

Guided Wave Inspection and Monitoring of Railway Track

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1. Introduction

Cost-effective NDE of the vast length of ageing railway track around the world remains a challenge for the community. Since continuously welded railway lines may be thought of as one-dimensional elastic waveguides, they are natural candidates for guided wave ultrasound, which offers the potential to interrogate a large length of rail from a single position. Continuously welded rail is installed in tension but temperature changes can result in rail buckling if the tension is insufficient or fatigue cracks and ultimately rail breaks if the tension is excessive. Guided waves have been proposed as a means of detecting the axial stress in rails to prevent buckling and also as a means of detecting complete breakage and cracks prior to breakage. This presentation will provide an overview of some of the approaches proposed for developing non-destructive inspection and monitoring systems and the modelling techniques used to support these.

2. Guided wave system approaches

2.1 Axial load measurement

Determining the axial load in a rail by measuring the wavelength of a flexural mode at 200Hz was proposed [1]. This approach requires the release of the rail from the sleepers for a considerable length. The influence of axial load on higher frequency guided waves was demonstrated by simulations [2]. Currently linear and non-linear features are being investigated as a measurement of axial load [3] in a very large experimental setup.

2.2 Damage Detection

Rose et al. [4] considered three approaches to damage detection: fixed sensors on the rail; guided wave inspection car; and sensor on train system.

An inspection system was developed by Imperial College and Guided Ultrasonics Ltd which utilized a piezoelectric transducer array wrapped around the circumference of the rail to transmit and receive (pulse-echo) guided waves [5]. The inspection of 100m of rail from one position was demonstrated and even buried rail at level crossings could be inspected. This was a sophisticated instrument and used mode coupling to differentiate between damage on the head, web and foot of the rail.

Scanning systems using guided waves to increase the speed of inspection and to detect transverse defects under shelling have been investigated [6] and a commercial system has been developed by WavesInSolids LLC. This system uses non-contact electro-magnetic acoustic transducers while a system developed at UCSD uses laser excitation and an air coupled receiver [7].

A monitoring system using permanently attached piezoelectric transducers in transmission mode was developed by IMT in South Africa [8]. The system was intended to detect complete rail breaks and used transmit and receive stations spaced approximately 1.5km apart. The system has detected cracks in the head of the rail prior to complete breakage. The option of using fixed receivers and train induced noise was analysed numerically in [9] where it was concluded that the damage would need to be large before it could be detected.

3. Modelling guided waves in rails

These systems typically operate in the frequency range where many modes of propagation exist. The semi-analytical finite element method has become a popular technique for calculating the dispersion characteristics of rails. The method can efficiently compute the influence of axial loads on the dispersion properties to provide inputs into the design of systems for measuring the axial load in rails [10]. The mode shapes determined by the SAFE method provide information required for designing transducer arrays to selectively transmit or receive individual modes of propagation. Damping representing the attachment to sleepers can be included in the models and attenuation of modes can be computed to identify which modes propagate with relatively low attenuation for long-range inspection and monitoring systems [11].

Numerical modelling has also been employed to predict the interaction of guided waves with damage. A thorough understanding of mode coupling can be useful when attempting to classify the type of damage [5]. The combination of SAFE and three-dimensional finite elements are proving to be very useful for modelling realistic situations [12]. SAFE has been combined with 3-D piezoelectric elements for modelling the transduction of guided wave modes by piezoelectric ultrasonic transducers [13].

4. Current challenges and future perspectives

The ageing of heavy duty rail lines and a move away from track circuits to communication based train control systems are causing increased interest in alternate methods of monitoring rails. There are a number of technical challenges involved in developing system that reliably detect damage without producing false alarms. However, as the technology becomes more available and specific applications are identified it is anticipated that adoption of the technology will increase.

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