Ultrasonic Welding of Aluminum Sheet

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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 Aluminum 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
## Relative Cost Comparison

<table>
<thead>
<tr>
<th>Joining Method</th>
<th>Relative equipment cost</th>
<th>Relative energy consumption</th>
<th>Variable cost/joint</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSW (8mm welding cap)</td>
<td>1.3</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>SPR (3mm rivet)</td>
<td>6</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>GMAW (25mm)</td>
<td>1</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Adhesive Bonding (25X13mm)</td>
<td>7</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>USW (5x7 mm)</td>
<td>2.5</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Typical Ultrasonic Metal Welders

Wedge Reed System

Lateral Drive System
Typical Pedestal Welders

Wedge Reed System

Lateral Drive System
Sheet Metal Welding Tip and Anvil

Tip Gripping Surface

Anvil Gripping Surface
Typical Welded Tensile-shear Coupons

Tip-side Surface

Anvil-side Surface

Painted Welded Coupons
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.
Example of Tensile-Pulled Lap-Shear Coupon
Typical Aluminum Tensile-shear Failure Loads

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness Range</th>
<th>Tensile-shear Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA6111-T4</td>
<td>0.9 mm to 0.9 mm</td>
<td>~3.5-3.9 kN</td>
</tr>
<tr>
<td>AA5754</td>
<td>1.0 mm to 1.0 mm</td>
<td>~2.9-3.2 kN</td>
</tr>
<tr>
<td>AA5754</td>
<td>3.0 mm to 3.0 mm</td>
<td>8.0-8.5 kN</td>
</tr>
</tbody>
</table>

(welded with a 5 x 7 mm tip)
Fatigue Performance of Different Joining Technologies

![Graph showing fatigue performance of different joining technologies with various markers for different processes: RSW (5mm welding cap), SPR (3mm rivet), GMAW (25mm), Adhesive (25mm x 25mm), USW (5mm x 7mm tip), USW & Adhesive.](image-url)
Technical Challenges in Applying Ultrasonic Metal Welding to Aluminum Structures

- Higher power transducers – to enable welding of thicker gauges, castings, extrusions, and hydroformed components
- Alternative welding configurations – to weld a wide variety of component geometries and joint configurations
- Vibration control strategies – to ensure weld quality across a wide range of component geometries
7 kW Sonobond Transducer

• Sonobond has developed a full wavelength design, 7kW transducer
Dual Wedge-reed Welding System

- Sonobond designed and constructed a two-sided over-and under welding system with ultrasonic activation above and below the weld coupons.
Dual Wedge-reed Welding System
Dual Wedge-Reed Welding System – Results

- Welding conducted on 0.9mm AA6111
- Welding parameters:
  - Standard wedge-reed system: 650 J, 2500 W, 90psi
  - Dual wedge-reed system: 330 J, 1650 W, 90psi
- Initial results show a dramatic decrease in the energy required to produce a good quality weld with the dual head system for 0.9 mm thick AA6111.
Dual Wedge-reed Welding System – Results

- Welding conducted on 0.9mm AA5754
- Welding parameters:
  - Standard wedge-reed system: 660 J, 2500 W, 90 psi
  - Dual wedge-reed system: 330 J, 1650 W, 90 psi
- As for the AA6111, initial results show a dramatic decrease in the energy required to produce a good quality weld with the dual head system for 1.0 mm AA5754.
Dual Wedge-Reed System with Perpendicular Drive Axes
Dual Wedge-Reed System with Perpendicular vs. Parallel Drive Axes

DUAL WEDGE-REED SYSTEM
330 JOULES 1650 WATTS 90 PSI 15 IMPEDANCE
UPPER REED TIP 651-6537  LOWER REED TIP 651-3579 modified to 0.40" DIA.

<table>
<thead>
<tr>
<th>Tensile-shear Failure Load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perpendicular Drive Axis</td>
</tr>
<tr>
<td>2.9</td>
</tr>
<tr>
<td>2.8</td>
</tr>
<tr>
<td>2.7</td>
</tr>
<tr>
<td>2.6</td>
</tr>
<tr>
<td>2.5</td>
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<tr>
<td>2.4</td>
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<tr>
<td>1.9</td>
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<tr>
<td>1.5</td>
</tr>
</tbody>
</table>

Perpendicular Drive Axis
Parallel Drive Axis
Dual Wedge-Reed System with Perpendicular vs. Parallel Drive Axes

- Slightly stronger weld strengths result with the axes configured parallel and the direction of motion at 180 degrees than with the axes perpendicular and the direction of motion at 90 degrees.
Vibration Control Strategy

- Vibration control strategies are required to ensure weld quality across a wide range of component geometries.
- There exist weldment geometries that are difficult to weld without clamps.
Weld Strength as a function of Coupon Overlap without Clamping

MH 2026/FC2026
AA6111 0.9 X 25 X 225
500 JOULES 2500 WATTS 90 PSI

Tensile-shear Failure Load (kN) vs. Coupon Overlap (in.)
Wedge-reed Welder with Floating Clamp
Weld Strength with and without Clamping

MH 2026/FC2026
AA6111 0.9 X 25 X 225
500 JOULES 2500 WATTS 90 PSI

Tensile-shear Failure Load (kN)

Coupon Overlap (in.)

WITH ISOLATION CLAMP
WITHOUT ISOLATION CLAMP
Weld Strength as a function of Coupon Overlap with Clamping

- With the floating clamp, tensile-shear weld failure loads were uniform and independent of overlap.
- These results indicate that a clamp can be used to effectively isolate the weld zone from the transmission of vibration through the parts.
Summary

- Ultrasonic spot welding of aluminum is an efficient, robust low-cost joining method suitable for aluminum sheet.
Acknowledgements

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