Noise control of tram and light rail transit (LRT) systems by rail surface treatment: the newly developed ATMO rail grinding trailer for quieter rails

Tram and light rail transit (LRT) systems are currently experiencing a renaissance. This poses challenges for infrastructure managers as regards noise control. Rail care can play a significant role in reducing noise emission levels. However, with traffic volumes increasing, the time windows for maintenance are becoming shorter. Therefore, a rethink of maintenance approaches, as well as the development and roll-out of new technologies, are required. This article looks at the new ATMO (Automatic Track Machine Oscillator) rail grinding trailer that has been developed by Plasser & Theurer within the framework of the Shift2Rail research initiative, which offers great scope for effective noise control in urban areas.

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Noise control in urban areas – a matter of great importance

The demand for mobility in cities has been steadily increasing in the last few years, and recent studies indicate that there will be a continued growth of cities. In fact, it is expected that, by 2050, two out of three people will be city dwellers, which poses great challenges for transport planning. One way to respond to this is to implement rail-guided transport systems, as these are well suited for handling large passenger volumes.

In recent years, there has been an increase in the construction and expansion of metro systems, as well as a large resurgence of tram and light rail transit (LRT) systems. This has also been confirmed by the study "Worldwide evolution of light rail transit (LRT) networks" conducted within the framework of the Shift2Rail research initiative [1]. This study notes that, since 2000, a significantly high number of new tram and LRT systems has been implemented globally and that, whereas in the beginning the focus was placed on constructing LRT systems, this trend has, in the meantime, shifted towards the implementation of at-grade tram networks. Further, the study foresees a significant expansion of existing systems. In Fig. 1, the development of tram and LRT system implementation for the time period 2000 to 2016, as established within the scope of the study conducted within the framework of the Shift2Rail research initiative, is depicted [2].

The creation of new tram and LRT systems comes with various challenges for transport system planners and operators. For instance, in densely populated areas, noise control is of very great importance. In a WHO report [3], it is noted that at least 100 million people in Europe are affected by road traffic noise. As environmental noise has a negative impact on the health of people – it may lead to cardiovascular diseases, hearing damage, tinnitus, mental health problems, as well as sleep disorders [3], protecting people from noise is a matter of high priority.

However, for structural and aesthetic reasons, the measures adopted for heavy rail systems, such as noise barriers, cannot be implemented in cities and, thus, a different approach is required

Noise control by means of rail grinding

In the case of tram and LRT systems, structure-borne and airborne noise occurs due to the wheel/rail (steel-on-steel) contact during the passage of rail vehicles. The resulting level of sound propagation depends to a large extent on the level of "smoothness" of the respective rails and wheels. The rougher the tread of the wheels and the larger the extent of rail surface irregularities are, the higher the resultant vibration and, thus, sound propagation is. Lower noise emission levels can be effected by smoothing out rail surface irregularities by means of grinding. Wheel tread roughness can be managed fairly well by turning the tyres at regular intervals.

Rolling noise is, besides on the surface condition of both rail and wheel, also dependent on vehicle travelling speed. As can be observed from Fig. 2 (see next page), rolling noise is prevalent for travelling speeds of up to 50 km/h, i.e. the speed range of tram and LRT vehicle operation [4].

Rail surface irregularities – how they arise

Rail wear is caused by the passage of rail vehicles, and the resultant static and dynamic loads. It manifests itself in a number of different ways, such as changes to the metallurgical structure of the rail, mechanical stresses, and solidification of the rail head material that may lead to the formation of cracks.

On urban rail (tram and LRT) systems, the following three rail defect types are commonly observed [2]:

— *wheel burns:* these occur when powered axles transition from static friction to kinetic friction, which causes the wheels to slip. Especially on tram systems, which are characterised by frequent braking and accelerating, wheel burns are a frequent occurrence;

— *rail corrugation:* this is defined as the occurrence of periodic rail surface irregularities with wavelengths of 3-30 cm.

The grooved rails on urban rail systems often exhibit corrugations with wavelengths of some 5 cm – these have a particularly noticeable impact on noise emission, as well as the service life of the rail;

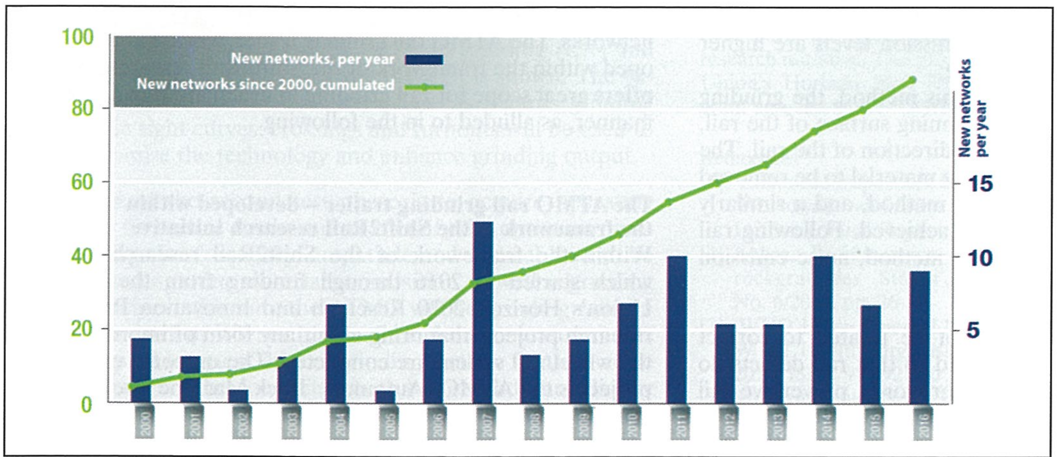

Fig. 1: Worldwide development of tram and LRT systems from 2000 to 2016 [1]

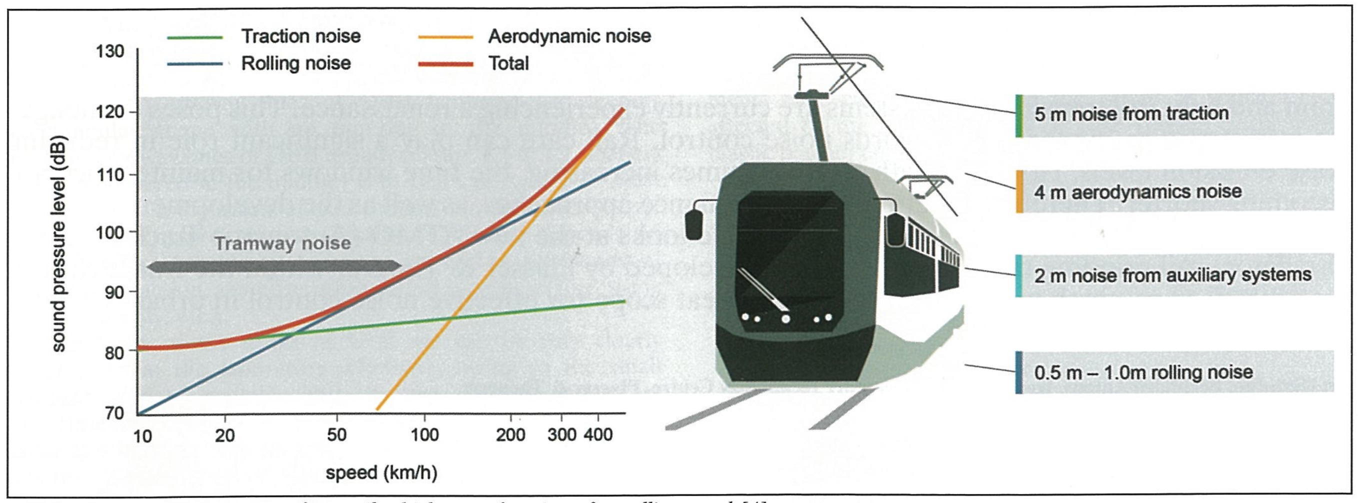

Fig. 2: Sources of noise emission from rail vehicles as a function of travelling speed [4]

— *rail breakages:* these occur relatively often on urban rail systems. Their occurrence may be influenced by factors such as rail temperature, storage conditions of the rails prior to installation, traffic loading history, rail type, and the metallurgical properties of the rails. Poor welding of rail sections can also lead to rail breakages.

Rail surface defects result in an increase in dynamic loading of track and rail vehicles, as well as vibrations which. in turn, lead to an increase in noise perceived by passengers on-board the rail vehicles, as well as the exposure to higher noise emission levels by lineside residents. Further, rail surface defects negatively impact the service life of the rail [2]. Rail surface defects can be corrected by means of grinding. The intervention threshold for correcting rail surface defects by means of rail grinding is, amongst others, defined by longitudinal rail profile defects with a depth of 0.10 mm [5].

Rail grinding methods adopted on urban rail systems

On tram and LRT systems, the adoption of three different rail grinding methods can be observed [2]:

— *the sliding stone method:* using this method, grinding stones are pressed onto the running surface of the rail with a certain pressure and then the rail grinding vehicle travels along the track – the stones, which themselves remain stationary, slide along the rail. In this manner, a minimal amount of material (within the micro-metre range) is removed, and a smooth rail running surface is achieved. As this method allows a working speed of up to 30 km/h, it can be adopted during train operating hours, thus obviating the need for line closures;

— *the rotating stone method:* using this method, the entire rail head is reprofiled by means of rotating grinding discs, and not just the running surface of the rail – up to 0.2 mm of material per pass is removed. This method produces a rougher rail running surface than that is achieved by the sliding stone method. Consequently, following grinding using the rotating stone method, noise emission levels are higher than following sliding stone grinding;

— *the oscillating stone method:* using this method, the grinding stones are also pressed onto the running surface of the rail, which then oscillate in longitudinal direction of the rail. The oscillating stone method allows more material to be removed than by means of the sliding stone method, and a similarly smooth rail running surface to be achieved. Following rail grinding using the oscillating stone method, noise emission levels are reduced to a minimum.

As a general rule, rails should not be treated to correct defects – rather, rails should be treated so that rail defects do not occur in the first place [5]. In other words, preventive rail grinding should be carried out, so that rail defects do not arise at all or that, if they do, they are corrected when they are still in an early stage of development.

Rail grinding in urban areas poses challenges

The deployment of rail grinding machines on rail systems in urban areas poses various challenges, which are different from those faced by their deployment on heavy rail systems. For instance, in urban areas:

— the vehicle clearance gauge may vary greatly, depending on prevailing conditions;
— the networks are often of a small size, each with their own specific requirements;
— a single network may feature different rail types (Vignole, as well as grooved rails);
— the presence of tight curve radii (of up to 17 m) is not uncommon;
— the networks are often located in close proximity to/traversed by (motorised) road vehicles and pedestrians, which requires special attention to safety;
— the rails are often embedded in the road surface;
— locomotives are often not available to tow the rail grinding machines, whereas road/rail-going vehicles are;
— the speed limits and driving rules governed by road traffic laws often need to be adhered to;
— the maximum permitted axle loads are relatively low (e.g. 10 kN);
— the time windows for maintenance are short.

Further, there are often also operational restrictions when conducting rail grinding in urban areas. As roads can only be closed to traffic for a very short time period, or not at all, rail grinding must take place during normal service hours and with other traffic. However, a consistent rail grinding quality has to be maintained at all times, also when grinding is performed in mixed traffic with other road users at varying speeds (even down to nearly 0 km/h).

All of these factors pose challenges for the design and construction of rail grinding machines for use on tram and LRT networks. The ATMO rail grinding trailer, which has been developed within the framework of the Shift2Rail research initiative, offers great scope for rail grinding in urban areas in an effective manner, as alluded to in the following.

The ATMO rail grinding trailer – developed within the framework of the Shift2Rail research initiative

Within the framework of the Shift2Rail research initiative, which started in 2016 through funding from the European Union's Horizon 2020 Research and Innovation Programme, research projects that bring about any form of improvement to the wheel/rail system are conducted. The outcome of one such project is the ATMO (Automatic Track Machine Oscillator) rail grinding trailer designed and built by Plasser & Theurer, which can work in tight curves and does offer a high degree of operation flexibility.

Rail grinding in tight curves

The ATMO rail grinding trailer has been designed with the specific requirements of tram systems in mind. Often, these are characterised by the presence of very tight curves.

The ATMO has been designed in such a manner that it can grind rails in curves with radii of down to 17.25 m. For this, it was necessary to redesign the way in which the oscillating stones are driven.

On the ATMO, frequency and amplitude for the oscillating grinding operation are generated in a completely different manner from that adopted by conventional oscillating drive systems.

Further, because of the geometrical constraints in curves prevalent on tram and LTR networks, the grinding saddle had to be designed in such a manner that, in tight curves, the grinding stones do not deviate from the ideal path, but remain positioned over the rail head and, thus, still can perform optimum rail surface grinding (Fig. 3).

Fig. 3: The grinding units of the ATMO oscillating rail grinding trailer

Operation flexibility

The ATMO rail grinding trailer can adopt both the oscillating stone and the sliding stone rail grinding methods, thus offering a high degree of operation flexibility as regards amount of material removal and working speed.

Fig. 4: A section of rail before (left) and after (right) oscillating rail grinding

The ATMO also offers a high degree of flexibility when it comes to selecting a suitable tractive unit. It has been designed in such a manner that it can be towed by regular power cars, as well as road/rail-going vehicles. The grinding units, however, are powered by a power supply system on-board the grinding trailer itself.

On the ATMO prototype, power is generated using a diesel engine. However, when the ATMO goes into series production, there will also be an electric option available.

The ATMO carries the water needed for wet grinding in a 2,600 litre tank, which is enough for a shift of approx. six hours. The thin water film produced by wet grinding enhances the grinding output and prevents sparks from flying around, thus reducing the risk of fire in dry surroundings and tunnels. The water tank can be refilled as needed at every hydrant.

With an overall length of just over 8 m and a total mass of 18 t, the ATMO is ideally suited for operation in urban areas.

ATMO – first test phase successfully completed

The ATMO has already successfully completed initial functional testing, which was conducted on depot tracks of Wiener Linien, the Vienna public transport operator. On average, 0.011 mm of material was removed during each grinding pass.

In Fig. 4, a rail surface section prior to grinding (left) and following grinding (right), using the ATMO, is shown. The experience gained from the first test phase as regards grinding behaviour in tight curves, crossings and turnouts will be used to further optimise the technology and enhance grinding output.

The aim of the second test phase is to acquire operating experience on service tracks and to identify the optimum parameter settings for frequency, amplitude and vertical load to be applied, grinding stone material composition, as well as grinding speed. To achieve this aim, the ATMO will be grinding rails on the tram network of Wiener Linien. Straightness measurements will be adopted to assess the rail grinding quality. Further, noise measurements will be conducted both before and immediately following grinding, in order to portray the effect of rail grinding on noise reduction. Further, it is planned to also conduct additional noise measurements at later stages.

Following successful completion of the second test phase, the ATMO technology will be tested during regular tram operations. In-depth field testing and measurements will allow the ATMO technology to be further optimised and its efficacy proven.

Final remarks

When trams travel along the track, the steel wheel/steel rail contact causes structure-borne and airborne noise, which may be perceived as irritating by lineside residents. When the noise is excessive, it may have a negative impact on their health. By smoothing the rail surface by means of grinding, the level of noise emission can be reduced. However, time windows for rail maintenance are becoming ever shorter, due to the longer operating hours of tram and LRT systems. At the same time, a higher rail traffic volume leads to an increased demand for rail maintenance. Therefore, new technologies are needed that ensure that maintenance can be conducted without any traffic hindrances and in an effective manner. The ATMO rail grinding trailer developed by Plasser & Theurer within the framework of the Shift2Rail research initiative, which can adopt both the sliding stone and oscillating stone rail grinding methods, has been specifically designed to meet these challenges.

Acknowledgements

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The ATMO rail grinding trailer for tram and light rail transit (LRT) networks

The ATMO (Automatic Track Machine Oscillator) rail grinding trailer, which is designed for operation on plain track and turnouts of tram and light rail transit (LRT) networks, is the first machine of its kind that can adopt both the sliding stone and the oscillating stone rail grinding methods – this offers a high degree of operation flexibility.

The ATMO features two grinding saddles per rail, each equipped with two grinding stones. When working in sliding stone modus, the grinding saddles, respectively the stones, remain stationary whilst the grinding vehicle travels along the track (at speeds of up to 30 km/h). When the oscillating stone method is adopted, a hydraulic mechanism moves the grinding saddles horizontally forwards and backwards in longitudinal direction of the rails, with variable frequency, whilst the vehicle travels slowly along the track (at speeds of up to 8 km/h). The oscillating stone operation is recommended to be applied especially in areas that are very prone to developing rail surface defects, such as waves at stations/stops or corrugations at other "hotspots".

By being able to adopt both the sliding stone and the oscillating stone methods, the ATMO can perform precisely fine-tuned grinding, meeting prevailing local conditions, in a single pass.

ATMO – especially designed for operation in urban areas

The ATMO rail grinding trailer, which has been especially designed for operation on tram and light rail transit (LRT) networks, offers great scope for effective noise control in urban areas.

Often, tram networks are characterised by the presence of tight curves. These do not pose any obstacle for the four-axled ATMO, as its specially designed grinding saddles do allow optimum rail grinding in curves with radii of down to 17.25 m.

When negotiating curves, the grinding stones remain aligned in relation to the curve radius in such a manner that they are always positioned over the rail head. Furthermore, unlike in the case of conventional rail grinding vehicles, the ATMO can travel freely over turnouts and crossings without needing to lift its grinding stones.

The ATMO can be towed by either a regular power car or a road/rail-going vehicle. No staff is required on the rail grinding trailer, as its operations are remotely controlled from the respective tractive unit. The ATMO, which allows bi-directional travel and operation, can grind at speeds of up to 30 km/h and, thus, blend in seamlessly with regular traffic – no line closures are required.

The standard-gauge ATMO prototype features a water-cooled, sound-insulated 100 kW diesel engine with exhaust after-treatment. When the ATMO goes into series production, there will also be an electric option available.

With an overall length of just over 8 m and a total mass of 18 t, the ATMO is ideally suited for operation in urban areas.

ATMO: the result of a collaboration between industry partners, university experts, and infrastructure operators

The ATMO rail grinding trailer, which was designed with practical requirements in mind, is the result of a successful collaboration between university experts, industry partners, and rail infrastructure operators, which took part in the In2Track (I2T) research project conducted within the framework of the Shift2Rail research initiative. A market study conducted by the Vienna University of Technology within the framework of this project provided the scientific basis for the development of the ATMO. Plasser & Theurer, the industry partner, provided the know-how that shaped its design and manufacture. Wiener Linien, the Vienna public transport operator, provided the rail infrastructure for initial functional testing.

Additional field testing and technology optimisation should see a further fine-tuning of its operational performance, thus making it ready for service operations.