Mechanised maintenance of ballasted track in tunnels: experience gained and latest methods and technologies

Track maintenance in tunnels poses various challenges, such as restricted space, emissions of dust, noise, exhaust gas and heat, insufficient ventilation, which affect machine use and pose a health and safety risk for staff. In this article, a number of methods and technologies are presented that enhance machine use and protect the health and safety of staff working in tunnels.

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Track maintenance and repair work follow a recurring pattern. Generally, track maintenance work starts with regular measurements, as defined in EN 13848 [1]. The measurement results are then processed and analysed and, following a planning phase, the required work is implemented.

Both the track type and the scope of the work determine the implementation phase. When it comes to track maintenance and repair work in tunnels, compliance with a large number of national laws, regulations and specifications is required, most of which aim to ensure staff safety – a number of these are noted in this article.

Mechanised track maintenance embraces a wide range of tasks. In Austria, in general, three types of track maintenance are distinguished, based on their scope, i.e.:
— *"short maintenance",* which includes preparatory and preliminary work, and ends with maintenance tamping;
— *"integrated maintenance",* which is a more comprehensive form of maintenance in that, in addition to the tasks of short maintenance, it also includes rail reprofiling;
— *"extensive maintenance",* which is an even more comprehensive form of maintenance, in that, in addition to the tasks of the previous forms of maintenance, it also includes ballast bed cleaning.

SHORT MAINTENANCE

The work processes of short maintenance may embrace, in chronological order:
— preparatory and preliminary work;
— a pre-measuring run;
— ballasting;
— tamping and ballast profiling.

Preparatory and preliminary work

To ensure staff safety and minimise costs, in many countries, a mobile maintenance unit is used to carry out the preparatory and preliminary work, such as rail fastening adjustments, exchange of sleeper pads, exchange of rail sections and insulated rail joints, exchange of single sleepers, etc. The "ROMIS Compact" of Robel is very suitable for this type of work in tunnels (Fig. 1) [2].

Fig. 1: ROMIS Compact (Photo: Robel)

The special design of the ROMIS Compact ensures staff safety during work. The position of the on-board equipment and the protective side walls allow both inspection and maintenance work to be carried out without the need to close the adjacent track to traffic.

All the preparatory and preliminary work can be carried out within the safety of the enclosed work area of the vehicle, thus staff is protected from traffic on the adjacent track, and their safety during work is ensured.

Furthermore, the ROMIS Compact is very suited for operation in tunnels, in that:
— exhaust-gas emissions cannot enter the enclosed work area;
— dust and heat produced during work are cleared from the air by means of an extraction system.

Options can be added to extend the range of operation of the vehicle, such as a drainage cleaning system on a container wagon, as well as a vacuum ballast excavation unit for the exchange of sleepers and local formation rehabilitation work.

The vehicle can be designed to meet the specific regulations, guidelines and directives governing the respective railway.

Pre-measuring run

The next step in the short maintenance process is the measuring of the track geometry in preparation for tamping, i.e. the pre-measuring run. Before tamping is conducted, a survey of the actual track geometry is performed by measuring both longitudinal level and alignment, in order to allow the correction values to guide the tamping machine to be calculated, and also the actual ballast profile is measured. The recording results enable decisions to be made about the lifts to be performed and the prevailing ballast requirements. Taking into account the lifts to be carried out, it is determined in an automated process where there is a surplus of ballast that must be picked up and where there is a shortage and ballast must be added.

Modern, state-of-the-art track recording cars ensure a maximum of staff safety, as new technologies allow the measurements to be conducted from within the safety of the cabin, i.e. without the operator having to leave the cabin or having to open doors or windows (a detailed insight into track geometry measuring is given in [3]). To minimise the development of dust inside the cabin, by means of a ventilator, an overpressure of about 0.5 bar is created. A filter purifies the air supply to the cabin, as defined in ISO 16890 [4].

Ballasting

Following the pre-measuring run, ballast is deposited in the track sections where there is a shortage – this usually generates a considerable amount of dust. Therefore, the regulations and specifications of the railways, as well as national workers' protection directives, define counter-actions that should be undertaken in this respect. For instance, in order to reduce the amount of dust generated during ballasting to a minimum, in the DACH countries (Germany, Austria and Switzerland), the ballast must be washed and wetted before it is placed in the track. This requirement is, for instance, also stipulated in the new "General Regulation for Construction Work in Tunnels using Large-Scale Machines (Allgemeinverfügung Tunnelbaustellen mit Großbaumaschinen)", which was issued by the German Federal Railway Authority (EBA) earlier this year [5]. Also, the ballast sweeper unit can be equipped with a water-spraying device to bind the dust (Fig. 2).

Fig. 2: Ballast sweeper unit with water-spraying device (Photo: Plasser & Theurer)

Tamping and ballast profiling

The highlight of the short maintenance process is the tamping and ballast profiling cycle, which requires special preparations that:

— protect the health and safety of staff;

— meet the quality requirements of the rail infrastructure operator.

When it comes to maintenance work in tunnels, in addition to the measures that apply when working in the track area, also the regulations of the respective rail infrastructure operator and the statutory provisions of the authorities (e.g. EBA [5]) that are aimed at enhancing staff safety need to be complied with. To meet these requirements, high-quality state-of-the-art-machines are needed. Plasser & Theurer tamping and ballast profiling machines are equipped with various tools and equipment that allow an efficient and safe operation in tunnels as alluded to in the following.

Tamping machines

The drive and work cabins of tamping machines of the latest generation are fully enclosed and insulated (Fig. 3). To minimise the development of dust inside the work cabin, a ventilator creates an overpressure of about 0.5 bar. A filter purifies the air supplied to the cabin, as defined in ISO 16890 [4] (all Plasser & Theurer machines of the current product portfolio comply with this standard).

Fig. 3: Fully enclosed and insulated work cabin of the UNIMAT 09-4x4/4S E^3 (Photo: Plasser & Theurer)

All relevant work units and measuring equipment of the tamping machines can be operated from within the work cabin, i.e. without the operator having to leave the cabin, which ensures maximum staff safety – besides, this also minimises the machine operator's exposure to dust.

Further, the E^3 drive technology already adopted by various tamping machines allows an operation that is free from exhaust-gas emissions, with a minimum of noise emission [6]. For instance, the UNIMAT 09-4x4/4S E^3 continuous-action universal tamping machine is equipped with an all-electric drive that is powered by current collected from the overhead line using a pantograph, which ensures an optimum energy efficiency during operation. The E^3 machine concept also includes an electric vibration drive of the tamping units. Another advantage of the all-electric operation is that the air filter of the diesel engine does not become overstrained. When current collection from the overhead line is not possible, then a diesel engine acts as a power generator and provides the current supply for the drive components (diesel-electric).

Ballast profiling machines

Following tamping, the ballast bed is profiled using a ballast profiling machine, which must be able to keep pace with the tamping machine. Moreover, this machine must also meet the requirements for machine operation in tunnels, i.e. during work, the doors and windows should remain shut, and all machine operations must be carried out and monitored from within the work cabin.

Furthermore, the development of dust during machine operation in tunnels should be minimised. Therefore, the sweeper units of modern ballast profiling machines (and the tamping units of modern tamping machines) are equipped with a dust-arresting atomiser unit.

INTEGRATED MAINTENANCE

Integrated maintenance is a more comprehensive form of maintenance in that, as noted earlier, in addition to the tasks of short maintenance, it also includes rail reprofiling. Following the tamping and ballast profiling cycle, the rails are reprofiled either by means of a rail grinding machine using rotating grinding stones or by means of a rail milling machine. The method that is adopted depends on various factors, but mainly on the type of the prevailing rail defect. The machines used for rail reprofiling must also meet the statutory provisions for machine operation in tunnels noted earlier. In addition, the waste produced during rail reprofiling must be taken into consideration.

Rail grinding produces dust that results from wear of the grinding discs and rail abrasion, which must be removed. During grinding, abrasion clumps can form that fall into the track; these need to be picked up and disposed of, without staff having to leave the work cabin. Milling machines produce both dust and small metal pieces that can reach the size of a fingernail – the metal pieces must be picked up from the track using magnets.

EXTENSIVE MAINTENANCE

"Extensive maintenance" is, as noted earlier, an even more comprehensive form of maintenance, in that, in addition to the tasks of integrated maintenance, it also includes ballast bed cleaning, which changes the work sequence to some extent as alluded to in the following.

Following the preparatory and preliminary work, the ballast cleaning machine comes into action, and ballast is placed in track sections where there is a shortage. Then, the track is tamped and the ballast is profiled and, as the final step, the rails are reprofiled.

For ballast bed cleaning in tunnels, new criteria have been established recently, such as the "General Regulation for Construction Work in Tunnels using Large-Scale Machines" issued by EBA noted earlier [5], which has led to a reassessment and re-design of ballast cleaning machines. Modern, state-of-the-art machines meet these criteria as alluded to in the following.

Ballast cleaning machines of the latest generation are mostly operated from insulated, air-conditioned and dust-protected work cabins. From the work cabin, all the work units and other equipment, such as the ballast screens and the ballasting unit, can be monitored and controlled via cameras, regardless of their distance from the cabin.

Fig. 4: Ballast being wetted (Photo: Schachner)

Minimising dust development during ballast bed cleaning in tunnels

Since a few years, special equipment has been tested on various machines that significantly reduce the emissions of ballast cleaning machines. This equipment includes particle filter systems, modern diesel engines (exhaust emission standard Level 5), and water-spraying units that bind the dust.

Experience gained during a pilot project in Germany, for which an adapted RM 900 high-capacity ballast cleaning machine was used, have shown that by wetting the ballast in advance and vacuuming it at crucial locations can lead to a significant reduction in dust development (Fig. 4). Up to now, however, it is necessary to transport the vacuuming units on the adjacent track (Fig. 5).

For future projects, a concept is being prepared that would allow ballast bed cleaning to be carried out with a minimum of dust development (Fig. 6), both in double-track tunnels – without the need to close the adjacent track, and in single-track tunnels. To ensure this, the air, as well as the vacuuming unit and the filter system, must be transported along with the machine, in addition to the material, instead of on the adjacent track, whilst observing the clearance gauge.

ACCEPTANCE OF WORK PERFORMED

Across Europe, the acceptance of the work performed is common practice [7]; thus, also in the case of the three types of maintenance described in this article (short, integrated and extensive). When it comes to track work in tunnels, ideally the machine that carries out the work is also used for the acceptance.

During short maintenance, it is common practice to carry out the acceptance immediately following tamping. The data recording processor (DRP) of the tamping machine produces a protocol of the completed track geometry during work operation. Again, this task can be carried out from inside the dust-protected and sound-insulated work cabin (this is also true for the acceptance of the reprofiled rails in the case of integrated and extensive maintenance).

In the case of extensive maintenance, ballast bed cleaning is followed by acceptance of the work performed, using the track recording car that is also used to conduct the pre-measuring run prior to tamping. The Plasser & Theurer EM-SAT 120 track recording car allows this task to be performed without the operator having to leave the cabin, at a measuring and working speed of no more than 5 km/h.

The new EM100VT track recording car can record the outer track geometry at speeds of up to 100 km/h (and higher) thanks to its non-contacting track geometry measuring system, in combination with a new fixed-point measuring system. The latter fully automatically detects the reference points located next to the track and records them with high precision using image recognition systems. QR labels on the overhead line masts make it possible to clearly identify and locate every fixed point. This saves time during track possessions and also enhances staff safety.

Fig. 5: Vacuuming unit on the adjacent track (Photo: Schachner)

Fig. 6: Minimising dust development during ballast bed cleaning in tunnels (Photo: Schachner)

FINAL REMARKS

Mechanised maintenance of ballasted track in tunnels requires both machine manufacturers and contracting companies to take a fresh approach. Machine design must meet the criteria of the regulations of the respective rail infrastructure operator and the statutory provisions of the authorities that are aimed at ensuring staff safety. To meet these requirements, it takes innovative machines. In addition to retrofitting machines that are already in operation, new ideas for machine design are needed.

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