Application of Adhesives and Bonded Joint Design in Improving Vehicle Structure Performance

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Presentation Outline

• Structural adhesives benefits and overview
• Selection of adhesive system
• CAE modeling for crashworthiness applications
• Frontal impact application development study
• Conclusions
**Structural Adhesives Benefits**

- **Improved Handling / Acoustics**: Increases the stiffness of car body
- **Improved Durability**: Overcome fatigue problems, improve long term durability
- **Safety**: Increased energy managment capability
  - Enables use of Advanced High Strength Steel (AHSS)
- **Cost Reduction**: Weld spot reduction
  - Downgauge steel
  - Optimize usage for combination of AHSS grades
  - Highly economical joining process
- **Mass Reduction**: Enables downgauged steel
  - Enables multi-material construction (Al, Mg, & Composites)
- **Vehicle Assembly**: Overcome weld access problems
Choice of Structural Adhesive

- Automotive industry criterion for structural adhesives
  - Modulus: Above 1000 MPa
  - Glass Transition Temperature: Above 80 °C
  - Impact Resistance f(T): From -40 °C to 80 °C
  - Oil Compatibility: Adhesion to oily substrates
  - Lower cure window: temperature and time
  - Robust to accommodate different steel coatings
  - Robust wash-off resistance

- Epoxy based systems
  - General purpose
  - Standard grades
  - Semi-fracture toughened
  - Superior fracture toughened

One component toughened epoxy is the industry choice
Impact Peel Test Results

- Increased ductility at low temperatures

<table>
<thead>
<tr>
<th>Strength (N/mm)</th>
<th>General Purpose Adhesive</th>
<th>Structural Adhesive</th>
<th>Semi Fracture Toughened</th>
<th>Superior Fracture Toughened</th>
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<td>-40C</td>
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- Increased crash resistance
- Increased durability
- Increased flexibility to down gauge metal & reduce welds
Why Structural Adhesives?

- Eliminates sudden change of stresses
- Significantly lowers stress acting across joined region
- Uniformly distributes the load
- Increases load carrying capacity
- Eliminates stress concentration

Patented toughening system is the enabler for the unique impact performance.

- The micromechanical behavior of the adhesive allows the reduction of stress peaks through distribution of three-axial load cases in the volume around the crack tip.
- The effects of cavitations (primary toughening mechanism) are often visible.
- There is a gradation of properties - dependent on pressure and state of deformation. This makes the problem extremely complex, non-linear and difficult to model the physics.
**CDA CAE Modeling Considerations**

- Shell elements of the substrates are modeled as ‘mid-plane’
- Adhesive element is modeled with the real bond-line thickness (BLT)
- Interface contact definition is used to connect the adhesive to the substrate
CDA CAE Correlation to High Velocity Dynamic Test

Profile thickness: 1.5 mm
Bondline thickness: 0.35 mm
Impactor mass: 32.66 kg (72 lbs)
Impactor speed: 5.17 m/s (11.57 mph)

Profile thickness: 1.0 mm
Bondline thickness: 0.35 mm
Impactor mass: 32.66 kg (72 lbs)
Impactor speed: 8.81 m/s (19.71 mph)
• Front rail bonded concept development

  Many studies has been performed to show at a component level it is possible to reduce no. of spot welds and use structural bond and achieve mass reduction as a result of reduced gauges

  Application of structural bonding for front rails at various OEM has not provided substantial crash and energy management performance benefits
Front Rail Joint Design Development

Baseline

Design 1

Design 2

20 mm

120 mm

70 mm

167 mm

70 mm

70 mm

70 mm
Component Level Analysis Performance Comparison

- Increased energy absorption
- Complete unzipping of the joint

Graphs showing force and displacement with blue, green, and black lines representing Baseline, Design1, and Design2.
Full Vehicle NCAP and Offset Performance CAE Study

Baseline

Modified Bonded Joint Design
NCAP Rail Energy Comparison

Energy absorption increase with new bonded joint design

Baseline design with adhesives degrades energy absorption performance
New bonded joint design reduces peak acceleration

Increased opportunity for further mass reduction
40 mph Offset Performance

- Increased energy absorption of rails allows:
  - Reduction of intrusion into the occupant compartment
  - Ability to reduce the gauge of the sheet metal
  - Ability to reduce no. of reinforcements
  - Reduction of spot welds (30-50%)
• Successful application of adhesives in front longitudinal members requires
  - Proper selection of steel thickness and steel grade
  - Proper joint design and adhesive that promotes increased energy absorption of the steel structure. The two cannot be de-coupled

• Joint design in combination with proper choice of adhesive can sufficiently increase energy absorption of the rails, while providing key benefits:
  - Improved frontal NCAP crash pulse – reduced peak acceleration
  - Significant intrusion improvement into the occupant compartment
  - Design and packaging freedom to accommodate multiple vehicle design theme
  - Increased bending stiffness of rails
  - Reduction of spot welds (30% to 50%)
  - Mass reduction of 0.5 kg
  - Cost reduction of up to 10%. However, there could be additional cost savings due to elimination or reduction of steel gauges in other parts of the structure, i.e., rocker, front body hinge pillar reinforcement, etc.
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