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RAILWAY WHEEL RING DAMPERS

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ABSTRACT
Railway wheel manufacturers are challenged to get a silent wheel, which in combination with a silent track, would drastically reduce noise disturbance due to rail traffic. Many different possibilities are nowadays offered. The paper describes in detail a cost-effective solution to add damping to the wheel that has been investigated in the framework of the Brite-Euram project "SILENT FREIGHT". It consists basically of a ring fitted under the tread and fixed to the wheel by bolts, that was called CAF ring damper. A description of the system is included and the differences with conventional ring dampers -steel rings fitted inside grooves cut under the wheel rim- are outlined. Results of the experimental work carried out in the laboratory and obtained in track tests are presented.

1 - INTRODUCTION
The high-pitched intense noise generated by railway wheels traversing narrow curves is known as squeal noise. Unlike traditional noise reduction systems (tuned dampers, compressed-layer damper, resilient wheels), ring dampers seem to be a cost-effective solution for squeal noise control. Conventional ring dampers are steel rings fitted inside grooves cut under the wheel rim, usually one at each side of the tread, Figure 1-(a).
As the wheel vibrates there is a relative movement between the wheel and the ring. The friction forces that act at the interface introduce a damping effect. Several railway wheel manufacturers currently use ring dampers but design solutions have not been optimised yet.
Results from previous work [2] and from the theoretical analysis of the wheel/ring system [3] showed that if the ring mass could be significantly increased, sound pressure level (SPL) reductions greater than those achieved by conventional ring dampers would be obtained. Within the Brite-Euram project "Silent Freight" a new ring damper solution, which will be termed CAF damper [1], has been studied and is shown in Figure 1-(b).
Full account of the theoretical and experimental analysis performed on the CAF damper is given in reference [3]. In this paper a summary of the experimental results, which shows the influence of ring mass and of the pre-load on measured SPLs, is given. These results are compared to similar data obtained for conventional ring dampers, which are thoroughly investigated in reference [3]. Results from pass-by noise measurements are also presented, which show the effect of CAF dampers.
Wheel modes can be classified as axial or bending modes and radial modes. The formers are classified according to the number of nodal diameters and the number of nodal circles, whereas the latter are classified according to the number of nodal diameters alone, as shown in Figure 2. The modes involved in squeal noise are the zero nodal circle axial modes (0Ln), while the modes responsible for rolling noise are the 1 nodal circle axial (1Ln) and radial (Rn) modes [4]. The index n is the number of nodal diameters. Results for these three mode types only will be presented.

2 - MEASUREMENT PROCEDURE
Wheel noise emission measurements have been performed in the laboratory. The high nonlinearity of wheel/ring interaction implies that the system response depend on the magnitude of the excitation force. This has some important implications:

(a): Conventional. **(b):** CAF.

Figure 1: Detail of ring dampers.

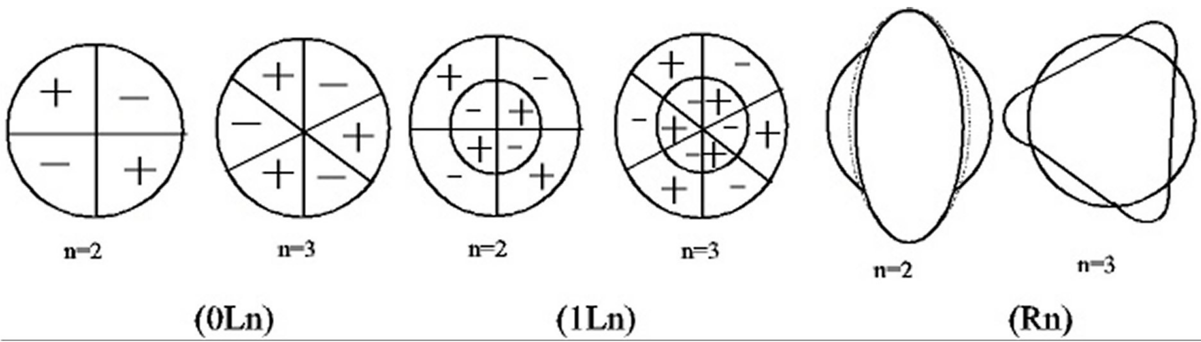


Figure 2: Wheel mode shapes.

- Repeatability of excitation force must be ensured in order to be able to compare different measurements
- High excitation amplitude levels are needed if response vibration levels are to approximate operation levels.

In order to fulfil the excitation requirements a simple test procedure, developed by the New York Transit Authorities [5] for the assessment of the squeal noise reduction capability of damping systems, has been used to measure the effect of ring dampers on wheel noise radiation and on modal damping ratios.
The test rig is shown in Figure 3. The test consists of applying calibrated axial and radial impacts to the wheel rim -a ball of 1lb (0.45 kg) mass dropped from a distance of 1 m hits the side or top of the wheel rim- and measuring the instantaneous SPL close to the wheel. The arrangement provides a high and repeatable impact force amplitude.

3 - SPL REDUCTION FOR CAF DAMPERS. COMPARISON WITH CONVENTIONAL RING DAMPERS

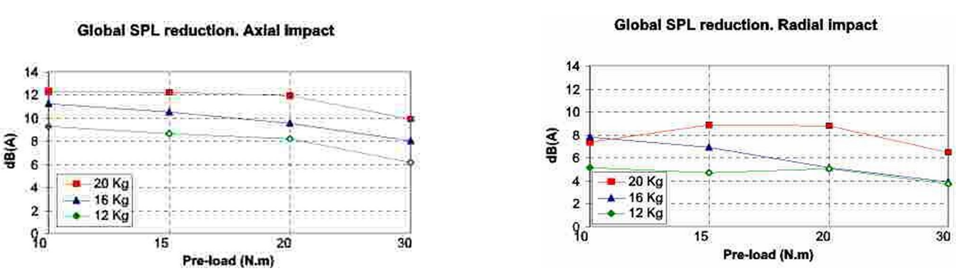
The ORE920 wheel has been used as the reference wheel to study the effect of the CAF damper. The main goal of the tests was to determine the influence of mass and pre-load on the efficiency of the damper. The CAF damper is attached to the wheel by four bolts, which are used to apply and keep the pre-load. Therefore, the pre-load values given are the magnitude of the torque applied to the bolts. Three different damper masses (12, 16 and 20 Kg) and four different pre-load values (10, 15, 20 and 30 N.m) were tested. Conventional ring dampers are included here in order to compare them to the CAF dampers. The reference wheel used in that case was an ϕ860 mm straight-webbed wheel. Steel rings of 12 mm cross-sectional diameter were used and measurements were made with 1 and 2 rings fitted.
The pre-load is applied to the rings by means of bolts that increase the ring circumference progressively, increasing the pressure between the surfaces of ring and groove. For this reason, the pre-load is not directly the contact force, but rather the torque applied to the bolts and it is measured in torque units.

Figure 3: Test set-up.

The global SPL reduction calculated as the mean value of five measurements is shown in Figures 4 (a) and 4 (b), axial and radial impact respectively. Noise reduction levels are given as a function of the pre-load. Each curve corresponds to a different damper mass value. Figure 5 shows noise reduction levels for conventional ring dampers. R1 corresponds to a single ring opposite to the flange, R3 to a single ring at the flange side and R13 to two rings, one at each side of the rim.

In Figure 4-(a) it can be seen that, if the ring mass is increased from 12 to 20 Kg, the overall noise reduction increases by approximately 3 dB(A) for all pre-load values. Looking at the effect of the pre-load, it can be seen that, for every mass value, the overall noise reduction increases as the pre-load decreases. The change is most dramatic from 30 to 20 N.m, where the noise reduction increases by 2 dB(A).

In the radial impact response, Figure 4-(b), the benefits of increasing the damper mass can also be seen, although not as clearly as in the previous case. The overall reduction increases by approximately 3 dB(A) if the damper mass is increased from 12 to 20 Kg. Here again the effect of the damper improves as the pre-load decreases, except for the 20 Kg ring, for which the optimum pre-load seems to be around 15 N.m.

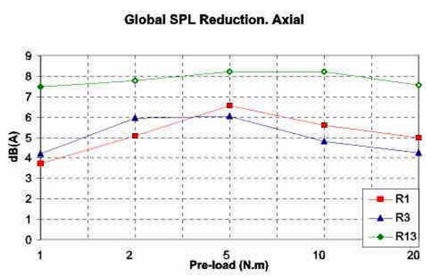


(a): Axial impacts. **(b):** Radial impacts.

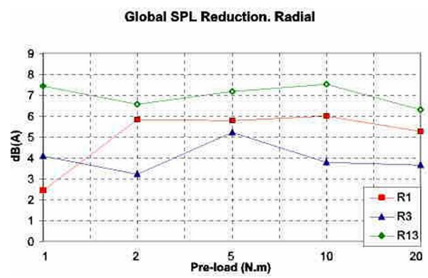
Figure 4: Global SPL reduction.

The results for axial impacts, given in Figure 5-(a), show that the maximum noise reduction occurs for a pre-load of 5 N.m in the four cases measured. The noise reduction increase due to the use of two rings instead of one is close to 2 dB(A). The differences between the two single ring cases are small which implies that the influence of the ring location is not significant when the wheel is excited by axial impacts. From these curves it is apparent that an optimum pre-load exists and that two rings are better than one.

In Figure 5-(b) the effects of the number of rings and pre-load are not so clear. In every case the reduction levels are lower than for axial impacts. The use of two rings compared to a single ring increases noise reduction. The pre-load for the maximum noise reduction is different in each case, but generally the results deteriorate for the lowest and highest pre-load values.



(a): Axial impacts.



(b): Radial impacts.

Figure 5: Global SPL reduction.

If the results in Figure 4 for the CAF ring damper are compared to those given in Figure 5 for the conventional ring dampers, it can be seen that, for axial impacts, the noise reduction achieved by the 20 Kg CAF damper is 4 dB(A) higher than the reduction measured for two conventional rings. However, for radial impacts the difference between the maximum noise reduction for the 20 Kg CAF damper and for two conventional rings is only 1 dB(A).

Since the wheel modes responsible for squeal noise are 0Ln modes, which are excited when axial impacts are used, it can be concluded that the CAF damper should be more efficient for squeal noise reduction than conventional ring dampers.

4 - PASS-BY NOISE MEASUREMENTS

Laboratory measurements have to be completed with track measurements in order to check if the system is effective in practice. The results from the two types of measurements can only be compared from a qualitative point of view, since different wheel types were used: different diameters, different cross-section, etc. However, track measurements allow gathering useful conclusions regarding the operating behaviour of the CAF damper.

Pass-by noise measurements were made during tests carried out at FGC (Ferrocarrils de la Generalitat de Catalunya). Two different U112 units, manufactured by CAF, were used: one had undamped solid wheels and the other was equipped with CAF dampers. These units are used in a metro line which has a 1 m gage track. The aims of these tests were to assess the effect of the CAF damper on squeal noise reduction.

The measurements were made in a tunnel section and the curve had a radius of 150 m and no corrugation. The microphone was located at the inner side of the curve, 2.5 m apart from the side of the inner rail and 0.2 m over the rail-head.

The maximum SPL octave band spectra measured in the non-corrugated track are shown in Figure 6. The SPL measured for the damped unit is smaller than that measured for the undamped unit above 1000 Hz the reduction being at least 10 dB(A) and as high as 17 dB(A) for the 4000 Hz octave band.

Although CAF dampers were mainly developed for squeal noise reduction, the effect on rolling noise was checked by making pass-by noise measurements on a straight track with the undamped and the damped units. The octave band curves of the maximum SPL measured at a speed of 50 km/h are shown in Figure 7. The SPL measured on a straight track is somewhat reduced if CAF ring-dampers are used. The maximum levels are smaller for all but the 1000 Hz band, the maximum reduction being about 5 dB(A) at 8000 Hz.

When looking at the data presented in this section it should be taken into account that a single microphone was used to perform the measurements, therefore it is not possible to establish the source of the measured noise. It should also be considered that at low frequencies (below the 1000 Hz band) the rail is the main source of noise and the SPL reduction at those frequencies by means that affect only the wheel

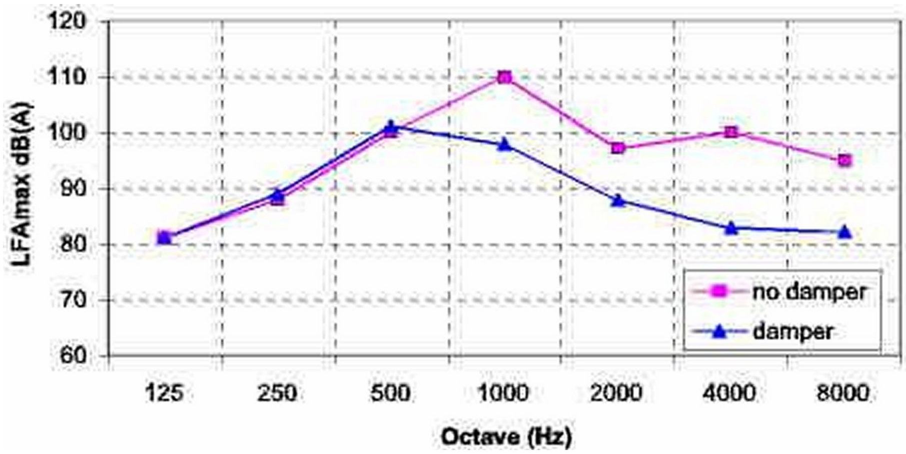


Figure 6: Octave band SPL on a non-corrugated curve; speed=25 km/h. 4 averages.

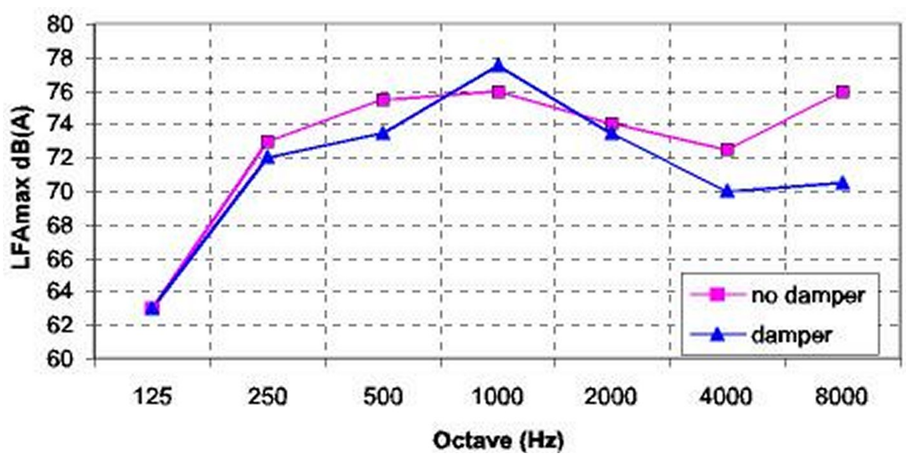


Figure 7: Octave band SPL on a straight track; speed=50 km/h. 4 averages.

is usually very small. Additionally, the results presented comparing CAF dampers and no damper were obtained using two identical U112 units which could however have small differences.
At the end of Silent Freight and Silent Track projects field tests were carried out (12/05/99 to 04/06/99) in Velim, Czech Republic). The objective of the tests was to assess the efficiency of the low noise solutions developed by the industrial partners. Different train configurations and track solutions were tested. The wheel noise reductions could not be obtained directly due to the weight of the track in the radiated noise. A method combining TWINS calculations and vibrations of the wheels was used [6] to obtain the wheel sound power. When comparing two wheels, a conventional 920 mm and another one having a CAF ring damper, the reduction of the wheel sound power was 6.8 dB(A).

5 - CONCLUDING REMARKS

Laboratory and track measurements for the CAF ring-damper have been presented. The results from the laboratory measurements show that CAF dampers are more effective at reducing squeal noise than conventional ring dampers and that an important squeal noise reduction can be expected. The track measurements show that CAF dampers eliminate squeal and reduce rolling noise.

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