LCA benefits of rCF

Conference: Composite Recycling & LCA
Stuttgart 9th March 2017
Outline

- ELG Carbon Fibre
- Carbon fibre reclaiming & conversion
- Rational of use of CF composites
- LCA for carbon fibre (virgin vs. recycled)
- Summary
# Introduction to ELG Haniel Group

- Recycling of High Performance Materials
- 3 business units with the core market segment in stainless steel
- Global market leading company with 45 operational yards worldwide

<table>
<thead>
<tr>
<th>Stainless Steel Scrap</th>
<th>Superalloys Scrap</th>
<th>Other Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling alloyed scrap</td>
<td>Recycling High-Ni Alloys, Titanium</td>
<td>Ferrochrome, Carbon Fibre Carbon Scrap, Long Products</td>
</tr>
<tr>
<td><strong>Europe</strong></td>
<td><strong>ELG Superalloys</strong></td>
<td><strong>Other Materials</strong></td>
</tr>
<tr>
<td>485 Employees*</td>
<td>110 Employees*</td>
<td>165 Employees*</td>
</tr>
<tr>
<td><strong>Overseas</strong></td>
<td></td>
<td></td>
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<tr>
<td>(incl. US, AUS, Asia)</td>
<td></td>
<td></td>
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<tr>
<td>270 Employees*</td>
<td></td>
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</tbody>
</table>

| ELG Haniel GmbH (Holding Company) | 23 Employees* |

*Total Employees = Ø 1055 Headcount*
The CF reclamation is the HEART of our process, but only one challenge to ‘close the loop’!
Carbon fibre Conversion

STAPLE CARBON FIBRE

Carbiso™ MF

Carbiso™ MB
Masterbatch
Q4/2017
Market launch

Carbiso™ TM

Carbiso™ M

Compounding Industry

Composites Industry
Why Recycle?

- **Cost:** recycled carbon fibre products can reduce the cost of lightweight structures and components.
- **Legislation:** increasing onerous legislation regarding the disposal of composite manufacturing and end-of-life waste.
- **Supply chain security:** mitigates against shortages in virgin carbon fibre supply.

![Carbon Fibre Supply and Demand](chart.png)

Recycling of manufacturing waste can help fill the forecast gap between carbon fibre supply and demand.

What about the environmental impacts of virgin vs. recycled carbon fibre?
### Regulatory Framework

**EU regulation by 2021:** fleet average of all new cars 95g/km; penalty: €95/g of exceedance onwards

- This means a fuel consumption of around 4.1 l/100 km of petrol or 3.6 l/100 km of diesel.
- Worldwide harmonized Light vehicles Test Procedure (WLTP); introduced in the EU in Sep 2017

**Two fold challenge for carmakers:** CO2 limits are globally becoming stricter and testing procedures are getting closer to reality.

### Comparison of NEDC and WLTP

<table>
<thead>
<tr>
<th>Key characteristics</th>
<th>NEDC since 1992</th>
<th>WLTP starting 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>1180</td>
<td>1800</td>
</tr>
<tr>
<td>Distance</td>
<td>11</td>
<td>23.3</td>
</tr>
<tr>
<td>Maximum velocity</td>
<td>120</td>
<td>131</td>
</tr>
<tr>
<td>Extra equipment</td>
<td>Not considered</td>
<td>Considered</td>
</tr>
<tr>
<td>Key characteristics</td>
<td>High amount of city tours with many stops</td>
<td>More dynamic with higher speed and acceleration</td>
</tr>
<tr>
<td></td>
<td>Ambient temperature up to 30°C allowed</td>
<td>Ambient temperature only up to 23°C</td>
</tr>
<tr>
<td></td>
<td>Short highway drive with limited acceleration</td>
<td>2 phases city tours and 2 phases highway drive</td>
</tr>
</tbody>
</table>

Source: PA Consulting

Source: ICCT
### CO2 fleet averages per carmaker

#### Ranking of carmakers:

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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PSA (Peugeot Citroen)</td>
<td>128.5</td>
<td>115.7</td>
<td>104.6</td>
<td>100.5</td>
<td>94.8</td>
<td>87.2</td>
<td>88.5</td>
<td>-1.3</td>
</tr>
<tr>
<td>2</td>
<td>Toyota</td>
<td>126.4</td>
<td>116.8</td>
<td>108.3</td>
<td>103.1</td>
<td>98.9</td>
<td>89.8</td>
<td>91.8</td>
<td>-2.0</td>
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<tr>
<td>3</td>
<td>Renault-Nissan</td>
<td>129.0</td>
<td>119.2</td>
<td>112.1</td>
<td>109.1</td>
<td>102.4</td>
<td>90.4</td>
<td>91.8</td>
<td>-1.4</td>
</tr>
<tr>
<td>4</td>
<td>Ford</td>
<td>132.7</td>
<td>121.8</td>
<td>118.0</td>
<td>114.9</td>
<td>108.1</td>
<td>93.5</td>
<td>91.7</td>
<td>1.8</td>
</tr>
<tr>
<td>5</td>
<td>General Motors</td>
<td>135.0</td>
<td>132.8</td>
<td>127.0</td>
<td>123.4</td>
<td>113.1</td>
<td>96.8</td>
<td>93.1</td>
<td>3.7</td>
</tr>
<tr>
<td>6</td>
<td>Hyundai-Kia</td>
<td>134.0</td>
<td>129.8</td>
<td>127.3</td>
<td>124.0</td>
<td>115.6</td>
<td>96.9</td>
<td>91.6</td>
<td>5.3</td>
</tr>
<tr>
<td>7</td>
<td>Volvo</td>
<td>154.0</td>
<td>130.8</td>
<td>121.9</td>
<td>117.4</td>
<td>109.7</td>
<td>97.4</td>
<td>99.5</td>
<td>-2.1</td>
</tr>
<tr>
<td>8</td>
<td>FCA (Fiat Chrysler)</td>
<td>118.3</td>
<td>123.8</td>
<td>122.2</td>
<td>119.3</td>
<td>113.3</td>
<td>98.6</td>
<td>92.1</td>
<td>6.5</td>
</tr>
<tr>
<td>9</td>
<td>Volkswagen</td>
<td>135.4</td>
<td>128.9</td>
<td>121.5</td>
<td>118.6</td>
<td>110.7</td>
<td>99.1</td>
<td>96.3</td>
<td>2.8</td>
</tr>
<tr>
<td>10</td>
<td>Daimler</td>
<td>153.0</td>
<td>136.6</td>
<td>124.7</td>
<td>120.3</td>
<td>111.3</td>
<td>100.8</td>
<td>99.7</td>
<td>1.1</td>
</tr>
<tr>
<td>11</td>
<td>BMW</td>
<td>145.0</td>
<td>134.4</td>
<td>126.4</td>
<td>122.1</td>
<td>113.4</td>
<td>103.5</td>
<td>100.1</td>
<td>3.4</td>
</tr>
<tr>
<td>12</td>
<td>Jaguar Land Rover</td>
<td>206.0</td>
<td>182.0</td>
<td>165.0</td>
<td>156.7</td>
<td>149.5</td>
<td>132.8</td>
<td>132.0</td>
<td>0.8</td>
</tr>
</tbody>
</table>

*Rank on 2021 forecast. **Data from ICCT 2016. ***Based on actual data until 2015 (ICCT) and PA forecast estimation.

**Source:**
PA Consulting Group Study examines manufacturers’ performance against the overall EU target of 95g CO₂/ km as well as the specific targets set for each carmaker’s business.

- Only four of the 12 are forecast to meet the 2021 targets of 95g CO₂/km.
- Penalties for those falling short on those targets could be significant, ranging from €350 million for BMW, above €600 million for Fiat Chrysler and up to €1 billion for VW.
Motivation to use CFRP

Opportunities exist for emissions reductions through:
- Increasing power train efficiency
- Alternative fuel approaches (fuel cell, hybrid etc)
- Lowering vehicle mass

Greatest opportunities for mass reduction offer besides High strength steels, Aluminium, Magnesium and in particular CFRP
Carbon Fibre raw material production requires up to 280 MJ/kg (5-6 times of steel); only less than magnesium and more than aluminium.

Functional units also need to be compared as 1kg of steel is not equal to 1kg of another material on a component level delivering the same performance.

For a final part the picture turns around between aluminium and carbon fibre due to the mass savings (estimated part weight: 67kg for AL vs. 45kg for CF).

Carbon fibre still shows a significantly negative environmental impact.
LCA of different vehicle concepts

- Life-cycle tradeoffs related to a switch to composites
- Negative impact in production and end of life (if not recycled)
- Mainly in use phase lower weights lead to fuel savings
- Breakeven point in automotive can vary between 132,000 – 180,000 km for CFRP versus steel depending on the application
- In aerospace the breakeven point can already realised after 70,000 km due to the significant weight reduction for CFRP vs aluminium
Production of recycled carbon fibres contributes to 99% of total GHG emissions of the recycling process chain:
- Total GHG emissions: 29.45 t (primary CF) vs. 4.65 t (secondary CF)
- Recycled carbon fibres have significantly less environmental impact.
Results LCA for rCF

Further reduction in energy consumption per kg (>30%) achieved in last two years

- Per tonne of material less GHG emissions are emitted by recycled carbon fibers compared to primary aluminum.
Main emissions (61 %) occur from treatment of exhaust gases (natural gas)

Electricity is used for heating the furnace (33 %)

6 % of GHG emission are caused by incinerating epoxy resins

Disposal of packaging material shows no significant impact
LCA Benefits of rCF

- The majority of energy consumption occurs during the virgin carbon fiber production.
- Recycling requires only 1/10 of this energy.
- Great motivation for recycling carbon fiber with positive impact on LCA.

The embodied energy for carbon fiber can be significantly reduced by recycling required carbon fibers.
Putting LCA benefits of rCF into Practice

**Project: Closed Loop**
- Introduction of a circular economy through development and implementation of [new rCF intermediate products](#) from the existing waste stream for manufacturing of next generation aircraft parts

**Project: eQ1**
- Development of [rCF parts](#) for the eQ1 electrical vehicle
- Reduce the weight of both, new energy and conventional vehicles in order to meet [environmental and performance targets](#)

**Project: Bogie Frame**
- Reduction of track wear and hence infrastructure maintenance costs by reducing vertical and transverse loads on the rails
- Improved reliability and operational availability through the use of an embedded health monitoring system
- Reduction in energy consumption and [global warming footprint](#)

Sources: Airbus, Chery, Alstom.
Putting LCA benefits of rCF into Practice

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

- iPannels based on recycled carbon fibre cost approximately €30 each, compared to €300 each for panels made from conventional woven fabric prepreg.
- iStream concept goes into small scale production for TVR in Q4 2017
- Volume adaptation followed by Yamaha electric city car in 2018/19

*iStream photos and information courtesy of Gordon Murray Design Ltd.*
Summary

- Virgin Carbon Fibre has more environmental impacts on production and disposal than more conventional materials.
- In many cases, these are offset by benefits in use due to the lower weight / improved performance of composites.
- Recycled carbon fibre facilitates the environmental competitiveness to other lightweighting materials already in the production stage.
- Recycled carbon fibre demonstrates significant LCA benefits for material selection processes and empowers eco-friendly lightweighting strategies in the transportation sector.
Thank You!

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