Network Rail’s Train-borne Infrastructure Condition Monitoring Fleet

Presentation to the IMechE, Worcestershire Branch
Paul Richards, 15 November 2016
About me - a quick resumé

Chartered Engineer (MIMechE) with 18 years working in the rail industry

Career history to date:

► Current – Ricardo Rail: Senior Consultant working on infrastructure and rolling stock engineering consultancy projects.

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About Network Rail

- 31,000 km track
- 12,000 km electrified railway
- 2,500 stations
- 35,000 staff
- 2015-2016 turnover was £6.098bn
- 24,500 trains run per weekday
  - Fastest growing railway in Europe
  - Twice the number of trains that are run in France over a network of similar size
- Delivering £38bn of modernisation and improvements in 2014-2019
- Passenger numbers continue to increase - capacity is a challenge!
  - 400,000 more passengers are carried per year than in 2009
  - 1.7bn passenger journeys are made each year – double that of 1995
About tonight’s presentation

I will aim to give you an insight into the weird and wonderful world of the Network Rail infrastructure condition monitoring trains that can be seen running over the whole of Britain’s railway network.

Topics that I will cover:

► Purpose of the infrastructure monitoring fleet, including examples of the types of infrastructure defects that they can detect
► Fleet overview – size of fleet and operations
► Slow speed fleet – rail defect and structure gauging
► Medium speed fleet – track geometry recording and Plain Line Pattern Recognition
► Specialist vehicles – Multi-purpose Vehicle and New Measurement Train
► Maintenance and operations
► Future of train-borne infrastructure condition monitoring
Purpose of the fleet

Network Rail owns and operates a fleet of twelve infrastructure condition monitoring trains, each of which is fitted with a variety of different measurement systems.

Their purpose is to collect infrastructure condition data, removing the need for manual inspection, which offers the following benefits:

- Improved workforce safety
- Higher productivity than manual inspection
- More reliable detection of faults with improved accuracy
- Improved network safety
- The capability to measure at line speed allows infrastructure monitoring trains to be pathed within the normal timetable
Fleet categorisation

For operational purposes, the fleet has been categorised according to the speed ranges over which they can measure.

Slow speed fleet

- Speeds are restricted as a result of limitations imposed by the instrumentation used for the measurements, or by the need for high output data resolution
- Whilst transiting and not recording, the trains can run at normal speeds

Medium speed fleet

- This category of train forms the largest proportion of Network Rail’s fleet
- These trains are generally more versatile than the slow speed fleet

There are also two specialised trains which we will consider towards the end of the presentation.
Slow speed fleet – Structure Gauging Train

Measures a profile around the vehicle using Balfour Beatty LaserFlex™ laser surveying equipment to detect obstacles within its field of view. The data obtained is used for the following purposes:

- Bridge and tunnel profiles, and any movement of these between recording runs which may indicate structural deterioration
- Platform heights and offsets
- Lineside vegetation management
- Rail vehicle gauge clearance

Origins

- A visible light measurement system was introduced by British Rail in 1986 on a purpose-built optical car. This was replaced with a laser system.
- The optical car has in recent years been replaced by an inter-vehicle mounted deployable installation. A second SGT will soon be in service.
- Operating speed up to 20mph, at night to minimise light interference.
Structure Gauging Train

The current Balfour Beatty LaserFlex™ measurement system offers considerable advantages over the visible light system:

- Less susceptible to errors caused by other light sources
- Greater accuracy
- Smaller footprint
Ultrasonic Test Units (UTUs)

Ultrasonic Test Units are trains that detect rail internal and surface defects.

Four Ultrasonic Test Units operate at measurement speeds up to 30mph.

- An additional vehicle with more limited capabilities provides cover when a production vehicle may be out of service.

Converted from former Southern Region electric multiple unit motor cars.

- Space freed up by removal of traction motors allows installation of the Rolling Survey Unit mounting frames.
Ultrasonic Rail Defect Detection

Defects are detected using rolling survey units with direct connection with the rail, and a fluid couplant.

Examples of internal rail defects:

- Squats
- Rail foot failure
Other UTU systems – Eddy-current

State-of-the-art system that measures rail surface defects such as rolling contact fatigue

Previously detected using visual inspection (unreliable, unscientific)

Why should we be concerned?

Hatfield, 17 October 2000
Compound rail break over two sites > 100m
4 deaths
Other UTU systems – Ground Penetrating Radar

2Ghz and 400Mhz antennae are fitted within the second UTU bogie frame.

Outputs are used to determine:
- Ballast fouling (including fines and wet spots)
- Trackbed intrusions such as bedrock outcrops
- Potential sites with differential trackbed stiffness
- Track renewals workscopes

Train-borne GPR has replaced manual inspection and has reduced the need to dig intrusive trial pits to investigate trackbed conditions.
Example GPR output – 2Ghz radargram

Ballast fouling down to a depth of 600mm from the top of the sleeper
Example GPR output – 400Mhz radargram

To a depth of 1500mm below top of sleeper showing sub-surface features
Other UTU systems – Rail Profile

Left- and right-hand KLD Labs laser rail profile measurement units are fitted to the inboard-side of the bogie.

Outputs are used to determine:
- Rail side-wear
- Rail head-wear
- Conformal profiles (derailment risk)
- Rail grinding planning
- Rail renewal planning

Courtesy of Wikipedia
Medium-speed fleet

Operate at speeds up to 90mph
Nine vehicles each fitted with a number of measurement systems
Most are conversions from former British Rail locomotive-hauled coaching stock

List of vehicles:
► Mentor
► Track Inspection Coach
► Track Recording Coach
► Track Recording Unit
► Radio Survey Coach
► Plain Line Pattern Recognition (PLPR) 1, 2, 3 and 4
Mentor: Overhead Line Measurement

Converted from a British Rail Mark 1 coach – the oldest vehicle in the Network Rail fleet dating from 1955
Fitted with flat roof sections at each end for installation of pantographs
Observation windows allows pantograph-contact wire interaction to be viewed by operators, and a video system
A laser measurement system also enables determination of:
► Contact wire height
► Contact wire stagger
► Pantograph uplift force
► Contact wire deflection
Used for:
► Proving newly-installed overhead electrification
► Routine inspection for compliance purposes

Courtesy of Flickr
Track Geometry Recording

A fundamental track monitoring activity; a significant proportion of the Network Rail fleet is fitted with track geometry monitoring systems

- Enables maintenance planning to maintain ride quality and derailment risk

Some history – the Great Western Railway DW139 “Whitewash Coach”:

Dates from 1911 and used up until 1989.

Human, then electro-mechanical detection of track geometry defects using Hallade method.

…technology has moved on considerably!
Examples of track geometry defects

Plain line geometry deterioration under traffic

Differential support stiffness
Inertial Track Geometry Recording

Position of rail surface is measured relative to an inertial measurement system to determine its absolute loaded position.

Transducers include:
- Linearly variable displacement transducers (LVDTs)
- Gyroscopes to measure yaw, roll and pitch
- Tri-axial accelerometers
Geometry channels recorded

Charts and statistics recorded by track geometry systems at 200mm intervals are:

- Vertical rail (Left and Right Top at 35m wavelength)
- Lateral rail (Mean alignment 35m and 70m wavelength)
- Mean Top (70metre wavelength)
- Cyclic Top
- Crosslevel
- Track Gauge
- Twist (over 3 metres)
- Dip Angle (Left and Right Rail)
- Gradient
- Curvature
- Cant Deficiency
- Vehicle Speed
Exceedence and fault reporting

For certain parameters, boundaries are set for acceptable limits, above which exceedance or fault reports are generated

- Warnings are given to the on-train technicians for appropriate action
1/8th mile standard deviations

For each 1/8th mile section, standard deviations are calculated for track geometry recording parameters

- These indicate the general condition of track geometry
- Trends can be identified and deteriorating sections of track targeted for maintenance (e.g. tamping or stoneblowing)
- Unresponsive sections can be scheduled for renewal
Plain Line Pattern Recognition

Train-borne inspection of track and its components to identify missing, incorrectly installed or faulty components.

Desk-based visual inspection has replaced manual inspection using foot patrols on higher category lines.

- Safety and productivity benefits

High-definition video cameras produce images of:

- Left and right rail heads and sides
- Rail fastenings
- Sleeper and ballast

Also detects visible rail surface damage, e.g.:

- Rail burns
- Broken rails

Approximately 4,000 miles have “gone live”, with an aspiration to reach 6,000 miles.
Plain Line Pattern Recognition
Multi-Purpose Vehicle

Dedicated low-speed inspection vehicle for switches and crossings in complex areas (i.e. major stations, termini and junctions)

Measurement systems fitted:

- Track geometry measurement system
- Balfour Beatty Omnicom video survey equipment
New Measurement Train

Network Rail’s flagship high-speed measurement train
► 2 power cars plus 5 measurement/service vehicles
► 110mph capability
► 8-week recording cycle that covers all of Britain’s main lines
New Measurement Train - systems

Measurement systems are (generally) fitted to two vehicles within the train

► Production vehicle – primary measurement systems
► Development vehicle – originally intended for development of new technology, but also has production systems fitted (e.g. Plain Line Pattern Recognition)

Measurement systems fitted to the New Measurement Train

► Track geometry recording
► Plain Line Pattern Recognition
► Ballast profile measurement
► Fraunhofer non-contact overhead line inspection
► Forward-facing video
► Unattended geometry measurement system
► Axlebox acceleration measurement
New Measurement Train - facilities

As well as comfortable facilities for the measurement system operators, there is also a Conference Car that is used by Network Rail to host visitors during visits to the train.
Infrastructure data positioning

Accurate geographical data location is essential for a number of reasons:

► Application of correct standards for the category of track for intervention levels and fault reporting
► Effective location of faults on site by track engineers
► Consistent calculation of standard deviations over 1/8th mile sections

More history…!
Real Time Positioning - OmniRTPS®

Most of the Network Rail fleet now uses Omnicom OmniRTPS® data positioning for enhanced geographical accuracy. Linear and spatial track location is determined via:

- High resolution axle end tachometers
- Differential GPS with inertial measurement
- Railway track centreline model
- Map-matching

Outputs are:

- Locational accuracy ± 1 metre
- Engineers Line Reference (ELR)
- Track ID
- Milepost location
- GPS location
Support to industry and academia

Network Rail provides access to its measurement trains for industry and academic research and development projects – here are two examples of specialised equipment fitted to the New Measurement Train:

► University of Birmingham EPSRC Real Train Aerodynamics
► RSSB T923 axle-end Acceleration Measurement
Network Rail development activities

Network Rail also undertakes its own technology development activities, for example, instrumented wheelsets have been fitted to Driving Van Trailers:

► Aim is to identify potentially high fatigue loads on train wheelsets
► Work will seek to correlate these loads with the track geometry features that impose them
Train and system maintenance

The bulk of the fleet has train and instrumentation maintenance undertaken at a purpose-built facility in Derby

- Four-road covered accommodation with inspection pits and overhead crane
- Yard facilities for train stabling and marshalling
- Workshop and office facilities for maintenance and train planning staff
Train operations

Trains operate from Derby, but they are often out-based at other depots for long periods of time

- Generally run in fixed formation with the requisite number of barrier vehicles to provide sufficient brake force for their operating speed
- Paths are included for them in the Working Timetable
- Yearly Train Plans ensure all trains deliver inspections at the mandated frequency
- Classes 37, 68 and 73 locomotives operate the trains
- Three are owned by Network Rail, but the majority are hired from freight operators
The Future of Train-borne Infrastructure Monitoring

Traffic growth means that pressure on train paths continues to grow.
There is an aspiration to remove “yellow trains” from the network to free up paths.
How is this being achieved?

► New passenger train fleets are being fitted with unattended monitoring systems (e.g. CrossRail, Thameslink and Intercity Express trains)
► Complementary fixed infrastructure monitoring: “intelligent infrastructure”.

However, there will continue to be a need for some dedicated train-borne capability:

► Some data streams do not lend themselves to service-train data collection, e.g. ultrasonic rail testing, structure gauging, Plain Line Pattern Recognition
► National coverage at the mandated frequencies will not be possible for all lines using service trains (e.g. freight only lines with sparse traffic)
Thank you for listening!