NATIONAL NUCLEAR LABORATORY

NNL RCNDE Newsletter

Issue 7 - July 2013

Introduction

Welcome to issue 7 of the NNL RCNDE Newsletter which is distributed to NNL's RCNDE network across the NDA estate. NNL is a member of the Research Centre for Non Destructive Evaluation (RCNDE) on behalf of the NDA. The RCNDE, formed in 2003, is an EPSRC (Engineering and Physical Sciences Research Council) sponsored collaboration between industry and academia to coordinate research into NDE technologies and to ensure research topics are relevant to the medium to longer-term needs of industry. More information on the RCNDE is available at www.rcnde.ac.uk.

Inside this issue

From Periodic Inspection to Continuous Monitoring

Revisiting Pipeline Blockage Detection using Guided Waves

Update on the Future of RCNDE

CDT in Quantitative NDE

Future Events

From Periodic Inspection to Continuous Monitoring

Non Destructive Testing (NDT) and Non Destructive Evaluation (NDE) refer to a range of measurement techniques used in industry to evaluate the properties of a material, component or system without causing damage. In the vast majority of cases, NDT/E involves inspection at regular intervals during planned maintenance periods.

On the other hand, Structural Health Monitoring (SHM) or Continuous Monitoring (CM) refer to a range of measurement techniques that monitor a system over time using periodically sampled dynamic response measurements from an array of permanent sensors. For example, vibration monitoring has been used for decades to evaluate the performance of rotating machinery.

In recent years, there has been a trend to develop permanently installed monitoring systems based on NDT/E measurement techniques. Permanent installed monitoring systems have many benefits over conventional periodic inspections including:

- Errors associated with measurement location are totally eliminated
- Higher measurement frequency enables averaging of random noise and hence higher measurement sensitivity
- Flaws are detected as soon as they become measurable, rather than allowed to develop until the next inspection date

When RCNDE began in 2003 all the core research projects were based on measurement techniques and associated enabling technology aimed at periodic inspection. However, in recent years an increasing proportion of RCNDE research is related to permanently installed monitoring systems. A brief review of RCNDE activity in this area is provided:

Corrosion Measurement by Guided Waves

RCNDE core research at Imperial and University of Bristol included an 18 month feasibility study between 2009 and 2011 on the application of ultrasonic guided waves to long term monitoring of engineering structures. Robust transducers and robust methods for fixing transducers to structures were developed. Baseline data was collected for a range of temperatures in an environmental chamber. A water tank was instrumented with multiple transducers to provide complete volumetric coverage and is currently on a long-term test.

Creep Measurement by Potential Drop

RCNDE core research at Imperial College between 2008 and 2012 investigated the measurement of creep using a permanently installed potential drop sensor. The research identified that the potential drop measurement was largely insensitive to material changes, such as voiding decreasing the electrical conductivity

Continued from Page 1

in the loading directions, but that the effect is largely geometric. The developed technology is effectively a high temperature strain gauge. This work is being taken forward via an RCNDE targeted research project with industrial sponsors EDF Energy, E.ON, RWE Npower and Rolls-Royce. It is expected to culminate in the technology being tested in a power station environment.

High Temperature Fatigue Crack Monitoring

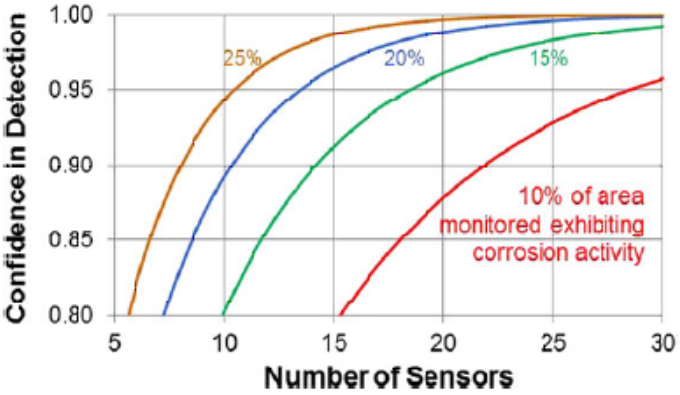
The aim of this study is to demonstrate the feasibility of monitoring the size of a fatigue crack at high temperature using an array of permanently installed high temperature wave guides.

Quantifying the Reliability of Permanently Installed Monitoring Systems

Current core research at Imperial College (2012-2014) aims to quantify the benefit gained from increasing the frequency of measurements in time for permanently installed monitoring system and help to unify the approaches to inspection (NDT) and monitoring (SHM/CM). Since permanently installed monitoring is a newer, less developed field, the project aims to develop strategies for deciding appropriate sensor placement and data collection frequency.

Above: *Wave guides exiting a furnace containing the sample*

Below: *Preliminary results showing the probability of detection as a function of number of sensors at difference fractions of area corroded*



Revisiting Pipeline Blockage Detection using Guided Waves

In 2003, Imperial College started a three year research project `On-line measurement of pipeline contents using ultrasonic guided waves' with industrial sponsors BNFL (EPSRC Grant Reference GR/S67074/01). Ultrasonic guided waves are now routinely used to screen long lengths of pipeline for defects which can then be examined in more detail with other NDT techniques. Guided wave inspection uses torsional waves that propagate along elongated structures such as pipelines. They are very sensitive to corrosion but are not attenuated significantly by pipeline coatings and low viscosity contents.

This project investigated the use of ultrasonic guided waves to detect and characterise sludge and blockages inside pipes through a combination of modelling and experimental measurements. The benefits of using ultrasonic guided waves are that they can be excited from the outside of the pipe (non-invasive) at a single location and propagate a long distance in the pipe wall.

A simple 2D model identified the guided torsional mode T(0,1) to be the most suitable for the application, and two measurement ideas were

Revisiting Pipeline Blockage Detection continued

developed: reflection and transmission. The reflection of the wave by the sludge layer inside the pipe indicates the location of the sludge and the transmission measurement provides further information on the nature of the sludge layer or blockage (stiffness, size, adhesion). The model was used to gain an understanding of the effects of bonding state between the sludge layer of or blockage and the internal pipe wall, the tapered nature of the surface of the sludge layer.

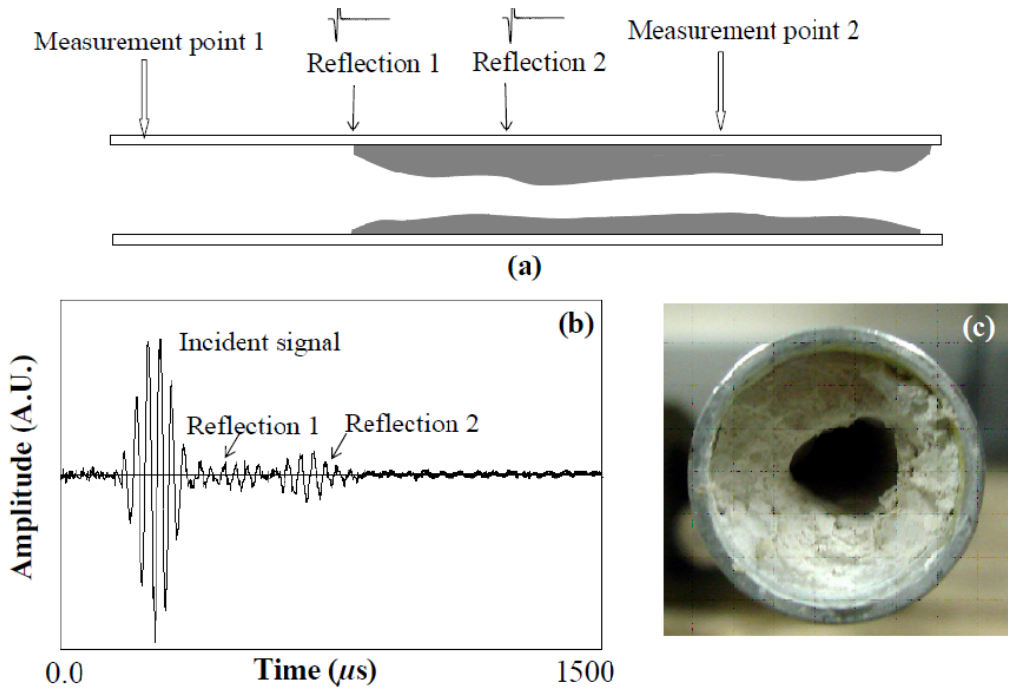
A more sophisticated 3D model was developed to investigate non-symmetric circumferential profile of the sludge layer on the reflection and transmission measurements and material damping effects.

The predictions of the modelling were then validated by a number of experimental measurements. This included an experiment performed on a 3.5 inch pipe with a sludge layer and blockage made from Magnesium hydroxide, magnesium oxide and water.

The results demonstrated that the reflection of the T(0,1) mode can be caused by any abrupt change of the properties of the sludge in its axial and circumferential profiles, including bonding state, thickness or material properties. The more abrupt these change are, the stronger the reflections will be. The strength of the reflection also enhances as the increase of the circumferential extent of the sludge layer. The best frequency to obtain strong reflection is determined by the thickness, material properties and the bonding state of the sludge layer. The dispersion change of the transmission signal of the T(0,1) mode from the blocked pipe region can be used to indicate the presence of the sludge since the mode is non-dispersive in the clean pipe. The dispersion change of the transmission is clear if the sludge layer is to a good extent axisymmetric, while it becomes complex as the sludge tends to be more non-symmetric.

The project concluded that ultrasonic guided waves have high potential to detect and locate sludge and blockages in long-range pipelines. A combination of both reflection measurements and transmission measurements should lead to a reliable detection in most circumstances. A broad band operating frequency range needs to be employed for both measurements. The characterisation of the extent of the sludge may be possible in certain situations but generally will be difficult due to the arbitrary shapes and properties of the sludge.

There is renewed interest in this research from other industrial members of RCNDE. If you would like further information or would like to register your interest please contact Gary Bolton (contact details can be found at the end of this newsletter).



Left: *(a) Schematic of pipe cross-section showing random sludge layer (b) Incident and reflected signals at point 1 (c) photograph of the pipe end*

Update on the Future of RCNDE

The current RCNDE EPSRC grant finishes in March 2014. Over the past 6 months, the industrial members of RCNDE, including NNL, have been laying the foundation for a further round of funding to continue with a UK research centre in NDE. A short-list of eight University groups, with Prof Peter Cawley of Imperial College invited to act as Principal Investigator (PI), has been selected from a list of all UK research groups performing NDE and NDE-related research. These eight groups have been invited to submit a number of outline research proposals. The industrial membership and the PI have reviewed these submissions and will shortly recommend the final university consortium and associated research topics for a full submission to EPSRC in September 2013. It is hoped, subject to successful EPSRC funding, a new programme of NDE research will commence in April 2014.

CDT in Quantitative NDE

In February 2013 EPSRC invited outline proposals against its £350 million investment in Centres for Doctoral Training (CDT) to address priority areas. A total of 356 proposals were submitted at the Expression of Interest stage from 56 universities with a total value of £1.6 billion. Following a review process approximately 50% of the outline proposals were invited to make full proposals by the closing date of 18th July 2013. One of the proposals chosen to go forward to the next stage was a CDT in Quantitative NDE lead by existing RCNDE academic partners Imperial, Bristol, Nottingham, Strathclyde and Warwick in addition to the University of Manchester. The new centre will build on the existing multi-university Industrial Doctorate Centre in NDE which is operated under a Strategic Partnership between EPSRC and the industrial members of the RCNDE including NNL.

Future Events

21-26 July 2013
QNDE Conference, Baltimore, USA

9 September 2013
RCNDE Management Board, Telford

10-12 September 2013
Annual Conference of British Institute of Non Destructive Testing

Further Information

If you require further information on any of the articles in this newsletter, back issues of the NNL RCNDE newsletter or any aspect of the RCNDE please contact:

Gary Bolton
Phone: 01925 289856
Email: gary.bolton@nnl.co.uk