WEAR OUT AND NOISE REDUCTION IN CURVES

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ABSTRACT
Curve squeal noise is an environmental noise pollution problem occurring in sharp-radius curves, where transport systems such as mainline railways, tramways and metro rail networks exist. This noise is extremely unpleasant for inhabitants and it can also be a source of discomfort to rail passengers. The aim of our research was a reduction of this noise and testing the influence of using materials/technology on a rail´s wear out. These researches were carried out at different railways in Europe. During the years of our research we first developed a new Composite Heavily Fluid Compound (CHFC) material which contains more than 40 % of solid particles, is capable of taking extremely high pressure loads, reduces noise and wear out and is environmentally friendly. In the next phase of our research we developed new technology for applying the CHFC material onto the rails. The results showed, in a very short time, positive ecological effects; with the use of CHFC material the wear out was reduced more than 2.5 times and a decrease of the squealing noise up to 14 dBA at low frequency and up to 30 dBA at high frequency, which is, in comparison to other noise solutions, a significant added value to noise mitigation on railways.

INTRODUCTION
One in three individuals is annoyed during the daytime and one in five suffers from sleep disorder at night because of rail noise (WHO Report, 2011). In June 2002, Directive 2002/49/EC on the Assessment and Management of Environmental Noise (Directive 2002/49/EC, 2002) was adopted by the European Parliament and the Council. This Directive aims to "define a common approach intended to avoid, prevent or reduce on a prioritized basis the harmful effects, including annoyance, due to the exposure to environmental noise". The abatement of noise is necessary not only for reasons of comfort, but also because of other important health effects such as cardiovascular problems and cognitive impairment (WHO Report, 2011).

According to the railways, both top-of-rail squeal and flanging noise are associated with curves, particularly sharp curves (R < 500 m), whereas rolling noise is associated generally with tangent track. A large proportion of the squeal noise originating from the top of the rail is associated with stick-slip lateral motion at contact between the wheel tread and rail head (Gerg & Sharma, 2010). However, the curve squeal originates from the unstable response of a wheel objected to large creep forces in the region of contact, which excite the wheel's axial (and radial) mates and thus the noise generated is strongly tonal in nature in the frequency range 250 Hz to 10 kHz. Flanging noise is the high frequency, broadband or multi-tonal noise which is common on tight curves. The flange contact generates a different form of squeal noise, referred to as flange squeal, which has a considerably higher fundamental frequency and is often intermittent in nature. The lateral creep on the top of the rail is the major culprit in generating the squeal noise, though flange rubbing and longitudinal slip are also contributing factors to the overall noise radiated while negotiating a curved track (Gerg & Sharma, 2010). Lubrication of the contact between the active rail gauge corner and the wheel flange is intended to reduce noise and wheel and rail degradation significantly and, thus, wear. The amount of applied lubricant is one important factor in controlling wear, but poor adhesion during braking is a safety issue as it extends braking distance (Lewis and Olofsson, 2009).Lubricant type and the addition of solid lubricants are also influencing factors. The lubricant type and effects from solid lubricants were examined in several independent tests (Clayon & Danks, 1993; Clayon & Danks, 1989; Sato et al, 1993; Reiff 1986; Abbasi et al, 2013; Wang et al, 2011). These tests basically aimed to find out if different types of grease and the added quantity of solid lubricants affected retention and spread ability. In Reiff (Reiff 1986) the wheel forces of a former locomotive were measured, showing that molybdenum disulfide (MoS_2) gave the best effect on retention while graphite greases did not reveal any clear evidence about spread ability or retention. MoS_2 gave low wear rates in a twin-disc test in Clayton (Clayon & Danks, 1989), while graphite added to lubricants did not indicate any opportunities according to wear. Abbasi with coworkers (Abassi et al, 2013) reported that the number of ultrafine particles decrease when biodegradable rail grease or oil-based friction modifier was used. In contrast, the concentration of ultrafine particles increased drastically when water based lubricant was used. However, the focus of this study was on developing a completely new material – a friction modifier which would, when applied to the rail, reduce the wear out and noise significantly, especially the high frequency squealing noise, but its friction characteristics would not change the braking properties. When we developed such material we also developed and patented the technology for applying it to the top of the rail. The result of our research was a complete system for wear out and noise reduction.

EXPERIMENTS

Dosing of material

Part of our research was development of the most appropriate way for applying the newly developed material onto the rail. For this purpose we patented (EP 1 747 134 B1) and verified (TÜV SÜD Rail GmbH) the dosing boring (just Φ 4 mm) made into the rail head, which enabled the expansion of the material onto the precisely defined point on the rail head (Figure 1). This enables also the possibility to select the appropriate proceeding to achieve noise reduction and/or wear out reduction of rail flanks and wheels. With doing so the throwing out of the material is reduced considerably as, on the other hand, utilization of it is increased maximally (~ 99.8%). However, the borings doesn´t have any negative impact on railway track and they are also consistent with Directive 2004/49/ES.

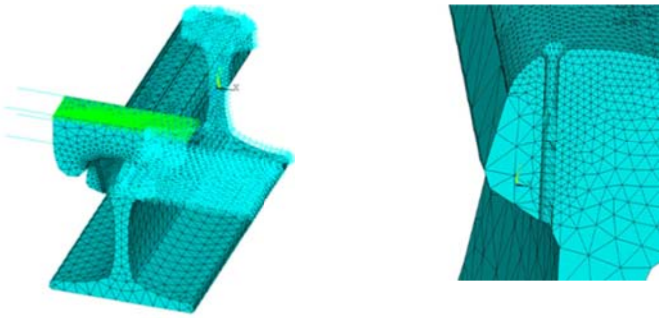


Figure 1: Dosing borings

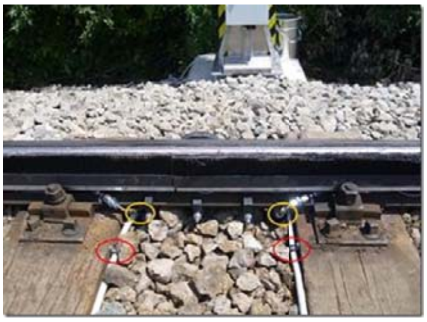
The dosing field can consist of one or more dosing points (borings). Dosing points can be in the same line and at the same height as the rail head, or not. Dosing quantity was between 0. 01 cm^3/sec and 0.18 cm^3/sec. The anti-noise and anti-wear system CL- E1top (Figure 2) included:

1. Aggregate

2. Dosing set or borings (Figure 2b)

3. Electro part: Solar system (voltage 230V AC)

The aggregate (except the sensor) and solar system were installed at the appropriate distance from the rails in order to ensure safer and easier maintenance and composite compound replenishing, while the dosing set and sensor unit were installed directly onto the rail.



(a) (b)

Figure 2: a) CL-E1top system b) Dosing borings

Wear out and noise reduction measurements

Measurement of noise reduction was performed at the two measuring points where the railway line makes a long sharp turn, therefore the direction of travel changes by approximately 180°. This railway is constructed with two lines which are spaced a certain distance from each other, where the left track is type S49 and the right track is type UIC 60. The radius of curve in this part of the track is 298 meters. Measurements were made at frequencies from 50 to 20 k Hz in two points, according to Standard method (EN ISO 3095, 2005). For measurements at each one of the measuring points Sonometers, Bruel & Kjaer brand, 2250 and 2270 with programmed modules were used. The acoustic measurement program consisted of short-term measurements and its purpose was to classify the sound pressure levels registered when a certain railroad composition passed by that railroad section. The weather was without rainfall and wind, with a temperature around 20 °C and relative humidity around 60 %.

The degree of wearing out was determined with a wheel/rail profile measuring device (Geismar, model P-110) which had reproduced the actual rail profile to scale and thereby had provided an accurate profile for comparing the wear.

CHFC material

The CHFC material used in our research contains more than 40 % of solid particles, is capable of taking over extremely high pressure loads and is environmentally friendly. Some characteristics of the CHFC material are present in Table 1. However more information cannot be given, because they are confidential. Before using the CHFC material it was tested according to numerous Standard methods and, according to these results and according to the characteristics of the CHFC material, we had presupposed that this material could be used efficiently.

Table 1: Characteristics of CHFC material

Appearance	Paste
Color	Gray
Odor	Mild
Solubility in water	Negligible
Hazardous reactive properties	None
Consistency – NLGI (DIN 51818, ASTM-D 217)	2
Worked penetration (ISO 2137)	295 mm/10
Density (at 20 °C) (ISO 12185)	1.3 g/cm^3
Viscosity (at 40 °C)(ISO 3104)	26.5 mm^2/s
Viscosity index	136
Flash point	> 300°C
Ignition temperature	> 350°C
Thermal decomposition	> 370°C
Drop point (ISO 2176)	Not applicable
Separation of base oil (40°C, 7 days) (DIN 51817)	2.1 %
Behavior of the product in the presence of water (DIN 51807-1-40)	< 1
Anti – corrosion properties (DIN 51802, ASTM D6138)	Non-corrosive
Weld Load (FOUR BALL TEST) (ASTM D 2596)	> 8000 N
Weld Load (ASTM D 2266)	< 1 mm

RESULTS AND DISCUSION

We performed examination of wear and tear of rails on a long-term basis for the CL-E1top device. It arises from our measurements that, after installation of the CL-E1top, the annual loss of material due to wear and tear is more than 2.5 times lower (annual side wear and tear of the rail was approximately 2 to 2.5 mm, since using CL-E1top the measured values were less than 1 mm), which confirmed the statements of Abbasi (Abbas et al, 2013). Measurement was performed every six months. In the last year of the research the wear of tracks practically stopped and, consequently, reduced maintenance costs (Slovenia Railways Report, 2010). Consumption of CHFC material was only around 7 kg/month, at approximately 40,000 carriage axles/month.

The noise was reduced by 6 to 14 dBA at low frequencies because of using the anti-noise device CL-E1top. Further reductions of noise levels had been observed in the area of middle and especially in the area of high frequencies, where the reductions were from 20 to 30 dBA. However, noise reduction was higher for freight trains and a little lower for passenger trains. The results from measuring the noise reduction are present on Figure 3 and Figure 4.

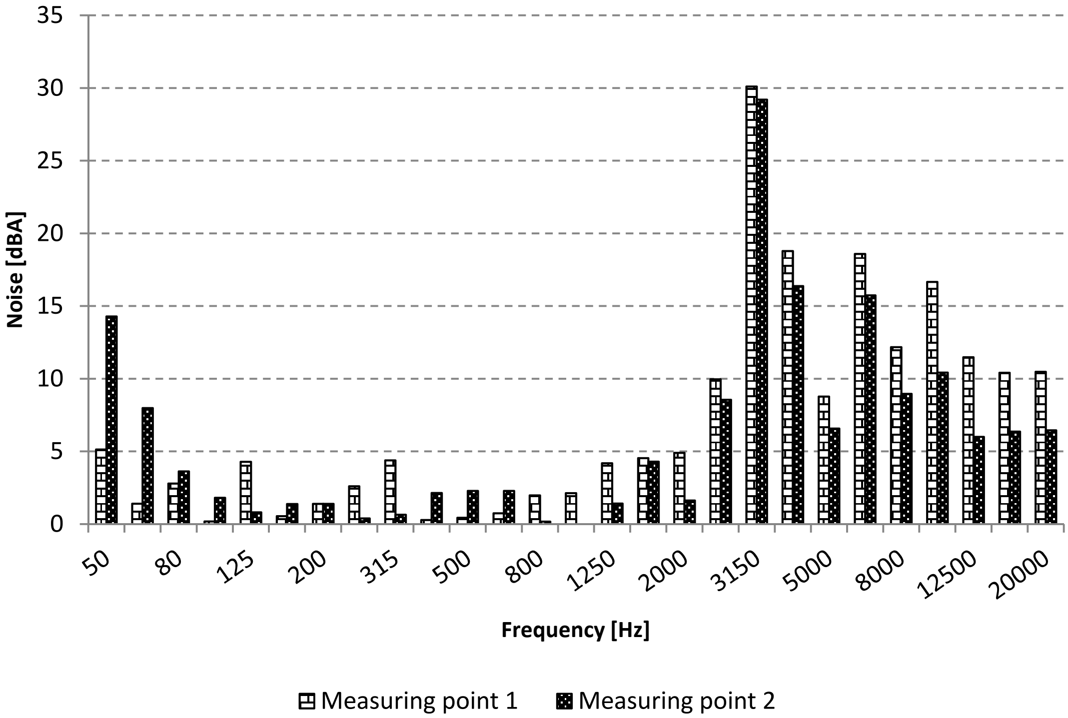


Figure 3: Noise reduction by using CL-E1top system (freight trains)

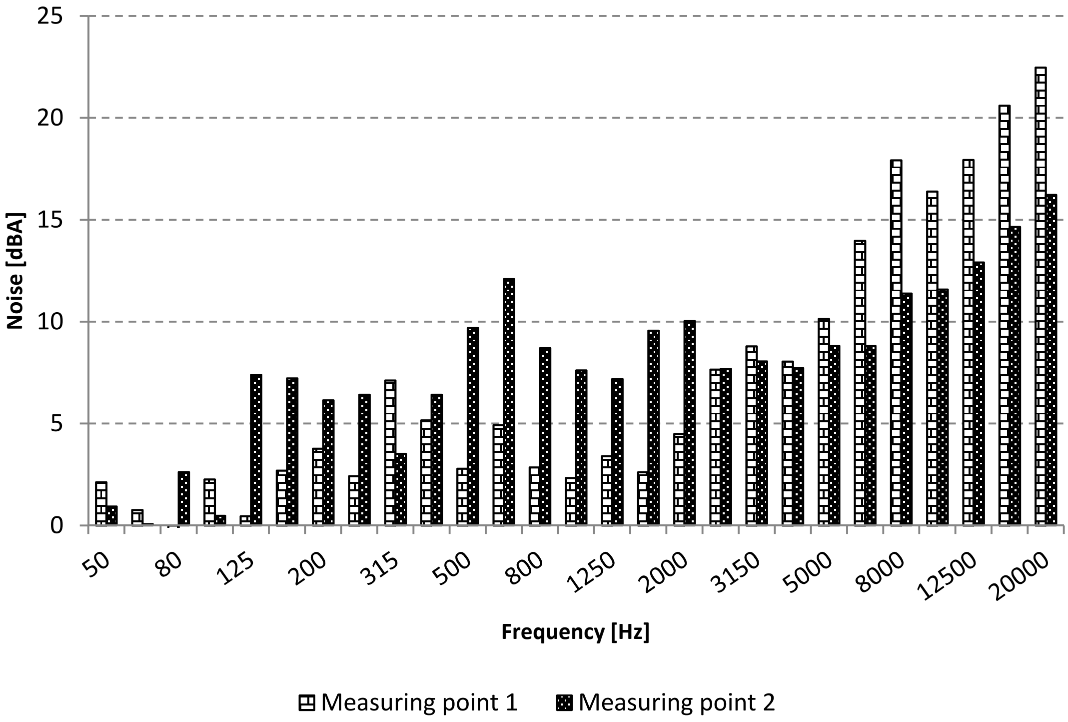


Figure 4: Noise reduction by using CL-E1top system (passenger trains)

CONCLUSION

With our research and results we had proven that by using only one but appropriate material applied to an exact position, it is possible to reduce significantly the wear out and the noise. The present work shows an effective solution by which more than 2,5 times lower wear out can be achieved and, at the same time, more than 30 dBA reduction of noise. Our results have therefore shown that CHFC materials have a positive economic and ecological effect and according to that we believe that this solution will be, like it is in Europe, well received also elsewhere around the world.

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