ADHESIVE BONDING PERFORMANCE OF GA COATED 590 MPa TENSILE STRENGTH STEELS

Susan Wolf
ArcelorMittal Global R&D – East Chicago
Chann Cheng, Benda Yan, Jayanth Chintamani, ArcelorMittal Global R & D – East Chicago

Mike Golden & Jagdeesh Bandekar
Dow Automotive
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  • Adhesives
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Background

• Light weighting in the automotive industry is a constant objective that is increasingly obtained using:
  • Advanced high strength steels (AHSS)
  • Crash resistant and fracture toughened adhesives

• In crash sensitive applications, adhesives are generally avoided on galvanneal (GA) coated steels.

• GA coated 780 MPa AHSS were shown to have cohesive failure and good bond strength.

• The subject study focused on the adhesive bonding performance of GA 590 MPa materials bonded with adhesives of different moduli of elasticity.

• GA coated IF EDDS steels were included for comparison.
Test Materials

• GA coated test materials include
  • 590Y (dual phase) – 0.7 & 1.6 mm
  • 590R (high yield to tensile ratio) – 1.2, 1.5, 1.7 mm
  • 590T (TRIP) – 1.5 mm
  • 270E (IF EDDS) – 0.7 & 1.5 mm

• Test materials were bonded with up to three adhesives.
  • BETAMATE™ 1488, crash resistant structural, modulus 1400 MPa.
  • BETAMATE™ 1022DUS, fracture toughened structural, modulus 2000 MPa.
  • BETAMATE™ 73305GB, structural, hem flanging, modulus 4100 MPa.
## Test Materials

<table>
<thead>
<tr>
<th>Material Code</th>
<th>Gauge (mm)</th>
<th>Coating Wt (g/m²)</th>
<th>% Fe</th>
<th>Fe Content (g/m²)</th>
<th>Width of GA removed by tape in 60° V-Bend Test (mm)</th>
<th>Residual Stress (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>590Y-C</td>
<td>0.7</td>
<td>37.5</td>
<td>10.5</td>
<td>3.9</td>
<td>2</td>
<td>-26</td>
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<td>590Y-96</td>
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<td>-58</td>
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<td>590T-897</td>
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Residual Stress Measured by XRD

- Opposite stresses are felt on both sides of the interface; i.e., compressive stress on substrate leads to a tension stress on the coating.

- Results show that there is a moderate to high compressive stress on the steel surface for all materials, except the thin gauge EDDS.

- Typically, a larger lattice mismatch exists between IF EDDS and the Γ phase in the GA, which may cause breakage of the lattice bonding at the interface to release the residual stress.
Residual Stress – Cracks in Coating

[Images of macroscopic views of coatings labeled 590Y, 590R, 590T, and EDDS]
Lap Shear Test Method

- The 25 x 102 mm samples were solvent wiped before bonding.
  - 12 test materials were bonded with BETAMATE™ 1488.
  - 6 test materials were bonded with BETAMATE™ 1022DUS & BETAMATE™ 73305GB.
- In some cases, backing plates of 1.6 mm sheet steel were bonded to the back of each specimen.
- The average joint had an overlap of 12.7 mm and a bond thickness of 0.25 mm controlled by glass beads.
- The adhesive was cured for 20 minutes at 170°C.
- Specimens were pulled on an Instron tensile test machine at 50 mm/minute at room temperature.
- The shear strength in MPa and the failure mode as % cohesive failure were reported.
Lap Shear Test Method

- Evaluation of failure mode

**OK**

Cohesive Failure (CF) = failure in the adhesive

**Avoid**

Adhesive Failure = failure of adhesive to substrate

- May be OK if bond strength is good.
- Not OK
  - Coating Delamination
Results – DOW BETAMATE™ 1488

Lap Shear Strength (MPa) of Test Materials Bonded with BM1488

Shear Strength (MPa)

590 MPa Materials

EDDS IF Materials

Back ing Plate
No Back ing Plate

590Y 590Y 590Y 590R 590R 590R 590R 590T 590T 270E 270E 270D
C 96 97 61 98 12 53 05 897 35 19 06

0 5 10 15 20 25 30 35 40
## Results – DOW BETAMATE™ 1022DUS

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<thead>
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<th>Material Code</th>
<th>No Backing Plates</th>
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<th>Backing Plates</th>
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<td>Cohesive Failure</td>
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<td>Shear Strength</td>
<td>Cohesive Failure</td>
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<tr>
<td></td>
<td>MPa</td>
<td>σ</td>
<td>%</td>
<td>σ</td>
<td>MPa</td>
<td>σ</td>
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<td>0.4</td>
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<td>77</td>
<td>23</td>
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</table>

**Images:**

- 0% CF
- 50% CF
- 99% CF

[www.autosteel.org](http://www.autosteel.org)
## Results – DOW BETAMATE™ 73305GB

<table>
<thead>
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<th>Material Code</th>
<th>No Backing Plates</th>
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<td>Shear Strength</td>
<td>Cohesive Failure</td>
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<tr>
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<td>MPa</td>
<td>σ</td>
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<td>590Y-C</td>
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<td>590Y-96</td>
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</table>

0% CF | 10% CF | 99% CF
Results – Three Adhesives

Lap Shear Strength (MPa) of the Test Materials with Different Adhesives

Shear Strength (MPa)

- 590Y-C 0.7 mm
- 590Y-96 1.6 mm
- 590R-12 1.5 mm
- 590T-897 1.5 mm
- 270E-35 0.7 mm
- 270D-06 1.5 mm

Legend:
- BM1488
- BM1022DUS
- BM73305GB
Results – Three Adhesives

Mode of Failure (% Cohesive Failure) of the Test Materials with Different Adhesives

<table>
<thead>
<tr>
<th>Material</th>
<th>BM1488</th>
<th>BM1022DUS</th>
<th>BM73305GB</th>
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<tr>
<td>270D-06</td>
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<td>40</td>
<td>30</td>
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</table>
Results – Three Adhesives

• BETAMATE™ 1488, with the lowest E-modulus, was the only adhesive to exhibit excellent cohesive bonding performance for all test materials except the thin gauge IF EDDS material.

• Lap shear performance using adhesives with a higher modulus was fair or poor, despite good adhesion at the steel/coating interface, suggesting that other coating and adhesive characteristics influenced the mode of failure.

• All test materials fell within acceptable variation of GA coated product and the low modulus adhesive appeared to compensate for subtle variations in the GA coated product.
Conclusions

• All 590 materials exhibited excellent adhesive bond strengths with all adhesives even when the mode of failure was less than optimal.

• The amount of cohesive failure decreased as the E-modulus of the adhesive increased.

• A low modulus, crash resistant adhesive has potential to be used with GA coated AHSS structures to reduce weight while maintaining or improving crash performance.

• The recommendation would remain to avoid joining GA IF EDDS steels with adhesives in crash sensitive applications.