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The Anti-Noise and Anti-Wear Systems for Railways

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Abstract**—**In recent years there has been a continuous increase of axle loads, tonnage, train speed and train length which has increased both the productivity in the rail sector and the risk of rail breaks and derailments. On the other hand, the environmental requirements (e.g. noise reduction) for railway operations will become tighter in the future. In our research we developed a new composite material which does not change braking properties, is capable of taking extremely high pressure loads, reduces noise and is environmentally friendly. Part of our research was also the development of technology which will be able to apply this material to the rail. The result of our research was the system which reduces the wear out significantly and almost completely eliminates the squealing noise at the same time, and by using only one special material.

Keywords**—**Active protection, composite material, lubrication, noise reduction, reduction at source, railway.

I. Wear Out and Noise

LUBRICATION was of great interest during the late 70s and early 80s, especially in the USA and Canada. A rapid investment in equipment for rail lubrication started without any research evidence of the effectiveness or negative effects of lubrication. Examples of negative effects are that the lubricant can immigrate to the rail ball and give low friction, as well as the use of liquids can cause crack tip pressurization. However, such fast change into new technology is unusual in this type of conservative business, see Welty [1]. On the other hand, fast change into technology where wagons are equipped with low-noise blocks (K and LL) is also evident. These wagons have an overall noise emission reduction of 8dB on average track. However, the general noise level for wagons with composite blocks is nearly at the level of a wagon with cast iron brake blocks if the wheel roughness of these two wagon types is at a similar level. It had been proven that several parameters can destroy noise reduction when using composite brake blocks. The noise of insufficiently greased bogies can decrease the noise reduction by 2.0–2.5dB(A). Wheel flats can compensate for the noise reduction completely. Just the noise of invisible wheel flats diminishes the noise reduction by 3–5dB(A); it is, however, possible that invisible wheel flats were present. Moreover, a 3–5dB(A) diminishing of achievable noise reduction was recorded as a consequence of unstable running, and even higher values are possible [2].

The noise levels of vehicles with composite brake blocks increases when the rail roughness dominates the total roughness. The rail roughness shall not be higher than the wheel roughness of composite block brake wagons, which is very hard to achieve. Furthermore, the roughness requirement of prEN ISO 3095 is not sufficient [2]. Does that mean that the rails would have to be ground more often when using composite brake blocks otherwise the noise reduction would be very small? Probably yes! This does not only mean additional costs, but also additional environmental pollution with airborne particles!

However, the retentiveness and spreadability of lubricants applied from wayside lubricators are related closely. The amount of applied lubricant is one important factor to control wear. 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 by Clayton [3], [4] and Sato [5] as laboratory tests. A field test was also carried out by Reiff [6]. These tests basically aimed to find out if different types of grease and the added quantity of solid lubricants affected retentiveness and spreadability. In Reiff [6] the wheel forces of a former locomotive were measured, showing that molybdenum disulfide (MoS_2) gave the best effect on retentiveness while graphite greases did not reveal any clear evidence about spreadability or retentiveness. MoS_2 gave low wear rates in a twin-disc test in Clayton [4], while graphite added to lubricants did not indicate any opportunities according to wear.

A laboratory test by McEwen and Harvey [7] with a full-scale wheel/rail test machine showed that the durability of lubricants at the rail could be best improved by using more viscous lubricants. Adding solid lubricants also improved durability. Rail lubrication was initially intended only to reduce wear, though as the rail curves became equipped with wayside lubricators, the energy savings became a new area of interest. Tests performed by Reiff [8] showed large energy savings where fuel savings of up to 30% were found. The possibility to save energy by lubricating the rail was strengthened further. However, its benefit on straight track was not of the same magnitude as the earlier tests, just about 5%, see Dahlman and Stehly [9].

However, the present work does not involve any studies concerning fuel or energy savings, but its focus was in developing a completely new material which would, when applied on the rail, reduce significantly the wear out and noise. We have to know that curve tracks may, besides excessive wear at the gauge corner of the rail, also cause a squeal noise. It is important to know that noise is one of the most widespread public health threats in industrialized countries. Public Health experts agree that environmental risks constitute 25 % of the burden of disease. Widespread exposure to rail noise contributes to this burden. One in three individuals is annoyed during the daytime and one in five suffers from sleep

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disorder at night because of the rail noise [10]. In June 2002, Directive 2002/49/EC on the Assessment and Management of Environmental Noise [11] 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 [10].

According to railways, both top-of-rail squeal and flanging noise are associated with curves, particularly sharp curves (R <500m), whereas rolling noise is associated generally with tangent track. A large proportion of squeal noise originating from the top of the rail is associated with the stick-slip lateral motion at contact between the wheel tread and rail head [12]. 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 the flange rubbing and longitudinal slip are also contributing factors to the overall noise radiated while negotiating a curved track. Table I shows the frequency ranges for the various types of rail noise [12].

TABLE I
FREQUENCY RANGE FOR DIFFERENT TYPES OF RAILWAY NOISE [12]

Noise type	Frequency range (Hz)
Rolling	30-5000
Flat spots	50-250 (speed dependent)
Ground born vibrations	4-80
Structure born noise	30-200
Top of rail squeal	1000-5000
Flanging noise	5000-10000

II. DOSING OF MATERIAL ON THE RAIL

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 4mm) made into the rail head, which enabled the expansion of the material onto the precisely defined point on the rail head (Fig. 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 [13].

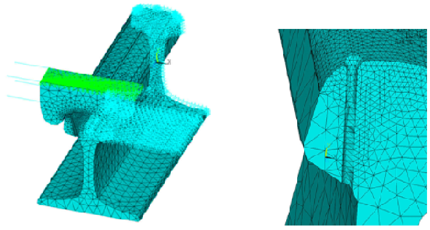

Fig. 1 Dosing boring

III. CL-E1TOP APPLICATION SYSTEM

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 0.01cm^3/sec and 0.18cm^3/sec. The anti-noise and anti-wear system CL- E1top (Fig. 2) included:

1. Aggregate
2. Dosing set or borings (Fig. 2 (b))
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)

Fig. 2 (a) CL-E1top system (b) Dosing borings

IV. 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 I. 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 II
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
Weld Load (Four ball test) (ASTM D 296)	>8000 N
Anti – corrosion properties (DIN 51802, ASTM D6138)	Non-corrosive
Weld Load (ASTM D 2266)	<1 mm

V. INSTALLATION OF CL-E1 DEVICES

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.

VI. WEAR OUT AND NOISE MEASUREMENTS

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.

The first measuring point was 7 meters away from the first track at a height of 2 meters from the plane of the railway line. The second measuring point was at a height of 4 meters and at a distance of 8 meters from the nearest track. The radius of curve in this part of the track is 298 meters. For measurements at each one of the measuring points a sonometers, Bruel&Kjaer brand, 2250 and 2270 with programmed modules were used. Measurements were made according to the standard method [14].

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, relative humidity around 60 %.

VII. RESULTS

A. Wear Out and Noise Reduction

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 2.5mm, since using CL-E1top the measured values were less than 1mm), which confirmed the statements of other researches [15]. Measurement was performed every six months. In the last year of the research the wear of tracks practically stopped and, consequently, reduced maintenance costs [16]. Consumption of CHFC material was only around 7kg/month, at approximately 40,000 carriage axles/month

The noise was reduced by 6 to 14 dBA because of using the anti-noise device CL-E1top which is, according to the A evaluation, a 4 to 25-times reduction of noise energy. Further reductions of noise levels can be observed in the area of middle and especially in the area of high frequencies, where the reduction is from 20 to 30 dBA which is, in this part of the spectrum from 100 to 1000-times lower noise energy emission. The results from measuring the noise reduction are presented in Fig. 3.

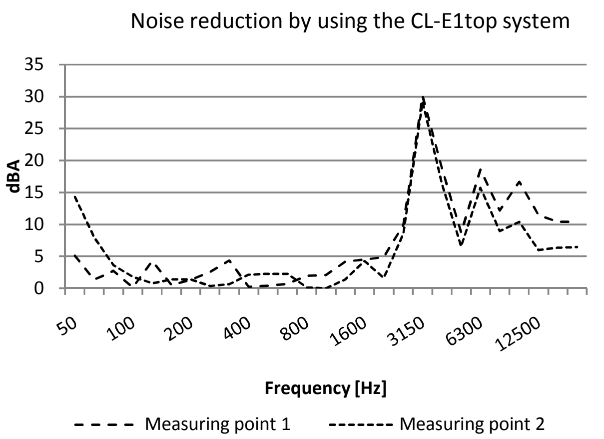

Fig. 3 Noise reduction by using CL-E1topsystem

In the study we had, by using the anti-noise device CL-E1top, achieved up to 14dBA noise reductions at low frequencies and up to 30dBA noise reductions at high-frequencies, as is evident from Fig. 3. Quite noticeable (30dBA) is the noise reduction with the tertian frequency component 3150 Hz, which occurred during the squealing of trains and to which the ear may be especially sensitive.

VIII. CONCLUSION

Noise elimination is an issue that is very complex and has to be solved; therefore we must use the best solution for that. In the case of composite blocks, we have very little researches and publications which would indicate the whole picture and introduce and compare the composite brake blocks with other solutions. Scientists [2] also recommend greasing of the brake system when using the composite brake blocks. Therefore we should ask ourselves about the reasonableness of such solutions if we know that noise could be reduced more efficiently and cheaply by using cast iron blocks and friction modifiers. Furthermore, some friction modifiers, like the CHFC, do not change the braking properties, but can reduce the wear out of wheels; rails and brakes, and they are environmentally friendly.

The present work shows an effective solution by which can be achieved more than 2.5 times lower wear out and, at the same time, more than 30dBA reduction of noise. The results of this research confirmed the hypothesis that, by using appropriate materials (CHFC materials) and technology (CL-E1top) a very high reduction of high frequency noise and wear out can be achieved in the curve. This solution can be also used efficiently everywhere where the frequency of train braking is higher and is known (e.g. train stations, stop sign, where the railway runs downhill).

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