ADVISE TRAINING SCHOOL ON NDE FOR NPP

15 FEBRUARY 2022

– EVENT BOOKLET –

ADVISE has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 755500.

WELCOME

Material choices for components in nuclear reactors are almost exclusively dictated by mechanical and operational requirements. The austenitic stainless steel alloys widely used in the nuclear industry have excellent corrosion resistance and high mechanical strength and creep resistance at elevated temperatures, are ductile and can be hardened by cold forming. The low carbon versions also minimize carbide precipitation during welding.

These excellent and desirable properties come at a price in terms of the inspectability of these materials: During solidification of austenitic steels, long columnar grains are formed with preferential growth along the direction of maximum heat loss during cooldown. These grains affect an ultrasound wave in two different yet inherently linked ways:

- The columnar grain structure results in a bulk anisotropic behaviour of the material, leading to beam skewing also directly affects ultrasonic imaging, which typically relies on the assumption of a known, constant and isotropic wave velocity.
- As these grains have dimensions of the order of the wavelength typically used in ultrasound inspections, scattering occurs at grain boundaries, severely reducing the signal to noise ratio.

As the microstructure is at the origin of both effects, ADVISE refers to this family of materials as “complex structured”, to include welds and castings, but also repairs, dissimilar welds and austenitic claddings on ferritic steel components.

ADVISE is a joint European effort, funded under the Horizon 2020 / Euratom research scheme and aiming to address the ultrasound inspection of complex structured materials. ADVISE readily admits that no single technological advancement is likely to solve the issue at hand. Rather than looking for the proverbial silver bullet, the project aims to improve the inspection capability of these materials by a number of incremental improvements in different fields.

Throughout this Training School, we will discuss the challenges involved in ultrasound imaging of complex structured materials, and present some of these developments which we believe are building blocks towards improved ultrasound inspection of austenitic stainless steel components.

Thank you for registering for this event!

Andreas Schumm & The ADVISE Consortium

PROGRAMME

15 February 2022		
14:00 – 14:05	Welcome & Introduction	Andreas Schumm, Project Coordinator (EDF)
14:05 – 14:25 14:25 – 14:35 14:35 – 14:55 14:55 – 15:15 15:15 – 15:35	Ultrasound propagation in complex elastic media Presentation and demonstration of FE Beam tools Presentation and demonstration of POGO simulation software Presentation of CIVA Plugin & CIVA Lab features for Signal Processing TFM imaging of complex and anisotropic materials	Nicolas Leymarie (CEA) Souad Bannouf (EXTENDE) Peter Huthwaite (Imperial College London) Stéphane Leberre (CEA) Sébastien Robert (CEA)
15:35 – 15:45	*Break*	
15:45 – 16:05 16:05 – 16:25 16:25 – 16:35 16:35 – 16:45	Presentation of Scattering Matrix feature on FMC data (measured or simulated) Ray inversion for determining weld maps from ultrasound Presentation and demonstration of TFM SEE feature in CIVA Presentation and demonstration of the SEE feature on Eddyfi acquisition system	Alexander Velichko (University of Bristol) Michal Kalkowski (Imperial College London) Souad Bannouf (EXTENDE) Hubert Voillaume (Eddyfi)
16:45 – 17:00	Questions & Answers Concluding remarks	 Andreas Schumm, Project Coordinator (EDF)

SPEAKERS

Souad BANNOUF
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Short Profile

Doctor in physics since 2013, Souad Bannouf research topic was carried out at CEA, where she worked on the development and the optimization of synthetic imaging methods, in particular Total Focusing Method imaging, for non-destructive testing of complex industrial parts. Souad is now R&D engineer at EXTENDE since 8 years. She manages collaborative R&D projects involving EXTENDE. Souad works with EXTENDE's consulting and support teams. She provides also CIVA UT training session.

Abstract

Presentation and demonstration of FE Beam tools

This video presents the FE Beam tool which is fully integrated into the CIVA ADVISE platform environment. The demonstration is made on a cylindrical welding component. The FE beam settings are described and the cartography of the beam through the weld is simulated. Results are compared with the ones obtained with a homogeneous component.

Presentation and demonstration of TFM SEE feature in CIVA

This video presents the TFM SEE feature available in CIVA 2021. This new feature is applied to a vertical notch breaking the complex backwall of a specimen.
The video shows how to define such a configuration. The results provided by this new tool are discussed and linked to TFM imaging.

Peter HUTHWAITE
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Short Profile

Dr Huthwaite is a Reader at Imperial College London; he has published nearly 50 journal papers on NDT and medical ultrasonic imaging, tomography and modelling. He developed the GPU-based finite element software package Pogo, enabling high speed FE modelling of ultrasound, including 3-billion degree-of-freedom simulations of complex 3D materials.

Abstract

Fast, general ultrasound simulations for NDE

Simulation of ultrasound is critical to developement of new NDE methods, inversion techniques, qualification and generation of training data for both human inspectors and novel machine learning techniques. Methods have been generated through the years which have given excellent results for specific applications. The finite element (FE) method provides general solutions this by fully discretising the whole domain, capturing complex geometry and the waves interacting within this. To compensate for the increased computational overhead of FE, the Pogo package (www.pogo.software) utilises the power of graphics cards (GPUs) for speed. This has had applications from guided waves to composites to phased array inspections, giving orders of magnitude speed-ups over other approaches. This talk will discuss the background of Pogo and present some examples.

Michal KALKOWSKI
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Short Profile

Michal Kalkowski is a Research Associate in the NDE Group at Imperial College London working for the ADVISE project. He obtained his PhD in Sound and Vibration from the University of Southampton in 2015, with the thesis on using structural waves to remove accretions from structures. He completed several projects as a post-doctoral fellow at the University of Southampton before moving to Imperial College London in 2017. His research interests focus on the application of mechanical waves to the characterisation and interrogation of structures. A significant proportion of his work is on developing analytical, semi-analytical and numerical models for wave propagation in a variety of contexts, such as piezoelectric waveguides, fluid-filled buried pipes, or coarsely-grained and textured polycrystals.

Abstract

Ray inversion for determining weld maps from ultrasound

Ultrasonic array images of complex welds can be difficult to interpret because of the weld microstructure. Long columnar grains with varying preferential orientation are responsible for deviating the beam from straight paths and a considerable level of grain noise. Using incorrect material information while computing the total focusing method (TFM) images results in misplacing and spatially spreading potential defect signatures, leading to a lower signal to noise ratio. This work presents weld reconstruction based on time of flight tomography, which can infer local orientations (called weld maps) from contact array measurements. Based on a gradient stepping approach and a shortest-ray path forward solver, the inversion algorithm minimises the difference between measured and simulated arrival times. This talk outlines the principles of the method and demonstrates it using some examples, including EBSD-based grain-scale numerical simulations and measurements on weld mock-ups. Determined weld maps are compared to material examinations and used to update the delay laws for experimental TFM images. Assessing the improvement for the example cases, we conclude with a discussion on the potential application scope and limitations of the approach.

Stéphane LE BERRE
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Short Profile

Stéphane Le Berre received his Master of Computer Science from Paris Sud University in 1993. From 2006 to 2015, he has been heading the Software Development Laboratory of CEA-LIST, which holds the software engineering and development of the CIVA platform. Since 2015 he is heading the CIVA Project.

Abstract

CIVA Plugin & CIVA Lab features for Simulation and Data Processing

Collaborative projects require many exchanges and a high level of sharing capabilities, connecting the results during the progress of the different work packages. This presentation illustrates through the NDT CIVA platform and the ADVISE project the different levels of integration, connection and interoperability that have been implemented in order to be able to federate, enhance and promote R&D results and partnerships within a common software environment.

Nicolas LEYMARIE
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Short Profile

Nicolas Leymarie is Senior scientist in the Non Destructive Testing and Evaluation department of CEA at the French Alternative Energies and Atomic Energy Commission (CEA), LIST. He is expert in ultrasonic modelling and simulation for NDT. He is contributing to the CIVA simulation software and in particular, to the development of ray models in complex materials as well as in hybrid numerical solutions combining finite element and asymptotic models.

Abstract

Ultrasound propagation in complex elastic media
Modelling approaches and practical applications on welding components in the framework of CIVA simulation tools

Ultrasonic testing (UT) of heterogeneous structures is an important issue for the nuclear industry. In particular, ultrasonic techniques may suffer from performance limitations due to the polycrystalline grain structure of welds inducing attenuation and deviation of the ultrasonic beam. In this context, the use of efficient simulation tools is particularly helpful to better understand these phenomena, to design and demonstrate the performances of inspections.
In this presentation we give an overview of the different modelling approaches for waves propagation in polycristalline media. We highlight on a recent 3D Finite Element solution developed in the framework of the ADVISE project and dedicated to the simulation of the ultrasonic inspection of complex welded parts. This solution, based on a macroscale description of the weld, is specifically designed to allow full 3D simulations with standard computer resources and without expertise in meshing procedures.

Sébastien ROBERT
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Short Profile

Sébastien Robert is a researcher and expert at CEA in the field of ultrasonic imaging for NDT. His current work focuses on linear or matrix arrays; imaging of complex geometries and materials; fast 3D imaging; multi-mode TFM or PWI; advanced characterization methods; real-time processing with NDT systems.

Abstract

TFM Ultrasonic Imaging of Complex and Anisotropic Nuclear Components

This communication focuses on TFM ultrasonic imaging of nuclear components with complex geometries and materials. As part of the ADVISE project, TFM was applied to various complex parts associated with different inspection issues: coarse-grained steels where images can be degraded by high scattering noise; austenitic welds with unknown anosotropic properties that require adaptive processing to reconstruct reliable images; and parts for which the complex and unknown geometries do not allow the characterization of cracks with the multimodal TFM imaging. In this talk, we present the different strategies studied to deal with these problems and we summarize the results obtained during the project. To improve the signal-to-noise ratio of images in coarse-grained steels, TFM was combined with TRL (Transmit Receive Longitudinal) arrays. For austenitic welds with unknown elastic properties, an optimization procedure was developed to improve the quality and reliability of images. And finally, for the characterization of crack-like defects, a machine learning approach was adopted to overcome uncertainties of the part geometry.

Andreas SCHUMM
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Short Profile

Dr Andreas Schumm is a research engineer and project manager with EDF R&D and has coordinated a number of national and international collaborations. He holds a PhD in electrical engineering with a specialty on ultrasound modelling, is a member of the inspection qualification commission at EDF, and a lecturer at the universities of Lyon and Manchester.

Abstract

The ADVISE project

The global objective of the Euratom project ADVISE (2017-2022) was to improve the ultrasonic inspection of corrosion resistant alloys used in nuclear power plants, in particular austenitic welds and cast austenitic steels. For these materials, a complex microstructure is responsible for both structural noise and attenuation, thus significantly degrading the performance of ultrasonic non-destructive testing.
The technical objectives of the project were to increase the comprehension and modelling of complex structures, to develop new tools for material characterization, and to improve inspection and defect evaluation methods. The project recognised the potential of computer modelling of ultrasonic NDE to assist both in inspection technique design and in the evaluation of results. This is particularly well illustrated in the proposed improvements of the imaging of full matrix capture acquisitions, introducing adaptive imaging methods, backscatter filtering and inversion strategies applicable on heterogeneous structures.
ADVISE proposed to use in-situ characterisation techniques to gain additional and current information about the actual structure under test. Results are capitalized in the CIVA platform and the M2M acquisition system.
This presentation will give a brief introduction, with more detailed presentations of key results following in the technical sessions.

Alexander VELICHKO
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Short Profile

Dr Alexander Velichko is a Senior Lecturer and a member of Ultrasonics and Non-Destructive Testing Research Group at the University of Bristol, UK. His research interests include mathematical modelling of propagation and scattering of elastic waves, ultrasonic imaging using arrays, defect and material characterization, and signal processing.

Abstract

Scattering Matrix feature on FMC data (measured or simulated)

The aim of ultrasonic non-destructive evaluation includes the detection and characterization of defects, and an understanding of the nature of defects is essential for the assessment of structural integrity in safety critical systems. In general, the defect characterization challenge involves an estimation of defect parameters from measured data. In this presentation general principles of small sub-wavelength defects characterisation based on ultrasonic array measurements are discussed. It is shown that the characterization information can be extracted in a form of defect's scattering matrix, which represents the directivity pattern of defect's scattering amplitude. The method naturally handles any measurement scheme (e.g. arrays, multiple probes and scanning) and allows us to consider different defect types. Importantly, the proposed approach naturally introduces the method for the characterization uncertainty estimation.

Hubert VOILLAUME
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Short Profile

Hubert Voillaume joined M2M/Eddyfi 5 years ago and holds the position of Applications team manager for M2M PAUT products in Eddyfi Technologies. He spent more then 25 years in NDT, mainly in the aerospace industry.

Abstract

TFM SEE feature in CAPTURE

The way that SEE can be used after its integration in the CAPTURE software will be presented.
Two examples will be highlighted: one with a lack of side wall fusion in a weld illustrated with 3 different modes TT, TTT and TTTT; and another one with the sizing of vertical cracks using the mode TTT.

EDITORIAL BOARD

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For further information on the project

Please visit the ADVISE project public website: http://www.advise-h2020.eu

Disclaimer

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