Implementation of Ultrasonic Metal Welding on an Aluminium Vehicle Structure

UIA Meeting
March 19, 2007

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What is Ultrasonic Welding?

Ultrasonic metal welding is a solid-state welding process that produces coalescence through the simultaneous application of localized high-frequency (20 kHz) vibratory energy and moderate clamping forces achieved via plant air at pressures up to 7 Bar.
Why Join Aluminium Sheet with Ultrasonic Welding?

• Less energy required than for resistance spot welding
• Lower cost than riveting
• No heat affected zone
• Relatively insensitive to range of lubricant types and levels
• Works on pretreated aluminum
Typical Aluminium Vehicle

Ford P2000 Body-in-White
Typical Aluminium Sheet Alloys for Automotive Vehicles

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Typical Gauges</th>
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</thead>
<tbody>
<tr>
<td>AA5182-O</td>
<td>0.9 mm- 3 mm</td>
</tr>
<tr>
<td>AA5754-H111</td>
<td>1-3 mm</td>
</tr>
<tr>
<td>AA6016-T4</td>
<td>1-1.5 mm</td>
</tr>
<tr>
<td>AA6111-T4</td>
<td>0.9 – 2 mm</td>
</tr>
</tbody>
</table>
Manual Ultrasonic Weld Gun

Transducer

Anvil

Tip
Sheet Metal Welding Tip and Anvil

Tip Gripping Surface

Anvil Gripping Surface

Tip Side of Welded Coupon
How Does the Weld Develop?

![Graph showing the relationship between welding energy (J) and tensile-shear failure load (kN).]
How Does the Weld Develop?

100 J, Wedge-Reed Welder

200 J, Wedge-Reed Welder
How Does the Weld Develop?

400 J, Wedge-Reed Welder

600 J, Wedge-Reed Welder
Weld Formation Summary

- Physical deformation at weld interface and at tip and anvil interfaces occurs concurrently.
- Mechanical mixing occurs at the interface.
- Some deformation of grains occurs at the interfaces of the tip and anvil with the weldments.
- There is no evidence of melting.
Cross-section of Welded AA6111-T4 (0.9 mm)
Hardness Across Weld AA6111-AA6111

Vickers Hardness (HV)

Anvil Side
Coupon AA6111

Tip Side
Coupon AA6111

Measurement Number
Cross-section of AA6016-AA6111 Weld

Tip Side

Vibration Direction

AA6016

Weld Zone

AA6111

69.5 Hv

85.9 Hv

AA6111

85.9 Hv

AA6016

69.5 Hv

Ford

Sandblonde Ultrasanics
Hardness Across AA6016-AA6111 Weld

- Measurement Number
- Vickers Hardness (Hv)
- Weld Interface Region
- Anvil Side Coupon AA6111
- Tip Side Coupon AA6016
Example of Tensile-Pulled Lap-Shear Coupon
Lap-Shear Failure Loads

Alloys Welded

- 0.9 mm AA6111-T4
- 1.2 mm AA6016-T4
- 1.0 mm AA5182-O
- 1.0 mm AA5754-H111
Fatigue Life of Joined 0.9 mm AA6111, R=0.1

Cycles to Failure

Peak Load (N)
Welding Structures

- Access to weld location
- Cycle Time
  - 0.4 s for 1 mm to 1 mm sheet
  - 2.0 s for 3 mm to 3 mm sheet
- Manual and Robotic Weld Applications
Manual Ultrasonic Weld Gun for Aluminium Vehicle Structure Welding

Multiple Handles Accommodate Welds Made at Several Orientations
Robotic Ultrasonic Welding Gun for Aluminium Vehicle Structure

C-Frame Robotic Weld Gun with Clamping System
Process Robustness

- Alloy Combinations
  - 5XXX
  - 6XXX
- Lubricant
  - Liquid
  - Dry Film
- Gauges
  - 0.9 to 3 mm
Effect of Stamping Lubricant on Weldability of Aluminium

0.9 mm AA6111-T4 to AA6111-T4 Welds
Lap-Shear Failure Loads

0.3 g/m²
0.6 g/m²
1.0 g/m²

Lubricant Level

Failure Load (kN)
Fatigue Life of Welded AA6111 with Various Lubricant Levels
## Typical Lap-shear Failure Loads of Different Aluminium Gauges

<table>
<thead>
<tr>
<th>Gauge Description</th>
<th>Load Range (kN)</th>
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<tbody>
<tr>
<td>1 mm 5754 to 1 mm 5754</td>
<td>2.8-3.0 kN</td>
</tr>
<tr>
<td>2 mm 5754 to 2 mm 5754</td>
<td>5.0-5.5 kN</td>
</tr>
<tr>
<td>3 mm 5754 to 3 mm 5754</td>
<td>7.5-8.5 kN</td>
</tr>
</tbody>
</table>
Application Challenges

- Presence of adhesive
- Cleaned Samples (no lubricant)
- Clamping weldments
USW Manual Gun for Automotive Assembly Fixture
Robotic USW Gun
for Automotive Closure Panels
Conclusions

- USW is a good, economical joining method for aluminium vehicle construction
- Utilization of USW joining technology is appropriate for a range of aluminium gauges, lubricant levels and aluminium alloys.
Acknowledgements

• Part of this work was performed under cooperative agreement 70NANB3H3015 with the US National Institute of Standards and Technology -- Advanced Technology Program