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Bristol Composites Institute

HiPerDiF: A New Route to Produce Sustainable Composites

Professor Ian Hamerton &
Dr Marco Longana

Composites Perspectives, BCI

12th September, 2022

bristol.ac.uk/composites

HiPerDiF – A Brief History (2010-2022)

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')
- Laboratory 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"

2020 Establishment of Spin out company (Lineat Composites)

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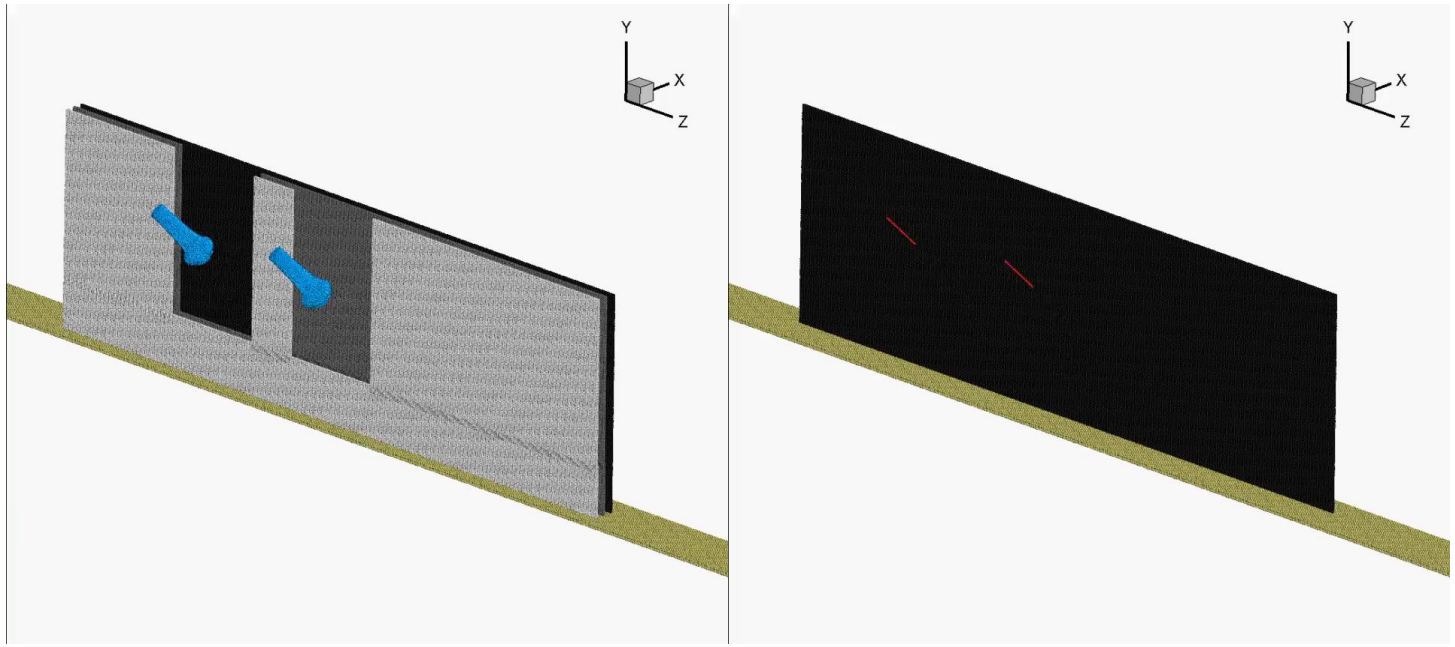
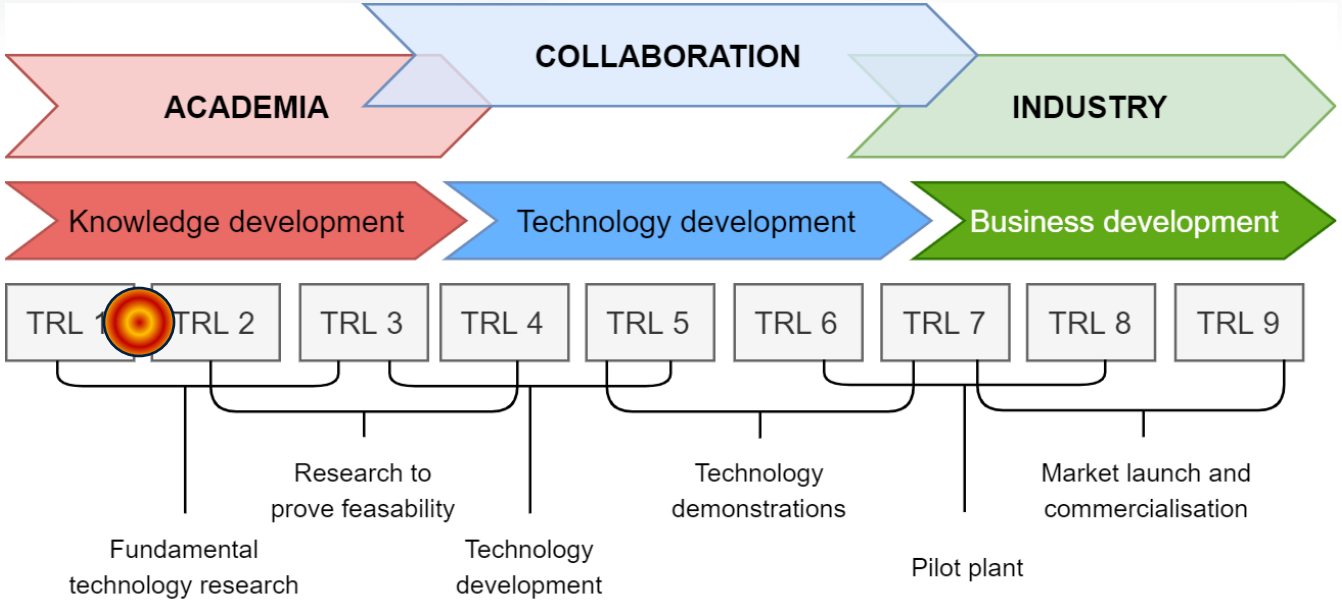
The Working Principle

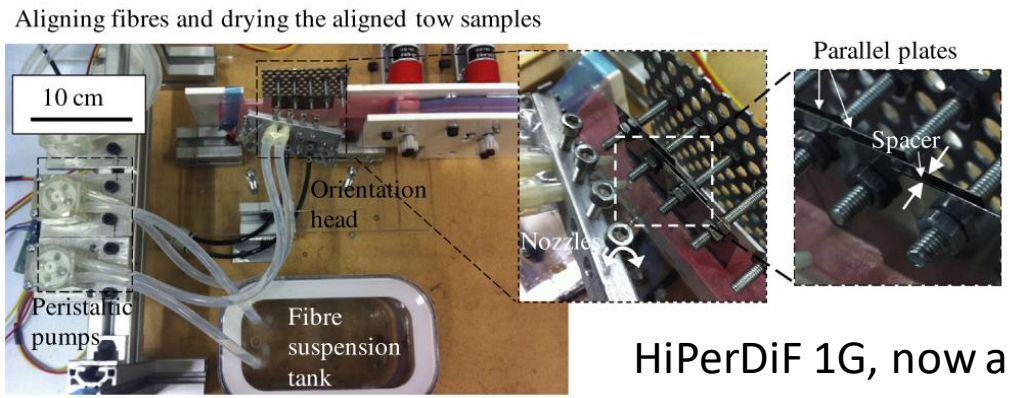
Fibres suspended in low-viscosity fluid, spayed between parallel plates, carrier fluid is extracted by suction and dried to allow for matrix impregnation.



Validation of a Smoothed Particle Hydrodynamics model for a highly aligned discontinuous fibre composites manufacturing proce ss,
S. Huntley, T. Rendall, M. Longana, J. Lee, T. Pozegic, K. Potter, I. Hamerton, Composites Science and Technology, 2020
SPH Simulation for Short Fibre Recycling Using Water Jet Alignment,
S. Huntley, T. Rendall, M. Longana, T. Pozegic, K. Potter, I. Hamerton, International Journal of Computational Fluid Dynamics, 2021

The Early Days





HiPerDiF 1G, now aka “BabyDiF”

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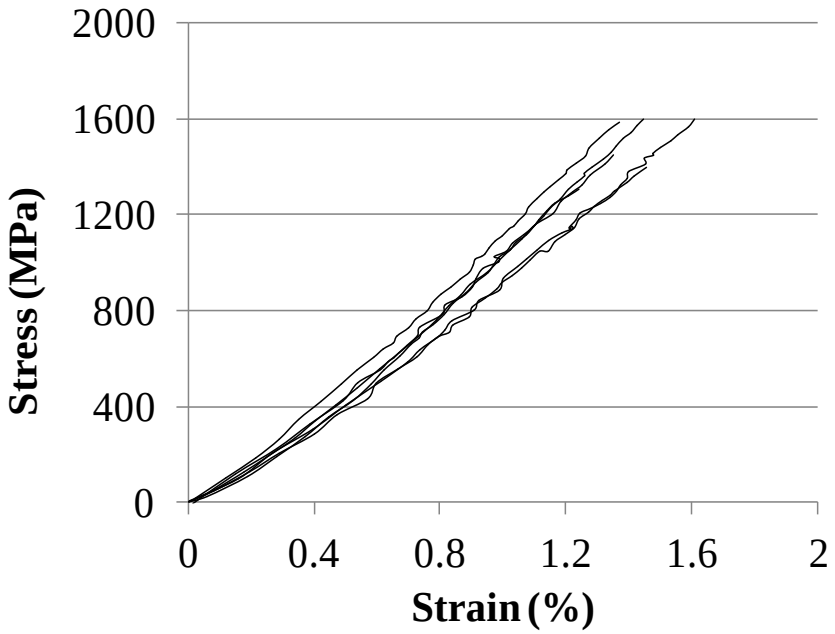
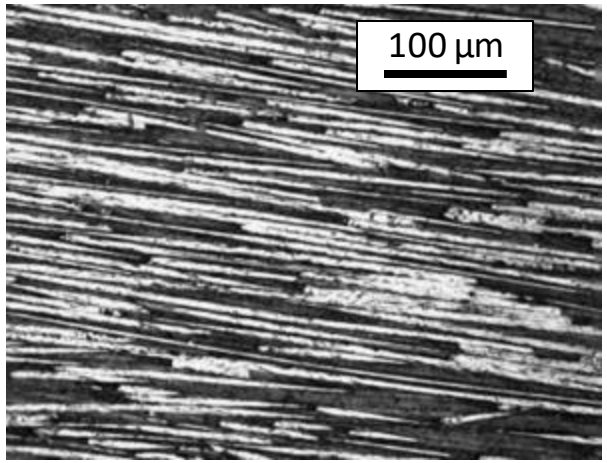
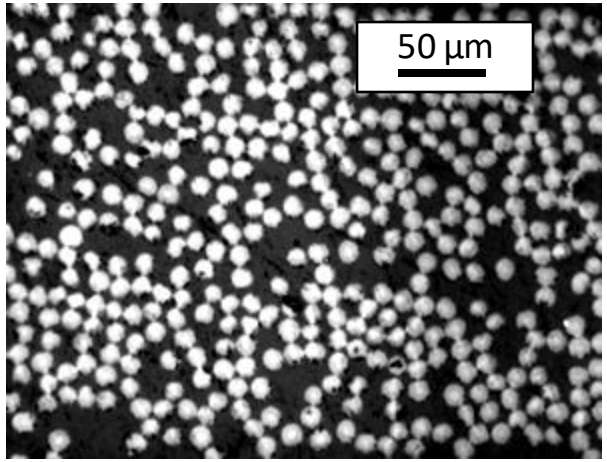
HiPerDiF High Performance Discontinuous Fibre

Aligned Discontinuous Fibre Composites



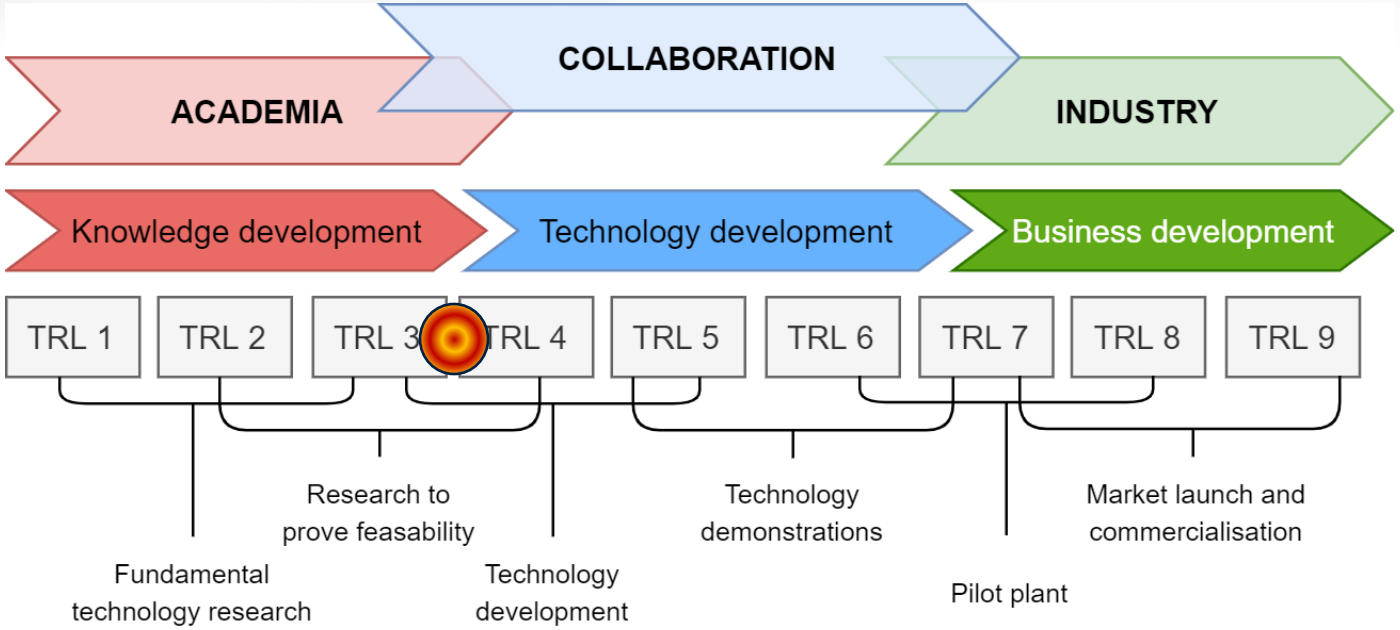
$v_f \approx 55\%$,
$E \approx 115$ GPa,
$\sigma_T \approx 1500$ MPa





H. Yu, K.D. Potter, M.R. Wisnom
A novel manufacturing method for aligned discontinuous fibre composites (High Performance-Discontinuous Fibre method)
Composites Part A: Applied Science and Manufacturing, Vol 65, 2014

Functionalised and Sustainable Composites



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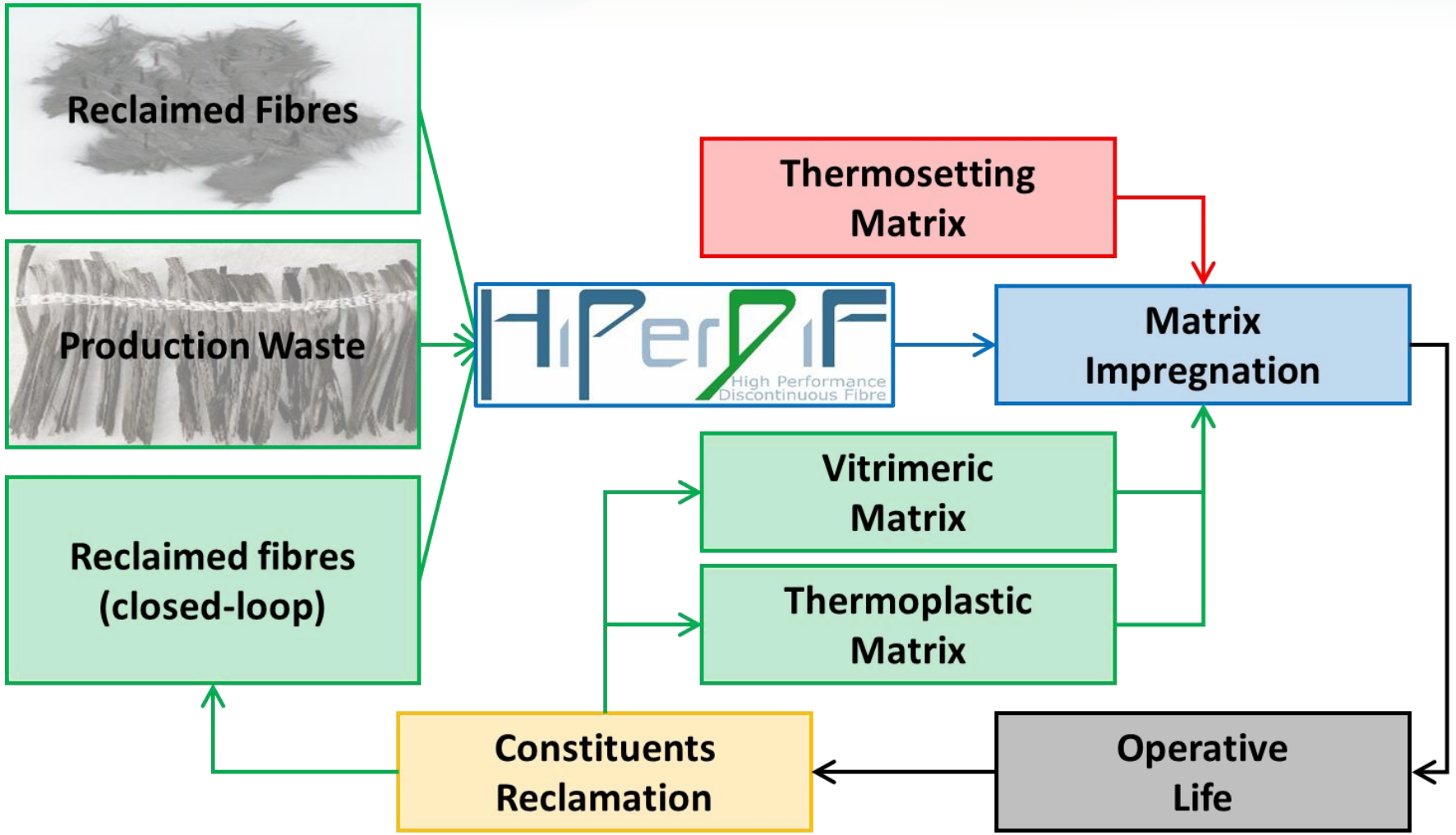
HiPerDiF High Performance Discontinuous Fibre

Raw Materials

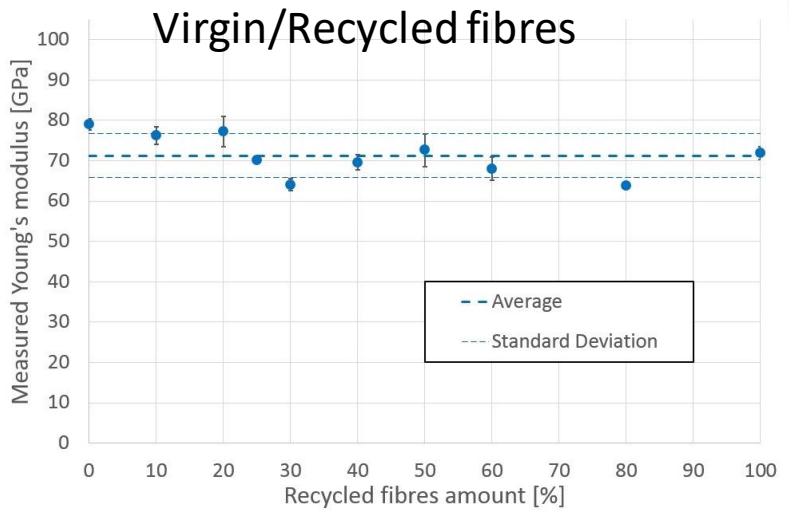
- Fibres (1 to 12 mm long):
  - Virgin synthetic fibres (*e.g.* Carbon, Glass, Kevlar, PVA, Basalt);
  - Reclaimed carbon fibres;
  - “Natural Fibres” (Flax, Jute, Curaua…).
- Matrices:
  - Thermosetting (Epoxy);
  - Thermoplastic (PP, Nylon, PLA, ABS, PET…);
  - Covalent Adaptive Network polymers (vitrimers).
- Further “phases”:
  - Sizing agents (*e.g.* water soluble epoxy);
  - Binders for dry preforms.

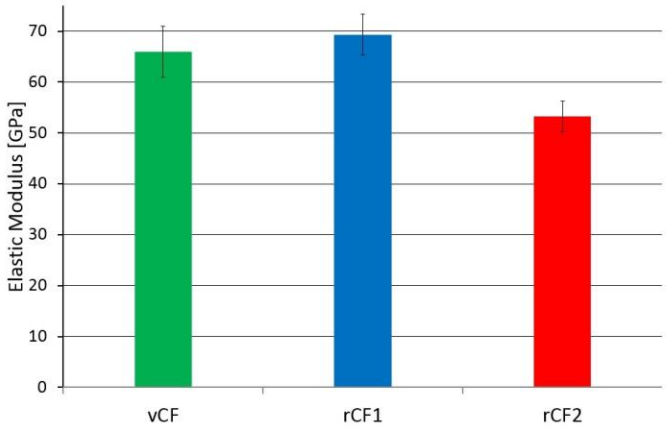
Basalt:
project in collaboration with
DBF - Deutsche Basalt Faser

HiPerDiF as Part of the Circular Economy

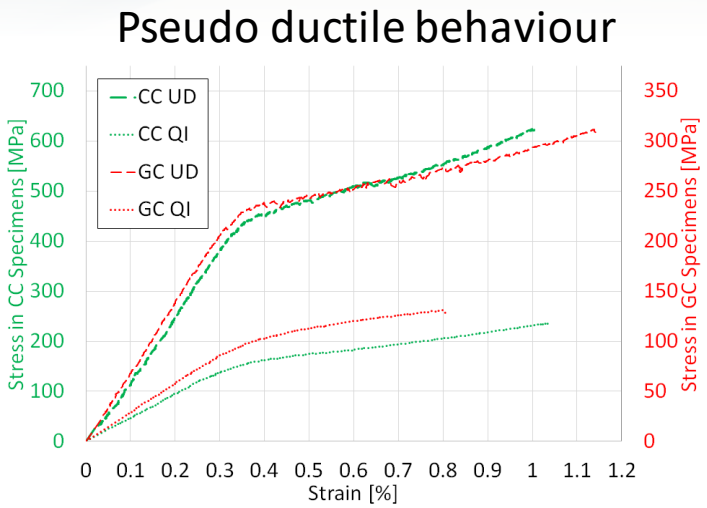


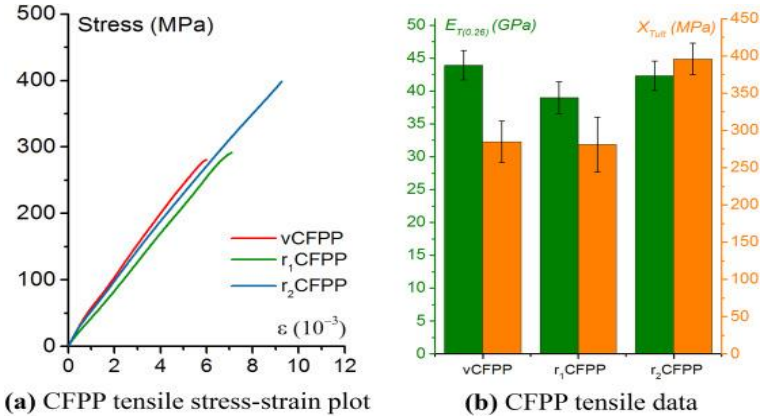
Past Research Highlights





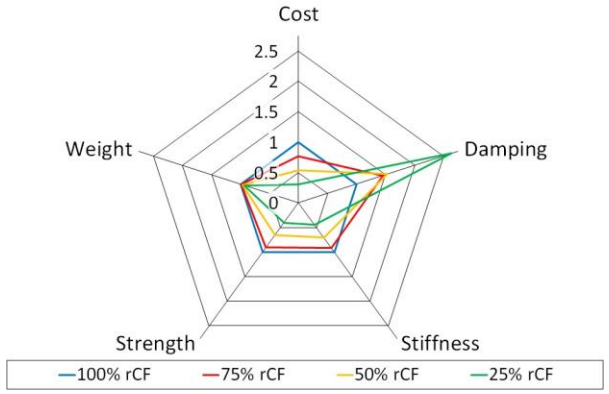
Reclaimed fibres from thermosets





Circular economy - thermoplastics

- **Stiffest** recycled carbon fibre composite (70 GPa)
- The **strongest** composite produced from manufacturing waste (800 MPa)
- **100% recyclable** high performance thermoplastic composites (PP & PA6)
- Capability to process "non-refined" waste (fibre length distribution 3 - 6 mm)
- Functionalised composites for NVH damping (rCF + Flax)



Tailoring vibrational frequency

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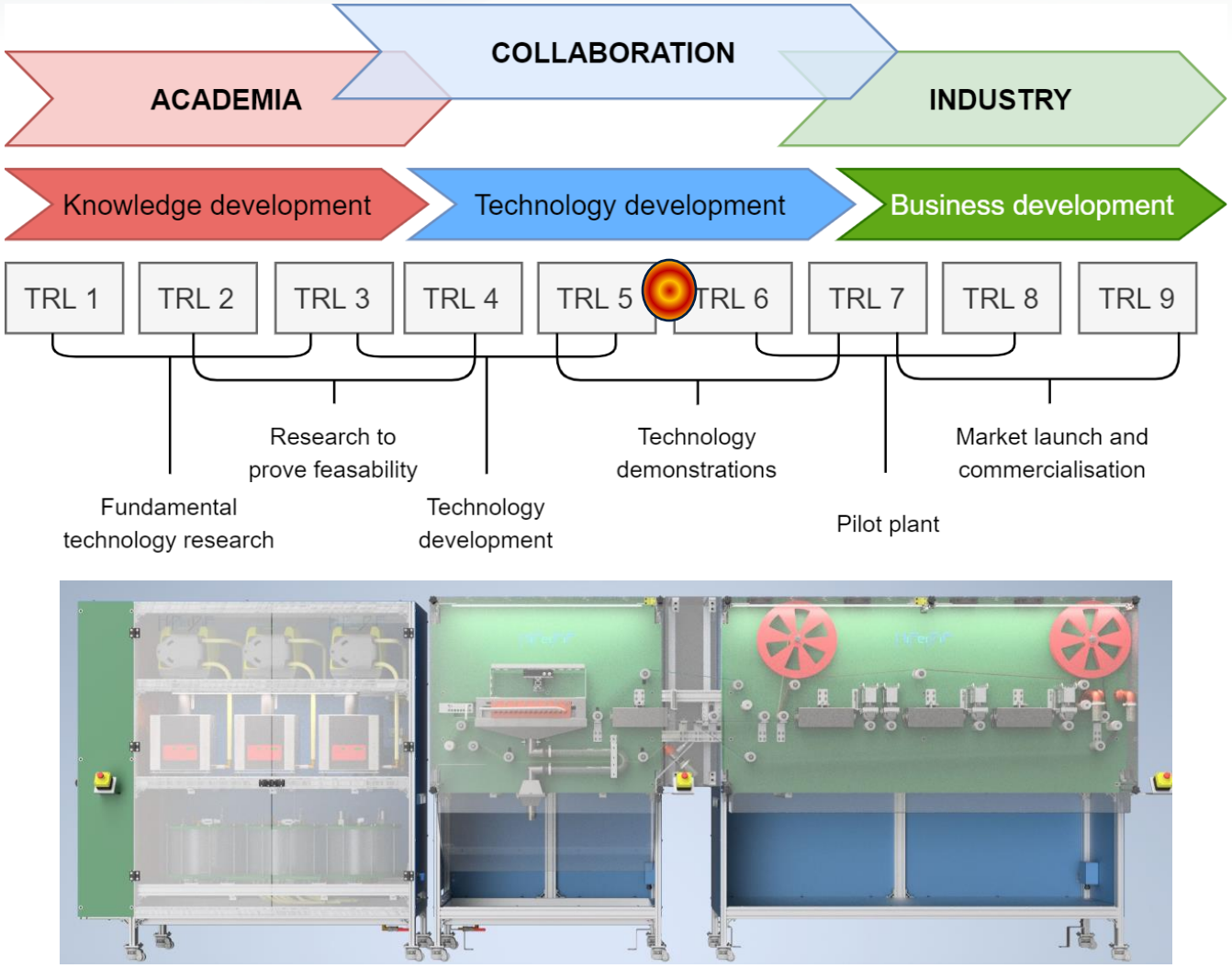
HiPerDiF High Performance Discontinuous Fibre

HiPerDiF 3G



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HiPerDiF High Performance Discontinuous Fibre

HiPerDiF 3G in Operation

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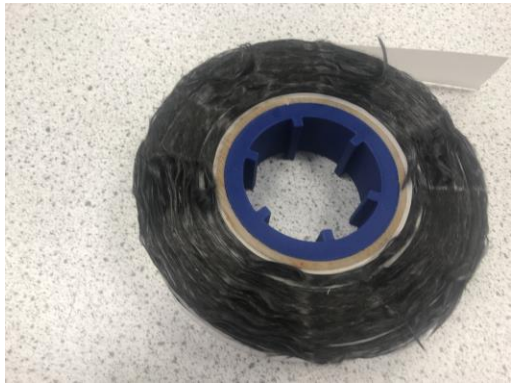
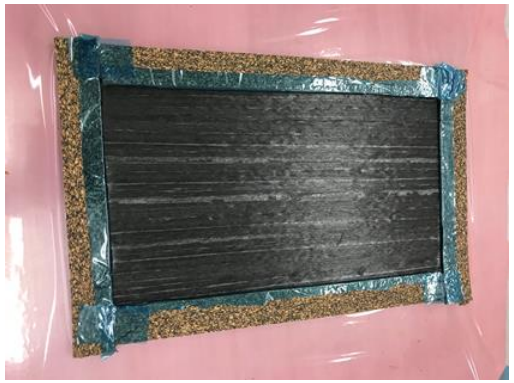
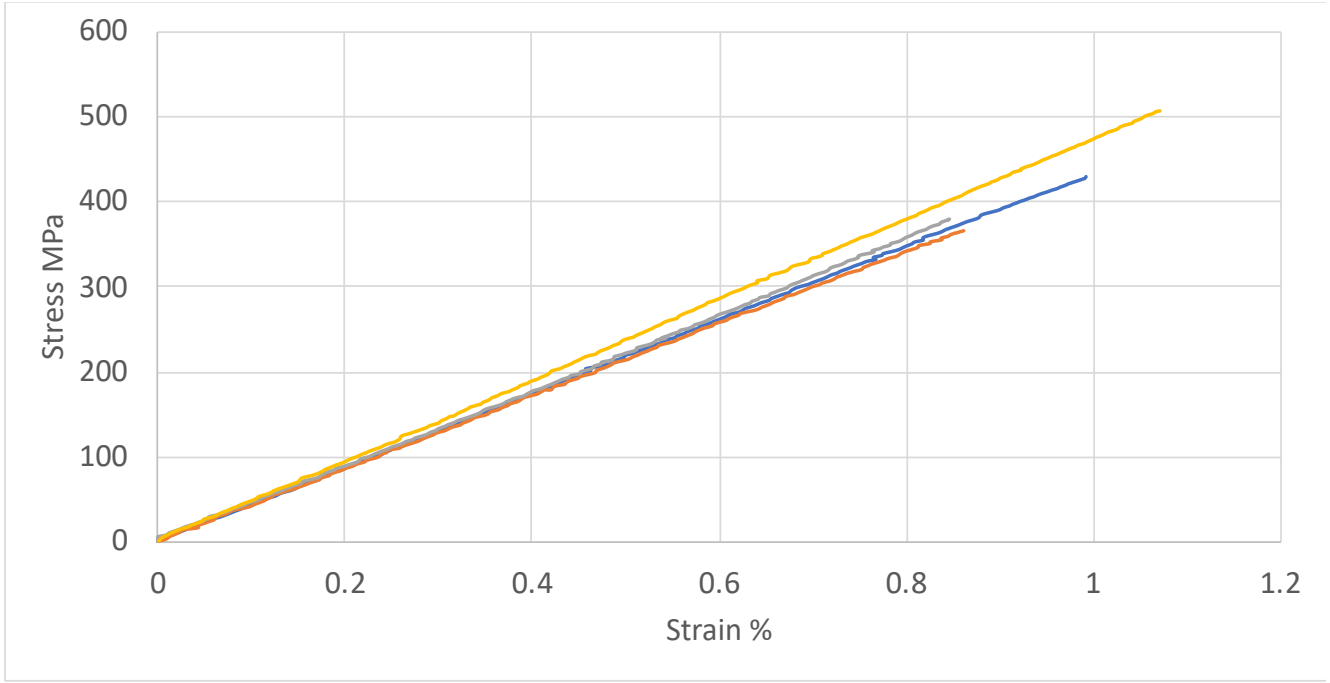
HiPerDiF High Performance Discontinuous Fibre

High Performance Composites







HTC C124 fibres & 977-2 resin $[0°]_8$ Vf = 39%

E_1 = 77.8 Gpa $\sigma_{failure}$= 751.2 Mpa

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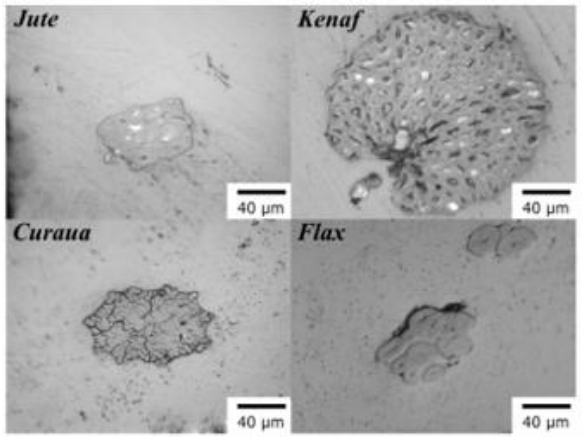
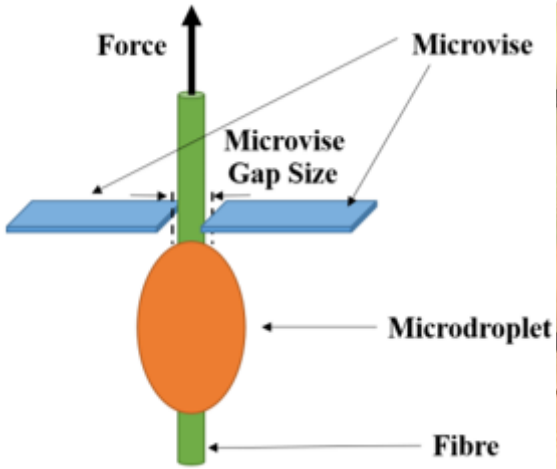
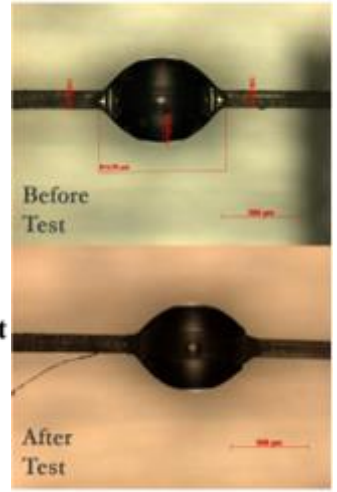
HiPerDiF High Performance Discontinuous Fibre

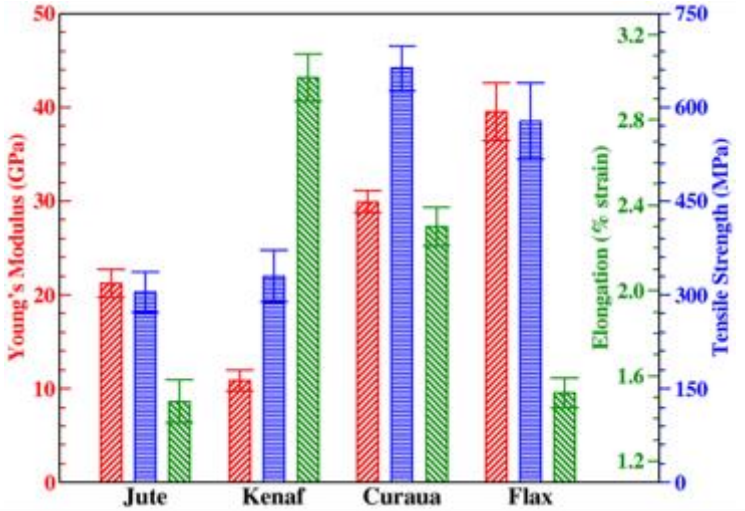
Natural Fibre Composites

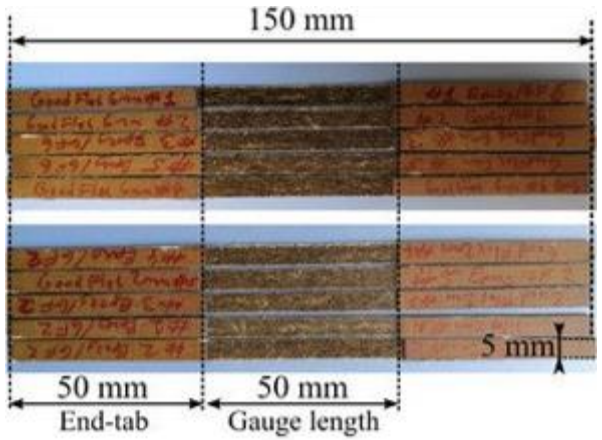
MALLINDA

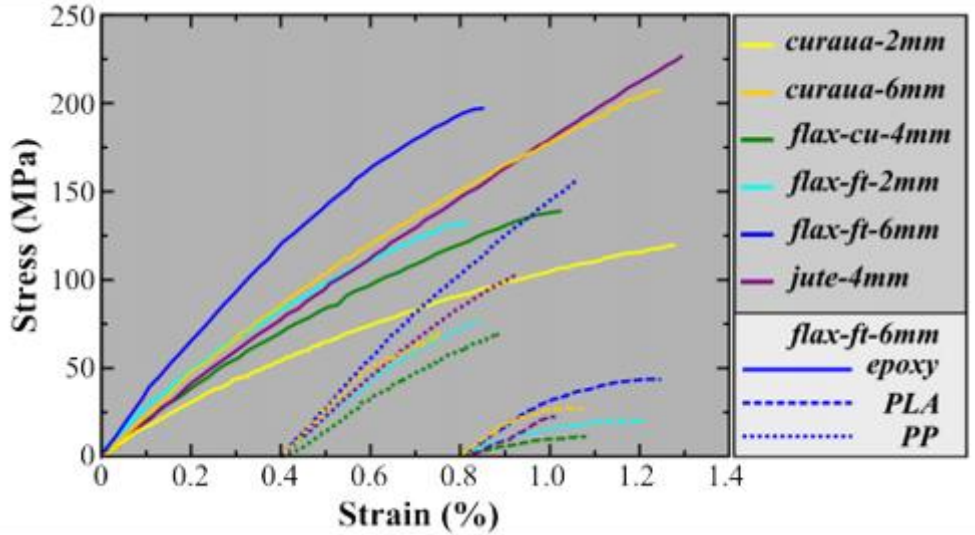












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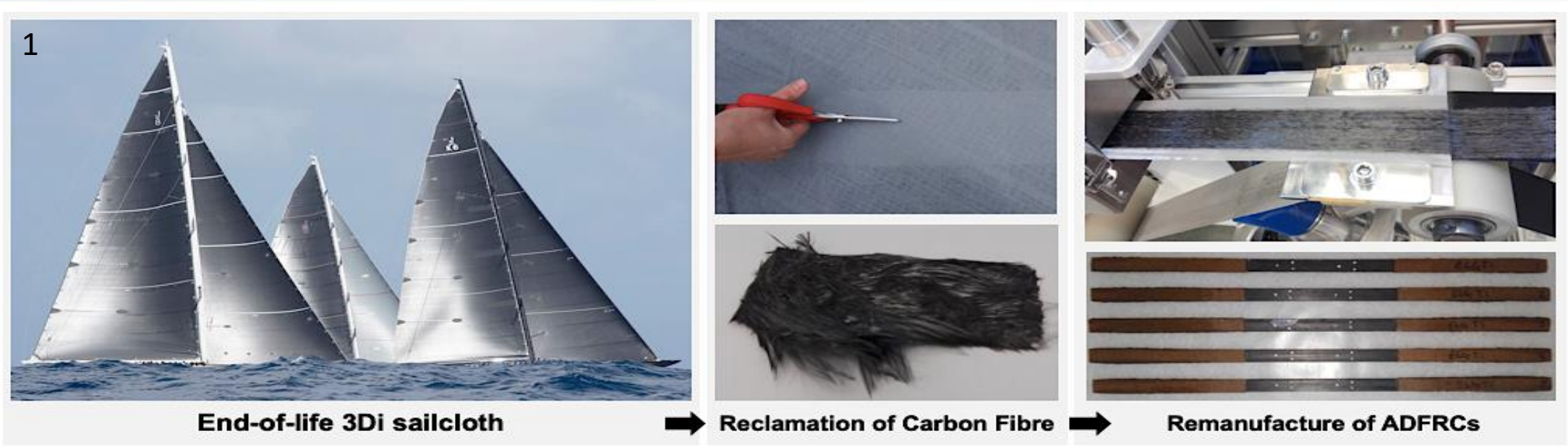
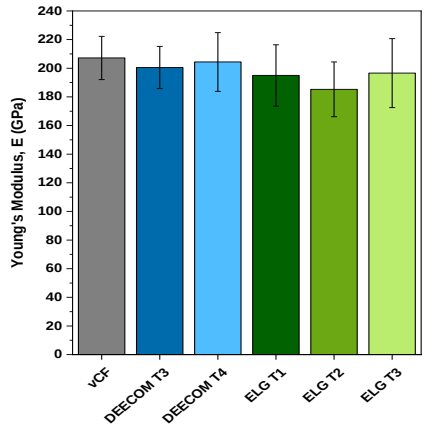
HiPerDiF High Performance Discontinuous Fibre

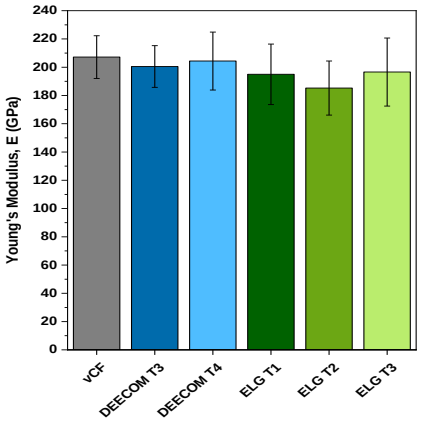
End-of-life 3Di composite Sails Recycling



Pyrolysis-based

Superheated steam





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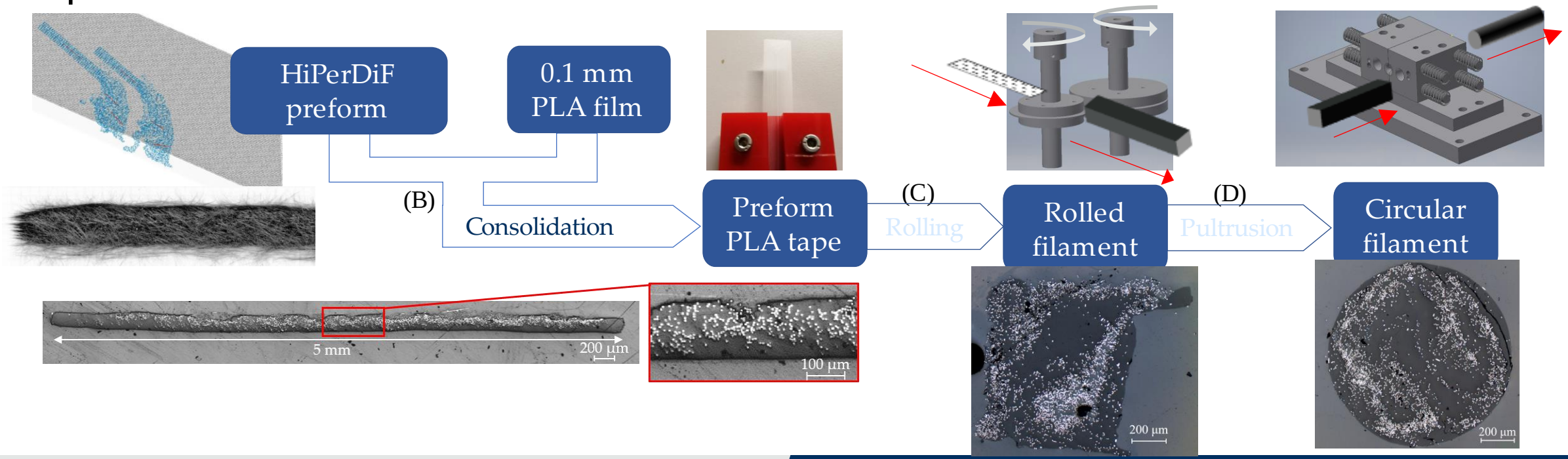
HiPerDiF High Performance Discontinuous Fibre

HiPerDiF as a 3D printed filament

- HiPerDiF as reinforcement for 3D printing thermoplastic material - promotes manufacturability & mechanical performance
- Currently, filament produced with modified industrial bulking machine with production rate of 200 mm/min.



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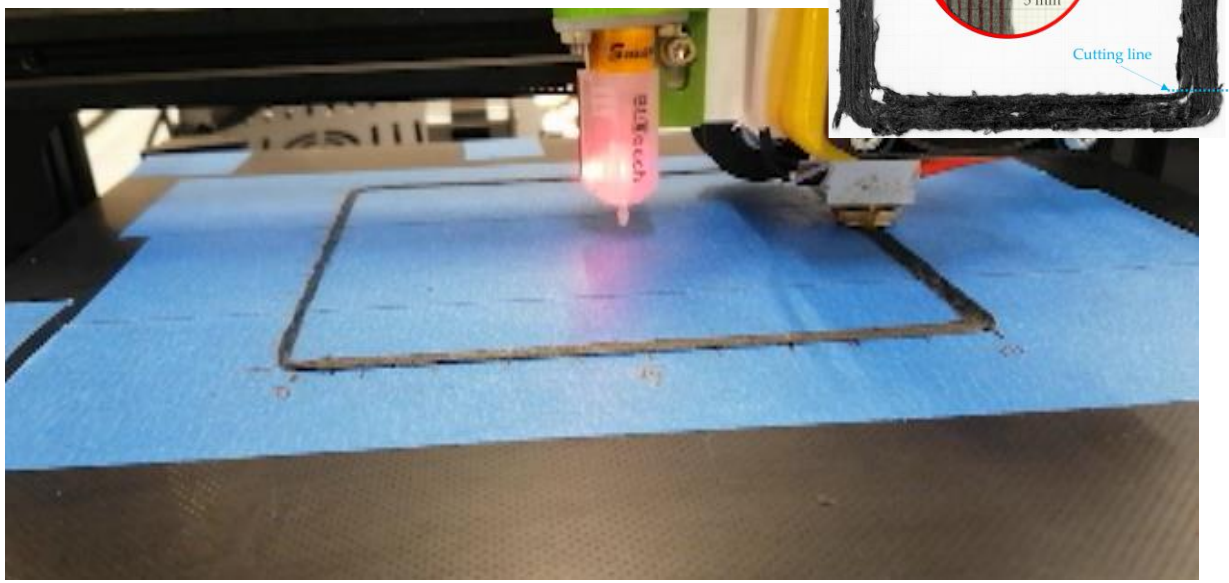
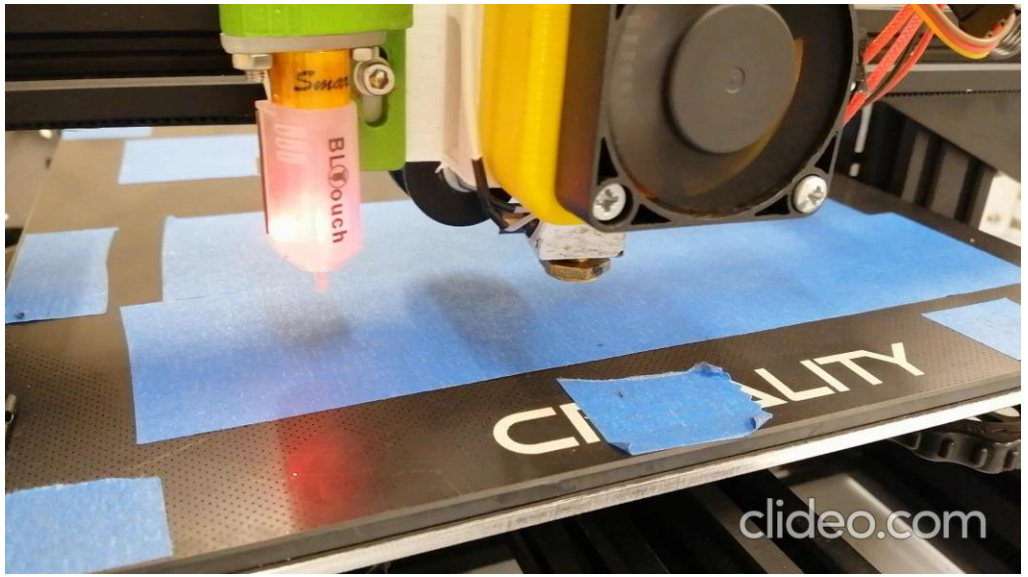
HiPerDiF High Performance Discontinuous Fibre
UKRI Engineering and Physical Sciences Research Council
University of BRISTOL
EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science

HiPerDiF as a 3D printed filament

- 3D printing of the produced filament to fabricate tensile testing samples



- 3D printing of a complex geometry, an aerofoil shape



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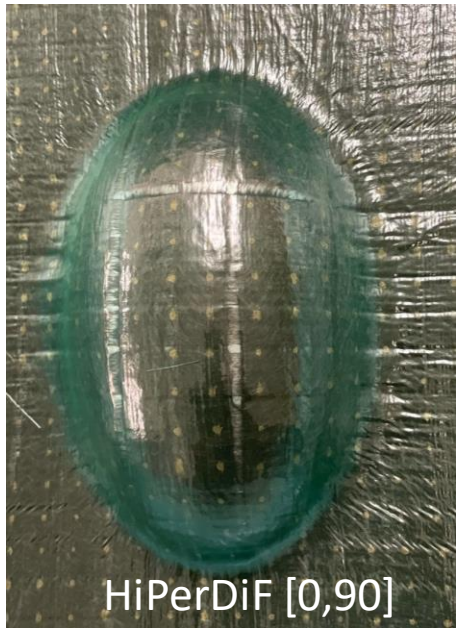
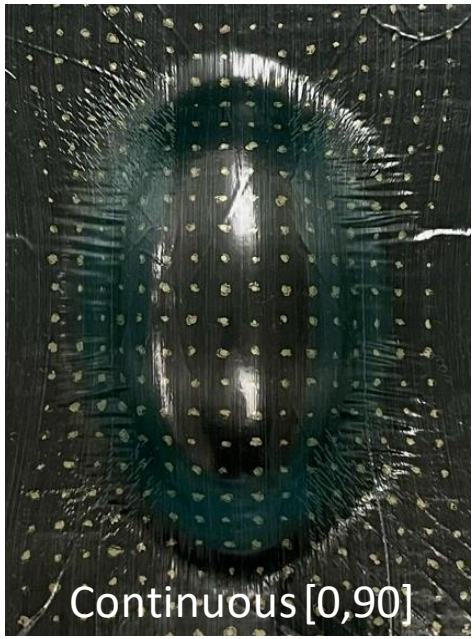
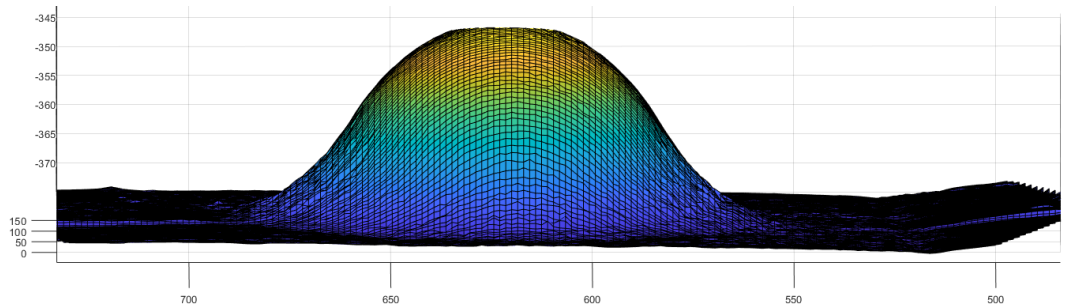
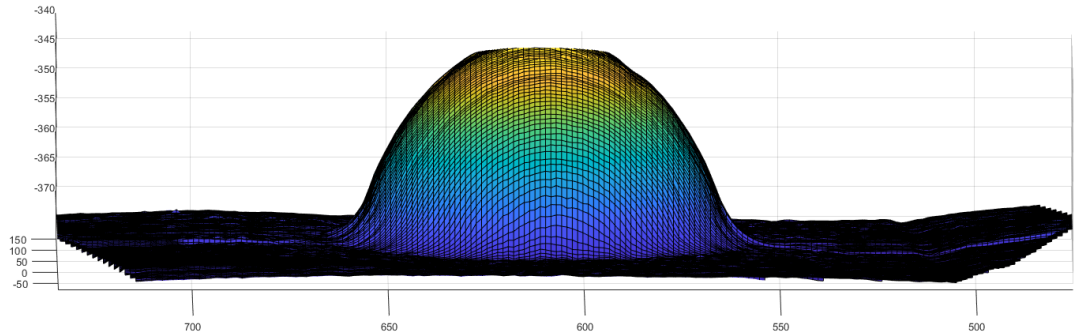
Forming Trials



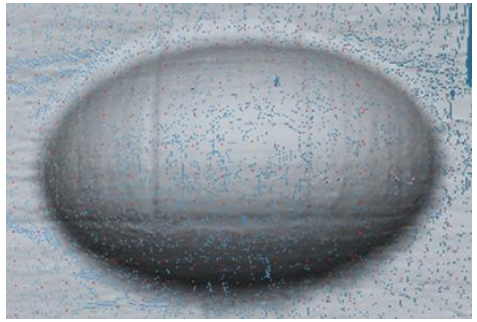


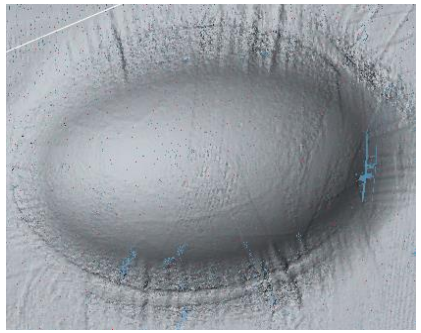


Continuous Fibres



HiPerDiF





Thanks to Dr Tharan Gordon, Dr Ric Sun, Dr Eric Kim, Dr Jonathan Belnoue, Prof. Stephen Hallett (work conducted within the Future Composites Manufacturing Research Hub core project ‘Fibre-steered forming technology’).

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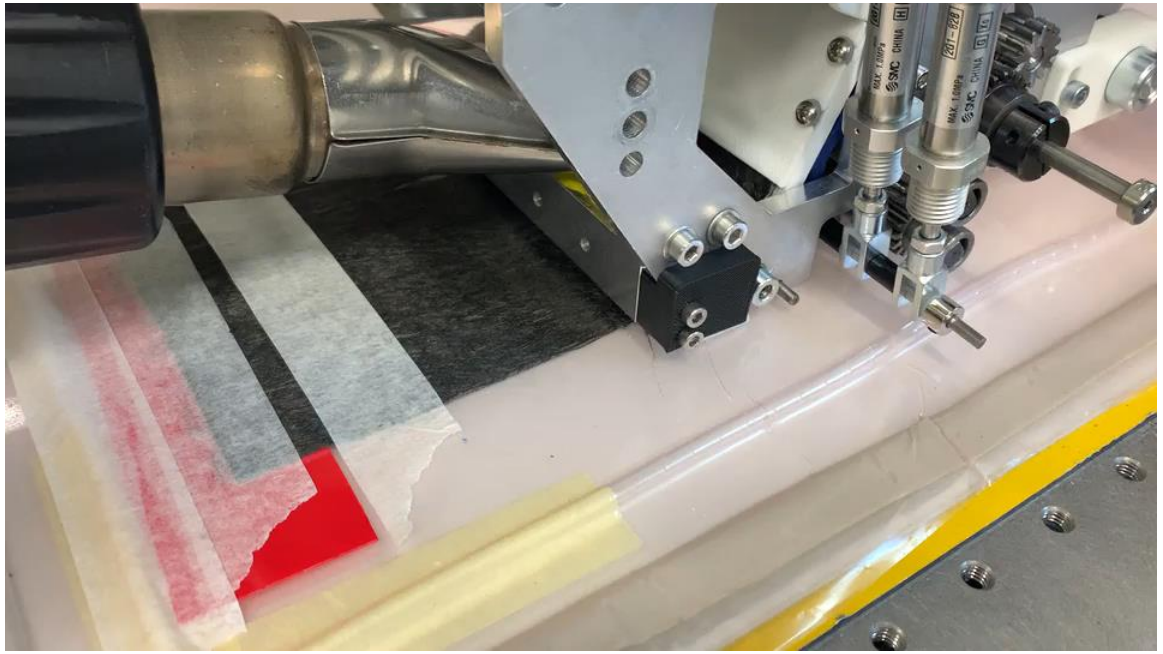
HiPerDiF & ContinuousTow Shearing



Thanks to Dr Bohao Zang and Dr Eric Kim, work conducted within the Future Composites Manufacturing Research Hub core project ‘Fibre-steered forming technology’.

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Technology Timeline

2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 ...the future...

At the University of Bristol

HiPerDiF 1G

HiPerDiF 2G

HiPerDiF 2.5G

HiPerDuCT
EP/I02946X/1 (£6.4M)

HiPerDiF
EP/P027393/1

Future Projects

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NATIONAL COMPOSITES CENTRE

EPSRC
Engineering and Physical Sciences Research Council

At the National Composites Centre

HiPerDiF 3G

TPT &
RecTec (CR 19/20)

Future Projects

- More than 25 Journal Publications
- More than 60 Academic Conferences
- 7 PhD projects (of which 2 completed)
- More than 20 undergraduates projects

UKRI Innovate UK

SETsquared PARTNERSHIP
Universities of Bath, Bristol, Exeter, Southampton & Surrey

LiNEAT composites

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Acknowledgements

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- EPSRC (EP/I02946X/1, EP/P027393/1)
- National Composites Centre (Technology Pull Through Project, RecTec Project)
- Studentships (Solvay Group, Ocean Family Foundation, North Sails, Turkish Government, Thai Government)

- The research team.

The HiPerDiF Team (Past and Present)

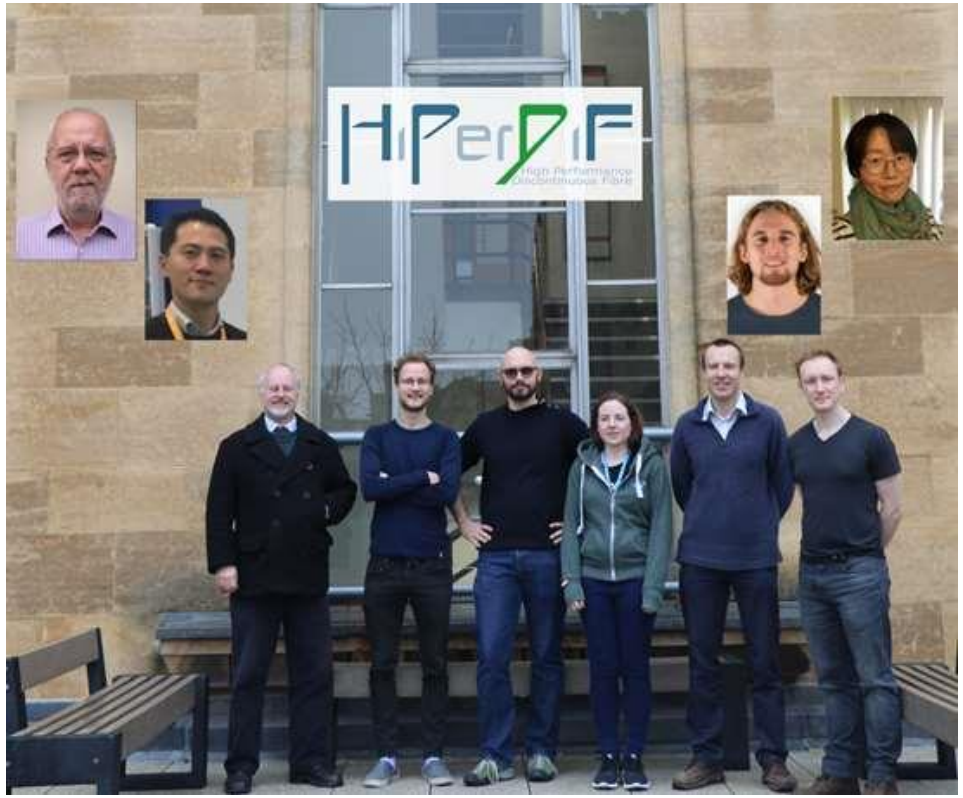
- Prof. Ian Hamerton, Dr Marco Longana, Dr Thomas Rendall,
- Dr HaNa Yu, Prof. Kevin Potter, Dr Carwyn Ward,
- Dr Samantha Huntley, Dr Thomas Pozegic, Dr Rhys Tapper,
- Dr Lourens Blok, Mr Luis Cunha, Dr Juhyeong Lee,
- Dr Kyungil Kong, Dr David Brigido.

Current PhD researchers:

- Ms. Chantal Lewis, Mr Ali Kandemir, Ms. Marcelle Hecker,

  Mr Narongkorn Krajangsawasdi, Mr Ogun Yavuz, Mr Ian Lee.

Numerous project students.



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Thank You
Any Questions?

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http://www.bristol.ac.uk/composites/research/hiperdif/

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