A Closed-Loop Recycling Method for Short Carbon Fibre Thermoplastic Composites

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Research Aims

Aim

• Develop a closed-loop recyclable material, and the relative methodology, that can retain properties over multiple loops.

Objectives

• Method should fit into Circular Economy paradigm.

• Maximum value obtained from constituent matrix and fibres.

• Material must be suitable for current industrial manufacturing processes.
Current CFRP Recycling

- **Mechanical Recycling**
  - Low value matrix.

- **Pyrolysis / Fluidised Bed Pyrolysis**
  - Only fibre. – random ‘fluff’

- **Solvolysis / Acid Digestion**
  - Fibres & low value matrix by-products.
  - Expensive & difficult to scale.

- **Extrusion**
- **Injection Moulding**
- **Shredding**

**High Shear & High Temperature**

<table>
<thead>
<tr>
<th>Thermoset</th>
<th>Thermoplastic</th>
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Bristol Composites Institute (ACCIS)
Closed-Loop Methodology

Remanufacture

- Fibre preforms
- Compression Moulding
- HiPerDiF alignment
- Thermoplastic composite

Fibre bundles

Reclamation

- Loose fibres
- Carding
- Size reduction
- Dissolution
- Filtration
- Size reduction
- Precipitation
- Polymer solution
- Coarse powder
- Fine powder

University of Bristol
Bristol Composites Institute (ACCIS)

EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science
Results - Polypropylene

Polypropylene matrix and 3 mm carbon fibres with a $V_f = 26\%$.

Competitive mechanical properties retained after each loop: $E = 43$ GPa, $\sigma_t = 285$ Mpa.

Tensile strength showed an increase after the final loop; $\sigma_t = 396$ Mpa.

Matrix residue left on fibres post recycling acts as a matrix-specific sizing, boosting adhesion.

$V_f = 26\%$ for rCF-PP

Applications

“Closed-Loop recyclable, lightweighting material”

High-Volume Automotive Manufacture

Fuel Economy Regulations

- **45.6 mpg** and **182 gCO₂ mile⁻¹** for 2020 (± 20 % 2016) models.[2]


End-of-Life Vehicle Recyclability

- CFRP waste is principally landfilled which is expensive! (**appx. £100 / t**).[3]
- **95 %** to be reused, recycled & recovered.[4]


Recycling Reduces Barriers

- **Production** of CFRP has **high financial and environmental costs** – severe deterrent.[6]
- Recycling provides multiple use-phases.[7]

Future Work

PA6 Recycling → CF-PA6 Recycling

Life Cycle Assessment → Optimisation

HIGH PERFORMANCE
RECYCLABLE
INEXPENSIVE

\[ E_t = 65 \text{ GPa}, \sigma_t = 860 \text{ MPa}. \]

\[ \sim 25\% \ V_f \ rCF-PA6 \]
Thank you for your attention

Any Questions?

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PP Characterisation

- Preliminary analysis determined minimal degradation in the polymer.
- This is reflected in unchanged neat PP mechanical performance.

PP Mechanical Testing

![Graph showing Tensile stress/strain and Shear stress/displacement curves for vPP, r<sub>1</sub>PP, and r<sub>2</sub>PP.]

>100 %

Residual Matrix

vCFPP fibres

r$_2$CFPP fibres

Fibre Length Distribution

- vCFPP 74% in EFR
- r₁CFPP 42% in EFR
- r₂CFPP evenly distributed