INNOVATIVE SYSTEMS AND METHODS FOR A DEEP UNDERSTANDING OF RAILWAY ASSETS

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Abstract

Modern diagnostic and decision support systems are oriented to better manage railway infrastructure assets by collecting and using more condition data. They allow to shift from corrective to condition-based/predictive maintenance, the most efficient existing approach to maintenance engineering. The purpose of diagnostic systems is usually twofold. The first, immediate reason is obviously the detection of the irregularities that could endanger safety and reliability of the railway traffic. However, in addition to this, if a monitoring technique is continuous and fast enough to allow consecutive monitoring runs to be performed in regular time intervals, an extremely important temporal aspect is obtained which is of essential importance for a successful condition-based asset management. Anyhow, the efficient continuous collection of data does not guarantee that the new acquired information will be used in an optimal way and in particular for time based analysis. A proper maintenance process and methods should be established in order to ensure that after the acquisition, new data are analysed and used for maintenance planning and control. Only then the monitoring techniques will be able to provide detailed insight into the infrastructure assets' behaviour over time, enabling condition-forecasting and consequent better maintenance & renewal planning. This paper will illustrate new innovative systems and methods, such as T-Sight 5000 and RAMSYS, adopted by several railways worldwide, and how data analysis over time allows the condition-based/ predictive maintenance. Such methods could be considered not only for railway assets but also for any linear asset including roads.

Keywords: Diagnostics, Tunnel Inspection, Condition-Based Maintenance, Decision Support, Asset Management

1 Introduction

In order to optimise the railway infrastructure maintenance management and eliminate the risks of failure occurrence, the ideal solution is to plan maintenance in a "condition-based" manner, determining whether, when, where and how to intervene. This eliminates "too early" preventive and "too late" corrective (after a fault already occurred) interventions and thus produces optimised plans for maintenance.

However, corrective maintenance cannot be eliminated; it can only be reduced to a minimum level by implementing planned preventive/predictive maintenance, Figure 1. This is a radical change in how diagnostic data are used, not only as a function of control, but also as a driver for maintenance activities. Moreover, diagnostic data can also be used to drive (in an objective way) renewals, in fact advanced planning methods can be used to balance maintenance and renewal activities and determine the optimal renewal time.

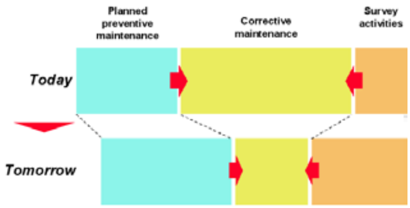

Figure 1 Change in use of diagnostic data

This paper presents two innovative systems, namely T-Sight 5000 and RAMSYS, to illustrate examples of how new parameters for the railway infrastructure can be measured and how the parameter analysis over time allows the condition-based maintenance.

2 From defects to trends

T-Sight 5000 as with many other innovative diagnostic systems (e.g. automatic head check defects) is at the early stage of its introduction at railways where the focus is mainly on the correct measurement and identification of defects.
When a measuring system is commissioned and starts producing data according to the frequency of inspection, the entire history of data becomes available and this is of essential importance for a successful condition-based asset management. The analysis of measurements and defects over time can provide detailed insight into the infrastructure assets' behaviour over time, enabling condition-forecasting and predictive maintenances.
When measuring a parameter that impacts on the safety, several levels of measured values can be defined (e.g. quality, warning, intervention, etc.). In general, corrective maintenance, speed reduction and interruption actions are taken when a parameter is outside proper threshold limits according to a set of rules. Planned Maintenance actions can be regulated by two types of rules, namely:

- *Condition-based*: prescriptive planning of works based on pre-fixed thresholds and intervention times
- *Predictive*: recommended planning of works based on a proper model of evolution of one or more parameters that estimates the date the threshold will be reached.

Both types of rule represent the evolution of the cyclic maintenance rules that plan the work considering the condition of the assets. Instead, predictive rules represent the evolution of the condition-based rules because they introduce also an additional dimension of analysis that is time.
It is clear though, that great differences in the resulting work plan can occur as a result of improved decision-rules being applied and better thresholds defined. Condition-based rules are the most common used rules based on some kind of maintenance norms that define parameters, thresholds and intervention times to consider in planning maintenance works. Instead, predictive rules are hardly adopted because they require historical data availability, correlation with other data types (e.g. work history, asset data, etc.) as well as tools to access, visualise such data and use them for trending. With current available tools often diagnostic data are used to only to generate a list of defects.
In general, the efficient collection of data does not guarantee that the new acquired information will be used in an optimal way. In order to use diagnostic data in optimal way, other data types (e.g. asset characteristics, work history, etc.) are important.

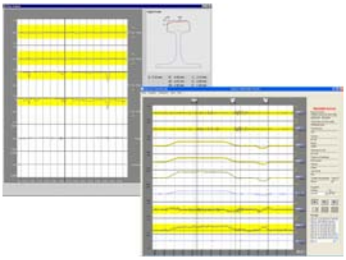

Figure 2 Track Geometry and Rail Profile Charts.

Sometimes the required data are partially present in Enterprise Asset Management (EAM), Enterprise Resource Planning (ERP) systems or vertical software applications dedicated to railway maintenance namely computer-aided track maintenance and renewal systems [1]. For railway users it is not easy to access to such data and manipulate them in a friendly manner, in fact some maintenance systems provide only text based interfaces while maintenance people have been used to work with paper and so called "linear" charts, so systems with graphic based interface are preferable (Figure 2).
In general, the predictive maintenance job is still in many cases still a paper-based and manual task where subjectivity plays a predominant role. Usually, maintenance planners – key individuals having high expert knowledge – are entitled to have the last word on what maintenance is planned. The maintenance staff knowledge is crucial for determining when certain assets require specific interventions, inducing more the human factor in the maintenance chain and hence making the overall procedure less objective and more prone to errors. In some isolated cases the planning and control job is supported by tools - developed in house by the railway themselves – such as spreadsheets and dedicated database management systems and they create several issues related to the efficient access, update and processing of data, sharing of the same rules and data for decision support, access to the official maintenance information, system evolution, etc.
The assessment of how data are used for maintenance can be carried out by analysing the condition-based maintenance chain that is traditionally composed by the following main processes:

- *Data Collection*, including either surveys made by measuring vehicles or other inspections that produce the diagnostic data
- *Data Analysis*, including the processing and the analysis of the diagnostic data producing new information like failures, defects, quality indexes, etc.
- *Planning*, including preparation of the maintenance and renewal plans to be scheduled requiring additional information on where, when and what maintenance is really required.
- *Control*, including the final steps oriented at checking the outcomes of the maintenance execution as well as the related policy.

Today, having new data available in digital form and automatic planning possible, manual subjective planning can be substituted by automatic objective planning. This allows for a deeper understanding of railway infrastructure behaviour and shifting the analysis from defects to trends.

3 Tunnel diagnostics

For most infrastructure managers, the task of collection of data requires a major commitment of both human and financial resources not to mention the rising and pressing requirements regarding safety and accessibility. For example some tunnel inspection data are collected by manually operated measuring devices at very low speed which when in use occupy track

capacity which could otherwise be used by revenue-earning trains. Today, the measurement of tunnels can be automated (e.g. with T-Sight 5000) and overcome the mentioned issues so a set of new data become available for both planning and control.
T-Sight 5000 adopts optical triangulation to convert the laser lights measured objects. As the object moves through the laser beam, contour slices are generated and the complete object shape is reconstructed by uniting the acquired sections.
T-Sight 5000 produces an accumulated image; all objects inside the cross section are scanned by the laser beam and acquired by high speed cameras.

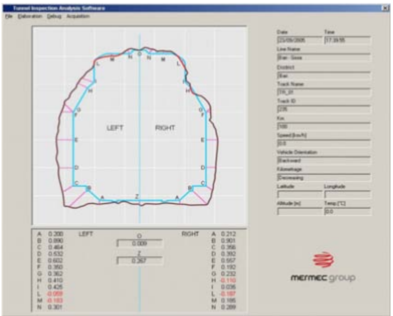

Figure 3 Scanned Cross Section.

Figure 4 Tensioning weights scanned image.

T-Sight 5000 can recognize defects with a resolution of 2mm travelling at 30km/h. The information acquired by the scanner can then be used to produce computer renderings of the infrastructure. The scanner module and software can automatically detect some types of infrastructure defect almost instantly (e.g. clearance defects, Figure 3), and profiles can be viewed in real time, although detailed analysis is normally made after the recording run because T-Sight 5000 produces such vast quantities of data – 4 million points are measured per second. The system has a 360° measurement field which means it can also be used to measure various other infrastructure clearances such as ballast profiles and track alignment. T-Sight 5000 can detect abnormal swelling or subsidence of the ballast, as well as deviation from the normal 3D profile (Figure 4).

Figure 5 Tensioning weights scanned image.

T-Sight 5000 can measure the position of weights used to tension catenary contact wire. Fluctuations in temperature cause the contact wire to expand and contract, which means the height of tensioning weights relative to the ground changes according to climatic conditions (Figure 5). Because of its high-frequency scanning capabilities, T-Sight 5000 can establish whether these fluctuations exceed the operator's specified limits, allowing catenary to be maintained to a safe standard. The system is also capable of measuring station platform clearances and the distance between adjacent tracks.

4 Using data in rules

Condition-Based Railway Asset Maintenance Management requires a great amount of data and proper systems in place that would efficiently integrate all the data coming from systems such as T-Sight 5000 and processes, and make the right information available to all the involved users in the suitable manner. This requirement led MER MEC to design and develop RAMSYS to integrate several functionalities to ensure the maintenance users access to the right data and tools to make critical decisions on maintenance [2].

In RAMSYS the result of any maintenance rules application is an Activity Plan, containing Activities and their respective dates and lengths and Costs. Simple cyclic maintenance rules can be defined using only age and/or accumulated tonnage data. For example:

WHEN Age of ballast becomes greater than or equal to 15 years (time-limit) OR Tonnage on the ballast becomes greater than or equal to 1000 MGT (load-limit) THEN PEFORM Ballast cleaning or replacement (action – work)

RAMSYS provides the environment to create those and more advanced rules using condition data similar to the following:

IF curve THEN PEFORM Rerail WHEN average head loss › threshold for head loss in curve (dependent from type of rail) ELSE PEFORM Rerail WHEN average head loss › threshold for head loss in tangent (dependent from type of rail)

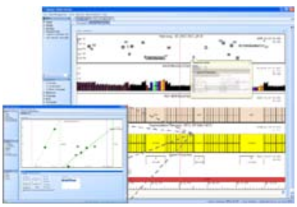

Figure 6 Rail Head Loss deterioration in time

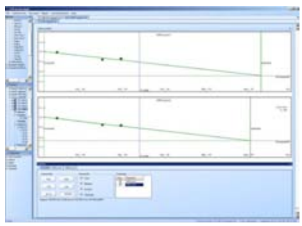

Figure 7 Linear deterioration of thickness for 2 wires.

The minimum value for the rail head loss can be calculated for each rail on track making difference between the rail located in curves and those in tangent, Figure 6. The rail renewal estimated date is calculated by a proper condition-based modelling of the rail wear [3].

In similar way to rail wear also overhead line geometry and wire wear can be analysed and related maintenance can be planned using the same rule engine.

RAMSYS provides the environment to create rules using overhead line condition data similar to the following:

WHEN Wire Quality Index ‹ Wire Quality Index Threshold (dependent from the type of wire) THEN PEFORM Renewal of Wire

A Wire Quality Index based on the minimum value for the wire thickness can be calculated at wire level or at shorter segment levels (e.g. between poles).

The wire renewal estimated date is calculated by a proper condition-based modelling of the Wire Quality Index, linear (Figure 6) or not linear.

These rules allow bridging diagnostics/inspection practices, mainly aimed at collection and first analysis of data, with the ones of maintenance engineering interested in the outcomes of data usage.

5 Diagnostic and decision support tools benefits

The Track Quality Index generated by the track geometry recording cars is a well known parameter for which diagnostic and related condition-based maintenance has been experimented over the last years.
Today the measurement of new parameters with innovative diagnostic systems as well as the introduction of decision support tools is a new strategy still to be exploited and it is the current challenge for many railways worldwide.
Systems such as T-Sight 5000 and RAMSYS are radically changing the way data are collected and used for maintenance activities. Considering the increased demand for higher availability, safety and the reduction of the maintenance budgets, benefits expected include:

- More efficient and effective monitoring of the railway infrastructure
- Transition from corrective maintenance to enhanced condition-based and predictive maintenance
- Better control, planning and balancing of maintenance and renewal activities

All the above benefits will directly lead towards significantly better control of the railway infrastructure condition and behaviour at any given point in time, thus enhancing traffic safety and line availability at a minimum maintenance cost.

6 T-SIGHT 5000 and RAMSYS acknowledgment

T-Sight 5000 is going to be installed onboard of the Swiss Federal Railways (SBB) measuring vehicle. SBB's 3011km network has 307 tunnels totalling 259km, and a dedicated team of engineers carries out inspections on an almost continuous basis [4].
RAMSYS has been appreciated by several railways worldwide. At the time of writing this paper RAMSYS is used by railways in Australia, India, France and Italy. The definition of RAMSYS is based on concepts and experiences drawn from: MER MEC railway infrastructure diagnostic business and analysis/planning applications; projects with several railways companies, universities and research institutions worldwide. The current users support and feedback are valuable and appreciated.

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