Abstract for RCNDE Showcase Track

Multi-Sensor Electromagnetic Inspection Feasibility for Aerospace Composites Surface Defects

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Abstract

UK's presence at the forefront of composite manufacturing in Europe has never been more important provided how vital these structures are for i) slowing the climate change through reduction of fuel consumption and carbon footprint in different industries, and ii) development of wind and tidal blades to generate cleaner energy to achieve the net-zero target by the middle of the century. Therefore, the composite technology, Carbon Fibre Reinforced Polymers (CFRP) in particular, has been dominating the aerospace, energy, and defense industries, and this trend is expected to grow in the years to come. Non-Destructive Evaluation (NDE) is essential during manufacturing: to identify any defects early in the process as, if defects remain undetected, they could have far-reaching implications for the cost of scraped/repaired parts and the safety of final components, and ii) at later stages of manufacturing and post-manufacturing: to ensure the quality, integrity, and fitness for service of these safety-critical components. Although Ultrasound Testing (UT) has been predominantly used for inspection CFRPs owing to its excellent performance for bulk NDE inspections, the method is not sufficiently sensitive to all defect types occurring in such components. Ultrasonic waves transmitted using array probes on CFRP components mainly interact with defects that are extended perpendicularly to the direction of the wave propagation such as delamination. The technique does not offer sufficient sensitivity for the detection of shallow and narrow surface defects commonly created by matrix transversal cracking and barely visible impact damage mechanisms.

The compound CFRP gives rise to the mixed electromagnetic properties where highly conductive carbon fibres are molded in a dielectric resin matrix. This provides a unique opportunity to explore the potential of electromagnetic NDE sensing modalities such as Eddy Currents (EC) and electrical Capacitance Imaging (CI) for inspection of surface defects. Accordingly, this feasibility study was aimed at investigating the design, automated robotic delivery, and performance assessment of different sensor technologies for the detection of surface defects through experiments. To this end, machined surface defects were fabricated in a CFRP sample. The automated robotic inspection was implemented for all UT, EC, and CI sensors individually where a novel sensor-enabled robotic system based on a real-time embedded controller was developed. The system components consisting of a KUKA robotic arm, Force/Torque (F/T) sensor, and NDE sensor and controller were interfaced through a core program in LabVIEW enabling a) real-time communication between different hardware, b) data acquisition from all sensors and c) full control of the processes within the cell. Moreover, real-time robot motion corrections driven by the F/T sensor feedback were established to adjust the contact force and orientation of the sensors to the component surface during the scan. All sensors, including the UT roller-probe, EC array, and CI sensor boards, were robotically delivered on the designated surface notches with varying depths of 0.1, 0.2, 0.5, and 5 mm. The

results of EC and CI testing showed enhanced detectability with high SNR for the defects shallower than 0.2 mm when compared to the UT B-scan images.