High-speed detection of rolling contact fatigue in railway rails

M J Nicholas and A D Hope

Eddy current and associated electromagnetic methods have long been used for the detection of surface defects on a variety of products. With the ever-increasing use of computer technology coupled with the availability of inexpensive memory, the trends have been toward software implementation of the detection process. The analogue/digital boundary has been pushed ever forward towards the defect detector. There is more use of computer techniques to enhance the presentation of results while ignoring the basic analogue detection function. Whilst this option is well-suited to many applications, there is a need to take the boundary a little further away from the defect detector for specific applications. Even with modern high-speed processors there is merit in the early stages of detection being analogue, both on cost and performance grounds. Here, one analogue method of implementing a high-speed sensitive and selective detection system for small defects is discussed.

1. Introduction

The Hatfield train derailment in October 2000 highlighted a need for a dedicated inspection method for the detection of rolling contact fatigue on the running surfaces of a railway rail. Indeed, it seems this has been confirmed by a HSE[1] report.

Current technologies tend to use an ultrasonic system adapted to inspect railway rails at a slow speed. It is not usual to use ultrasonic techniques for the detection of small surface defects.

With this in mind, private work has been undertaken by Mr M J Nicholas, based on a detection system he developed. The detection system received the Hugh MacColl award for innovation from the British Institute of Non-Destructive Testing, resulting in patents pending[2] and granted[3]. The work is now being taken forward jointly with Prof A D Hope of Southampton Solent University with the aim of integrating the analogue detection stages to form the basis of a complete defect detection, tabulation and location inspection system.

2. Balanced bridge sensing system

Current trends tend to push the analogue to digital barrier as far as is possible towards the detector coil, see Figure 1. This reduces the maximum available inspection frequency and increases the analogue to digital conversion costs. This forward movement reduces the analogue processing costs, resulting in increased hardware and software costs within the digital signal processing stages. There is room for further work to address the advantages of an analogue front end.

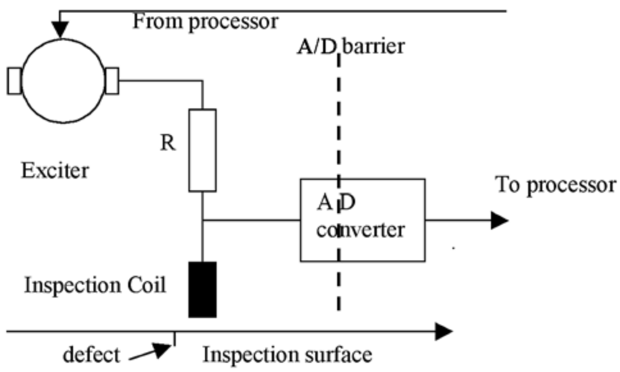

Figure 1. Simple system with A to D barrier forward

With this barrier moved a little further away from the detector coil, an advantage was evident and various experimental test equipment was constructed. The basic equipment was able to demonstrate the ability to detect surface defects between 0.5 mm and 1.5 mm deep, with excellent depth discrimination and signal-to-noise ratios. This was accomplished with a working clearance between the probe and the surface under test of up to 12 mm, with a nominal working range of 3-8 mm, at predicted surface speeds of above 120 km/h. This range of defect depths, 0.5 mm to 1.5 mm, is the critical range when defect monitoring is required to predict further propagation of identified defects, prior to any further local, critical inspection.

3. Objective

The objective of the work was to detect and tabulate defects between 0.5 mm and 1.5 mm deep at inspection speeds above 100 km/h in order to demonstrate the sensitive and selective advantages of the analogue balanced bridge sensing device.

4. Approach

Two types of detection equipment (A and B) were used, one of which, (B), having the benefits of some simple analogue and digital signal manipulation, was designed for an earlier application. As such, equipment 'B' was limited in the maximum speed of inspection, due to analogue limitations not present in the specifically designed equipment 'A'. The reduced speed response result from detector 'B' is included in the results to indicate the consequences of simple signal processing.

Both types A and B incorporate the techniques of a balanced bridge sensing system implementing a differential testing function. Manipulation of the bridge status by the probe parameters results in an increased rejection of lift off and other erroneous signals prior to any further digital signal processing. The results obtained from

Mike J Nicholas. Tel: 01202 419394; E-mail: Mike@mikenicholas.wanadoo.co.uk

Professor Tony Hope is with the Faculty of Technology, Southampton Solent University. Tel: 02380 319173; E-mail: tony.hope@solent.ac.uk

The current partners would be delighted to hear from any additional potential partners or investors with an interest in the further development and exploitation of this work. Further details can be obtained by contacting either Mike Nicholas or Tony Hope.

both sets of equipment illustrate the defect magnitude capability of the balanced bridge sensing device.

The defects were aligned and scanned at various speeds in excess of 120 km/h. The test surface had two defects, one 0.5 mm deep and one 1.5 mm deep. The defects were situated some 600 mm apart. The probe was arranged to scan all the defects at stand-off distances within a range of 4 mm to 10 mm. The technique used was to take the output from the balanced bridge, resulting from surface anomalies, and to demodulate this using the fundamental of the bridge excitation frequency as a reference. The result was a signal voltage generated as the defect passed the pole pieces of the detection probe, the magnitude of which related to the size of the defect. The frequency of this signal directly related to the speed of inspection and the size of the inspection probe. As various parameters of the test function were known, for example the test speed, distance to target and material, this information was fed back to the bridge control circuits, see Figure 2. Computer techniques are required to interrogate the signal, which is now at a frequency much lower than the excitation frequency, prior to display and evaluation for all the required defect data and tabulation. This differs from a simple digital system where a single probe is used and the parameters of the inspection coil are directly interrogated, at the excitation frequency, with no control of the probe by external elements.

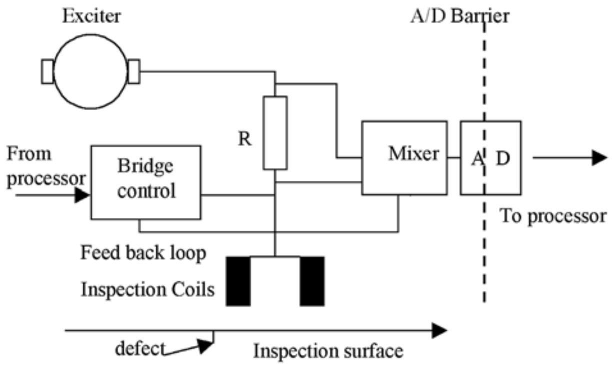

Figure 2. Detector 'A' prototype system

5. Results

Figure 3 clearly shows the two defects 0.5 and 1.5 mm deep at approximately 600 mm spacing. This is a reproduction of the raw data from the detector 'A' at high speed. This signal can then be readily converted to digital format at relatively low cost (compared to the requirements to convert at the inspection frequency) to obtain comparable results relating to defect size and location, enabling further interrogation and tabulation. In this case the inspection frequency was 150 kHz, but it could be many times higher, and the defect frequency is shown to be in the region of 1 kHz.

The type 'B' detector as shown in Figure 4 was used at a lower test speed and revealed the results shown in Figure 5. These results were produced with scans of a lower speed, due to the limitations

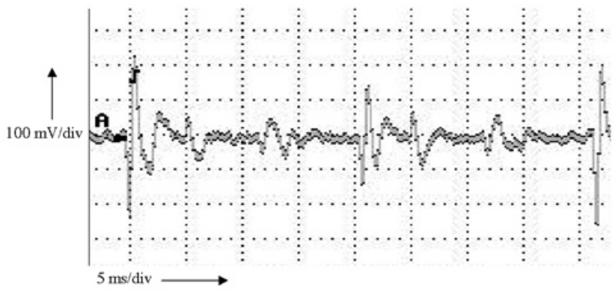

Figure 3. Result from detector 'A'

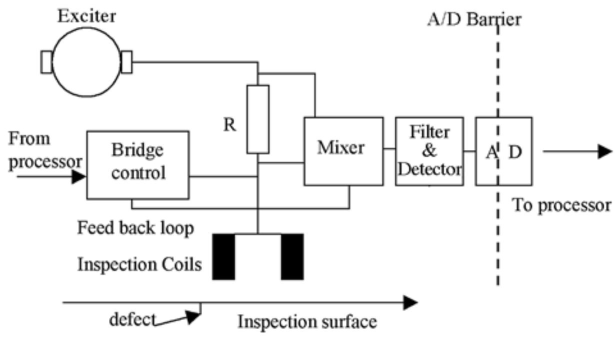

Figure 4. Detector 'B' with added analogue filter to mixer

previously stated, and are included to illustrate the advantages of further simple analogue signal conditioning prior to digital signal processing.

The trace in Figure 5 shows the scan obtained with analogue filtering of the defect signal at a scan speed of approximately one third of that shown in Figure 3. This was with the same probe and defect spacing of 600 mm.

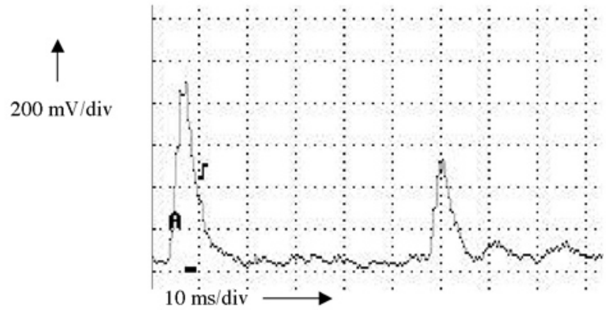

Figure 5. Results from a slower scan with detector 'B'

6. Conclusions

As defects within the range 0.5 to 1.5 mm deep are reproduced with adequate depth discrimination from the demodulated output, there is a cost benefit. This is due to the absence of a high-speed analogue-to-digital converter and the slower requirements of the real-time defect analysis software.

Although defects within this depth range, 0.5 to 1.5 mm, may not present an immediate hazard, their growth must be recorded on a continuous basis over this range. This system, preserving depth discrimination without loss of detection performance, is ideally suited to high-speed inspection.

7. Further development

The purpose of the work was to establish the detection of cracks in the running surfaces of railway rails, in particular the 'gauge corner cracks' at high speed, using an electromagnetic method. A simple cost-effective high-speed inspection system fitted to trains performing constant comparisons of the condition of the running surfaces of railway rail is the ultimate objective.

In order to achieve this objective and commercially exploit the results obtained from the current laboratory-based systems, further research and development is required.

References

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