Lightweighting Through Innovative Steel Panel Reinforcement

Sriram Sadagopan, Min Kuo, Michael Lizak, ArcelorMittal
Rajan Eadara and Jorlbeth Joseff, Diversified Chemical Technologies, Inc.

www.autosteel.org
Technology Objective

• Continue exploring lightweighting opportunities with steel used in conjunction with reinforcements
• Target immediate studies for closure panel materials
  – 0.6mm BH250
• Conduct comparative dent and oil canning testing
  – With and without the C fiber filled epoxy reinforcement product
Carbon Fiber Filled Epoxy

- Carbon fiber filled formulated epoxy composite materials
- A robotically dispensed paste applied with spray, swirl, or shovel applications
- Cures at 150°C to 200°C temperatures
- The material forms into a high modulus coating on steel substrates
Product Benefits

• Achieve the same structural performance while reducing the weight of the steel panel by down gauging

• By robotically applying the product, instead of the current manually applied patches, the following is achieved;
  – Increased precision and repeatability of product application
  – Cost savings
  – Increased panel design flexibility
Product Benefits

• The presence of carbon fiber allows for
  – No read through
  – Minimized shrinkage of the coating
  – Improved corrosion resistance
• Improved
  – Dent resistance
  – Oil canning resistance
• E-coat compatible
• Weldable
Factors Affecting Performance

• The product was designed to meet a broad spectrum of performance requirements
  – Epoxy matrix – toughener – fibers
  – Composite modulus
  – Toughener – high glass transition temperature
  – Fiber type and critical volume fraction
  – Coefficient of thermal expansion (CTE)
  – Carbon fiber – low coefficient of thermal expansion, no shrinkage
  – Corrosion resistance – durability
  – No morphology change in thermal cycling
## Product Properties

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color</strong></td>
<td>Black</td>
</tr>
<tr>
<td><strong>Density (g/cc)</strong></td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Solids</strong></td>
<td>99.5%</td>
</tr>
<tr>
<td><strong>Initial Viscosity</strong></td>
<td></td>
</tr>
<tr>
<td>(SAE J1524, 550kPa, 2.64mm)</td>
<td>80 sec.</td>
</tr>
<tr>
<td><strong>Aged Viscosity</strong></td>
<td></td>
</tr>
<tr>
<td>(7 days @ 40°C)</td>
<td>90 sec.</td>
</tr>
<tr>
<td><strong>Shelf Life</strong></td>
<td>3 months when stored below 38°C and away from sources of heat and direct sunlight</td>
</tr>
</tbody>
</table>
# Product Properties

## Performance Properties (Cured at 177°C for 30 min.)

<table>
<thead>
<tr>
<th>Property</th>
<th>Conditions</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adhesion Lap Shear Strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>23°C</td>
<td>16 MPa</td>
</tr>
<tr>
<td></td>
<td>80°C</td>
<td>14 MPa</td>
</tr>
<tr>
<td></td>
<td>- 40°C</td>
<td>18 MPa</td>
</tr>
<tr>
<td>Peel Strength</td>
<td></td>
<td>6,500 N/m</td>
</tr>
<tr>
<td>Cold Adhesion</td>
<td>(SAE J243, ADS-2)</td>
<td>No flaking &amp; No loss of adhesion</td>
</tr>
<tr>
<td>Wash Resistance</td>
<td>(CILTM 9090, 2000psi)</td>
<td>No measurable movement, displacement or wash off</td>
</tr>
</tbody>
</table>
# Product Properties

<table>
<thead>
<tr>
<th>Performance Properties (Cured at 177°C for 30 min.)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E-Coat Compatibility</td>
<td>Rating 10 – No clusters</td>
</tr>
<tr>
<td>Dimpling Test (CEPT 01.00 L-200)</td>
<td>70+ lbs</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>40 MPa</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>3 – 5%</td>
</tr>
<tr>
<td>Modulus</td>
<td>4.5 – 5.0 GPa</td>
</tr>
<tr>
<td>Poisson’s Ratio</td>
<td>0.2 – 0.3</td>
</tr>
</tbody>
</table>
Deflection Strength Testing
## Product Flexural Strength (N)

<table>
<thead>
<tr>
<th>Material Thickness</th>
<th>0.60 mm</th>
<th>0.66 mm</th>
<th>0.70 mm</th>
<th>0.80 mm</th>
<th>0.93 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mm</td>
<td>25 N</td>
<td>30 N</td>
<td>35 N</td>
<td>42 N</td>
<td>52 N</td>
</tr>
<tr>
<td>0.5 mm</td>
<td>40 N</td>
<td>45 N</td>
<td>50 N</td>
<td>55 N</td>
<td>70 N</td>
</tr>
<tr>
<td>1.0 mm</td>
<td>60 N</td>
<td>65 N</td>
<td>70 N</td>
<td>80 N</td>
<td>95 N</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>100 N</td>
<td>115 N</td>
<td>120 N</td>
<td>130 N</td>
<td>135 N</td>
</tr>
</tbody>
</table>
Performance Evaluation Test Plan

- **Piepan Radii and Heights**
  - 940mm:
    - Height: 5.0 mm (0.5% stretch)
    - Thickness: 1 mm
    - Thickness: 2 mm
    - Height: 10.92 mm (2% stretch)
    - Thickness: 1 mm
    - Thickness: 2 mm
  - 5080mm:
    - Height: 1.27 mm (0.5% stretch)
    - Thickness: 1 mm
    - Thickness: 2 mm
    - Height: 7.11 mm (2% stretch)
    - Thickness: 1 mm
    - Thickness: 2 mm

- **Application of CF Epoxy**
  - Thickness: 1mm & 2mm
  - Application area: Piepan face + sidewall

- **Dent testing**
  - 25.4mm steel hemispherical indenter
  - A/SP Procedure
  - Initial stiffness
  - Load vs. dent depth

- **Oil Canning**
  - Displacement controlled
  - 75mm flat wood indenter
  - Load vs. displacement
Material Properties

- Steel – 0.6mm CR BH250

<table>
<thead>
<tr>
<th>YS (MPa)</th>
<th>TS (MPa)</th>
<th>UE (%)</th>
<th>TE (%)</th>
<th>n-value</th>
<th>R-bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>272</td>
<td>383</td>
<td>21.3</td>
<td>37</td>
<td>0.207</td>
<td>1.2</td>
</tr>
</tbody>
</table>

- Selected Properties of CF Epoxy
  - Color: Black
  - Lap Shear Strength: 16.4 MPa
  - As Received Peel Resistance: 7800 N/m
  - Application Methods: Paste, Swirl, or Shovel
  - Viscosity at Room Temperature: 80 sec.
Factors Affecting Performance

- Piepans were formed to achieve a biaxial stretch of 0.5% and 2%
- Radii of curvature of piepans: 940 mm, 5080 mm
- Half the piepans were cut to enable oil canning testing
- Piepans were then shipped to DCT for application of the Reinforcement on the back of the loaded surface
Experimental Results: Initial Stiffness

Initial stiffness was significantly enhanced by use of the reinforcement coating.

940 mm Radius Piepan

Initial Stiffness (N/mm)

- 0.5% Stretch
- 2% Stretch

CFE Thickness

- None
- 1mm
- 2mm

5080 mm Radius Piepan

Initial Stiffness (N/mm)

- 0.5% Stretch
- 2% Stretch

CFE Thickness

- None
- 1mm
- 2mm
Experimental Results: Dent Resistance

Stretch: 0.5%, 940 mm Radius

- Significant influence of C-F Reinforcement on dent resistance

Stretch: 2%, 940 mm Radius
Experimental Results: Dent Resistance

- Significant influence of C-F Reinforcement on dent resistance.
Experimental Results: Oil Canning Resistance

- Significant improvement in oil canning resistance with reinforcement
- Lower magnitude of load drop (lower sound magnitude) even with 1mm of reinforcement material
Experimental Results: Oil Canning Resistance

- No hard oil canning was observed for this sample, however the stiffness was substantially improved with reinforcement application.
Conclusions

• Substantial improvements were observed in both the dent and oil canning resistance for the two curvatures studied
• During oil canning testing, the resulting noise was substantially lower for the C-F Epoxy coated piepans than the uncoated piepans
• C-F Epoxy application with reduced thickness steel grades provides an attractive lightweighting and cost effective solution for closure panels
• More studies and trials are in progress on production panels
Contacts

• ArcelorMittal
  – Min Kuo - Min.Kuo@arcelormittal.com
  – Michael Lizak - Michael.Lizak@arcelormittal.com
  – Sriram Sadagopan - Sriram.Sadagopan@arcelormittal.com

• Diversitak, Inc.
  – Todd Brewer – TBrewer@dchem.com
  – Rajan Eadara – REadara@dchem.com
  – Joribeth Joseff – JJJoseff@dchem.com
PRESENTATIONS WILL BE AVAILABLE MAY 16

Use your web-enabled device to download the presentations from today’s event

Great Designs in Steel is Sponsored by: