Plasser & Theurer machines and technologies applied for track maintenance of high-speed railway lines: a selection

Whenever the speed or capacity of a railway line is increased, or a new high-speed railway line is built, the application of appropriate track maintenance procedures is very important to enable optimal and efficient use of these lines, as well as to maintain a high level of ride quality and safety. Track maintenance technologies are developed continuously to meet the demands of high-speed and high-capacity railway lines. This article looks at a selection of Plasser & Theurer machines and technologies applied for track maintenance of high-speed railway lines.

By: Ing. Rainer Wenty, Plasser & Theurer Export von Bahnbaumaschinen GmbH, Vienna, Austria.

HIGH-SPEED RAILWAY TRACK

Although alternative track designs, such as paved track, have been developed, the majority of high-speed railway lines today features ballasted track. Over the past years, the laying and maintenance methods for ballasted high-speed railway track have been optimised, making ballasted track a very economical solution with regard to life-cycle costs. The track of high-speed railway lines requires a precise geometry, allowing only very tight tolerances that must be kept in the millimetre range, and must be serviced accordingly from the outset. Neglect of maintenance in the initial phase of the service life of high-speed railway track will cause inherent faults that cannot be compensated later.

Interaction between track and rolling stock

Track faults of different wavelengths stimulate railway vehicle bodies with different frequencies. Frequencies in the range of between 0.5 and 10 Hz are regarded as critical for rolling stock. At lower speeds, these frequencies are caused by short-wave errors, in which case it is sufficient to correct the track using the smoothing method. However, at higher speeds, faults in track geometry with larger wavelengths also cause considerable dynamic forces and must, therefore, be eliminated.

Fig. 1 shows that, at a speed of 160 km/h, faults with wavelengths of up to 100 m must be taken into consideration and that, at a speed of 350 km/h, even faults with a 200 m wavelength cause rolling stock reactions [1]. This corresponds with experience gained in practice by high-speed rail operators and has, recently, brought about a change in the track maintenance strategy adopted by some railways - changing from the smoothing method to the absolute track geometry method.

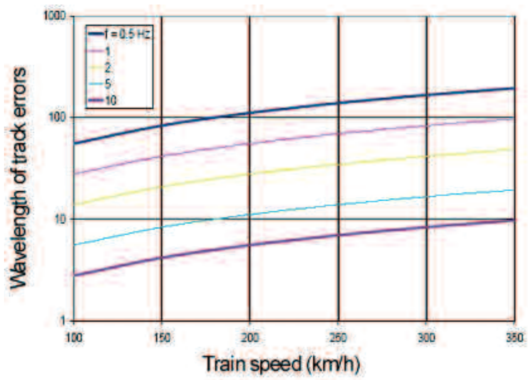

Fig. 1: Reaction-oriented evaluation of track geometry at the critical frequency of 0.5-10 Hz

Absolute track geometry method

On high-speed railway lines, deviations in track geometry from the target position have to be kept to a minimum. High-speed railways, therefore, use absolute reference systems for track geometry.

In Austria and Germany, from 1972 onwards, fixed reference points were set up, generally on catenary masts, allowing the position of the track to be defined in relation to the fixed points and the versines in between (Fig. 2). In other countries, e.g. the United Kingdom [2], France [3] and Switzerland, similar systems have been introduced.

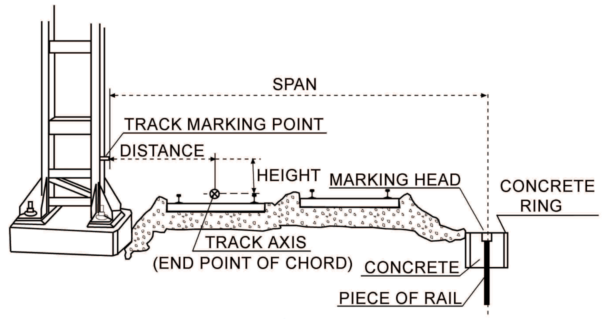

Fig. 2: Fixed-point reference system adopted on DB AG and ÖBB

TRACK CONDITION MONITORING AND DIAGNOSIS

Track condition monitoring of high-speed railway lines is a task of major importance, in order to ensure ride quality and safety.

The basis of all track maintenance operations is an exact observation and recording of the state of the track. On Austrian Federal Railways (ÖBB), for instance, this is carried out using the Plasser & Theurer EM 250 ([4], [5]) and EM 80 track recording cars. The core unit on the electronic track recording cars of the EM series, which are available for various recording speeds and are in use on a great number of high-speed railway lines, is the PAC (Plasser American Corp.) Non-contact Inertial Navigational Track Geometry Measuring System with optical dual-gauge measuring system (OGMS).

The PAC Inertial Navigational Track Geometry Measuring System for accurate measurement results

On track recording cars for high-speed railway lines, non-contact track geometry measuring systems are used to enable high measuring speeds and ensure accurate and repeatable measuring results. For high-speed railway lines, it is important to obtain information about both short-wave and long-wave deviations in track geometry. Therefore, chord measuring systems, which are based on a limited measuring length, have been replaced by inertial measuring systems that record a spatial curve. The PAC Inertial Navigational Track Geometry Measuring System uses the Applanix POS/TG which, based on a three-dimensional laser gyroscope combined with GPS positioning, delivers accurate position and orientation data for the precise measurement of track geometry parameters (gauge, superelevation and calculated twist, longitudinal profile, horizontal alignment, curvature and grade), even at low speeds.

The core POS/TG system consists of an Inertial Measurement Unit (IMU) and a POS Computer System (PCS) with embedded Global Positioning System (GPS) receiver.

Distance Measurement Indicator (DMI) and Optical Gauge Measurement System (OGMS) sensors are used to provide the POS/TG system with accurate data on distance travelled and half-gauge measurements.

Unlike vertical gyro-based systems, which are notorious for false orientation readings while subjected to centrifugal forces during turns, the POS/TG system provides the user with accurate track geometry output data under all dynamic conditions. During its operation, POS/TG constantly calibrates the inertial sensors of the IMU (three accelerometers and three gyroscopes) for improved track geometry and navigation performance. This calibration and the nature of the track geometry computation algorithms implemented in POS/TG result in the ability of the PAC Inertial Navigational Track Geometry Measuring System to construct the track geometry measurements for a wide range of vehicle speeds.

The EM-SAT track survey car

Before any efficient and accurate track maintenance work can be carried out, a survey of the actual track geometry has to be made by measuring longitudinal level and alignment.

The EM-SAT track survey car (Fig. 3) enables fully mechanised measurement of the actual track geometry, using a laser reference chord. The EM-SAT consists of a main vehicle, equipped with a computer system and a laser beam receiver, and an auxiliary ("satellite") trolley that carries a laser transmitter. Measurements are taken in a cyclic sequence. The machine moves forward along a laser beam, emitted by the laser transmitter on the satellite trolley. Any deviations from the target track geometry are measured and recorded. Every 50 to 150 m, the satellite trolley stops at a fixed point and, then, moves forward again. The average measuring speed (including all stops) is 2.5 km/h.

Fig. 3: EM-SAT track survey car on Network Rail, United Kingdom

Besides displacement and lifting values, superelevation and gauge faults can also be measured. The recorded data and the calculated correction values are displayed on the computer screen on-board the main vehicle, in a similar fashion as on the ALC automatic guiding computer screen on-board the tamping machine.

Electronic transmission of data to the tamping machine guarantees highest precision and, at the same time, prevents any transmission faults that can occur in manual measuring. Experience gained on German Rail (DB AG) has shown an accuracy of 1 mm, a measuring speed of 1.5 to 2.6 km/h, and a cost reduction of EUR 3.00 per metre of measured track.

Satellite-supported track surveying

Maintaining fixed reference points is rather labour-intensive and, therefore, quite costly. Furthermore, it is often found that their position has changed in the range of some centimetres. Also, manual measurement of the track position in relation to the fixed reference points slows down the measuring speed, and is also a source of inaccuracy and further costs.

When building new lines, and when surveying existing lines with regard to their general layout, the application of the satellite-supported Global Positioning System (GPS) is already standard technology.

The latest development now is the combined use of EM-SAT and GPS (Fig. 4) to check the track geometry. The simultaneous surveying of the actual track geometry using laser reference chords and GPS makes it possible to transmit the highly accurate laser reference chord data in absolute track coordinates.

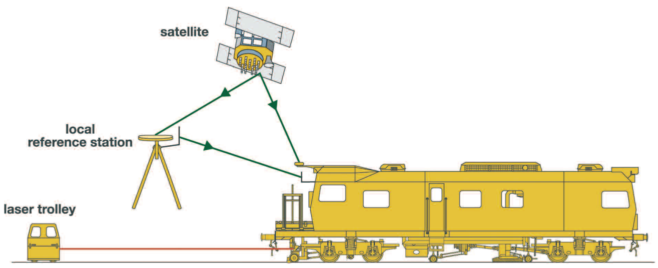

Fig. 4: Combined use of EM-SAT and GPS

Incorporation of a ballast profile measuring system

The EM-SAT track survey car can further be equipped with a non-contact ballast profile measuring system, which records the ballast profile by means of a laser scanner. The contour of the ballast profile is computed from the sequence of pulses received and stored every 2 m (maximum speed 15 km/h). On the computer display, the measured profile is superimposed by the image of the target profile appropriate to the line, which is selected by the operator at the start of work (Fig. 5). A surplus (green bars) or a lack of ballast (red bars) is indicated separately for the left and right-hand side of the track, allowing the ballast profile to be checked immediately during the measuring run. The recording results, which can be exported onto a disc or ZIP for in-depth office evaluation, enable decisions to be made about the lifts to be performed and the ballast requirements.

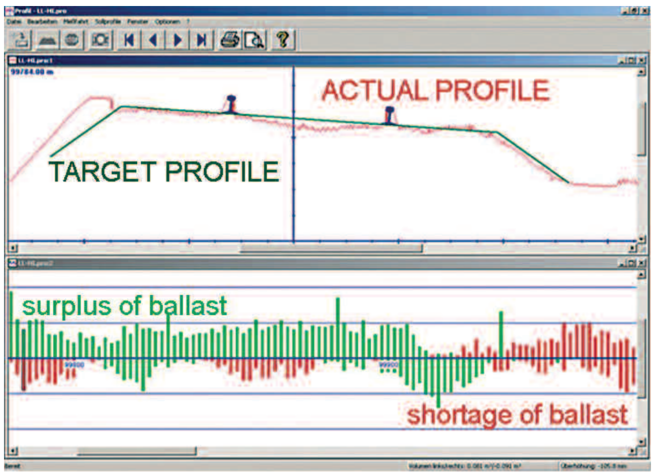

Fig. 5: Computer display showing the measured ballast profile superimposed by the image of the target profile

EFFICIENT MAINTENANCE OF HIGH-SPEED RAILWAY TRACK

The maintenance of high-speed railway track requires a range of work processes that must be coordinated as efficiently as possible. The better the work technologies act together, the higher will be the achievable work output, the quality of work and, ultimately, the cost-efficiency.

The mechanised maintenance train (MDZ)

Today, it is state-of-the-art in track construction and maintenance to use a group of machines - a high-capacity mechanised maintenance train (MDZ), the individual machines of which are matched in output, travelling speed and design parameters, thus forming a harmonic group of machines. MDZs are available in different levels of output; in each case, the tamping machine leads and determines the output (Fig. 6).

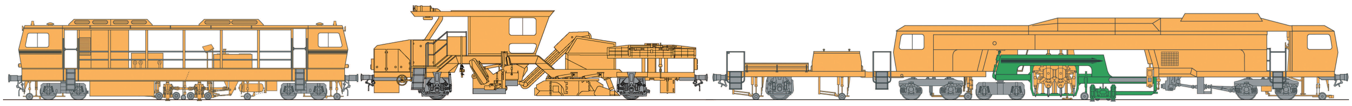

Fig. 6: High-capacity MDZ featuring a Tamping Express 09-3X as the lead machine

To put a track into its correct geometrical position and to achieve a durable work result requires the following basic operations:

— *track geometry correction, using a continuous-action levelling, lining and tamping machine:* in 1996, the continuous-action three-sleeper 09-3X Tamping Express was introduced on ÖBB, which features a total of 48 tamping tines, arranged in pairs and interlaced, thus keeping the ballast penetration reaction force to a minimum and enabling optimal squeeze operation. The standard work technology of the 09-3X Tamping Express is continuous-action three-sleeper tamping but, at any time, the units can be changed to single-sleeper tamping operation.

Using the 09-3X Tamping Express, which has a nominal output of 2,200 m/h, an increase in average daily output (shift output) from 2.4 to 4 km has been observed on ÖBB, i.e. an increase of around 42%. This means a much better utilisation of track possessions and, thus, a rise in the cost-efficiency of machine operation due to lower costs per unit of output. Since all its main lines have been maintained by three-sleeper tamping machines, ÖBB also observed a substantial increase in track quality. The average track quality index has improved by 21%.

One of the latest machines for high-performance tamping is the 09-4X Dynamic Tamping Express continuous-action four-sleeper tamping machine with integrated dynamic track stabilisation, which has a nominal output of 2,600 m/h;

— *ballast profiling, using a ballast regulating machine:* considering that one kilometre of conventional double track holds between 3,000 and 5,000 m^3 of ballast (depending on type and spacing of the track), the absolute necessity for economical handling and management of this valuable asset becomes evident. Some sections of a track may lack ballast, while others have a surplus. So the goal has to be to regain the surplus ballast and add it to where it is needed. Ballast regulating machines combine the task of ballast distribution and profiling.

Standard ballast regulating machines reshape the ballast bed by performing several runs backwards and forwards. However, with the development of continuous-action tamping machines, it became necessary to re-design the ballast regulating machines also.

Thus, "one pass" continuous-action ballast regulating machines, such as the USP series, featuring a ballast storage capacity of 5-15 m^3, were introduced. The machines are fitted with large-scale hoppers that enable a better distribution of the ballast and, thus, achieve savings in new ballast;

— *final compaction and homogenisation of the ballast bed, using a dynamic track stabiliser:* ballast profiling is followed by track stabilisation using a Dynamic Track Stabiliser (DTS), which has the task of re-stabilising the track following maintenance. This reduces the resistance to lateral displacement by around 50%. Contrary to the natural settlement caused by train loads, the application of the dynamic track stabiliser anticipates the initial settlements in a controlled manner without altering the track geometry. After tamping work, the dynamic track stabiliser lowers the track as required, gripping the rail heads with roller clamps and setting the track into horizontal oscillation. At the same time, each rail is pressed down in accordance with the readings of the levelling device and the superelevation gauge.

The dynamic track stabiliser produces an uniform initial settlement that is equal to a load of approx. 700,000 to 800,000 tons. Thus, the range for further settlements is restricted and the corrected track geometry is preserved for longer. The result of this is an extension in maintenance intervals of approx. 30%.

On German Rail (DB AG), a long-term trial to determine the effect of dynamic track stabilisation on the development of track quality was conducted on a main-line track of average condition near Regensburg [6]. After tamping, in September 1999, the track quality was improved by around 25%. In January 2001, i.e. 16 months later, the track section that had been stabilised still showed an improvement of 21%, whereas the other track section that had not been stabilised had dropped to 8% improvement (Fig. 7); thus, a longer durability of stabilised track is obvious.

Maintenance of high-speed switches and crossings using three-rail lifting and four-rail tamping machines (Fig. 8)

The use of switch tamping machines featuring three-rail lifting and four rail-tamping ensures safe handling of high-speed switches and improves the durability of track geometry correction achieved [7].

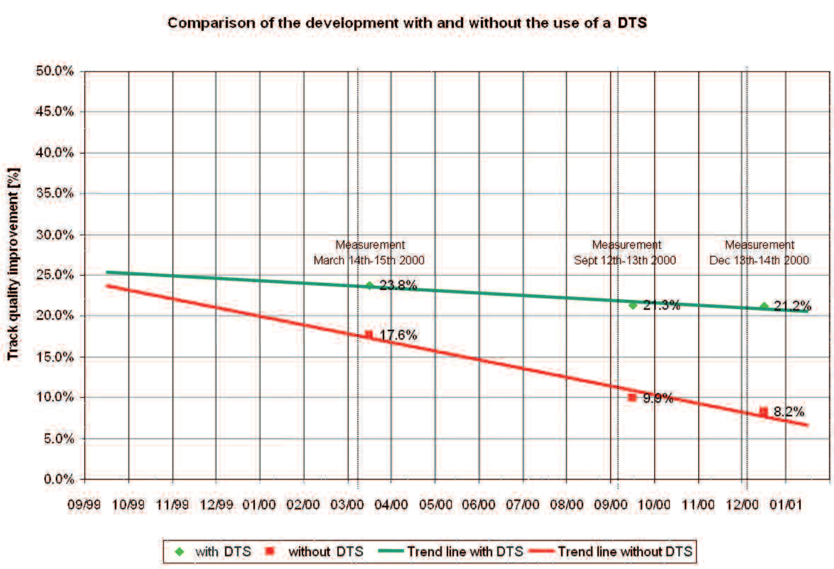

Fig. 7: Results of a track quality trial (with/without dynamic track stabilisation (DTS)), conducted near Regensburg, Germany

Three-rail lifting

Heavier designs of switches and crossings, due to the use of concrete sleepers and heavy rail profiles, demand additional measures for their treatment. When lifting such turnouts in the area of the long sleepers, using the standard two-rail lifting unit, the reaction forces on the rail fastenings exceed their yield strength. This was first detected on DB AG and, therefore, an additional lifting arm was developed for switch tamping machines [8]. Using this additional lifting arm, the diverging rail is lifted simultaneously with the rails of the through track, thus avoiding undue stress on rail fastenings and sleepers. Today, three-rail lifting is a standard feature on switch tamping machines. On most railways in Europe, three-rail lifting of turnouts featuring concrete sleepers is mandatory.

Four-rail tamping

In addition to three-rail lifting, the introduction of four-rail tamping brought a further improvement in the quality of switch maintenance.

Fig. 8: Tamping of a high-speed switch in France

The Unimat 08-475 4S, for instance, features four tamping units. The outer units are mounted on telescopic arms, allowing the tamping tools to reach a distance of 3,200 mm from the track axis. This enables both the through track and the diverging track to be tamped in one operation. Thus, there is no danger that the switch may tilt.

CONCLUSIONS

It is worthwhile investing in high-tech machines featuring sophisticated work units. The output of the machines for track laying and maintenance has increased significantly and, more and more, use is made of intelligent control circuits. This has a decisive effect on the cost-effective performance and the quality of the work performed.

The focus is always on the long-term effect of a maintenance operation and, at the same time, optimisation of the costs.

As they ensure that a high level of maintenance is upheld, new high-technology machines contribute to the sustainability of the investments in high-speed railway lines.

REFERENCES

[1] Haigermoser A.: ‘Demands of rolling stock on track quality’, Paper presented to the Working Committee on Railway Technology (Infrastructure) of the Austrian Society for Traffic and Transport Science (ÖVG), 8 November 2004.

[2] Spoors R.: ‘Introduction of fixed point based track geometry maintenance in the UK’, Rail Engineering International, Edition 2004, Number 4, pp. 12-16.

[3] Le Bihan A.: ‘Track geometry maintenance on high-speed lines - SNCF’s experience’, Proceedings 15th International ÖVG Conference “Optimising the wheel/rail system - quality, cost efficiency & financing”, Salzburg, Austria, 14-16 September 2004.

[4] Presle G.: “The EM 250 high-speed track recording coach and the EM-SAT 120 track survey car as networked track geometry diagnosis and therapy systems’, Rail Engineering International, Edition 2000, Number 3, pp. 14 and 15.

[5] Hanreich W.: ‘Modern permanent way inspection using the track geometry recording coach EM 250’, ZEVrail, September 2004, pp. 18-27.

[6] Lichtberger B.: ‘Longer maintenance cycles achieved by DTS’, Track Compendium, 2005, pp. 490-491.

[7] Lichtberger B.: ‘Careful and cost-effective installation, surveying and tamping of high-capacity switches: a selection of Plasser & Theurer machines applied’, Rail Engineering International, Edition 2004, Number 3, pp.11-14.

[8] Lichtberger B.: ‘Die neue Weichenstopftechnologie’, ETR-Eisenbahntechnische Rundschau, No. 11/1992, pp. 759-762.