Intelligent wheel-rail conditioning can reduce noise and wear

Advances in the control of wheel-rail conditioning are helping to facilitate a transition from stand-alone wayside and onboard applicators to an intelligent network that continually optimises the management of both friction and noise.

An onboard spraying unit, with the nozzle set to apply top-of-rail conditioning product to the wheel tread.

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The use of wheel-rail conditioning to manage the safety-critical interface between rolling stock wheel treads and the railhead has become well established over many years, offering a range of well-understood benefits including reductions in wheel and rail wear, corrugation, noise and vibration.

In the past two decades, advances in both friction management consumables and application systems have helped to overcome legitimate concerns related to braking distances and train recognition. Numerous field tests and extensive experience have proved that purpose-designed, top-of-rail friction management materials can be safe and highly effective, notably in European light rail and urban rail networks.

More recently, it has become clear that the effectiveness and efficiency of such conditioning systems can be further improved by the use of intelligent control techniques to ensure that product is only applied where and when it is needed. Even so, there is still scope to improve.

In this article, we are not aiming to reiterate the reasons for adopting wheel-rail conditioning, as the benefits are widely recognised[1]. However, it is important to consider the factors influencing past technical development in order to understand the opportunities that are now opening up and the potential future capabilities. We would like to emphasise the need for an integrated approach across both rolling stock and infrastructure in order to maximise the benefits of any investment in friction management systems.

Perhaps the most exciting development is the potential emergence of a holistic conditioning solution, where onboard and trackside systems communicate real-time noise and vibration data and application records to a cloud database. This in turn would inform the creation of automated conditioning plans to be distributed back to the intelligent network equipment, continually optimising overall performance.

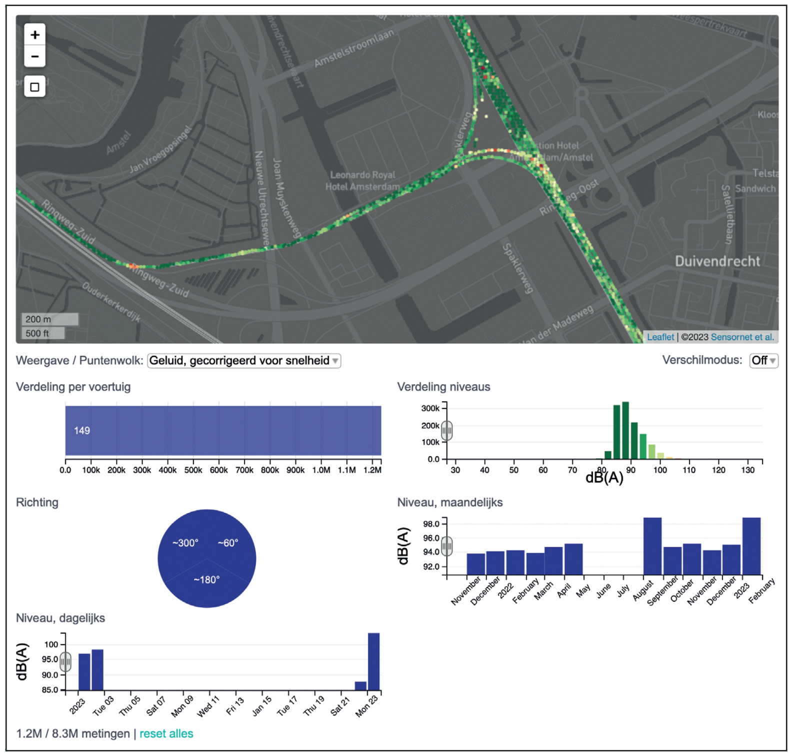
Design constraints

Historically, technical and performance requirements have not been the only factors influencing the implementation of top-of-rail conditioning, particularly in Europe where train operations and infrastructure are commonly managed by separate organisations.

This split has resulted in some fundamental divergence in the choice of technologies between trackside and onboard applicators.

Noise and vibration is often perceived as being an infrastructure problem, so the infrastructure managers end up trying to tackle the issue themselves. However, trackside applicators typically deliver relatively large quantities of friction management material to ensure pickup, but with little control over the quantities that actually enter the wheel-rail interface. This comes with the added risk of over-application and localised environmental contamination.

By contrast, weight and space are critical for rolling stock, and the development of onboard conditioning systems has therefore focused on applying very small quantities of highly effective products exactly where they are needed. The importance of application rates is well understood, and this approach also minimises any risk of over- application.



Noise and vibration hotspots can be displayed on a dashboard to feed into the management of wheel-rail conditioning systems.

Trackside or onboard

In Europe, the main drivers behind the use of wheel-rail conditioning are noise mitigation and the reduction of wear and damage. Other benefits such as reduced energy consumption and pollution are less easy to quantify, although significant energy savings have been reported in some heavy freight environments.

Top-of-rail conditioning using trackside systems has been used widely outside Europe, notably in the US rail freight sector. Trackside applicators are also used in the UK where, with the exception of a few tram networks, the industry structure has provided no incentive for train operators to fit onboard conditioning.

The drawbacks of using multiple trackside applicators on busy commuter, metro and light rail networks are obvious; too much product over short distances, reliance on passive distribution and the inability to control the application quantities accurately. By contrast, onboard systems can deliver conditioning products more accurately where they are needed and the equipment can be checked in a safe depot environment as part of the vehicle maintenance routine. There are also significant safety and cost benefits from not having to deploy maintenance teams to service and refill trackside equipment in the field.

Onboard systems development

The development of onboard conditioning systems began around 2000 with theoretical studies and tribological analyses. With onboard space constraints allowing the fitment of only small storage tanks compared to the larger reservoirs found in trackside applicators, it was necessary to develop a more concentrated conditioning product in order to carry enough for several weeks or even months between refills. Most therefore contain a high level of solid content which acts as the active friction management material.

Perhaps the biggest hurdle to overcome though, was concern from both infrastructure managers and operators that introducing an oil-based layer into the wheel/rail interface would jeopardise safety and braking. This led to extensive field trials using manual methods to mimic onboard spray application scenarios, and brake testing with real rolling stock to show that safe vehicle braking could still be achieved with carefully controlled application. That opened the door for forward thinking operators to engage in full scale trials using spray systems to apply conditioning materials direct to the top-of-rail from trains.

Delivery systems have also evolved. Trainborne wheel flange lubrication can be traced back more than a century, but by the mid-1990s the most common systems used 'dual tube' technology. One pipe supplies pressurised air, while another feeds the lubricant to a nebulising nozzle mounted adjacent to the wheel flange. These systems worked well with lubricating oils but often struggled to achieve the required spray patterns if used to deliver top-of-rail conditioning materials containing a high solid content. The answer was the introduction of 'monotube' systems where the air and lubricant are mixed centrally, and one pipe transports the mixture to much simpler spray nozzles that are able to achieve the desired spray performance.

With the safety concerns addressed and suitable spray technology available, suppliers were able to start working with operators to develop the most effective application strategies. In most cases this initially focused on the elimination of curve squeal in the most critical hotspots. To address this issue, a few vehicles in a revenue fleet would be retrofitted with conditioning equipment. Where that was not possible, some operators used maintenance vehicles to apply product on specific curves in addition to their primary tasks.

Early work revealed that the correct application quantities for effective and safe conditioning depended on a number of variables, such as type of rolling stock, curve radius and the required benefits (wear reduction and/ or noise mitigation). Operators typically undertook a series of tests to establish the number of vehicle passes with known product application quantities that could be made before the effect on braking became unacceptable. These results were then translated into how frequently a vehicle-based application should be

Field testing to assess the impact of friction management products on braking performance.

made at a specific location to get the required benefits without causing difficulties.

Control systems evolve

As more operators understood the benefits of top-of-rail friction management, the method of triggering product application became another area of focus. The simple distance or time interval triggers most commonly used for onboard wheel flange lubrication were not seen as the most efficient approach, as they could lead to wasted product by applying where it was not needed. Many operators therefore adopted a simple manual control, instructing the train driver to activate the conditioning system where the environmental or operating conditions tended to cause curve squeal.

This manual option was very effective for some operators but not for others, where a too cautious approach could compromise the effectiveness of noise mitigation. That led to a divergence in application strategies among European tram operators in particular. Some preferred to develop the onboard concept, while others installed trackside lubricators with simple control options, such as using axle counters to apply product after a known number of trains or axles had passed. However, such lubricators still lacked the flexibility of onboard systems, could not always control the application quantities accurately, and needed in-situ replenishment and maintenance.

As the onboard technology continued to mature, some operators began to evaluate more advanced control options such as mechanical triggers based on gyrosensors, inclination sensors or bogie angles. However, none of these were adopted widely, most likely because of an inadequate and/or slow response to differing infrastructure configurations and curves.

Meanwhile, more sophisticated options were becoming widely available and affordable, notably GPS and RFID. These were also easier to explain to senior management and external stakeholders. As a result, these types of onboard conditioning equipment are becoming increasingly common. They are fitted to standard vehicles in revenue service, providing fully automated and efficient product application with no need for special rolling stock or manual intervention.

Not all vehicles in a fleet need to be fitted; a number of variables influence the optimum number, including different vehicle types, equipment and control infrastructure acquisition costs, network layout and operating patterns. Typically, between 20% and 40% of the fleet on a given network would be fitted, but careful vehicle scheduling is still required to ensure the necessary network coverage.

Programmable controls

In recent years, systems offering 'intelligent' control have become more common. Three methods have tended to dominate: GPS, RFID and the use of Passenger Information System data. GPS and PIS both use train location as the trigger for an application, but may also make use of additional information to improve the process. This would typically factor in the vehicle speed to improve spray accuracy. Other train-based parameters might include:

- minimum spray speed, so the system does not activate when the train is almost at a stand;
- wetness detection, to suppress spraying in rain or very high humidity;
- wheel slip, to suppress spraying in poor traction and adhesion conditions, such as leaves or over-greasing.

With RFID based systems, once the reader receives an activation trigger the controller can be programmed to check for additional data before issuing the spray command.

Although these control systems can apply conditioning products accurately and also have the ability to suppress spraying in conditions that could lead to over-application or affect traction and braking, they all rely on pre-defined spray locations. A key limitation is that they do not have the ability to analyse the physical characteristics of the wheel/rail interface to determine if spraying is required at all. It would perhaps be more accurate to refer to them as 'programmable', rather than 'intelligent'.

Recent advances in real time monitoring for different types of noise and vibration including curve squeal and flanging, together with the ability to detect associated track damage such as corrugation as it develops, offer potential for optimising the way that onboard conditioning is triggered. We believe that it should be possible to design wheel-rail conditioning systems that respond to the constantly changing requirements of different rolling stock and environmental conditions, and tailor product application to actual need. This would be much closer to a truly intelligent system than the existing control options.

Intelligent conditioning

It is possible to envisage a future system concept which would ensure that the final activation command at any given location is only triggered if pre-defined levels of specific squeal and/or flanging noise were detected. This would be enabled by new developments in cloud and server data handling, machine learning and AI to provide automated, consistent and accurate categorisation of noise types for different combinations of infrastructure and rolling stock.

Current developments are tending to focus on curve squeal and flanging noise, as these are relatively well defined because of the increased emphasis on mitigating railway noise as environmental pollution in recent years. We believe it should be possible to develop analysis tools and algorithms to detect wear types such as corrugation that occur over time and often have more complex root causes, but this is likely to take more time.

Noise-based wheel-rail conditioning could therefore analyse any detected railway noise to identify the characteristics and frequencies associated with curve squeal and flanging, in order to trigger the appropriate system response.

Taking this approach one step further, we could consider the conditioning-equipped rolling stock as an integrated system of systems — an analogy being the world of social insects where pheromones attract other members of the colony to a specific location for mutual benefit. Any vehicle detecting track or environmental conditions that require a wheel-rail conditioning intervention would transmit this information to other vehicles, proactively alerting them to apply conditioning in the designated area without any human intervention.

Thinking beyond top-of-rail friction control, it is clear that these concepts could be used as part of an integrated network-wide friction management plan. This could also incorporate onboard wheel flange lubrication systems and even trackside lubricators as part of an integrated 'system of systems'. This could deliver a comprehensive range of capabilities from simple noise mitigation to optimised wheel-rail conditioning and eventually an integrated friction management network.

Patents covering the concept of a fully integrated network of friction management assets already exist, and we can expect such systems to offer comprehensive and flexible capabilities in the coming years.

References

1. Harmon M and Lewis R. Review of top of rail friction modifier tribology. *Tribology – Materials, Surfaces & Interfaces*, Vol 10:3 2016, pp150-162

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