Bristol Composites Institute

The Use of Polarisation for Hi-Rate Defect Detection

Matt Miller[1,2], Chris Dighton[2], Iryna Tretiak[1], and Byung Chul Kim[1]

[1]Bristol Composites Institute, [2]National Composites Centre

Bristol Composites Institute

PGR Symposium

08.04.25

Presentation outline

- Background
- Motivation
- Project aim
- Why Polarisation?
- Current & Future Plans

Introduction

- **High-rate automated manufacture** is essential to meet the growing demand of the aerospace industry.
- **Autoclave processing** is not cost-effective for scaling production rates.
- **Out-of-autoclave processing** and **large volume deposition** techniques show potential to meet rate requirements.
- **Inspection** and rework often consumes over **50%** of the deposition cycle time [1,2].

[1] Brasington et al, Automated fiber placement: A review of history, current technologies, and future paths forward, 2021
[2] Maass D, Progress in automated ply inspection of AFP layups, 2015

Introduction

Aim

Target Inspection and Rework Processes During Deposition

Develop an In-process inspection system for high-volume automated material deposition processes.

Impact

Facilitating Manufacturing Rate

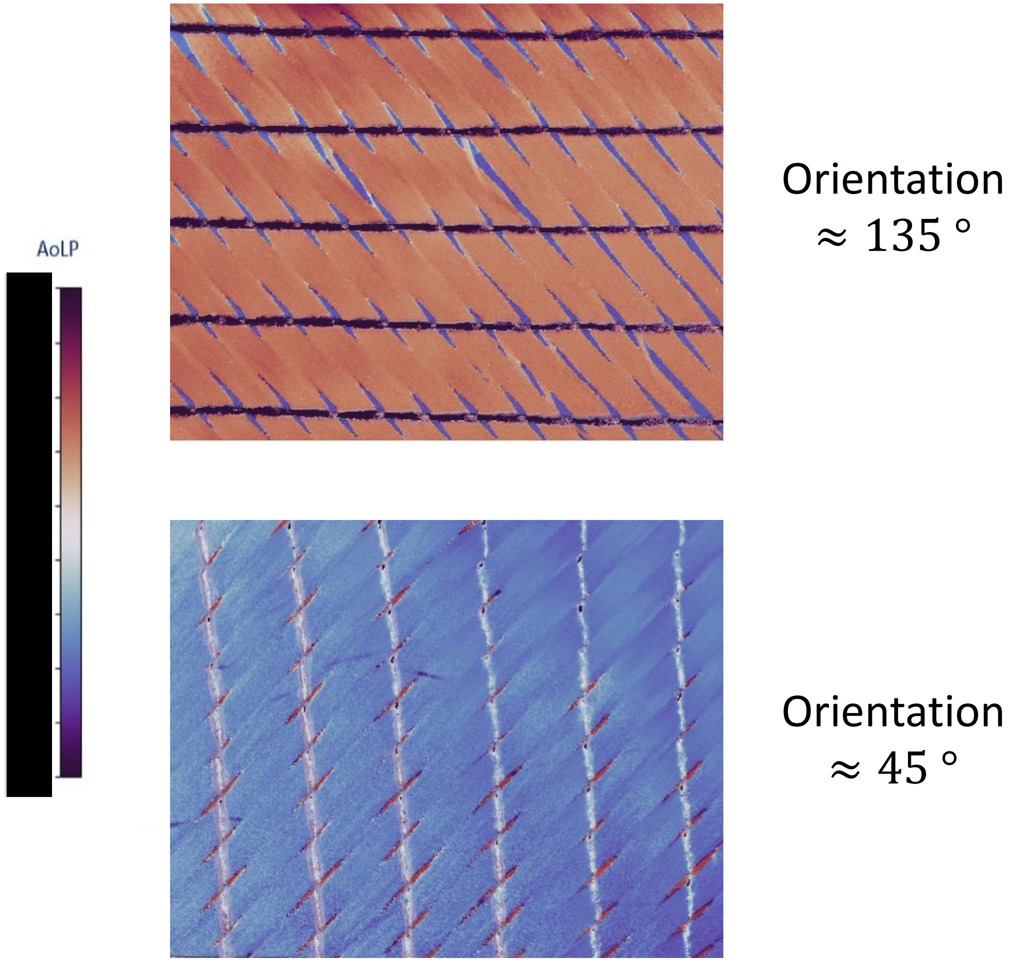
Meeting the manufacturing rate, demands in-process systems capable of detecting defects and ply positional accuracy.

Fewer Scrapped Parts & Less Waste

Undetected defects during manufacture lead to part rejection, wasting materials and raising costs.

Why Polarisation?

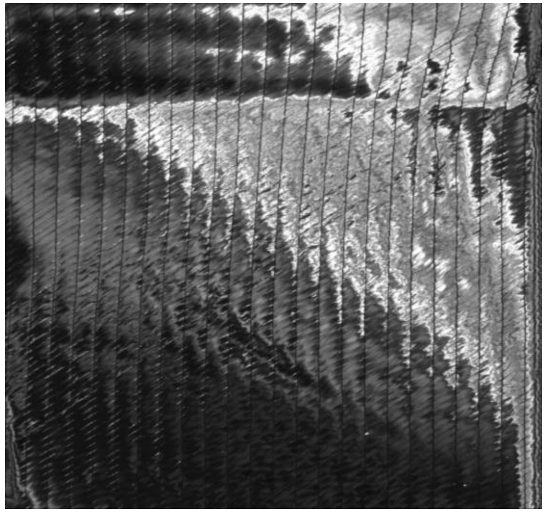
- The optical characteristics of carbon fibre polarise incident light in the fibre direction [1].



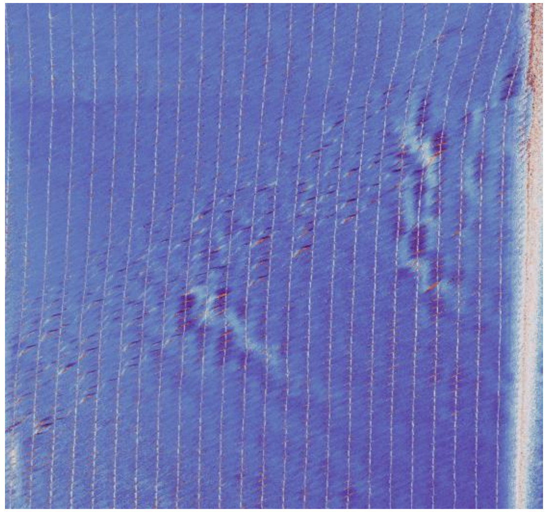
[1] Ernst et al, Measuring a fibre direction of a carbon fibre material and producing an object in a carbon-fibre composite construction WO2014/076128
[2] Atkinson et al, Precision fibre angle inspection for carbon fibre composite structures using polarisation vision.

Why Polarisation?

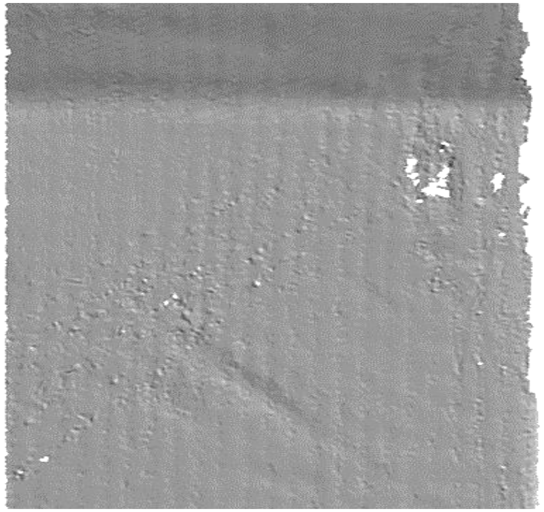
Reference image



AoLP



Laser Scan



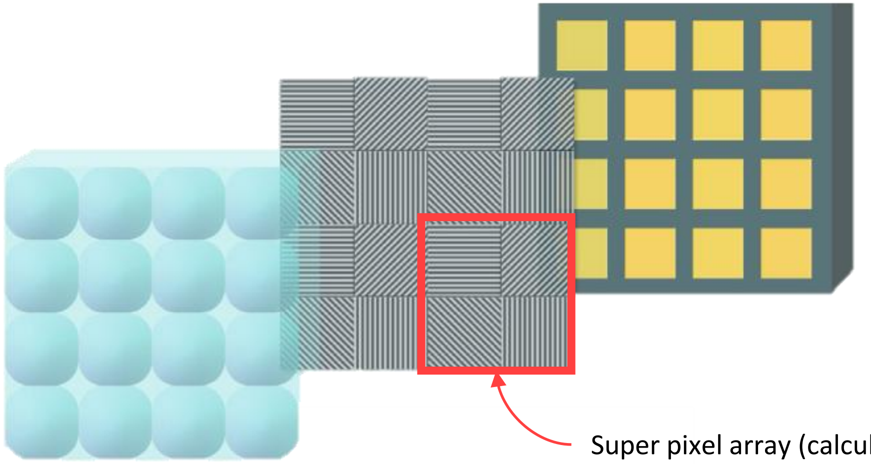
Polarisation method is more robust to lighting variance [1].

Polarisation method shows potential to reduce defect detection pre-processing and segmentation.

[1] Atkinson et al, Precision fibre angle inspection for carbon fibre composite structures using polarisation vision.

Polarised imaging for fibre angle detection

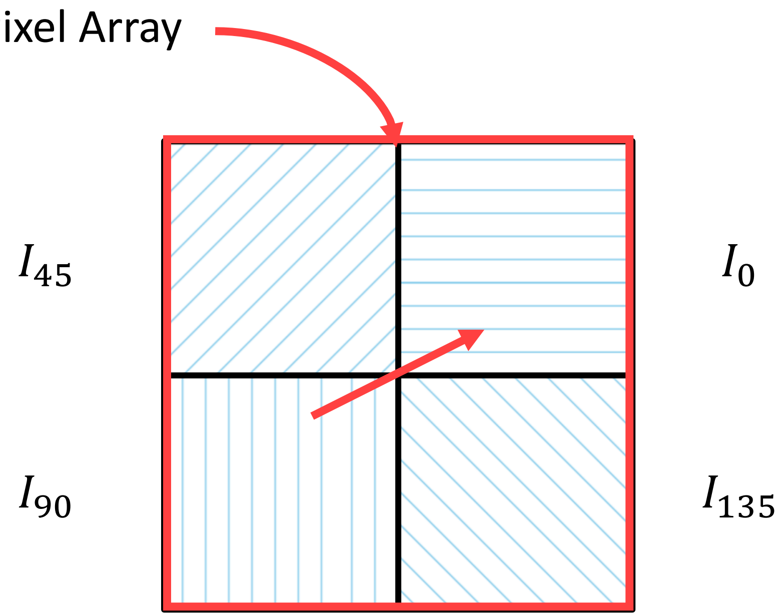
- Sensor developments allow the capture of polarised state of light from a single exposure.



Super pixel array (calculation unit)
four different directional polarisers

Polarised imaging for fibre angle detection

- Sensor developments allow the capture of polarised state of light from a single exposure.



$I_\theta = Intensity\ at\ microfilter\ angle$ within super pixel unit.

$$Stokes\ Vector\ = \begin{bmatrix} S_0 \\ S_1 \\ S_2 \end{bmatrix}$$

AoLP $\phi = \frac{1}{2} arctan_2(S_2, S_1)$

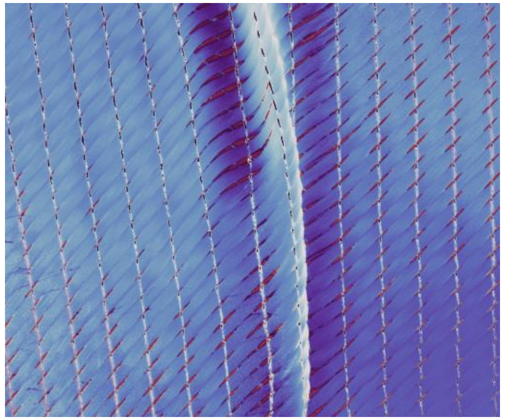
Where; $S_0 = \dfrac{I_0 + I_{45} + I_{90} + I_{135}}{2}$, $S_1 = I_0 - I_{90}$, $S_2 = I_{45} - I_{135}$

Current Investigations

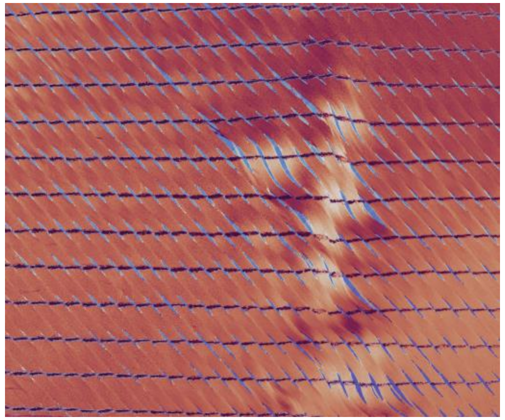
Characterising defect capability

- What defects are identifiable?

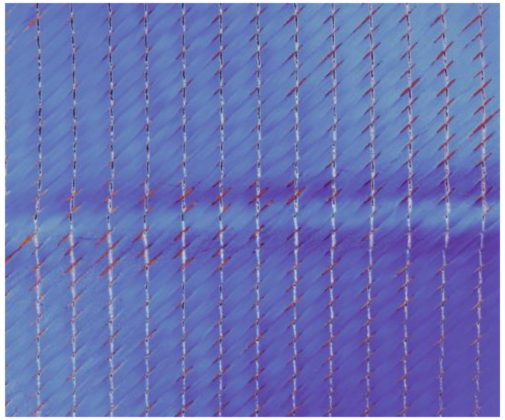
Fold



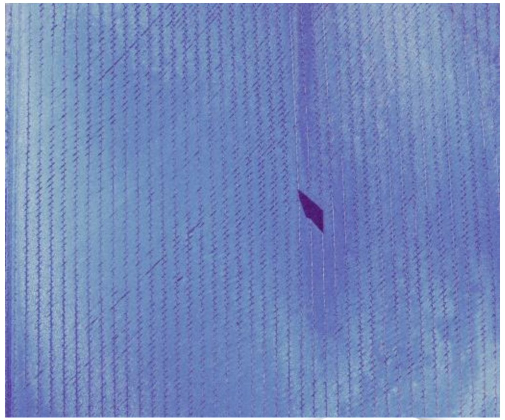
In-Plane Waviness



Out-of-Plane Waviness



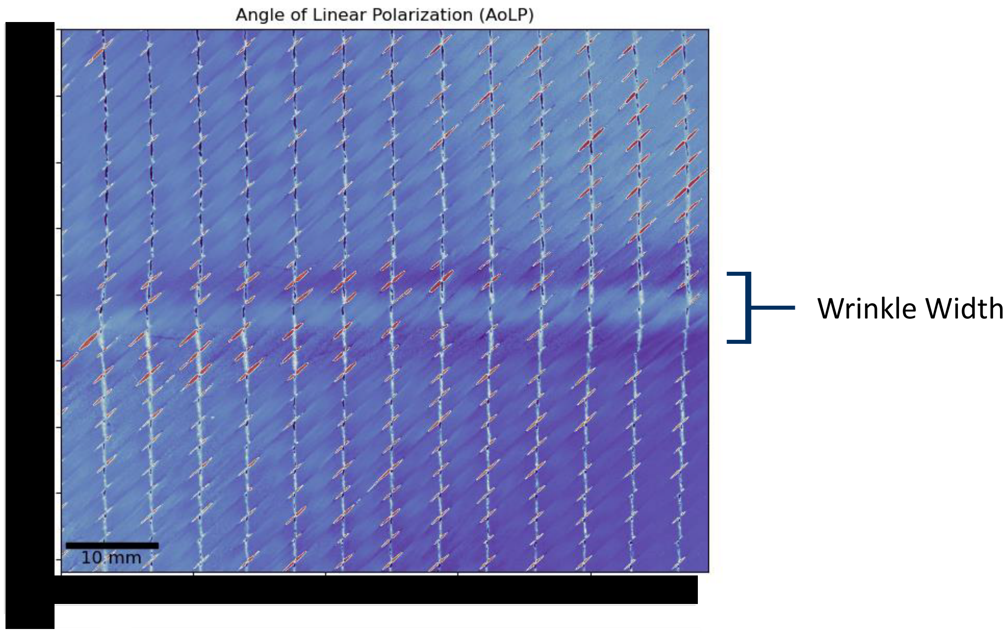
FOD



Current Investigations

Characterising defect capability

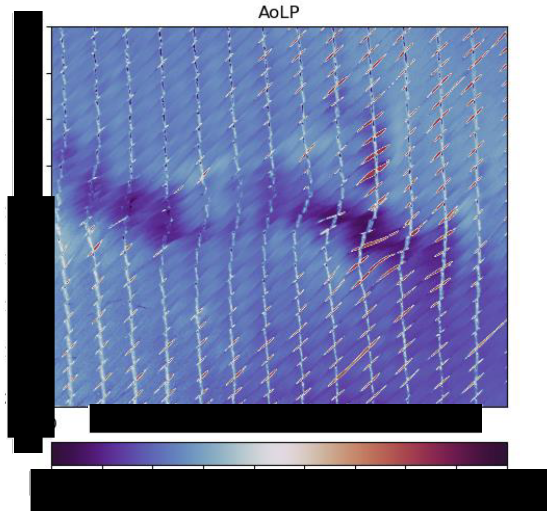
- What defects are identifiable?
- What features can be measured?

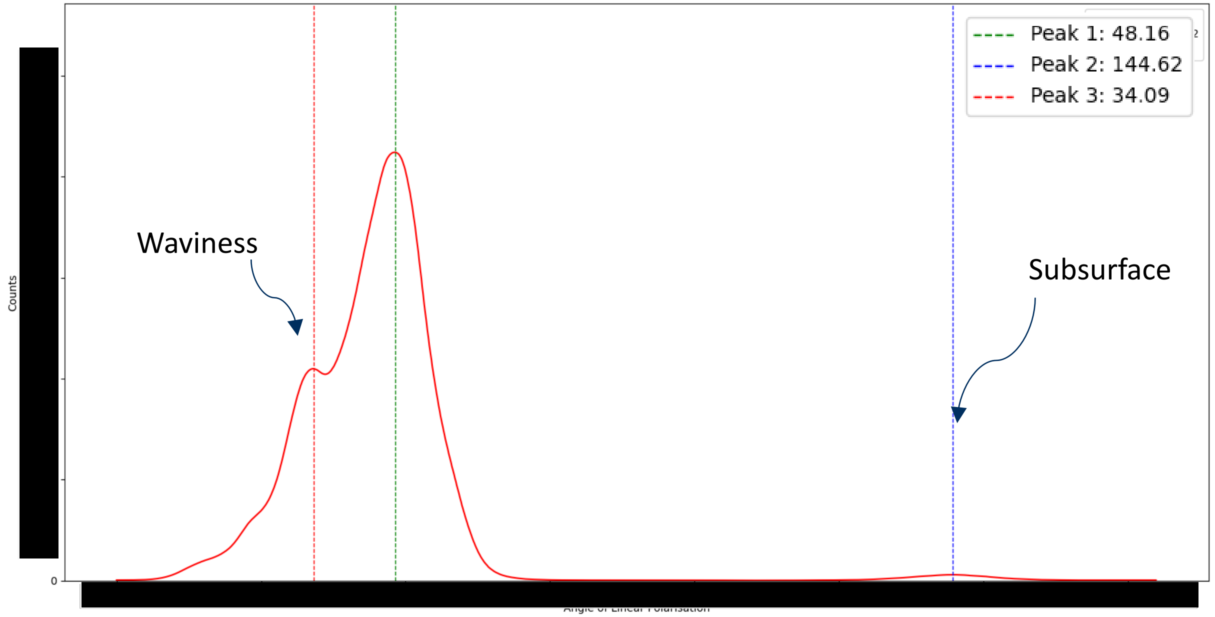


Current Investigations

Characterising defect capability

- What defects are identifiable?
- What features can be measured?

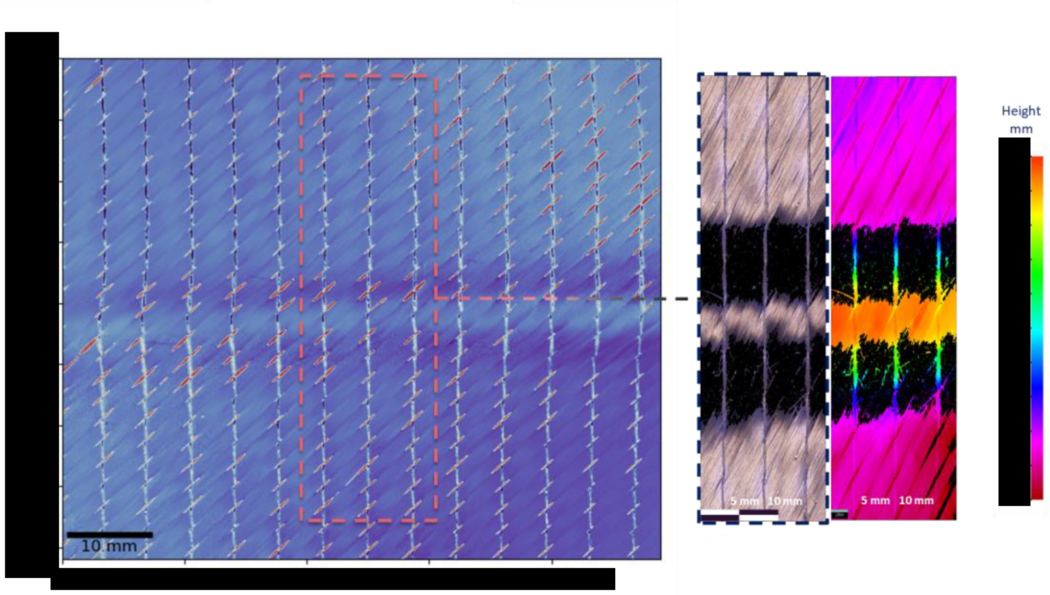




Current Investigations

Characterising defect capability

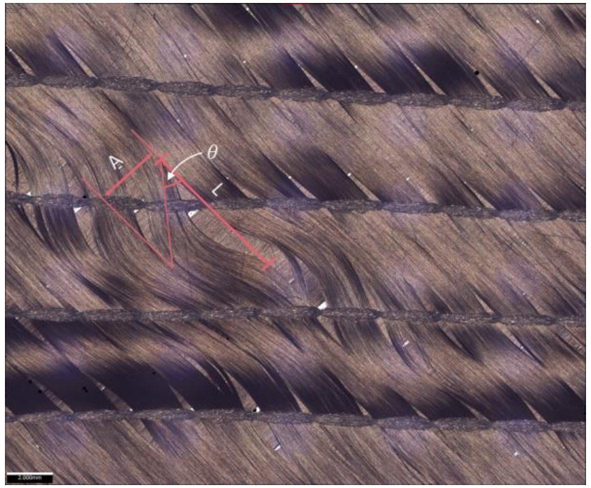
- What defects are identifiable?
- What features can be measured?
- How do the measured values compare with baseline?

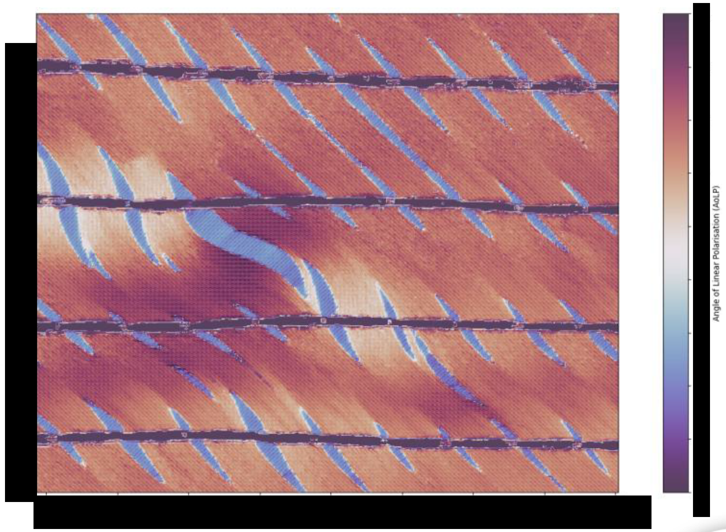


Current Investigations

Characterising defect capability

- What defects are identifiable?
- What features can be measured?
- How do the measured values compare with baseline?





Long Term Plans

- Optimising process parameters & and setup for maximum defect detection accuracy.
- Evaluating high-speed in-line inspection feasibility for NCF Materials.
- Implementing and experimentally validating polarisation imaging in a high-rate material deposition system.

Questions?

Matt.miller@bristol.ac.uk

Matthew.Miller@NCCUK.com

Bristol Composites Institute

NATIONAL COMPOSITES CENTRE

EPSRC Industrial Doctorate Centre in COMPOSITES MANUFACTURE