The EM-SAT 120 Track Survey Car, an integrated part of the track geometry data base of the Austrian Federal Railways ÖBB

One of the last fields of track renewal and track maintenance not yet mechanised was the measurement of the actual track position relative to the subsequent correction work carried out by levelling, lining and tamping machines. The following report presents the results of long years of experience (trials as early as 1985) using the EM-SAT 120 on Austrian Federal Railways (ÖBB).

1 Introduction

One of the central tasks of the Track division (FW) of the ÖBB is to maintain the track in a condition which meets all requirements from the point of view of safety and passenger comfort. The permissible tolerances for the track position are laid down in international standards (UIC, CEN) and ÖBB regulations.

Measurement runs to check and record the actual track position are carried out at regular intervals. If the track position of a certain section no longer meets the technical and economic requirements, maintenance work has to be performed [1]. The use of tamping and lining machines is almost always part of such maintenance. Exact preparatory work and surveying measurements have to be performed to utilise these tamping machines in an economical way.

Since April 2000 the ÖBB (Track division) use three track survey cars (EM-SAT 120) [2] for these surveying measurements.

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2 The EM-SAT 120 track survey car components and function

The EM-SAT 120 track survey car is a well proven recording vehicle for modern track maintenance [3].

The track survey car consists essentially of three units:

▷ the track recording car (EM)
▷ the satellite trolley (SAT), and
▷ the reference point and fixed point measuring unit

2.1 The Track Recording Car (EM)

The recording car (Figure 1) is a self-propelled vehicle. The engine output (370 kW) and the two-axle bogie enable travel at maximum speeds of 120 km/h.

The recording car is equipped according to the latest standard (e.g. clearly arranged operator's desk, comfortable seats, air conditioning unit).

All safety equipment required by the ÖBB (e.g. train radio system) is provided, the external design [4] is attractive.

Fig. 1: Recording car with lifting device for the SAT

The recording car includes a powerful on-board computer, control and receiver devices for laser-chord measurement, distance measurement, track gauge measurement and the positioning cameras, etc.

2.2 The Satellite Trolley (SAT)

The satellite trolley (Fig. 2) is a component of the EM. A lifting device lowers the SAT onto the track and lifts it up again after completion of work. The SAT is equipped with an electromotor to travel forward.

The laser transmitting device (high-quality diode laser with visible red light), as well as the required sighting device may be removed for transfer.

Fig. 2: Satellite trolley

Constant accuracy of the alignment measurement is assured by a device pressing the measuring system against the rail. Furthermore, the SAT is equipped with a detachable cabin for cold or bad weather conditions, a direct radio connection to the recording car and suchlike.

2.3 The Reference Point and Fixed Point Measuring Unit

The fixed point measuring unit (Fig. 3) is used to establish the difference between the actual and target position of the track.

This measuring device is equipped with an inclinometer which measures the actual superelevation at the respective pole base point, and an electronic tacheometer which measures the lateral distance and the height of the fixed point relative to the respective reference rail [5].

The measured data are stored on a chip card (data storage card, Fig. 3a) and transferred from this to the recording car.

The measurement accuracy of 1–3 mm for alignment and level (distances for alignment up to 20 m and level up to 5 m) meet the requirements of the ÖBB.

2.4 Mode of Operation

A laser chord (Fig. 4) is projected between the satellite trolley (SAT) and the actual recording car (EM), then the recording car travels towards the satellite, while a camera records the deviations of the laser beam. Superelevation and track gauge are measured at the same time. When the recording car has reached the satellite, it stops at the pole base point and the satellite moves forward another span; the measuring procedure starts anew.

Here is a brief description of the sequence of work:

1. The target geometry data is read in and prepared.
2. The EM is positioned at the first pole base point (Fig. 4) and the SAT is set down in the track; all preparatory work, such as mounting the laser transmitter and receiver, positioning the measurement axle.
3. The SAT is sent ahead to the next fixed point (Fig. 4).
4. The measuring chord is projected between SAT and EM.
5. The measuring run of the EM to the next pole base point is started.
6. Steps 3–5 are repeated.
7. Measured data are stored and printed while the SAT travels forward.

2.5 Working Range and Accuracy of Measurements

The EM-SAT 120 is applied in the following areas:

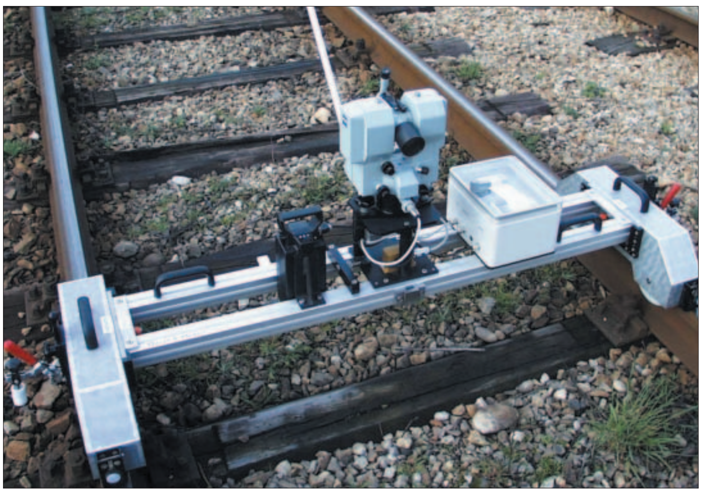

Fig. 3: Reference point and fixed point measuring unit

Fig. 3a: Storage card at the fixed point measuring unit

- ▷ approx. measurement speed 5–7 km/h
- ▷ laser chord length up to 200 m
- ▷ measurement of alignment and level in one pass

The accuracy of measurements is:

- ▷ for alignment and level: + 1 mm
- ▷ for cross gradient (Ü): + 1 mm
- ▷ for track gauge: approx. 1–3 mm
- ▷ alignment versine: max. 1000 mm
- ▷ level versine: max. 400 mm

3 Range of application of the EM-SAT 120 track survey car

The EM-SAT 120 track survey car automates the entire track surveying work on the open lines of the ÖBB (around 2,000 km/year) to a great extent. Track surveying establishes the correction values (displacement and lifting) by comparing target geometry contained in the track geometry data base (GDB) with the actual track geometry data of the track.

Whenever major track renewal work is carried out (around 300 km/year), the electronic recording car (EM-SAT) is used for surveying the track, as well as for performing post measurements at the end of the warranty period. The post measurements of the track are those measurements which are also called control measurements after tamping which have to meet the acceptance regulations of the ÖBB (ZOV 54).

In exceptional cases the EM-SAT is also used to survey individual track faults.

When track maintenance is scheduled, the EM-SAT is used about 4 weeks before the tamping machine. This is to ensure that any preliminary jobs which may be necessary, can be carried out in good time.

4 Data flow and networking

A major requirement for the software package of the EM-SAT was the flow of electronic data (Figure 5) between the track geometry data base (GDB) and the track survey car.

The basis is the track geometry data base (GDB), which is an Oracle data base linked up to a network that has been used successfully by the ÖBB since 1999 [6].

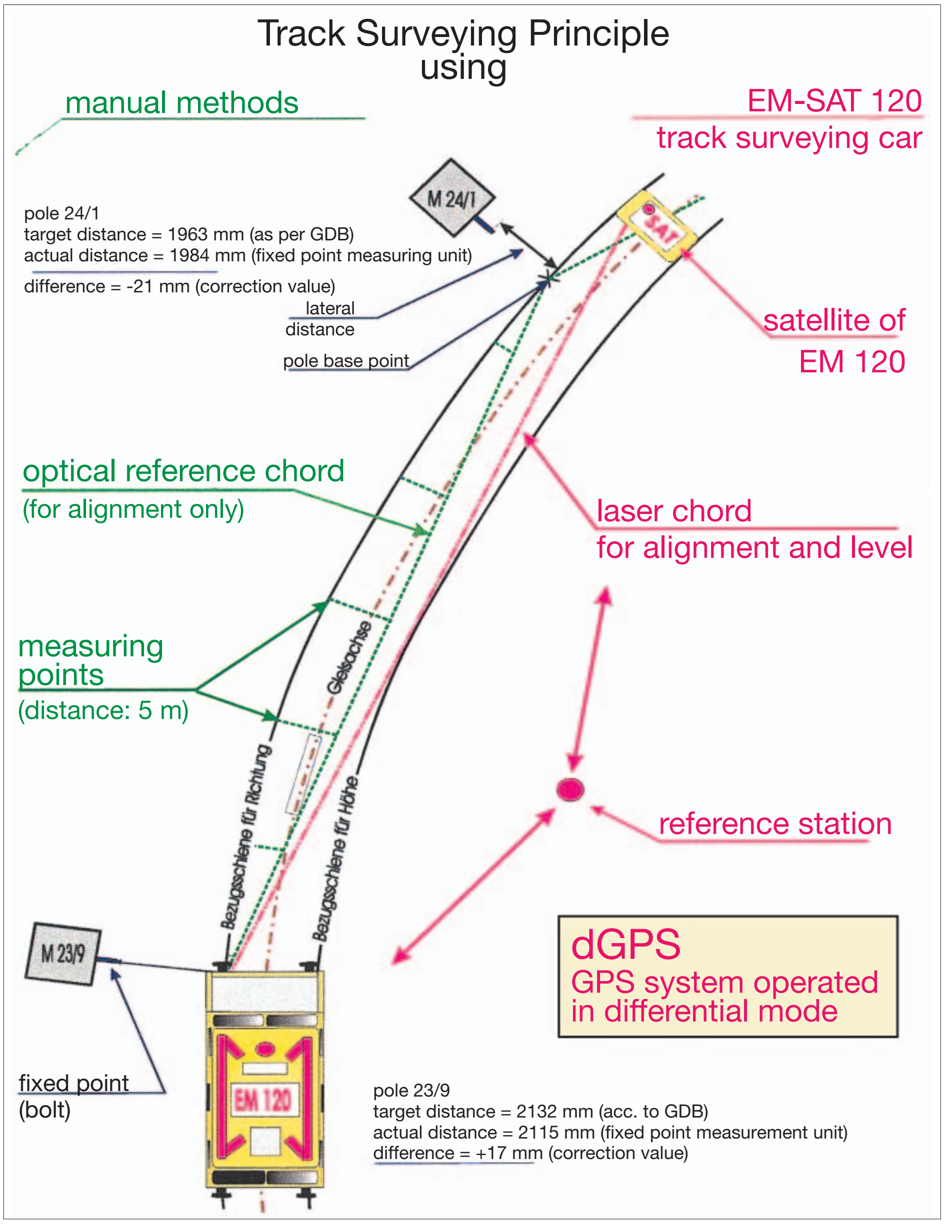

Fig. 4: The principles of track surveying methods

The task of the track geometry data base is to display the entire data flow (Figure 5), beginning from the recording of actual geometry data, up to the control measurement (after work has been performed), and to make a final comparison of the target data and the data of the control measurement, or to support this data flow electronically, as far as possible.

In brief, the track geometry data base is characterised by the following structures and tasks:

Structures:

- ▷ Centralised data base with about 820 users linked up to a network
- ▷ Uniform data structure for alignment and level data of the entire track
- ▷ Localisation of all data in a standardised "frame"
- ▷ Interfaces, particularly:
  - – to and from the track survey car (EM-SAT 120),
  - – to electronic logbooks for recording and reconstruction
  - – to evaluation programs (RPA, RLA) and coordinative calculation tools.
  - – to all heavy-duty permanent way machines equipped with the automatic guiding computer (ALC), from the DOS 2.43 version

- from the dynamic track stabilizer (DGS) ➞ control measurement for acceptance, using an 8-channel recorder
- to and from other permanent way applications, such as: VzG (table of admissible speeds), existing permanent way elements, settlement of accounts for an order, etc.

▷ Tasks:
- administration of measured data (data recorded by electronic logbooks and levelling devices)
- administration of project data (to make measured data available via interfaces to the individual evaluation tools, such as: computer-aided versine and longitudinal level evaluation programs, as well as coordinative calculation programs ➞ to take calculations of variants and projects back into the GDB).
- administration of released data (after a version has been selected from the projects it is released for implementation ➞ not visible on the data base surface until now)
- administration of data on existing tracks (all track geometries existing for tracks and switches, for level and alignment, are stored in this data base section and, if necessary, are available to any user of the data base; by mid 2000 about 95 % of all main lines and about 75 % of all secondary lines had been recorded)

▷ reports and lists available from the GBD:
- table of all required alignment data (BVZ)
- table of all required level data (LHVZ)
- various work lists necessary to establish target geometry manually on the spot
- acceptance lists for all control measurements
- list of reference points (all fixed points are contained in this list)

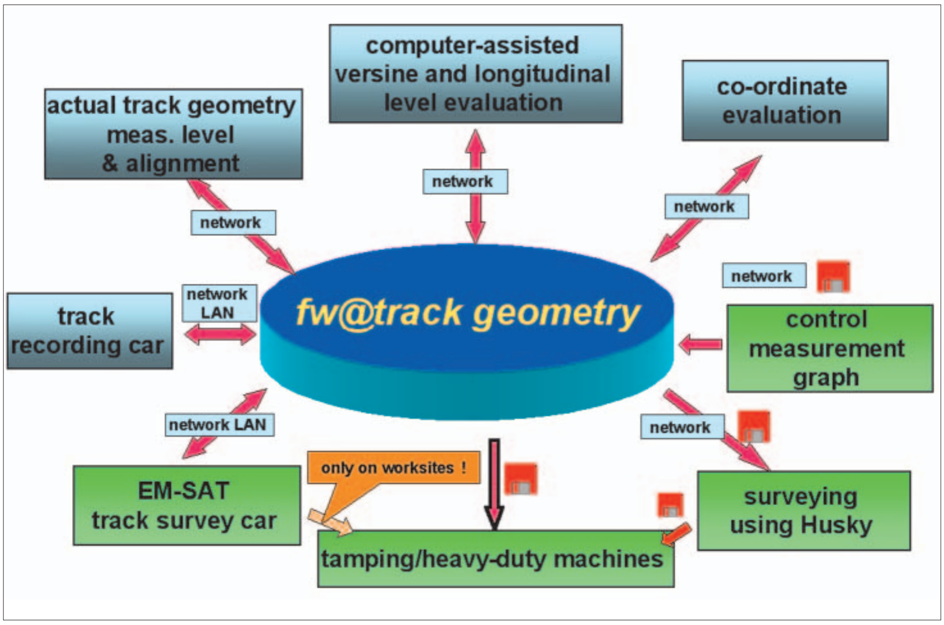

Fig. 5: The electronic data flow

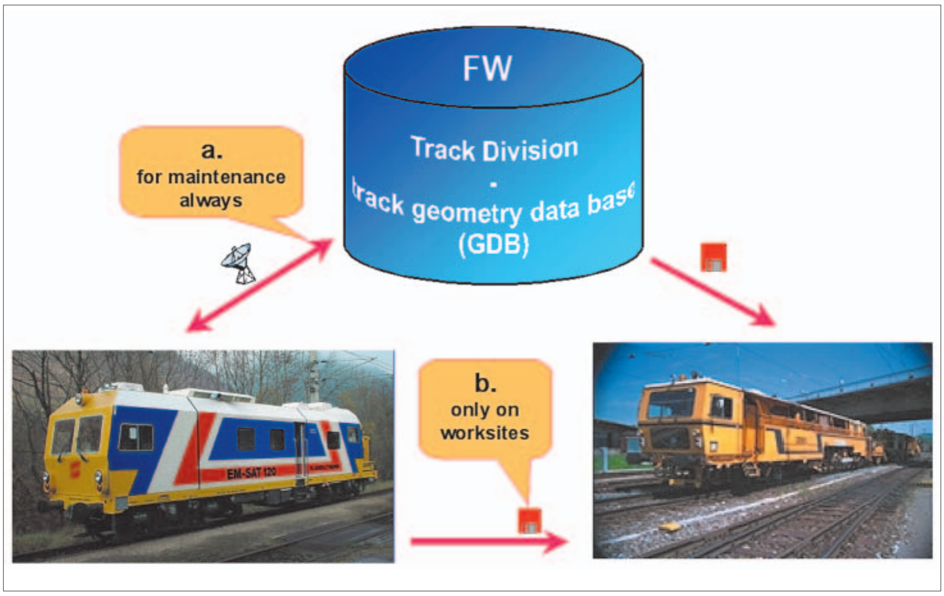

Fig. 6: Electronic integration of the EM-SAT 120

In addition there are some special modules, such as:

▷ Import of coordinative calculation data into the structure of the GDB,
▷ Conversion of location of all data from track axis to running edge and back,
▷ Automatic consideration of all fault profiles and location compensations, as well as
▷ speed investigations with freely selectable parameters

These data are stored on electronic data carriers and transferred to the track geometry data base via the TrackLAN or note-books.

The correction values (Figure 7) calculated for maintenance tamping are always transferred to the track geometry data base.

In the case of major renewal projects where the EM-SAT is used, data may be transferred directly from the EM-SAT to the tamping machine, if intermediary tamping runs are required.

5 Data Evaluation

Due to the networking (Figures 5 and 6) the calculated correction data are available to all data base users immediately after they have been entered in the data base. A simple evaluation tool allows the track engineer or district inspector to view these data and, if necessary, to adapt them. As soon as he releases these data to be implemented in situ, the district inspector accompanying the tamping machine can retrieve them from the GDB (a simple telephone connection is sufficient).

Another advantage is that these correction values of the GDB (a sub-module) offer the responsible technicians / district inspectors exact estimates of costs and materials (such as expected costs of the

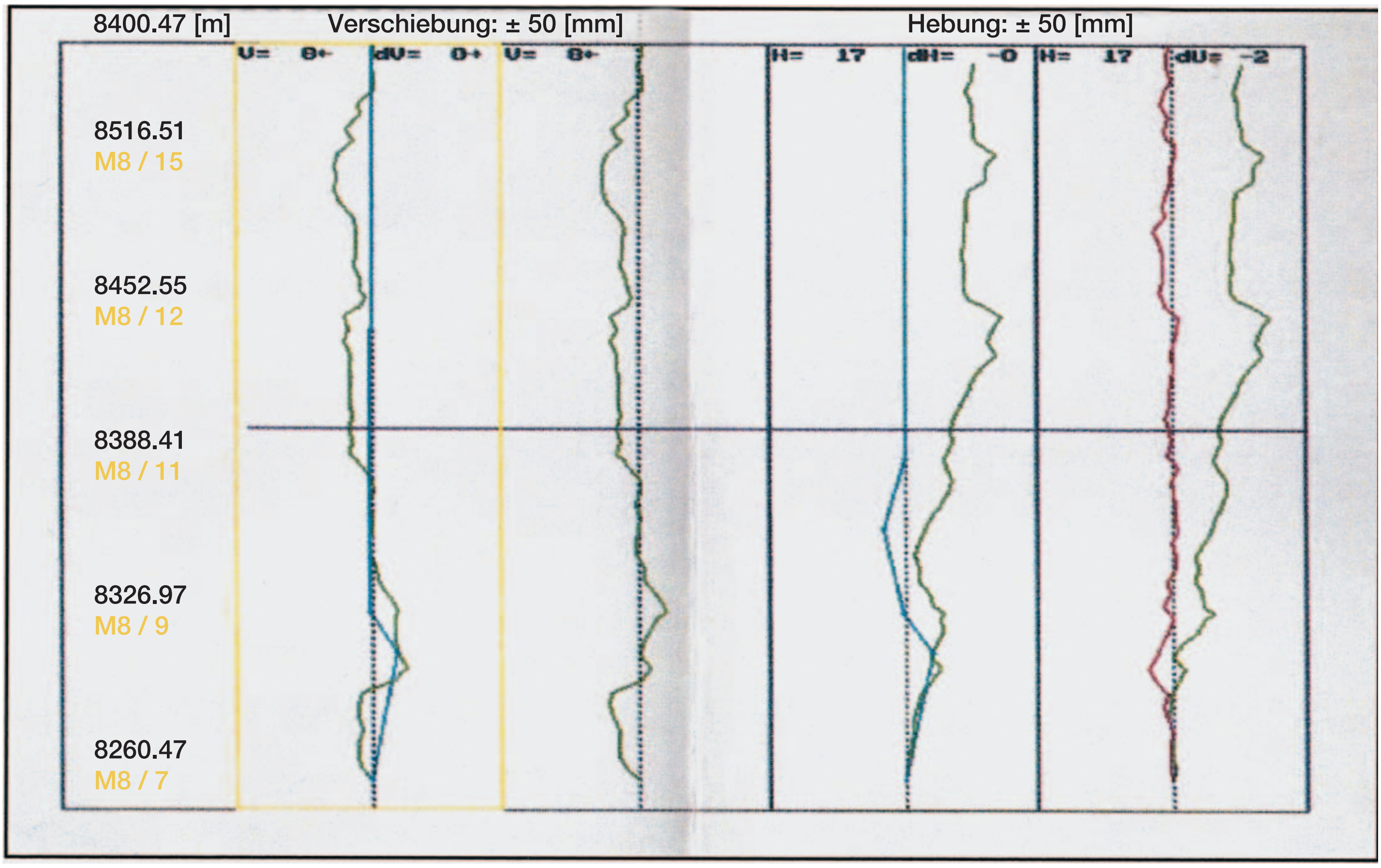

Fig. 7: Graph of the correction values in the track survey car

entire tamping work, expected ballast quantities required – on the basis of the lifting values). Furthermore, it is possible to correct the data about the initial / end point of the section to be tamped. With the „Track“ data base it is also possible to make a quick comparison with the latest data measured by the track recording car (EM 250).

All correction data for worksite tamping are stored and entered into the track geometry data base. The differences of individual correction values are required as proof why the ballast bed has to be inserted layer by layer (maximum lifting value per tamping pass: 80 mm).

The ÖBB do not intend to change the correction values or determine a new target geometry using the EM-SAT, however, according to the manufacturer this should be possible.

6 Benefits

The application of the EM-SAT 120 offers the following multi-dimensional advantages:

- ▷ Due to the high measuring accuracy of the EM-SAT, the tamping machines are able to work faster, with greater precision and, thus, more efficiently [7]. Furthermore, measurement errors (e. g. reading, calculation or writing errors) which occurred in manual measurement, are excluded.
- ▷ No look-out men are required when the EM-SAT is used. The worksite track is closed, no measurements are required for the adjacent track.
- ▷ The required target geometry for alignment and level is always re-established. Thus, the track is always held in its optimum position. Stresses (longitudinal and lateral forces) are quite low and are kept within the required range.
- ▷ Optimum use of the EM-SAT allows the limited funds available for maintenance to be used very economically. Costs for surveying could be reduced by around € 0.5 per running metre compared with the former manual methods.
- ▷ Another advantage of the EM-SAT is that most of the fixed points in the track are no longer needed and therefore do not have to be maintained. The potential savings of expenditure here amounts to a further € 0.45 per running metre.
- ▷ An output per shift (10 hours) of about 5–7 kilometres is possible due to the high measuring speed of the EM-SAT. A manual surveying gang achieves about 4 km per shift.

Today the ÖBB (Track division) are the European leaders in this field, thanks to the combination of fully automated track surveying and the track geometry data base.

7 Outlook

In cooperation with Plasser, a dGPS satellite navigation system (differential Global Positioning System) is being added to the equipment of the EM-SAT track survey car. The combination of two measurement systems (Figure 4) – the high-accuracy laser measurement and the dGPS – enables the existing track geometry to be recorded also by coordinates. The measured data are transmitted to the track geometry data base and processed there using the respective evaluation programs.