Publishable JRP Summary Report for JRP ENG57 VITCEA
Validated Inspection Techniques for Composites in Energy Applications

Background

The excellent mechanical properties, low weight, fatigue and corrosion resistance of fibre reinforced plastic (FRP) composites gives them considerable advantages in renewable energy (wind, wave and tidal), oil and gas and transport applications. The use of FRP composites has the potential to reduce fossil fuel reliance, consumption and greenhouse gas emissions. However, full exploitation is hindered by the diverse range of defects and damage mechanisms that reduce the strength, stiffness and life of FRP structures. Non-destructive evaluation (NDE) is the process used to ensure material quality (e.g. maximum defect size) of a component and that parts are fit for purpose.

Need for the project

Defects in FRP structures may be introduced during the processing and fabrication of composite components and can initiate or grow in-service. In the context of this JRP, the term 'defect' refers to imperfections introduced during manufacture/processing and/or secondary machining operations, as well as damage sustained during a component's service life. One of the challenges facing accurate and repeatable defect detection in FRP composites is the multitude of defect types that exist, each with characteristics that present different challenges to the NDE practitioner. In order for a particular NDE technique to achieve broad acceptance by industry, it is desirable for the technique to be able to detect a range of defect types with a high level of confidence.

Scientific and technical objectives

The work proposed in this JRP will develop and validate traceable procedures for novel NDE techniques with contrasting detection capabilities, which will underpin the increased use of FRP composites for improved efficiency and reliability in energy related applications e.g. wind and marine turbine blades, nacelles, oil and gas flexible risers.

- Work package 1 (WP1) will (i) design and manufacture defect artefacts that will be used in WPs 3-5 for the development of operational procedures for each NDE technique and assessments of defect probability of detection (POD) and; (ii) define an objective POD benchmarking framework that can be used to compare the merits of each NDE technique for different defect types,
- Work package 2 (WP2) will manufacture reference materials and characterise the elastic, dielectric, thermal and optical properties of specific importance to the assessment and development of phased array and air-coupled ultrasonic, laser shearography, microwave and active thermography NDE methods,
- Work package 3 (WP3) will optimise and validate scanning NDE techniques, namely phased array and air-coupled ultrasonics and microwave, for quantitative defect detection and characterisation of FRP structures. In addition to the practical development and optimisation of each NDE technique, this work package will develop models for the simulation of defect detection. WP3 will also address the experimental and, where possible, theoretical assessments of POD for phased array and air-coupled ultrasonics, and microwave inspection techniques, in accordance with the POD benchmarking framework defined in WP1,
- Work package 4 (WP4) will optimise and validate active thermography and laser-shearography as full-field, fast and non-contact NDE techniques for quantitative testing of FRP structures. In addition to the practical development and optimisation of both NDE techniques, this workpackage will develop models for the simulation of active thermography defect detection. WP4 will also address the experimental and,

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where possible, theoretical assessments of POD for active thermography and laser shearography inspection techniques, in accordance with the POD benchmarking framework defined in WP1,

- Work package 5 (WP5) will focus on the assessment of the suitability of the operational procedures developed within WP3 and WP4, via two key methodologies; (i) intercomparison exercises, and (ii) field trials. These activities will also constitute an invaluable opportunity to demonstrate the benefits of the JRP outputs to the energy industry,

Expected results and potential impact

Within WP1, an industrial survey was undertaken by NPL in consultation with BAM, PTB, CMI and REG(CEA) that established the material systems, components/structural elements and defect types (including size and location) that are most routinely required to be inspected, and those that present significant challenges to NDE inspection. The survey sought the input of at least 10 organisations but a total of 26 responses were received from a variety of organisations across the oil & gas, renewable energy, lightweight transport, regulatory, material supplier and NDE equipment specialist sectors. All JRP-Partners contributed to the compiling of a list of 17 existing defect artefacts. From the findings of the survey a total of 13 designs for reference defect artefacts (RDAs) and natural defect artefacts (NDAs) have been proposed by NPL and BAM covering marine and automotive transport, renewable energy and oil and gas sector applications. The RDAs and NDAs will be used to develop the operational procedures for phased array and air-coupled ultrasonic, laser shearography, microwave and active thermography NDE methods. The defect types included cover artificial delaminations, porosity, kissing bonds, fibre misalignment, pipe wall thinning (back-face drilled holes), core damage, impact delaminations and matrix cracking. A range of materials have been procured including composites based on thermoset and thermoplastic matrix systems reinforced with glass and carbon unidirectional and multi-directional tape and fabric formats. These materials are currently being used in the construction of RDAs and NDAs in WP1 by NPL and BAM. The elastic, dielectric (for glass fibre based materials only), thermal and optical properties for each material used in the RDA and NDA designs are currently being characterised within WP2 by all Partners. These data will enable the optimised practical application of phased array and active thermography techniques, and for the theoretical simulation of NDE techniques. Within WP2, modification of PTB's current emissivity measurement equipment has been undertaken enabling an uncertainty of 0.005 for emissivity measurements of anisotropic materials to be achieved. This is a significant improvement on current state of the art uncertainty levels which are typically 0.02.

Impact activity highlights to date include invited representation on the Composites Group committee of the British Institute of Non-Destructive Testing (BINDT) and attendance at an industrial engagement meeting of the UK National Composites Centre's NDE Defect Library initiative. These new alliances between the VITCEA project and NDE/Composites communities will provide excellent mechanisms with key members of the stakeholder community, ensuring industrial relevance of the technical work and routes for early adoption.

The optimised NDE techniques, operational procedures and modelling capability developed by the JRP-Partners, in conjunction with industrial collaborators, will lead to improvements in safety, life expectancy, energy efficiency and sustainability; and reductions in fossil fuel reliance, greenhouse gas emissions and maintenance costs for FRP assets in the energy sector. At least four operational procedures (one per NDE technique) will be written in the style and format of ISO and/or CEN standards with the intention of future standardisation. The applicability and robustness of the operational procedures will be assessed via several intercomparison exercises, field trials and assessments of POD. The JRP will continue to interact closely with the stakeholder community and collaborators to ensure the relevance and suitability of the procedures developed to the energy industry.

JRP start date and duration:	1st July 2014, 36 months
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