ATMO takes to the tracks

New rail grinding technology currently in development is expected to support tram and light rail operators faced with maintaining their networks while meeting tighter noise restrictions in densely populated areas.

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The prototype ATMO rail grinding trailer developed for urban rail applications is currently being tested on the Wien tram network.

Earlier this year, Wiener Linien began testing a prototype Automatic Track Machine Oscillator rail grinder on the Austrian capital's tram network. Developed as part of the Shift2Rail In2Track research programme, the ATMO has been manufactured by Plasser & Theurer in collaboration with industry partners, university academics and infrastructure operators, following a market study by Technische Universität Wien.

With two in three people around the world expected to live in cities by 2050, the demand for urban mobility has been increasing in recent years, and studies point to continuing growth. This has made transport planning particularly challenging, and driven the expansion of urban rail networks able to handle large volumes of passengers with minimal land take.

A Shift2Rail study on the *Worldwide evolution of light rail transit networks* [1,2] identified an increase in the development of new tram and light rail networks over the past two decades (Fig 1). This posed different challenges for planners and operators, given the growing awarenesss of the harmful effects of noise.

The EU's Environmental Noise Directive defines the assessment criteria for analysing the impact of environmental noise on human health. Some of the harmful effects of environmental noise include cardiovascular disease, hearing damage, tinnitus, and mental health problems. Sleep disorders are also frequently observed. At least 100 million people in the EU are affected by road traffic noise.[3]

Hence the growing awareness of the need for noise control, especially in densely populated areas. However, measures applied in main line rail, such as noise barriers, are difficult to implement in inner-city locations.

In the case of tram and LRT systems, rolling noise is the principal component for speed ranges up to 50 km/h (Fig 2).[4] Much of the structure and airborne noise is generated by the contact between the steel wheel and rail as the vehicles travel along the track. The 'smoothness' of rails and wheels therefore has a significant influence on sound propagation, as greater roughness leads to more vibration.

Wheel roughness can be managed fairly well by regularly turning the tyres, but keeping the track in good condition can be more challenging, and the maintenance work itself can be a noise generator.

How do rail defects develop?

Rail wear is caused by a combination of static and dynamic loads as vehicles travel along the track. Deterioration manifests itself in a number of ways: changes to the material's structure, mechanical stresses, and solidification that can lead to the formation of cracks. Such defects negatively impact the service life of rails. The In2Track studies confirmed that the most common rail defects in the light rail sector differ from those affecting the flat-bottomed rail sections that are commonly used in heavy rail applications in terms of how they manifest themselves.[5]

Three main types of rail defect are commonly found in the light rail sector.

Wheel burns occur when the wheels spin as powered axles transition from static to kinetic friction. These are frequently found on tram tracks because of the comparatively high acceleration rates used as well as regular stops and starts.

Corrugation is defined as a periodic track unevenness with wavelengths between 30 mm and 300 mm. Grooved rails used on urban rail applications typically exhibit wavelengths of approximately 500 mm. Corrugation defects have a particularly noticeable effect on acoustic emissions and the service life of rails.

Rail fractures occur more frequently on urban networks, being influenced by factors such as temperature, storage, loading history, rail type and rail condition. Poor welding of rail sections can also lead to fractures.

Rail defects result in an increased dynamic load on tracks and vehicles, generating noise and vibration. As well as a higher noise level inside the vehicle, sound propagation exposes lineside residents to more noise emissions. One of the intervention thresholds for correcting rail defects through grinding is typically defined by a longitudinal profile error of 0·1 mm. The intervention threshold for acoustic rail grinding to reduce noise is far lower than that necessitated to address issues related to the structural integrity or dynamic performance of the track.[6]

Treating rail surfaces

The In2Track study identified three main rail grinding techniques that are being used in the light rail sector to create a smooth rail surface.

In the **whetstone** method, fixed grinding stones are pressed onto the rail surface as the vehicle travels along the track. This removes a minimal amount of material, typically within the micrometre range. A working speed of 30 km/h means that this method can be used during service hours, with the grinder operating between passenger-carrying trams.

Rotary grinding relies on powered stones, and is more aggressive, being able to remove up to 0·2 mm of material per pass. Rotary grinding also enables the reprofiling of the entire rail head, rather than just the surface. However, it leaves a rougher rail surface compared to the whetstone method, so the subsequent noise emissions are also higher.

A more recent technique is the use of **oscillating** rail grinding. In this method, the grinding stones oscillate in the direction of the rail axis. This removes more material than the whetstone method, but creates a similarly smooth rail surface to minimise any subsequent noise emissions. No minimum speed is required for the grinding, as the stones are powered rather than passive.

However, the general rule for good track maintenance is that rails should not be treated to correct defects. Instead a regime of preventive rail care in the form of regular rail grinding should ensure that defects do not occur in the first place, or are addressed before they become significant.

Grinding in urban areas

In developing their rail management regimes, urban operators face different challenges to those of main line infrastructure managers. In many cases, tram and light rail networks are relatively small with varying requirements, and include a mix of different rail types, both grooved and flat-bottomed. Curve radii are tighter, with a 17 m radius being not uncommon, while the clearance gauge can vary greatly based on the track configuration and the proximity of adjacent structures.

> 'Rail defects result in an increased dynamic load on tracks and vehicles, generating noise and vibration'

Below: Fig 1. Global development of tram and light rail systems in 2000-16.[1]

Bottom: Fig 2. The primary sources of noise emissions from rail vehicles vary as a function of speed.[4]

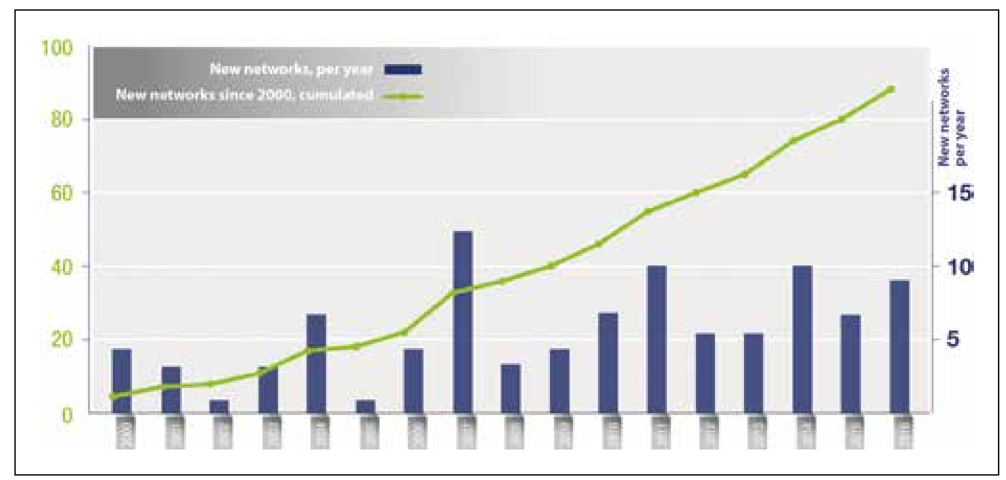
Street-running tram systems have their rails embedded into the road surface, while the route is shared with motor vehicles and pedestrians, whose presence and safety must be taken into account. In such situations, speed limits and driving rules are generally governed by road traffic legislation. And the maximum axleload of trams and LRVs is typically much lower than those of heavy rail trains.

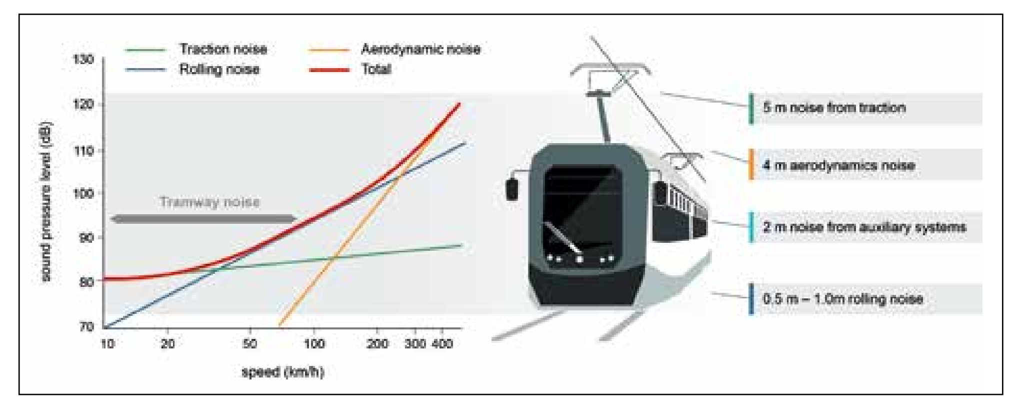
The time available for maintenance can be very short, due to the need to provide regular services for much of the day and the constraints on closing streets to other traffic. A lot of urban rail operators use road-rail vehicles to support their maintenance work, as conventional locomotives are rarely available.

These factors and other operational restrictions have greatly influenced the development of rail grinding machines for tram and light rail networks. In order to maintain a consistent quality, grinding has to be performed at various speeds, down to almost 0 km/h in some cases. But as roads can only be closed for a very short period, or not at all, rail grinding must take place during normal service and in mixed traffic with other road users.

Enter the ATMO

While the EU-backed Shift2Rail research initiative is generally thought of as addressing main line railways, one of the objectives for the joint undertaking is to bring about any form of improvement to the wheel/rail system. One of the workstreams for the In2Track project





which began in 2016 was therefore to look specifically at the challenges of rail grinding on urban networks.

The result has been the development of the Automatic Track Machine Oscillator, or ATMO, a rail grinder trailer designed for deployment on tram and light rail tracks. Completed during 2020, the machine has been designed and built by Plasser & Theurer as part of the In2Track project consortium.

In order to meet the specific requirements of tram systems, the ATMO has a minimum working radius of less than 17 m. This required a redesign of the grinding units, as the frequency and amplitude of the grinding motion are generated in a completely different way from a conventional oscillating drive.

Because of the constrained track geometry, the grinding saddle had to be designed in such a way that the grinding stones do not deviate from the ideal path in tight curves while still providing for optimum grinding of the rail surface (Fig 3). The machine can also be deployed using the whetstone method, offering maximum flexibility in terms of both working speed and the amount of material removal.

High flexibility was also very important in terms of propulsion. The prototype trailer is designed to be towed by either conventional rail or road-rail vehicles. In order to allow stand-alone operation independent of the tractor, the grinding units have their own power supply. The prototype uses a diesel generator, but the intention is that the series build will include an electric option powered from an onboard battery storage unit.

Fig 3. The grinding units of the ATMO oscillating rail grinder have been configured to cope with tight curve radii.

With a length of slightly more than 8 m and a total mass of 18 tonnes, the trailer is ideally suited to urban rail applications. To facilitate wet grinding, a 2 600 litre tank is provided. This holds enough water to cover a shift of approximately 6 h, but it can be easily refilled from a hydrant as needed.

Following the development of the prototype ATMO, the consortium has embarked on a programme of in-depth field testing to demonstrate the viability of the process and further optimise the grinding technology.

The first functional tests with the prototype were undertaken in conjunction with Wiener Linien. On average, 0·011 mm of steel was removed from the rail surface for each grinding pass. Fig 4 shows a typical section of rail before and after a grinding pass. The experience gained from this initial test phase in terms of grinding behaviour in tight curves, crossings, and turnouts will be used to further optimise the technology and improve the grinding output.

A second test programme will also be carried out on the Wiener Linien tram network, in order to acquire more experience with track in service and to identify the optimum parameter settings for frequency, amplitude, load, grinding stone composition and grinding speed. Straightness measurements will be used to assess rail grinding quality, while noise measurements will be taken before and immediately after each pass to demonstrate the effect of rail grinding on noise reduction.

Another plan for keeping track of further developments entails additional noise measurement at regular intervals after rail grinding. Following the successful completion of the second phase, the machine will be deployed for routine surfacing work during regular tram operation.

Fig 4. A section of rail surface before (below) and after (right) oscillating rail grinding.

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