ISMEM 2017
- 2nd International Symposium on Multiscale Experimental Mechanics: Multiscale Fatigue

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Towards a new paradigm for high-fidelity testing and integrated multi-scale modelling of composite substructures and components

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Janice Dulieu-Barton is a Professor of Experimental Mechanics in the Faculty of Engineering and the Environment at the University of Southampton. She received her PhD from the University of Manchester in 1993 where she started her research on the topic now known as 'Thermoelastic stress analysis'. She has published around 300 papers with more than 100 in archival journals. Janice's expertise is in imaging for data rich materials characterisations and assessments of structural performance, with a focus on lightweight structural design particularly composite structures. She has developed novel approaches in experimental mechanics, especially the development of infra-red imaging recently covering high speed data capture, new approaches to residual stress analysis and strain-based NDE. Janice is a Fellow of the Institute of Physics, the Society for Experimental Mechanics and the British Society for Strain Measurement. Recently Janice was chairman of the 16th International Conference on Experimental Mechanics in 2014, which attracted over 500 international delegates to Cambridge in the UK.

Professor Ole Thybo Thomsen is Professor of Structures and Materials, Faculty of Engineering and the Environment, University of Southampton. His research interests include characterization and optimization of lightweight structures made of composite materials with applications across the aerospace, wind turbine blade, civil construction, marine and transportation sectors. He has published more than 100 papers in in archival journals. Professor Thomsen was the Chairman of the Danish Council for Independent Research | Technology and Production Sciences (equivalent to EPSRC in the UK and NSF in USA) 2011-2014, and he is a Fellow of the Danish Academy of the Technical Sciences (equivalent to the UK Royal Academy of Engineering). Professor Thomsen was appointed Knight of the Royal Danish Order of 'Dannebrog', by Her Royal Majesty Queen Margrethe II of Denmark in 2012. Professor Thomsen has been the principal investigator for numerous research projects on composite materials and structures covering applications across sectors, where most of these projects have been carried out in close collaboration with industrial partners. Recently he was the general chair for the 20th International Conference on Composite Materials which attracted nearly 2000 people to Copenhagen, Denmark in August 2015.

Abstract

It is well established that failure data based on simple (uniaxial) coupon tests renders information of limited value with respect to understanding and explaining the in-situ failure behaviour experienced in complex full scale composite structures subjected to multiaxial loading conditions. Moreover, computational predictions of the load response and failure behaviour of complex large scale composite structures are typically based on input in the form of experimental data obtained from simple/conventional coupon tests. This makes the prediction of initiation and propagation of failure inaccurate and in many cases completely erroneous.

Full scale structural testing would be a more consistent approach to obtain valid experimental data with respect to load response and failure initiation and progressive collapse behaviour of complex composite structures. However, the costs associated with full scale structural testing are often prohibitive, the large amount of data and the complexity associated with conducting and controlling the actual testing make full scale testing less attractive, and providing sufficient data for obtaining a statistically significant design data base is problematic. Accordingly, there is a need for the development of high-fidelity mechanical testing methodologies that enables realization of realistic loading conditions on substructures/components that can be instrumented conveniently using state of the art full field imaging and sensor techniques, and which will generate sufficient data for providing a statistical base for design. This will enable the conduction of data rich testing that will include

quantitative monitoring and assessment of the multiaxial load response, failure initiation and progression in complex composite structural assemblies. This in turn can be used to inform and improve computational models with an aim to improve their predictive capabilities.

Based on recent research the presentation will outline a general methodology for high fidelity experimental characterization of complex composite substructures subjected to complex multiaxial loading conditions integrated with multi-scale modelling. Recent advances with full field imaging, in particular thermoelastic stress analysis (TSA) and a novel technique referred to as lock-in digital image correlation (LIDIC) enabling simultaneous capture of full field data on strain and stress during cylcling loading, will be discussed. The advantages of high-fidelity composite substructure/component testing and its integration with multi-scale modelling will be demonstrated through recent demonstrations involving composite aero-structures and wind turbine blade structures.

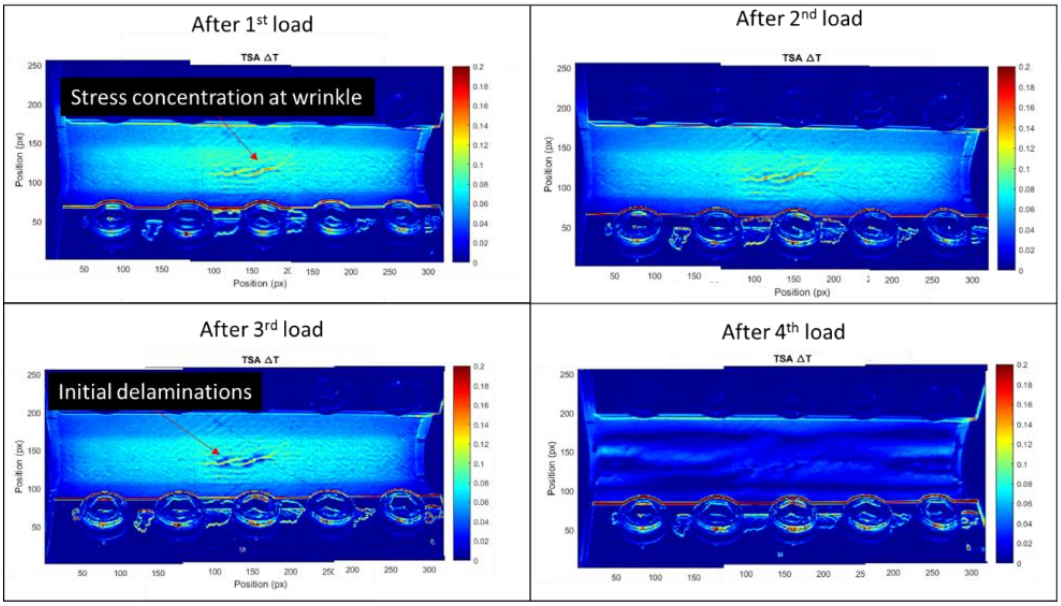

Figure 1. TSA data demonstrating stress concentrations and evolving debond damage in CFRP aircraft spar.