IM2000 Infrastructure Measuring Car: the application of recording results

In 1999, in order to improve maintenance management decision making, Spoornet placed a contract with Plasser Railway Machinery (South Africa) Pty. Ltd. (Plasserail) to supply and operate a recording car capable of measuring track geometry, catenary and rail parameters. This resulted in the development of the highly sophisticated IM2000 Infrastructure Measuring Car which, since August 2000, has been working on freight, heavy-haul and commuter railway lines in South Africa. This article first looks at the parameters recorded by the IM2000 and, then, at how the results obtained are used for maintenance management decision making.

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The IM2000 Infrastructure Measuring Car
The fully air-conditioned IM2000 Infrastructure Measuring Car (Fig. 1) features a driver's cab at each end, a basic kitchen, a work area, and an office area with flat-screen monitors enabling real-time observation of measuring results.

The IM2000 is self-propelled by two Detroit V8 diesel engines driving through power shift transmission. An auxiliary generator powers the on-board computers, lighting and air-conditioning. It carries a full-time crew of four, including a pilot from the client, and is capable of measuring at speeds of up to 120 km/h. On Spoornet and Metrorail, though, a measuring speed of 90 km/h is used.

The IM2000 measures, processes and stores data concerning the condition of the track geometry, the catenary and the rails.

Track geometry parameters
The IM2000 receives inputs from its core Position and Orientation System for Track Geometry (POS/TG), which consists of an Inertial Measuring Unit (IMU) and the POS Computer System (PCS) with embedded Global Positioning System (GPS) receiver.

A Distance Measurement Indicator (DMI) and an Optical Gauge Measurement System (OGMS) using laser beams are used to provide the POS/TG with accurate distance-travelled and half-gauge measurements. The latter measurement is used as the reference to the rails.

The IMU and other track measuring units are mounted to the axles of the bogie; this allows tracking of the rail surfaces and accurate computation of the track geometry parameters. The POS/TG also provides a full set of navigation outputs, i.e. position, velocity, altitude, angular rate and acceleration of the bogies. Unlike conventional gyro systems, the POS/TG provides these outputs under all dynamic conditions. The POS/TG system is compact and lightweight, very accurate, requires little maintenance, has a high immunity against GPS dropouts, thus allowing continuous recording, and is capable of working at lower speeds.

The IM2000 records track geometry parameters at 250 mm sampling frequencies, i.e.:
— *profile of the left and right rail:* variation in the vertical plane of the rail along its length;
— *cant/superelevation:* the difference between the vertical height of the left and right rail;
— *alignment/versine of the left and right rail:* variation in the horizontal plane of the rail along its length;
— *gauge:* difference between design (specified) gauge and actual gauge.

Specific events, such as the presence of bridges, level crossings, splice joints, etc., may also be recorded by pre-programmed manually operated buttons. This information is kept on a database for access during future measuring runs.

Fig. 1: IM2000 Infrastructure Measuring Car

Catenary parameters
The catenary condition monitoring system of the IM2000 has been developed by Spoornet Engineering. It uses a specially adapted pantograph that allows the continuous measurement of the catenary. The roof-mounted system, which can measure under both 3 kV DC and 25 kV AC power supply, makes use of fibre optic equipment to transfer signals to and from the control computer. The system can be activated, calibrated and de-activated from inside the car, thus making it safe and easy to operate.

The following catenary parameters are measured:
— *vertical force:* the deviation of the actual vertical force from 80 N. A kink in the contact wire will, for instance, cause a sudden increase in vertical force, which indicates the presence of a defect;
— *longitudinal force:* the force experienced by the pantograph in the direction of travel. A badly aligned section insulator will, for instance, cause a sudden longitudinal force on the pantograph, thus indicating a defect;
— *contact wire height:* the actual height of the contact wire is measured;
— *contact wire slope:* the rate of change in contact wire height between mast poles;
— *horn contact:* if the contact wire touches the horn on the pantograph, a defect is recorded;
— *contact wire stagger:* the zig-zag of the contact wire, from mast pole to mast pole;
— *no stagger:* if no stagger is detected for more than 150 metres, a defect is recorded.

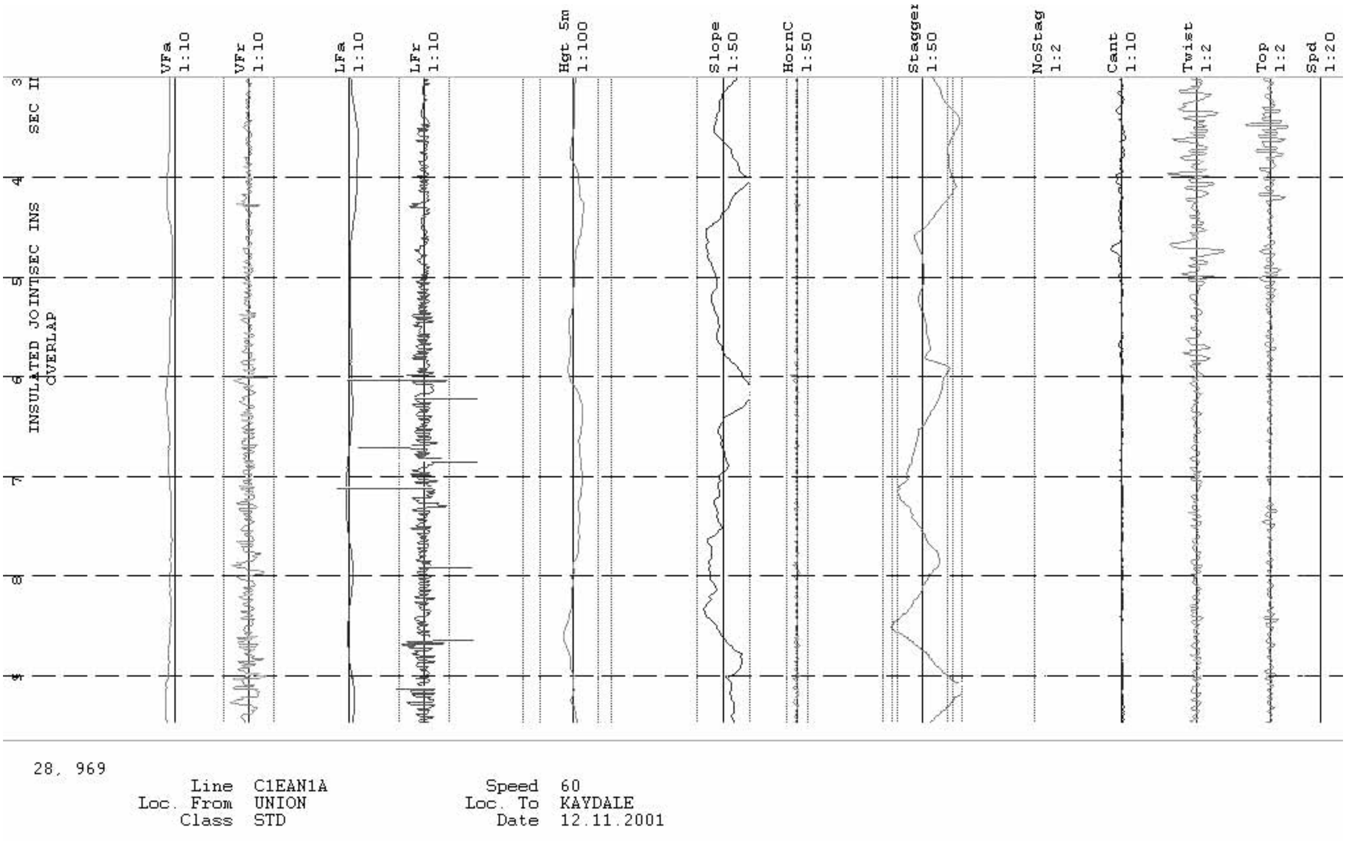

Fig. 2: Stripchart of catenary measurement results

The catenary parameters are measured at the same time as those of the track geometry, also at 250 mm sampling intervals. The main advantage of this simultaneous measurement is that seemingly catenary defects actually caused by track defects can be separated. Processing of the data recorded is carried out in real time.

Rail parameters

The IM2000 is equipped with the Orion rail profile and wear measuring system which, by means of a real-time optical laser system, is capable of carrying out measurements at speeds of up to 120 km/h. A laser creates a plane of light that surrounds almost the full rail profile. Using a high-resolution camera, the image of the full rail profile is acquired, which is then converted and analysed by computer, and the extent of rail wear is calculated. Measurements can be taken at various sampling intervals (from 2 metres upward).

The rail parameters measured are:

— deviations from the 1:20 rail angle on both left and right rail;
— crown wear on both left and right rail (a vertical measurement);
— side wear of both left and right rail, measured 14 mm under the crown on the gauge side of the rails (a horizontal measurement);
— 73° crown wear on the gauge side of both left and right rail.

Use of recorded data for maintenance management

At the end of the day, the data recorded on the hard-disk of the on-board computer is written to a CD-ROM, which Plasserail retains for post processing. Within seven days, the processed results are provided to Spoornet, in a file type that meets its requirements, where they are uploaded into its Infrastructure Applied Maintenance Management (IAMM) system. The information is now available to both infrastructure management at head office level, as well as at depot level.

Plasserail produces various reports in table and graphic formats, some of them unique, for use by the client, such as:

— *Stripcharts and Single Exceptions Reports:* three of these are produced in real time (geometry, catenary and rail wear), and immediately made available to the client at the end of the measuring day (Fig. 2).

The Stripcharts feature all the parameters measured, with threshold lines indicating 'B' and 'C' standards: 'A' is the required standard. 'B' is a deviation from the standard, and 'C' is a deviation requiring an urgent repair. The scale of the graph is also provided, which allows maintenance staff to establish the size of the defect.

The Single Exceptions Reports reflect, among other things, the exceeding parameter (i.e. alignment, twist, etc.), the maximum deviation in millimetres, and the location and the percentage of exceedence. The client will usually further process these details by categorising the exceedences from large to small to determine the order of priority.

Depending on the management style at the depot, the Stripcharts and Single Exceptions Reports may immediately be used to locate and rectify priority defects. Alternatively, action may be held back until the processed data has been received from Plasserail. Usually, the maintenance manager will embark on a trolley inspection to investigate the defects found by the IM2000;

— *Recurrence of Exceedences Reports:* these are graphs that display the location of defects exceeding the C-standard over six measuring runs. The recurrence of an exceedence tells the maintenance manager that either maintenance has not been carried out or, if it has been, that there is still an underlying problem which has to be resolved first, in order to ensure durability of maintenance activities. Thus, the Recurrence of Exceedences Reports provide immediate information concerning the natural maintenance cycle of an area, the location of built-in defects, neglect by maintenance staff, etc.

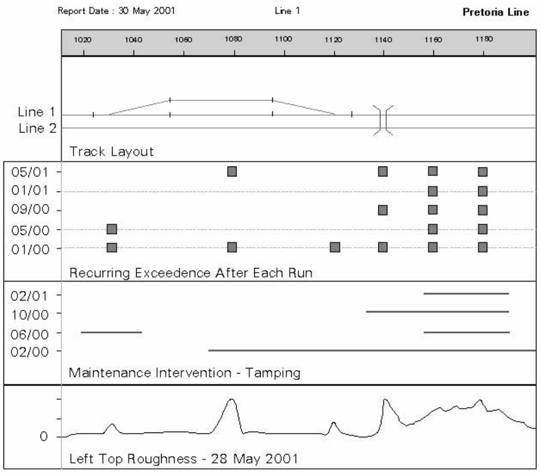

Fig. 3: Recurrence of Exceedences Report

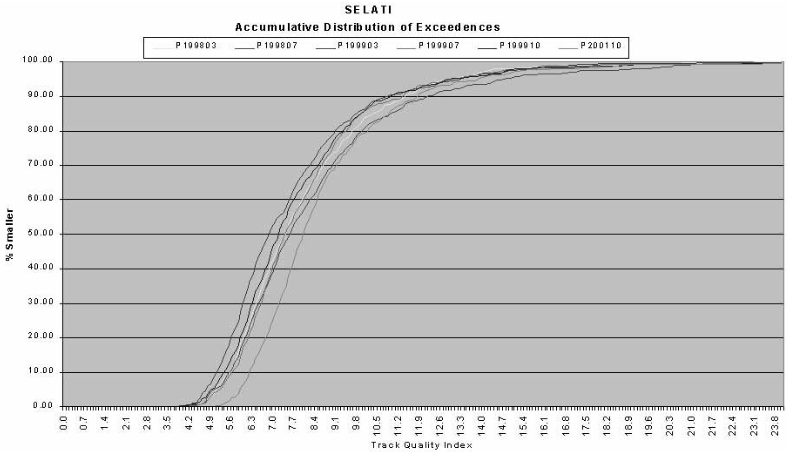

Fig. 4: Accumulative Distribution of Exceedences Graph (S-curve), as yielded by six different measuring runs

To evaluate the recurrences, it has become popular to display the graph together with other data, such as track layout, maintenance interventions, etc., as illustrated in Fig. 3. Where already available, information from the Fli-map system is also incorporated (Fli-map is a helicopter-based laser-scanning system used to capture three-dimensional terrain features of the track geometry in digital format);

— *Zone Reports:* these reports are used by the maintenance managers as a monitoring tool to timely predict the requirement of maintenance inputs. Zone Reports, provided in table format, reflect a vast amount of information, such as standard deviations of the parameters measured, track quality indices (TQIs) and ride quality indices (ADAII).

The Zone Reports are supported by various graphs, one of which is the extensively used Accumulative Distribution of Exceedences Graph (an S-curve), shown in Fig. 4, which is produced per track section. It shows the percentage of track section that features a value below that of a specific TQI value. This is a valuable tool for maintenance managers, since it indicates improvement, or deterioration, in track quality over the past six measuring runs. Of particular interest to management is the trend in the 10%, 50%, 90% and 100% monitoring zones of the curve (see Fig. 4), i.e. the geometrical monitoring zones (GMZ):

— 10% zone: no maintenance is required in this area (assuming that the general condition of the track section is within standards). This area is monitored to ensure that exceedences are corrected at least as fast as the good track deteriorates;

— 50% zone: the preventative mechanised maintenance programme is planned around this area. Deterioration (a movement of the curve to the right) implies that insufficient, or ineffective, mechanised maintenance is applied;

— 90% zone: these are priority areas (requiring urgent repairs), which are usually corrected by manual methods. Deterioration shows insufficient input;

— 100% zone: this zone reflects built-in defects;

— *Curve Analysis Reports:* these list the characteristics of the curves, derived from the data collected during measuring runs, and include information such as radii, transition lengths, rates of change in transition curve offset, and superelevation. The Curve Analysis Reports are used in order that the natural characteristics of the curves (i.e. where the train will tend to move the curve to), as opposed to the design characteristics, are retained during maintenance tamping;

— *Turnout Zone Reports:* these feature data concerning turnouts such as standard deviations measured, turnout geometry quality indices, and ride comfort indices (ADAII).

The Turnout Zone Reports are used to plan maintenance inputs and turnout replacement programmes;

— *Tamp Model Reports:* these reflect the standard deviation of profile (top) per 200-metre track sections, which enables the user to identify track sections requiring tamping inputs. The client decides on cut-off indices, depending on the importance of the line. For instance, on Spoornet's heavy-haul lines the cut-off is a standard deviation of 1.6;

— *Rail Profile Reports (Curves):* these list the radius, the location, and the rail side and crown wear on both rails of curves. This data, together with the results of ultrasonic measurements and historical rail break data, is used to plan the grinding and replacement programmes of rails in curves.

Various other reports are produced that can either be used directly to rectify defects, or be used by management for budgeting and planning purposes.

Conclusions

The IM2000 Infrastructure Measuring Car is used to annually measure approx. 40,000 km of line owned and operated by Spoornet. It is also used on the lines of Metrorail, owned by the South African Rail Commuter Corporation (SARCC). On lines featuring no electrification, only track parameters are measured.

If one considers that 25 to 30% of the total annual operating costs, and up to 70% of the total life-cycle costs of a railway is spent on maintenance, the influence of good maintenance management should not be underestimated.

The IM2000 is a valuable tool if the product produced is used to capacity, Spoornet and Metrorail are striving to achieve maximum benefit from it, by using the results measured for:

— locating and prioritising spots that require corrective maintenance (short-term maintenance planning and priority work);

— planning mechanised maintenance programmes (routine maintenance);

— track condition monitoring: by superimposing the graphs of several runs of the vehicle, the extent of track condition degradation is determined;

— indicating to managers the need to intensify and, in some cases, even to reduce financial investment in certain areas, by imposing minimum and maximum thresholds for track condition;

— auditing the effectiveness and quality of maintenance work performed.

In an ever-increasing cost-conscious environment the IM2000 Infrastructure Measuring Car ensures economical measurement of track and catenary condition.