Remote condition monitoring into the next millennium

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Abstract

Train services can be seriously affected by the failing or malfunction of railway subsystems. Consequences of this range from a minor delay to the derailment of trains. The need to reduce costs in today’s competitive environment is increasingly important, therefore the opportunity to cut costs by remote condition monitoring of railway equipment is becoming a matter of urgency. State-of-the-art technology being developed should grasp the concept of maintenance requirements based on feedback from the remote monitoring of critical components; thus eliminating the need for costly time-based maintenance plans.

This paper intends to give an overview of the state-of-the-art remote condition monitoring systems currently in use world-wide, as well as the results of research activities in this area being carried out with industrial collaboration at The University of Birmingham.

This paper also draws conclusions from questionnaires compiled by the University and completed by rail operators world-wide. The questionnaires addressed issues as to whether there is a world market for remote condition monitoring and individual country’s progress in implementing the technology.
1 Introduction

Since privatisation of the railways in the UK there has been a renewed motivation to decrease the cost of maintenance and increase the availability of the railway. One of the methods which enables maintainers to reduce their costs is the use of data loggers and remote condition monitoring systems. Many Railtrack Zones in the UK have taken part in extensive programmes to install a wide range of equipment to monitor civil, power systems, signalling and telecommunication assets.

In tandem with these initiatives The University of Birmingham, with collaboration from a number of rail companies, have been researching the state-of-the-art in the usage of data logging and remote condition monitoring, particularly for railway single throw mechanical equipment, examples of which include a number of safety-critical track-side signalling equipment and onboard operating systems, such as level crossings and train door operators. The work is more precisely described by Fararooy & Lehrasab, Fararooy & Allan, Fararooy, Allan & Lehrasab.

2 Present Monitoring Systems

The condition monitoring systems which are found in the field today have been selected and installed by engineers with different functional roles: civil, power systems and signalling. This practice has led to a large number of systems being installed with little or no commonality, therefore the interactions between cross discipline systems has not naturally followed. This is particularly apparent with the example of a point monitoring system. Here, all three disciplines mentioned play a part in maintaining and operating the asset: civil (ballast movement, tamping), power systems (point heating) and signalling (relay interlockings); an ideal condition monitoring system should address all of these issues.

2.1 Civil Monitoring Systems

Currently, there are two main types of assets monitored by the civil engineer, track quality and structural damage. Track quality monitoring, which is often determined using specific test vehicles, is becoming of increased importance to the civil engineer due to current media attention. The civil engineer also uses condition monitoring to help determine the
effects of bridge damage due to weathering, water flow and accidental *bashing* by motor vehicles as well as the geological movements in and around tunnels, as reported by George*.

### 2.2 Power Systems Monitoring

Railway power systems condition monitoring has developed considerably quicker than in other areas of the railway. This is mainly due to the fact that a number of initiatives have led to the purchasing of equipment already containing condition monitoring technology - this is true for assets such as point heaters where approximately 80% of units in the field have some kind of condition monitoring capabilities.

### 2.3 Signalling Monitoring

Information regarding interlockings and signalling equipment such as level crossings, points, axle-counters, train-describers and track circuits can be recorded using data loggers. Commonly, the data loggers are only capable of collecting and storing digital switching information, for example relay contacts on/off or point throw normal/reverse. Once data has been collected analysis can be carried out to determine whether assets are working to their correct time sequences, the number of operations per asset and information which can be used for fault diagnostics, as explained by Clements⁵. Data loggers, which are extensively used on level crossings, are also useful for analysis of incidents, whether they be allegations by members of the public or intermittent faults reported by railway personnel. In most cases, due to the large amount of data already being collected, data is simply stored in its original format and is only analysed to retrieve useful information on the occurrence of an incident.

### 3 Feedback from Rail Companies

Questionnaires regarding company’s implementation status and policy on remote condition monitoring were circulated among a selected number of railway operators and equipment manufacturers world-wide. Thirteen questionnaires were returned from seven different countries (UK, Netherlands, USA, Canada, Australia, South Africa and Japan).

The observations made were as follows:-

- All respondents were currently using remote condition monitoring in some form;
Applications were mainly in signalling and rolling stock (points, level-crossings, hot axle box detectors, flat wheel detectors, air condition monitoring, track temperature, braking systems, etc.);

Very few of the systems incorporated any kind of early warning/predictive alert for failures;

Little analysis has been carried out into the cost-benefit of using current condition monitoring systems to aid maintenance, although many companies felt that substantial savings had been made since the installation of equipment;

Over 50% of those questioned felt than the main limitation with current systems were their lack of standardisation, others felt that too much data was being collected with little information and user interfaces were cryptic and not clear.

### 4 Post-Mortem of Monitoring Systems

It is apparent that remote condition monitoring techniques make the load of the operator and maintenance engineer lighter. The systems which are in place have helped to reduce maintenance costs by improved fault diagnosis and post-incident analysis in a number of railway engineering disciplines. The main limitations of current remote condition monitoring systems have been identified to be the lack of standardisation, the lack of relevant information rather than pure data and the inability of systems to display data in a user-friendly fashion which operators are used to.

### 5 Motivation of Current Research

The main objectives of the work currently being carried out at The University of Birmingham are to use condition monitoring techniques to:-

1. Further increase the cost-effectiveness of asset maintenance by reducing rapid-response costs;
2. Decrease the number of intermittent faults found on our railways today;
3. Improve operating performance of assets; and hence reduce train delays and their associated costs;
4. Reduce the cost of spares held by maintainers;
5. Improve safety to track workers by decreasing the amount of time spent on site;
Work which has been carried out in recent years has concentrated on equipment case studies which are the key contributors to unavailability on railways world-wide, these include level crossings, points, train-stops and train doors. These and other assets have been identified by the IRSE Technical Committee as being the primary causes of unavailability of railway control systems.

5.1 (RCM)²

A novel methodology currently being implemented in practical applications at the University is known as (RCM)², the methodology is proposed by Fararooy. This approach to failure prediction draws upon two very powerful techniques of Remote Condition Monitoring (RCM₁) and Reliability-Centred Maintenance (RCM₂).

Reliability-Centred Maintenance involves an in depth review of the maintenance strategy taken for a particular asset which results in a new optimised maintenance regime for that particular type of asset. The use of the technique is described in detail by Moubray and has been implemented by a number of rail companies, as reported by Lingfield, Peacock, Sothcott and Edwards and Long.

The underlying principles of the (RCM)² approach is to integrate the two techniques in such a way as to:

- Combining qualitative knowledge and quantitative information (statistical and condition assessment data) about the assets to improve their performance. This combined knowledge is used to achieve the inherent reliability of the assets, as well as predicting failures. As a result this reduces the life-cycle maintenance and operation costs associated with the assets;
- Employing advanced electronics, intelligent computing and communications technology to gather useful information and knowledge about asset condition. A great deal of effort is channelled into choosing the correct analogue/digital transducers for collecting the physical data. Before installation of the transducers a detailed cost-benefit analysis is required to calculate which combination of transducers produce the greatest amount of information at minimal cost and with greater reliability as would be expected from condition monitoring systems;
- Information regarding the state of the asset should be provided to operators, engineers and maintainers as deemed appropriate, either by flagging qualitatively potential failures or continuously feeding back the quantitative state of the assets;
Pro-active condition-based maintenance implies more control over resources, and less business and safety risk.

(RCM)\(^2\) starts with identifying the functionality of the asset and the possible functional failures. The effects of each failure and the criticality is also determined. This process follows the well defined and systematic approach known as Fault Mode, Effects and Criticality Analysis (FMECA) as defined by British Standards Institute\(^1\).

Using the results of the FMECA a list of key parameters or features which are essential for the reliable operation of the asset are then identified. Research into condition monitoring technology is required at this stage to determine whether the key parameters can be monitored effectively. Next, the cost-benefit analysis of condition monitoring should be considered. The question 'Is it worth monitoring?' should be asked at this stage - for example a component which is not prone to fail and has little safety or functionality impact is not worth monitoring, whereas a component which has been known to failure regularly causing significant delays to the availability of the railway would be worth monitoring. Artificial intelligence techniques such as neural networks, fuzzy logic and expert systems can then be utilised to implement failure prediction based on the analogue and digital data from the chose transducers and expert knowledge of functional failures identified in the FMECA.

The (RCM)\(^2\) approach is being utilised in a current collaborative research project for improving the reliability and maintainability of railway signalling equipment. This is a UK-based industry-academia collaboration funded by the Engineering and Physical Sciences Research Council (EPSRC) and the Department of Trade and Industry (DTI) under the LINK - Inland Surface Transport programme. The project is being led by The University of Birmingham with partners including: Railtrack, WS Atkins Rail, Jarvis Facilities, GTRM, Solartron and Computer Controlled Solutions. The research is generic, concentrating on an STME case study. Besides the technical considerations, the project demonstrates the increased productivity that can be achieved through collaborative agreements to address common problems and seek solutions.

6 Conclusions

Remote condition monitoring is currently found on railways world-wide in various applications, they have proved their worth in fault diagnosis applications and allegation investigations. Recently, there has been a
drive to increase the number of monitoring systems and also to purchase new equipment with condition monitoring capabilities. However, a number of pitfalls and limitations for remote condition monitoring systems currently exist, namely:- the non-interoperability of different systems, the limitations in intelligence of current systems and the tendency for current systems to produce a lot of data but little or no information in real-time. The (RCM)² methodology endeavours to overcome these limitations and to lead the way in truly intelligent remote condition monitoring in the next millenium.

7 References


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