Non-Destructive Inspection of Adhesive Bonds in Metal-Metal Joints

USAMP/NDE601
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This presentation does not contain any proprietary or confidential information

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Outline

- Purpose of work
- Address Previous Review Comments (if applicable)
- Barriers
- Approach
- Performance Measures and Accomplishments
- Technology Transfer
- Publications/Patents
- Plans for Next Fiscal Year
- Summary
Purpose of Work

- Develop non-destructive inspection methods to verify adhesive bonds in automotive metal-metal joints
- Nondestructively assure the strength of adhesive bonds
Barriers addressed

- Adhesives increasingly being used because they
  - Increase body stiffness - without significant mass increase
  - Increase body strength – without significant mass increase
  - Enable dissimilar materials, e.g. steel + Mg, or composite + steel to be used next to each other

- Reduce cost of light-weight materials.

- Adhesive bonding is a critical technology
  - Present in ~95% of the Mg Front End joints
  - Present in all the Composite Underbody joints
  - Allows less expensive sheet product to be used instead of castings or extrusions

- Spread strain for more brittle light-weight materials, especially around joints.
Approach

- Work with adhesive suppliers to identify key features that determine the adhesive bond strength quantitatively.

- Work with NDT experts, especially from aerospace, to identify leading NDT technologies to measure these properties in vehicle structures.

- Verify targeted methods on coupons (NDT prediction vs. quantitative strength measurements):
  - Skips, bond-thickness and -width variations, 3 adhesives, 2 substrates, cure state, welds
  - Kissing bonds (intimate, but weak)

- Test performance of methods on production vehicle bodies.

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Technical target: demo flange following tool

- **Requirements**
  - Lap joints with 2-t & 3-t stackups
  - Single-sided inspection
  - Hand or robot capable
  - 25-mm wide flange
  - <1 mm resolution
  - >1 m/min (off line)
  - Cured or uncured

- **Detect**
  - Area wetted
  - Location on flange
  - Thickness
  - Adhesion strength
  - (Cure state)
Accomplishments – demonstrated that requirements are sufficient

- After testing three alternatives, developed new wedge peel method to obtain high-resolution strength map

- Developed gold-standard NDE method (ultrasonic through transmission in immersion tank) to predict strength
Accomplishments – designed & built unique high-frequency ultrasonic phased array probe

- Manual
- Portable – closed loop water
- Water use: <1 cup/100 m
- Resolution: 0.5 mm
- Speed: 5 m/min

Electronic scan

Mechanical scan
Accomplishments – four technologies evaluated on steel & aluminum (shown) coupons with good bonding

- Immersion tank
- Ultrasonic phased array
- Pulsed thermography
- Laser ultrasonics (steel sample shown)
Accomplishments – Body in white inspections

- Hem flanges
  Front of vehicle

- Row bows - uncured
  Front Right of Car
  Approx 36”
  Left Rear of Car
  20 mm
## Accomplishments – four technologies with good bonding

<table>
<thead>
<tr>
<th>Technology</th>
<th>Resolution</th>
<th>Speed</th>
<th>On vehicle</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>&lt;1 mm</td>
<td>&gt;1 m/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonic immersion tank</td>
<td>✓ 0.5 mm</td>
<td>✓ 5 m/min</td>
<td>No</td>
<td>Gold standard on flat coupons</td>
</tr>
<tr>
<td>Ultrasonic phased array</td>
<td>✓ 0.5 mm</td>
<td>✓ 5 m/min</td>
<td>Yes</td>
<td>Best near-term, needs thickness</td>
</tr>
<tr>
<td>Laser ultrasonics</td>
<td>✓ 1 mm</td>
<td>0.3 m/min</td>
<td>Not tested</td>
<td>Under development for in-line inspection</td>
</tr>
<tr>
<td>Pulsed thermography</td>
<td>5 mm</td>
<td>0.3 m/min</td>
<td>Yes, with coatings</td>
<td>Dropped</td>
</tr>
</tbody>
</table>
Accomplishments - Weak ("Kissing") Bond Detection

- Prepare carefully controlled lap-shear coupons with repeatable amounts of grease contamination

- Inspect contaminated interface with conventional ultrasonics
Technology Transfer

- Ultrasonic phased array has been used to answer engineering questions on OEM pre-production and production vehicles

- Working with NDE vendors to commercialize the phased array and laser ultrasonics technology

- Working with Automotive Composites Consortium (ACC)
  - Ultrasonic through transmission has been used by ACC Energy, Focal Projects 3 & 4 to verify plaques and components

- Working with AMD 603/604 Mg Front End
  - Apply to Mg Front End joints as they become available (riv/bond)
  - Applied to corrosion tests of Mg bonded lap joints
Record of invention filed for phased array probe

Presentations/extended abstracts


Activities for coming fiscal year

- Miniaturize / productionize phased array
  - Reduce size by 50%, articulated
    - 18 mm flanges, smaller confines
    - 95% of vehicle should be accessible
  - Use commercial circulation system

- Ultrasonic signal processing – adhesive thickness

- Kissing bond evaluations
  - Phased array performance on grease bonds
  - Access requirements of other kissing bonds
    - Dry lube
    - Mold release

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Summary

- Adhesives (with good bonding) are a lightweight material enabler
  - Allow reduced gauges and reduced # of welds or rivets – reduced costs
  - Adhesives are critical technology for composites, Mg, AHSS where brittleness is a limit
  - Adhesives provide corrosion barrier in dissimilar metal structures

- Aug. 2006-Dec. 2007: Tasks 1-9 completed on time; Gates 1 and 2 passed
  - Demonstrated that strength (when adhesion is good) can be predicted quantitatively from NDE bond width and thickness measurements
  - Demonstration of NDE performance using commercial technology on steel and aluminum flat coupons
  - Demonstration of NDE performance on production bodies-in-white
  - Demonstration of grease kissing bond sample prep and detection

- Technology transfer is well in hand
  - Commercial vendors involved in development
  - Engaged in production and related USAMP Mg and composite problems

- Plans for Next Year
  - Productionize phased array and laser ultrasonic technology
  - Methods to inspect kissing bonds
Questions?

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