Ultrasonic Welding of Aluminum Sheet

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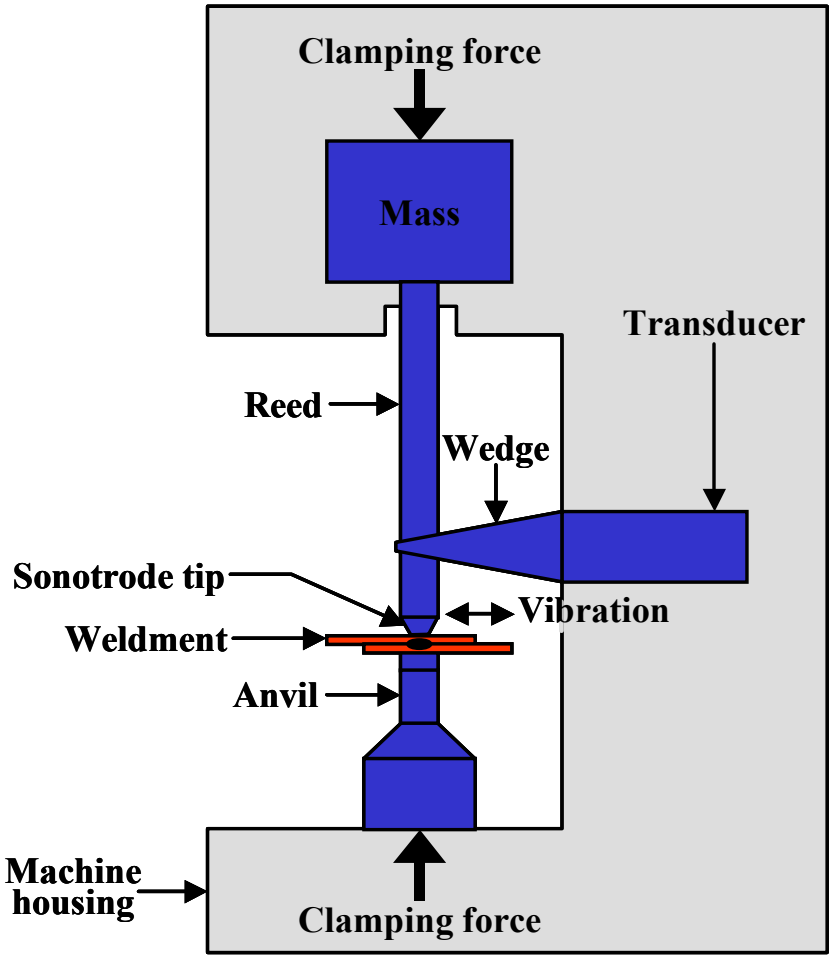
What is Ultrasonic Welding?



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.

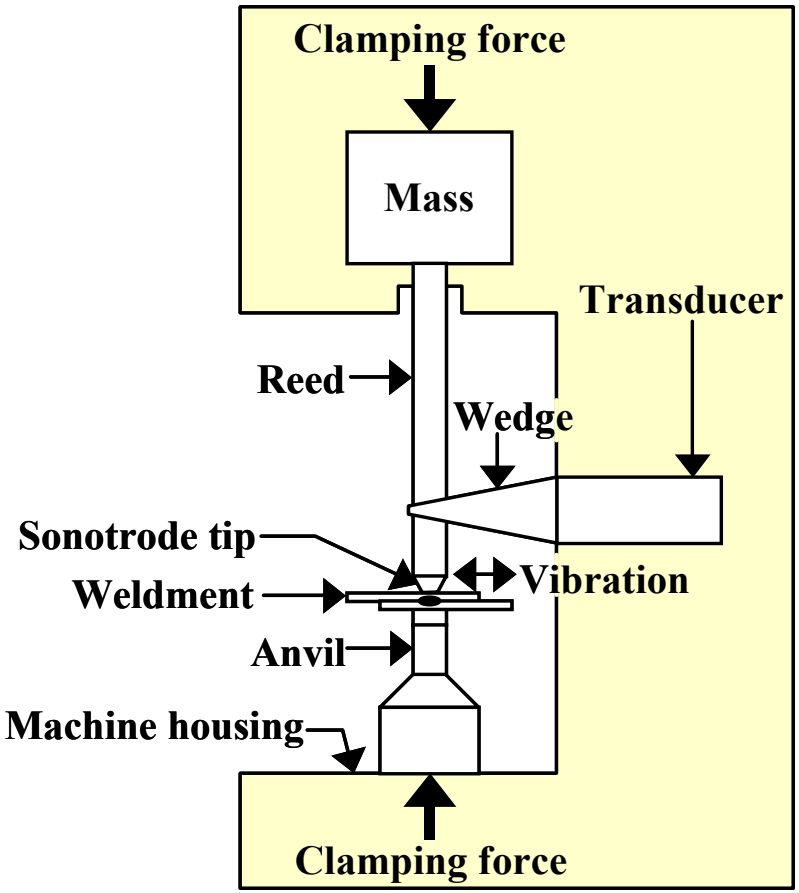
Why Join Aluminum Sheet with Ultrasonic Welding?

- 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

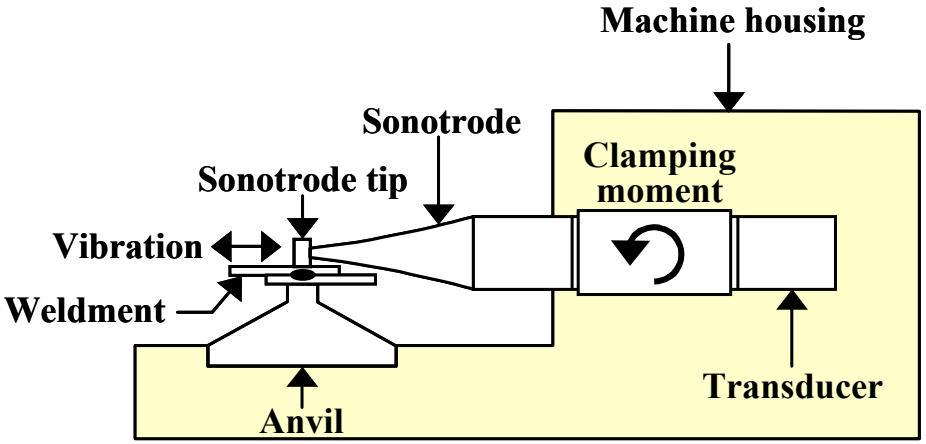
Relative Cost Comparison

Joining Method	Relative equipment cost	Relative energy consumption	Variable cost/joint
RSW (8mm welding cap)	1.3	6	5
SPR (3mm rivet)	6	1	10
GMAW (25mm)	1	18	3
Adhesive Bonding (25X13mm)	7	1	2
USW (5x7 mm)	2.5	1	1

Typical Ultrasonic Metal Welders

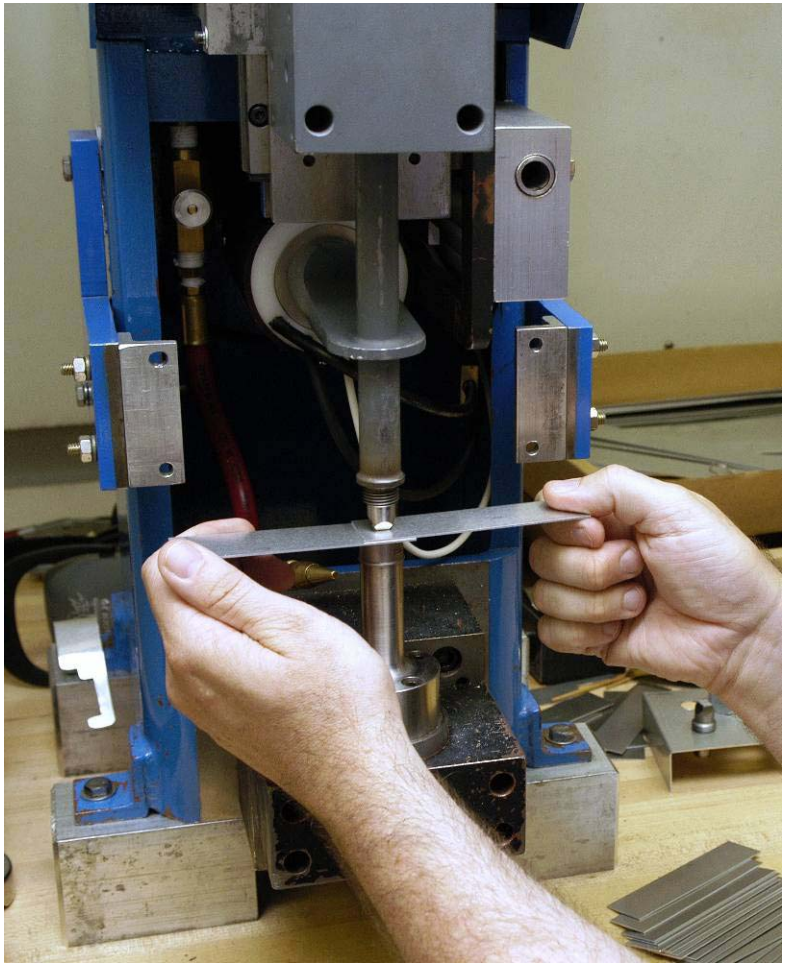


Wedge Reed System

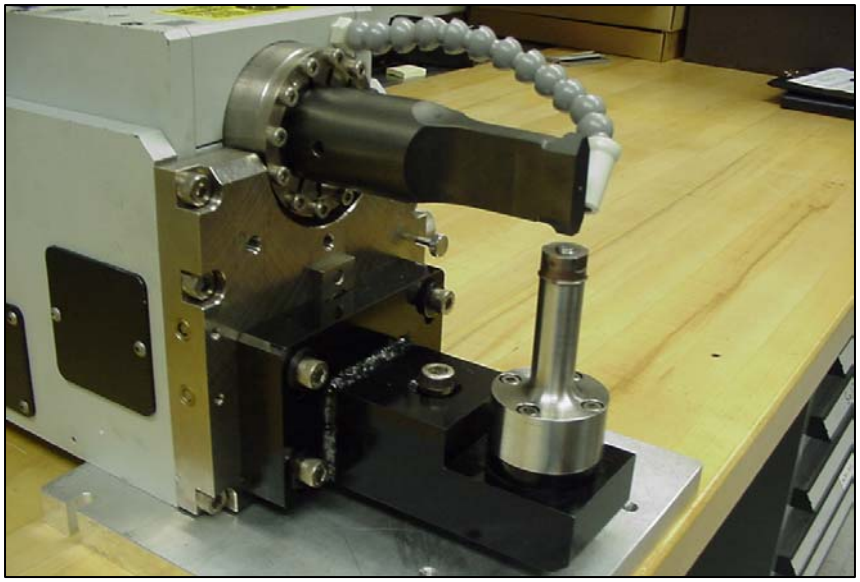


Lateral Drive System

Typical Pedestal Welders

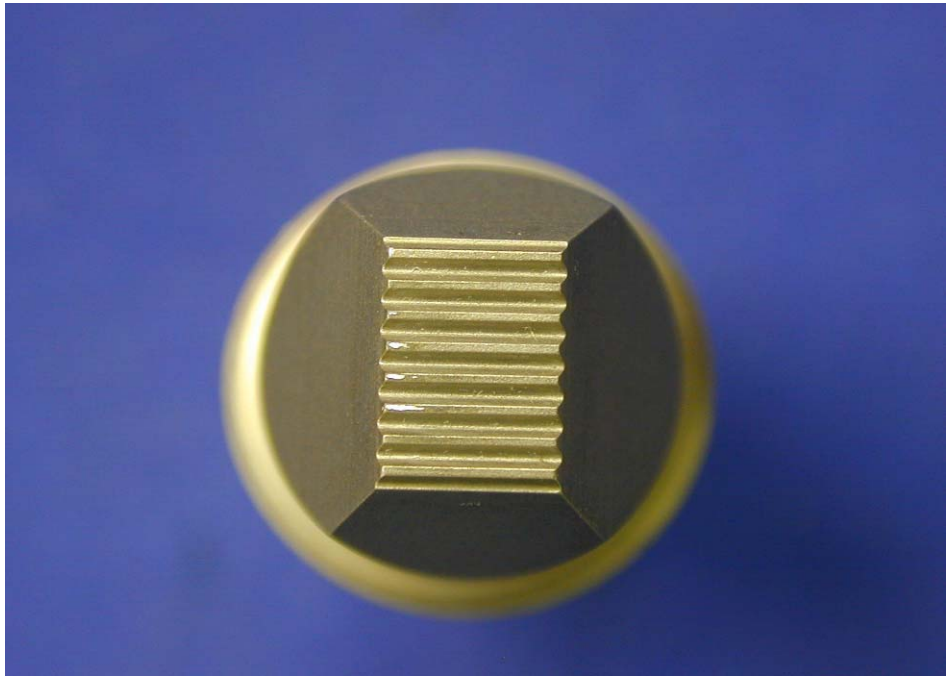


Wedge Reed System

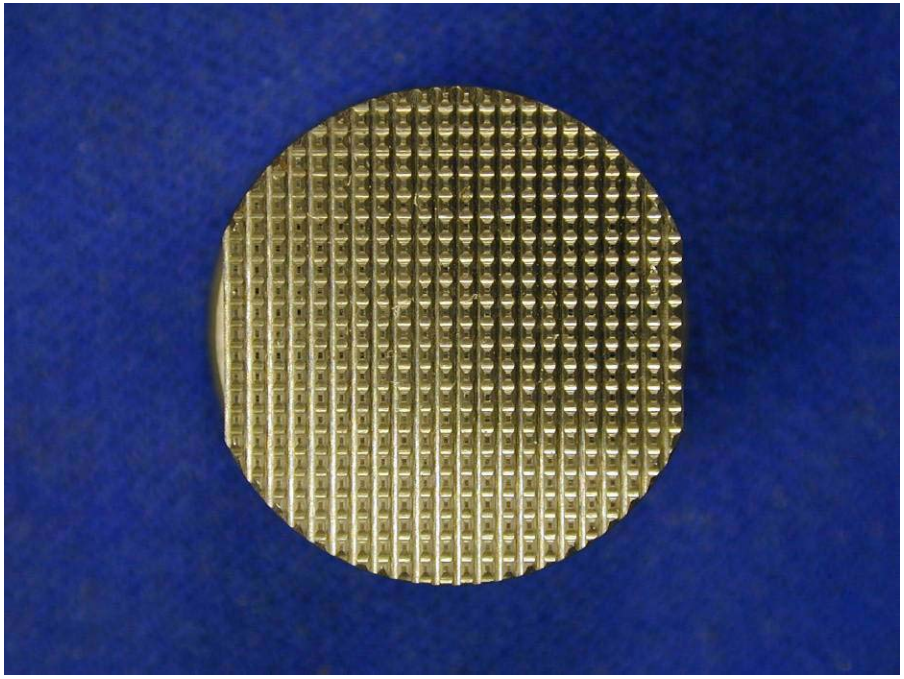


Lateral Drive System

Sheet Metal Welding Tip and Anvil



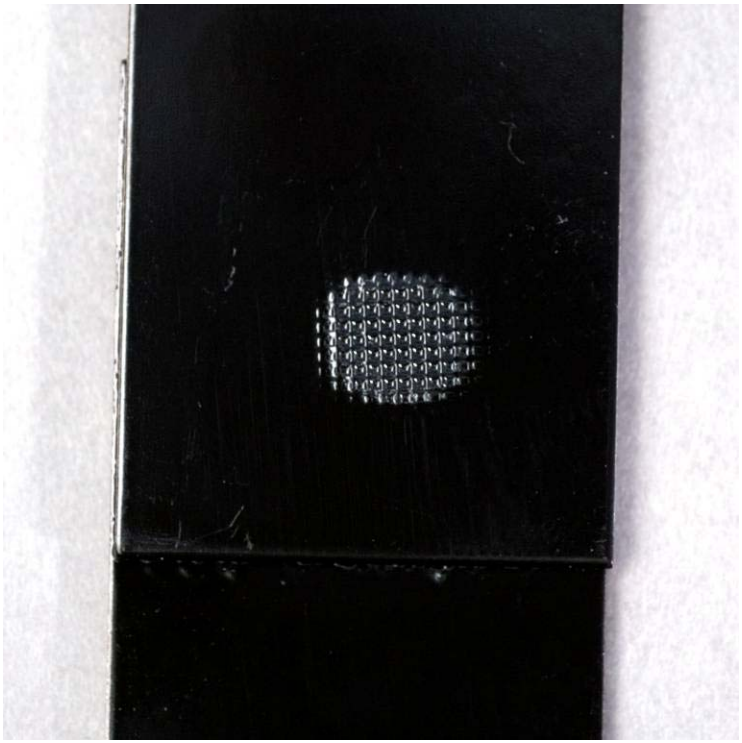
Tip Gripping Surface



Anvil Gripping Surface

Typical Welded Tensile-shear Coupons

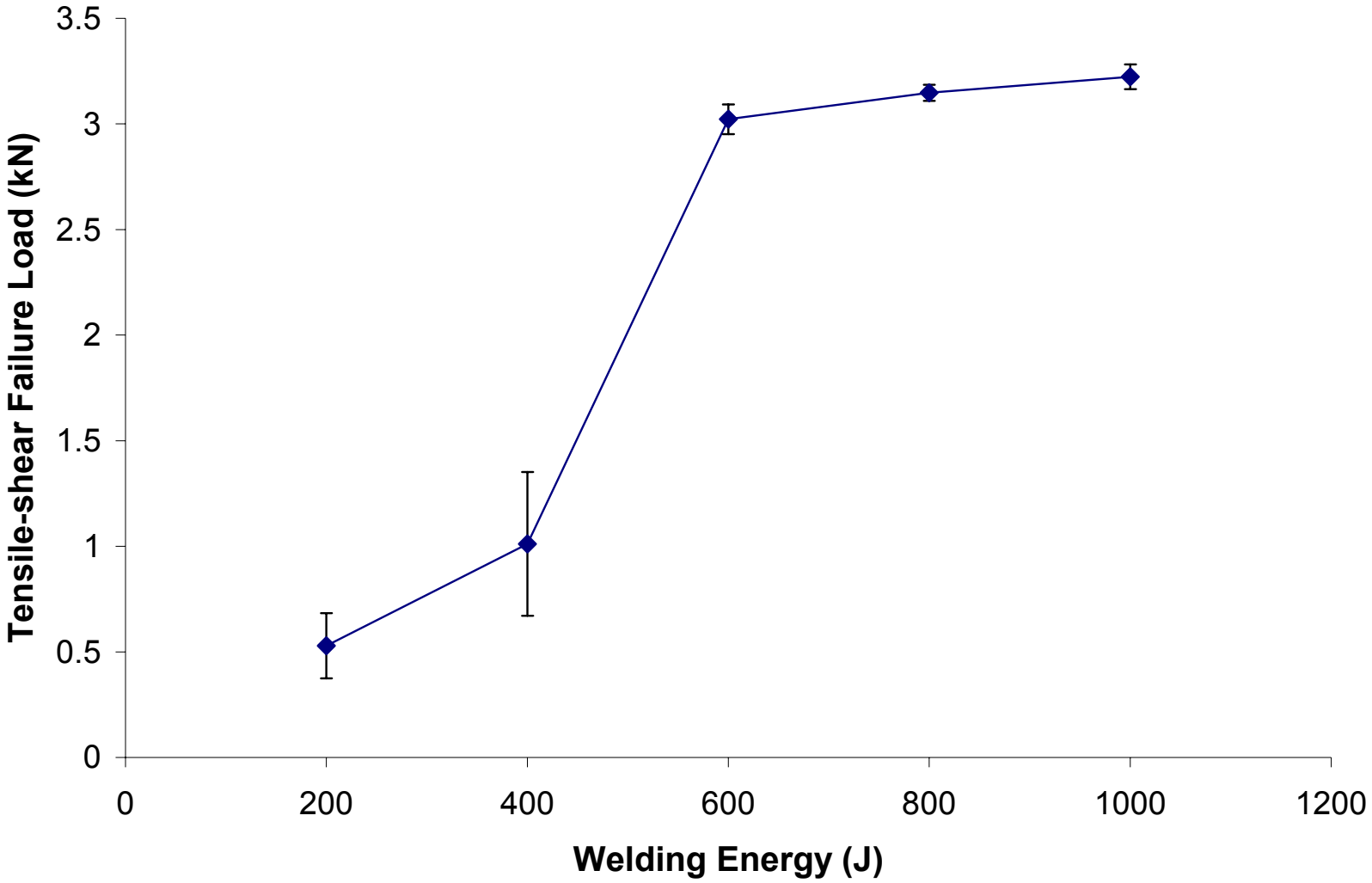
Tip-side Surface



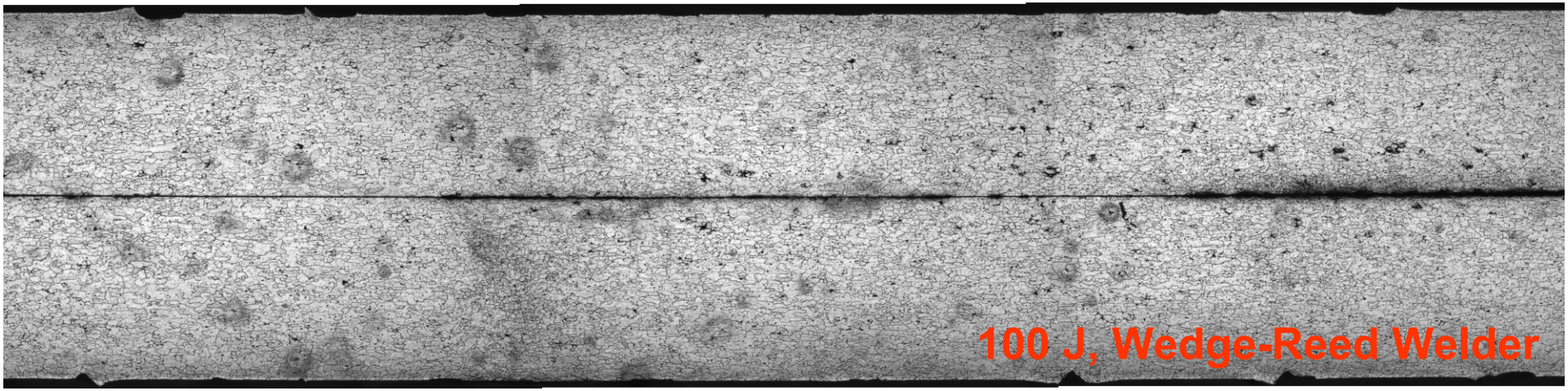
Anvil-side Surface

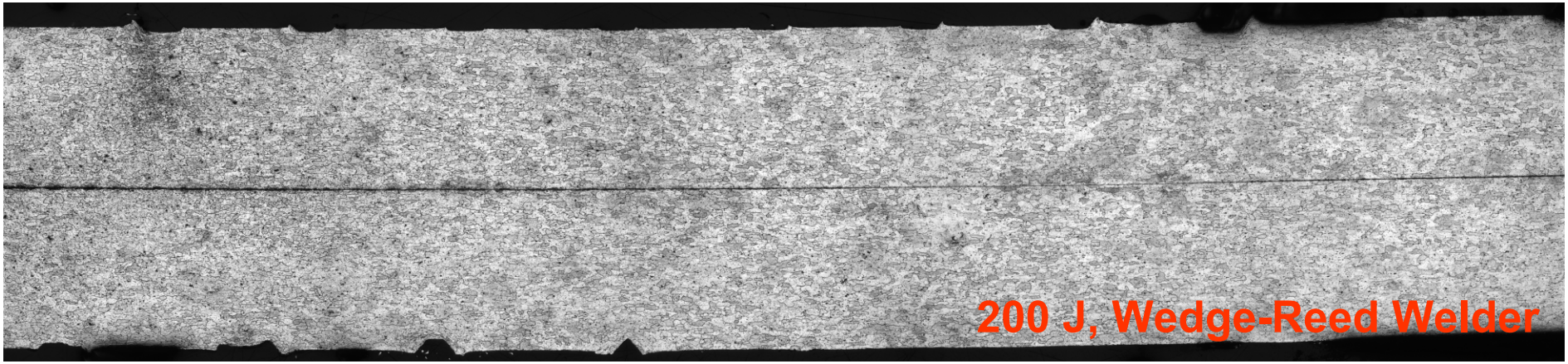
Painted Welded Coupons

How Does the Weld Develop?



How Does the Weld Develop?





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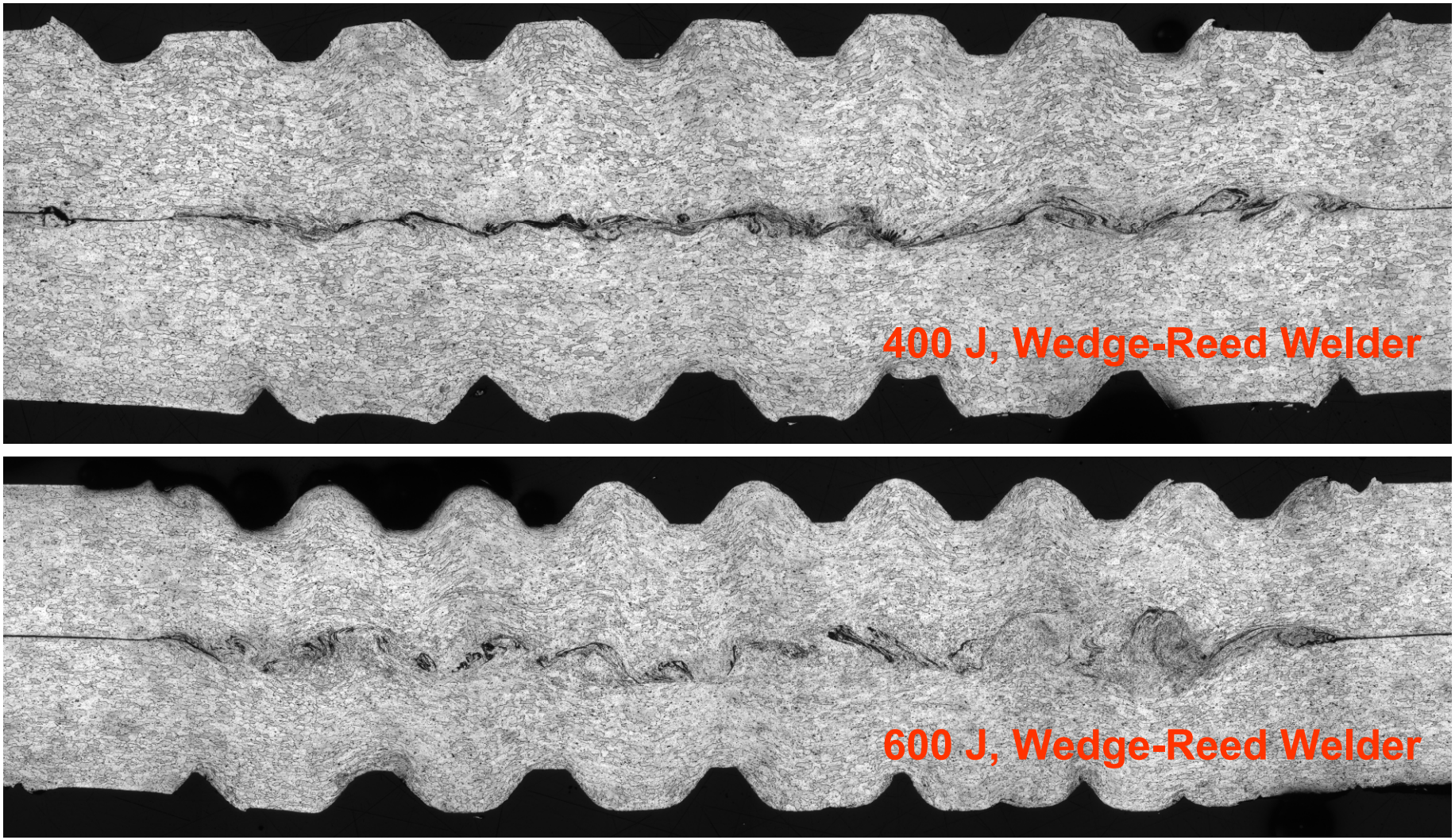
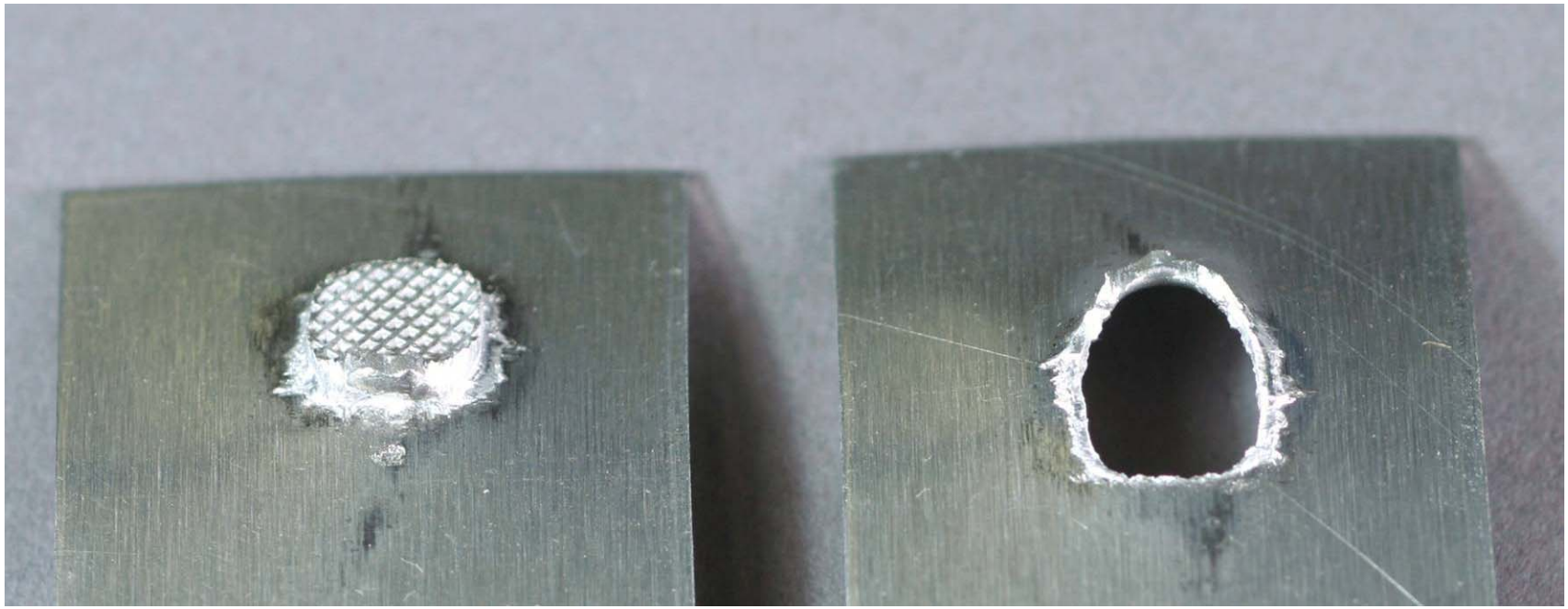


Weld Formation Summary

- 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

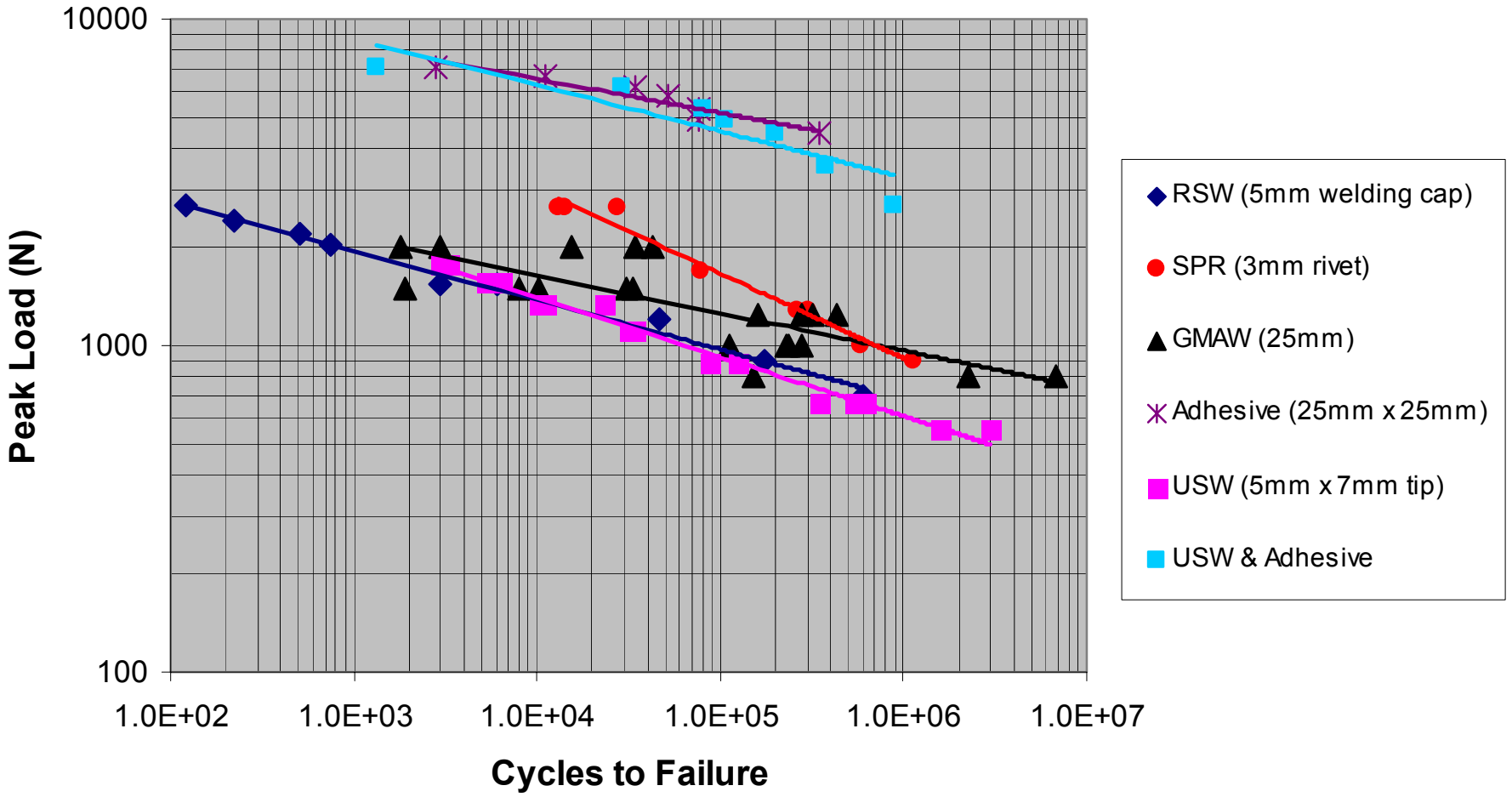


Typical Aluminum Tensile-shear Failure Loads

AA6111-T4 (0.9 mm to 0.9 mm)	**AA5754** (1.0 mm to 1.0 mm)	**AA5754** (3.0 mm to 3.0 mm)
~3.5-3.9 kN	~2.9-3.2 kN	8.0-8.5 kN

(welded with a 5 x 7 mm tip)

Fatigue Performance of Different Joining Technologies

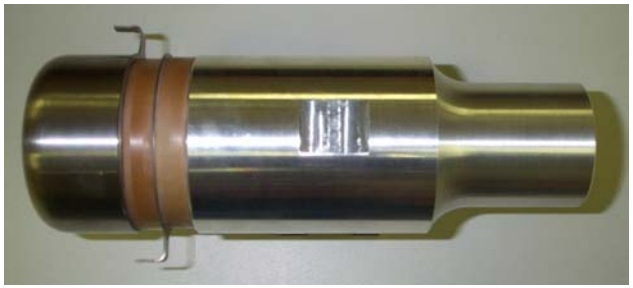


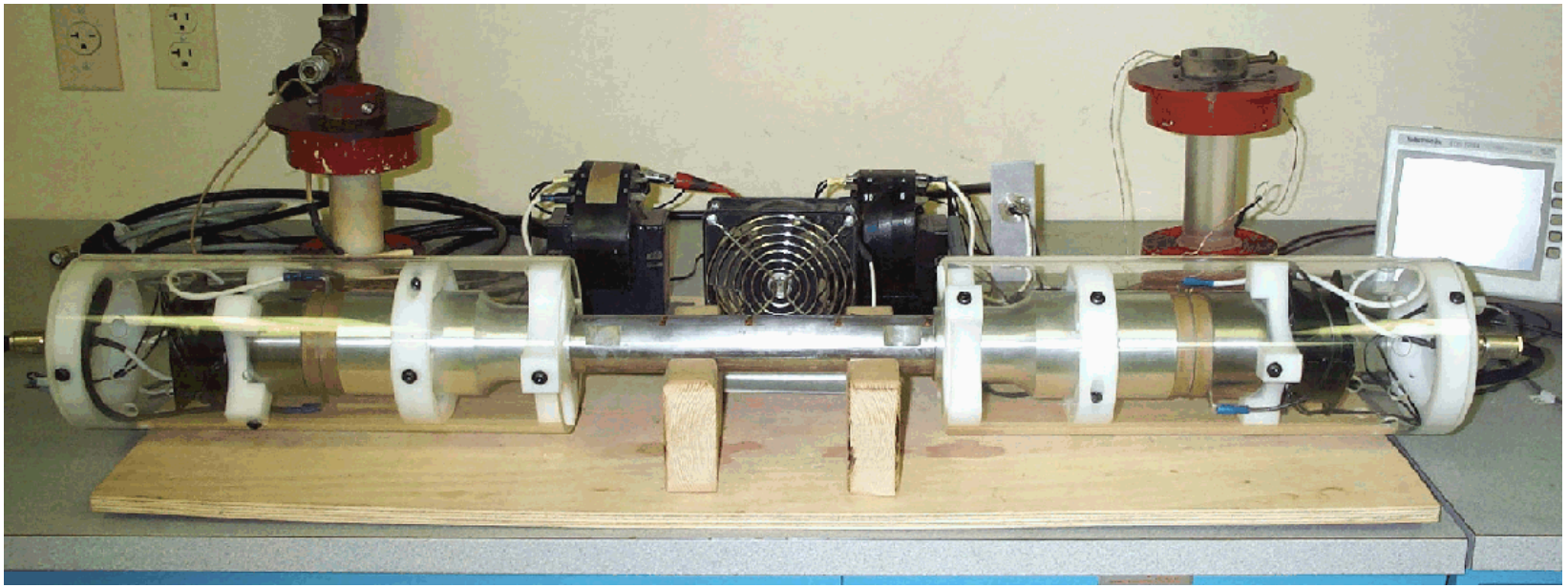
Technical Challenges in Applying Ultrasonic Metal Welding to Aluminum Structures

- 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

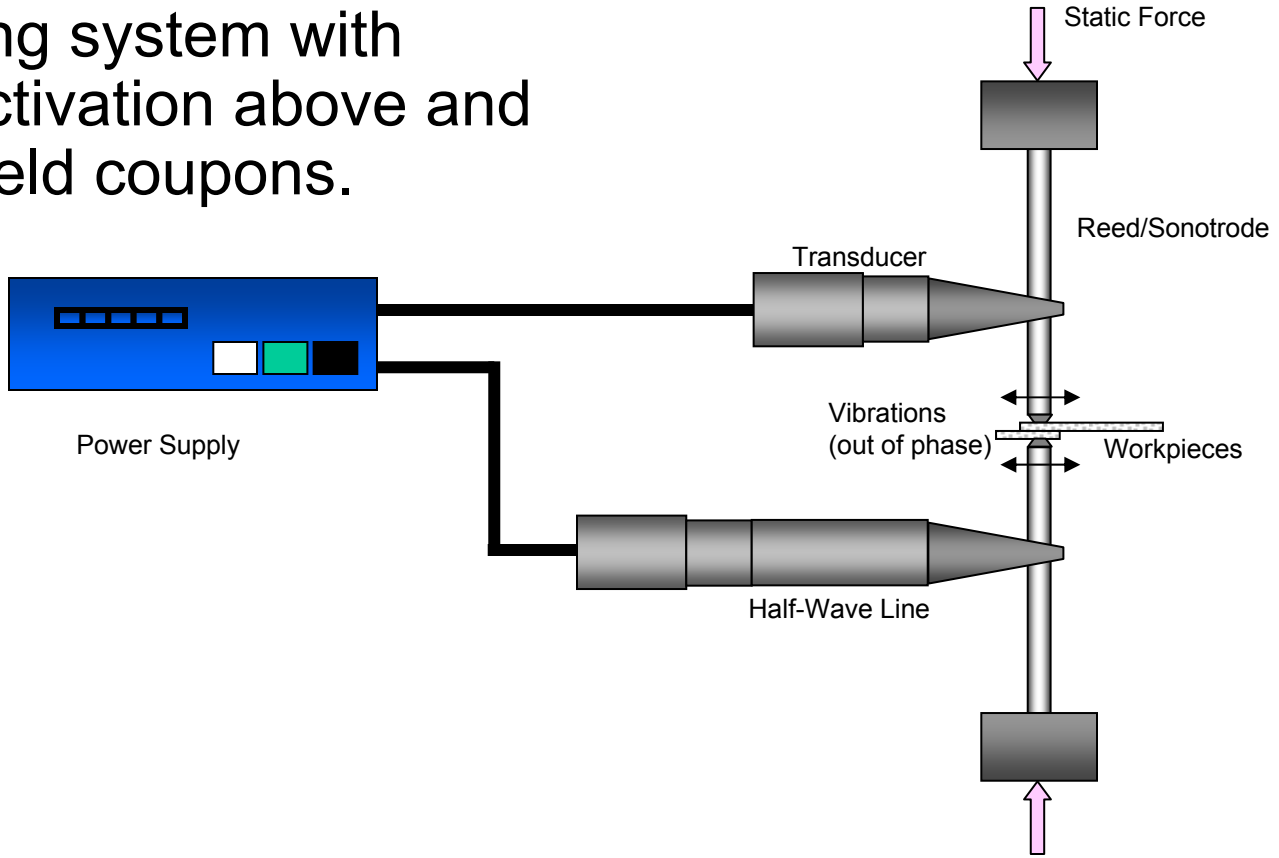
- Sonobond has developed a full wavelength design, 7kW transducer



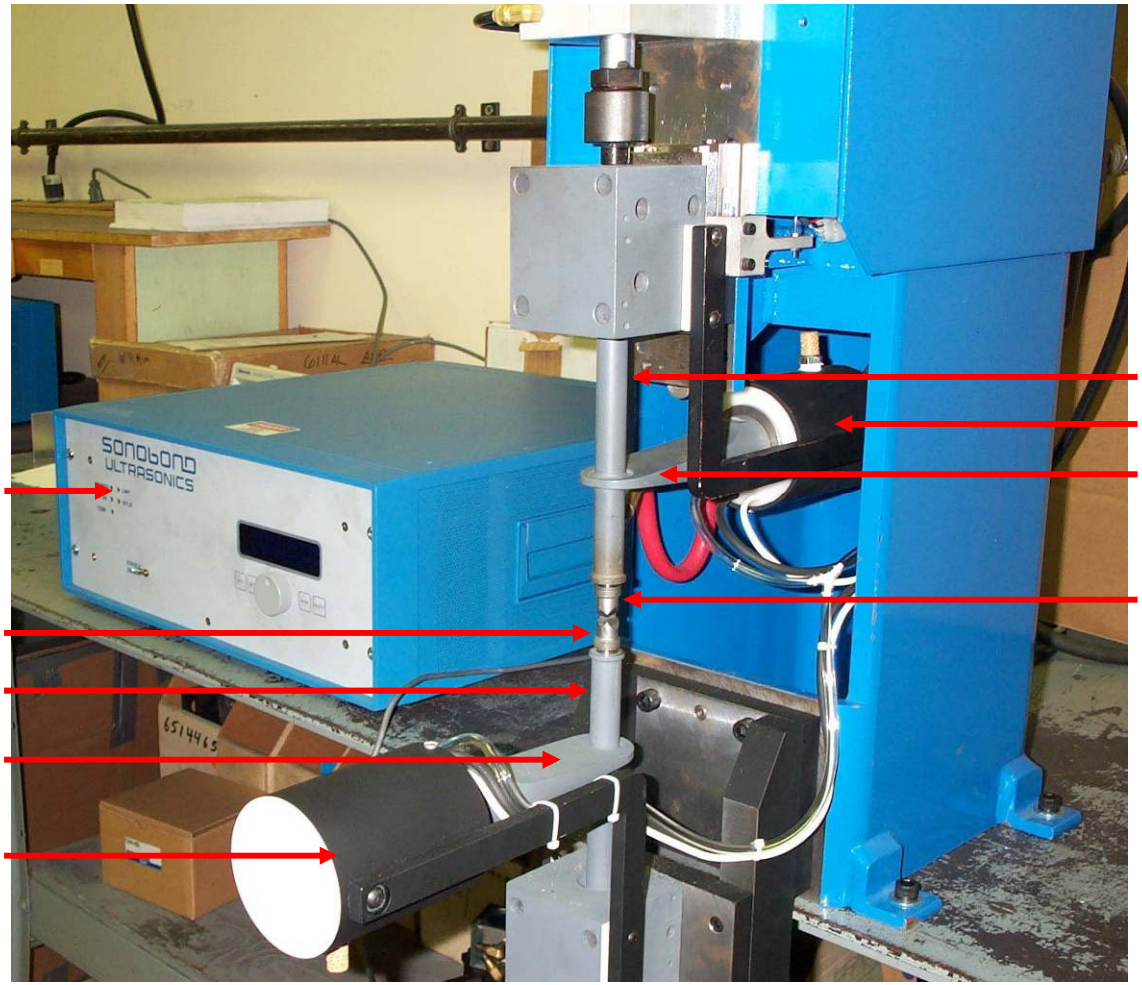


Dual Wedge-reed Welding System

- Sonobond designed and constructed a two-sided over-and under welding system with ultrasonic activation above and below the weld coupons.

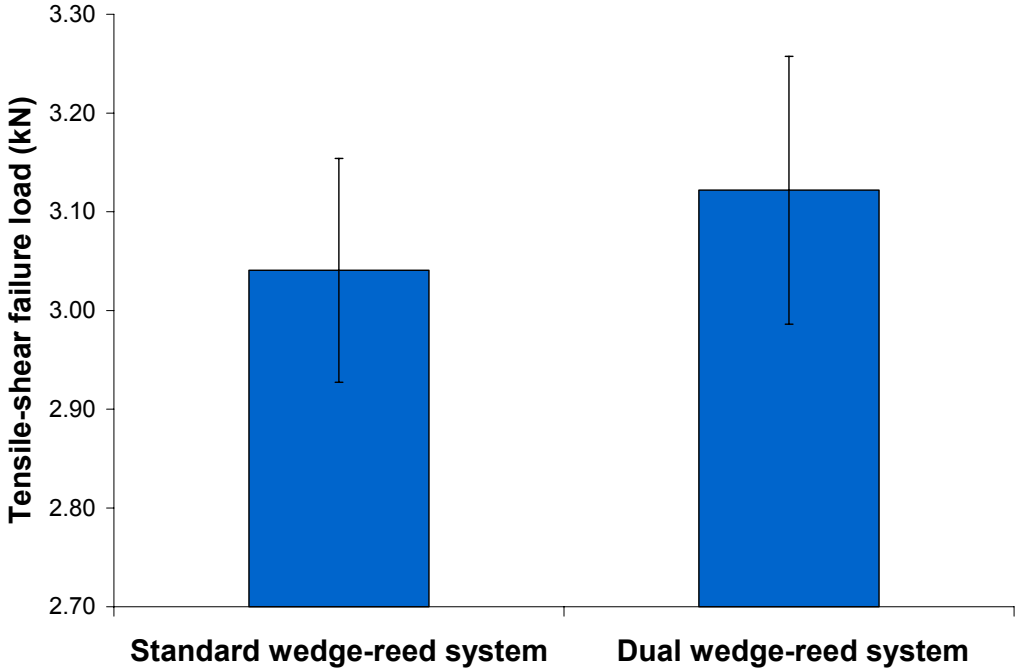


Dual Wedge-reed Welding System



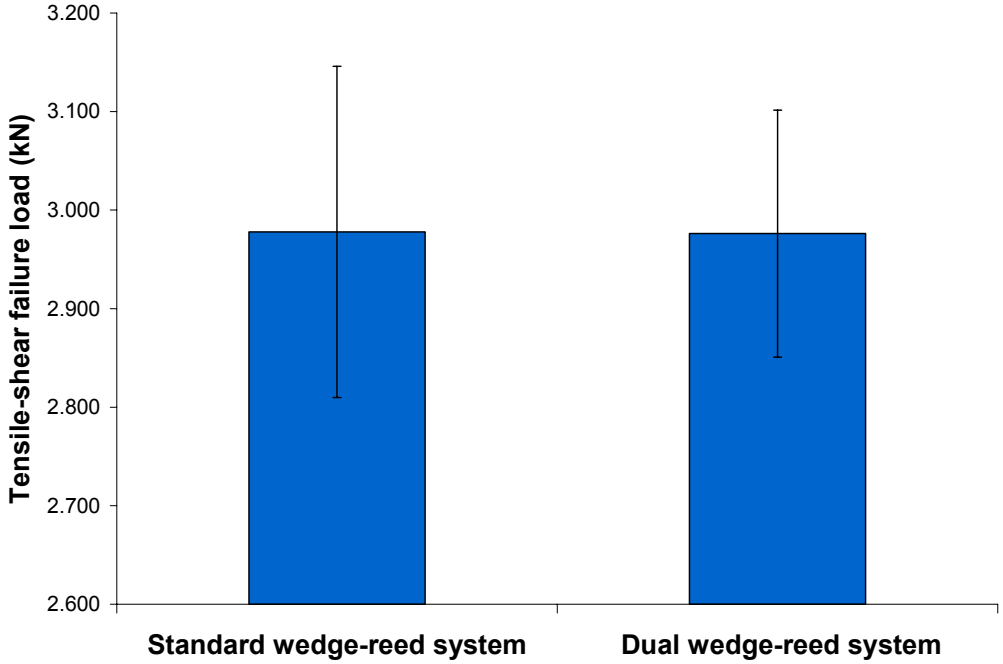
Dual Wedge-Reed Welding System – Results

- 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.

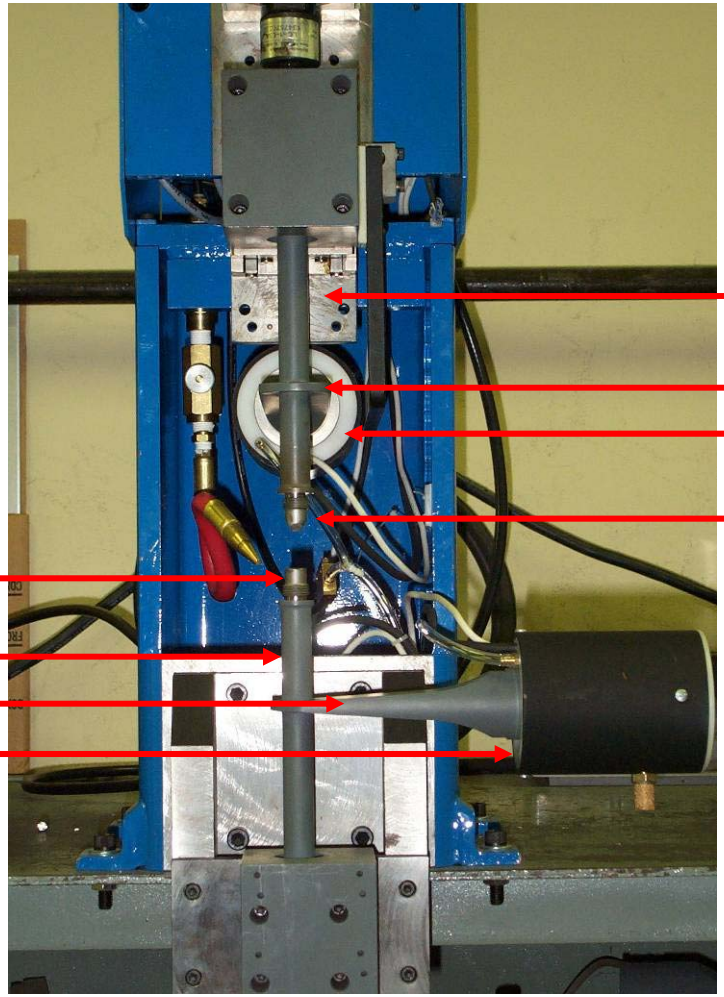


Dual Wedge-reed Welding System – Results

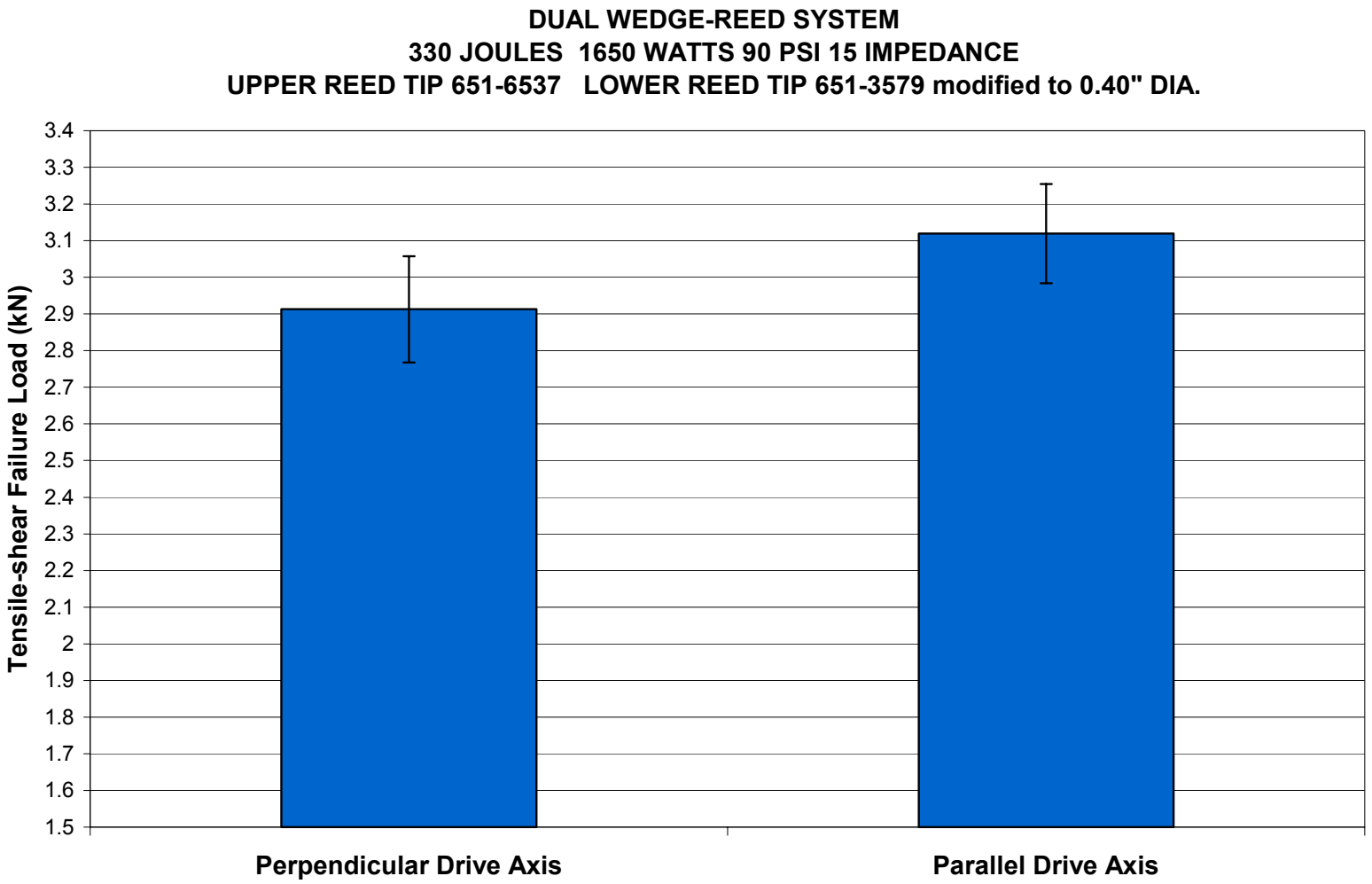
- Welding conducted on 0.9mm AA5754
- Welding parameters:
  - Standard wedge-reed system: 660 J, 2500 W, 90 psi
  - Dual wedge-reed system: 330 J, 1650 W, 90 psi
- As for the AA6111, initial results show a dramatic decrease in the energy required to produce a good quality weld with the dual head system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



Dual Wedge-Reed System with Perpendicular Drive Axes



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



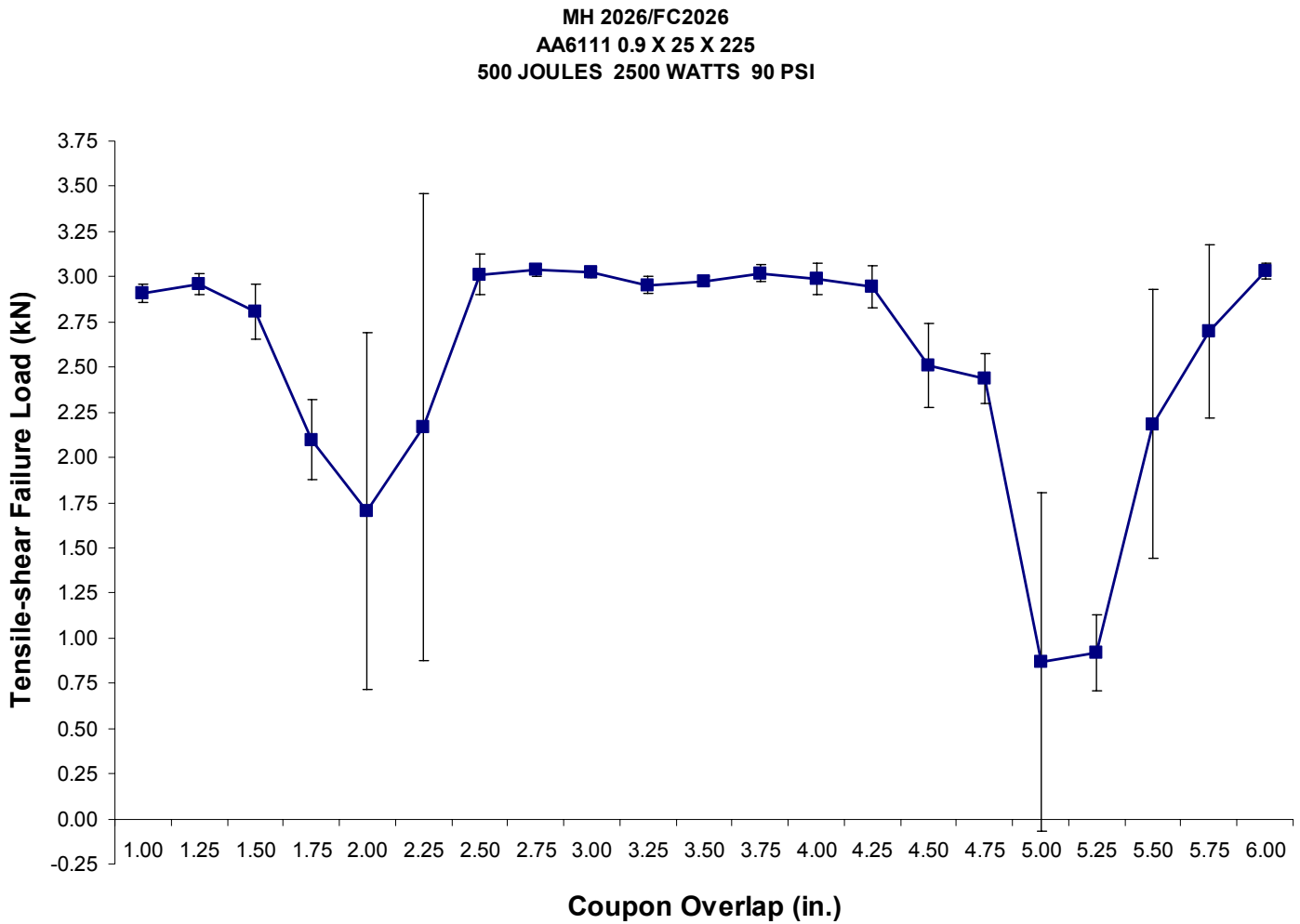
Dual Wedge-Reed System with Perpendicular vs. Parallel Drive Axes

- 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.

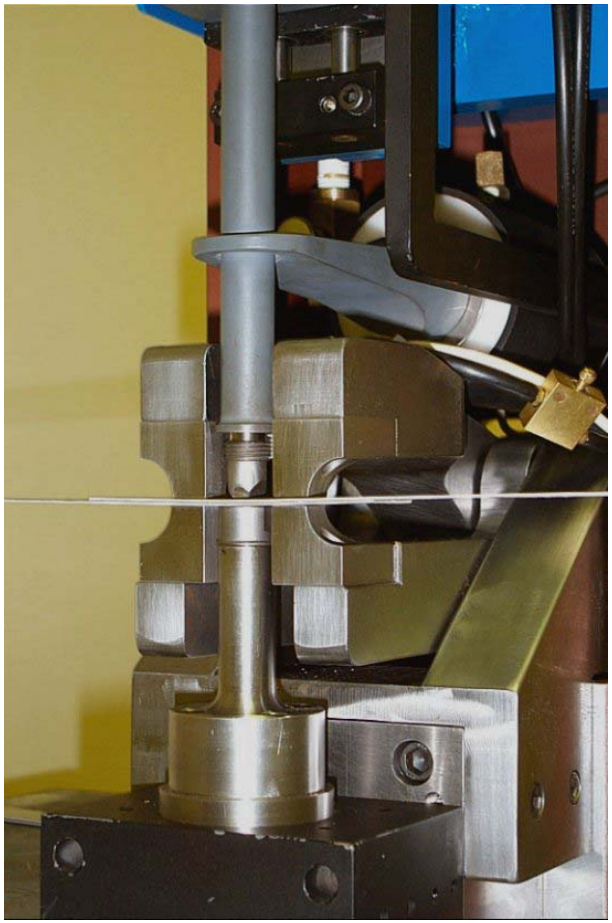
Vibration Control Strategy

- 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.

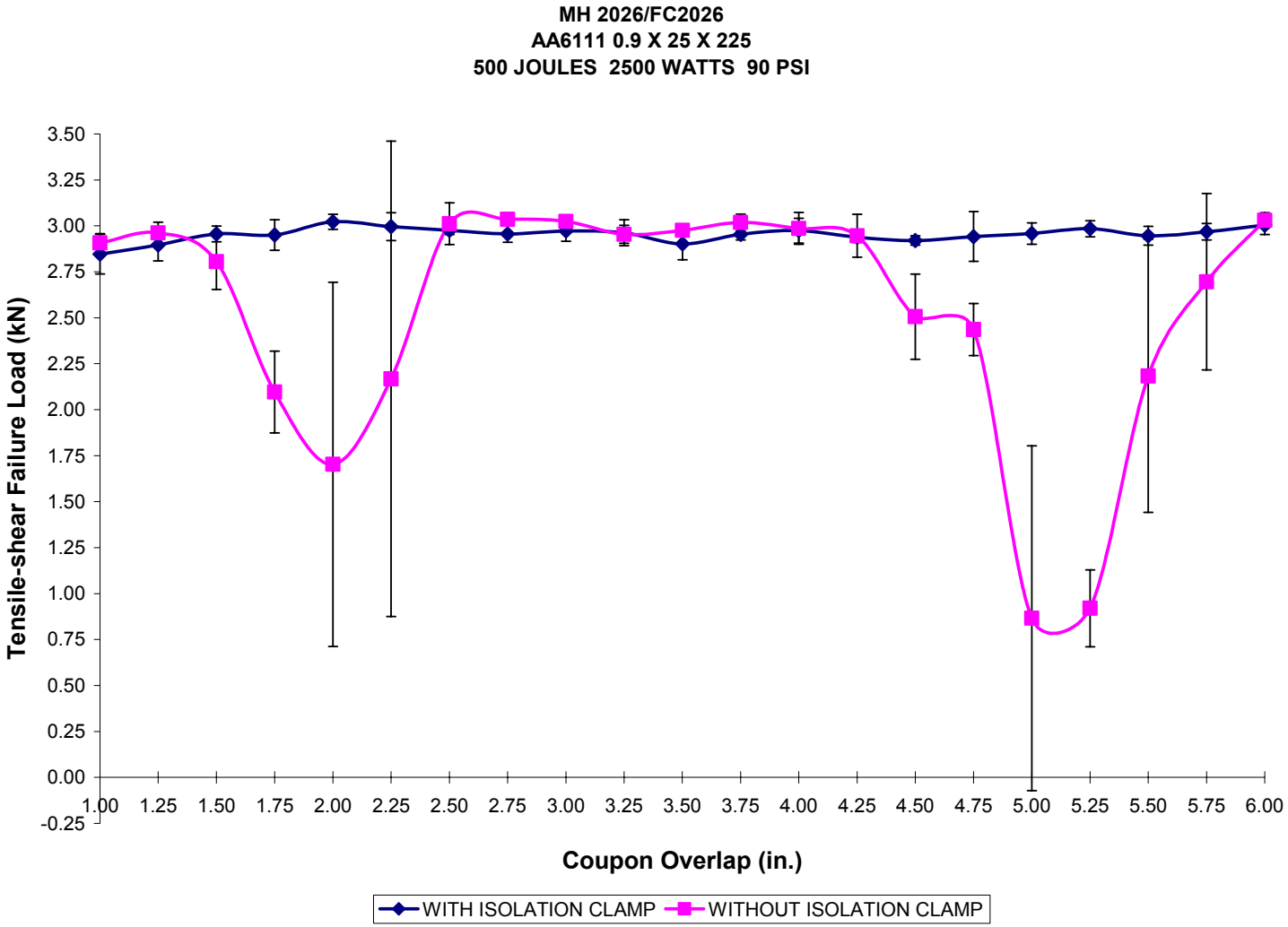
Weld Strength as a function of Coupon Overlap without Clamping



Wedge-reed Welder with Floating Clamp



Weld Strength with and without Clamping



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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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