

High-tech machinery for efficient maintenance of heavy-haul railway track

On high-capacity railway lines, especially when high axle loads are applied, it is very important to use appropriate track maintenance and upgrading procedures, in order to enable their optimal and efficient use. By this, also a low level of dynamic wheel/rail forces can be maintained, which minimises strain on both track and rolling stock. Track maintenance technologies are being developed continuously, in order to meet the high demands of heavy-haul railway track. Today's machines for track construction and maintenance achieve a far higher output than ever before, and also an increasing number of intelligent control circuits is being adopted. This has a decisive effect on the cost-effective performance of the tasks and the work result achieved. The focus is very much on the long-term effect of a maintenance operation, as well as cost optimisation – investment in high-tech machines with state-of-the-art work units for maintenance of heavy-haul railway track is worthwhile.

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According to the International Heavy Haul Association (IHHA), a railway can be defined as heavy haul if it meets at least two of the following criteria [1]:

- it regularly operates or is contemplating the operation of unit trains or combined trains of at least 5,000 t gross mass;
- it hauls or is contemplating the hauling of revenue freight of at least 20 million gross tonnes (MGT) a year on a given line segment that comprises at least 150 km in length;
- it regularly operates or is contemplating the operation of equipment with axle loads of 25 t or more.

Even though heavy-haul railway lines are very often dedicated to freight traffic only, time windows for track maintenance are increasingly becoming shorter.

MAINTENANCE OF HEAVY-HAUL RAILWAY TRACK – COST CONSIDERATIONS

With respect to maintenance of heavy-haul railway track, the considerations alluded to in the following should be taken into account.

Track maintenance – the cost conflict

Engineers and financial controllers acknowledge the need to keep track maintenance efforts and costs to a minimum. The way in which to achieve this, however, forms the basis for lengthy discussions. In this respect, it should be noted that cost cutting by reducing expenditure on maintenance, regardless of the long-term effect, can lead to railways having to spend the “savings” many times over later on, in order to bring the track back into a reasonable condition, i.e. enabling railway traffic without excessive slow orders.

LCC optimisation – key for minimising daily cost

In 1998, the track management at Austrian Federal Railways (ÖBB), together with the Graz University of Technology (TU Graz), started an investigation into different options for all track maintenance strategies with respect to their long-term cost effects [2]. It entails that the investment and maintenance costs of the different strategies are summarised for the life cycle of a track and then the respective difference in annuities is calculated. If a new strategy shows a more positive cash flow as compared to an existing one, then it can be concluded that it is more cost effective. In addition, a present net value calculation is made, and the internal rate of return on investment is calculated. This method of life-cycle-cost (LCC) calculation has become state-of-the-art, as it delivers a sound basis for management decisions with respect to rail infrastructure investments and maintenance strategies – ÖBB still cooperates with TU Graz in checking the LCC effects of all its major rail infrastructure projects.

LCC of railway track and levers for its reduction

On 2 May 2018, Prof. Peter Veit, Head of the Institute of Railway Engineering & Transport Economy at TU Graz, in a presentation he delivered at the World Bank in Washington, D.C., USA, noted that, based on the cost analysis of about 5,000 km

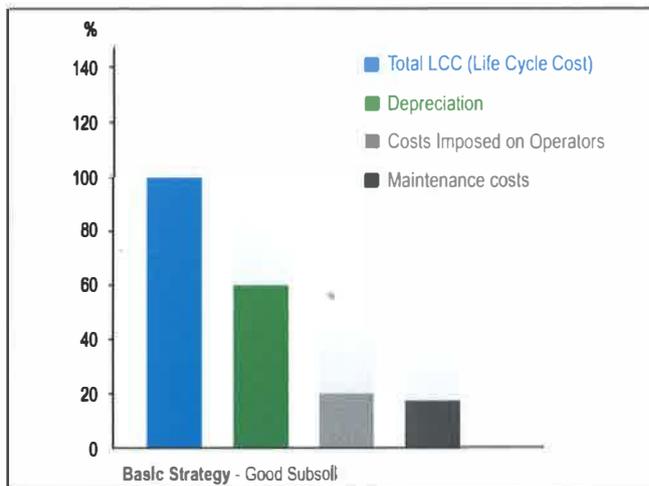


Fig. 1: LCC distribution for a track with a good subsoil [1]

of track in Austria, a basic model of LCC distribution as regards railway track had been developed (see Fig. 1), and pointed out how the respective costs could be reduced:

- *depreciation costs (about 60%)*: as this is the largest cost block, any measure that leads to an increase in the service life of the track will result in an overall cost reduction. This could be achieved by adopting better components (track, ballast, formation), by ensuring a high initial track quality and by adopting a sustainable maintenance strategy;
- *traffic hindrance costs, i.e. costs imposed on operators that result from slow orders, traffic disruption or re-routing due to the rail infrastructure (about 21%)*: these costs could be reduced by avoiding slow orders that result from deferred maintenance or maintenance operations, and by keeping any necessary track possessions as short as possible by using high-capacity machines;
- *maintenance costs (about 19%)*: these costs could be reduced by adopting cost-effective high-capacity machines and timely maintenance. To reduce maintenance costs by deferring maintenance is not a viable strategy, as this only leads to a shorter service life of the track – increasing its depreciation costs, as well as to higher traffic hindrance costs

MAINTENANCE OF HEAVY-HAUL RAILWAY TRACK – A MATTER OF GREAT IMPORTANCE

The aforementioned considerations show very clearly that it is essential to keep the track in top condition – not only that of railway lines carrying high-speed passenger traffic, but also of those carrying high-capacity freight traffic. Deferred maintenance will not only lead to higher costs at a later stage but, if track faults are allowed to develop further, also to an increase in the dynamic impact of high axle-load traffic on the track, which may result in a complete failure of the system.

Therefore, as with any other production plant, it must be ensured that any necessary track maintenance is carried out in a timely manner.

Furthermore, track possessions for maintenance should be scheduled in such a manner that customers do not switch to other traffic carriers because of unexpected production breakdowns or delays. In this respect, it is advisable to bundle various planned infrastructure maintenance work, such as that of overhead line systems, signalling installations, rails, track fastenings, track geometry, etc., in the same track possession.

New track must be serviced from the outset, as neglect of maintenance in the initial phase of its service life will cause inherent failures that cannot be compensated for later on.

Heavy-haul railway track can be effectively and cost-efficiently maintained by machines that adopt state-of-the-art work units – track maintenance machines are increasingly equipped with intelligent control circuits, which has a decisive impact on the cost-efficiency and quality of the work performed. The long-term effect of a maintenance measure, as well as cost optimisation, is paramount in this respect – investment in high-tech machines for maintenance of heavy-haul railway track offers benefits.

The above principles coincide with the best practices for rail infrastructure construction and maintenance that were published by the International Heavy Haul Association (IHHA) in 2009 [3].

HIGH-TECH MACHINES FOR MAINTENANCE OF HEAVY-HAUL RAILWAY TRACK: A SELECTION

In the following, a selection of high-tech Plasser & Theurer machines for maintenance of heavy-haul railway track, which are in operation in various countries around the world, is presented.

Australia

On the East Coast of Australia, there are two large heavy-haul railway operations: in New South Wales, the line that serves Hunter Valley (coal) and, in Queensland, the lines that serve Mount Isa (copper) and Goonyella Riverside Mine (coal). In North-West Australia, the area of Pilbara, well known for its iron ore, is served by a number of dedicated heavy-haul railway lines – high-axle load (up to 40 t) trains transport the ore from the inland mines to the coast.

Because of the importance of the aforementioned lines and the dense traffic on them, the adoption of sustainable and fast maintenance methods is a must. Therefore, high-capacity continuous-action multi-sleeper tamping machines are at the heart of track maintenance on all these lines. Fig. 2 shows an example of such a machine – a 09-2X Dynamic.



Fig. 2: The 09-2X Dynamic continuous-action two-sleeper tamping machine with integrated dynamic track stabilisation (Aurizon).



Fig. 3: The RM 900 QR high-capacity ballast cleaning system (Aurizon)



Fig. 4: MFS material conveyor & hopper cars

The machine shown in Fig. 2 is named “Banga Yulgabari Gudyara”, in tribute to its traditional work area. It is decorated on both sides with artwork of the local Aboriginal tribe Barada Bara – in this manner, Aurizon, the owner of the rail freight infrastructure of Queensland, wanted to express its special respect for the indigenous people of Australia.

Another important matter that deserves attention is the rehabilitation of ballast of these high-capacity tracks. Over the years, ballast becomes fouled due to abrasion resulting from the heavy traffic loading and contamination by the spillage of freight (ore or coal dust). In all mining areas, high-speed ballast cleaning systems [4], such as the one that is shown in Fig. 3, are in operation, complemented by high-capacity material conveyor and hopper cars of the MFS series (Fig. 4), which allow a high output in ballast cleaning to be achieved in a highly efficient manner.

Aurizon has ordered a high-capacity ballast cleaning machine system that embraces a shoulder ballast cleaning machine (FRM 802) and a ballast undercutter cleaning machine (RM 802) that can achieve a very high ballast cleaning output, like the one that is operated on BNSF railroad in the USA, which is described further on in this article.

Brazil

In Brazil, there are two big players in heavy-haul transportation: MRS Logística S.A. and VALE S.A. – MRS operates its trains on 1,600 mm gauge track, and VALE on 1,600 mm and 1,000 mm gauge track. MRS is a general freight railway with a substantial amount of iron ore transport. VALE is one of the biggest iron ore companies in the world with dedicated heavy-haul railway lines; it also carries out some general transport (both freight and passenger).

Both railways face a common problem: time windows for track work are scarce, and the high axle-load (35 t and more) traffic has a heavy impact on the tracks. This creates a demand for track maintenance machines that can achieve a high output, as well as an accurate and sustainable work result, such as the tamping machines shown in Figs. 5 and 6. The precise track geometry produced by such machines results in lower dynamic forces. Also, the high working speed and the long-lasting work result achieved by these machines lead to shorter and fewer track possessions.



Fig. 5: A continuous-action universal tamping machine on its way to VALE



Fig. 6: The 09-2X 275/3S universal tamping machine – maintaining track of MRS Logística S.A.

Another important matter is ballast quality. Due to the dense high axle-load traffic on the heavy-haul railway lines of MRS and VALE, there is quickly a high level of ballast abrasion. Therefore, the adoption of high-output ballast cleaning systems has become an important part of the track maintenance strategy in recent decades.

China, India and Russia

China, India and Russia are long-standing members of the heavy-haul community. The maximum axle load of 25 t that is adopted in these countries is not much higher than the 22.5 t in European UIC member countries. However, their heavy-haul status is additionally defined by the amount of transport. There are many railway lines that have a traffic volume of more than 150 MGT per annum – statistics of freight traffic volume illustrate the heavy usage of railway lines in these countries (see table below).

Country	Railway company	Year	MGT	Billion tonne-km
China	CHR	2014	3,813	2,753
India	IR	2017	1,111	621
Russia	RZD	2017	(not available)	3,176

Freight traffic volume per annum [5], [6], [7]

All three countries share the typical heavy-haul problem: a shortage of time windows for maintenance and ballast abrasion. India was therefore one of the first countries worldwide to adopt the continuous-action three-sleeper tamping technology (Fig. 7), followed by China. Today, there are 70 continuous-action three-sleeper tamping machines of the 09-3X series in operation in India and 200 in China. Fig. 8 shows a machine that is used for local maintenance in India – even for these “auxiliary” jobs, it is important to use machines of robust design that deliver a high-quality and sustainable work result.



Fig. 7: Continuous-action three-sleeper tamping



Fig. 8: A compact universal tamping machine that is used for local and spot maintenance

For ballast maintenance, both India and China rely on ballast cleaning machines of the RM 80 series, 155 of which are in operation in India and 145 in China. In India, there are an additional 60 shoulder ballast cleaners of the FRM series in operation. Recently, the two countries have also started to operate high-capacity ballast cleaning machines of the RM 900 series, which are equipped with two vibrating ballast screening units that achieve a high output – this is certainly the right strategy for tracks with dense high axle-load traffic.

North America (USA/Canada)

In North America, heavy-haul railway lines play a very significant role in freight transport. For instance, in the USA, more than 40% of annual freight (in tonne-miles) is transported by rail. In 2016, it amounted to 1,585 billion tonne-miles (2,536 tonne-km) [8], which ranks the USA third in terms of freight transport following China and Russia. On top of that, the Class 1 railroads in the USA achieve an outstanding revenue: from 2005 to 2016, the return on investment varied from 9-12% [9].

High axle loads of up to 35 US short tonnes (31.75 metric tonnes), very long trains and a growing rate of intermodal transport with double-stack containers are the challenges that face the rail infrastructure maintainers, and – yet again – short time windows for maintenance.

High-performance maintenance of heavy-haul track by means of tamping and dynamic track stabilisation

To maintain the track geometry, tamping machines of different sizes are used for both day-to-day and scheduled maintenance. The tamping process is combined with dynamic track stabilisation, which enables the track to be travelled at standard train speed immediately following tamping – this is very important, as slow orders following tamping would cause very high additional costs for the operation of heavy and long trains. In addition, dynamic track stabilisation reduces the risk of track buckling [10].

A typical range of tamping machines combined with dynamic track stabilisation that are used on heavy-haul railway lines in North America may include (see also Fig. 9):

- a *GRM 3000*: this is a heavy-duty, high-performance tamping machine for plain track and switches. This multi-function tamping machine has fully automatic track lifting, lining and levelling capabilities specially designed for the stringent requirements of high-density, high-tonnage carrying railway lines, shortlines and contractors. Its compact design and low weight allow for flexibility in its transportation, either on flat-bed wagons or road trucks;
- a *09-2X DYNACAT*: this is a heavy-duty, high-speed and continuous-action tamping machine with integrated dynamic track stabiliser for both plain track and switches.

All tamping, lifting and lining units are mounted on a separate satellite frame that is attached to the main frame of the machine – whilst the satellite tamps and indexes two sleepers at a time during the actual work process (lifting, lining, levelling and tamping), the machine's main frame along with the track stabiliser system moves forward smoothly and continuously at a speed determined by the machine operator. The two-sleeper tamping units of the *09-2X DYNACAT* allow either two sleepers to be tamped in a single operation, resulting in a high tamping output, or one sleeper at a time in case of irregular sleeper spacing;

- a *09-3X CW DYNAMIC TAMPING EXPRESS*: this is a high-output continuous-action tamping machine that is equipped with tamping units that allow multi-sleeper tamping of both wooden and concrete sleepers, despite their big difference in spacing – its Automated Tamping Tool Adjustment (ATTA) system allows the machine to react quickly to changing sleeper conditions. The machine has the capability to detect prevailing sleeper spacing with its ATLAS system, position the satellite and adjust the tamping units/tines accordingly and, thus, carry out three-sleeper or single-sleeper tamping automatically – this development in technology has raised multiple-sleeper tamping to the next level.

Ballast cleaning with highest output: the RM 802/FRM 802

The ballast bed distributes traffic loads uniformly onto the track substructure and ensures a firm, unshifting position of the sleepers. To withstand dynamic impacts, the ballast bed must be very elastic. A proper functioning of the ballast bed depends on its thickness, the size of the ballast stones, and the degree of fouling.

Ballast fouling occurs under normal traffic loading. The latter causes the edges of the ballast stones to break off, as well as a settlement of the stones and friction processes. Other causes of fouling are material rising from the subsoil, and external environmental influences. Overall, this causes an increase in the proportion of fines, which reduces the elasticity of the ballast bed, its water permeability, as well as the durability of the track geometry. Consequently, there will be an irregular settlement of the track, which tamping can compensate only for a short time period. From a certain point in time, it is more economical to clean the entire ballast bed. This work can be performed highly efficiently using ballast bed cleaning machines.

Ballast bed cleaning machines achieve a high ballast cleaning quality, allowing the re-use of large quantities of ballast, a very costly resource, making their adoption very cost effective. Also, thanks to their high working speed, even short track possessions can be utilised.

On BNSF railroad, for instance, the high-output RM 802 ballast cleaning machine with integrated supply of new ballast has performed successfully since 1995.

In 2011, the world's fastest system for ballast cleaning followed (Fig. 10): the RM 802/FRM 802 which, by combining shoulder ballast cleaning and ballast undercutting in a single machine system, and using four high-capacity vibrating ballast screening units, can achieve a very high working speed – typically, 2,000 ft/h (610 m/h).

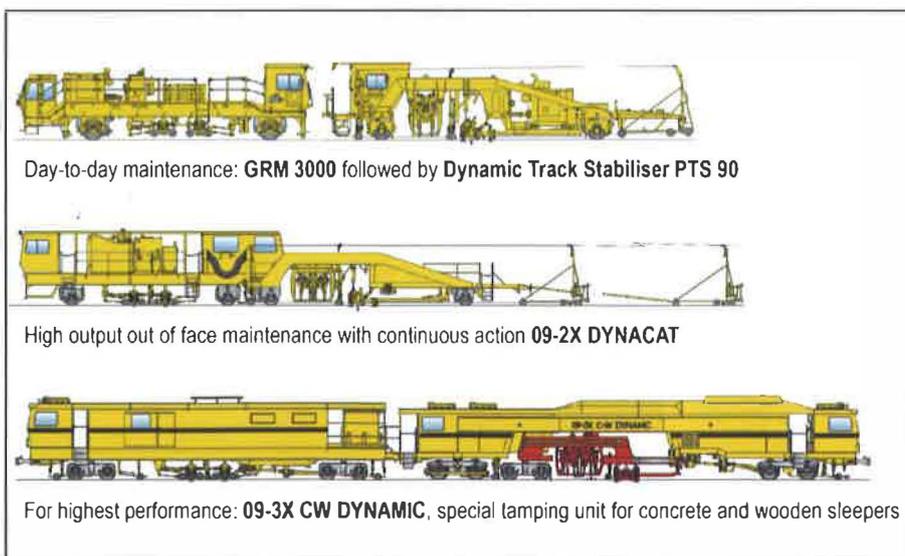


Fig. 9: A range of tamping machines combined with dynamic track stabilisation that are typically used in North America



Fig. 10: The RM 802/FRM 802 high-capacity ballast cleaning system in operation on heavy-haul railway track of BNSF

The work process using the RM 802/FRM 802 is as follows (see also Fig. 11):

- before the machine system starts to work, new ballast is deposited on the track (orange);
- the ballast excavation units of the FRM 802 Shoulder Cleaning Machine (4) pick up the ballast on both sides of the track (blue) and convey it to the dual ballast screening unit of the machine;
- during the ballast screening process, the fines (red) are separated and conveyed to the front of the FRM 802, where it is stored in the MFS material conveyor and hopper cars (3), and the re-usable cleaned ballast (green) is conveyed to the rear into intermediate MFS cars (6), where it is temporarily stored;
- the FRM 802 is followed by a Ballast Pickup Unit (5) that picks up the pre-deposited new ballast (orange), which is transported to the same MFS cars (6) as the re-usable cleaned ballast;

- the next unit is the RM 802 Ballast Undercutter Cleaner (7), which excavates the remaining ballast and feeds this into its dual ballast screening unit. Again, the fines (red) are separated and transported to a set of MFS cars (8) at the rear of the RM 802. The re-usable cleaned ballast (green) is conveyed back to the RM 802, where it is mixed with new and cleaned ballast coming from the intermediate MFS cars (6). Then, all the clean ballast (orange and green) is returned to the track directly behind the undercutter bar of the RM 802;
- waste unloading stations (2 & 9) and utility cars (1 & 10) complete the machine system configuration.

The ultra-fast RM 802/FRM 802 ballast cleaning system is operating successfully on tracks with the heaviest traffic loading of BNSF – it optimally utilises track possessions. As noted earlier, a similar system has been ordered by Aurizon, the owner of the rail freight infrastructure of Queensland, Australia, which is scheduled to be put into operation at the end of 2019.

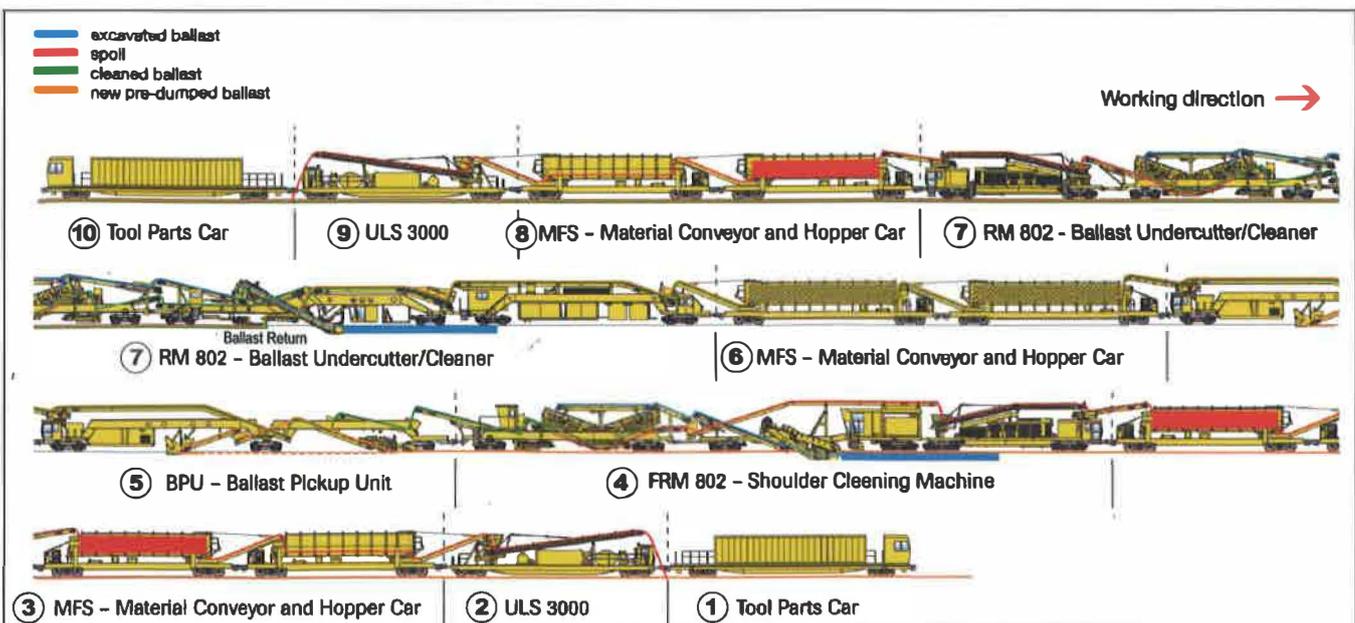


Fig. 11: Operating principle of the RM 802/FRM 802 ballast cleaning system

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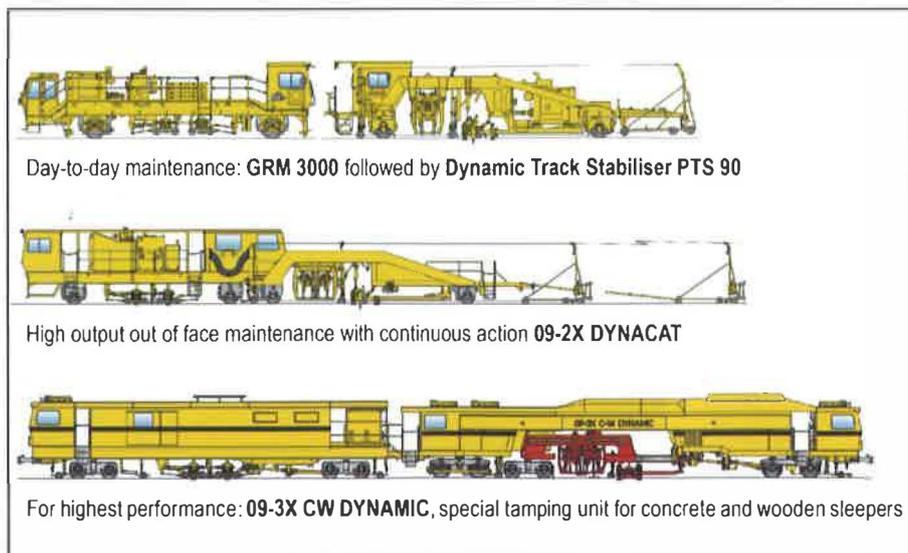


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DIGITALISATION AND HEAVY-HAUL RAIL

Rio Tinto of Australia successfully deploys its AutoHaul technology for the autonomous operation of iron ore trains in the Pilbara region of Western Australia. The first autonomous loaded train ran in July 2018, carrying 28,000 t of ore over 280 km between the Tom Price mine and the port of Cape Lambert. The number of autonomous journeys has since been steadily increased, with more than 1 million train-km operated autonomously by the end of 2018. Results indicate a significant potential to improve productivity, provide increased system flexibility and reduce bottlenecks [11]. This shows the importance of digitalisation for heavy-haul railway operation.

Furthermore, the recent Heavy Haul STS Conference 2019, Narvik, Norway, 10-14 June 2019, also focused on digitalisation, as in its announcement it read: "International Heavy Haul 4.0 – Achieving Breakthrough Performance Levels – Technologies are transforming heavy-haul maintenance and operations. Can new possibilities and innovations be inspired from the Industry 4.0 concept?" Digitalisation will also form the foundation for full transparency and sustainability in track maintenance, as alluded to in the following.

Digitalisation and track maintenance

Infrastructure managers, track maintenance contractors and machine manufacturers are facing great challenges to make the railway fit for the future. Sustainable rail infrastructure management needs a holistic view of the railway system. Digital technologies and artificial intelligence enable machines to evolve from classic track maintenance machines into smart, fully networked maintenance machines, as exemplified by, for instance:

- the "Plasser & Theurer SmartMaintenance", which describes the smart machine in the context of optimised fleet management and track maintenance;
- the "PlasserSmartTamping – the Assistant", which is a machine operating system that provides an automated support for tamping work in turnouts. In addition, it provides a full documentation of the track maintenance work executed [12];
- the "Smart Geometry Computer's new AutoSync function", which enables track recording cars to send data on track geometry, via the cloud, directly to the maintenance machine. Thus, a separate pre-measurement for track geometry optimisation is eliminated;
- the fact that the machines themselves can also carry out exact pre-measurements for geometry optimisation – at a speed of 100 km/h. This makes it possible to locate spot faults quickly and eliminate them sustainably;
- smart machines are increasingly turning into sensors that supply data on the rail infrastructure.

With respect to the latter, in the future, the data obtained will serve the optimisation of rail infrastructure asset and life-cycle management systems in a sustainable and holistic manner even more.

Classic measuring tasks, until now exclusively carried out by track inspection vehicles, are making their way into tamping machines. Infrastructure managers are now able to have digital access to all the complex information needed to plan maintenance operations and track inspections. Combining this information makes it possible to take data security and process reliability to a new level.

FINAL REMARKS

The continuous development and improvement of track maintenance machines has led to a series of designs for all applications that not only meet the high demands of heavy-haul railway track, but also provide cost-effective solutions – by increasing the working speed and/or by implementing technologies that save precious raw material. New high-tech machines contribute to the sustainability of investments in heavy-haul railway lines, as they enable the maintenance level to be kept high. This is important, in order to reduce strain on the infrastructure and minimise track possessions for maintenance activities. Furthermore, digitalisation of machines, machine and infrastructure management and supervision, as well as a further automation of machine operation, will contribute to a further increase in efficiency and safety of mechanised maintenance of heavy-haul railway track.

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