The ReCoVeR Project

Regenerating the Performance and Value of Glass Fibres Thermally Recycled from End-of-Life and Waste GRP

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ReCoVeR

- Introduction

- ReCoVeR GF Performance Regeneration
  - ReCoVeR-0, Proof of Concept, HF
  - ReCoVeR-2&3, NaOH

- Some Conclusions

- Future Developments?
Glass Fibre is the most important reinforcement in the global composites market.

- **2000**: 2550 KTon/year
- **2006**: 3300 KTon/year
- **2011**: 4300 KTon/year
- **2015**: 5050 KTon/year

- **Glass**
- **Carbon**
- **Aramid**
Global Glass Fibre Demand

Production waste 10-20%

Source Owens Corning
Global End-of-Life Blade Material

Assuming 20 year Blade Life

Year

EU Landfill Directive 99/31/EC?
ReCoVeRable GF in EoL GRP and Manufacturing Waste

Assume we could recycle just 10% = 260 KTpa business potential today.

50% of Global Demand could be met from ReCoVeRable GF.
**Thermal Processes**

- Incineration
  - Energy recovery
  - Not suitable for inorganic products
  - Recover organic components with subsequent combustion of organic products

- Pyrolysis
  - Energy recovery
  - Not suitable for inorganic products
  - Recover organic components with subsequent combustion of organic products

- Fluidized bed
  - Recover organic components
  - Clean fibres and length retains

**Thermo-chemical processes**

- Solvolysis
  - Recover organic components
  - Clean fibres and length retains

**Mechanical grinding**

- Some energy recovery from composites
- Not clean fibres
- Mainly reused as very low value filler

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**Recovered Glass Fibre has very poor performance**
Single Fibre Tensile Strength of RGF

Av. Fibre Strength (MPa) vs. Conditioning Temperature (°C)

€, $, £ Value ≈ 0
(perhaps even <0)
Global Glass Fibre Use

Mainly to chopped fibre thermoplastic composites. Intrinsically recyclable

ReCoVeR and replace new chopped fibre

Mainly to continuous fibre thermoset composites

At end-of-life - challenging to recycle - so = landfill? (or zero value filler)
The ReCoVeR Project

Regenerated Composite Value Reinforcement

The ReCoVeR Mission
Enable the development of cost-effective, drop-in, glass fibre and composite products based on recycled glass fibres with regenerated mechanical performance

The Research Goals
• Research fundamentals of (300-600°C) RGF property changes
• Cost effective treatments to regenerate RGF performance?
• Produce examples of GF or composite products using RRGF
Target Strength for ReCoVeRed Fibre?

Commercial chopped strand products - Average single fibre strength

1.5 GPa

At 20 mm gauge length should be sufficient

4mm chopped fibres for GF-PA Injection Moulding applications

Composites Part A 32 (2001) 85-90
Strength Loss Mechanism and Regeneration

• Griffiths theory tell us that the strength of brittle fibres (glass, carbon) is dominated by the effect of surface flaws

• *If fibre strength after heating is related to increasing number or severity of flaws can we regenerate strength by etching the fibre surface?*

• ReCoVeR-0 proof of concept – HF etching
ReCoVeR-0, HF Surface Etching

Fibre strength

Interface strength

Single Fibre Strength (GPa)

IFSS (MPa)

- Furnace 500C
- Furnace 600C
- Fluidised Bed 500C

As received
Heat-treated
HF-treated
HF+APS-treated

60% recovery

Composites Part A 72 (2015) 167-172
ReCoVeR-0 Composite Performance

60% GF CSM-Epoxy Composites

- As received
- Heat-treated
- HF-treated
- HF+APS-treated

60% decrease

>50% recovery
Conclusions ReCoVeR-0

- Tensile strength of thermally conditioned/recycled glass fibre regenerated by HF etching process (+200%)
- Surface of HF etched RGF can be reactivated by silane treatment (>60% recovery in IFSS)
- Proof of Concept demonstrated
  - regenerating both fibre strength and surface functionality results in significant recovery of composite performance
- But HF cannot lead to cost-effective ReCoVeR technology
ReCoVeR-2 (NaOH treatment)

- HF work demonstrated proof of regeneration concept
- Any less aggressive chemicals giving a similar effect?
- Hot alkalis known to attack silica
- Literature is almost universally negative about alkali effects on E-glass fibres
- But until now everyone was concerned about maintaining the performance of strong fibres
- **Can NaOH regenerate the strength of weak fibres??**
ReCoVeR-2, NaOH Treatment

Av. Fibre Strength (GPa)

Molarity NaOH Treatment Solution

Fibres heat treated 450°C and then 10 min in NaOH at 95°C
ReCoVeR-2, NaOH Treatment

Fibres heat treated 500°C

10 min in 3M NaOH at 95°C + rinse in HCl and water

Can also post-treat with a silane coupling agent (ReCoVeR-3)
Fibre Diameter Change?

<table>
<thead>
<tr>
<th>Before NaOH</th>
<th>After NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.5 ± 0.1 µm</td>
<td>10.4 ± 0.1 µm</td>
</tr>
</tbody>
</table>
ReCoVeR and E-Glass Formulation

<table>
<thead>
<tr>
<th></th>
<th>Owens Corning</th>
<th>3B-Fibreglass</th>
<th>PPG Fiber Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>As Received</td>
<td>No Boron</td>
<td>No Boron</td>
<td>Contains Boron</td>
</tr>
<tr>
<td>500C Heat Treated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT+NaOH</td>
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</table>

Av. Fibre Strength (GPa)

- As Received: Owens Corning, 3B-Fibreglass, PPG Fiber Glass
- 500C Heat Treated: Owens Corning, 3B-Fibreglass, PPG Fiber Glass
- HT+NaOH: Owens Corning, 3B-Fibreglass, PPG Fiber Glass
ReCoVeR and Composite Performance

- GF-PP glass mat thermoplastic composites produced by wet deposition (paper-making) and compression moulding. Random-in-plane 30% wt. fibre content.

- PPG 8069 GF 9 mm long, 10.5 μm diameter, with Goonvean DA3/60 chopped PP homopol fibres (no MaPP coupling agent)
ReCoVeR on PPG 8069 Fibres

Fibre strength at 5 mm gauge

IFSS = microbond test

GF Strength (GPa)

Tensile
IFSS

ReCoVeR on PPG 8069 Fibres

As Received 500C Heat Treated (HT)

HT + NaOH HT + NaOH + APS

IFSS (MPa)

GF Strength (GPa)

As Received 500C Heat Treated (HT) HT + NaOH HT + NaOH + APS

IFSS = microbond test
ReCoVeR Composite Performance

Wet Laid 30%GF-PP GMT (9mm fibres, no MaPP)

Tensile Strength (MPa)

-24%

-11%

PP Only  As Received  500C Heat Treated  HT + NaOH  HT + NaOH + APS
Conclusions

• The world needs an environmentally and economically acceptable solution for dealing with GF and GRP waste and end-of-life GRP

• Glass fibres lose their strength after heat treatment above 400°C

• Thermal conditioning of fibres during recycling also drastically reduces end-use composite performance

• Development of a cost-effective technology to regenerate the properties of thermally recycled GF could have major environmental benefits

• The ACG is developing treatments to ReCoVeR the strength (and value) of thermally recycled glass fibres
Future Development?

• Continue fundamental research of GF strength loss and regeneration

• Integration of ReCoVeR technology into full recycling/regeneration/reuse process - requires
  – Formation and funding of consortium of vested interests
  – Defined input material stream, end-of-life GRP, production waste (GRP or GF)?
  – Defined recycling process for fibre input to ReCoVeR
  – Defined target end-use application (GF-PP in Automotive?)