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17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



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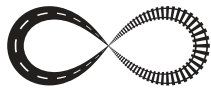
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NOISE MITIGATION WITH RAIL LUBRICATION DEVICE ON TRAMLINE

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Abstract

Rail lubrication can reduce the rail and wheel wears, and it mitigates the noise effect, generated by uneven wears and the dynamic rail-wheel contact. Nowadays, clever lubrication devices are used to automate and control the lubrication process. The units are usually installed on curved tracks. Depending on the requirements, the lubrication bars or in some cases only bores deposit the grease precisely at the right positions on the rails. Various types of lubrication devices have been installed in Hungary throughout the country on railway, tram and suburban railway lines. In the course of our research work we carried out a multitude of tests on the noise mitigation with the rail lubrication device installed on a tramline, in the framework of three measurement series. We accomplished noise measurements in case of corrugated and lubricated/non-lubricated rails, grinded rails and finally, grinded and lubricated rails. By comparing the results, the real value of the noise mitigation achieved by the rail lubricated device and grinding can be obtained. We investigated the diminishing effect of noise mitigation by switching off the units and the effect of grinding on the efficiency of the lubrication. In addition, Tatra T5C5 and CAF Urbos 3 trams ran on the line, so the results of the two types are directly comparable. The measurements supported that the rail lubrication and the grinding have adequate noise attenuation effect. We confirmed the expectation that the smoother rail surface improves the noise mitigation of rail lubrication. Finally, we also showed the reduction of tram wheel squeal by analysis of frequency spectra.

Keywords: noise measurements, tramway, noise attenuation, rail lubrication, grinding

1 Introduction

Rail lubrication is primarily used to reduce the wear of rails and wheels, usually in small radius curves. With rail lubrication, the noise emission caused by the friction between the outer flange and rail, and the sliding due to the different peripheral speed of the wheels can be reduced. One of the most significant and most undesirable noise, the wheel squeal can also be eliminated or at least reduced.

In Budapest, the Budapest Transport PLC (BKV Zrt.) has installed several rail lubrication devices for the prevention and treatment of residential noise complaints and keeps in mind the extension of the lifespan of the rails and the reduction of maintenance costs too. In urban environments and densely populated areas, it is particularly important to comply with the noise limits [1], therefore efficient solutions are also needed in tram transport.

We anticipate that the feedback of resident population is positive at those places where rail lubrication devices have been installed. In our research – being aware of feedbacks – we

have planned a complex noise measurement procedure to determine the efficiency of the rail lubrication devices installed on the track, more precisely of the stationary automated rail lubrication. We also had the opportunity to examine the effect of grinding, so it was provable that the noise emission of trams which are running on smooth and even rail surface is lower. We could measure the noise emission of lubricated/non-lubricated worn rails and lubricated/non-lubricated grinded rails, furthermore detect the ceasing noise control effect after having terminated the lubrication. Finally, we analysed the elimination of squeal by comparing the frequency spectra.

2 Wheel squeal

In curves, as the vehicle is guided by the flanges, undesirable and very disturbing noise is generated which is typically the wheel squeal (aka rail squeal). Squeal is the intense high frequency tonal noise that can occur when a railway vehicle traverses a curve, [2]. The predominating part of squeal noise energy is related to the occurrence of one or several pure tone frequencies ranging from about 400 Hz to more than 10 kHz according to the rolling conditions. Squeal noise levels can exceed usual rolling noise levels by more than 15 to 20 dB, [3]. The two wheels, which are extruded on the common axle, must run along different lengths in the curves. The axle does not have a differential, so the profile of the wheels is coned. The coned wheel tries to equalize the rev difference in the curve which can only be satisfied up to arc range $R > 100$ m. When this equalization can no longer be ensured, the wheels slip on the running surface of rail, causing rail corrugations and considerable noise emission (squeal), which can be reduced by lubrication, [4].

The efficiency of rail lubrication is affected by numerous factors such as curve radius, curve length, properties and dosage of grease, location of lubrication points, the vehicle, axle load, speed, wheel and rail profiles, weather, etc, [5]. For a correct understanding of the results we detail all the influencing factors affecting the measurements.

3 Measurement conditions

It is very difficult to find a track on the tram network of Budapest that guarantees ideal measurement conditions. We could only choose a location where we would not disturb the residents by switching off the devices and where there was minimal or even absolutely no road traffic. Therefore, we were able to carry out the noise tests at the expense of greater compromises.

After several discussions and on-site visits, we have chosen the curves before the end station of tram line 17, which is between the station Budafok kocsiszín and Savoya Park end station (Figure 1). The curves run mostly in an underpass. We are fully aware of the fact that the measuring site was not acoustically appropriate and did not meet the conditions for free space specified in the standard [6]. For this reason, the measurements can only be compared with themselves. However, the underpass has minimized the background noises, so we could clearly measure only the noise of the passing trams.

The examined section is a two-centered curve, where two compound curves connect without straight section or transition. The curvature changes at the connection of the two-centered compound curve by leaps and bounds, therefore this design should be basically avoided. The circular curves connect to the straight sections with transition curves. The right track according to chainage (in the direction of Savoya Park) is the external track. The sharp circular curves connect with 75.00 m and 79.14 m radii in the inner track. Implicitly, the radii of external track are greater with the distance between the centre lines, which is 3.20 m. The total length of the curve of the inner track is 130.336 m. The curves were built with 1435 mm gauge without expansion. The superelevation is 30 mm. During the measurements a speed limit of 20 km/h was in effect, [7].

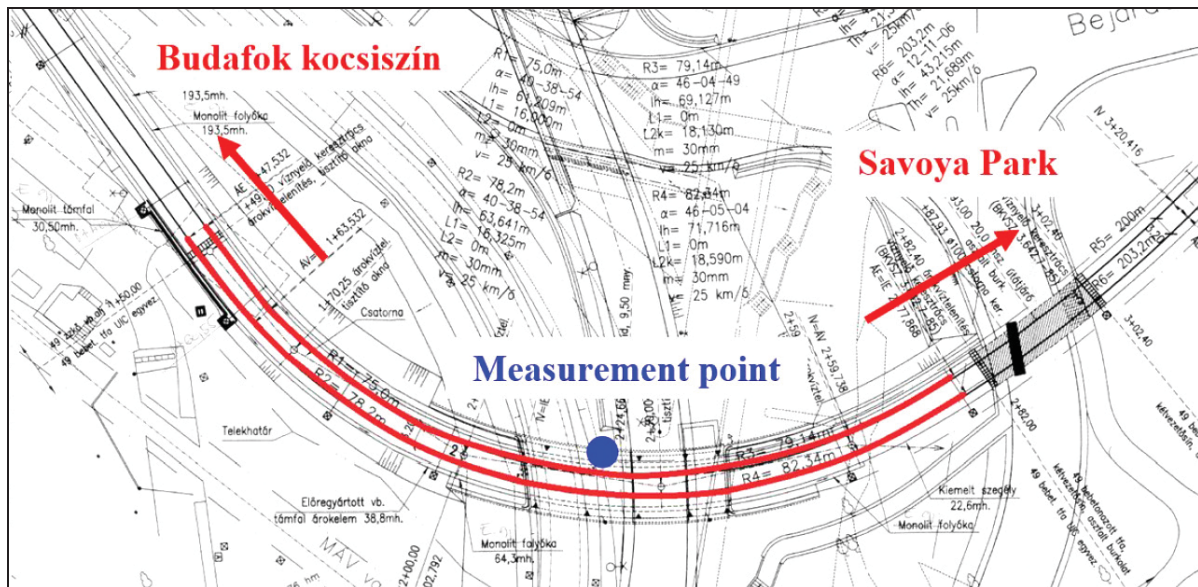


Figure 1 Measuring site, the examined curves of tram line 17

The track was built in 2004 with 49E1 rails, ribbed plate fastening systems with Skl-3 tension clamps and wooden sleepers which are in concrete slab. Beside the inner rails of both tracks there are guide (check) rails with 33C1 profile, [7]. Due to the inadequate design of the horizontal alignment (two-centered curve with small radii) and running-gear techniques (symmetric 1:20 inclination, guide rail beside the inner rail [see further in 4]), the wears of the rails are close to the size limit of the exceptional measures (25 mm) [8], and the corrugations are considerable too. The wear of the worn rails is 18 mm on average. By designing the right geometry and running technique and optimising the wheel/rail interface [9], these wears and corrugations can be fundamentally delayed. The section is also characterized by concave fault (negative) weldings per 24 meters which generate additional stresses and noise in the track. Two rail lubrication devices type TRACKSAFE LUBE were installed at the beginning of the first curve of both tracks according to the direction of traffic. The grease is delivered by bores (drilling the rail heads at a proper angle) which deposit the grease precisely at the right positions. The rails are lubricated at four points here. On the external rails, two bores on the gauge corner of the railhead, on the inner rails one bore on the running surface and one bore on the guide (check) rails provide lubrication. Latter is to assure the lubrication on the back of the flange. The devices use WSW BIO SK-2016 CG type lubricant which made of biodegradable materials, base oils and greases, and high-efficiency additives. The lubricant contains solid components such as fine graphite and zinc powder as well.

Two types of vehicles are running on the line: the nearly 40-year old, Czechoslovakian-made ČKD Tatra T5C5 and the new, short (34 meters long), Spanish-made CAF Urbos 3 trams. The Tatra tram is a railcar with two bogies and four axles which are driven separately. The total length of the attached vehicle is 30340 mm. The CAF tram is a two-way articulated railcar with suspended modules and bogies. Two of three bogies are driven. The vehicle is equipped with a time-based wheel lubrication device, [7]. The vehicle is one of the predominant factors of the noise generation mechanism. We considered this fact by evaluating the measurement data obtained for the two tram types separately. Nevertheless, individual vehicles of the two types varied from measurement date to date, hence we could not examine the same trams under all conditions.

4 Measurement process

The measurements were carried out during summer 2017, on different days, but in the same time interval (9-12 a.m.), at approximately the same temperature (25-30 °C), on sunny, win-

dless or mildly windy weather and at the same measuring point. The measuring point was set at the connection of the two circular curves (approximately in the middle of the underpass), at 2.5 meters from the centre line of the left (inner) track. The microphone was set vertically 1.2 meters above rail top level. The noise measurements were performed with Class 1 Larson Davis System 824 sound pressure level meter, which was calibrated. The instrument measured and recorded short time (1s) equivalent sound pressure levels (SPL) for each and every second of the passby.

We investigated different conditions for 13 days (Figure 2). The first measurements were made during the operation of the installed lubrication devices. Afterwards the devices were switched off to investigate the diminishing attenuation effect of lubrication. To examine the non-lubricated condition and perform a suitable comparative analysis, it was necessary to degreasing the rails. On the railheads were significant corrugations, therefore we intended grinding to remove them. It is important to note that the grinding machine (AT VM 8000-12 Extended type) only removed the corrugations from the railheads, the worn profiles remain unchanged. After removing the rail corrugations, we could measure the noise reduction of grinding. Finally, since the grinding work resulted smoother surface of the rails, we switched on the lubrication devices and waited until the grease layer built up again. By doing so, in the last tests we examined the combined effect of lubrication and grinding.

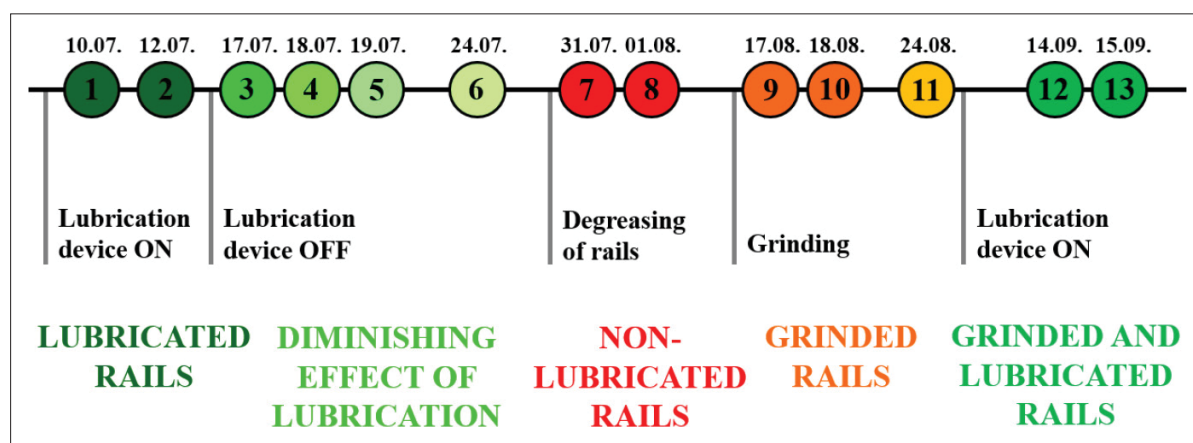


Figure 2 Measuring days and their conditions

5 Measurement results

From the measured SPLs, we selected the max. value (this was usually observed in the moment when the centre of the vehicle was in line with the microphone) and 10 second intervals before and after this point, so we considered 21 seconds passing time by every tram. The passby equivalent sound pressure levels (Leq) were calculated from the 21s long data series. We present the results of the external track, which is the right one according to the chainage. The reason is that the distance between the microphone and the centre line of the track was only 5.7 m which is closer to the 7.5-meter distance required by the standard [6]. We measured the same tendency, but apparently different results on the inner track.

5.1 Sound pressure levels

Instead of presenting the recorded 77 passbys of different trams, we show an illustrative graph which includes all the results of the measurement series (Figure 3). The horizontal axis of the graph shows the various conditions of the tests. From the vertical axis the equivalent continuous sound pressure levels (Leq) can be read which contain the result of all trams (collected by type), that passed on those days.

It was foreseeable that the Tatra trams will be noisier than the CAF trams. Unfortunately, the diminishing effect of lubrication was not detectable on the first three days, the results show a minimal downward trend. Probably trams in better condition travelled on those days, and the remaining grease layer still had an effective damping effect. It is promising that the differences are not remarkable. We received significant differences on day 8, which means that by discontinuing lubrication it takes about a week for the unpleasant noise effects to return. As expected, the results increased and reached the maximum SPLs after the grease has been manually removed from the rails. Then, both tracks were grinded, resulting in noise reduction for both tram types. It is very positive that together with grinding and lubrication we can achieve adequate damping value. In this case the sound pressure levels are the lowest. Surprisingly, the two measures are so effective together that the results of the two different tram types were approaching each other. While with lubricated rails 4.3 dB(A) and with non-lubricated rail 6.4 dB(A) were the differences, we finally gained just 1.6 dB(A).

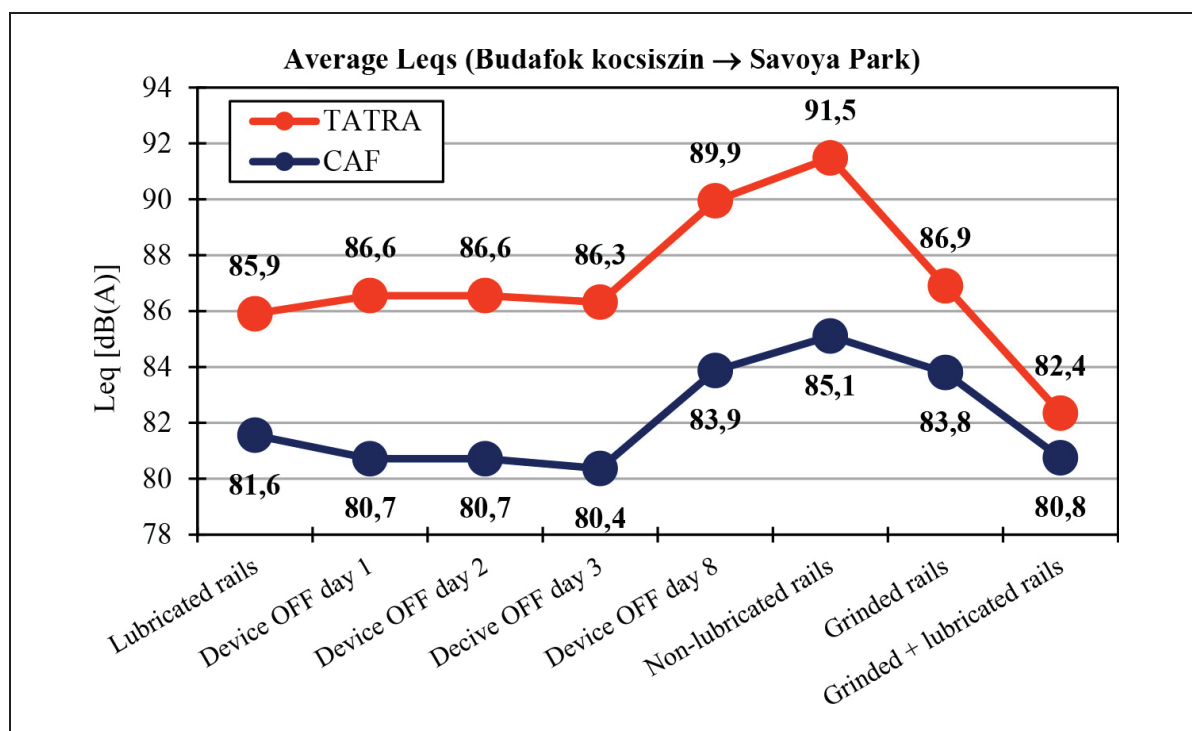


Figure 3 Average Leqs at each condition

Table 1 summarizes the numerical results of the graph obtained with the three measures relative to non-lubricated condition. It can be stated that all three measures have noise reduction effect. We received greater attenuation in case of Tatra trams, but the result of the CAF trams are not negligible either. Nearly the same noise reduction can be achieved if the worn rails are only lubricated or grinded. With their simultaneous use appropriate noise reduction can be obtained on the tramway track. Considering the nonlinear perception of the ear and the associated logarithmically formed sound pressure level, the attenuation results of 5 dB(A) or more already have a significant effect.

Table 1 Average noise reduction with three measures to non-lubricated rails

Tram	Average noise reduction with [dB(A)]		
	Lubricated rails	Grinded rails	Grinded and lubricated rails
Tatra T5C5	- 4,7	- 5,0	- 8,1
CAF Urbos 3	- 2,6	- 2,1	- 3,9

We could conclude from the difference between the two trams that the operation of the CAF trams can solve the noise problems easily. However, the results are average values which includes trams also in better and worse conditions. Furthermore, the differences could have caused by the time-based wheel lubrication devices of CAF trams. Based on our subjective judgement we can state that there were deafening squealing trams from both types. Rail noise is high noise amplitude sound event, consisting of both periodic and random components of various frequencies. For these reasons, we analysed the frequency spectra for more detailed exploration of squealing.

5.2 Frequency analysis

The sound can be described not only as temporal variation of the vibrating medium, but also as a spectrum of its components. The spectrum consists of different intensity sounds at different frequency ranges. The frequencies of noise perceived by the ear are between 20 and 20.000 Hz and the instrument measured also in this range. Each frequency spectrum belongs to a recorded equivalent SPL (21s long data history).

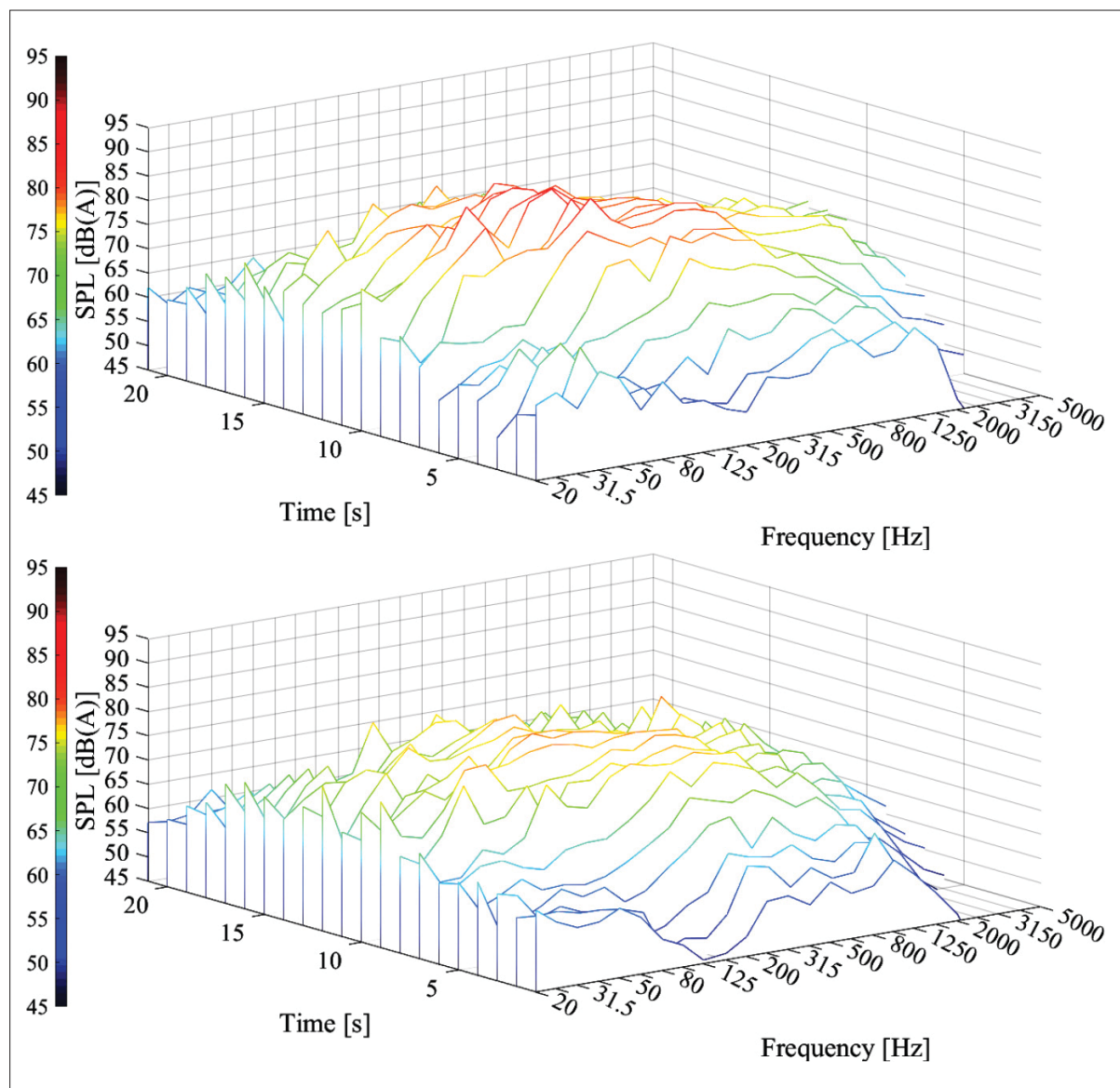


Figure 4 Frequency spectra of the CAF tram no. 2220 at non-lubricated (above) and at lubricated and grinded (below) conditions

Figure 4 illustrates the passing of the CAF tram no. 2220 as an example at non-lubricated and at lubricated and grinded rails. The graphs only show a 5 kHz spectrum as the squeal occurred below this. The high peaks indicate the presence of squeal which are formed between 200 and 1.000 Hz. The colours are well depicted as the values decreased. Almost all frequencies decrease due to lubrication and grinding, and eliminate the squeal. Considering further measurement results, it can be stated that the squeal is usually the highest for 400 Hz. Human hearing is more sensitive to higher frequencies (1-3 kHz), and we can even decrease several dB reductions with lubrication and grinding at these range. Reduction in the higher frequencies provide more tolerable passbys.

6 Conclusions

The results confirmed the expectations. As a summary of our findings it can be stated, that noise reduction can be achieved with continuous maintenance and removing deformations and irregularities from rails, as well with the simultaneous, automated lubrication of the rails. Basically, rail lubrication and grinding reduce disturbing noise originating from tram traffic, but we have confirmed the lower noise emission of trams that ride on flat and smooth surface rails. Together they are so effective that the squeal noise is eliminated (at higher frequencies too), thereby result in much more tolerable passbys of trams for our hearing. Not expected, but more promising outcome is that the significant initial difference between the two types of trams can also be reduced. Based on these results, the use of automated rail lubrication in curves of the new-built tramway tracks should be considered. In the case of an existing track, it is better to install rail lubrication device after removing corrugations from the rail surface. The measurements have also proved that grinding is one of the basic maintenance works that can be used to achieve noise reduction, while extending the lifetime of the rails too. Because of these, BKV Zrt. is continuously integrating the grinding work into its maintenance strategy and installing lubrication devices in the small radius curves. Since measurements were performed in an acoustically inappropriate place, and because many other factors affect the efficiency of the rail lubrication, it is necessary to repeat the tests at another location and under different conditions, as well to support the results.

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