Accepted Manuscript

Characterisation of carbon fibre-reinforced polymer composites through radon-transform analysis of complex eddy-current data

R.R. Hughes, B.W. Drinkwater, R.A. Smith

PII: S1359-8368(17)32281-3

DOI: 10.1016/j.compositesb.2018.05.007

Reference: JCOMB 5677

To appear in: *Composites Part B*

Received Date: 5 July 2017

Revised Date: 30 April 2018

Accepted Date: 3 May 2018

Please cite this article as: Hughes RR, Drinkwater BW, Smith RA, Characterisation of carbon fibre-reinforced polymer composites through radon-transform analysis of complex eddy-current data, *Composites Part B* (2018), doi: 10.1016/j.compositesb.2018.05.007.

Characterisation of carbon fibre-reinforced polymer composites through Radon-transform analysis of complex eddy-current data

R.R. Hughes[1,], B.W. Drinkwater[1] and R.A. Smith[1]

[1] *Department of Mechanical Engineering, Queens Building, University Walk, University of Bristol, BS8 1TR, UK*

Abstract

Maintaining the correct fibre orientations and stacking sequence in carbon-fibre reinforced polymers (CFRP) during manufacture is essential for achieving the required mechanical properties of a component. This paper presents and evaluates a method for the rapid characterisation of the fibre orientations present in CFRP structures, and the differentiation of different stacking sequences, through the Radon-transform analysis of complex-valued eddy-current testing (ECT) inspection data. A high-frequency (20 MHz) eddy-current inspection system was used to obtain 2D scans of a range of CFRP samples of differing ply stacking sequences. The complex electrical impedance scan data was analysed using Radon-transform techniques to quickly and simply determine the dominant fibre orientations present in the structure. This method is compared to 2D-fast Fourier transform (2D-FFT) analysis of the same data and shown to give superior quantitative results with comparatively fewer computational steps and corrections. Further analysis is presented demonstrating and examining a method for preserving the complex information inherent within the eddy-current scan data during Radon-transform analysis. This investigation shows that the real and imaginary components of the ECT data encode information about the sacking sequence allowing the distinction between composites with different stacking structures. This new analysis technique could be used for in-process analysis of CFRP structures as a more accurate characterisation method, reducing the chance of costly manufacturing errors.

Keywords: Carbon fibre, Orientation, Non-destructive testing, Lay-up, stacking sequence, CFRP, Radon transform, Data analysis, Quality control, In-line monitoring

1. Introduction

Carbon fibre reinforced polymers (CFRPs) are being increasingly used in sophisticated industrial applications [1]. High strength-to-weight ratios, tolerance to fatigue damage and the ability to form complex geometries make them attractive materials for use in many industries including aerospace and automotive. Fibre rienforced composites owe their strength to the sequence and alignment of fibres along designated axes [2–4] prompting significant research interest into the modelling and evaluation of the mechanical properties of such structures and their manufacturing processes [5–13]. The structural integrity of CFRP is therefore greatly dependent on achieving a highly reliable manufacturing processes.

Misalignments and stacking errors in laminate structures can easily occur during the layup process of complex geometries and may lead to in-plane fibre waviness, out-of-plane ply wrinkling and ply-bridging in the finished component, introducing structural weaknesses [14–17]. Current industrial practice is to manufacture mechanical parts with more layers than are necessary in the hope of counteracting any potential structural weaknesses from undetected manufacturing errors - a costly waste of material. Such manufacturing errors can be easily corrected if found during the layup process, thus allowing manufacturers to reduce the level of redundant material used. However, this is only possible through the development of new non-destructive testing (NDT) techniques to provide accurate quality-control on these parts during

☆

Email address: robert.hughes@bristol.ac.uk (R.R. Hughes)