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SYOPE THE LOW NOISE WHEEL

Summary. In this article the low noise wheel has been presented. This wheel is called „Syope wheel". It is designed for passengers coaches and high speed trains. The innovation consists in the application of a viscoelastic layer on the two sides of the wheel. The aim of usig this wheel is reducing of the noise during wheel service. The weight increase for Syope wheel is low and the costs of modernization is not high.

SYOPE - KOŁO O NISKIM POZIOMIE HAŁASU

Streszczenie. W artykule przedstawiono nowe koło o niskim poziomie hałasu. Nosi ono nazwę „Syope". Koło to jest przeznaczone do wagonów pasażerskich i pociągów wysokich prędkości. Innowacja obejmuje pokrycie obu stron tarczy koła warstwą lepko-sprężystą. Jego zastosowanie ma na celu redukcję hałasu powstającego podczas współpracy koła z szyną i jest osiągane przy niewielkim wzroście masy koła i niewielkim kosztem.

1. INTRODUCTION

Syope is a railway wheel with a special damping system to be used for disc braked wheelsets designed for passengers coaches and high speed trains.

The innovation consists in the application of a constrained viscoelastic layer on the two sides of the wheel (fig.1); the layer is made of a high mechanical and chemical resistant viscoelastic adhesive, covered by an aluminium or steel layer. Existing standard wheels do not require any geometrical modification for the application of this type of damper and also no mechanical fixing systems are required. The assembling of the dampers to the wheel follows a simple technology developed by Lucchini.

The weight increase for Syope wheels is extremely low only: 3,5 for the aluminium constrained layer and 8,5 kg for the steel constrained layer.

The damping system has been developed to obtain the best acoustic benefits together with a low weight increase and at a low cost.

2. LABORATORY ACOUSTIC TEST

The vibro acoustic characterisation procedure developed by Lucchini CRS enables the comparison of different low noise wheels. This procedure refers to the ISO 3744 norm for source sound power emission calculation in free field conditions by sound pressure measurements. In this case the sound power which depends on the exiting force is normalised by this force and it's measured in dB10 [re pW/N2]. The acoustic measurements are brought over in a semi - anecoic room according to the engineering method of ISO-3744 in the frequency range of 250 - 6000 Hz. The wheel hub leans through a rubber block on a support (40cm high from the ground); the wheel plane is horizontal. The exiting force is an impulse in a fixed position on the rim rolling surface, radial direction. The measurements are done by 8 microphones mounted on a vertical arc (90° and r = 2m). The arc is turned in 5 positions (every 45°) so to cover half hemisphere with 36 measurement positions.

The laboratory results of the Syope wheel show a very good sound emission reduction compared to the standard wheel. Particularly, by using the aluminium layer, it can be seen that in the frequency range of 2-6 kHz (that is considered the band in which the wheel emission appears to be dominant over the rail) the level reduction is over 20 dB for the higher picks.
Much better results are obtained with the steel constrained layer (5 kg more compared to aluminium) where for the same frequency band, the level reduction is over 30 dB for the higher picks.

3. PASS-BY ACOUSTIC TEST

Field acoustic tests have been brought over on the railway line between Florence and Arezzo near Renacci. Two bogies of the Fiat Ferroviaria ETR 470-0 (Pendolino Train) were equipped with Syope wheels as in fig. 4. The test aim was to separate single sound source and to evaluate the relative noise levels by using special processing tecniques of signals measured from a microphone array placed on the ground near to the rail during the pass-by of the train.

3.1. Measurement set up

The pass-by tests were performed with an array of 21 microphones placed on the ground at 3,3 m from the nearer rail and at the same height. The microphones were equally spaced at a distance of 0,08 m and the total length of the array was of 1,6 m. To identify the exact position of the different wheels during the microphone signal acquisition an optical barrier was placed near the rail to detect the passing time moment of each wheel.

All sensors (together with two accelerometers mounted on the rail) were measured, filtered at a cat-off frequency of 6 kHz and sampled at 12 kHz, providing significant results up to 4,8 kHz. On the window of the train driver a sound source was installed to enable a valuation of the space and frequency resolution. Following the acoustic results for the train travelling at a speed of 225 km/h will be presented.

3.2. Preliminary analysis

Already from a first simple analysis it was possible to see a difference in the noise emission of the two type of wheels. This first type of analysis was brought over in the following way:

- first the train speed was calculated from the optical barrier signal considering the distance from the wheels,
- all the 21 microphone time signals were then shifted (in time) on to the optical barrier

DT = Li/Vtrain   Li = microphone *i* – optical barrier distance

- each signal analysed in the time and frequency domain to obtain the sound pressure level spectrum during the pass-by of the train
- at each time sample the 21 spectrums were then averaged

Pj = 1/21 S i=1,21 Pij   j = 0, dt, 2 sec.   dt = 0,1 sec.

The result of the analysis is the coloured map in fig. 5 where on the time axis has been placed the train configuration and the optical barrier signal with the positions of each wheel. It is possible to see quite clearly that for each bogie (or couple of bogie) is associated a "noise column" showing that the area around wheels is the major responsible for noise generation; but also the Syope wheels result to produce less noise compared to the standard ones with differences up to 10 dB.

3.3. Array technique analysis

In the preceding analysis is still present the doppler effect which generates a shift of the sound frequencies components depending on the train speed. This can be seen clearly from the "S" red line coming from the sound source which was generating a pure tone of 2 kHz (fig. 5). Moreover the analysed spectrums at each instant are influenced mainly from the sources in front of the array but in same way also from the other sources in other positions such that a good source separation is not possible. Array technique enables to analyse separately each single source. In practice for each position on the train (each wheel) it is possible to derive a map similar to the one in fig. 5 in which the noise generated from the source in that position is "cleaned" from the doppler effect and afterwards is "separated" from the other sources present in other positions along the train; this means that all the noise coming from other different sources is reduced. The processing procedure is first applied to the position on the train ware the sound source is mounted. The processing steps are in fig. 6: first the original signal in the time-frequency domain, then the dedopplerized signal and finally the sound source noise isolated from the rest. The same analysis has been brought over on a standard wheel and on a Syope wheel (fig. 7 where the final maps for each wheel are presented).
The sound pressure spectrums calculated at the passage of the two wheels has then been represented in 1/3 octave bands (fig. 8); the comparison shows that from the 1600 Hz band to the 4000 Hz there is a reduction for the Syope wheels of 5 to 10 dB.
For how the test and the analysis has been bought over, such reduction can be considered equal to the sound power level reduction emitted from the wheel component.

4. SYOPE WHEEL RELIABILITY

Many test have been brought over from 3M and Lucchini to guarantee the complete reliability of the Syope wheel. The polymer material used in the Syope wheel absorbers has been tested in the most harsh environments by performing adhesion resistance tests, accelerated weathering, outdoor weathering, thermal cycling and fatigue resistance.

Mechanical Resistance

The polymer adhesion to the wheel surface has a normal resistance of 8 kg/cm2 ; this means that the adhesion safety factors are very high. Infact if we consider the inertial forces distributed on the damper surface (4200 cm2), due to its very low weight and to the inertial accelerations present on the wheel wile rolling on the rail, we find safety factors > 1000.

Impact tests show that the complete adhesion and the disc mechanical performance will not deteriorate the wheel reliability, because of the high bonding and of the damping properties of the polymer that can absorb impacts. That means that also the wheel surface will be better protected from accidental impacts.

What is really important, is that this performance will not deteriorate even in presence of particularly harsh environments as is shown in the following tests:

Accelerated weathering

Accelerated aging test have been conducted in weatherometers which subject the bond to cycling heat, humidity and concentrated ultraviolet light exposure. The figure 9 indicates that the bond strength does not deteriorate below its original performance level even after exposure of 7000 hours in the weatherometer under these test.

Moisture and Solvent Resistance

Adhesion tests have been performed on the polymer bonding to steel which were subjected to over 8 years of submersion in 5% salt water. After testing, bright clean steel surface were observed underneath the adhesive bond, proving an excellent protection against steel corrosion. After short submersions with solvents such as fuels, alcohol's, adhesive removers like MEK, and even weak acids or bases, no affect is measured on the bonding performance.

Thermal Resistance

Thermal tests on the polymer have defined the following temperature limits:
Tmin= -30°C,
Tmax= 90°C (continuously for weeks),
Tmax= 120°C (for short periods).

Behaviour of polymer to fire

According to the French norm NF F 16-101 and 102 (October 1988), the polymer has been classified as F2 regarding to the combustion gas composition and M1 regarding to the flame propagation.

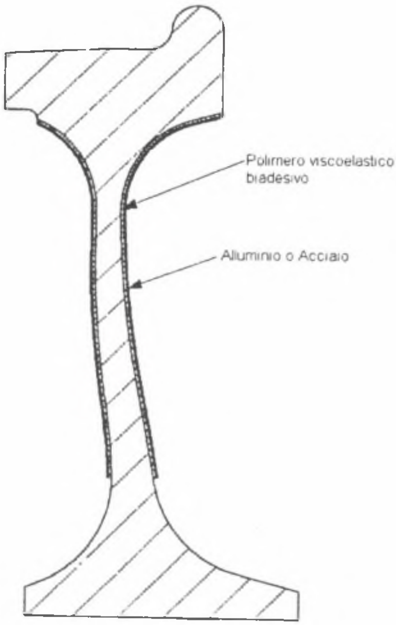


Fig. 1. Syope wheel configuration
Rys. 1. Konfiguracja koła Syope

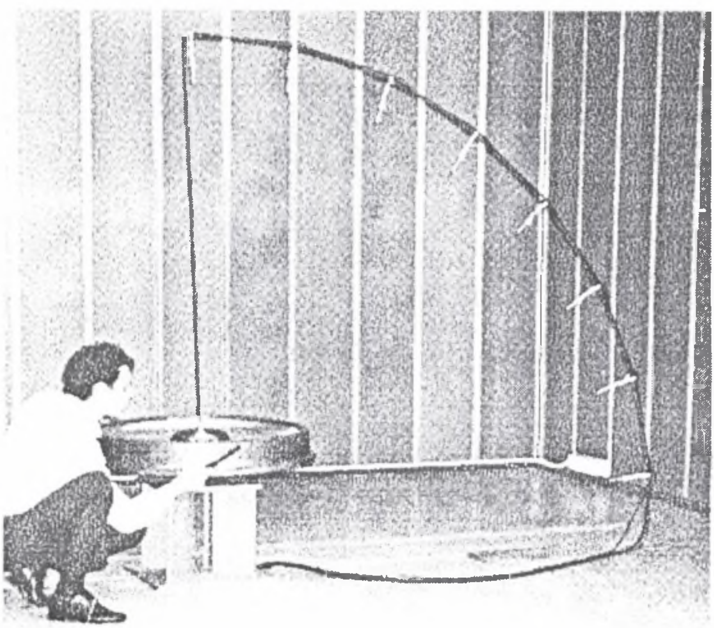


Fig. 2. Laboratory Vibro-acoustic analysis
Rys. 2. Wibroakustyczna analiza w laboratorium

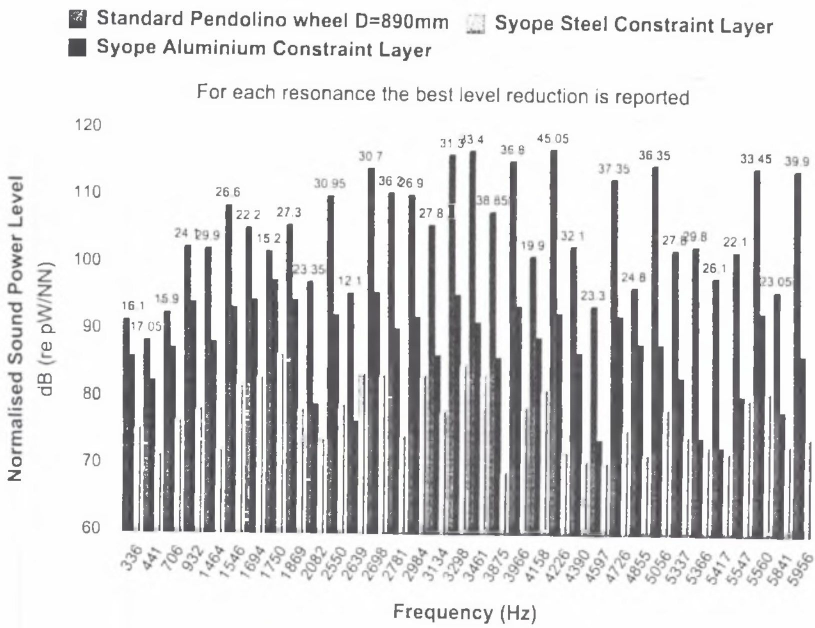
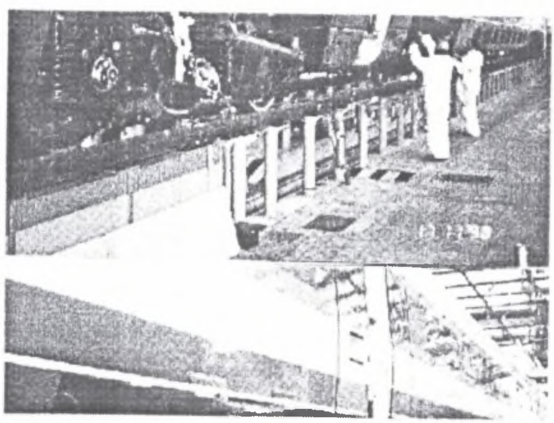


Fig. 3. Sound Power Level for each resonance
Rys. 3. Poziom mocy dźwięku dla każdego rezonansu



Syope wheels mounting

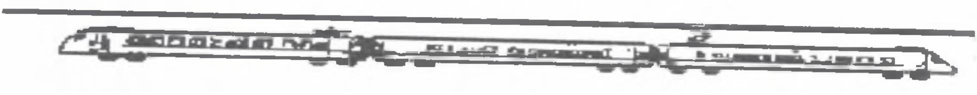
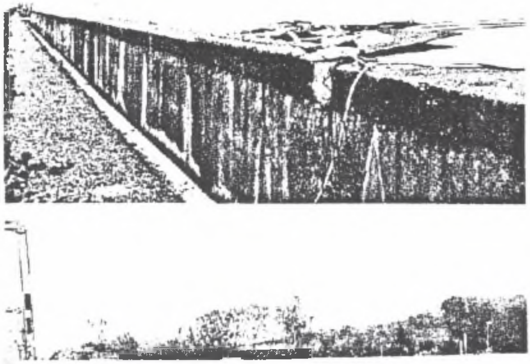


Fig. 4. ETR 470-0 train (Syope wheels are the red ones)
Rys. 4. Pociąg ETR 470-0 wyposażony w koła Syope



Microphone array

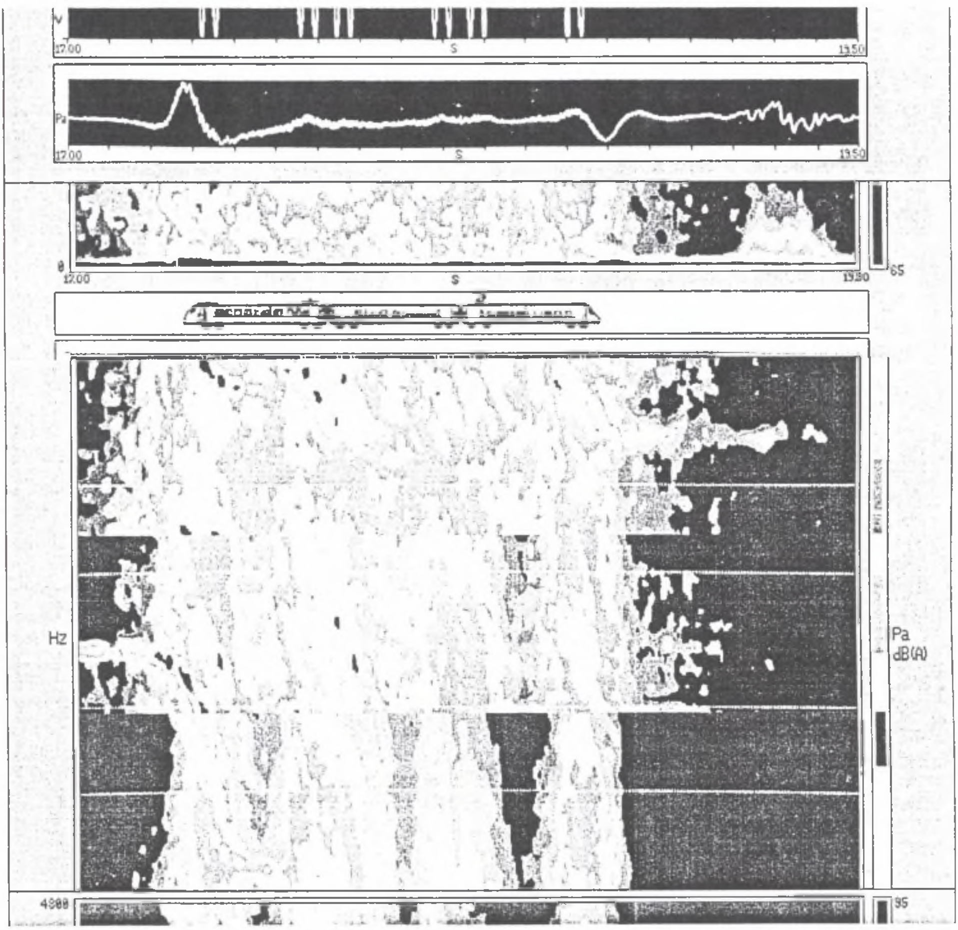
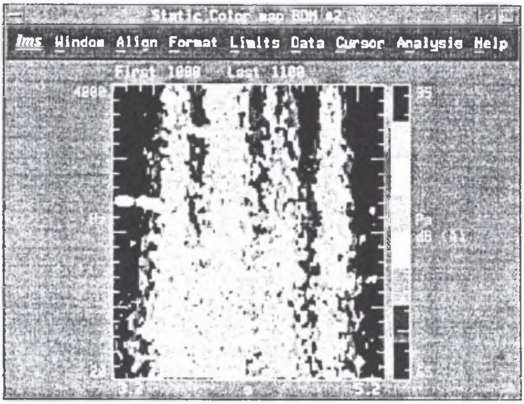
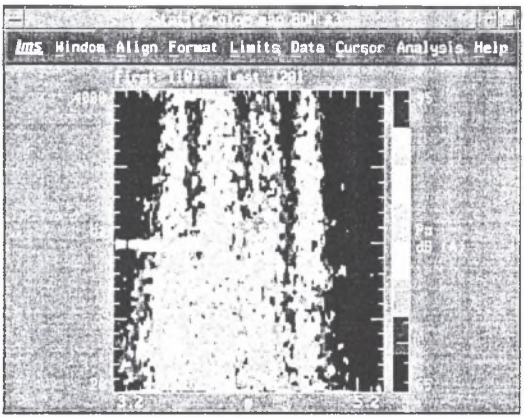


Fig.5. Short time frequency analysis of sound pressure averaged on 21 microphones. Train speed: 220 km/h

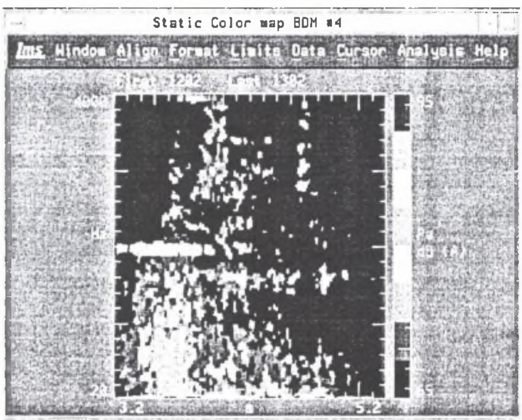
Rys. 5. Analiza częstotliwościowa ciśnienia akustycznego dokonana za pomocą 21 mikrofonów obejmująca krótki czas. Prędkość pociągu 220 km/h



Original signal



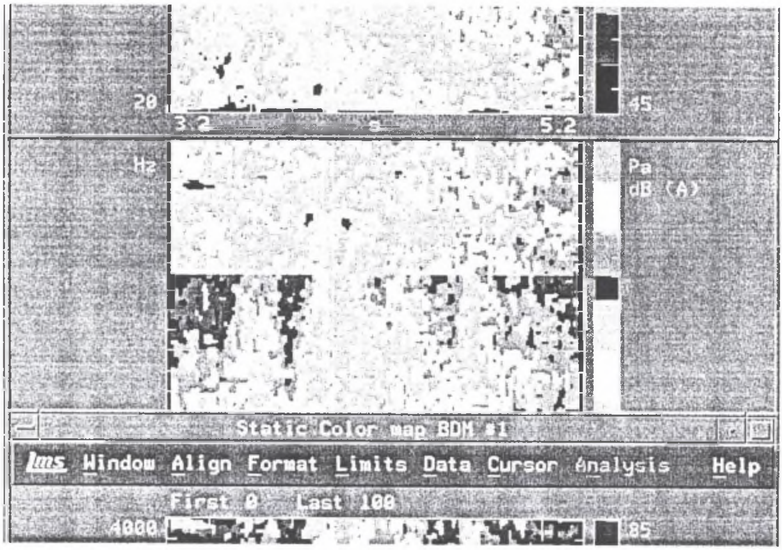
Dedopplerized signal



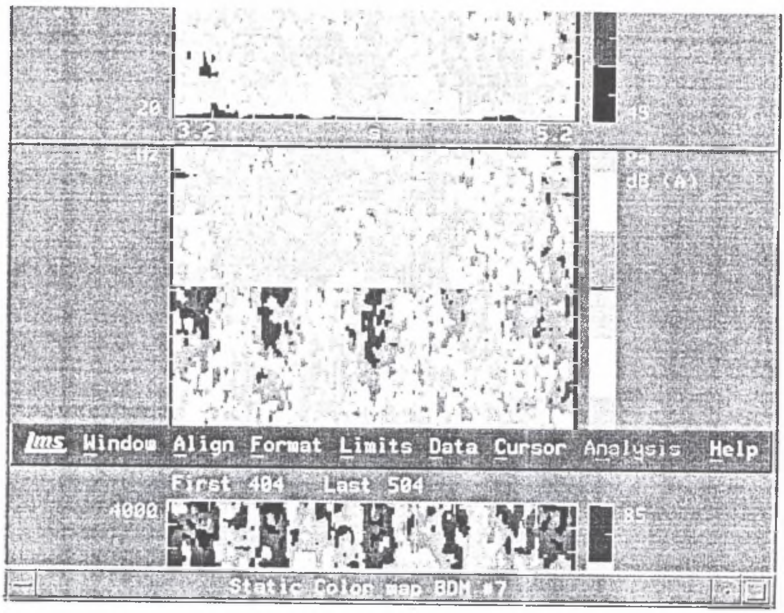
Source noise isolated

Fig.6. Advanced analysis of the sound source mounted on the train with the array technique

Rys. 6. Zaawansowana analiza źródła dźwięku przeprowadzona za pomocą urządzeń umieszczonych w pociągu



Analysis of a standard wheel with array technique



Analysis of a Syope wheel with array technique

Fig.7
Rys.7

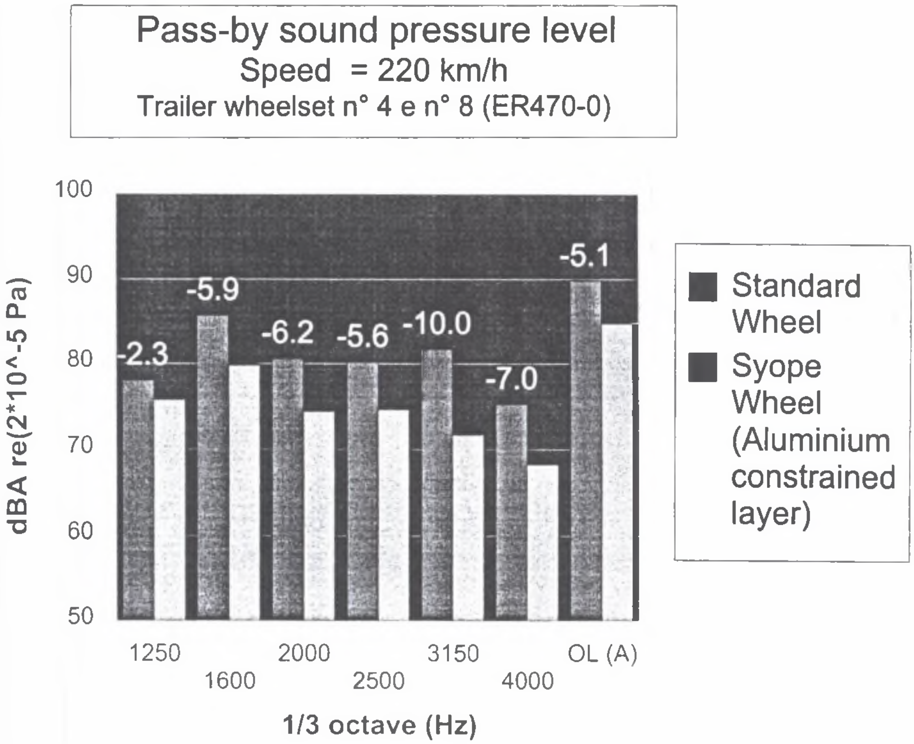


Fig.8
Rys.8

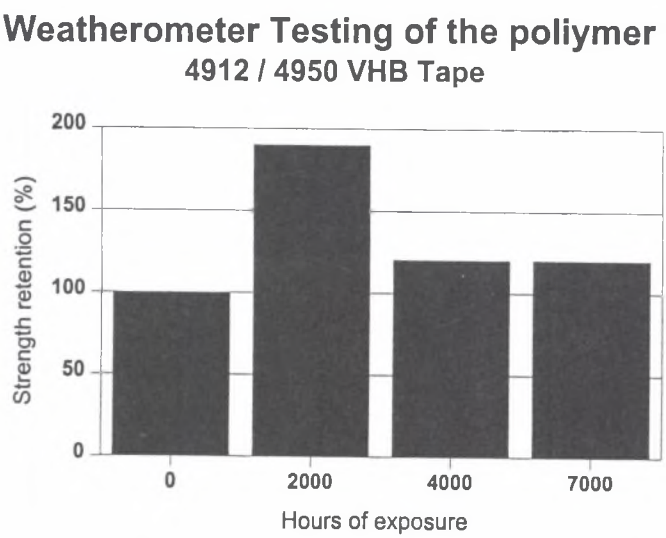


Fig.9
Rys.9

Abstract

The demand for low noise railway wheels has been growing in the last years together with the new environment policy heading for strict noise emission limits.
Lucchini has developed a new wheel damping system called Syope and it has been tested on the high speed wheel for the Fiat Ferroviaria Pendolio Train; the acoustic performance is surprising and will surely help the railway noise problem in the near future.

The paper shows the characteristics of the damping system and much emphasis is given to its low weight (3,5 - 8 kg per wheel) and to the wheel reliability; following are presented the results of the acoustic tests brought over in a semianecoic room in which sound power emission normalised to the exciting force is measured, enabling the acoustic performance comparison.

The paper ends with the results of the acoustic pass-by tests brought over on a Pendolino train in which two bogies were equipped with Syope wheelsets.
Comparison between Syope and standard wheel has been done by using a special microphone array technique that enables a better sound source separation.