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TESTING AND MODELLING OF LIGHTNING STRIKE INDUCED DAMAGE IN CFRP WIND TURBINE BLADE STRUCTURES

Timothy M. Harrell[1], Janice M. Dulieu-Barton[2], Ole T. Thomsen[2]

[1]University of Virginia, Department of Mechanical and Aerospace Engineering, 122 Engineer's Way, Charlottesville, VA, 22904, USA
Email: tmharrell@virginia.edu

[2]Bristol Composites Institute, University of Bristol, Bristol, BS8 1TR, UK
Email: janice.barton@bristol.ac.uk & o.thomsen@bristol.ac.uk

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ABSTRACT

Carbon fibre reinforced polymer (CFRP) composite materials are increasingly used in the wind turbine (WT), aerospace, and automotive applications to reduce the structural weight of components. The introduction of CFRP components creates challenges when protecting structures from lightning strikes as they are semi-conductive in nature. CFRP materials facilitate conduction of heat and current in the fibre direction, but in the direction transverse to the fibres they have relatively low thermal and electrical conductivity resulting in significant Joule heating following a lightning strike. In a laminated polymer composite structure, the through-thickness conductivity is also low. Hence there is a build-up of voltage in the material, which eventually causes dielectric breakdown, allowing heat and current conduction to occur in the transverse and through thickness directions. Previous work [1,2] has mostly focused on aircraft structures subjected to lightning strikes, where the laminates are usually multidirectional and quasi-isotropic, which allows more in-plane conduction. In contrast, WT blade laminates are UD and more anisotropic, but the effects of lightning damage on their structural response has received limited research attention.

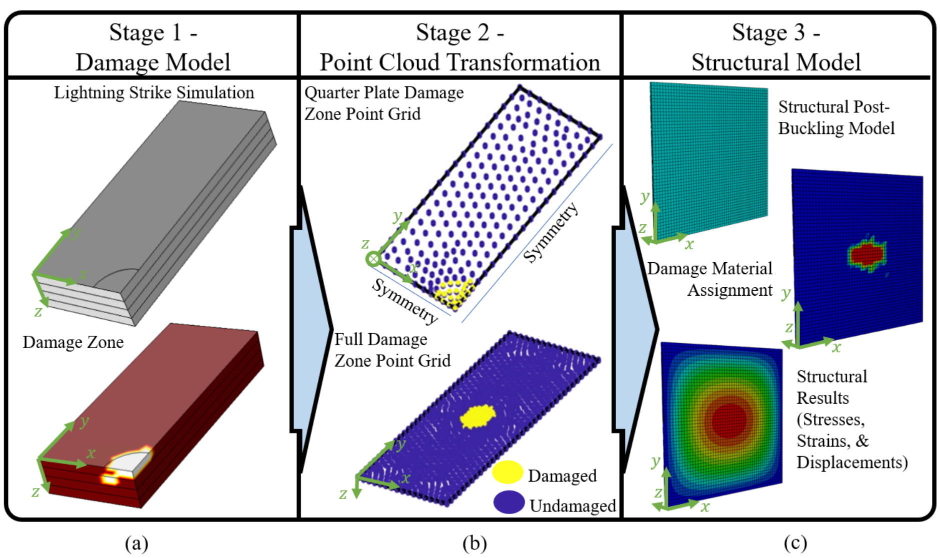

Figure 1: Multi-scale modelling approach – from meso-scale lightning strike damage model to structural scale model [3,4].

This presentation will provide an overview of recent research [3,4] on the structural responses of CFRP laminate structures used for WT blades damaged by lightning strike. Predictive results obtained using a novel multi-scale modelling technique combining a meso-scale lightning damage model [3] and a structural scale finite element model [4] are presented and compared against load-displacement data obtained from ten CFRP test panels manufactured at a scale representative of actual WT blades. Varying degrees of damage were introduced into the CFRP panels using lightning strike intensities of 50, 75, 100, and 125 kA with 10/350 μs waveforms.

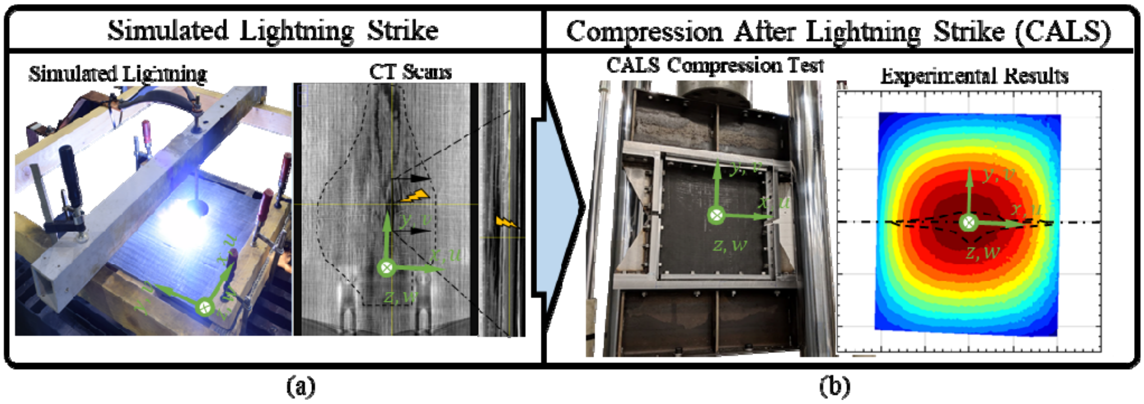

Figure 2: CALS testing procedure [3,4].

The representative WT blade laminate panels were tested using a novel and specifically designed test procedure referred to as “Compression After Lightning Strike (CALS)”, which includes a novel test fixture and the application of digital image correlation (DIC) to assess the load response of damaged and undamaged composite panels. The CALS test allows the full extent of lightning damage in a large CFRP panel to be included. Stereo DIC was used on both sides of the CFRP panel to obtain the strain and displacement fields that developed during the CALS test. Thus, for the first time, the effect of a lightning strike on the load response and buckling/failure behaviour has been determined experimentally at a representative scale. The model predictions showed excellent agreement with the experimental observations for all cases.

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