# A development in the management of absolute track geometry

**Track engineering consultant Richard Spoors describes some newly-developed equipment for the task.**

The successful management of track geometry is a key aspect in the asset management of rail infrastructure. Today, the ballasted track system on main lines, especially where the line speed exceeds 100 miles per hour, has been designed for strength and durability. It is maintained for a maximum whole life by timely interventions as its geometry degrades through use.

These planned interventions to maintain geometry are executed by computer-guided, on-track tamping machines, where there are two principal modes of operation - reference geometry and absolute track geometry.


**Figure 1: Plasser & Theurer EM100VT at St. Valentin during the test run.**

## Reference geometry

Reference geometry requires no knowledge of the original track design. The tamping machine is provided with a mileage that requires improvement, together with information regarding any locations where lifts and slues are limited. A straight section of track is located immediately prior to the start mileage and a start position is marked on the track. The machine then travels through the track to be maintained, recording the geometry. It then returns to the marked starting position and the machine supervisor analyses the recorded geometry and selects an ideal new alignment, limiting the maximum slues and lifts generally to +/- 25mm or as instructed by the client.

Once selected, the machine commences work, smoothing the defects and effectively installing a new design, respecting the existing geometry definitions, where present, such as the top and bottom of transition curves, the curve radius and cross level. A disadvantage of this method is that it fails to totally correct longwave faults in an alignment greater than the measured chord length between the machine's bogies. On a Plasser & Theurer 09-3X, for example, this would be 15 metres. Furthermore, over time and with successive interventions, the original design geometry can be lost as transition lengths move and curve radii are changed. Examples of overshot curves and poor alignment either side of level crossings are frequently seen when looking at long focal length photographs or videos of trains. These are a consequence of reference tamping. Therefore, the durability of reference tamping is limited until the defects, that have only been partially removed, return. Furthermore, the infrastructure manager will find it necessary to frequently measure clearances to structures, overhead line masts and the six foot to ensure the safe lateral and vertical position of the track.

## Absolute track geometry

Absolute track geometry differs from reference geometry in that the modus operandi is to preserve the original design geometry for the life of the track. Each maintenance intervention is more expensive. However, over the track life there are less interventions. It is more expensive because, before each maintenance activity, the track must be surveyed, but this is counteracted by a longer asset life as the track is maintained to a constant geometry. With less tamping, ballast life is increased. Absolute track geometry needs a through alignment design file and fixed points alongside the track at 40 to 50 metre intervals. The through alignment design is set to each fixed point (usually, a spigot screwed to a mast about 1 metre above the ground facing the track) with x, y and z coordinates. When the geometry needs to be corrected, a survey is undertaken to establish where the track is in relation to the fixed points. A comparison between the survey results and the design geometry (the through alignment design) enables a lift and slue file to be calculated and input to the tamping machine's guidance computer. This computer also holds the through alignment design such that, when the machine commences work, it restores the geometry to the design and eliminates any longwave defects. It is, of course, critical that the machine commences work at the correct longitudinal point, to an accuracy of 100mm.

In Europe, the whole of the Austrian and Swiss rail networks are maintained by the absolute track geometry method, as are some classic lines in Germany, German high-speed lines (where ballasted track is used), parts of the Italian rail network and the French TGV lines. Here in the UK, absolute track geometry is applied to the ballasted sections of HS1 and the fast lines of the West Coast Main line where Enhanced Permissible Speed (EPS) is authorised.

## Surveying for absolute track geometry

In the 1990s, techniques were developed in Austria and Switzerland to bring manual optical surveying of track, including the offsets to spigots into on-track machines. Matisa developed its 'Palas' system, which is designed to be integrated within its tamping machines while Plasser & Theurer opted for a system that more closely replicated the principles of long chord manual track surveying used by the engineers of the German and Austrian railways. This was the independent EM-SAT track recording car that used a small satellite trolley to generate a laser beam in order to measure longwave faults in height and alignment on plain track and switches. Equipped with three measuring axles, the EM-SAT has an average output of 2.5km/h and takes measurements every 200mm. Data is transmitted to a tamper by radio or on a USB stick and, when equipped with an eight-channel recorder, it can be used for track acceptance measurement after renewals.

Two EM-SAT machines were purchased by Network Rail to be used on the upgraded EPS routes of the West Coast Main line in 2003. Whilst they were very accurate, measuring track to an accuracy below 1mm, the way Network Rail chose to use them, outside the main contract for on track machines, made their use expensive.

Manual surveying of track was also being developed during the early years of the new millennium with the adoption of a total station surveying instrument on a trolley. The track geometry was then surveyed by walking down the track, placing targets on the fixed point spigots. Within 10 years, as digital data management developed, so did this concept, including the use of GPS, so that today with modern surveying trolleys, such as the Amberg Tamping GRP 3000, it has become the preferred method of surveying in the UK to manage absolute track geometry. However, it is a slow process where the best rate of surveying is 1.2km/h and requires track possessions and the associated resources.

The challenge for the future maintenance of routes to absolute track geometry with line speeds at or above 200km/h is to


**Figure 2: The stereo laser scanners fitted to the EM100VT.**

find a survey method that manages the conflict between speed of survey, cost and accuracy. A recent piece of research undertaken, and available as a free source on the internet[1], claims to have improved the speed of trolley surveys that include a reference to fixed points to 2.5km/h by integrating an inertial navigation system with the geodetic surveying apparatus. What if an accurate method could be found that increases the survey speed to 100km/h?

## The EM100VT survey car

Railway engineers, who have been fortunate to attend recent exhibitions at Münster (iaf) and Berlin (InnoTrans), will be aware that Plasser & Theurer has decided to invest in digital technology to support the development and utilisation of its wide range of on-track machines. The company has adopted four work streams within which there are more software developers than engineers! One of these work streams is to develop the ability to read targets on lineside fixed points using stereo digital cameras with a recording speed of up to 200 frames per second.

In order to develop the hardware side of this new technology, Plasser & Theurer decided to use one of its EM-SAT vehicles already authorised for 100km/h operation. The actual car, built in 2000, has been fitted with two lateral digital video cameras (see Figure 2 above) and one of the bogies has been modified to receive the necessary track survey scanners and sensors to record the longitudinal, horizontal and vertical track geometry. In the roof of the car is a GPS receiver. A second feature of the car is that it has been fitted with the most up-to-date point cloud 3D laser scanning cameras, together with infrared cameras and colour cameras to ensure the comprehensive photo documentation of the line. Together with Ground Penetrating Radar (GPR) sensors detecting the lower edge of the ballast, a 3D model of the entire line surroundings is captured. This is being developed to create a 'digital twin' of the infrastructure that can be used to optimise the life-cycle management of the infrastructure sustainably and holistically.

The EM100VT is not quite ready for production and, each month, the software that records the lateral offsets to the fixed points is tested when the car runs along a section of the line between Vienna and Linz. One of the first challenges for the team was the design of the fixed point on the mast together with the ability to read it accurately at speed. A section of line was chosen with the cooperation of Austrian Railways between Amstetten and St. Valentin on the classic twin track bidirectionally signalled route. The section chosen is approximately 800 metres long and includes curved track with transitions. A total of 43 masts are surveyed together with the geometry and this is referenced to a survey undertaken with an EM-SAT. Survey line speed has been gradually increased in parallel with modifications to the software and four varieties of fixed point designs. On 13th December, I was invited to join the car on a test run. Two runs were made, the first at 80km/h and the second at 100km/h. As each of the 43 fixed points is passed, a screen in the operator's cab shows the results of the survey in real time. When a fixed point is missed, this is shown on the screen by a colour difference.

Good progress is being made. However, as with all projects requiring reliable and stable software, there is still some work to be done. A precision between successive test runs of between 0.1 and 0.2mm has been achieved. The design of the fixed point target has been decided and the digital video stereo camera is successfully recording lateral dimensions at 150 frames per second. The means by which the track geometry is recorded by the bogie is proven. The relationship between this recorded geometry and the dimension to the fixed point is synchronised by a digital clock. By comparing the results of each test with the pre-recorded EM-SAT survey, the success of the project can be measured. It is hoped to declare the production accuracy of the measuring system in early 2019.

In parallel with the project work in Linz, a second development is taking place in Italy. Through a joint cooperation with RFI (Rete Ferroviaria Italiana - the Italian railways infrastructure manager), one of its on-track machines has been fitted with two sets of stereo digital cameras (they have fixed points on either side of the line) and the test results are reported back to Linz.

Once in production with both fixed point surveys and 3D point cloud laser scanning operational, the EM100VT enables lines with overhead electrification masts as fixed points to be surveyed. By importing the survey data into a design package such as Bentley's Rail Track, a TAD can be created enabling the future maintenance of the line to be managed as absolute track geometry.

## Summary

Accurate track surveying is key to the management of track assets, whether undertaken by on-track machines or digital surveying instruments. Referencing surveys to lineside fixed points is also an integral element in producing maintenance plans that will eliminate longwave defects and maximise track asset life at the lowest whole-life cost. The new EM100VT survey car from Plasser & Theurer has the potential to create a step change in this aspect of rail infrastructure management.

The author would like to thank Plasser & Theurer for access to its test run on 13th December 2018.

Reference 1: https://www.mdpi.com/1424-8220/18/2/538/pdf

*All photographs by the author.*

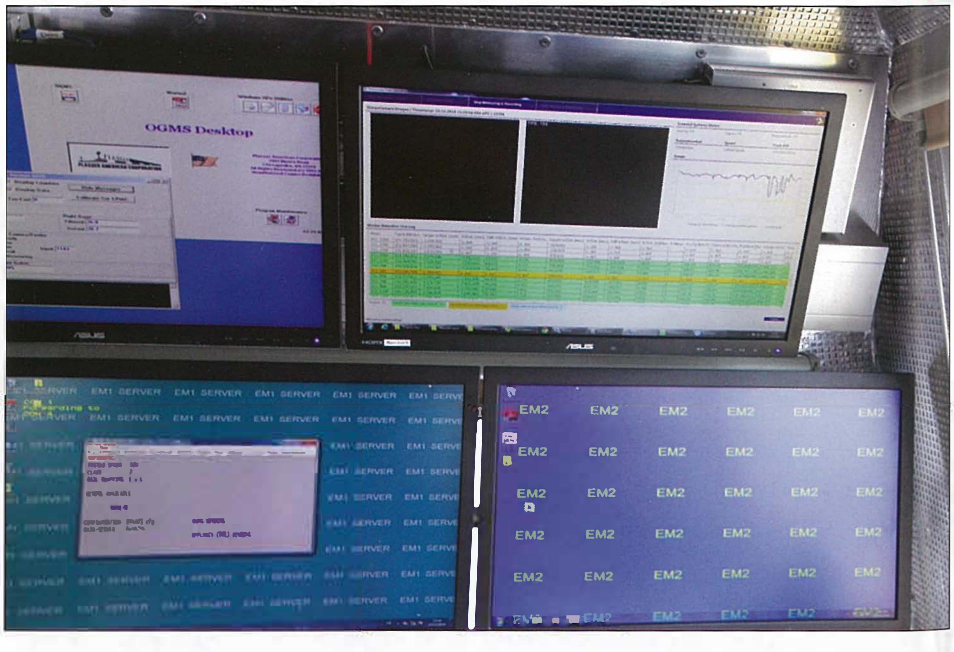


**Figure 3: Recording the results on 13th December 2018 at 100km/h.**