



# Damped wheels as an efficient measure to reduce railway noise

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The University of Florence was involved in a large programme in which several noise reduction solutions applied to a High-Speed ETR500 train set were tested. The most promising proved to be a damped wheel designed by Lucchini CRS, named *Syope*<sup>®</sup>, that has been recently evaluated by Italcertifer (Italian Institute for Railway Certification) who declared the validity of the product. The paper discusses the results obtained by the analysis of a particularly numerous fleet of trains with concentrated and distributed power equipped with the standard 890 mm wheel, and compares these results with the performance measured during the experimental campaign made with a specific ETR500 train.

## 1. INTRODUCTION

Railway noise is due to the emission of the wheelset and of the track, that are excited by the combined wheel and rail roughness. Tread-braked wheels are much rougher than disc-braked wheels, making freight traffic particularly annoying, and the situation is worsened by the fact that freight trains often run during the night, when passenger traffic is reduced or absent.

Not surprisingly, therefore, most of the efforts have been done in the direction of reducing the noise from freight trains, for example by using sintered brake blocks. In these situations, tight constraints for thermal loads from braking phases must be taken into account, considering also that maintenance cycles of freight cars are particularly long and that these vehicles run through several countries with minimum control.

Unfortunately, “for reasons of safe operation of freight wagons internationally, the standards for thermal stresses are being set even more tightly than in the draft version used in shape optimization. It seems therefore that the scope for acoustically optimized tread-braked wheels will, in the future, be very limited” [1].

Another important reason for high noise levels is speed. The classical law for speed dependency of railway noise is  $L_p = a + 30 \log_{10}(v/v_0)$ . The use of low-noise wheels can significantly reduce the overall railway noise only at the higher speeds, where the contribution of the wheel is much greater than that due to the track.

At these speeds the only possible braking is with discs mounted on the wheelset axle, a system that naturally leads to a reduction of 8 to 10 dB(A) compared to tread braked wheels and that eliminates thermal stress in the wheel, allowing the adoption of damping treatments of the wheel web.

The University of Florence has been involved in a test campaign aimed at the qualification of some noise reduction measures applied to an Italian high-speed train ETR500 PLT (multivoltage). One of these measures was the application of a constrained layer damping to the standard 890 mm diameter high-speed wheel. These treatment, patented by Lucchini Sidermeccanica SpA and 3M Italia SpA, is called *Syope*<sup>®</sup>. The reader interested in numerical simulations and theoretical considerations on the behaviour of damped wheels is referred to [2]. A special trainset was prepared for the test campaign, including several combinations of these measures; normal trains were measured too, allowing the comparison of specifically prepared train with standard trainsets.

## 2. BEHAVIOUR OF 890 mm WHEEL IN NORMAL SERVICE

The test campaign lasted three weeks during October and November 2000, and in this lapse of time the following trains were measured, all equipped with the standard wheel:

- 4 pass-by of Pendolino ETR460 (9 coaches);
- 11 pass-by of ETR500 3kV (loco+11 coaches + loco);
- 5 pass-by of ETR500 PLT (loco+11 coaches + loco).

Measurements of external noise were made at 7.5 m from the track axis. This choice, certainly unusual for the evaluation of noise emitted by high-speed trains, is mainly due to the need to compare the noise emitted by *each bogie pair* passing in front of the microphone; the use of the standard 25 m position would not have been in fact sufficient to highlight the contribution of the different situations present in the test trainset shown in the next paragraph.

As an indicator of noise the  $L_{pAFmax}$  was used instead of more specific train noise indicators, such as TEL or SEL, as the global train behaviour was considered not interesting.

Signals were acquired with a digital system operating from DC, allowing the measurements of *all* noise characteristics, including the pressure blow at the train head. A-weighting and Fast time constant were applied by using simple Matlab<sup>®</sup> codes.

Tables 1 and 2 summarize the behaviour of standard wheels for ETR500 3kV (tread-braked locomotives) and ETR500 PLT (disc-braked locos). Trains at around 200 km/h and at around 250 km/h have been grouped; locomotives and bogies close to locomotives have been removed. It can be seen that standard deviation for each train is normally around 0.5 dB(A) (meaning that the noise emitted by all the bogies of the same train is more or less the same) while the standard deviation of the noise emitted by the same bogie pair for different train is slightly higher, meaning that the position has a little influence. For these trains large pressure peaks (sometimes leading to saturation) have been observed; only those trains where the signal could be considered good have been taken into account.

Table 3 summarizes the behavior of standard wheels for Pendolino ETR460. All these trains ran at around 205 km/h; the standard deviation is even lower (around 0.3÷0.4 dB(A)) for each train, and the pressure peak is much less pronounced than that of ETR500 at the same speed, resulting in a limited emission at the train ends.

Train number - ETR500 3kV	691	989	688	594	592	499	694	687	986	987	984	Bogie	Standard	Bogie	Standard
	Speed [m/s]	36.4	54.5	54.6	55.2	55.2	55.4	56.0	59.3	62.2	67.9	Average	deviation	Average	deviation
Speed [km/h]	131.0	196.4	196.5	198.6	198.7	199.3	201.7	213.6	224.1	244.5	247.3	200 km/h	200 km/h	250 km/h	250 km/h
Bogie #1 - near loco	85.3	93.5	95.2	92.9	90.6	91.3	94.3	94.9	93.3	95.4	96.2	93.0	1.8	95.8	0.5
Bogie #2	81.6	88.5	88.1	90.5	88.2	89.7	89.8	89.5	91.2	92.5	93.7	89.1	1.0	93.1	0.8
Bogie #3	81.4	88.6	87.3	89.5	87.5	89.4	89.7	89.6	91.1	92.2	92.5	88.7	1.1	92.4	0.2
Bogie #4	81.8	88.7	88.0	90.2	89.2	89.7	89.3	89.9	91.2	93.0	93.0	89.2	0.8	93.0	0.0
Bogie #5	82.0	89.0	88.0	89.9	88.0	89.6	90.5	89.5	90.3	93.3	93.1	89.2	1.0	93.2	0.2
Bogie #6	82.4	87.7	88.0	88.3	88.6	89.8	89.8	89.4	90.5	92.8	92.3	88.7	0.9	92.6	0.3
Bogie #7	83.5	88.4	87.4	90.7	88.0	90.1	89.4	89.5	90.1	91.8	92.0	89.0	1.3	91.9	0.2
Bogie #8	82.6	88.4	87.7	88.9	88.0	89.6	89.6	88.4	90.9	92.9	92.2	88.7	0.8	92.6	0.5
Bogie #9	82.8	88.5	87.4	90.0	88.7	88.6	88.7	88.8	90.9	92.6	92.7	88.6	0.8	92.7	0.1
Bogie #10	82.2	88.8	87.4	89.2	88.6	89.0	89.6	89.1	90.5	92.6	92.6	88.8	0.7	92.6	0.0
Bogie #11	82.3	88.8	88.2	89.6	89.3	88.6	89.3	89.4	90.0	91.7	92.6	89.0	0.5	92.2	0.6
Bogie #12 - near loco	86.0	92.1	93.7	90.1	88.4	90.9	95.8	93.3	93.0	95.1	96.6	91.8	2.7	95.8	1.1
Train average	82.3	88.5	87.7	89.7	88.4	89.4	89.6	89.3	90.7	92.5	92.7				
Standard deviation	0.6	0.3	0.4	0.7	0.6	0.5	0.5	0.4	0.4	0.5	0.5				
Total average		Av. Speed		198.5	88.9		Av. Speed		245.9	92.6					
Total standard deviation				0.9					0.5						

Table 1:  $L_{pAFmax}$  data for ETR500 3kV.

Train number - ETR500 PLT	699	686	799	597	596	Bogie	Standard
	Speed [m/s]	58.4	68.2	68.6	69.1		
Speed [km/h]	210.4	245.5	247.0	248.7	250.3	250 km/h	250 km/h
Bogie # 1 - near loco	92.6	92.7	93.9	97.7	93.6	94.5	2.2
Bogie # 2	88.6	92.4	94.0	93.1	93.0	93.1	0.7
Bogie # 3	88.4	92.3	94.0	92.0	92.9	92.8	0.9
Bogie # 4	88.6	91.1	94.2	92.7	93.1	92.7	1.3
Bogie # 5	88.9	91.3	94.2	91.8	93.4	92.7	1.4
Bogie # 6	89.2	91.1	93.5	91.4	93.0	92.3	1.2
Bogie # 7	88.8	92.1	93.5	91.8	93.9	92.8	1.1
Bogie # 8	88.8	92.4	94.1	91.3	95.1	93.2	1.7
Bogie # 9	89.0	91.7	94.0	91.6	93.3	92.7	1.2
Bogie # 10	88.9	92.2	94.4	91.8	93.6	93.0	1.2
Bogie # 11	89.3	91.3	92.8	90.5	93.1	91.9	1.2
Bogie # 12 - near loco	91.9	91.1	93.1	91.3	93.0	92.1	1.1
Train average	88.9	91.8	93.9	91.8	93.4		
Standard deviation	0.3	0.5	0.5	0.7	0.7		
Total average		Av. Speed		247.9	92.7		
Total standard deviation				1.1			

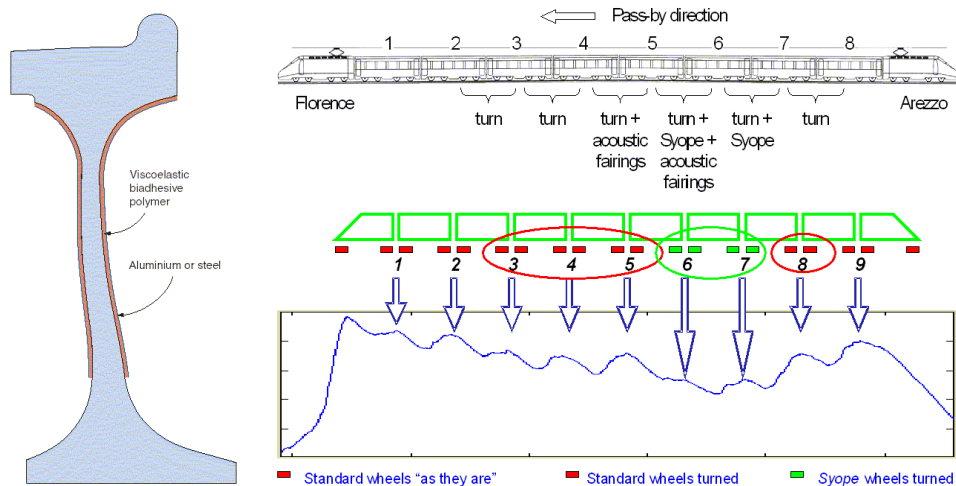
Table 2:  $L_{pAFmax}$  data for ETR500 PLT.

Train number - ETR460	992	689	991	598	Bogie	Standard
	Speed [m/s]	57.0	57.5	57.9		
Speed [km/h]	205.3	207.1	208.6	209.9	200 km/h	200 km/h
Bogie # 1	86.4	87.5	88.6	89.2	87.9	1.3
Bogie # 2	88.7	89.2	89.7	88.5	89.0	0.5
Bogie # 3	90.0	89.8	89.9	89.1	89.7	0.4
Bogie # 4	89.9	89.5	89.9	89.1	89.6	0.4
Bogie # 5	90.4	89.6	90.2	88.8	89.7	0.7
Bogie # 6	89.4	89.5	89.9	89.2	89.5	0.3
Bogie # 7	89.9	88.9	89.7	89.2	89.4	0.5
Bogie # 8	89.3	88.7	89.7	88.9	89.2	0.5
Bogie # 9	90.4	89.1	89.1	89.4	89.5	0.6
Bogie # 10	86.7	87.4	87.5	87.3	87.2	0.3
Train average	89.8	89.3	89.8	89.0		
Standard deviation	0.6	0.4	0.3	0.3		
Total average		Av. Speed		207.7	89.5	
Total standard deviation				0.5		

Table 3:  $L_{pAFmax}$  data for ETR460 Pendolino.

### 3. BEHAVIOUR OF *Syope*<sup>®</sup> WHEELS

Some of the wheels of the ETR500 PLT test trainset were treated (turned and damped); a sketch of the wheel damping treatment and the test trainset composition are shown in figure 1.



**Figure 1.** Standard 890 mm high-speed wheel cross-section with *Syope*<sup>®</sup> treatment with a 2 mm-thick steel constraining plate (left). Test trainset composition and typical acoustic signature during a pass-by (right). Some fairings were treated with damping materials.

The test trainset was measured a total of 15 times, as follows:

- 6 pass-by of ETR500 PLT test trainset (loco+8 coaches + loco) without bogie fairings;
- 9 pass-by of ETR500 PLT test trainset (loco+8 coaches + loco) with bogie fairings.

Partial data were already published, for example in [3], but are reported here again for clarity in table 4, where only data pertinent to *Syope*<sup>®</sup> wheels are listed with the additional new information on data from bogie pair #2, made of non-turned standard wheels

Speed km/h	Standard non-turned dB(A)	Standard turned dB(A)	<i>Syope</i> dB(A)
190	92.3	88.4	84.4 (-4.0)
235	97.7	93.2	88.6 (-4.6)
260	99.2	97.0	91.8 (-5.2)
295	101.3	98.4	94.1 (-4.3)

**Table 4:**  $L_{pAFmax}$  data for ETR500 PLT test train.

### 4. COMPARISON OF STANDARD AND *Syope*<sup>®</sup> WHEELS

Figure 2 shows the trend of  $L_{pAFmax}$  vs. speed in linear scale, after grouping similar speed for trains in normal service, together with the relevant uncertainty bars. The expected trend for this heterogeneous group of trainsets is respected even without any control on the wheel surface

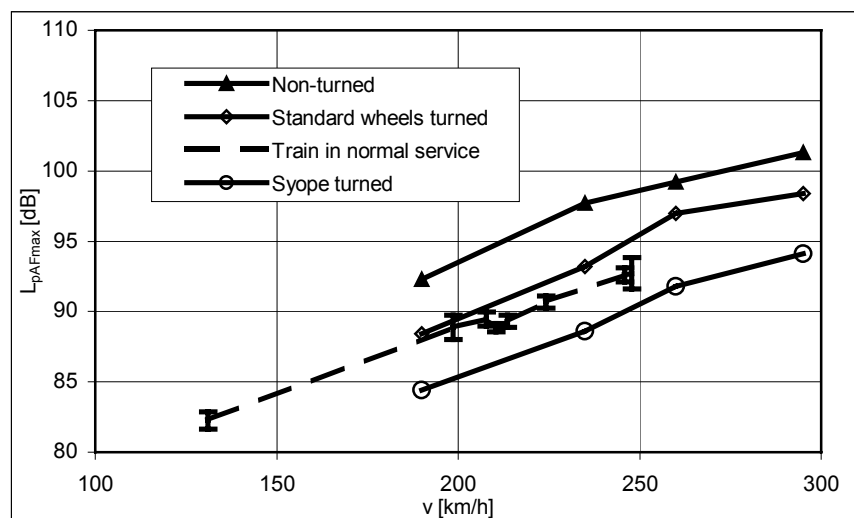
conditions. As all these trains are in service since several years, normally their wheels have already been turned several times or even changed. Quite surprisingly, the dispersion of the values is really very limited. Pendolino trains are not louder than ETR500 trains, despite the fact that they have motors and transmission mounted under each coach.

Some unexpected behaviour comes out from the comparison of this large fleet of trains with the results of the measurements from the test train. In this case there are three sets of interesting values:

- bogie pair #2, made of standard wheels “as they are”;
- bogie pairs #3, 4, 5 and 8, made of standard wheels turned;
- bogie pairs #6 and 7, made of *Syope*<sup>®</sup> wheels.

Limiting the analysis of the test train, the average trend is still respected; the advantage of turning ranges from 2.2 to 4.5 dB(A) depending on the speed, and the additional advantage of the use of *Syope*<sup>®</sup> wheels is, as already shown in [3], between 4.0 and 5.2 dB(A). Less clear is the relationship of the behaviour of the test train compared to the standard fleet. The test train seems much louder than the all the other trains. Probably the reason must be searched in the particular usage of the train in that period (test runs in France and in Italy at high speed).

Extrapolating the data of the standard fleet at higher speeds (260 and 295 km/h), the advantage of *Syope*<sup>®</sup> wheels seems to reduce to around 3.0÷4.0 dB(A), but probably this comparison is not strictly correct. Also considering this penalty as a worst case, this figure remains significant and justifies the use of the *Syope*<sup>®</sup> wheels as a measure to immediately reduce the noise emitted by high-speed trains without expensive works on the infrastructure.



**Figure 2.** Comparison of the standard 890 mm fleet (dashed line) and the results from the measurement of the ETR500 PLT test train.

## 5. CONCLUSIONS

The analysis of a large fleet of trains has allowed the analysis of the noise emission of a significant portion of the Italian high speed trains.

The results from a test train, equipped with wheels with a low noise emission, shows that these wheels can be an efficient measure to immediately reduce the noise emitted by high-speed trains. Currently this type of wheel, already evaluated by the Italian institute for railway certification (Italcertifer), is going to be mounted on a number of high-speed trains for extensive series tests.

It is important to underline how the *Syope*<sup>®</sup> treatment is not a laboratory exercise but is an industrial product whose characteristics and production features have been studied, from TLCC to recycling. Any disc braked wheelset can therefore use fruitfully *Syope*<sup>®</sup> treated wheels without sensibly increasing the cost and without limitations to normal operation.

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