LIGHTWEIGHT COMPOSITES

Epoxy - Matrix materials for faster RTM processes

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Presentation Agenda

- Introduction
- Market Pull, Drivers
- Product Attributes
- Value Proposition
- Questions
Introduction - Chemistry

Epoxy resin

Amine

Epoxy systems are highly cross linked, high Tg systems

2 component system plus IMR

Epoxy polymer

Heating
Introduction – RTM Process

- High pressure injection
- Elevated material temperatures
- Mold temperatures of 100°C+

Component A

Component B

Mixing chamber

Press / mould

GRP/CRP – preform

Source: Fraunhofer ICT
Market Drivers

- Reduction in fuel consumption in vehicles
  - Consumption of non-renewable resources
  - Reduction in pollution, environmental concerns
  - Reduction of crude oil consumption
    - Less dependency on Middle East
  - Consumer cost of energy
    - $4.00+ per gallon gal prices
Market Pull – Why the Interest?

Time schedule for fleet MPG in the U.S.

- **Energy Independence & Security Act 2007**: Revised April 1, 2010 to reach 34.1 mpg by 2016
- CAFE increase > 40% by 2016
- Potentially, 140% to reach 60 mpg by 2025
- Light Weighting vehicle is essential to meet 2017 – 2025 scenarios
Market Pull – Why the Interest?

Schedule for average CO$_2$ emissions, EU

<table>
<thead>
<tr>
<th>Year</th>
<th>CO$_2$ emission in [g/km]</th>
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<tbody>
<tr>
<td>2008</td>
<td>165</td>
</tr>
<tr>
<td>2011</td>
<td>130</td>
</tr>
<tr>
<td>2015</td>
<td>EU target</td>
</tr>
<tr>
<td>2020</td>
<td>95</td>
</tr>
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</table>

"Phase-in" percentage of new vehicle registrations:

- 2012: 65%
- 2013: 75%
- 2014: 80%
- 2015: 100%
Resin Transfer Molding
Process requirements for medium series

- Short cycle time
- No post-curing/annealing required
- Fiber content ≥ 50%
- Low viscosity for fast infusion and optimum fiber wetting
- Fast curing
- High glass transition temperature
- Very good mechanical properties

Can conventional chemistry achieve this?
Can conventional chemistry achieve this?

Current Situation

- Customers look for a combination of...
  - Fast infusion with good fiber wetting through low reactivity
  - Fast polymerization / vitrification through high reactivity
Product Attributes

- A lesson learned from the wind turbine market…

- Large parts with non-uniform thicknesses and irregular shapes

- Unique challenges for conventional chemistry
Product Attributes

- Latent curing
- High temperature injection
- Excellent fiber wetting
Processing of reactive resins

Processing:

Mixing and filling
- Mixing quality
  - Compatibility
  - Viscosity
  - A/B mixing ratio
- Reactivity
  - Catalysis
  - Gelling
  - Mould filling

Curing
- Gelling
- Phase separation
- Vitrification

Post-curing
- Final properties
Steerable Viscosity Properties

Viscosity increase measured at different temperatures

Viscosity increase of the mixture Baxxores® ER 2200 / Baxxodur® EC 2115 at different temperatures

*Viscosity increase: rotation viscosimeter, plate-plate configuration, diameter 25 mm, gap 0.25 mm, shear rate 100 s⁻¹
Viscosity Profile

Viscosity of the mixed system at different temperatures

Viscosity of the mixture Baxxores® ER 2200 / Baxxodur® EC 2115 as a function of temperature (heating rate 10°C/min)

* Viscosity measurement: rotation viscosimeter, plate-plate configuration, diameter 25 mm, gap 0.25 mm, shear rate 100s⁻¹
Solution: Latent accelerators

- Conventional curing
- Curing by latent accelerators
- Exothermic
- Long open time

Product Attributes
Product Attributes

Resin Transfer Moulding (RTM)

Potential solution for fast EP systems: Latent accelerators

Latent Epoxy Systems: longer pot life AND quicker curing!
### Key Material Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Mixture #1</th>
<th>Mixture #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin/Hardener ratio (w/w)</td>
<td>100 : 9</td>
<td>100 : 13.5</td>
</tr>
<tr>
<td>Viscosity at 80 °C</td>
<td>Approx. 100 cps</td>
<td>Approx. 40 cps</td>
</tr>
<tr>
<td>Tg</td>
<td>Approx. 150 °C</td>
<td>Approx. 130 °C</td>
</tr>
<tr>
<td>Cure Temp</td>
<td>100 °C – 120 °C</td>
<td>100 °C – 120 °C</td>
</tr>
<tr>
<td>Infusion Time</td>
<td>30 – 90 secs, depends on many things</td>
<td>30 – 90 secs, depends on many things</td>
</tr>
<tr>
<td>Cure Time</td>
<td>2 – 5 mins, depends on part size, mold temp</td>
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# Mechanical Properties

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<tr>
<td><strong>Flexural Strength (MPa)</strong></td>
<td>95</td>
<td>116</td>
</tr>
<tr>
<td><strong>Elongation at Max Strength (%)</strong></td>
<td>5.4</td>
<td>&gt;6.1</td>
</tr>
<tr>
<td><strong>E Modulus (MPa)</strong></td>
<td>2850</td>
<td>3100</td>
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RTM / RIM processes for medium-volume production need shorter cycle times.

Shorter cycle times require faster matrix systems.

BASF is working on fast RTM systems with enhanced properties based on epoxy resin.

Processing technology for EP is established.

There is no such thing as "the" matrix material, the specification, application and cost will dictate the material.

BASF is the cooperation partner for developing epoxy, polyurethane and polyamide systems.