Novel Powder Epoxy Composites for

Thick-Section Renewable Energy Structures

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ABSTRACT

This seminar discusses the ongoing work at The University of Edinburgh on the processing, design and testing of thick-section composites for industrial structures such as large wind and tidal turbine blades, via powder epoxy resin systems.

Thick-section composite parts are difficult to manufacture using thermosetting resins due to their exothermic curing reaction. If processing is not carefully controlled, the build-up of heat can lead to warpage or material degradation. This risk can be reduced or removed with the use of a low-exotherm resin system. Material and process models are presented which describe vacuum-bag-only processing of thick-section composites using a novel, low-exotherm epoxy powder. One-dimensional resin flow and heat transfer models are presented which govern the fabric impregnation and temperature evolution, respectively. A semi-empirical equation is presented which describes the sintering of the epoxy powder. The models are coupled via laminate thickness change, which is determined for a simplified ply microstructure. The resulting system of equations is discretised and solved numerically using a finite difference code. A case study is performed on a 100-ply laminate, and the advantages and disadvantages of using epoxy powders are discussed.

An experimental apparatus is developed which heats the laminates from one side while insulating the remaining sides (i.e. approximating one-dimensional heat transfer conditions). Temperatures within the laminate are measured using thermocouples and a linear variable differential transformer is used to measure the thickness change of the laminate, with respect to time, due to powder sintering and fabric impregnation. The experimental results are analysed and used to validate process models for the epoxy powder system.

The materials and process models for this system are then implemented in a commercial finite element software via user-defined subroutines and the results compared to the previous finite difference scheme. Two virtual composite parts are investigated: a flat laminate, and the root section of a full-scale wind turbine blade. Additional simulations are used to modify an existing process cycle and reduce thermal and cure gradients within the parts, and to explore alternative heating methods for manufacturing tapered thick-section parts, such as the root section of a wind turbine blade.

Finally, a pilot-scale towpregging line was developed for production of unidirectional fibre powder-towpreg. Electrostatic attraction was used to coat fibre tows with powder epoxy and either joule or radiant heating employed to heat and melt the polymer, followed by consolidation between rollers. Unidirectional carbon-fibre and basalt-fibre reinforced polymer laminates (UD-CFRP and UD-BFRP, respectively) were manufactured from the towpreg. Tensile testing shows 0° properties that are similar or better than commercially-available CFRP systems. The influence of hygrothermal ageing due to water immersion on the tensile properties of the materials was also investigated.

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BIO

Professor Conchúr Ó Brádaigh is Chair of Materials Engineering and Head of the School of Engineering at The University of Edinburgh, Scotland, UK. He joined the University in 2015, having been Professor of Energy Engineering at University College Cork, Ireland, where he was also Director of the Science Foundation Ireland-funded Marine Renewable Energy Ireland (MaREI) Research Centre. He also lectured at the National University of Ireland, Galway from 1990 to 2014.

He was a Co-Founder and Director (from 1999 to 2018) of two composite materials and manufacturing companies in Ireland. The companies designed and tested products and tooling and manufactured lightweight composite material structures for the international aerospace, automotive and wind-energy sectors.

His research interests include manufacturing, testing and modelling of composite materials for renewable energy applications (wind and ocean energy), design and fatigue testing of composite tidal turbine blades, liquid moulding of thermoplastic composites using in-situ polymerisation systems, cryogenic properties and space applications of advanced composite materials.

He is Principal Investigator for the FASTBLADE accelerated structural testing facility, which will be the world's first dedicated tidal blade test facility, and the first testing facility to employ regenerative hydraulics, when is currently under construction in Rosyth, Fife, Scotland.

Conchúr has a PhD from the University of Delaware, USA and Masters and Bachelors degrees from NUI Galway, Ireland, all in Mechanical Engineering. He is a Chartered Engineer and a Fellow of the Institution of Mechanical Engineers (IMechE) and of the Institute for Materials, Minerals & Mining (IOM3).