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Testing and Modelling of Lightning Induced Damage in CFRP Wind Turbine Blade Structures

Tim Harrell, University of Virginia

Janice Dulieu-Barton & Ole Thomsen, University of Bristol

UKRI Engineering and Physical Sciences Research Council

University of Southampton

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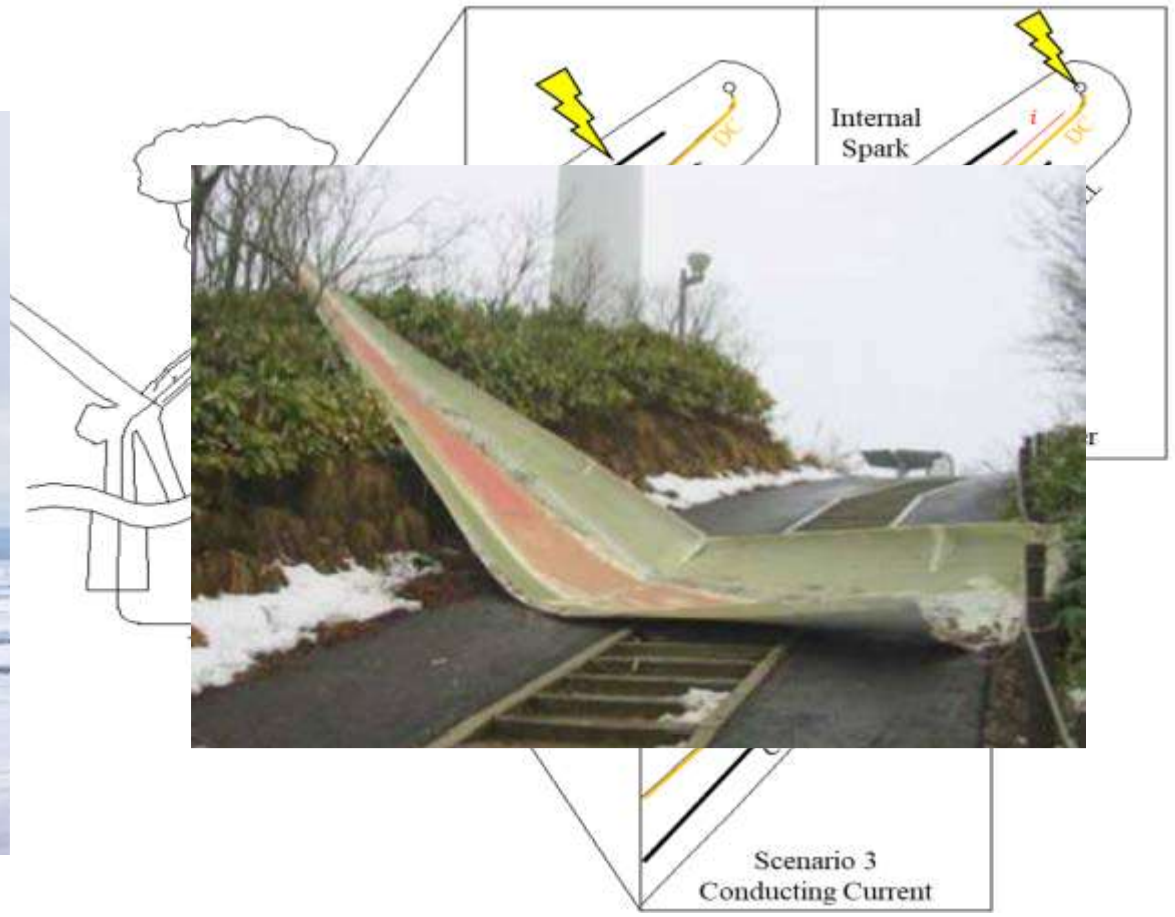
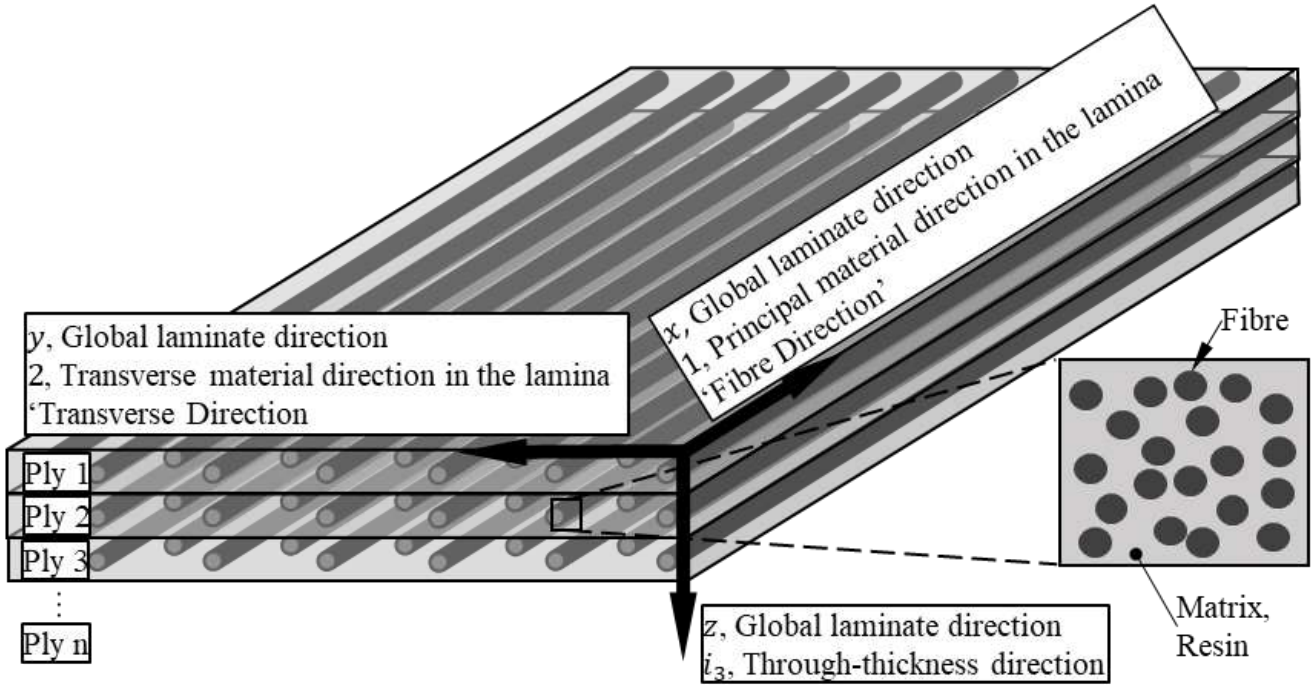
Background and motivation

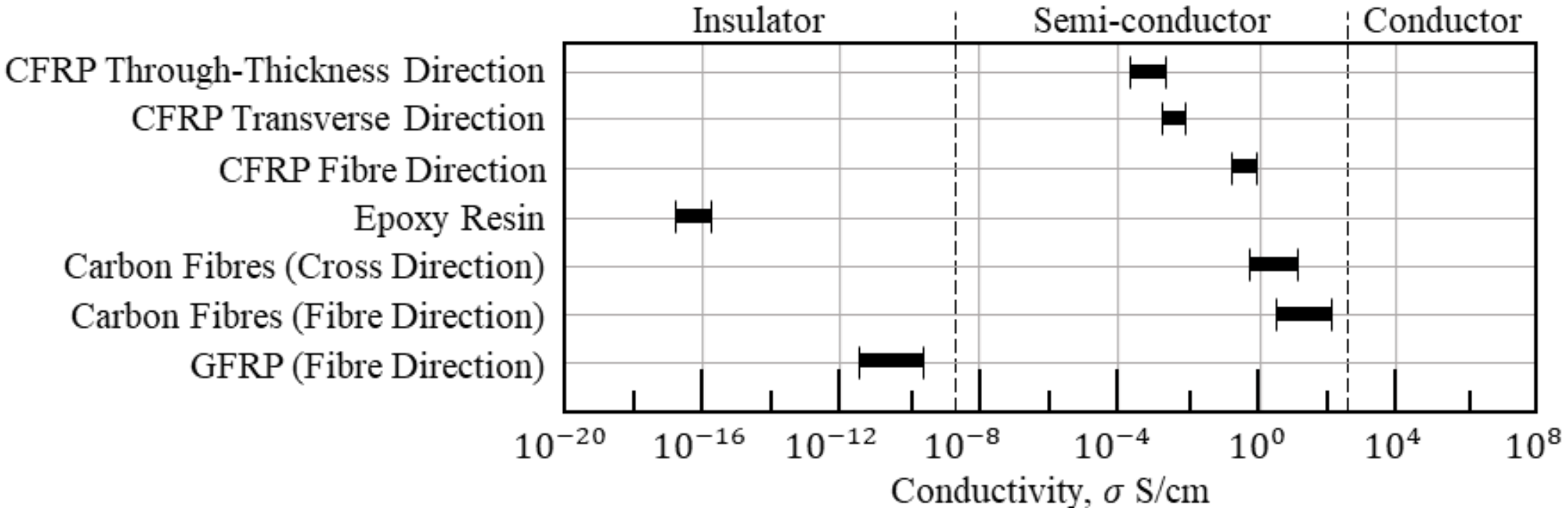
- Wind turbine rated power increases – ex. Vestas V236, rated power output 15MW (blade length 115.5m)
- Wind turbines - multiple lightning strikes during service life
- Recent (almost 20 years) large WTs use large amounts of CFRP in blades
- CFRP elements electrically conductive
- Lightning strikes can cause significant damage
- Lightning protections systems (LPTs) used





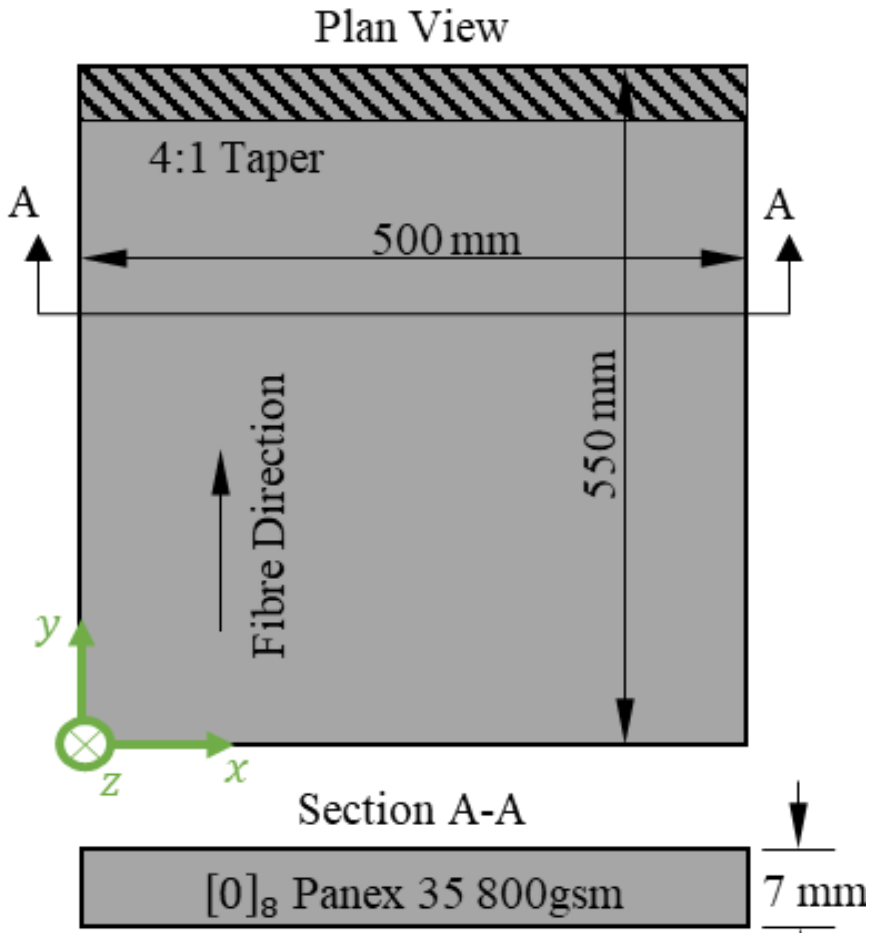
- UD CFRP used in WTB sparcabs
- UD CFRP materials effectively semi-conductors with strongly anisotropic electrical and thermal properties
- Susceptible to lightning damage
- Limited electrical and thermal conductivity transverse to the fibres

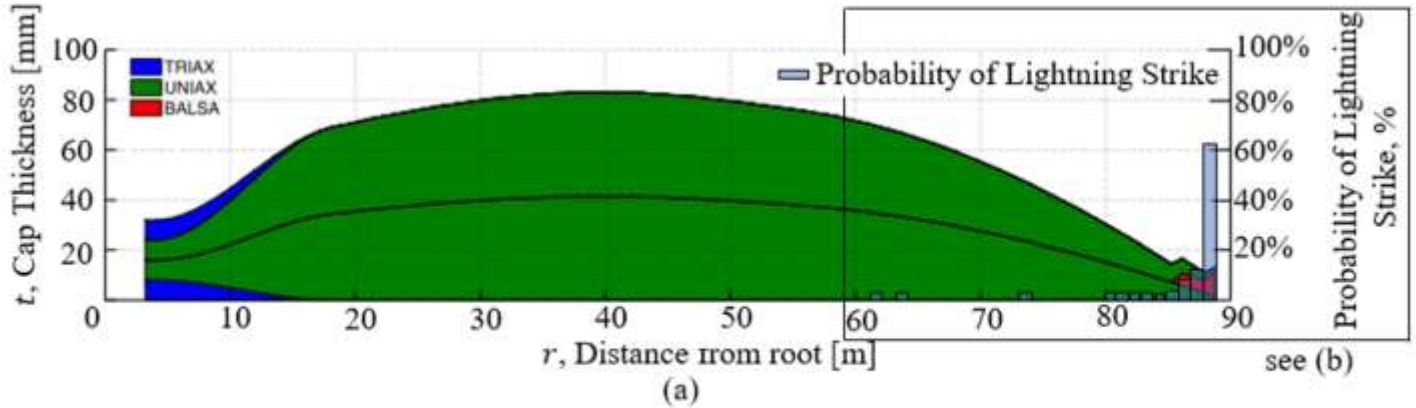
Material Properties – Dielectric Breakdown

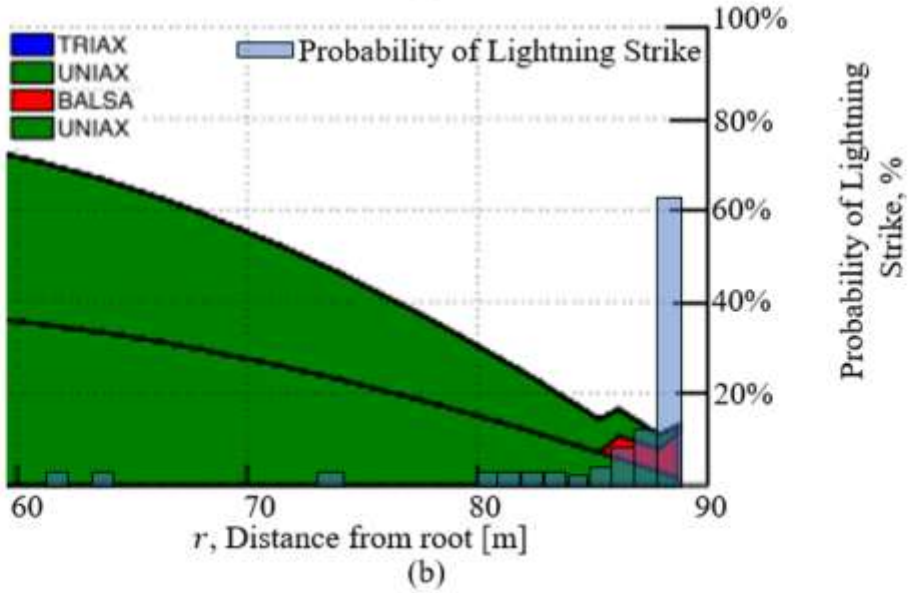


- For CFRP WT blades direct strikes occur when lightning attaches normal to the blade surface.
- Large current densities, result in large temperature rises and damage

Representative CFRP laminate from the Sparcap

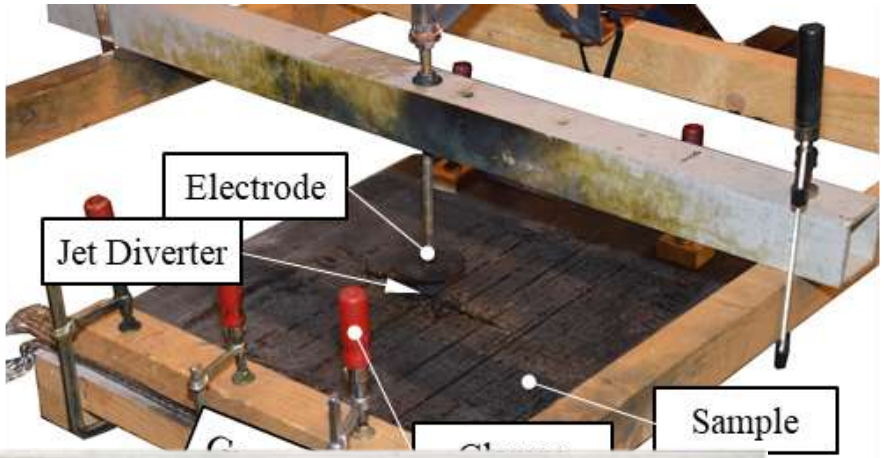


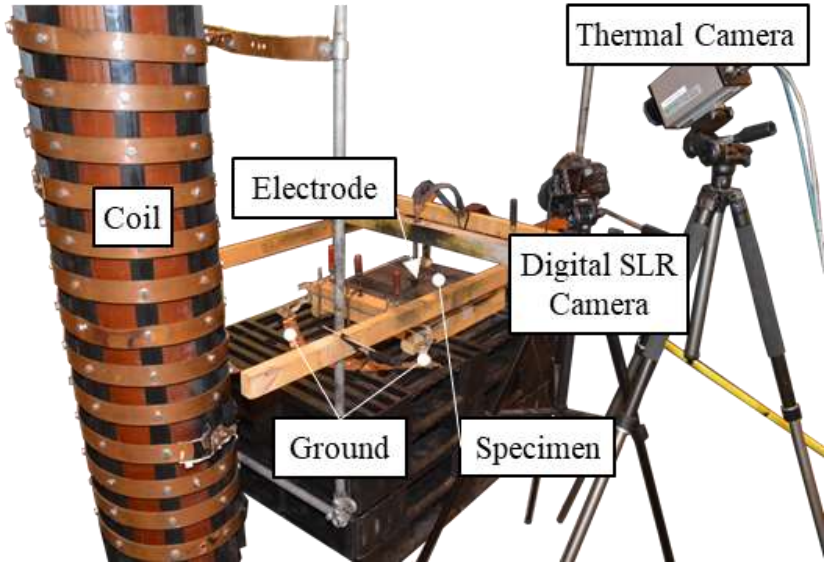


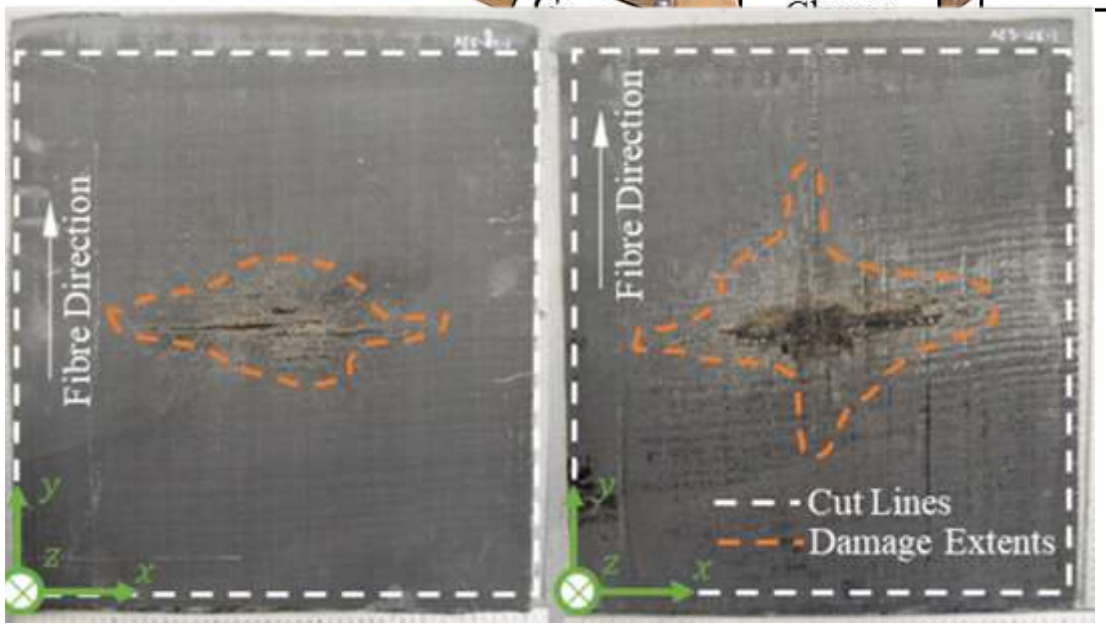


Simulated lightning strike damage

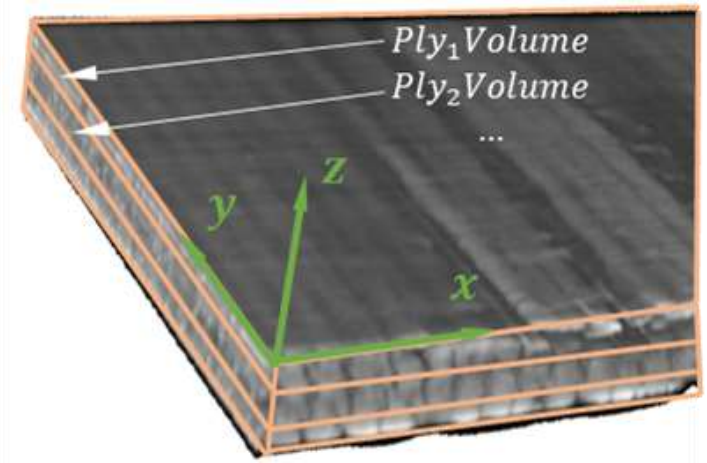
Simulation of direct attachment lightning strike: Idealized by so-called 10/350µs waveform according to IEC61400-24 (wind turbine blade lightning protection standard)

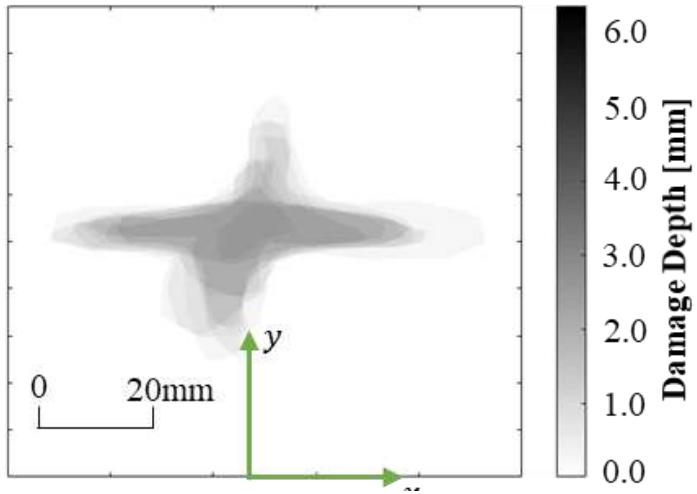


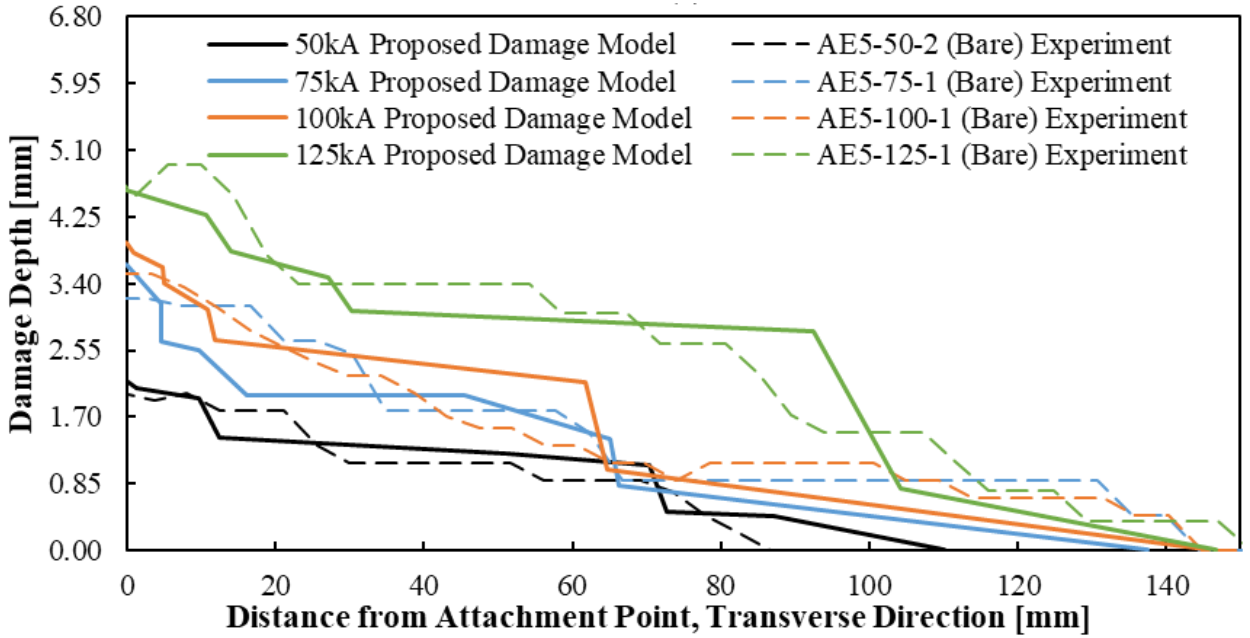




X-ray CT validation of meso-scale model







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Check for updates

On the Effect of Dielectric Breakdown in UD CFRPs Subjected to Lightning Strike Using an Experimentally Validated Model

T. M. Harrell[1] · S. F. Madsen[2] · O. T. Thomsen[3] · J. M. Dulieu-Barton[3]

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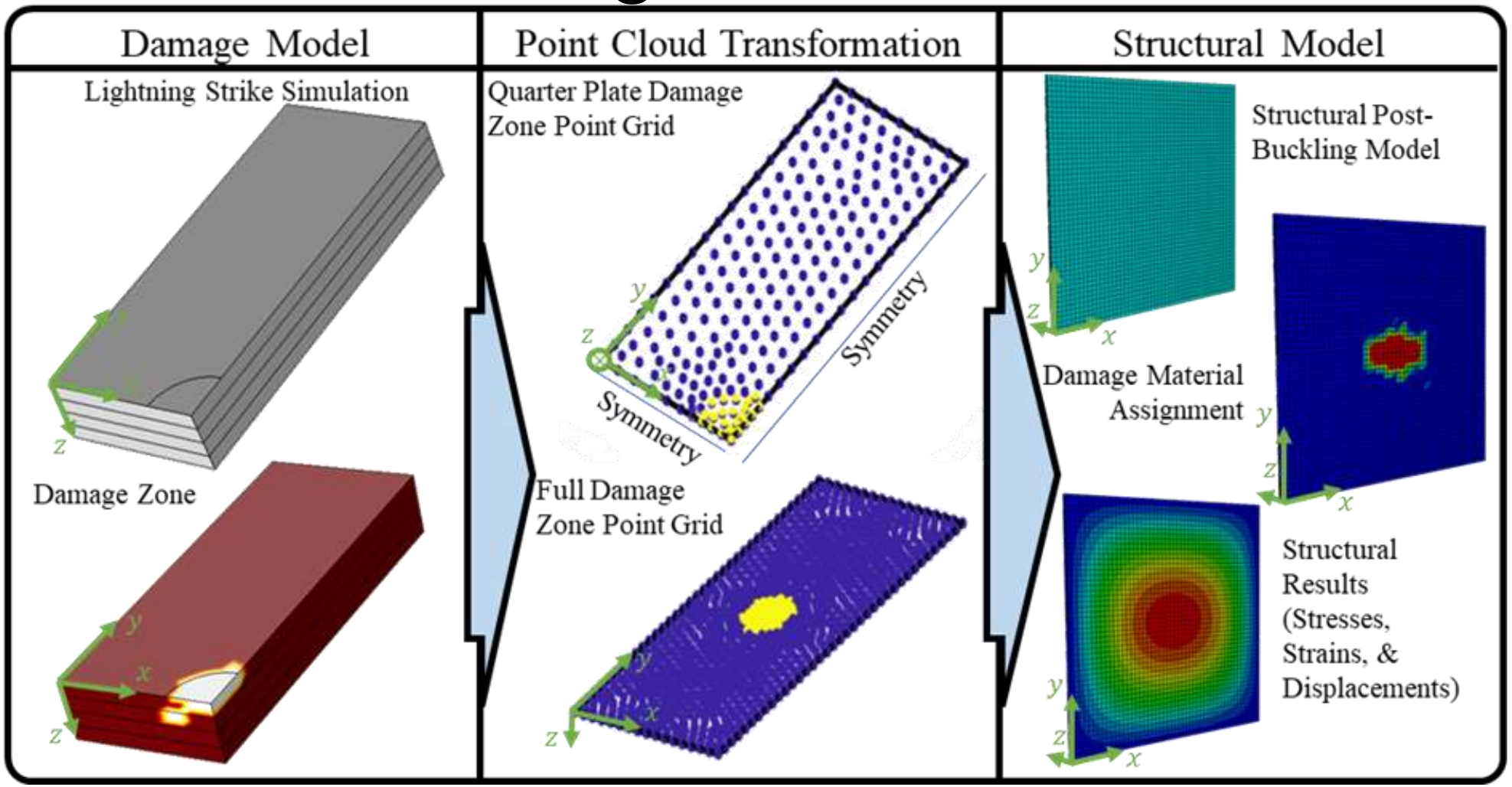
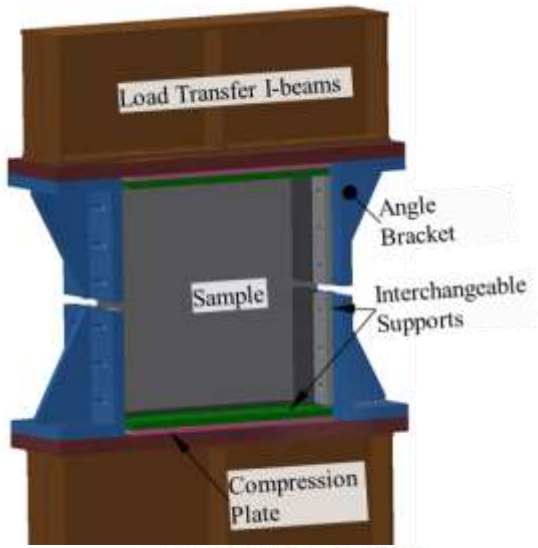
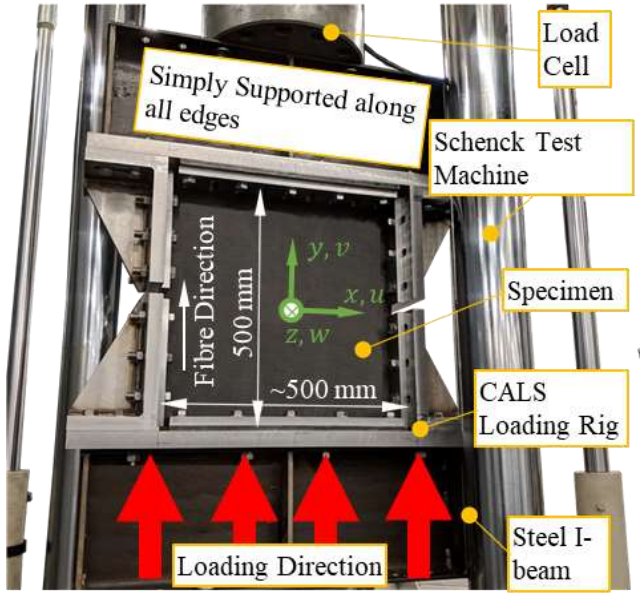
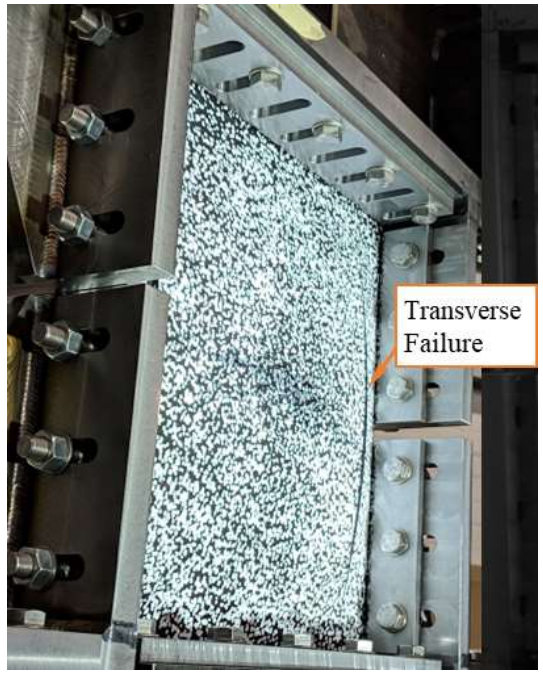
Multiscale modelling framework



Compression after lightning strike (CALS) rig







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Predicting the effect of lightning strike damage on the structural response of CFRP wind blade sparcap laminates

T.M. Harrell [a,*], O.T. Thomsen [b], J.M. Dulieu-Barton [b]

[a] University of Virginia, Department of Mechanical and Aerospace Engineering, 122 Engineer's Way, Charlottesville, VA 22904, USA
[b] Bristol Composites Institute (BCI), University of Bristol, Bristol BS8 1TR, UK

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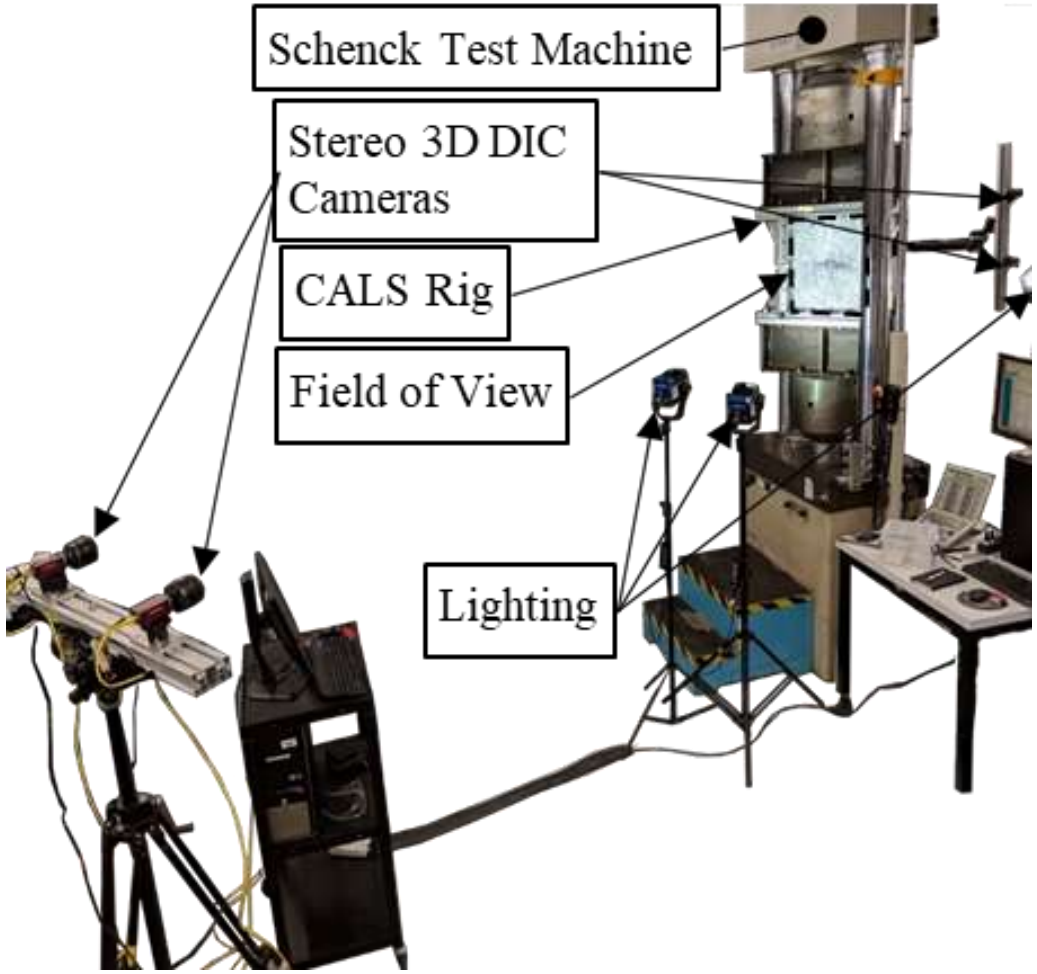
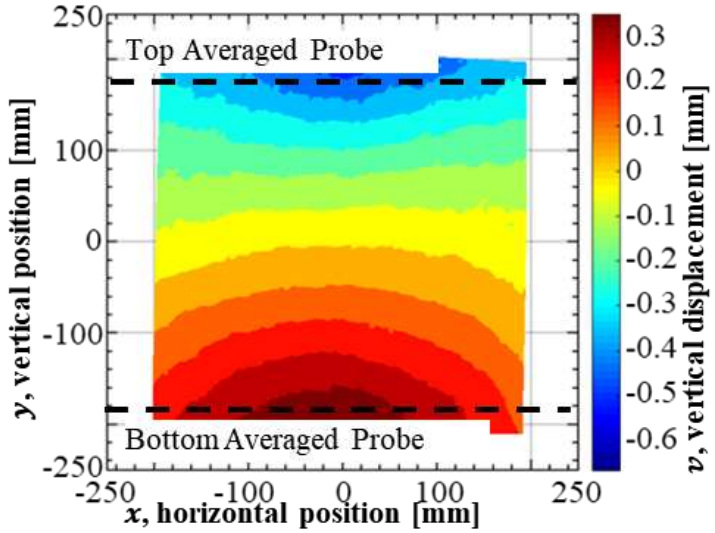
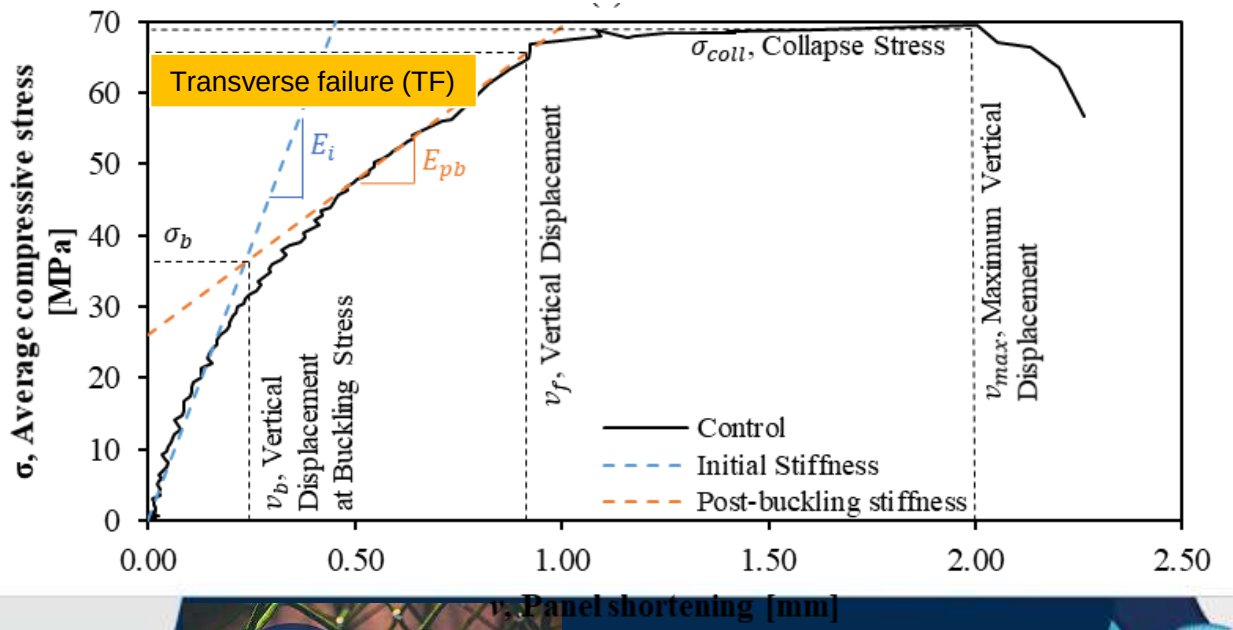
DIC - panel end shortening







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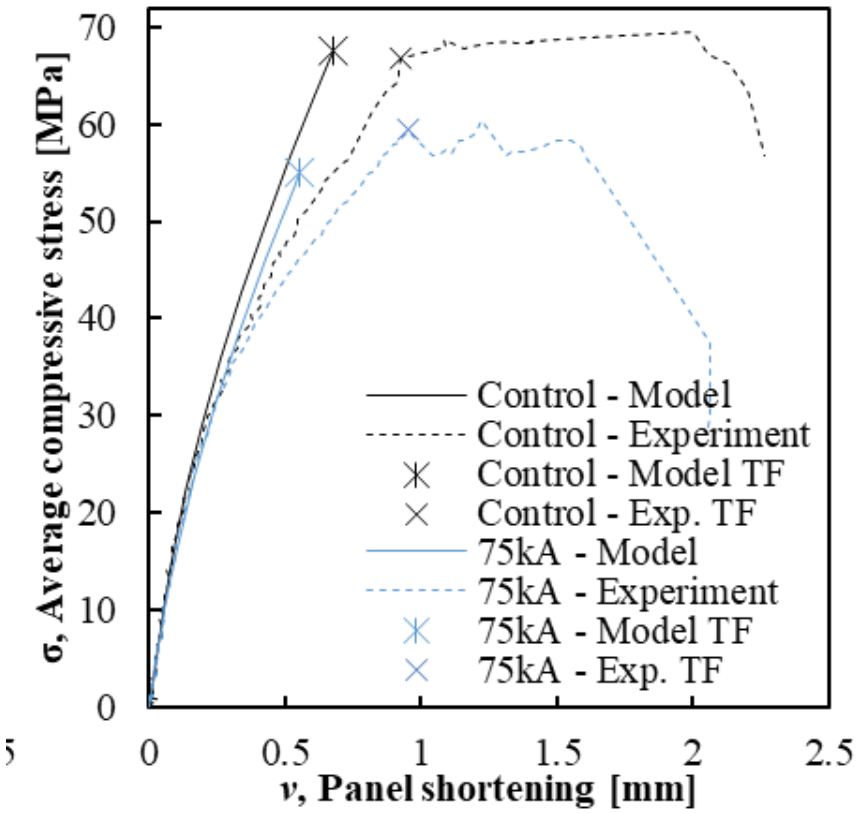
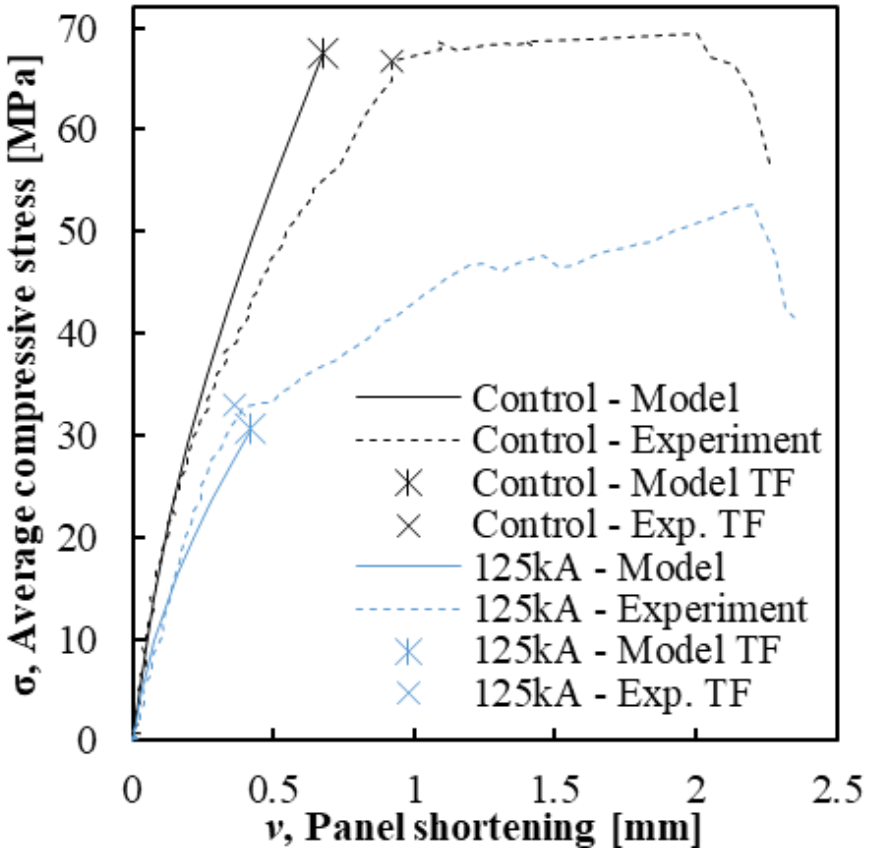
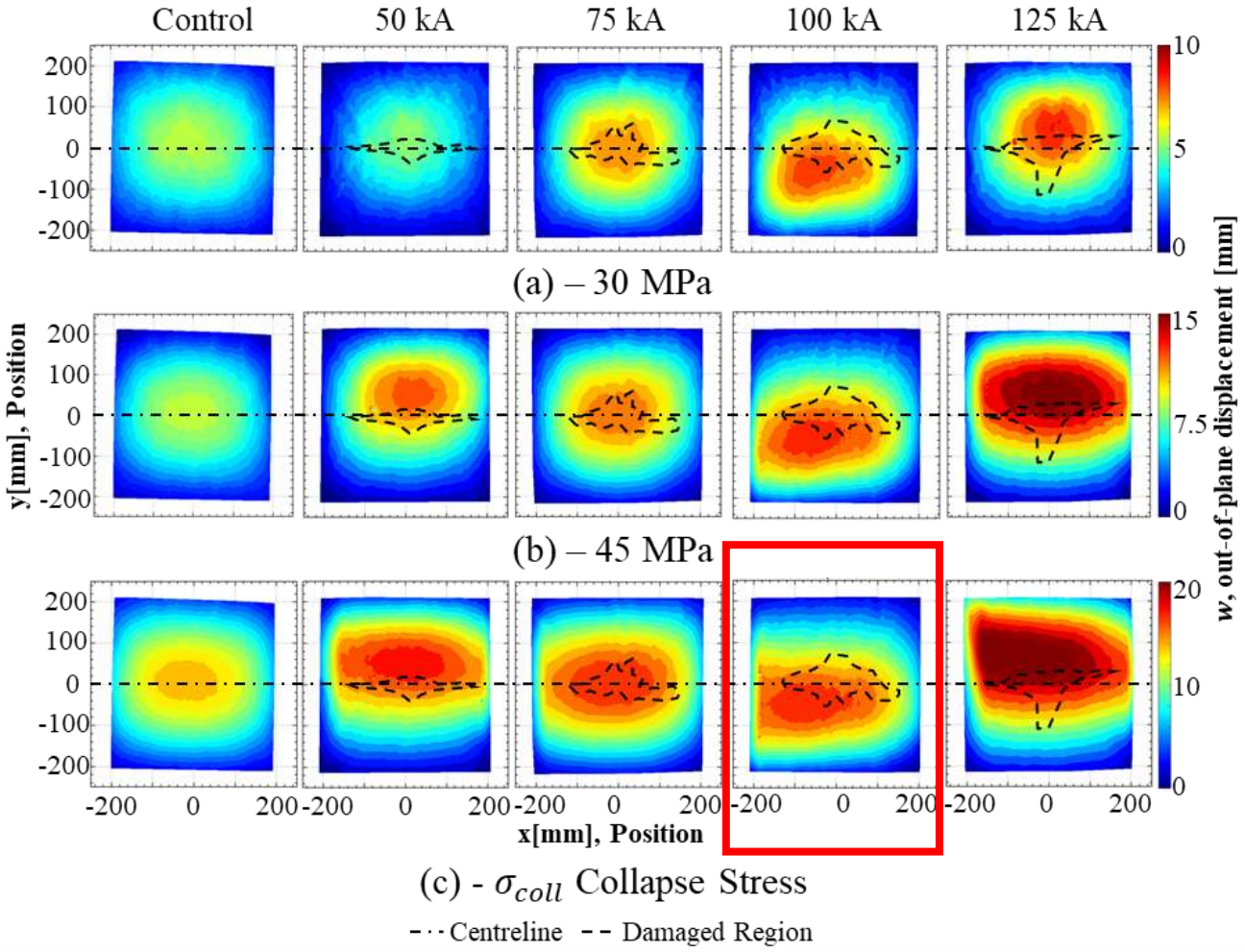
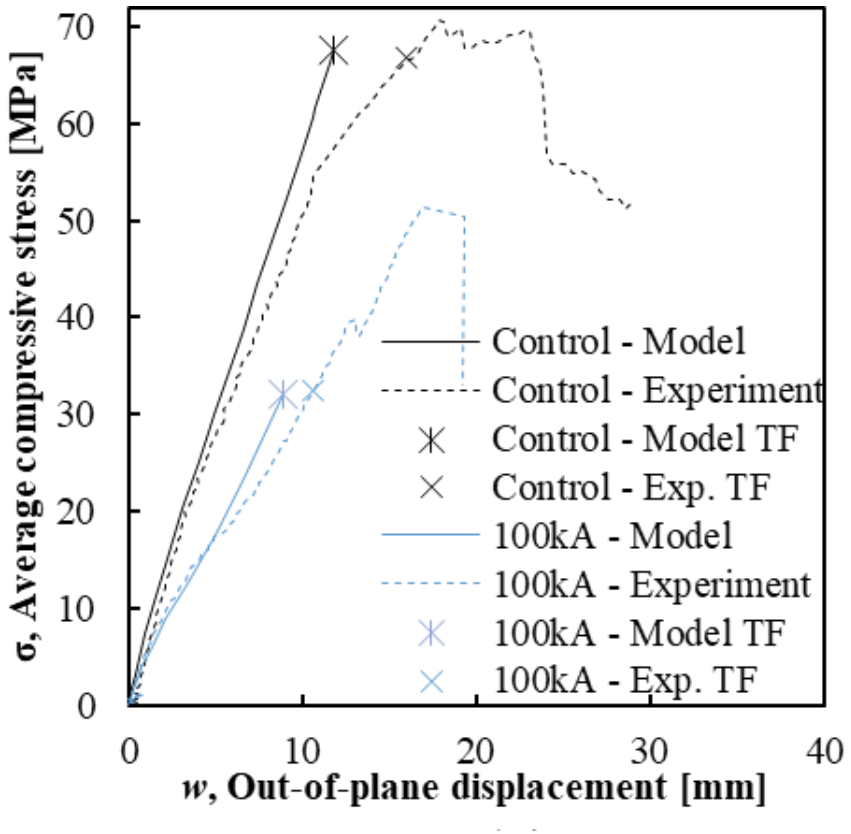
Model validation - panel end shortening



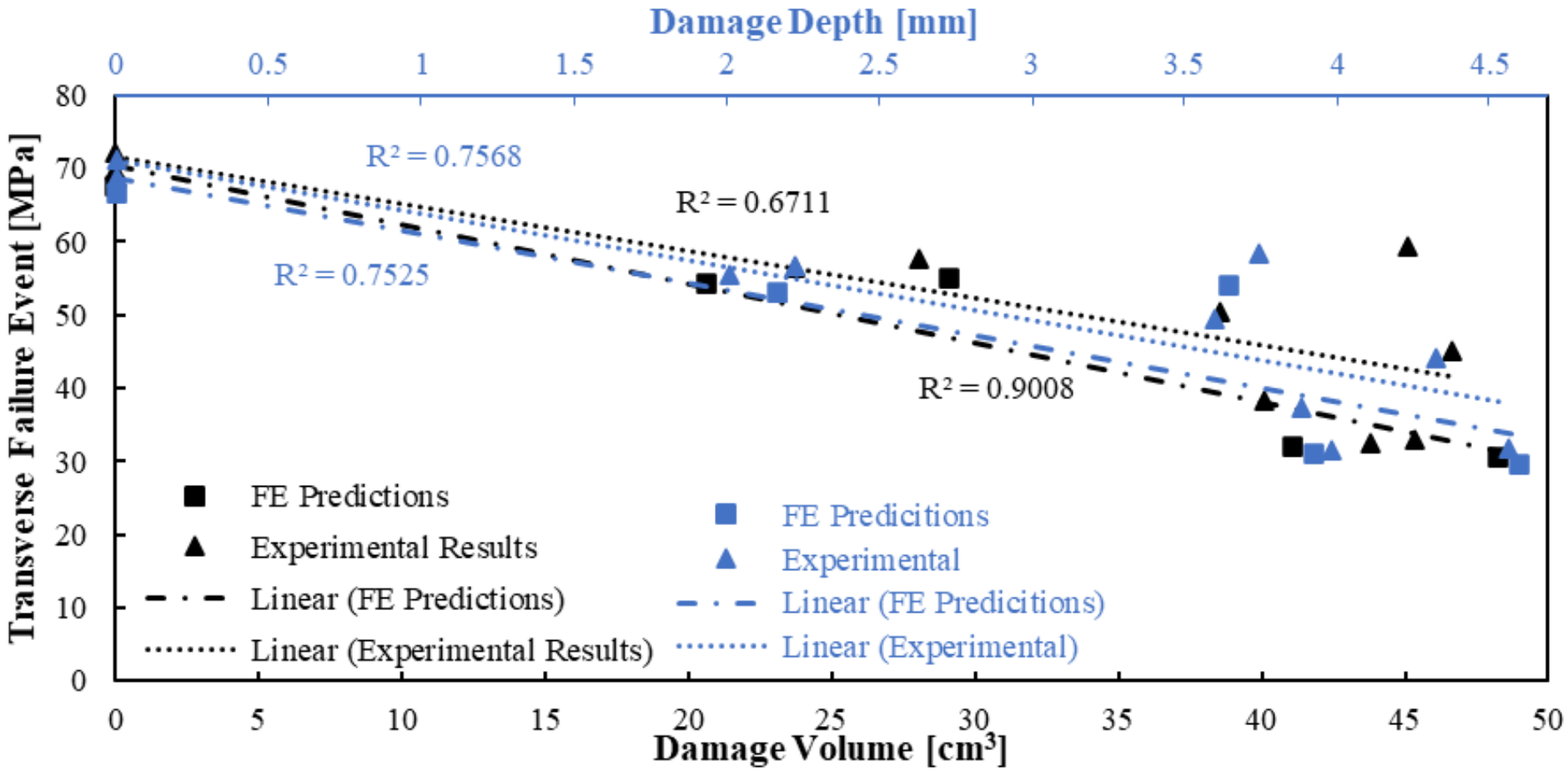


Multiscale model validation- out of plane displacements





Damage severity prediction vs. experiment



Conclusions

Meso-scale FE model developed and validated against extensive simulated lightning strike conditions on realistic scale CFRP UD laminates

CALS Procedure combining DIC with large scale compression rig developed

Non-linear structural scale FE model validated using CALS

Modelling approach has the potential to be used as a design tool for CFRP WT Blades and for design of lightning protection systems

Acknowledgements

Marie Skłodowska Curie Action, Innovative Training Networks (ITN), H2020-MSCA-ITN-2014, as part of the Grant Award #642771, SPARCARB (Lightning protection of wind turbine blades with carbon fibre composite materials) SPARCARB project

European Commission

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Questions?

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University of Southampton

The simulated lightning strike tests were conducted in full scale test facilities at Polytech A/S, Denmark.

Polytech
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