HiPerDiF Technology
A Route to More Sustainable Composites

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bristol.ac.uk/composites
Presentation Outline

• Discontinuous composites (see Dr Soraia Pimenta).

• HiPerDiF – A brief history and operating principles.

• Aligned discontinuous fibre reinforced composites (ADFRC).

• Using HiPerDiF to tailor functionality and improve sustainability.

• The future - HiPerDiF 3G.

• Acknowledgements.
What are the Benefits of using HiPerDiF?

• Reduction of stress concentration at the ply drop;
• Increase steering capabilities;
• Avoid fibre bridging in 3D forming;

• Feedstock material for:
  • Automated Fibre Placement (AFP);
  • Automated Tape Laying (ATL);
  • Fused Filament Fabrication (3D printing)
HiPerDiF – A Brief History (2011-2020)

• Initially developed within EPSRC Programme Grant EP/I02946X/1 (£6.4M)
  “High Performance Ductile Composite Technology” (HiPerDuCT)
  Co-invented by Dr HaNa Yu & Prof. Kevin Potter, patented by UoB.

• First generation, desktop prototype (‘BabyDiF’)
• Lab. scale HiPerDiF 2G – yielded multiple publications.

• 2017 Further EPSRC Grant EP/P027393/1 (£1M)
  “High Performance Discontinuous Fibre Composites – A Sustainable Route to the
  Next Generation of Composites” to scale up and develop HiPerDiF 3G.

• 2020 EPSRC Manufacturing Hub feasibility project (£437k)
  “Forming of Steered Fibre Preforms for high rate, sustainable production of complex parts”
Working Principles of the HiPerDiF 2G Machine
Remanufacturing of Reclaimed Carbon Fibre Reinforcements

CFRP recycling:
0) Collection, sorting
1) Reclamation*
2) Remanufacturing*

Challenge:
Reclaimed fibres are fragmented in short length, filamentised, randomly oriented.

- Reclaimed fibres (external sources) -> New fibres
- Reclaimed fibres (closed-loop) -> Constituents Reclamation*
- Thermosetting Matrix -> Matrix Impregnation*
- Thermoplastic Matrix

* Quality assurance

 Operative Life
Aligned Discontinuous Fibre Composites (ADFRCs)

High performance aligned carbon/epoxy composites:
• Fibre type: Carbon (3 mm)
• Resin: Epoxy (MTM49-3)

\[ \nu_f \approx 55\%, \quad E \approx 115 \text{ GPa}, \quad \sigma_T \approx 1500 \text{ MPa} \]

H. Yu, K.D. Potter, M.R. Wisnom
"A novel manufacturing method for aligned discontinuous fibre composites (High Performance-Discontinuous Fibre method)"
ADFRCs vs. Random Mat

Aligned discontinuous fibre prepreg tapes:
100% High Strength Carbon & K-51 Resin

Hand lay-up (Human AFP...)

$V_f = 25\%$

Stiffness [GPa]

Failure Strain [%]

Strength [MPa]

HiPerDiF ADFRC Random Mat HiPerDiF ADFRC Random Mat HiPerDiF ADFRC Random Mat

$\uparrow$ 5 mm $\downarrow$

0° $+60°$ $-60°$ $+60°$ $0°$

0 50 100 150 200 250

Stress [MPa]

0 0.2 0.4 0.6 0.8 1 1.2

Strain [%]

HiPerDiF ADFRC Random Mat

HiPerDiF ADFRC Random Mat

HiPerDiF ADFRC Random Mat

University of Bristol HiPerDiF

Bristol Composites Institute (ACCIS)
Chosen Configurations for quasi isotropic lay-up:
- High modulus carbon/High strength carbon: 50/50
- High modulus carbon/E Glass: 40/60

- The yield strain is the same for UD and the QI;
- The knee point in the QI is less evident.
Sustainable Composites

- Alignment ⇌ Volume fraction ⇒ Mechanical performance:

- Highest recorded stiffness for a recycled composite;
- Strength is dependent on the reclamation method/recyclate content.

M.L. Longana, H. Yu, M. Jalalvand, M.R. Wisnom, K.D. Potter

*Aligned discontinuous intermingled reclaimed/virgin carbon fibre composites for high performance and pseudo-ductile behaviour in interlaminated carbon-glass hybrids*

*Composites Science and Technology, Vol 143, 2017*
Sustainable Composites

• Possibility to remanufacture fibres reclaimed multiple times from thermoset matrix:

• Reduction in mechanical properties observed, but still of value for engineering

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*Aligned discontinuous intermingled reclaimed/virgin carbon fibre composites for high performance and pseudo-ductile behaviour in interlaminated carbon-glass hybrids*

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Sustainable Composites

- Processing mixtures of recovered carbon fibres of multiple lengths (3 mm and 6 mm).
- Mixed fibre bed has little influence on mechanical properties of composite.
Circular Economy

“A regenerative and restorative economy that keeps the resources in the manufacturing loop for as long as possible”
100% Closed Loop Recycling (Thermoplastics)

*Development of a closed-loop recycling process for short carbon fibre polypropylene composites*

- Highest Properties in a CF/PP Composite:
  - $V_f = 26\%$;
  - $E_{11} = 43$ GPa;
  - $\sigma_{11} = 285$ MPa.

- Properties retained over several loops (also for Nylon 6).

- Material strength increase is caused by matrix residues left on the fibres during reclamation, this enhances adhesion by acting as matrix-specific sizing.
Functionalised Composites (Carbon/Flax Fibres)

- Intermingled rCF/flax fibre composites offer enhanced secondary properties (noise, vibration, and harshness (NVH) mitigation) and reduce cost but at the expense of primary mechanical properties:

M.L. Longana, V. Ondra, H. Yu, K.D. Potter, I. Hamerton
The Future: HiPerDiF 3G

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The HiPerDiF Team

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Thank You
for Your Attention

Any Questions?

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