Adhesives and Technical Considerations for Automotive Composite Bonding

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- Recent Developments in Adhesives for Composite Bonding
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MARKET DRIVERS
Market Drivers, Challenges and Trends

- Powertrain improvements alone cannot achieve the fleet fuel efficiency/emissions targets
- Mass reduction is vital
  - 10% less mass → up to +7% fuel efficiency
Novel materials like composites bring significant weight saving potential

Body Structure & Closures contribute to ~ 1/3 of the total weight

Significant weight saving potential
Additional benefit of composites: part integration

Multi-Piece Stamped & Welded Steel Floorpan

One-Piece Carbon Fiber Epoxy Floorpan

>50% weight reduction

>95% part integration
VEHICLE BODY ASSEMBLY TRENDS
Vehicle Body Bonding

**Body Shop**

- Steel or Aluminum Bonding

**Trim Shop**

- Full Body Bonding

**Multi-Material Bonding**

- Steel, AHSS
- Aluminum
- Magnesium
- Composites

*Fastest growing application*
Assembly Trends

Trend to move assembly to Body Shop for large light weight panels (roofs) and e-coat capable composites

SUBSTRATE

Steel, AHSS

Assembly

Body Shop  Paint  Trim Shop  Repair

Aluminum  Composites, Plastics
The CLTE challenge

<table>
<thead>
<tr>
<th>Coefficient of Linear Expansion $\alpha$ of Substrates at 20°C, $\mu$m/m/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
</tr>
<tr>
<td>Aluminum</td>
</tr>
<tr>
<td>Magnesium</td>
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<tr>
<td>Continuous CFC</td>
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<tr>
<td>CFC Molding Compound (CLTE influenced by fiber content, fiber length and orientation)</td>
</tr>
</tbody>
</table>
Challenges for multi-material vehicles

Joining

- Thinner substrates
- Dissimilar Materials
- Earlier in manufacturing process
- Challenges:
  - Coefficient of linear expansion differences
  - Residual stresses
  - Component distortion due to thermal and mechanical loads
  - Impact of residual stresses on adhesion performance
- Strength, fatigue/durability, and corrosion
- Hybrid joining (secondary attachment)

Performance

- Safety
- NVH performance
- Ride, handling comfort
- Fuel economy
WHY ADHESIVES?
Why Adhesives?

• Structural adhesives are an enabling technology for composite and dissimilar material assembly

• Benefits of structural adhesives:
  o Increased load bearing capability, static and dynamic stiffness
  o Improved fatigue performance
  o Lead to improved safety and crash behavior
  o Reduced vibrations and noise
  o Optimized ride, driving and handling
  o Vehicle durability
## Adhesive Technologies Address Key Auto Industry Drivers

<table>
<thead>
<tr>
<th>Category</th>
<th>Drivers</th>
</tr>
</thead>
</table>
| **Durability & Driving Comfort** | Increased static stiffness  
                          | Increased dynamic stiffness  
                          | Fatigue durability          |
| **Design**                | Composite-intensive or Multi-material mix  
                          | • Greater design flexibility  
                          | • Non-traditional materials |
| **Safety**                | Increased energy management capability  
                          | • Continuous bond lines  
                          | • Improved crash performance |
| **Environment**           | Weight reduction  
                          | • Composite usage  
                          | • Panel thickness reduction or part simplification  
                          | • Multi material design |
| **Savings**               | Cost savings capabilities  
                          | • Metal content reduction  
                          | • Process speed improvement  
                          | • Meet requirements for mass production |
Adhesive Selection Considerations

- Assembly requirements
- Substrates bonded
- Substrate coatings
- Cure profile
- Functional performance
- Body or Trim shop
- Manufacturing process

BMW i3
Adhesives formulation and application challenges

- Improvement of elongation and impact resistance can reduce adhesive strength and glass transition temperature (Tg)
- Heat during fixturing and cure might be needed for best results, but also can contribute to bond line read-through in bonded assemblies at the trim shop
- Differences in coefficients of thermal expansion (CTEs) and surface properties
- Surface preparation and cleaning prior to adhesive in trim shop applications
- Sag resistance for vertical applications
RECENT DEVELOPMENTS IN ADHESIVES FOR COMPOSITE BONDING
Structural Adhesives in Mass Manufacturing

Body Shop
- Body Structure Bonding

Trim Shop
- Full Body Bonding
- Module Bonding
Recent Innovations in PU Adhesives

- Balance of modulus and elasticity to compensate stresses due to different thermal expansion coefficients in multi materials mix design
- Combination of long open times with fast heat accelerated curing
- Pre-treatment free adhesion to e-coat and grinded CFRP
- New catalyst technologies enable fast heat accelerated curing
- Handling strength after 1 min $\Delta T$ process
## Application Examples

### - PU adhesives

<table>
<thead>
<tr>
<th>High Modulus Applications</th>
<th>Mid Modulus Applications</th>
<th>Low Modulus Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E-modulus ~ 300 MPa</strong></td>
<td><strong>E-modulus ~ 30 MPa</strong></td>
<td><strong>E-modulus ~ 15 MPa</strong></td>
</tr>
<tr>
<td>• B-pillar, tunnel, rear seat elements (e-coat aluminum/CFRP/PA): heat-accelerated, $\Delta \alpha$ management</td>
<td>• roof (e-coat aluminum/steel/CFRP): IR accelerated</td>
<td>• roof module, side panels (CFRP, e-coat, steel, aluminum) in heat accelerated processes</td>
</tr>
<tr>
<td>• seating (e-coat aluminum/CFRP/PA): Latent ambient temperature cure, pre-treatment-free</td>
<td>• live cell (CFRP/CFRP), IR heat accelerated process, grinded CFRP</td>
<td></td>
</tr>
<tr>
<td>• tailgate (CFRP/CFRP/SMC): Induction heat accelerated process, power-washed CFRP</td>
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</table>
Application Example
- Epoxy adhesives for Body Shop Composite Bonding

Low-Modulus Crash Durable Epoxy Adhesives

- High-impact peel resistance and crash durability
- Low-modulus at high Tg
- Designed for CFRP and high-strength steel
- Good strength and adhesion on steel and aluminum substrates, and on CFRP
- Good failure mode and corrosion resistance
CASE STUDIES
POLYURETHANE STRUCTURAL ADHESIVES
Case Study: Lightweight Closures

- **Product:** Structural polyurethane adhesive
- **Vehicle Application:** Body closures bonding
- **Enabling Technology:** Adhesive provides a reliable joining solution for multi-material designs enabling OEMs to use advanced ultra-lightweight materials to reduce weight and improve fuel economy

- Fast, low cost joining solution for composites and dissimilar materials (CFRP-SMC) in general assembly
- Little to no pretreatment on composites
- 40% weight savings compared to steel
- Substrates bonded:
  - Primerless bonding of CFRP and SMC
  - Fast cure in select locations through induction heating eliminating the need for secondary fasteners
  - Remaining bond areas cure at room temperature
Case Study: BMW 7 Series roof

• Product: Structural polyurethane adhesive
• Vehicle Application: Roof beam BMW 7 Series
• BMW uses 4% CFRP in the 2015 7 Series
• Significant weight savings for overall vehicle:
  - 2008 model: 1820kg
  - 2015 model: 1725kg
• Enabling Technology: Adhesive provides a reliable joining solution for multi-material (CFRP to steel) roof design enabling BMW to design advanced ultra-lightweight structures
  - Tailor-made to BMW’s requirements for IR curing
  - Pre-treatment free bonding
  - Good handling strength after short curing cycle
  - Excellent bulk elongation at different modulus meets the targets for part stiffness
CONCLUSIONS
Adhesives are an Enabler for Lightweighting

- **Structural Adhesives** enable vehicle lightweight strategies by
  - Bonding **dissimilar materials** including **carbon fiber reinforced composite materials** to many lightweight substrates
  - Managing **thermal expansion differences** with dissimilar materials

- **Benefits include**
  - Bond many substrates, including metals and composites without priming
  - Designed for mass production and compatible with existing infrastructure
  - Provide excellent corrosion resistance
  - Increase body stiffness, improves crash performance
  - Increase vehicle body durability
  - Reduces vibration and noise
  - Compatible with other mechanical and thermal joining techniques
What the future holds

- More multi-material vehicle body constructions
- Increased use of composites and plastics
- Increased use of adhesives as enabler for composite and multi-material light weight structures
- Customized adhesives solutions to meet specific manufacturing and substrate conditions - one solution does not fit all
THANK YOU!

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