Issue 11 - July 2015

NATIONAL NUCLEAR LABORATORY

RCNDE News

Research Centre for Non Destructive Evaluation

Welcome to Issue 11 of the NNL RCNDE Newsletter which is distributed to NNL's RCNDE network across the NDA estate. NNL is a proud 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 and longer-term needs of industry.

Funding was secured in 2014 to continue RCNDE for a further six year period covering 2014 to 2020.

More information on the RCNDE is available at www.rcnde.ac.uk.

Inside this issue

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Three-Dimensional Geometrical Model Capture of ILW Container

The NDA published Industry Guidance on the interim storage of higher activity waste packages in 2012 which established a method to define generic package performance criteria. The method consists of the following steps; identification of the package safety function, identification of evolutionary processes that may affect safety function performance, determination of measurable indicators of these evolutionary processes and calibration of the indicators into package performance zones. An example of an evolutionary process which may affect a number of the waste package safety functions is wasteform expansion so there may be a need to measure the dimensions of some waste packages.

The University of Strathclyde have developed a novel approach using an artificial kinematic field which provides autonomous and distributed control for multiple robots to perform a visual inspection of a target. The kinematic field provides the robotic vehicles with smooth trajectories, relative to the central target, while also ensuring collision avoidance. A mock inspection of an ILW container was completed using a swarm of unmanned aerial vehicles in a laboratory environment although the approach can also be used for other forms of robotic vehicles such as crawlers/ tractors.

The picture below shows the acquired visual inspection date which has been photogrammetrically meshed to generate a 3D surface-meshed model of the drum. This final textured model was achieved by a stitching process where points were selected that appeared in at least three images.

Above Left: *3D surface-meshed model of ILW container.* ***Above Right****: Comparison of the photogrammetry to actual dimension measurements*

The resultant mesh point cloud was then compared to reference CAD to highlight any deviations, which in terms of ILW storage could be attributed to expansion of the contents. The image on the right uses a colour scale to show the accuracy of the photogrammetric data compared to the reference dimensional measurements of the container.

This approach provides benefits including good coverage capability, reduction in inspection times and intelligent collision avoidance. The scheme has been demonstrated for aerial vehicles but is suitable for scaling to larger fleets of vehicles and also to other vehicles modalities. Remote visual inspection of ILW packages offers potential to measure the extent of package expansion which may be a key measurable indicator of the performance of some waste packages during interim storage.

This work is due to be published in the following article:

RA Clark, G Punzon, CN MacLeod, G Dobie, R Summan, GT Bolton, SG Pierce and M Macdonald, Three-dimensional Model Capture by an Autonomous Inspection Swarm, IEEE Transactions of Automation Science and Engineering, In Press.

Future Events

25-31 July 2015 – Quantitative Non Destructive Evaluation, Minneapolis USA

7 September 2015 – RCNDE Management Board, Telford

8-10 September 2015 – British Institute of Non Destructive Evaluation (BINDT) annual conference, Telford

19-20 November 2015 – EDF Ultrasonic Inspection of Complex Structured Materials, Paris

January 2016 – RCNDE Technology Transfer Event and Management Board, London

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Inspection of AGR Fuel Cladding

The Nuclear Decommissioning Authority (NDA) has an obligation to safely manage stocks of spent Advanced Gas-cooled Reactor (AGR) fuel. The current strategy for oxide fuels is to complete the spent fuel reprocessing contracts and place the remaining AGR fuel, including any future arisings, into interim wet storage pending a decision to dispose to a Geological Disposal Facility (GDF).

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. Therefore, it would be beneficial to have means of monitoring the condition of the fuel during its interim storage. The intention is to implement a diverse and robust monitoring and inspection regime that will determine whether deterioration in the condition of the fuel and/or its storage environment has occurred.

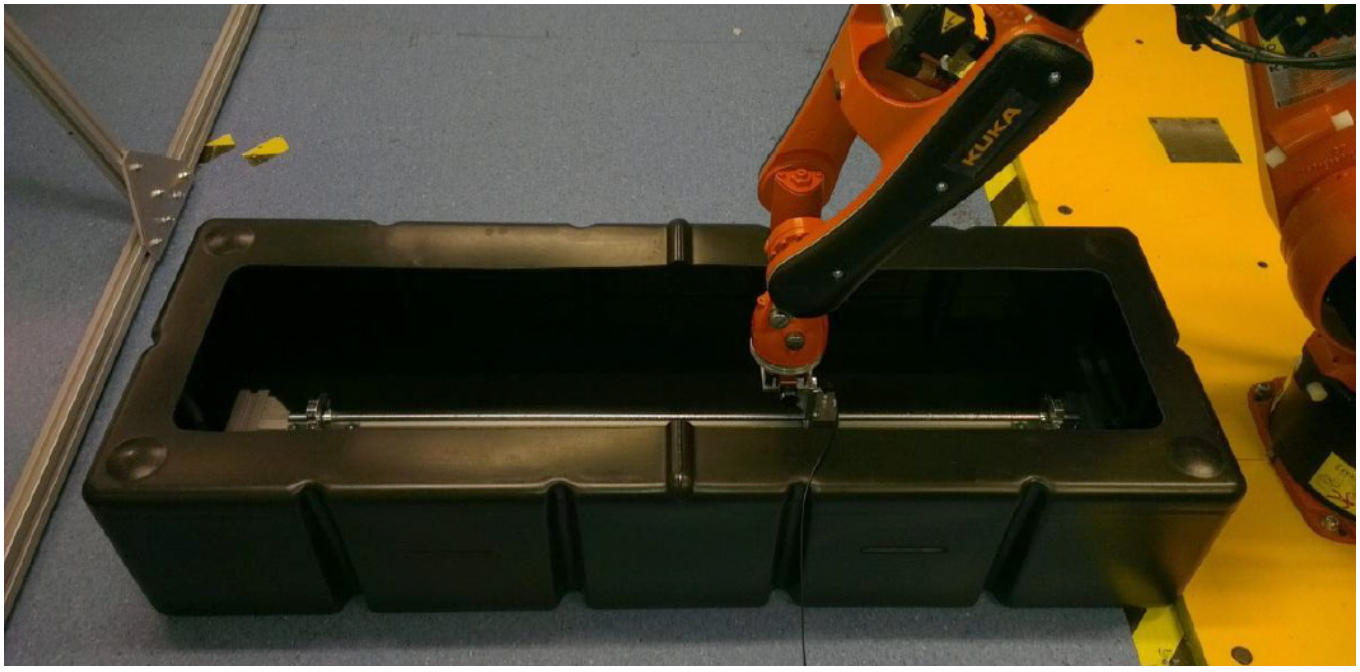
Eddy Current (EC) testing is a well-established Non-Destructive Evaluation (NDE) method for identifying and characterising surface and near surface defects in electrically conductive materials. In a recent Sellafield Ltd funded project, NNL in partnership with RCNDE academic partner University of Strathclyde have recently demonstrated the inspection of dummy AGR fuel pins with simulated localised corrosion defects using EC testing.

In EC testing an alternating current flows through a wire coil and generates an oscillating magnetic field. If the probe and its magnetic field are brought close to a conductive material like a metal test piece, an eddy current will begin to move through the metal. The eddy current flowing through the metal will in turn generate its own magnetic field, which will interact with the coil and its field through mutual inductance. Changes in metal thickness or defects like near-surface cracking will interrupt or alter the amplitude and pattern of the eddy current and the resulting magnetic field. This in turn affects the coil by varying the electrical impedance of the coil.

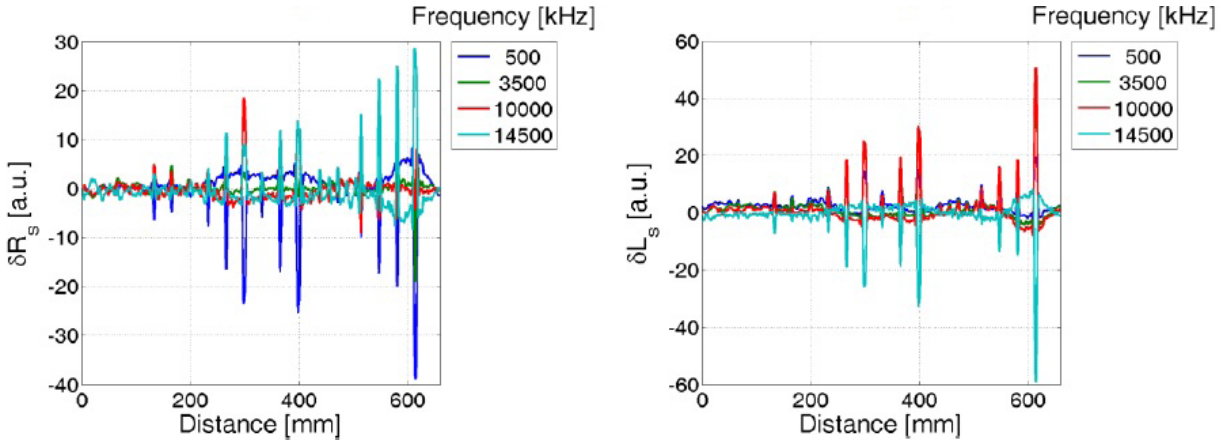
Twelve helical notches of length 2.5, 5 and 10 mm and with depths of 25, 50 75 and 100% of wall thickness and three localised patches of clad thinning of principle length in the scan direction of 4, 6 and 7 mm and depth 100, 200 and 300 µm respectively were created on the dummy AGR fuel pin.

A probe was designed which was capable of fitting between the heat transfer ribs on the cladding of the dummy AGR fuel pin. The photograph below shows the eddy current probe connected to a fixed arm robot scanning a dummy AGR fuel pin submerged in water.

The main limitation highlighted from this experimental study is the impact of the changing stand-off distance between the coil and the defects when the defects are located in the Anti-Stacking



Above: *The eddy current probe connected to a fixed arm robot scanning a dummy AGR fuel pin submerged in water. Below: Eddy current response for a complete helical scan of the fuel pin with the fifteen defects.*



Grooves (ASGs) on the fuel pin. Using the SFEC approach, signals are collected at multiple frequencies and it is recommended that further work is performed on signal processing and defect recognition algorithms as the signals caused by changing stand-off and defects may have different spectral effects.

In addition it is recommended that samples with real corrosion defects are created to enable a further programme of experimental programme to be undertaken to demonstrate the feasibility of EC testing on AGR fuel pins with realistic defects of the corrosion mechanisms possible during pond storage.

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NNUMAN-RCNDE Workshop

New Nuclear Manufacturing (NNUMAN) is a major EPSRC funded programme at the Universities of Manchester and Sheffield delivering new long-term research into innovative manufacturing techniques for the future needs of the UK nuclear industry. The programme focuses on early-stage research into a range of manufacturing technologies, the most promising of which will go into advanced development at the Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC).

NNUMAN addresses the fundamentals of advanced manufacturing for new reactors and the next generation of nuclear power stations. This key research effort is driving progress towards new, high productivity nuclear manufacturing technologies and their transition from the laboratory to production-readiness. A joint NNUMAN and RCNDE workshop was held in June 2015 to cover the principal NDE challenges required to meet the design objectives of achieving 60-plus year lifetimes for the main nuclear components with high plant availability. This included NDE requirements for advanced manufacturing technologies, with a specific topic of 'narrow-gap welding'.

The workshop was opened with a keynote presentation from Jean Dhers (Areva) on the NDE requirements and challenges for the major components of the emerging new generation of nuclear plant. One of the main challenges facing Areva is the replacement of radiography with ultrasonic phased array technology. Where radiography cannot be replaced there is pressure to suppress the use of gamma sources and move from conventional film to digital radiography. An example of a component that requires inspection at manufacture is the steam generator tube support plate which contains 10,000 holes.

This was followed by a series of academic and industrial presentations:

- Rolls-Royce Nuclear: Start of life NDE requirements and NDE methods
- Hitachi Europe: In-service inspection techniques for boiling water reactors
- AMEC Foster Wheeler: NDE & SHM inspection development and qualification
- EDF Energy: Hinkley Point C and qualified inspections on high integrity components
- Manchester: NNUMAN Overview
- Nuclear AMRC: Small Modular Reactors welding, cladding and inspection issues
- Manchester: Quantum Well Hall Effect Camera
- Manchester: Narrow-gap welding – progress on NNUMAN & potential inspection challenges

Two structured work sessions were held; identification of the overall industry requirements and priorities for next generation nuclear manufacturing inspection and in-service NDE and monitoring and a focused session on the issues and requirements for inspection and certification for narrow-gap welding for next generation nuclear power plants.

The output from the workshops is to be incorporated into the RCNDE 5/10/20 year industrial vision and to steer the research priorities of NNUMAN and any follow-on research projects.

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Further Information

For back issues of the RCNDE newsletter, please visit www.nnl.co.uk/rcnde. If you require further information on any of the articles in this newsletter or any aspect of the RCNDE please contact:

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