New economics and ecology in tunnel maintenance

Technical solutions for greater economic efficiency, climate protection and occupational health and safety during underground track maintenance

MARTIN RUDHOLZER I OTTO WIDLROITHER

Infrastructure work in tunnels is a complex and demanding task. In addition to time pressure, there are usually difficult lighting, visibility and space conditions as well as high levels of emissions. Exhaust gases and noise, in particular, caused by diesel-powered work vehicles, two-stroke machines and ventilation, have a much greater effect on the workers in the tunnel than in any other area of infrastructure maintenance. Robel has been developing track construction machines for this particular application for many decades, with the objective of a quiet, clean and safe worksite.

Like everywhere on the track, the aim is to complete the work as safely, ergonomically and quickly as possible. In addition, aspects such as value for money and environmental compatibility have to be considered. The European Green Deal [1] and the associated tasks for a climate-friendly railway [2] increasingly drive the developments in infrastructure maintenance. Appropriately specialised work vehicles and small machines are already in use.

Track vehicles as all-rounders in an urban environment

The cities are growing fast, and the rail and tunnel infrastructure is stressed like never before due to the increase in traffic and the higher train frequency. Maintenance is always carried out when the city is asleep; incidents have to be dealt with rapidly whilst normal operation continues and, if possible, without affecting other transport users. Thus, an increasing number of network operators convert their fleets to vehicle systems which can be used flexibly for a variety of work due to their modular components and thus accelerate the processes considerably.

As early as 2007, Stadtwerke München, the Munich municipal utilities, as well as VAG Nuremberg decided to deploy Robel track vehicles (GKW) specially for construction work on the underground train network as well as for interventions, e.g. to tow stationary stranded trains from the steepest gradients. One of many tasks which these vehicles have been taking care of reliably so far. Kölner Verkehrs-Betriebe AG, the transit company in Cologne, has been using a system of GKW, container wagons, trailers with jetting and vacuum unit as well as rail and ballast trailers on all municipal lines since 2016 [3] – see Box 1.

On London's Elizabeth line, which plans to be operational from mid-2022, a transport system with modular add-on units will carry out overhead line maintenance, closure rail and switch replacement as well as drainage and tunnel cleaning [4]. Where cranes and large machines reach their limits, Robel works with automatic positioning technology specially developed for the use in tunnels (Fig. 1) – see Box 2.

Tunnel maintenance without emissions: track vehicles with hybrid drive

The next logical step following on from optimising process speed and quality is the reduction in the use of fossil fuels and the reduction of atmospheric and noise emissions and thus an appreciable improvement in the environmental and working conditions in tunnels. A new series of hybrid track vehicles takes account of this development. The first order has been placed by Stadtwerke München. From 2024, six electric track vehicles will be deployed on the municipal underground system (Fig. 2: GKW SWM CAD).

The 20 m long four-axle work vehicles are optimised for maximum availability in tunnels with central cab, loading areas on both sides at platform level and one crane/grab at each end of the vehicle for bidirectional operation. Double and triple traction is available for extended tasks, and transport wagons can be coupled on both sides. The trailing load is up to 125 t, equivalent to an underground train which has to be towed up 6 % gradients.

Electrical energy from the third rail is used to drive to the work site. The current collectors on the bogie are designed to fold in so that they do not obstruct the work in the restricted space in the tunnel. A battery provides the energy for working mode travel and crane operation. The battery is charged in the depot, but also during travel when braking and on gradients via regenerative braking. A diesel-electric drive is also available.

Fig. 1: Replacement of switches/rails in tunnels without a crane: Automatic positioning system for the London Elizabeth Line.

References Fig. 1 – 9: Robel

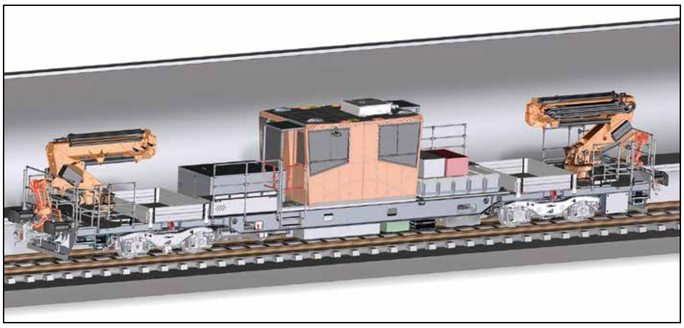


Fig. 2: Stadtwerke München, the Munich municipal utilities, will receive six electric track vehicles in 2024. The energy is provided by third rail, battery or generator.

Fig. 3: The open side wall of the Mobile Maintenance System facilitates the protected access for cleaning of drainage channels in tunnels.

Fig. 4: An overhead crane, ventilation, lighting and the use of hand-operated battery-powered machines provide for maximum ergonomics and work safety in the mobile maintenance system.

The 100 kW diesel engine that drives a generator is equipped with state-of-the-art exhaust gas treatment.

Safe working in the mobile workshop

To be able to carry out localised maintenance work in critical rail environments quickly, safely and completely independently of external conditions, railways in Europe, America and Japan deploy mobile maintenance systems [5]. These are open to the track in the work section between the bogies; parts of the side walls can be extended outwards. This provides a protected work area around both rails with safe access, fully illuminated and ventilated, while the adjacent track is open, and with an independent supply of all machines and equipment.

The compact version (Fig. 3) with a length of 15 m is designed especially for underground deployment and creates, over two levels, a protected space for up to eight people with crew room and sanitary facilities as well as storage for tools and small parts. Sliding doors in the side walls of the work unit provide access to tunnel walls and walkway, cables and ducts. Optional front feedthroughs for pressure, suction and flushing hoses support track, tunnel and drainage cleaning as well as drain clearing using high-pressure lances. As the walls of the system protect not just the work crew, but also completely screen the tunnel section, it is not necessary to close the adjacent track with de-energised overhead line equipment which is normally required due to the volume of jetting water.

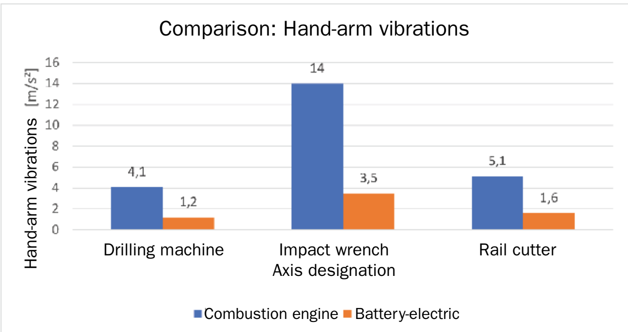
In addition to optimisation of the processes, the special feature of the mobile maintenance system are the significantly improved working conditions: manual work and the associated stresses are reduced by the deployment of overhead cranes. Small electric manual machines fed without emissions from the system or by batteries support efficient and ergonomic work on the track, from replacement of closure rails and sleepers to repair and resurface welding and inspection of switches, alarm and signalling equipment (Fig. 4).

Small electric machines – clean, quiet and ergonomic

It is not just railway construction vehicles and systems that are being converted to electric drives. For small hand-operated machines, too, the current technologies point clearly in the direction of climate protection and enhanced occupational health and safety: even today it is possible to carry out electrically many – and frequently all – tasks arising on a track construction site. The development of alternative drive and energy supply solutions as well as improved storage leads to a growing number of battery-powered machines.

HAV [m/s²]

	Combustion engine	Battery-electric
Drilling machine	4,1	1,2
Impact wrench	14	3,5
Rail cutter	5,1	1,6



Schalldruckpegel [dB(A)]

	Combustion engine	Battery-electric
Drilling machine	97	78
Impact wrench	104	86
Rail cutter	104	87

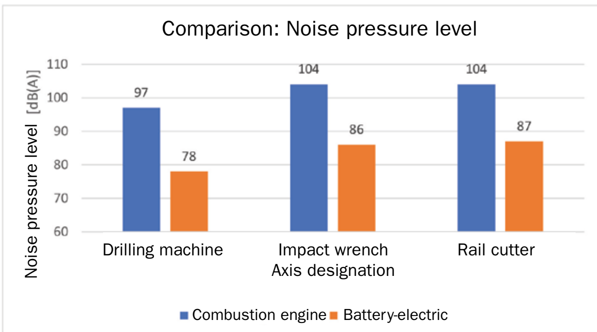


Fig. 5: Health and safety at work with battery-powered machines:
the comparisons with internal combustion engines show clearly reduced hand-arm vibrations and noise emissions.

Fig. 6: Driven by a 2300 Wh battery, the electric rail cutter manages up to 20 cuts on a UIC60 rail.

Fig. 7: A battery-operated high-pressure hydraulic power pack supplies energy to the rail stressor and the weld trimmer.

Lithium batteries and powerful electric motors represent a real alternative to the internal combustion engine. They are efficient and durable, clean and considerably quieter, lighter and have low vibrations (diagrams 1 + 2). They enable ergonomic working, are economical and environmentally friendly. Moreover, electric energy can be obtained much more cheaply than that generated by hydrocarbon fuel. It is assumed in the railway industry that as early as 2025 two out of five railway construction machines will be battery-powered.

The advantages of an electric motor in the critical construction site environment

Fuel tanks, handling of fuel, oil and filters, hot exhaust and engine components during operation and the associated maintenance required become unnecessary with electric drives. Doing without a heavy internal combustion engine which inherently has strong vibrations enables a light-weight, but nonetheless robust aluminium design for the machine. A battery-powered impact wrench weighs about 20 percent less than a comparable model with a 4-stroke petrol engine for the same power. The compact electric motor provides for additional design options, for example with regard to placement on the machine, centre of gravity and ease of handling. The work area is visible, the posture of the operator is always ergonomic.

Machines without cables are ideal, particular in tight spaces. A battery-powered machine is easy to transport and quickly ready for work. It reaches full speed and power independent of the air temperature without having to warm up. In March 2121, three-month test series were completed during the Russian winter. Even at –27 °C, the battery-powered versions of several hand-operated machines provided excellent work results with constant availability.

Battery-powered machines in tunnels

In some cases, maintenance of the infrastructure only becomes possible with the use of alternative drives, for example in areas where the regulations prohibit the use of liquid fuels. By substituting internal combustion engines with battery-powered electric drives, new applications open up in tunnels and also in an urban environment. The careful and time-consuming laying of power supply cables or the setting up of generating sets required for cable-connected electric drives is no longer necessary as battery-powered machines are available for all main activities of rail maintenance. Apart from welding, a complete replacement of closure rails can be carried out free from emissions.

The battery-electric track construction site

The battery-powered rail drilling machines and impact wrenches cover three main areas of work: horizontal drilling of holes in the rail web for fishplates or switching equipment, the associated horizontal wrenching and the releasing and tightening of sleeper screws in the vertical position. A battery-powered version of the vertical tamper is available for spot tamping of ballast. Moreover, the following battery-powered machines are used for the replacement of closure rails:
The rail cutter (Fig. 5) cuts through the rails in less than a minute and can also cut the rail section to be inserted to size. The battery-powered rail band saw offers another possibility for cutting through the rail before replacement. It provides a uniform cold cut without sparking, cleanly, quickly and without almost any noise. Once the new rail section is in position, it must be welded. To do this, the rails adjoining at both ends must first be tensioned. This, too, is possible with battery power: The battery-powered high-pressure hydraulic power pack (Fig. 6) first builds up the required oil pressure and then the appropriate tensile stress, maintains this and, after thermite welding, finally provides the pressure for the hydraulic weld trimmer. Finally, the weld must be ground. This is done with the battery-powered rail head grinding machine. Tightening of the sleeper screws and spot tamping are carried out with the battery-powered machines mentioned above. If the old rail is nailed, the battery-powered spike extracting machine is used first; it can be fitted for various nail types.

Battery technology specifically adapted for track construction

The requirements on track construction machines are markedly different from those on battery equipment available for industry and trade. High power, high torque, endurance and robustness are required here. Therefore, a special maintenance-free and wear-resistant rechargeable battery was developed for use on construction sites. High-quality lithium-ion battery cells housed in an impact-resistant aluminium casing ensure a long service life; the design precludes battery fires.

Robel's hand-operated battery-powered machines are currently being used in Europe, Australia and North America as well as Japan. All machines and equipment work basically with the same battery pack, with proven rechargeable lithium-ion batteries with a voltage of 43 Volt or 52 Volt and several

Fig. 8: The transport system for Kölner Verkehrsbetriebe is used on the underground as well as on public roads.

energy levels – 400, 700 and 2300 Wh. The detachable battery is connected to the machine via robust contacts, a positive fit and secured with turnbuckles, but can be released and replaced in two movements.

Independent of activity, one battery charge lasts for at least one work shift and usually much longer. With the rail cutter, trained staff can carry out up to 20 cuts per battery charge. The battery-operated power wrench completes more than 1000 wrenching cycles without recharging. The battery power of the high-pressure hydraulic power pack is sufficient for work on several welds. As there is usually enough charging time between shifts or there are replacement batteries available, the decision was made in favour of economical and sustainable charging at 250 W which also protects the battery. The battery life is at least 750 charging cycles before its capacity falls to 80 percent of the initial value.

REFERENCES
(1) Press release, European Commission, 14.07.2021, https://ec.europa.eu/commission/presscorner/detail/en/IP_21_3541
(2) Press release, Alliance for Rail, 26.08.2021, https://www.allianz-pro-schiene.de/presse/pressemitteilungen/vor-der-wahl-breiter-konsens-in-bahnpolitik-alle-parteien-versprechen-mehr-schiene/
(3) Pfingstl A.: Urbanität in der Gleisinstandhaltung (Urban Rail Maintenance), EI 08/2017
(4) Schnellere Instandhaltung mit System (Systematic faster maintenance), Nahverkehrspraxis 11/12-2018
(5) Schmid G., Hechenberger P., Mühlbacher C., Mobile Instandhaltung löst neue Aufgabenstellungen im Bahnbau (Mobile Maintenance solves new tasks in track maintenance), EI 02/2019

Authors:

Dipl.-Ing. (FH) Martin Rudholzer,
Head of Work Vehicles,
ROBEL Bahnbaumaschinen GmbH,
Martin.Rudholzer@robel.com

Dipl.-Ing. (FH) Otto Widlroither,
Head of the Machines & Tools Business Unit,
ROBEL Bahnbaumaschinen GmbH,
Otto.Widlroither@robel.com

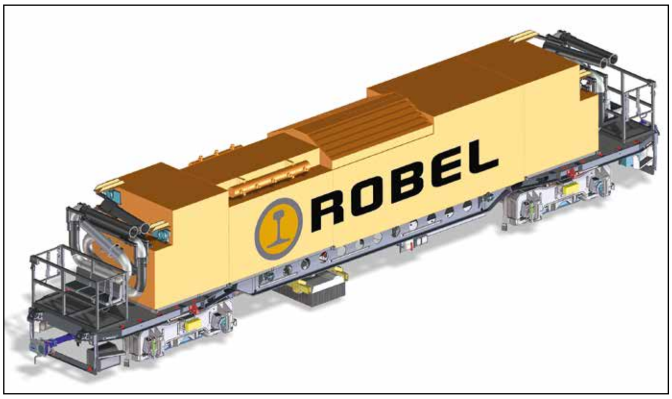


Fig. 9: Clean in every corner: the cleaning system for Wiener Linien is mounted on a flat wagon and has suction bars, suction hoses and soil tank.

Fig. 10: Economic, Ecologic, Ergonomic: The blue-green E³ brand can now be found on the Robel battery family as well as on handheld machines with with alternative drives. *Source: A. Uhlenhut*