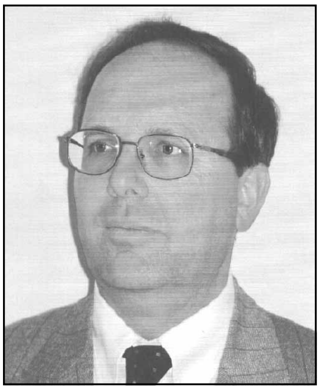
The EM 250 high-speed track recording coach and the EM-SAT 120 track survey car, as networked track geometry diagnosis and therapy systems

The riding behaviour of railway vehicles depends on both the design of the vehicles used and the quality of the track. Therefore, one of the most important tasks of the Infrastructure Division of Austrian Federal Railways (ÖBB) is the continual monitoring and maintenance of the track in order to ensure riding comfort and safety, and to reduce environmental impacts, especially noise. The basis for all maintenance operations is an exact observation and recording of the state of the track. On ÖBB, this is effected by the EM 250 high-speed track recording coach and the EM-SAT 120 track survey car, both from Plasser & Theurer, Austria.



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On 26 January 2000, ÖBB took delivery of three EM-SAT 120 track survey cars. Also on this day, the converted and modernised EM 250 high-speed track recording coach was taken into operation.

The EM 250 high-speed track recording coach

The EM 250 high-speed track recording coach of ÖBB, which is designed for measuring speeds of up to 250 km/h, was first built in 1992 [1]. It is not only used to investigate the track geometry in order to guarantee the safety of train services, but also to obtain full information on the state of the track geometry, in order to enable maintenance measures to be undertaken, if required (Fig. 1).

Optical and inertial measuring systems are applied for the exact recording of the track geometry. Two non-contact optical measuring systems, positioned in a measuring bar mounted between the running axles of a bogie, are used for inertia-free scanning of the running edges of the rail and the rail head profile, thus recording the track gauge and the horizontal curvature of the rails (Fig. 2).

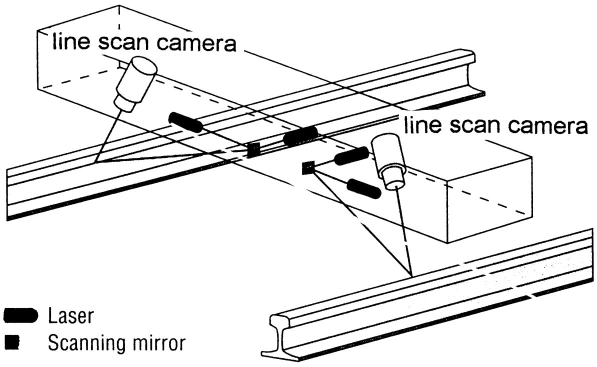


Fig. 2: Optical gauge measuring principle

Each optical measuring system consists of a laser and a matching deflecting mirror, which aligns the laser beam in relation to the actual position of the measuring bar to the rail. The latter takes place with the aid of a line scan camera with which the horizontal distance between the light spot, formed by the laser beam on the running edge of the rail, and the measuring bar is measured (the light spot is always held at the gauge point, i.e. 12 mm below the upper edge of the rail head). From the measured data obtained, the track gauge and the versines or lateral position of the rails can be determined. Thus, together with the reference level in horizontal direction formed by means of the linear acceleration transducers of the inertial measuring system, continual measurement of the track geometry is effected.

Fig. 1: Plasser & Theurer EM 250 high-speed track recording coach

Refurbishment
The EM 250 high-speed recording coach has been modernised to include the installation of:

— *a new inertial measuring system:* in addition to the old inertial system, which is based on mechanical gyroscope systems and acceleration transducers, a new inertial measuring system - an APPLANIX navigation system working on an optical basis (laser gyroscope) - has been installed, which enables a high measuring accuracy even at low speeds;

— *a new computer system and network:* the measuring, recording and evaluation system of the EM 250 high-speed track recording coach is fully computer-based. The entire processing, registration, kilometre marking and evaluation of the data for the measuring chart and production of track analysis data is performed by means of complex real-time operating, control and evaluation software.

The EM 250 track recording coach has been newly equipped with a combination of modern hardware and a new MS-Windows-NT network operating system, complemented by LAN (Local Area Network), which enables efficient measuring data transmission from the recording coach to the computer network of the Track Division, and vice versa. This enables staff at the regional divisions and permanent way depots to have access, at all times, to the data concerning their sphere of operation, at their places of work;

— *a GPS satellite navigation system:* the EM 250 is now also equipped with a GPS satellite navigation system, working in differential mode. As a sole locating system, GPS allows the civilian user only an accuracy of 30 - 100 metres. If a higher accuracy is required, the signal of a reference station must also be received. Tests carried out in the course of a diploma thesis yielded accuracies of under one metre in a range of 80% of the track network where it is possible to receive the GPS satellite signal [2]. Thus, and thanks to a database holding the track locating data, it will in the future be possible to automatically position the recording coach;

— *an on-line rail analysis system:* in order to be equipped for future demands on the railway infrastructure (opening of the network to other users, freeways, etc.) an on-line rail analysis system has also been installed. It not only enables the automatic classification of the rail type and measurement of rail profile wear, but also allows the equivalent conicity to be determined and recorded on-line via simulation calculations. The ÖBB track recording coach is the only vehicle worldwide that can determine these values, required under UIC approval regulations, on-line in the course of a measuring run.

The measured data obtained by the EM 250 form the foundation for the planning of track maintenance operations. Such operations usually include the application of tamping machines, which are used to re-establish, by lifting and lining, the required target geometry of the track, if faulty. This new track geometry should be produced as accurately as possible, meeting the predetermined parameters for curvature, superelevation and longitudinal level, in order to ensure riding comfort, good dynamics and cost-effectiveness (requirement 1 mm).

The EM-SAT 120 track survey car

The correction values for the tamping machine used to be determined by manual measurements, with an output of only 3 km per shift. Subsequently, the differences to the target track geometry had to be calculated and the correction values for the tamping machine marked manually on the track every five metres. The operator of the tamping machine had to read the values and then enter them by hand onto the computer of the machine. All in all, a very time-consuming process.

On ÖBB, this manual method has now been replaced by using the EM-SAT 120 track survey car, which records the actual track geometry using an electronic laser reference chord. It has a measuring output of 2-3 km/h (Fig. 3).

Fig. 3: Plasser & Theurer EM-SAT 120 track survey car

Also, a track data base has been compiled at ÖBB’s Track Division, which contains all the data on the track geometry, the markings and the state of the track. The data collected by the EM-SAT 120 are entered into this data base, and the correction values for the required lifting and lining are calculated. Subsequently, these values are transferred on data carriers to the ALC automatic guiding computer of the tamping machine, which then produces the required target track geometry (Fig. 4). The EM-SAT 120 thus fully electronically surveys the track.

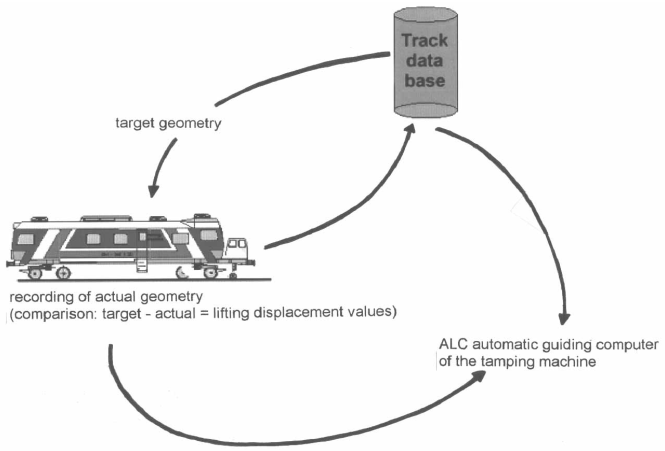


Fig. 4: Data flow from the track data base and the EM-SAT 120 track survey car to the ALC automatic guiding computer of the tamping machine

Conclusions

For reasons of cost-effectiveness, also in the railway sector is the capture (measurement) and handling (data base) of information becoming more and more important. Both vehicles, the EM 250 high-speed track recording coach and the EM-SAT 120 track survey car, are part of a strategy aimed at making ÖBB’s Track Division more efficient and cost-effective.

References

[1] Eglseer F.: ‘Recording track and catenary geometry at 250 km/h’, Railway Gazette International, August 1995, pp. 507-509.

[2] Zolles W., Weber R.: ‘Untersuchung zur Verfügbarkeit von dGPS-Diensten in Österreich’, Thesis, Institute for Theoretical Geodesy, TU-Vienna, Austria, October 1999.

PLASSER & THEURER
EM-SAT 120 TRACK SURVEY CAR

The EM-SAT 120 track survey car offers fully mechanised measurement of the actual track geometry with regard to subsequent track maintenance using tamping machines – one of the last remaining sectors related to track maintenance to be mechanised – by accurately and absolutely simultaneously measuring the longitudinal level and alignment, using laser reference chords.

The four-axle vehicle, which features a self-propelled transfer speed of 120 km/h, comprises a main vehicle featuring a laser beam receiver unit and a separate self-propelled satellite with laser transmitter unit.

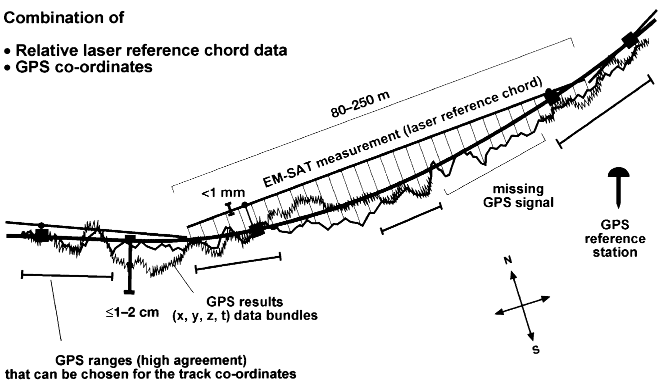
Measurements are taken in a cyclic sequence at an average speed of 2.5 km/h, with simultaneous recording of longitudinal level and alignment. Besides displacement and lifting values (measuring accuracy < 1 mm), superelevation and gauge faults can also be recorded at the same time.

Data interface with the tamping machine
The calculated correction values can be electronically transmitted - by radio or on disk - to the ALC automatic guiding computer of the tamping machine, thus guaranteeing highest precision and, at the same time, preventing any transmission errors which can occur in manual measuring.

GPS navigation system obviates the need for fixed points
The EM-SAT 120 is equipped with a GPS navigation system which obviates the need for marking and subsequent measurement of fixed points on masts, thus further automating surveying work and making it more accurate.

The simultaneous surveying of the actual track geometry using laser reference chords and GPS, makes it possible to transmit the highly accurate relative laser reference chord data in absolute track co-ordinates. Also, in those cases where the actual geometry measured by the laser reference chord and GPS are very similar, the reliable GPS data can serve as support points for the endpoints of the chord; thus obviating the need for fixed points.

For highly accurate GPS measurements (1 - 2 cm) it is necessary to have fixed GPS reference stations (at 10-20 km intervals, e.g. in stations or GPS reference networks).



The integration of Global Positioning System (GPS) technology into the EM-SAT 120 further automates surveying work. In conjunction with the laser reference chord measurements, the GPS data supply highly accurate, absolute track co-ordinates

Cost-effectiveness of the EM-SAT 120
Operating the EM-SAT 120 track survey car requires only two men. As the safety zone of the adjacent track is not infringed either during measuring work, or during set-up and close-down of the vehicle, no look-out men, as previously needed for manual surveying, are required.

	Manual Method	EM-SAT 120
No. of look-out men	2-3	0
No. of supervisors	1	1
No. of surveying staff	3	2
Measuring speed	0.5 km/h (alignment) 0.7 km/h (longitudinal level)	2.5 km/h (simultaneously)
Accuracy (standard deviation)	2-3 mm	< 1 mm
Recording mode	manually	electronically

Comparison Manual Method vs. EM-SAT 120

Advantages of mechanised surveying
Mechanised surveying by means of the EM-SAT 120 track survey car offers certain advantages. For instance:
— it is faster, more accurate and cost-effective than using the manual method;
— it is accurate and, as it measures the alignment and longitudinal level (including long waves) simultaneously, it requires only one measuring pass, as compared to the two required by the manual method;
— it is more error-free in that it eliminates typing and transmission errors: data is transferred directly to the ALC automatic guiding computer of the tamping machine, where it is automatically processed;
— it requires shorter track possessions.

Further advantages, as compared to manual measurement methods, besides the far greater measuring speed and accuracy, is the availability of more additional information on the track in the form of measuring values for gauge and superelevation.

The decisive advantage of the EM-SAT 120 track survery car is the faster, more accurate and lower-priced surveying it offers, as compared to the manual methods still in use today.

Length over buffers	15,940 mm
Height over top of rail	4,275 mm
Width	3,020 mm
Distance between bogie pivots	9,500 mm
Total mass (approx.)	52 t
Engine output	370 kW
Measuring output	2.5 km/h
Speed during transfer travel (max.)	120 km/h

Technical data - EM-SAT 120 Track Survey Car