NNL RCNDE Newsletter

Issue 8 - February 2014

Introduction

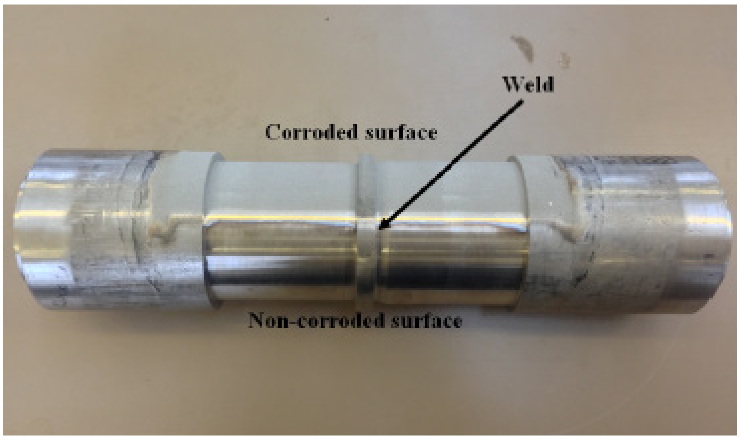
Welcome to issue 8 of the NNL RCNDE Newsletter which is distributed to the NNL's RCNDE network across the NDA estate. NNL is a member of the Research Centre for Non Destructive Evaluation (RCNDE) on behalf of the NDA. The RCNDE, formed in 2003, is an EPSRC (Engineering and Physical Sciences Research 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. Funding runs until 31st March 2014 with a new proposal for a further 6 years currently under review by EPSRC. More information on the RCNDE is available at www.rcnde.ac.uk.

Inside this issue

Evaporator Coil Inspection

NNL's Plant Inspection and Development team have developed and applied a number of inspection vehicles to measure the thickness of steam heated coils within evaporator vessels at Sellafield's Nuclear Reprocessing plant. These incorporate a radial array of up to x16 ultrasonic transducers held concentric within the pipework and sound coupled by water immersion. Lines of data at 2mm intervals have been generated for up to 20m lengths of pipework. This vast data set required evaluation. To decrease the time taken for this evaluation NNL is working in partnership with the University of Bristol on the development of automatic methodologies to speed up this process. The following developments are being trialled.

- A mathematical procedure that automatically measures thickness by two different methods; peak to peak from the 1st and 2nd back wall reflections (current NNL approach), and a relative thickness method that uses the two dimensional matrix of time and scanning distance coordinates
- Provision of confidence levels for thickness values thereby increasing the reliability of the thickness measurements
- The thickness measurement procedure has been applied to real measurement data and manual intervention used to test the reliability of the predicted pipe wall thicknesses
- The procedure has been demonstrated to be accurate with good quality ultrasonic data. However, it sill requires more trialling with lower quality ultrasonic data to determine when the process cannot be applied
- A mathematical model for predicting the ultrasonic signal measured by the probes has been developed which allows the effect of the probe head angle relative to the coil surface on the received signal to be investigated



Test specimen to simulate evaporator coil

In general the automatic measurements system compares well with the manual assessment of A-scan data and shows significant potential as a future

Evaporator Coil Inspection cont.

measurement tool. However manual intervention will always be necessary to underpin the accuracy of the critical thinner regions of the coil pipework.

In a second strand to this work, the University of Bristol reviewed the feasibility of using ultrasonic phased arrays to inspect the evaporator coils for external corrosion. Laboratory experiments were performed on a weld test specimen using 5 MHz, and 15 MHz phased arrays with a standard 3 m cables and with a 50 m extension cable (which would be required to gain access to the evaporator coil). The study concluded that the 5 MHz phased array probe with 50 m extension cable combined with TFM was suitable for identifying and sizing external corrosion on a pipe test specimen from within.

NNL are currently developing an inspection vehicle that will deploy the 5MHz phased array transducer within the HA evaporator coils as a tool to generate an external wall topographical profile and accurately measure thickness in these targeted regions. Martin Armstrong of the NNL Plant Inspection and Development team is the contact for this work.

Inspection Trial of Phased Array Full Matrix Capture

RCNDE funded research at the University of Bristol has focused on ultrasonic phased arrays for several years. In recent years research has focused on data acquisition by Full Matrix Capture (FMC) and resulting imaging by the Total Focusing Method (TFM).

FMC is a data acquisition technique that allows for the complete time domain signal to be captured from every element of a phased array probe and was originally developed for medical ultrasound imaging. Data is acquired using a 'transmit on one and receive on all' data capture approach, with the first element initially acting as transmitter, with every element (n) acting as receiver. The process repeats until all elements have transmitted; generating a complete set of time domain signals containing n2 A-scans. In TFM imaging a grid of pixels representative of the region of interest is defined with relevant amplitude information from the full matrix of data being extracted, allowing every pixel in the image to be treated as a focal point allowing for fully focused imagery of the region of interest to be rendered.

The application of NDE techniques is covered by standards which provide the user with confidence that a particular technique is capable of identifying particular defects when used in accordance with a particular standard. The downside of this approach is that it can provide a barrier to the application of new NDE techniques as standards can take several years to flow through following new developments in NDE technologies. Despite this, new NDE techniques can be useful to increase the capability of an inspection but any new technique requires experimental testing to provide evidence of its capability and to identify its region of applicability. A new technique is often tested against a known defect population to show that it works for a range of defect species. The technique is optimised until the defects are detected and determined to be of the correct size and character. The results are published and the technique is labelled as being proficient in the detection and analysis of those particular defect types. It should be emphasised that the capability of the technique is also related to other parameters such as geometry, frequency, size and placement of the ultrasonic probe, the material and its microstructure, etc. Therefore before an industrial end-user of NDE can rely on a technique, it must have a defined inspection procedure to remove variation between inspections that could reduce this capability.

This RCNDE funded technology transfer project performed by the University of Bristol and AMEC aimed to test the techniques incorporated within the University of Bristol's ultrasonic phased array FMC

Inspection Trial of Phased Array Full Matrix Capture cont.

software package called Bristol Array Inspection (BRAIN) which involves several post-processing algorithms including TFM. The project was planned around the following tasks:

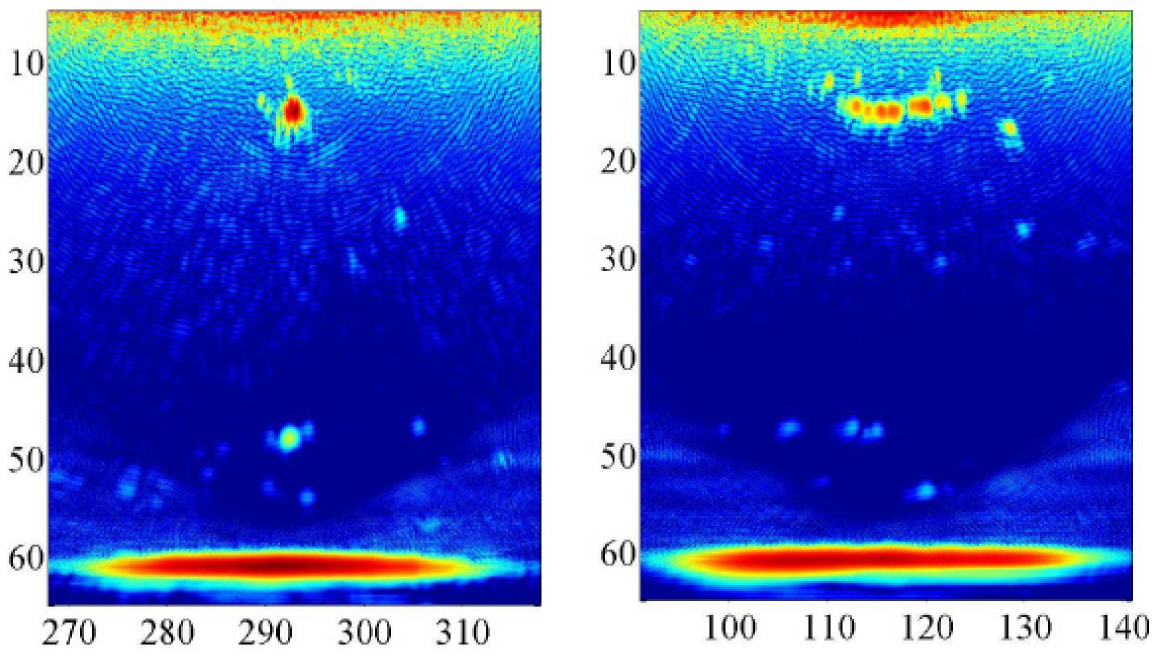
- Development of a working inspection procedure to provide a repeatable inspection against which the performance can be assessed
- 'Open' trial to allow the development of the inspection procedure
- Witnessed 'blind' trial to test the effectiveness of the procedures in a realistic industrial environment; and
- Destructive examination of defects in one of the test specimens to improve confidence in the capability of the techniques

The University of Bristol was responsible for developing the procedure and for carrying out the open and blind trials. AMEC assessed the procedure and the open and blind trials, and provided feedback and guidance where required, and undertook the destructive examination.

Three 600mm x 200mm x 60mm ferritic steel specimens were used each with a double-V ferritic butt weld (with the caps ground flat) running across the width of the specimen. These contained a series of typical realistic manufacturing and in-service volumetric and planar defects located along each weld. These defects included a lack of fusion at the weld interface, porosity, slag, and rough and smooth cracks.

AMEC prepared an Inspection Specification, containing details of the planned trial process and reporting requirements, which was supplied to the University of Bristol. This included details of the test specimen dimensions, inspection volumes and likely defect types to aid initial inspection procedure development. The University of Bristol prepared a draft Inspection Procedure.

It was intended to begin with an 'open' trial for development of the inspection procedure, however, it was thought beneficial to initially provide no information regarding defect location and character other than to provide an inspection volume and possible defect types to more accurately simulate a real industrial inspection. At this stage, a full inspection procedure had not been produced. During the first blind trial of specimen 1, two of the four intended defects (slag and lack of fusion) were detected and correctly characterised. Two other defects (rough cracks) were missed. After the initial blind trial, the specimen 1 specification was provided to Bristol who revised the Inspection Procedure and performed an open development trial on this



Left: TFM images from Specimen 2 across and along a slag defect

Inspection Trial of Phased Array Full Matrix Capture cont.

sample. In this open trial, all four intended defects were detected with the revised procedure. Length and height sizing accuracy was good on three of the four intended defects. A blind trial was performed on specimen 2 with the revised procedure and three of the four intended defects were detected and several other signals reported from unintended defects.

Following a further revision to the defect characterisation procedure, the final inspection procedure was produced and tested in a final blind trial from the opposite side of that previously inspected on specimen 2 (the inspector was unaware that the same sample was being used).

AMEC performed destructive examination of all four intended defects and selected unintended defects in specimen 2 to provide detailed characterisation for comparison to the results from BRAIN. All four intended defects in specimen 2 were identified along with several unintended defects. Accurate height and length sizing was achieved for the four intended defects in specimen 2.

In addition an open inspection of the four identified intended defects in specimen 3 was performed to test the sizing and characterisation properties of BRAIN. Length and height sizing accuracy was very good on all four intended defects. The type of defect was successfully identified in three of the four defects. A porosity type of defects was misclassified which may have been due to the inspector not being familiar with this type of defect.

The open and blind trials and associated procedure development provided important information on the strengths and weaknesses of FMC imaging techniques for the inspection of ferritic butt welds and their potential use as part of an inspection procedure for such welds. The importance of good inspection design was reinforced to ensure full-weld coverage and optimised defect discrimination and characterisation for the full range of potential defect types. The inspections were independently witnessed throughout, and there were no performance weaknesses that could be attributed to human reliability factors.

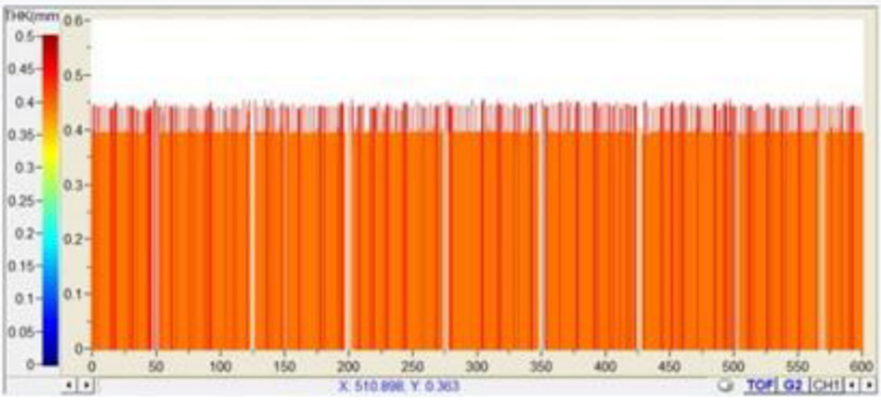
Overall FMC and TFM performed well regarding detection, sizing and characterisation of the intended and several unintended defects. The decision rules developed to aid defect identification, discrimination and characterisation made use of known differences in ultrasonic response between different defect types. Further analysis of these inspection and destructive examination results is likely to offer further improvements to the decision rules.

Where intended defects were missed initially, basic improvements made to the inspection procedure corrected these weaknesses. Several unintended defects detected by FMC/TFM were also found by pulse echo techniques so confirming the sensitivity of the FMC/TFM imaging techniques and its compatibility with conventional UT methods. However, numerous additional weak images were presented in the FMC/TFM results which, although dismissed during the defect decision process, confirm the sensitivity of the technique to small discontinuities in the weld region. The improved imaging from FMC and TFM comes at the cost of higher sensitivity which carries with it the increased false call rate from small insignificant reflectors. Therefore care is needed in selecting a reliable calibration technique regarding inspection sensitivity. Also, further optimisation of the FMC/TFM inspection procedure for the full range, types and orientations of likely defects would increase the amplitude difference between very small (innocuous) and larger defects, so simplifying defect identification and discrimination.

This project has provided valuable information to RCNDE industrial members who wish to use ultrasonic phased arrays for real world inspection challenges and is accelerating the technology transfer of ultrasonic phased array FMC and TFM.

AGR Fuel Cladding Thickness Measurement

The Nuclear Decommissioning Authority (NDA) has an obligation to safely manage stocks of spent Advanced Gas-cooled Reactor (AGR) fuel. The current strategy is to complete the AGR reprocessing contracts as soon as reasonably practicable and cease reprocessing at THORP. It is planned to place unreprocessed spent AGR fuel and any future arisings of AGR fuel into interim wet storage pending disposal in a Geological Disposal Facility.

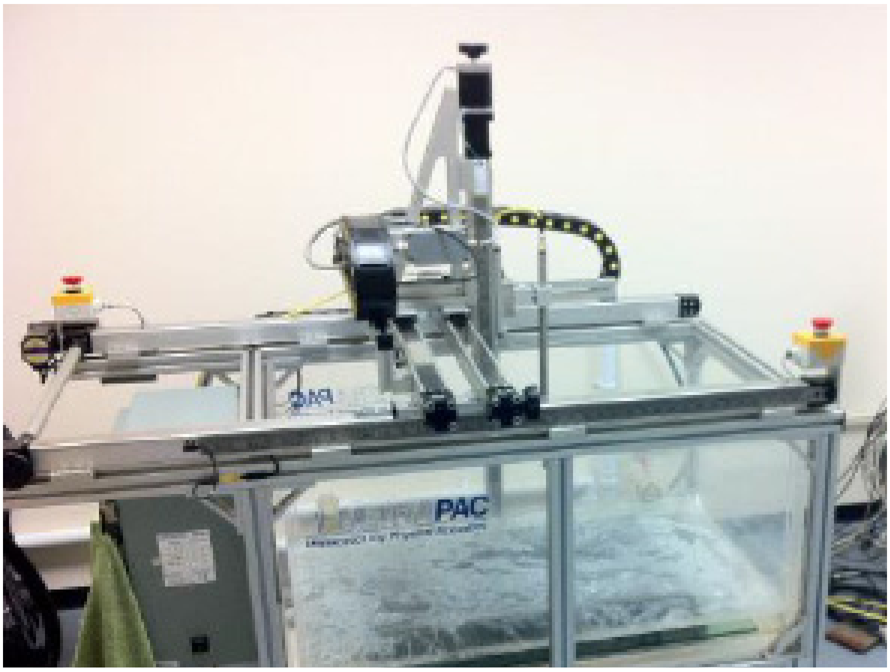


B-scan image indicated cladding thickness along AGR fuel pin

Spent AGR fuel is currently buffer stored in ponds and will typically spend less than 10 years in storage prior to reprocessing, although there is a very small quantity of AGR fuel that has been stored in ponds at Sellafield for over 20 years. There is confidence in wet storage of spent AGR fuel, especially over a period of up to 25 years. Over longer timescales, such as those until a Geological Disposal Facility (GDF) is operational and able to receive spent nuclear fuel, there is good reason but less evidence to demonstrate that corrosion of the fuel will remain low (effectively nil) and that the storage arrangements will be fully adequate.

In a recent NDA Direct research Portfolio (DRP) project, NNL have recently demonstrated ultrasonic immersion testing to measure the cladding thickness on dummy AGR fuel pins in a laboratory environment. Automated pulse-echo axial scans were performed along the length of the dummy AGR fuel pin section at four orientations and along the weld cap at one orientation using a high frequency focused probe. Results are presented in the form of A and B-scans. A-scans show the strength of the reflected ultrasonic signal as a function of time and B-scans show a cross-sectional profile through one vertical slice of the sample indicating the thickness of the sample.

The technique was successful in offering a means to undertake non-contact thickness measurements of the cladding for the vast majority of the sample length which shows that the technique is viable for general thickness measurements.



Immersion tank and scanning frame

NATIONAL NUCLEAR LABORATORY

Update on the Future of RCNDE

The current RCNDE EPSRC grant finishes on 31st March 2014. A proposal for a new UK research centre in NDE was submitted to EPSRC in late 2013. The academic partners have been revised and the new proposal is based around Imperial College and the Universities of Bristol, Manchester, Nottingham, Strathclyde and Warwick. The industrial members have been involved throughout the process to ensure that the proposal meets their industrial vision for NDE. A decision from EPSRC is expected in March 2014 and, subject to successful EPSRC funding, a new programme of NDE research is planned to commence in April 2014.

Update on CDT in Quantitative NDE

In 2013 an outline proposal for a new CDT in Quantitative NDE was successful at the Expression of Interest stage and EPSRC invited academic partners comprising Bristol, Imperial, Manchester, Nottingham, Strathclyde and Warwick to prepare a full proposal. This would replace the existing Industrial Doctorate Centre in NDE which will receive its last cohort of EngD students in 2014. Unfortunately this proposal was not one of the 91 successful applications from a total of 177 applicants. However, feedback from EPSRC has been positive with the proposal described as being of 'fundable' quality but constrained by available funding, it was not possible to fund the proposal. In addition EPSRC stated that the proposal was strong on its successful existing Industrial Doctorate Centre (IDC) track record, industrial engagement, technical/scientific scope, and fit with the industrial vision of the RCNDE industrial members. EPSRC recognise there are probably some key gaps in the overall provision for CDTs in relation to the strategic industrial requirements. NDEvR (the organisation representing the RCNDE industrial members) is currently making the case to EPSRC that doctoral training in NDE should be considered as a strategic gap and how to address it within the funds currently available, or perhaps extra funds, if more were to be made available by Government.

Future Events

13th May 2014 – Centre for Doctoral Training Research Review

14th May 2014 – Annual Core Research Review

15th May 2014 – Management Board

16th May 2014 – Industrial Working Group, University of Warwick

9-11th September 2014 – BINDT Annual Conference, Manchester

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:

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Winner
RESEARCH & DEVELOPMENT
Sector Award

Winner 2004-2008, 2010-2011
Highly commended 2009, 2012, 2013

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