**Enabling Cost-effective Process Simulation for the Composites Industry: Efficient Characterisation of Complex Fibre Preforms**

A Marie-Curie Incoming Fellowship

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A Marie Curie Fellowship was undertaken, from May 2012 to April 2014. The project focussed on working towards efficient characterisation techniques for permeability and compaction properties of fibrous reinforcements, as used in composites materials. A new facility for the characterisation of the permeability and compaction response of dry fibrous reinforcements was developed at the Institute for Carbon Composites (LCC), Technical University of Munich (Figure 1). The facility utilised the radial flow injection methodology and image capture to monitor flow front progression. Figure 2 shows example of the image analysis steps necessary to calculate permeability for each test. The new facility is considerably faster than the existing rectilinear injection facilities at the LCC, and uses less material.



Figure 1: Schematic of 2D in-plane permeability and through thickness compaction measurement facility.

An extensive experimental programme was undertaken to identify the key processing parameters affecting permeability and compaction response. A range of manufacturing parameters were tested, including fibre volume fraction, the effect of nesting, in-plane shear, number of layers and different material types. Permeability as a function of fibre volume fraction for two carbon fibre reinforcements is given in Figure 3.

A survey of industrial end-user requirements for material characterisation was under taken. While the number of responses to the survey to date was less than desired, some preliminary findings were combined with the experimental results to propose a way forward in developing an efficient characterisation facility.

Throughout the fellowship, considerable knowledge transfer activities took place. These range from direct knowledge transfer in the area of material characterisation through to general research knowledge, through paper revision and the development of a Formal English language lecture for academics.

A number of postgraduate students were supervised by the fellow during the course of the fellowship. These student projects have helped further the links of the LCC with both industry partners (BMW AG, GE Global Research) and with other institutes (Centre for Advanced Composite Materials, Auckland, New Zealand). In addition to the student projects, the fellow furthered international collaborations with a number of research institutes through working together and research visits. Primarily these have been; the Centre for Advanced Composite Materials, University of Auckland; Research Institute in Civil Engineering and Mechanics, Ecole Centrale de Nantes; Polymer Research Group, University of Nottingham; and Institut für Verbundwerkstoffe, Technische Universität Kaiserslautern.

The fellow published four journal papers and five conference papers during the time frame of the fellowship.

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| E:\Publications\Conference Papers\2014 - ECCM\example processed data.jpg | | |
| a) Lens distortion correction | b) Black/white thresholding | c) Flow-front fitting |

Figure : Image analysis steps.

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| K11 K22 baseline NCF  a) | K11 K22  Baseline_Weave  b) |
| Figure . Example output data - Permeability as a function of Vf for a) non-crimp fabric, and b) woven materials. | |