Composite Developments for Lightweighting Heavy Duty Vehicles

Rhys Tapper

12-Nov-14

www.bris.ac.uk/composites
Lightweighting Incentives: Regulations

**Fuel emission regulations**
- The US DOE mandated a 50% improvement in freight efficiency for heavy duty vehicles (HDVs).
- DOE stated a 50% reduction in greenhouse gas emissions by 2030.

**Lightweighting**
- 6-8% increase in fuel economy can be achieved by a 10% weight reduction.
- Fuel is the single largest expense for fleet owners, ~50% of a HDVs total operating cost.
- Increased payload as fleet owners are reported as working within tight (2-4%) profit margins.
Composite Materials

• Superior specific strength is the main impact factor for composite usage.

• Significant advantages over traditional materials include;
  – Corrosion, scratch and dent resistance.
  – Reduced noise vibration harshness.
  – High specific energy absorption.
  – Increased design flexibility.
  – Reduced tooling costs.
  – Dimensional stability.
Heavy Duty Vehicles: Classifications

- There are two main elements, the tractor unit and trailer unit, the latter is mounted directly onto the chassis frame.

- HDV’s and SUV’s represent 93% of the fuel used by all US trucks.

- They can cover between 150,000 and 200,000 miles a year.

- Average fuel consumption for new HDV’s is ~ 6 mpg, this needs meet 10 mpg.
Heavy Duty Vehicles: Classifications

- The tractor unit, empty trailer and payload represent approximately 16%, 20% and 64% of the GVWR (36,300 kgs) respectively.

- Main load-bearing elements are heavy steel-girder frame assemblies.

- US and EU/UK model powertrain orientation can differ due to size restrictions.

US DOE; Energy, materials and vehicle weight reduction; 2009
Composite Developments and Opportunities

**Cab unit – 18% of tractor weight**

- Compression moulded SMC is currently the most common composite process used in truck part mass-manufacture. Injection moulded methods are less widely used.

- SMC is usually made using cheap thermoset resins and discontinuous glass fibres.

- SMC is the most cost-effective for moderate production volumes, offers agreeable cycle times and automotive grade quality and finishes.

- Part production volume for HDVs averages 5,000 and 20,000 parts per year, for cars it can be between 80,000 and 500,000 per year.
Composite Developments and Opportunities

Powertrain – 48% of Tractor weight

- Engines always cast from iron/steel.

- HDV drivetrain components are subjected to high stresses, i.e. torsional for driveshafts, composite materials must be able to withstand these.

- A CFRP driveshaft has been made by filament winding for LDVs.

- Inadequate manufacturing capacity for these components

- Lightweight materials that can withstand the high-demand of HDV propulsion systems are not cost competitive.
Composite Developments and Opportunities

Chassis & suspension – 31% Tractor weight

- Steel frames sometimes with wooden cross members - leads to major corrosion and rotting issues.

- Steel truck chassis claiming to offer 30% weight reduction.

- FRP leaf and coil springs are used in LDVs and CFRP compression rings.

- Inadequate material properties to withstand part environment.

- Manufacturing capacity to produce these components is lacking.
Composite Developments and Opportunities

Trailer – Box or Flat-bed

- Floor is usually wooden decking laid into a steel frame. Stiff, cheap, durable material that can be replaced easily.

- Walls are sheet metal with plywood backing – rotting issues. UK/EU trailers can have curtain sides attached by metal fasteners/rails.

- Sandwich panels are available for trailer wall panels and aerodynamic skirts. CF panels should be considered for trailer beds.

- Trailer life time 3 x that of tractors and sales have dropped 72% since 2009 - new technologies could be slow to return investment costs.
The DOE, under the ‘SuperTruck’ project, has previously funded OEM’s and vehicle manufacturer collaborations to help stimulate composite growth.

<table>
<thead>
<tr>
<th>Component</th>
<th>Material(s) used</th>
<th>Weight savings</th>
<th>Team</th>
</tr>
</thead>
<tbody>
<tr>
<td>door and aperture</td>
<td>hybrid composites and composite metal</td>
<td>40%</td>
<td>PACCAR, PNNL</td>
</tr>
<tr>
<td></td>
<td>hybrid structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hood</td>
<td>Carbon Fiber Sheet Molding Compound</td>
<td>30%</td>
<td>Volvo Trucks North America, Meridian</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Automotive Systems</td>
</tr>
<tr>
<td>tie rods, trailing arms, and</td>
<td>Composites and aluminum</td>
<td>50% lift axle (100lbs saved)</td>
<td>Delphi, National Composite Center</td>
</tr>
<tr>
<td>axles</td>
<td></td>
<td>50% tie rods (11 lbs) Trailing arm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(56 lbs)</td>
<td></td>
</tr>
<tr>
<td>Composite Cab Structures</td>
<td>Resin transfer molding of composites</td>
<td>30% +</td>
<td>Delphi, National Composite Center</td>
</tr>
<tr>
<td>Bus structure and chassis</td>
<td>Ultra high strength Stainless Steel</td>
<td>64%</td>
<td>Autokinetics Inc</td>
</tr>
<tr>
<td>Truck Body Panels</td>
<td>Superplastically Formed (SPF) Aluminum</td>
<td>40%</td>
<td>International Truck and Engine Company</td>
</tr>
<tr>
<td>Support Structures</td>
<td>polymer composite</td>
<td>50%</td>
<td>National Composite Center</td>
</tr>
<tr>
<td>large area structural panels</td>
<td>hybrid composite</td>
<td>45%</td>
<td>Freightliner, LLC, Profile Composites, PNNL</td>
</tr>
<tr>
<td>Light duty frame for Dodge truck</td>
<td>Aluminum</td>
<td>&gt; 40%</td>
<td>DaimlerChrysler, PNNL</td>
</tr>
<tr>
<td>cab component</td>
<td>Superplastic formed Aluminum</td>
<td>50%</td>
<td>Peterbilt</td>
</tr>
</tbody>
</table>
Technological Barriers

Cost
- GF remain the most competitive but CF and metal alloys are far too expensive – manufacturing and precursor alternatives.

Manufacture
- Part production volume is moderate but capacity for lightweight components is lacking.

Modelling
- Lack of design tools, design data and adequate testing methods. High-fidelity computation modelling for micro/meso/macro is needed for composites which is expensive.

Joining, Repair and Detection
- Lack of robust, cost-effective methods for joining composites especially for load-bearing applications. Detection of damage is difficult for large composite pieces. Policy of ‘replace’ – modular design - could be necessary whilst technology develops.
Thank you for your attention at the end of a long day of presentations

Any Questions?