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Abstract

Characterisation of damaged tubular composites by acoustic emission, thermal diffusivity mapping, and TSR-RGB projection technique †

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1. Introduction

An increase in the use of composite materials, owing to improved design and fabrication processes, has led to cost reductions in many industries. Resistance to corrosion, high specific strength, and stiffness are just a few of their many attractive properties. However, damage tolerance remains a major concern in the implementation of composites and uncertainty regarding component lifetimes can lead to over-design and under-use of such materials.

Non-destructive evaluation (NDE) techniques are often adopted for periodic inspection of composite structures while they are in service. Inspection of structures in this way can reduce the life cycle cost of a component by preventing premature replacements, while also improving safety and reducing the likelihood of catastrophic failure. Common methods of NDE include the use of x-rays, ultrasonic waves [1], eddy currents [2], shearography [3–5], and infrared thermography [6–17]. Though non-destructive techniques (NDT) offer an insight into the performance of composite materials and the environments in which they operate, their implementation can represent significant downtime and labour costs. The use of structural health monitoring (SHM) systems has sparked interest in recent years as they can be integrated directly into a composite structure during manufacture [18,19]. Sensors and embedded networks can be used to monitor various parameters such as local stress, strain, temperature, impact, delamination, and crack propagation in-situ and in real time [20–23]. Where the use of SHM and NDE are combined, it becomes possible to carry out "focused" inspections using non-destructive techniques, saving both time and money.

2. Experimental methodology

In this work, infrared thermography (IRT) was employed for NDE of tubular composite specimens before and after impact. Four samples were impacted with energies of 5 J, 7.5 J, and 10 J by an un-instrumented falling weight set-up. Acoustic emissions (AE) were monitored using bonded piezoelectric sensors during one of the four impact tests. IRT data is used to generate diffusivity and thermal depth mappings of each sample using the thermographic signal reconstruction (TSR) red green blue (RGB) projection technique.

3. Results

The diffusivity mapping was obtained for each sample by calculation of the diffusivity of each individual pixel in the raw image. This is done by calculation of t^* which requires the fitting of two tangents. A minimum correlation coefficient of 0.99 is used to fit the tangent to the curve. Fig.1 shows the thermal diffusivity mapping of the four samples after impact. The coloured scale indicates the value of thermal diffusivity for each pixel in the image. Measurement of the width of each sample here allows for comparison between each of the defects.

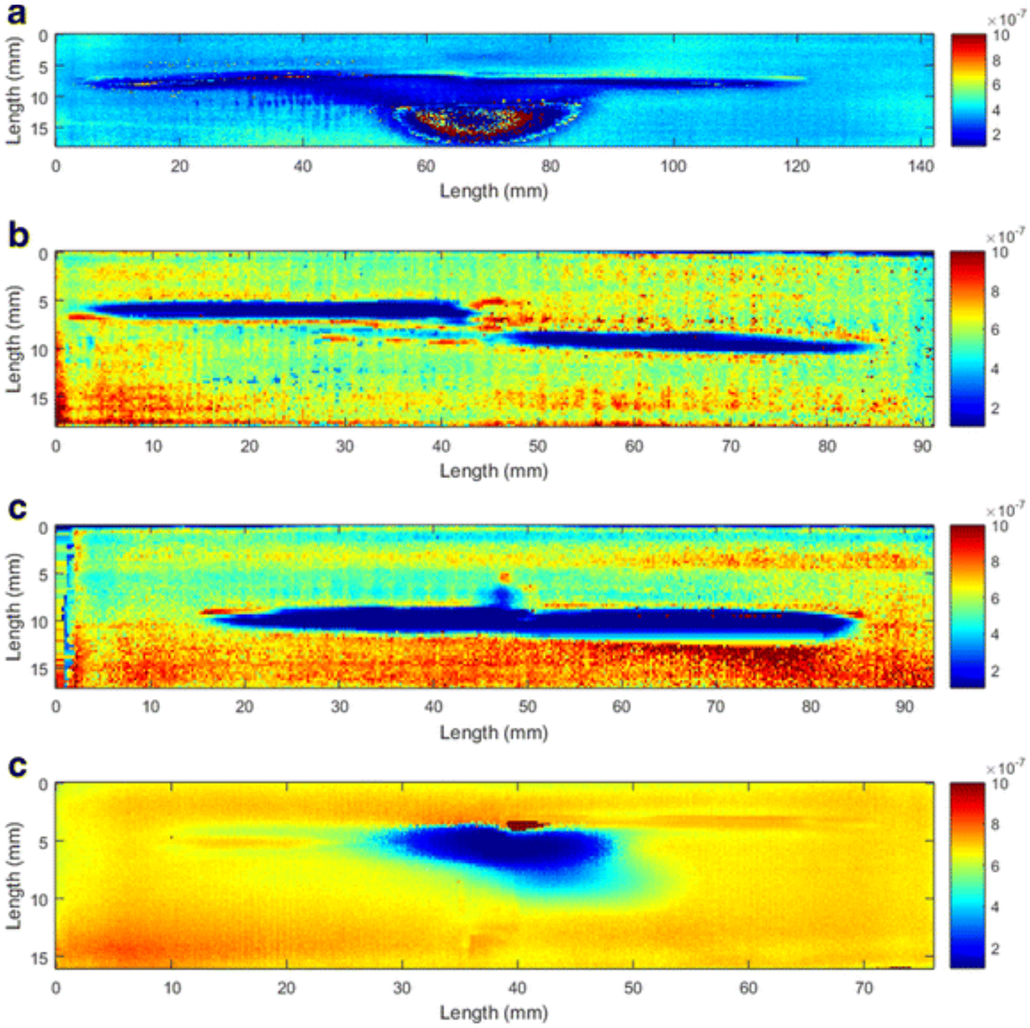

Figure 1. Thermal diffusivity mapping focused on the impact location on (a) Sample 1–10 J impact, (b) Sample 2–7.5 J impact, (c) Sample 3–5 J impact, and (d) Sample 4–10 J impact. The scale bar shows the thermal diffusivity, α (m2/s

Analysis of AE data alone for a 10 J impact suggest significant damage to the fibres and matrix; this is in good agreement with the generated thermal depth mappings for each sample, which indicate damage through multiple fibre layers. IRT and AE data are correlated and validated by optical micrographs taken along the cross section of damage.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing—original draft preparation, X.X.; writing—review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y. All authors have read and agreed to the published version of the manuscript." Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

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