampers.

210 km/h and run every 10 min. The newly constructed line passes through residential areas and stringent requirements were set out regarding external noise. In order to reach the target it was decided that the train should be equipped with wheel dampers.

Two different types of wheel dampers were used on the train. For the three motor bogies with cheek-mounted disc brakes, ring dampers were mounted on the wheel tyres. For the three trailer bogies, with axle-mounted disc brakes, plate dampers divided into tuned absorber fins were mounted on the wheels, as illustrated in Fig. 1. Both types of wheel dampers were supplied by Gutehoffnunghütte Radsatz GmbH (GHH). The plate damper consists of two aluminium plates separated by a thin visco-elastic layer. The fins on the dampers are tuned to absorb energy in the wheel-mode frequency range [1]. This study aims at assessing the efficiency of these plate wheel dampers.

2. Test method

The Airport Express Train is an Electrical Multiple Unit (EMU) with three powered cars. The configuration is shown in Fig. 2, where black indicates powered wheels and white indicates trailer wheels. The pantograph is placed above the fourth bogie.

During type testing of the Airport Express Train additional measurements were performed in order to evaluate the acoustic effect of the plate wheel dampers. Two test series were performed with the same train set; first with the train in standard configuration and secondly, 5 days later, with the wheel dampers removed from the second and third bogie. By the use of a microphone placed as close as 5 m from the centre of track (c.o.t.) it was possible to reduce the influence from the other four unchanged bogies. To further improve the time resolution a time constant of only 35 ms instead of the normal 125 ms was used in the averaging process.

Each car is 26.5 m long, the bogie separation is 19 m and the wheelbase is 2.7 m. With a wheel diameter of 870 mm for all wheels the distance from the beginning of the second bogie to the end of the third is 11 m as indicated in Fig. 2. The pass-by time for the two bogies at 200 km/h becomes

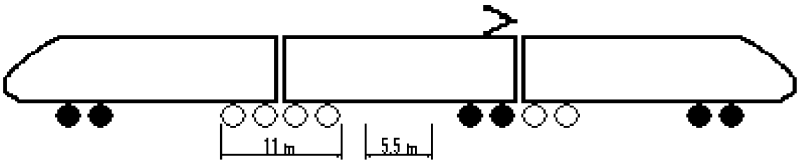

Fig. 2. Train configuration for the Airport Express Train.

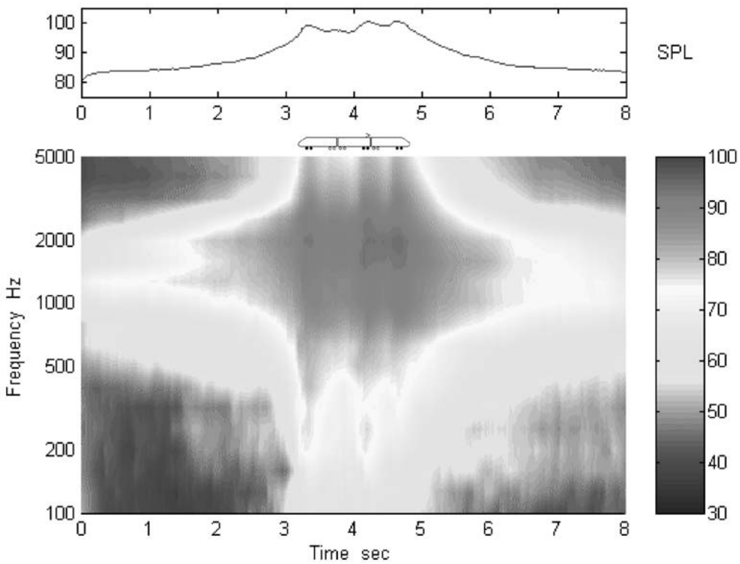

Fig. 3. Pass-by levels in dB(A) at 200 km/h 5 m from c.o.t. for train with dampers.

0.2 s and 0.5 s at 80 km/h. The equivalent level, L_{Aeq}, during this pass-by time was evaluated for all time histories. Another time segment, corresponding to the central part of the second car, was also analyzed in order to study the rail noise. To evaluate the frequency dependency of the effect of the wheel dampers, third-octave filtered time histories were also analyzed.

3. Results

The first test series was performed with the train in its standard configuration in parallel with the type testing of the vehicle. Fig. 3 shows the time history of the total sound pressure level, L_{pAF}, together with a colour map made up of the 18 third-octave filtered time histories. In these graphs a time constant of 125 ms has been used just to produce smoother curves, whereas 35 ms will be used in the detailed analysis later. It can be seen from the graphs that the second and third bogie had significantly lower noise levels. Note also the higher levels at lower frequencies, 200–250 Hz, which occur when the front of the train and the pantograph pass the microphone. The maximum

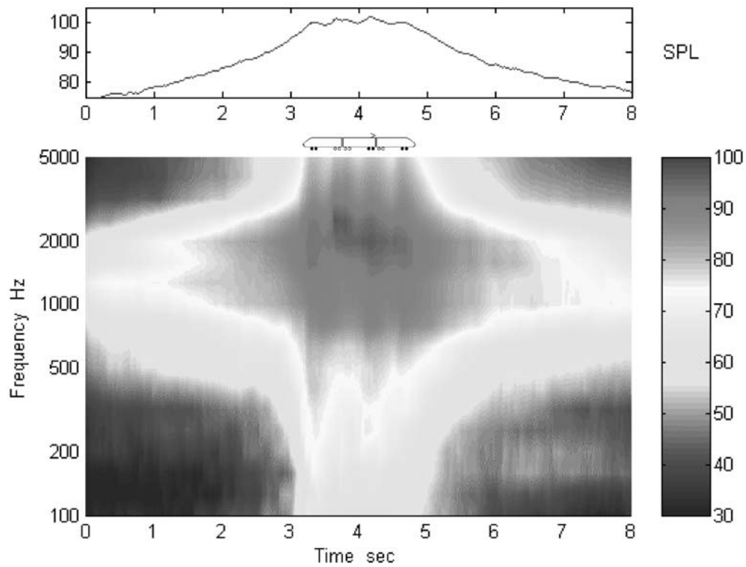

Fig. 4. Pass-by levels in dB(A) at 200 km/h 5 m from c.o.t. for train without dampers.

A-weighted sound pressure level, L_{pAFmax}, measured 5 m from c.o.t., was 100.5 dB and 25 m from c.o.t. it was 90.3 dB.

In Fig. 4 the results from the second test series with the wheel dampers removed from the second and third bogies are shown. These tests were made with the same train at exactly the same position only 5 days later. The track had not yet been opened for regular traffic during the tests. With the wheel dampers removed the noise contribution from the second and third bogie is now similar to the powered bogies but slightly shifted towards higher frequencies. The maximum A-weighted sound pressure level, L_{pAFmax}, measured 5 m from c.o.t., was 101.8 dB and 25 m from c.o.t. it was 92.1 dB. In Fig. 5 the difference between the two colour maps is illustrated in order to see more easily the differences. The time histories show that there is a noise level difference in the frequency bands 800 and 1000 Hz before the train arrives. However, the major difference is when the modified trailer bogies pass the microphone where the noise levels in the frequency range from 2000 to 5000 Hz increases significantly with the wheel dampers removed.

In Fig. 6 the time histories of the total sound pressure level are compared. These results have been obtained with a time constant of 35 ms in order to improve the time resolution, although this leads to a greater variation in the noise level. In Table 1 different values for the two time histories are presented. The reductions of approximately 1 dB in levels do not reflect the large reduction apparent in Fig. 6. To assess the effect of removing the wheel dampers from only two bogies a detailed study of the time histories was needed. The pass-by time histories were filtered in third octave bands in the frequency range from 100 to 5000 Hz; the results for 2500 Hz are shown in Fig. 7 as one example. For each time history the equivalent level, L_{Aeq}, was calculated during the 0.2 s corresponding to the time segment when the microphone was in front of the bogies. The averages from two pass-by tests for each configuration are summarized in Fig. 8. A similar calculation for the 0.1 s segment corresponding to the time when the microphone was between the bogies (bogie 3 and 4) was made. The segments are indicated in Fig. 2.

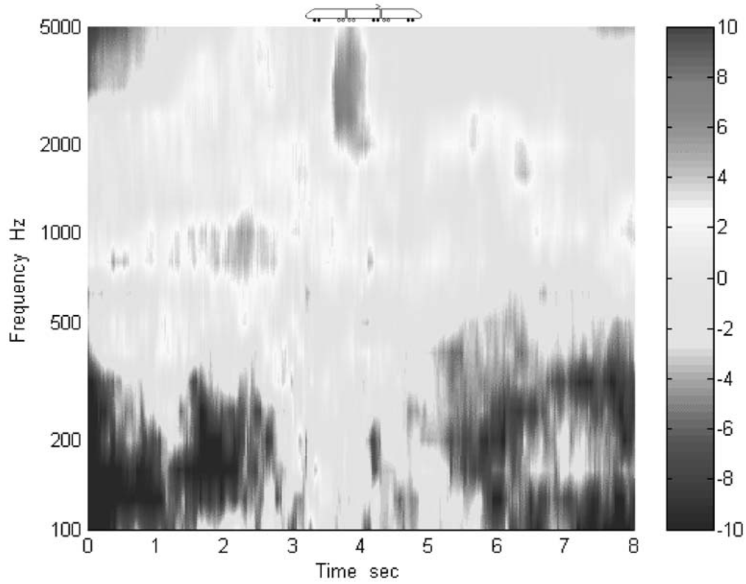

Fig. 5. Pass-by difference in dB at 200 km/h 5 m from c.o.t. between dismounted and mounted wheel dampers.

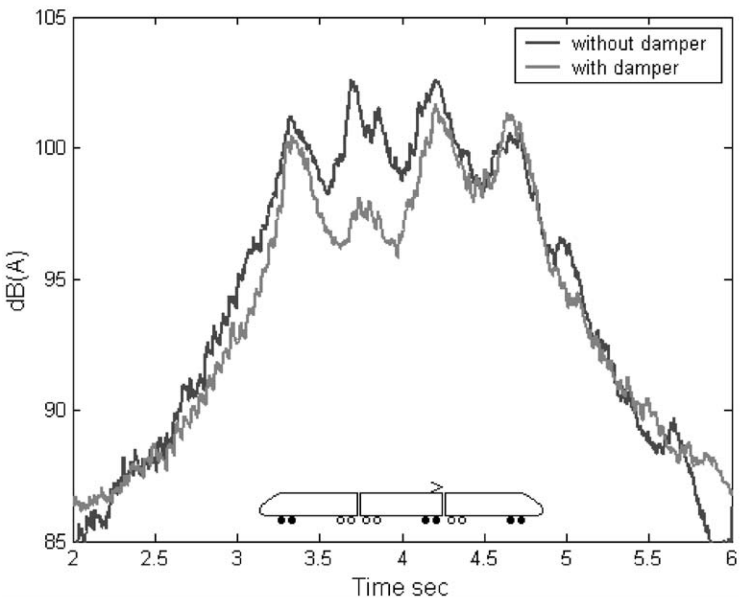

Fig. 6. Pass-by levels at 200 km/h 5 m from c.o.t. without and with wheel dampers.

Fig. 9 shows the reduction in the noise levels resulting from mounting the wheel dampers. The reduction is highest for the time segments when the bogies are in front of the microphone but there is a significant reduction also in the time segments when the microphone is between the bogies. It is especially interesting to note the reduction at 800 Hz, which is within the rail

Table 1
Measured noise levels in dB(A) for pass-by at 200 km/h 5 m c.o.t. (*TEL*: transient exposure level)

	L_{pAImax}	L_{pAFmax}	L_{Aeq}	*TEL*
With wheel dampers	101.7	100.5	98.9	100.7
Without wheel dampers	102.6	101.8	100.4	101.7
Reduction	0.9	1.3	1.5	1.0

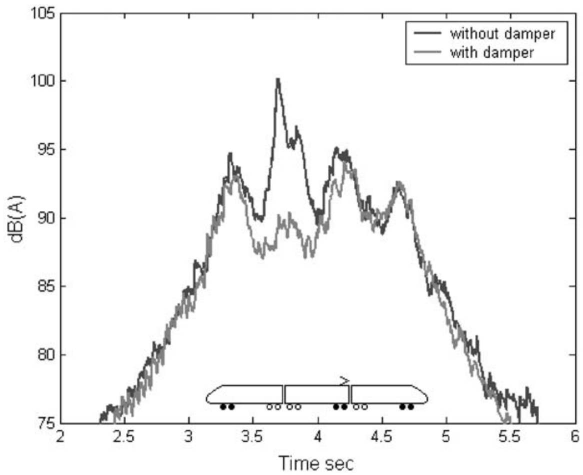

Fig. 7. 2500 Hz third octave band levels at 200 km/h 5 m from c.o.t. without and with wheel dampers.

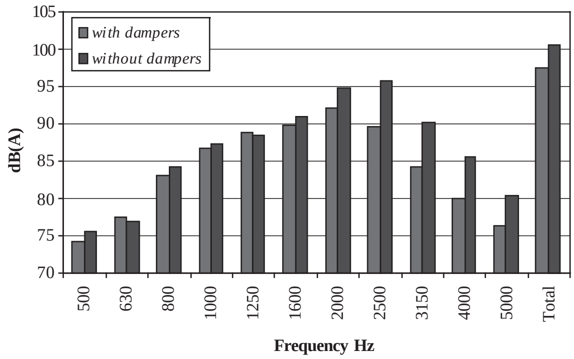

Fig. 8. Pass-by noise levels in at 200 km/h 5 m from c.o.t.

dominated frequency range. The total reduction gained from the wheel dampers was 3 dB. The wheel noise reduction is about 4–5 dB assuming that the wheel noise dominates above 2000 Hz.

The results from tests at 80 km/h are shown in Fig. 10. In this case only one pass-by was measured with and without dampers. Fig. 11 shows the noise reduction resulting from mounting wheel dampers at 80 km/h. The effect on the wheel noise seems to be around 3–4 dB but the overall noise was dominated by lower frequencies where only small effects were noticed. This explains why the overall reduction effect was only 1 dB at this low speed.

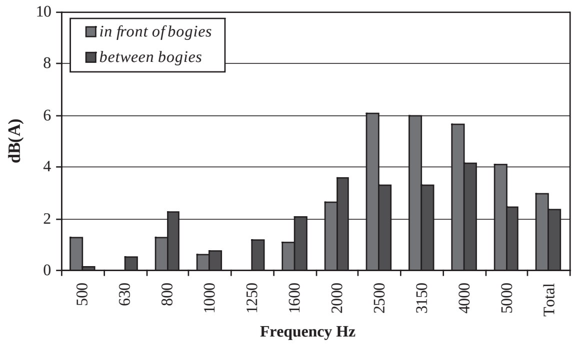

Fig. 9. Noise reduction at 200 km/h from mounting wheel damper.

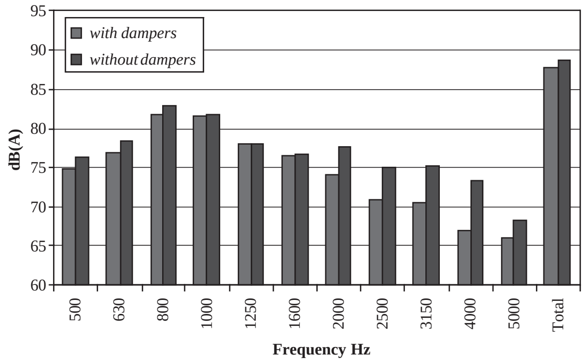

Fig. 10. Pass-by noise levels at 80 km/h 5 m from c.o.t.

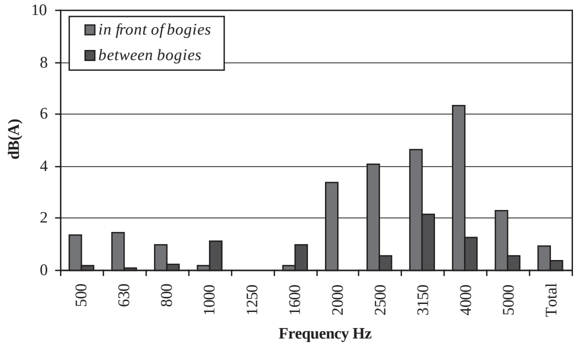

Fig. 11. Noise reduction at 80 km/h from mounting wheel dampers.

4. Discussion

For the tests at 200 km/h there was, as expected, a significant reduction of 4–6 dB for frequencies above 2000 Hz, but it was also found that there was a reduction of 2 dB for frequencies as low as 800 Hz. This reduction was also found in the parts of the time histories when

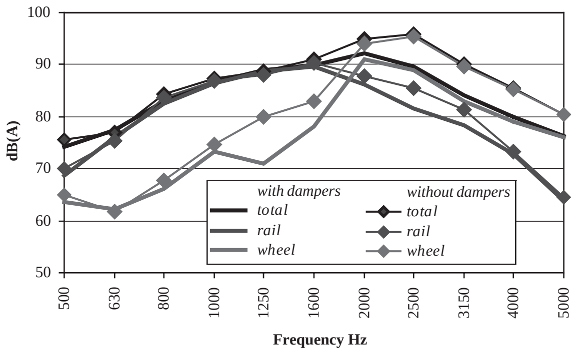

Fig. 12. Pass-by noise levels at 200 km/h 5 m from c.o.t. with source contribution from rail and wheel (from the TWINS model).

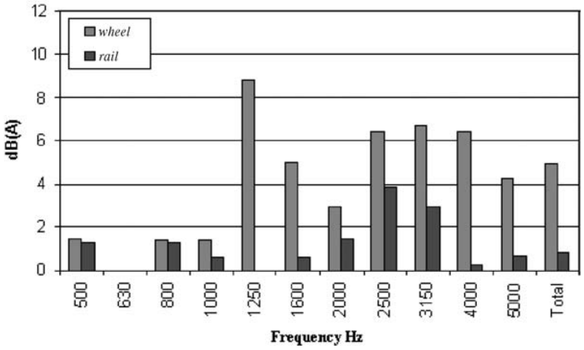

Fig. 13. Noise reduction at 200 km/h for wheel and rail noise.

the rail noise should be dominant, that is, when the microphone was between the bogies. This implies that the wheel dampers have a reduction effect also on the rail noise. This observation is not in line with TWINS calculations, which predict only marginal effects on the rail noise.

In order to split the change in rolling noise into a change in wheel and rail noise, two TWINS-models were made. First, a TWINS model for the damped case was tuned to fit approximately to the total spectrum shown in Fig. 8. An estimate of the distribution between wheel and rail was thus obtained. A separation of the actually measured total spectrum for the damped case with this distribution is shown in Fig. 12. The second model assumed non-damped wheels but with all the other parameters as in the first model. The same procedure was then applied to the total spectrum for the undamped case. The spectra for total, rail and wheel noise for the undamped case are also shown in Fig. 12. From the estimated wheel and rail contributions with and without wheel dampers the wheel and rail noise reductions can be estimated, as shown in Fig. 13. In total this gives a wheel noise reduction by 5 dB and a rail noise reduction by 1 dB at 200 km/h.

The low noise reduction for frequencies below 2000 Hz make the estimation of the total rail reduction very sensitive to both measurement accuracy and data input to the TWINS models. The use of accelerometers on the rail could improve both the measurement accuracy and the updating the TWINS model.

5. Conclusions

The use of plate wheel dampers with tuned fins reduces the rolling noise by 3 dB at 200 km/h and by 1 dB at 80 km/h. Wheel noise can be reduced by 4–5 dB at 200 km/h and by 3–4 dB at 80 km/h. By using the TWINS model, the wheel noise reduction is calculated to be 5 dB and the rail noise reduction to be 1 dB at 200 km/h.

References

[1] P. Dings, R. van Haaren, Wheel dampers state-of-the-art, AEAT/00/0110045/7, AEA contract report, December 2000 (restricted availability).