INTELLIGENT INFRASTRUCTURE ASSET CONDITION MONITORING

David C Shaw BA MIET MIoD
Managing Director
ADT Rail Systems (A Transmitton Company)
BR Building, Siding Road, Fleetwood,
Lancashire, FY7 6RG, United Kingdom
Email dshaw@adt-rail.com
Tel +44 (0)1253 777111
Fax +44 (0)1253 773923

Keywords: Intelligent Infrastructure, Signal Infrastructure, Remote Condition Monitoring

Abstract

This paper seeks to identify what developments and technological advances can be made to the existing railway maintenance regime by the application of intelligent condition monitoring systems. This paper has been specifically tailored to focus on the railway industry, in particular the signalling infrastructure.

1 Introduction

There is a current requirement to progress from a “Find and Fix” regime to a “Predict and Prevent” regime within the rail industry.

Key rail companies such as, Network Rail and other rail associations and bodies have identified this and are actively working alongside industry suppliers in order to turn this proposed change into a reality.

The application of condition monitoring as a maintenance tool can assist in driving forward with these industry changes. This can be realised by moving from a time based maintenance regime to one focused on asset performance.

To realise the true usage of intelligent condition monitoring a holistic approach has to be taken. It is important to focus, not only on the equipment and parameters measured but to ensure that this data is actually translated into valuable information for both operational and maintenance experts.

This paper discusses the key areas for consideration in order to create an intelligent infrastructure, it highlights examples of condition monitoring and includes a selection of case studies demonstrating its successful implementation.

2 Condition monitoring principles & how they can be applied to the Railway Infrastructure

In order to successfully implement a condition monitoring solution which has the ability to assist in maximising maintenance time, reducing penalties and improving safety, there are certain fundamental areas that must be considered;

Identify key parameters in order to obtain valuable data
It is necessary to understand and identify which parameter(s), when measured and the interrelation between them will provide valuable information of an asset.
For example, while measuring the motor current of a points machine will provide credible information, it will not offer a detailed picture of the asset. By incorporating the measurement of pressure and/or force and temperature it is then possible to appreciate how the surrounding environment affects the operation.

Use suitable equipment
The rail infrastructure is a harsh and hazardous environment. Sensors must be resilient and manufactured to withstand extremes of weather and vibration. Low maintenance is also a priority as the reduction of track side visits is paramount to the safety of the technicians.
All these factors must be considered when applying for the appropriate rail approvals.

Location of Equipment
Consideration needs to be taken when identifying the ideal location to install sensors.
In addition to the environment and safety aspects, sensors should not be installed in items which are may require replacement during maintenance.
Where possible equipment with integral sensors should be used, if this is not possible then the sensors should be fitted remotely from the equipment.

Interpretation of Data
It is necessary to look at how any data is translated and presented.
Information from these systems will beneficial to many disciplines within the rail infrastructure.
Fault Control require basic alarm information, indicating potential failures. Technicians require more detailed information such as trends, profiles and absolute values. Maintenance and Planning require long term data for analysis and aiding the process of moving from a time based maintenance regime to one which is more asset based.

Quality of Alarms
Remote alarm annunciation provides early indication of a potential asset failure and can reduce penalty costs incurred by delay minutes. It is paramount that this alarm reporting is accurate and concise. In order to associate realistic values against alarm thresholds it is necessary to understand how these assets behave under normal and abnormal conditions; how the surroundings can impact on operation and how various other assets and conditions relate to each other. Dynamic alarm thresholds take the above into consideration and automatically adjust the alarm values accordingly therefore reducing the number of erroneous alarms and maintaining the integrity of the monitoring system.

Maintenance Regime
The data collected from all of the assets being monitored provides an overview of the performance and utilisation of the infrastructure. This information can then be used to review how planned preventative maintenance is carried out. Maintenance based on asset performance as opposed to time based can make resource management more efficient; improve spares handling and provide key information as to the life-costs of each asset.

2 Examples of Condition Monitoring

Condition monitoring can be applied to virtually any type of equipment. This paper provides examples that are applied to railway signalling systems and in particular to points machines.

Significant studies and investigations have been carried out over the past 10 years to ascertain the best practice of monitoring points machines.

One key factor which has been identified is that the majority of reported points failures are not due to the points machine itself but to the surrounding equipment and/or environment external to the points machine. The following case studies demonstrate some examples of this.

The first case study is an example of extended investigations, where it was considered beneficial to monitor certain parameters to establish if these could be used to identify potential failures.

Often there is data and experience available from previous studies that can be used in the design of an intelligent condition monitoring system. In this case, to the knowledge of the author, these parameters had never been monitored before so there wasn’t any past experience or trials to draw upon. This case study displays a milestone in the success of monitoring solutions.

The second case study is an example which clearly identifies the best parameters to monitor and where the long term trend data provided by condition monitoring can be used to make changes to the maintenance regime.

The third case study is an example that shows the importance of interpreting the data correctly and the interaction with other parameters.

Study 1 of Points detection

One of the most common faults on points machines is often associated with the loss of detection.

A points failure was recently avoided when the OnTrack system (the remote condition monitoring solution from ADT Rail Systems) highlighted that the detection voltage was starting to fluctuate when trains passed over the points. (See figure 1A)

It can be seen from the trend in figure 1A that the detection voltage was only fluctuating slightly. However it was considered enough to warrant a full investigation. A thorough investigation of the points equipment and wiring was carried out during “out of service hours” and found a broken wire inside a crimp. This would definitely have caused a failure of the points and caused a serious interruption to the service which would have incurred delay costs.

Figure 1B shows the detection voltage trend after having replaced the broken crimp.

In order to design a condition monitoring system to provide such advanced warning of failures it is necessary to establish in the first case exactly what the data provided by the system means and secondly how the system can be configured to automatically provide advanced warning of a failure.

Typical Points Detection circuits

All types of points have some form of proximity device in order to detect when the points have completed their movement and remain in that position until moved.

These proximity devices can also be used to detect movement in either the track or, in some cases, the points machine when trains pass over the points.

The proximity devices can either be internal or external to the points machine or be a position transducer.
In this case external proximity devices are used with clamp lock type hydraulic points machines.

The detection proximity devices operate the detection relays and when combined with the track circuit relays provide a rapid indication of any loss of detection under a train (Points Flashing). This often happens to quickly for the signaller or the signal control system to see it, however the OnTrack Condition Monitoring system will detect this and raise an alarm.

The loss of detection under a train is usually the first indication of a detection or adjustment problem.

In this case, due to the proximity of both 25kV ac traction and 650V dc traction, a 414/477Hz system is used to differentiate between the Normal and Reverse position of the points.

On 414/477Hz system there is an inherent delay in the receiver modules of between 1 and 2 seconds before the detection relays change state hence the early warning of a detection fault may be lost.

Loss of detection failures are often caused by the proximity devices going out of adjustment or by track movement. They can also be caused by degradation of the detection module or associated components causing a change in the circuit resistance.

In this example the amplitude of the 414Hz & 477Hz signal is measured.

To measure this change of resistance in the dc and 50Hz ac circuits the circuit current is monitored, in the 414/477Hz circuits the input voltage to the receiver unit is monitored.

**Condition Monitoring of Detection Circuits**

An enhancement to the OnTrack Points Condition Monitoring system has been developed to include monitoring of the amplitude of the 414 & 477Hz signal at the receiver module.

This voltage in addition to providing rapid indication of a loss of detection by overcoming the inherent delays it also provides data about the condition of the detection circuit.

The standard configuration already includes automatic points “flashing” detection using the track circuit and detection relays.

A system was implemented to provide a long term trend of the detection voltage with a view to identifying degradation of the detection circuit by changes in the detected voltage. On the completion of each movement of the points the relevant detection voltage is logged to provided a long term trend for both Normal and Reverse positions.

The detection voltage is usually between 4 and 5 Volts and the receiver units are set to de-energise the detection relay at approx 1 volt.

An initial alarm setting of 3 volts was applied to the measurement.

The intention being that the system provided an alarm when there was a significant change in performance but well before the failure level.

During the movement of the points the detection voltage drops to zero, hence the live value cannot be alarmed as this would cause a false alarm when the points moved.

To overcome this, the alarm was placed on the logged value after each points movement.

In a twelve month period some of the points being monitored operated over 40,000 times.

During this period several “Points Flashing” alarms were identified most of which were caused by out of adjustment or faulty proximity devices.

Apart from the detection voltage being lost during these alarms there wasn’t any significant change in the detection voltage with these faults.

**Points Failure**

Figure 2B shows the trend of the detection voltage at the time of a points failure. It can be seen that for more than an hour before the failure the detection voltage was becoming very unstable.

It can be seen in figure 2A that there had been slight fluctuations in the detection voltage when trains crossed over the points a few hours before the failure.

There had been a loss of detection 24hrs prior to the points failure which caused a single “Points Flashing” alarm, this can be seen in figure 2C.

Typically “Points Flashing” alarms tend to increase in frequency indicating that the detection equipment needs attention hence this single occurrence wasn’t considered as a warning of an imminent points failure.

Following this points failure all the relevant data was examined to investigate how an advanced warning of this type of failure can be provided.

As the detection relay isn’t de-energised until the voltage drops below 1 volt, the significant changes in detection voltage for the hour before the failure would not have been seen by the signalling system as the detection relay would not have dropped out.

Even though the detection voltage dropped below the alarm threshold this wasn’t logged as the points hadn’t changed.

Further investigation showed that the dips seen in figure 2A were caused when trains went over the points and that it had
only been happening for about a month, prior to that the detection voltage trend was virtually a straight line.

The configuration and alarm thresholds of the system were modified to provide continuous monitoring of the detection voltage and avoid false alarms during points swing and the “Points Flashing” alarm linked to the detection voltage in addition to the detection relays.

The users of the system were also trained how to identify such a potential fault from the trends.

Within 2 months of making these changes the system highlighted that the detection voltage had again started to become erratic and a thorough investigation of the points wiring found a broken wire inside a crimp. On this occasion a failure was averted.

This is an example of where a system can provide all the necessary data but needs the knowledge of how a fault will present itself for it to become a truly intelligent system.

Case Study 2
Pressure Measurement

This case study shows which are the best parameters to measure and how the data provided can be used to make changes to the maintenance regime.

There have been many discussions over the years as to what are the best parameters to measure to provide an indication of the condition of a set of points.

Identify any interaction between the parameters and their effects and choose parameters that provide a very clear indication of a pending problem and don’t cause false alarms.

Measurement Parameters

In this example the following parameters are measured.

Points Operation Time
This can be monitored by measuring the detection relays or the motor operation time.
In this example the motor operation time is monitored

Motor Current
The points motor current is monitored by placing a current transducer in the output circuit of the final drive relay. This relay is usually located in a relay room or in a trackside apparatus case. It is not advisable to fit the current transducer inside the points machine.
To measure the points motor current it is necessary to obtain a profile of the motor current during points movement by using a high speed data capture device.

There is a trade off between the data capture speed and the size of the profile data files. The OnTrack system uses a 50mSec sample time which, as can been seen from the profiles, provides sufficient resolution.

It is important that the system provides a very clear and concise indication of the condition of the points, without the need to transfer large quantities of data to a central data collection system.

The average and peak motor currents are automatically calculated from the points motor current profile and provide a very clear indicator to the condition of the points. It is important that only the section of the profile which relates to the points movement is used in the calculation. E.g. the motor start up surge current is not included.

Motor Power
The average and peak power is also calculated from the motor current and the points motor supply voltage.

This provides a better indication of a problem than the motor current.

Hydraulic Pressure
Clamp locks use hydraulic rams to move the points. The manufacturers of the hydraulic pumps now provide integral pressure transducers and hydraulic fluid level indication as an option.

During the points movement the hydraulic pressure is monitored using the same data collection module as the motor current.

This provides a hydraulic pressure profile for each points movement.

As with the motor current profile it is important that the correct section of the pressure profile is used to calculate the average and peak pressures.

On multi ended points the signalling system doesn’t stop the points motor until all the points detection relays have been activated. This causes the motor to continue running and the hydraulic pressure to increase up to the relief valve pressure. Using the type of detection as in the previous case study this can increase the motor running time by up to 2 seconds

It is important that the system is capable of detecting where the relief valve pressure starts within the profile and ensuring that it is not included in the calculation of average and peak pressure.

Example Tends

Figure 3A shows that during August all the parameters were steady and that the points are operating correctly.
If a routine maintenance was due at this time then it would be an unnecessary cost.

The trend shown in figure 3B, for the following month, shows a very noticeable increase in the average and peak pressure.

It can be seen that at the same time there was very little change in the motor current or timing trends. It would be very difficult to clearly identify the need for points maintenance from the motor current trends.

The points care team were called out to the points and the effect of their work can be seen clearly on the long term trends.

The pressure profiles shown in figures 3C and 3D clearly show the change in the pressure before and after the work being carried out.

This case study provides a clear example where it is important to monitor the most effective parameters, which in the case of clamp locks is clearly the hydraulic pressure.

It also shows how the existing time based maintenance regime could easily be changed to an asset performance based maintenance regime.

Case Study #3
The effects of temperature on points measurements

The effect of temperature on points motor current and operational time has been well documented over the years.

The motor current can change more due to temperature changes than to a change due to a fault.

When the OnTrack system was initially designed this was taken into account on the motor current, motor power and operation time alarms.

At that time there wasn’t any evidence to show that the temperature had any noticeable effect on the pressure measurements.

During the period shown in figure 4A several pressure alarms occurred. Checking the trends it was noticed that the hydraulic pressure was fluctuating but there wasn’t a general upward trend which would have been an indication of an impending failure as in the previous case study.

The ambient temperature was being monitored and logged in order to compensate the motor current, power and time alarms so the long term trends already included an overlay of the ambient temperature.

Temperature compensation was not provided on the pressure measurements.

Figure 4B clearly shows the increase in power as the temperature reduces. The power alarm settings were automatically temperature compensated and hence didn’t give any false alarms.

It is therefore important that temperature compensation is included on the pressure measurements.

The OnTrack system was then modified and all subsequent systems include temperature compensation on all the parameters being measured.

This a very clear example of the effects of temperature on the parameters being monitored.

Conclusion

This paper has discussed the principles of condition monitoring and how the knowledge gained is used to provide a very clear indication of the condition of the asset.

It has also provided examples of how we can progress from a “Find and Fix” regime to a “Predict and Prevent” regime within the rail industry.

In order to provide a complete intelligent asset condition monitoring system the data obtained from the various asset condition monitoring systems needs to be used to change the maintenance regime.

The systems discussed in this paper in addition to providing data for a central system also immediately provide very clear and concise alarms information to fault control so that the appropriate fault team can be despatched.

The alarm data is transmitted in a format that removes any possible delays within the communication systems and able to accommodate the very limited data communications bandwidth available in some areas.