Developments in Recycled Carbon Fiber for High Volume Manufacturing

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Overview of ELG Carbon Fibre

- Established in 2011 when ELG Haniel acquired the operations of Recycled Carbon Fibre Ltd.
- Patented process for recovery of carbon fibre from manufacturing waste and end-of-life products, using a modified pyrolysis process. Recovered and converted more than 1000 tonnes of carbon fibre in 2015.
- R&D programmes have led to the development of recycled carbon fibre products for the compounding and composites industries.
- **Goal:** to provide affordable, high performance materials to enable weight reduction in the transportation market.
What We Do

**Carbon Fibre Reclaiming**
- Metal removal and cutting of large composite structures to sizes suitable for downstream processing.
- Shredding of laminates and prepreg to enable efficient and consistent processing.
- Fibre recovery via a modified pyrolysis process.

**Carbon Fibre Conversion**
- Milling.
- Nonwoven mat production.
- Pellet production.

**Product Research and Development**
- Aligned fibre materials—future product line.
- Intermediate materials—capability demonstration.
Meeting The Industry’s Needs

Automotive Industry Needs
- Carbon fibre at $5-$7/lb
- Low cost conversion techniques to intermediate products.
- Stable supply chain.
- Low carbon footprint.

Recycled Carbon Fibre Delivers
- Carbon fibre at less than $5-$7/lb
- Potentially low cost conversion techniques to products suitable for use in injection moulding and high volume composites manufacturing.
- 24,000 tonnes of carbon fibre from manufacturing waste, much of this coming from long term programmes using high quality fibres.
- Less than 10% of the global warming potential of virgin carbon fibre.

The key challenge in delivering the potential benefits is development of usable products.
Recycled Carbon Fibre

Similar mechanical properties to virgin fibre but...

- Low bulk density = difficult handling
- Variable fibre lengths
- Variable nature of material—fibre clumps, single filaments

Challenges
Carbon Fibre Conversion Routes

Focus on products suitable for high volume manufacturing

Reclaimed Fibre Length

Compression moulded composites

Thermoplastic and thermoset compounds

Coatings and compounds

Carbon Nonwoven | Hybrid Nonwovens | Chopped and Pelletised Fibres | Milled Fibres

80mm
50mm
10mm
1mm
Pellet Development

- Designed for use in reinforcing thermoplastic compounds.
- Intended as a low weight replacement for glass fibres or a low cost replacement for virgin carbon fibres.

Challenges:

- Achieving sufficient fibre length to provide the same mechanical properties as 6mm chopped virgin carbon fibre.
- Achieving a sufficiently high fibre loading to make the product viable as a base for further compounding.
- Ensuring a dust-free product.
## Manufacturing Routes

<table>
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<tr>
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<th>Dice Fibreboard</th>
<th>Ring Die Pellet Mill</th>
<th>Extrusion</th>
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<tbody>
<tr>
<td><strong>100% carbon fibre. 6mm fibre length.</strong></td>
<td>High carbon fibre content.</td>
<td>Dust free. Polymer compatibility ensured. Low number of processing steps.</td>
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Fibre Length

- Critical fibre length dependent on the shear strength of the fibre/resin interface.

- Once targets had been established based on testing, these were verified by comparing mechanical properties with compounds made using 6mm chopped virgin carbon fibre.
Recycled carbon fibre products provide at least the same performance as virgin carbon fibre products.
Influence of Processing Parameters

- Processing parameters for compounding and injection moulding being investigated in a project being carried out with the University of Warwick.
- Investigating the effects of changing processing parameters on mechanical properties and fibre length.

![Main Effects Plot for Tensile Modulus](chart)
Influence of Processing Parameters

- Mean fibre length in part 0.48mm
  - 2.6% of fibres longer than 1.5mm
- Mean fibre length in pellet 0.67mm
  - 6.4% of fibres longer than 1.5mm
- Significantly shorter fibre length in pressed fibre pellets
Recycled carbon fibres give the same mechanical property enhancement as virgin carbon fibres.

10% loading of recycled carbon fibre provides the same mechanical properties as 30% loading of glass fibres—15% density reduction.

30% to 45% loadings of recycled carbon fibre provide mechanical properties comparable to magnesium castings and aluminium castings.
**Performance comparison**

30% glass fibre reinforced PA66  
56.9g

10% rCF reinforced PA66  
48.7g

15% weight reduction

Higher mechanical properties

- 15% weight reduction can be achieved whilst providing the same mechanical performance without any change to the design. Higher weight savings achievable with product optimization.

- Part cost increase to achieve this weight saving ~2%.

- Over 750,000 tonnes of 30% glass reinforced PA66 compounds used for air inlet manifolds and cam covers each year by the automotive industry—potential for over 110,000 tonnes of low cost weight saving!
Recycled Carbon Fibre in Composites

- Nonwoven mats are the basis of the products for composites manufacturing.
- These can be either 100% carbon fibre or blends of carbon fibre with thermoplastic fibres.
- Carbon fibre products can be used in liquid, prepreg and SMC applications.
- Hybrid products can be used in compression moulding applications.
Carbon fibre nonwovens have different processing characteristics and mechanical properties compared to conventional composite materials.

With proper design, they can be used to manufacture low cost, lightweight structures using most high volume manufacturing processes.
Mechanical Properties of Nonwovens

Typical fibre volume fractions 27% to 43%.
Specific Mechanical Property Comparison

Specific Tensile Modulus vs. Specific Tensile Strength

- High strength steel
- Aluminium
Affordability

- Fibre cost $5-$7/lb.
- Reinforcement products cost $8-$12/lb.
- Weight savings depend on design criteria, but typically the weight of a recycled carbon fibre part is within 5%-10% of the weight of a virgin carbon fibre part.
- Hybrid designs comprising approximately 10% virgin carbon fibre and 90% recycled carbon fibre, typically show no weight disadvantage but have a significantly lower cost.
Case Study—iStream Carbon

- Conventional stamped steel chassis: Typically hundreds of stamped metal panels.
- iStream hybrid structural composite chassis: Simple, low cost steel tubular members. 14 composite panels.

iStream photos and information courtesy of Gordon Murray Design Ltd.
Environmental Benefits

- The use of recycled carbon fibre significantly reduces the global warming footprint and improved the life cycle analysis for lightweight structures.

Global warming potential comparison prepared by Fraunhofer UMSICHT based on ELG CF 2014 operational data. Further 36% reduction in energy consumption per kg achieved in 2015.
Summary

- Carbon fibre recycling has been established at an industrial scale.
- Products for the plastics compounding and composites industries offer the potential for cost effective weight saving in the automotive industry.
- The use of recycled carbon fibre products also offers significant environmental benefits and an improved life cycle analysis where carbon fibre structures and components are used.