MULTI-SCALE MODELLING OF PROCESSING AND PERFPORMANCE FOR TEXTILE COMPOSITES

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This presentation will describe a multi-scale modeling approach to predict the effects of variability and complexity on the processing and mechanical behavior of textile composites. Based around the TexGen textile modeling schema, this will consider variability in micro-scale fibre arrangement and meso-scale variability in yarn paths and ply nesting, Along with complexity associated with three-dimensional geometries.

Modelling tools for laminated composites are now fairly mature, for example designers can perform structural analyses routinely for composites built up from unidirectional prepreg using laminate theory and finite element analysis. Composites based on textile reinforcements can also be analysed using similar techniques but with limited accuracy. Simulations of composites manufacturing processes are also reasonably advanced, with relatively mature simulation tools in existence for resin flow and cure and prepreg consolidation. A key requirement for resin flow modelling is accurate permeability data for the reinforcement, which are usually determined experimentally although analytical models do exist for simple fibre arrangements. There is now a growing interest in the use of process modelling tools to predict the occurrence and consequences of defects such as meso/ macro-scale voidage, which would significantly increase their utility for manufacturers. In theory such tools could also be used by materials suppliers to improve or optimize the performance of their materials, although there is limited evidence that this is currently taking place.

Fundamental modelling techniques for textile composites are less advanced in terms of industrial usage: traditional 'laminate' based methods are limited, and unable to determine the effect of fibre architecture on mechanical and processing behaviour. Several groups have demonstrated the use of unit-cell models to provide this fundamental modeling capability. However these usually focus on idealized textile structures, ignoring the variability that can exist at all length scales which largely explains the scatter in measured processing and mechanical behavior. Usually such models represent a local repeating unit, which does not capture the complex fibre architecture associated with three-dimensional geometries (for example the “noodle” region in a 3D woven T-section). In this presentation, a multi-scale modelling approach will be described, within which models at the micro-, meso-, and macro-scales are connected to provide a fully predictive approach. These are based in particular around the TexGen open source textile modelling schema, which can generate geometric models for arbitrary textile reinforcements, from which composites processing and mechanical properties can be predicted. Here this approach will be utilized to study variability and complexity in fibre arrangement at the micro-, meso- and macro-scales and the effects of such variability on permeability, resin flow and composite mechanical properties. The use of

such models to improve manufacturing process reliability will be explored, and initial studies aimed at optimization of the textile fibre architecture will be presented.

Andrew Long

Professor Andy Long is Pro-Vice-Chancellor for the Faculty of Engineering at the University of Nottingham, having previously served as Dean and as Associate Dean for Research. He is also Director of the *EPSRC Future Composites Manufacturing Hub,* leading basic and applied research in composites manufacturing for the UK academic community. He has worked for over 25 years on design and manufacture of advanced polymer composite materials, focusing on simulation of composites manufacturing processes, development of materials characterisation techniques for composites processing, and predictive modelling of the processing and performance of textile composites. The latter is best illustrated by Nottingham's "TexGen" open source code for modelling of textile composite unit cells, which underpins much of the modelling work at Nottingham and is used widely by many other groups around the world.

Andy has led a number of collaborative research council (EPSRC), UK government and industry funded projects on polymer composites, with a career portfolio of over £55million including £33million as Principal Investigator. His research has involved collaboration with a large number of industry partners, in particular from the aerospace and automotive sectors. He has supervised 28 successful PhD students and 22 post-doctoral research fellows, and has published 3 textbooks and around 340 papers. He is a member of the Composites Leadership Forum, responsible for delivery and development of the UK Composites Strategy, reporting to the UK Government Department of Business, Energy & Industrial Strategy (BEIS); a Director of the Manufacturing Technology Centre, part of the High Value Manufacturing Catapult; and a member of the Midlands Innovation Executive Management Group.