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NATIONAL NUCLEAR LABORATORY

RCNDE News

Research Centre for Non Destructive Evaluation

Welcome to Issue 13 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

Core Research: Accurate Characterisation

RCNDE embarked on its third phase of long-term core research in April 2014, which will run until 2020. This programme is co-funded by EPSRC and by industrial members. The core research programme is structured into the following four themes:

- Enhanced imaging
- Accurate characterisation
- New technologies
- Permanent monitoring technology

Accurate characterisation looks to make a step change in our ability to perform accurate characterisation of defects and internal microstructure. Integral to this challenge is to understand how practical constraints, such as access restrictions, affect the quality of the characterisation information and how to achieve an appropriate balance between measurement complexity and the accuracy of the result. Overall, the aim is to convert NDE data into decision-making information and thereby enable a less conservative approach to plant design, operation and life extension.

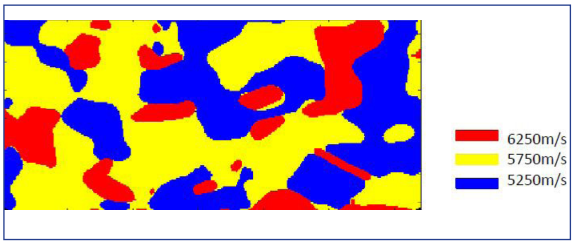
In general, current NDT imaging algorithms based on ultrasonic array data assume that the host material is homogeneous. In many important applications this assumption is clearly invalid and can lead to defects being missed or at best poorly classified or characterised.

One of the three projects within the accurate characterisation theme is investigating the feasibility of non-destructively determining the interior microstructure of safety critical components (in particular coarse grained materials such as welds) and then using this in imaging algorithms to improve flaw detection and characterisation.

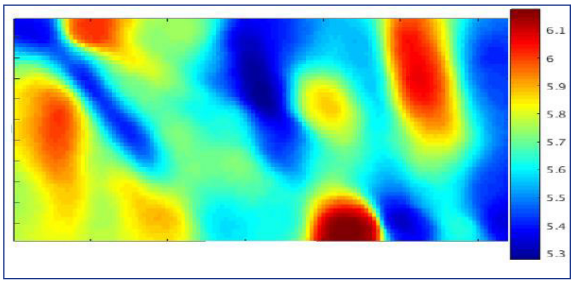
This project at the University of Strathclyde aims to use ultrasonic arrays to extract this internal microstructure information from components entirely non-destructively and use this in imaging algorithms to improve flaw detection and characterisation.

A 2D algorithm which reconstructs a spatial map of the dominant grain orientations (ie regional information rather than the full grain structure) in weld materials has been developed.

The figure on the next page shows a 2D simulation of the sound velocity in a sample of heterogeneous (locally isotropic) material.



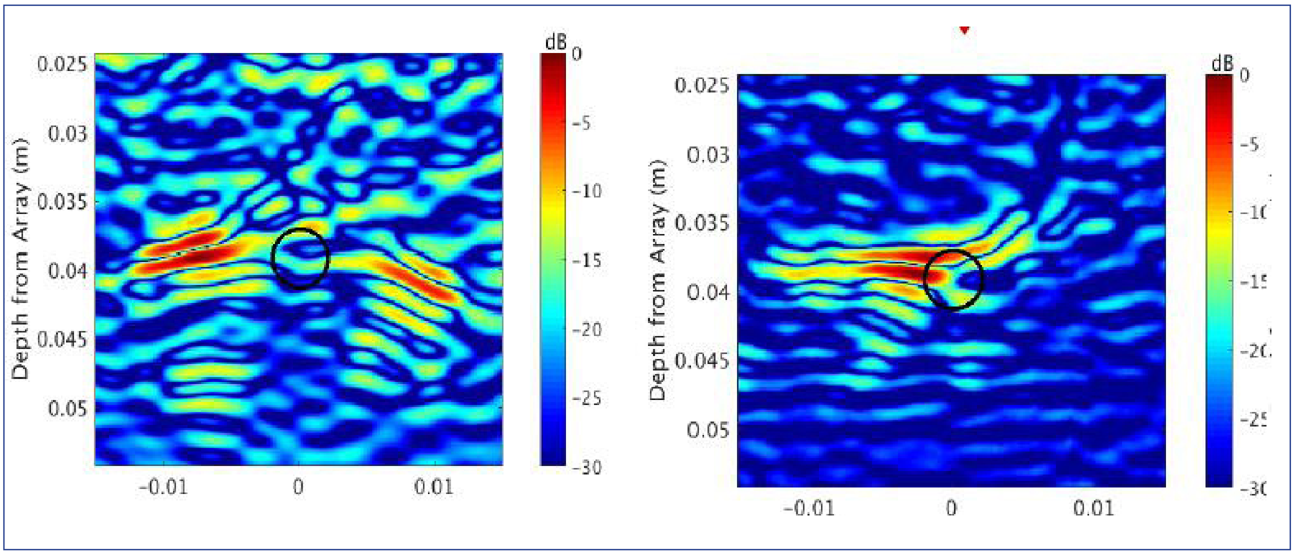
2D map of simulated velocity for heterogeneous material



Velocity map reconstructed from simulated ultrasonic phased array data

The (far right) image shows a reconstruction of the velocity map from the finite simulation of ultrasonic phased array measurements. There is good agreement between the simulated raw data and reconstructed data.

The images below show simulated images for a heterogeneous material with a centrally located defect in which the material grain structure has been determined by EBSD. The image on the left is based on an assumption that the velocity of sound within the material is homogeneous and the image on the right uses a velocity map from simulated ultrasonic array data from the EBSD data. Defect detection is clearly improved by using the microstructure information determined from the ultrasonic array data.



The project has developed an ultrasonic array based travel-time tomography system and from simulations it has been shown that knowledge of the regional material map (grain orientation) can be used to markedly improve existing defect imaging algorithms. This early work has used a simple imaging algorithm for comparison between the homogeneous assumption and the ultrasonic array derived velocity map. The use of improved imaging algorithms offers the potential to make further significant improvements to the quality of the images. Looking forward the project aims to develop the mathematical modelling of the interaction of ultrasound with material microstructure, investigate alternative algorithms and perform experiments on industrial samples.

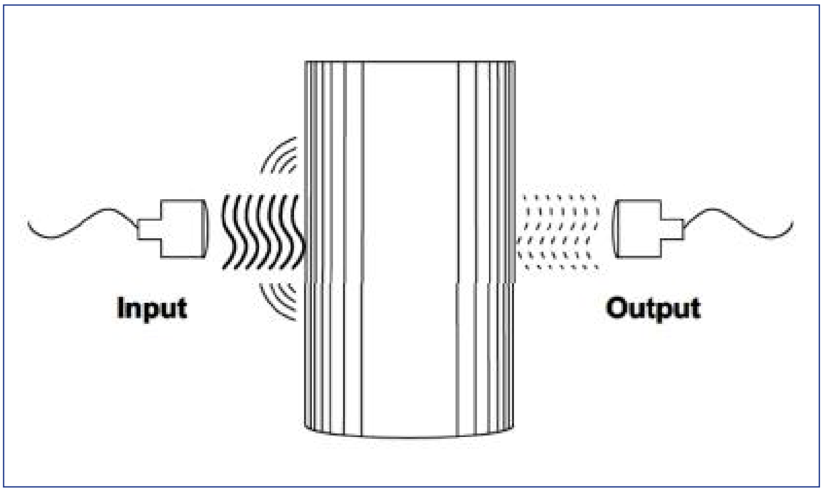
Nonlinear Ultrasonic Inspection of Product Storage Containers

Conventional ultrasonic NDT monitors the scattering of ultrasound waves caused by their interaction with defects, leading to amplitude and phase variations of the input signal due to the wave-defect interaction.

The efficiency of conventional ultrasound depends on the size of defects and a degradation of linear material properties (stiffness variation) caused by damage to the material. For early-stage damage, the contribution of these factors is often very low and this determines the unacceptably low sensitivity of conventional ultrasonic NDT techniques for some type of defects/cracks.

Nonlinear ultrasonic inspection makes use of the phenomenon that small cracks cause frequency changes to the input signal. Basically, the intact parts of the material outside the defect vibrate linearly, ie with no frequency variation in the output spectrum, while a small cracked defect (invisible to a linear ultrasonic NDT) behaves as an active source of new frequency components rather than a passive scatterer as in conventional linear ultrasound NDT.

During 2015-16 Sellafield Ltd (SL) supported an MPhil research project via NNL at former RCNDE academic partner the University of Bath to investigate the use of non-contact nonlinear ultrasonic inspection for detection of small cracks in product storage containers.

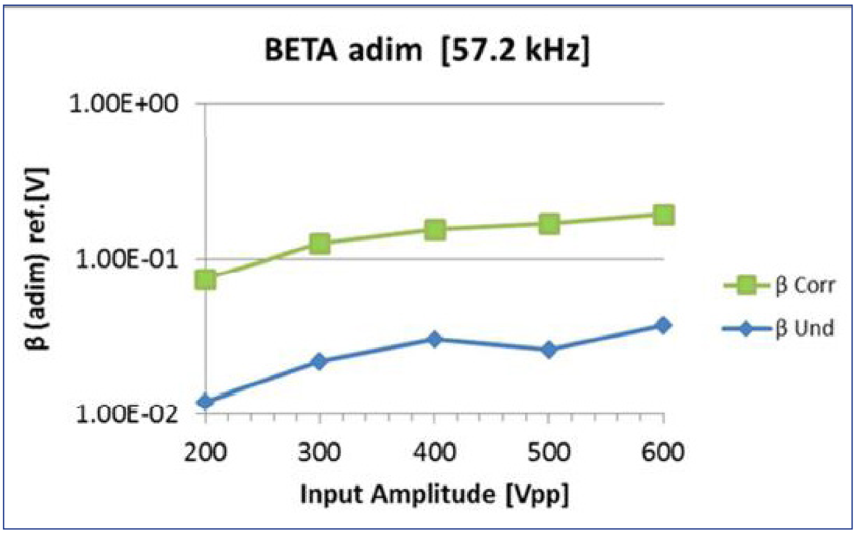


Schematic of non-contact nonlinear ultrasonic inspection of product storage containers.

Experiments were performed on outer product storage containers. It is known that when a specimen with damage is excited with an external ultrasonic wave at fixed frequency, the local vibration spectra contain a number of new frequency components due to nonlinear contact interaction of any crack-type defects.

These are called harmonics and by comparing their amplitude with respect to the fundamental amplitude, it is possible to calculate the nonlinear parameters which refer to the second, third, etc harmonic amplitudes.

The figure below shows the second harmonic nonlinear parameter β for an undamaged can (blue) and can with small stress corrosion cracks (green). The SCCs had previously been demonstrated to be invisible to conventional linear ultrasonic inspection. It can be seen that β is around an order of magnitude higher for the damaged can compared to the undamaged can.



Based on the success of this MPhil project an application was made to continue the work to the NDA PhD bursary scheme. This proposal was successful and the follow on project is due to start at the University of Bath later in 2016.

CDT in Quantitative NDE

RCNDE has been providing Engineering Doctorate (EngD) training for over ten years. The EngD is a four year research degree of equivalent standing to a PhD. The students, or research engineers, are based in a sponsor company where they carry out applied research on a topic of interest to the company. During the four years, each research engineer spends about 9 months on advanced technical and professional development courses.

The new Centre for Doctoral (CDT) in Quantitative NDE recruited its first cohort of ten students in 2015. This is made up of six research engineers funded by EPSRC and sponsored by an RCNDE member and four PhD students funded from other sources eg university funding. Details of the six EngD projects from the first cohort to the CDT in QNDE are shown below.

Project	University	Sponsor
Improving inspection reliability through data fusion from multi-modal array inspections	Bristol	BAE Systems
Integrated ultrasonic imaging for the inspection of near-surface defects in safety-critical components	Imperial	Rolls-Royce
Automation of image based detection	Imperial	Rolls-Royce
Measurement of microstructural damage in cylindrical components using guided waves	Imperial	Guided Ultrasonics
Life prediction of composites based on NDT data	Bristol	Defence Science and Technology Laboratory
Advanced remote visual inspection	Strathclyde	Inspectahire

Access to the CDT in QNDE is open to NDA, Sites License Companies and NNL under the NDA membership of RCNDE.

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Future Events and Further information

12-14 September 2016, British Institute of Non Destructive Testing Annual Conference, Nottingham

14 September 2016, RCNDE Industrial Working Group, University of Nottingham

15 September 2016, RCNDE Board Meeting, Nottingham

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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