The ReCoVeR Project

Regenerating the strength and value of glass fibres thermally recycled from end-of-life GRP composites

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ReCoVeR

- Introduction

- Some Results
  - Performance ReCoVeRed Glass Fibres
  - Composite Performance
  - *(Fundamentals of Glass Fibre Strength Loss)*

- Some Conclusions

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

Global Reinforcement Fibre Usage

K Ton/year 2013
Global Reinforcement Fibre Usage

2000
2550
3300
4300
4660

KTon/year
Global Glass Fibre Demand

Source OCV (E-glass excluding yarns)

Production waste 10-20%
Composites in Automotive
BMW photo as shown in Modern Plastics Magazine

ELV directive 2000/53/EC?
Global GF in End-of-Life Wind Turbine Blades

Assuming 20 year Blade Life

Source - Composites Technology, June 2008, GWEC 2013
Global Glass Fibre Numbers

- Global Demand [1]
- Total Recoverable GF
- In 20y EoL GRP
- In GF Man. Waste (15%)
- In GRP Man. Wast (15%)

Assume 60% in Thermoset

Approximately = 50%

Million Tons Glass Fibre

If we could recycle just 10% = 280KTPa business potential today (value approx $420M)
**GRP Recycling Techniques**

**Mechanical grinding**
- Not clean fibres
- Mainly reuse as very low value filler

**Thermal Processes**
- Incineration
  - Some energy recovery from composites
  - High content of inorganic material – no longer fibrous
- Pyrolysis
  - Energy recovery
  - Not suitable for inorganic products
- Fluidized bed
  - Recover organic components and length retains
  - Energy recovery with subsequent combustion of organic products applies

**Thermo-chemical processes**
- Solvolysis
  - Recover organic components
  - Clean fibres and length retains

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Recovered Glass Fibre has very poor performance.
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

2012-16, £1M EPSRC funding, 8 Researchers in ACG team
Strength after Thermo-Mechanical Treatment

![Graph showing the effect of conditioning temperature on glass fibre strength.](image)

**Effect on Composite Performance?**

- Thomason OC 1999
- Pickering et al 2000
- ACG 2008
- Feih et al 2009 E
- Feih et al 2009 A
- ACG 2009
- ACG 2012
GF Heat Treatment & Composite Performance

Tensile Strength (MPa) vs. GF Preconditioning Temperature (°C)

- TS
- UC

Injection Moulded 30%GF-PP (1% MaPP)

ReCoVeR Target Zone
Target Strength for ReCoVeRed Fibre?

Commercial chopped strand products - Average single fibre strength

1.5 GPa
At 20 mm gauge length should be sufficient

Single Fibre Strength (GPa) vs. Gauge Length (mm)

- Chopped Fibre 1
- Chopped Fibre 2

4mm chopped fibres for GF-PA Injection Moulding applications
Glass Fibre Strength ReCoVeRy

![Graph showing glass fibre strength recovery with varying pretreatment temperatures.](image)

- **Latest values for ReCoVeR-4 after 500°C HT** are 1.8-2.0 GPa.
- **No ReCoVeR**, **ReCoVeR 1**, **ReCoVeR 2**, **ReCoVeR 3**, and **HF Treated**.
Glass Fibre Strength ReCoVeRy

600°C Heat Treated Fibres

Fibres Recycled from Composite at 600°C

Average Fibre Strength (GPa)

No ReCoVeR | ReCoVeR 1 | ReCoVeR 2 | ReCoVeR 3
ReCoVeR Composite Performance

![Graph showing the performance of ReCoVeR 1 under varying GF preconditioning temperatures. The graph plots Tensile Strength (MPa) and Unnotched Charpy (kJ/m²) against GF Preconditioning Temperature (°C). The material used is Injection Moulded 30%GF-PP (1% MaPP).]
ReCoVeR Composite Performance

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

- GF as received
- GF 500°C HT
- GF 500°C HT +ReCoVeR 2
- GF 500°C HT +ReCoVeR 1
- GF 500°C HT +ReCoVeR 3

Tensile strength (MPa)

- 71% ReCoVeRy
- 57% ReCoVeRy
- 42% ReCoVeRy

PP strength
Initial Results on ReCoVeR Glass Fibres in PP Composites

72% ReCoVeRy of Composite Tensile Strength

87% ReCoVeRy of Unnotched Charpy Impact

• Non-optimized sizing on ReCoVeR fibres
• Higher potential ReCoVeRy performance to come
• Patent Application submitted
Strength Loss Mechanisms Investigation

- TMA for single fibre modulus and dimension changes during conditioning
- TGA of silane film degradation
- AFM/SEM analysis of surface morphology changes
- *Fibre strength after heating (or composite recycling)*
- TVA of water evolution and dehydroxylation
- IR analysis of silane NH$_2$ group on fibre
- XPS surface analysis of %N on fibre
- XRD for crystal growth (devitrification)
Current State of Strength Loss Mechanisms Investigation

Strength loss probably involves

- sizing degradation
- surface flaws (number/severity increase)
- change/relaxation in glass structure
- removal of water/dehydroxylation

More work required for full understanding
Conclusions

• The development of a cost-effective technology to regenerate the properties of thermally recycled glass fibres will have major environmental benefits.

• Glass fibres lose most of their strength after a short heat treatment above 400°C.

• Mechanism of strength loss involves both sizing degradation and changes in glass fibre structure.

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

• The ACG is developing cost-effective treatments to ReCoVeR the strength of thermally recycled glass fibres.
Future Development?

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

- We are seeking partners to move this technology forward