Common Joining Methods Used in Aluminum Structures

D.J. Spinella – Alcoa Technical Center

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Common Joining Methods Used for Aluminum Structures Agenda

- Introduction
- Trends in Automotive Structures
  - Design
  - Manufacturing Approaches
- Automotive Joining Technology
  - Baseline
  - Joining Technologies
  - Fusion-Based
  - Solid State
  - Mechanical
- Conclusions
- Questions
High Volume Auto Body Evolution

Aluminum Intensive Vehicle
(Strength & ductility for safety, Robust joining)

Steel & Aluminum Hybrid
(High scrap utilization, Steel to aluminum joining)

Multi-Material

Tailoring Products

Aluminum Closures
(Increased formability for design/styling)
Jaguar Land Rover Aluminum Vehicles

- 2013 Jaguar XJ
  Aluminum since 2003

- 2013 Jaguar XK
  Aluminum since 2006

- 2013 Range Rover

- 2013 Jaguar F Type

www.jaguarusa.com
2014 Mercedes-Benz S-Class

Aluminum roof, doors, hood, decklid, rear package shelf, frontend, front subframe

Saved 50 kg using aluminum over the steel body

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014 S-Class BIW Weight</td>
<td>362</td>
</tr>
<tr>
<td>Front Doors (2)</td>
<td>21.8</td>
</tr>
<tr>
<td>Rear Doors (2)</td>
<td>21.2</td>
</tr>
<tr>
<td>Hood</td>
<td>12.7</td>
</tr>
<tr>
<td>Liftgate/Decklid</td>
<td>6.7</td>
</tr>
<tr>
<td>Front Fenders</td>
<td>3.3</td>
</tr>
<tr>
<td>Front Bumper/Other</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total (kg)</strong></td>
<td><strong>434.7</strong></td>
</tr>
</tbody>
</table>

Ref: 2013 Euro Car Body Conference


Automotive Joining – North American Industry Trends

**Today**

**Steel Assembly Line (Single / Multi)**
- Closures: RSW, Laser
- Structures: RSW, Adhesives, MIG

**Aluminum Assembly Line (Single Platform)**
- Closures: RSW, Laser, SPR, Clinch, Friction Spot
- Structures: MIG, Adhesives, SPR, EJOT

**Future State**

**Aluminum Assembly Line (Multi Platform)**

**St / Al Assembly Line**

**St / Al / Hybrid Assembly Line**

**Can you process multiple materials down the same flowpath?**

**Multiple Al Platforms**

**Steel or Al Vehicle**

**Steel, Al or St/Al Hybrid Vehicle**

- Moving to aluminum intensive vehicles requires separate pieces of capital in addition to assets in place for steel vehicles
- Several aluminum joining technologies not considered as flexible to product changes as those employed for steel

- Can you process multiple materials down the same flowpath?
Automotive Joining Today – Steel Sheet RSW

- 3k to 5k resistance spot welds per vehicle in galvanized sheet steels
- **Gauge Ranges**
  - 0.6 to 1.0mm (closures)
  - 1.2 to 2.5mm (structural)
- **Cycle Time:** 1.5 – 2.0 sec/weld to weld
- **Costs**
  - Capital
  - Electrodes (~$0.0003/weld)
  - Labor, Electricity, Water Cooling
- Robotic RSW is well entrenched
  - Extensive integrator & supply chain
  - AWS, ISO, JIS weld specifications
  - Decades of data & experience
  - QA & NDE procedures established
- Weld through lubricants & adhesives
- Very flexible to product changes
Automotive RSW Lines – Flexibility is King

Multiple automotive models flow down single respot lines. Each gun dynamically changes it’s weld schedule to accommodate the multiple stackups for each individual assembly.

Example – Two different auto assemblies run down the same respot line

Gun A welds each assembly in seven locations by electronically changing weld schedules rather than tooling.

RSW process flexibility enables OEMs to make gauge or product changes without the downtime and capital costs to retool.

<table>
<thead>
<tr>
<th>Stackup Range: 2.3 to 4.6mm</th>
<th>Current Range: 8 to 13kN</th>
<th>Force Range: 3.1 to 6.5kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto 2 Stackup Gauge, mm</td>
<td>Weld Parameters</td>
<td></td>
</tr>
<tr>
<td>Weld #</td>
<td>Sht1</td>
<td>Sht2</td>
</tr>
<tr>
<td>1,2,3</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>4,5</td>
<td>0.9</td>
<td>1.4</td>
</tr>
<tr>
<td>6,7</td>
<td>1.4</td>
<td>1.6</td>
</tr>
</tbody>
</table>

| Auto 1 Stackup Gauge, mm    | Weld Parameters          |                           |
| Weld # | Sht1 | Sht2 | Sht3 | Total | F, kN | T, ms | I, kA |
| 1,2    | 1.0  | 1.6  | 2.6  | 3.7   | 180   | 9.0   |
| 3,4    | 1.0  | 1.6  | 2.0  | 4.6   | 350   | 13.0  |
| 5,6,7  | 1.6  | 2.0  | 3.6  | 5.5   | 280   | 11.0  |
# Aluminum Joining Technologies

## Fasteners & Adhesives
- Adhesives
- Blind Fasteners
- Solid Rivets
- Bolts
- Self-Pierce Rivets
- Clinching
- Flow Drill Screws
- Mechanical Interlock
- Electromagnetic Forming

## Soldering
- Dip
- Furnace
- Induction
- Infrared
- Iron
- Resistance
- Torch
- Wave

## Brazing
- Atmosphere
- Diffusion
- Dip
- Furnace
- Infrared
- Laser
- Resistance
- Torch

## Solid State
- Cold
- Cold Spray / Welding
- Dip
- Diffusion
- Explosion
- Friction
- Friction Stir Seam
- Friction Stir Spot
- Magnetic Pulse
- Ultrasonic

## Resistance
- Resistance Spot
- Weldbonding
- Resistance Seam
- Projection
- High Freq Resistance
- High Freq Induction
- Flash
- Upset, Pressure

## Arc Welding and High Energy Fusion
- Gas Metal-Arc (MIG)
- Gas Tungsten-Arc (TIG)
- Plasma
- Electron Beam
- Laser Beam
- Laser Hybrid GMAW

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**Room Temperature** → 450 °C → 620+ °C (Above Melting Point)
Comparison of Various Joining Processes

- Many welding processes don’t reach the melting point of the material
- Alloy of parent, heat & pressure profile, and filler metal determines
  - Mechanical Properties (tensile, yield, elongation, fatigue)
  - Physical Properties (corrosion, electrical resistivity, color match)

![Diagram showing comparison of various joining processes with temperature and pressure axes.](image-url)
## Competing Technologies vs. Robotic Steel RSW

<table>
<thead>
<tr>
<th></th>
<th>Mechanical Performance</th>
<th>Consumable Cost</th>
<th>Flexibility to Gauge Changes</th>
<th>Gun Accessibility</th>
<th>Aluminum to Steel Joining</th>
<th>High Strength Materials</th>
<th>Surface Pretreatments</th>
<th>Adhesive Compatible</th>
<th>Process Speed</th>
<th>Precision Alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aluminum RSW</strong></td>
<td>Lower</td>
<td>Low</td>
<td>Yes</td>
<td>2 Sided</td>
<td>No</td>
<td>Special Practices</td>
<td>No</td>
<td>Yes</td>
<td>Fast</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Self Pierce Rivet</strong></td>
<td>Good</td>
<td>Yes</td>
<td>Limited</td>
<td>2 Sided</td>
<td>Yes</td>
<td>Special Practices</td>
<td>No</td>
<td>Yes</td>
<td>Fast</td>
<td>Low</td>
</tr>
<tr>
<td><strong>EJOT, Flowdrill</strong></td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>1 Sided</td>
<td>Yes - w/ pilot</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Mod</td>
<td>Mod</td>
</tr>
<tr>
<td><strong>Mechanical Clinch</strong></td>
<td>Lower</td>
<td>Yes</td>
<td>Limited</td>
<td>2 Sided</td>
<td>Yes</td>
<td>Special Practices</td>
<td>No</td>
<td>Yes</td>
<td>Fast</td>
<td>Low</td>
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<tr>
<td><strong>Adhesives</strong></td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>1 Sided</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Fast</td>
<td>Mod</td>
</tr>
<tr>
<td><strong>Blind Fastener</strong></td>
<td>Good</td>
<td>Yes</td>
<td>Yes</td>
<td>1 Sided</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Slow</td>
<td>Mod</td>
</tr>
<tr>
<td><strong>Ultrasonic</strong></td>
<td>Lower</td>
<td>Low</td>
<td>Limited</td>
<td>2 Sided</td>
<td>Limited</td>
<td>Yes</td>
<td>No</td>
<td>Limited</td>
<td>Mod</td>
<td>Mod</td>
</tr>
<tr>
<td><strong>Friction Stir Spot</strong></td>
<td>Lower</td>
<td>Low</td>
<td>Limited</td>
<td>2 Sided</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Limited</td>
<td>Mod</td>
<td>High</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Baseline</th>
<th>Lower</th>
<th>Limited</th>
</tr>
</thead>
</table>

*Image of the page with the table.*
Joining Technology Example

2014 GM Corvette Stingray

- Resistance Spot Welding
- EJOTS (Flow Drill Screws)
- Laser Beam Welding
Aluminum sheet is spot welded in several high volume closure applications

Structural applications have been limited to only a few niche vehicles

Issues versus steel RSW

1. *Process consistency (it’s all about surface)*
2. Requires higher capacity welding transformers (2.5X weld current)
3. Questions on process robustness to production conditions (electrode angularity, gaps, etc.)
4. QA and NDE procedures are not as mature
5. Lubricant and adhesive impact on weld quality

Advantages

- Equipment designed to weld aluminum can easily process steel
- Leverages steel RSW infrastructure & logistics
### Aluminum RSW Size, Spacing, Edge Distance & Overlap

<table>
<thead>
<tr>
<th>Metal Thickness (mm)</th>
<th>0.65</th>
<th>0.81</th>
<th>1.02</th>
<th>1.27</th>
<th>1.60</th>
<th>1.80</th>
<th>2.03</th>
<th>2.29</th>
<th>2.54</th>
<th>3.18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Weld Button Diameter (mm)</td>
<td>(4\sqrt{t})</td>
<td>3.1</td>
<td>3.6</td>
<td>4.1</td>
<td>4.6</td>
<td>5.1</td>
<td>5.3</td>
<td>5.7</td>
<td>6.1</td>
<td>6.4</td>
</tr>
<tr>
<td>Recommended Weld Button Diameter (mm)</td>
<td>(5\sqrt{t})</td>
<td>3.8</td>
<td>4.3</td>
<td>4.8</td>
<td>5.3</td>
<td>6.1</td>
<td>6.6</td>
<td>6.9</td>
<td>7.2</td>
<td>7.6</td>
</tr>
<tr>
<td>Minimum Weld Spacing (mm)</td>
<td>9.5</td>
<td>12.7</td>
<td>15.9</td>
<td>19.0</td>
<td>22.2</td>
<td>25.1</td>
<td>31.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Edge Distance (mm)</td>
<td>5.6</td>
<td>6.4</td>
<td>7.9</td>
<td>9.5</td>
<td>11.1</td>
<td>12.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Overlap (mm)</td>
<td>11.1</td>
<td>12.7</td>
<td>14.3</td>
<td>15.9</td>
<td>19.0</td>
<td>20.6</td>
<td>22.2</td>
<td>23.8</td>
<td>25.1</td>
<td>28.6</td>
</tr>
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</table>

Ref: AA Welding Aluminum, Table 13.1
## Parameter Guidelines for RSW Aluminum Sheet

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Metal Thickness (mm)</th>
<th>0.60</th>
<th>0.80</th>
<th>1.00</th>
<th>1.30</th>
<th>1.60</th>
<th>1.80</th>
<th>2.00</th>
<th>2.30</th>
<th>2.50</th>
<th>3.20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radius (mm)</strong></td>
<td>Radiused</td>
<td>50.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>152.4</td>
</tr>
<tr>
<td></td>
<td>Truncated</td>
<td></td>
<td>76.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Electrode Diameter (mm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15.9</td>
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<tr>
<td><strong>Electrode Face Diameter (mm)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.2</td>
</tr>
<tr>
<td><strong>Angle (Degree)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td><strong>Weld Force kN (lbs)</strong></td>
<td>Radiused</td>
<td>3.6</td>
<td>4.0</td>
<td>4.5</td>
<td>5.3</td>
<td>6.2</td>
<td>7.1</td>
<td>8.0</td>
<td>10.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Truncated</td>
<td>2.2</td>
<td>2.5</td>
<td>2.7</td>
<td>3.1</td>
<td>3.8</td>
<td>4.1</td>
<td>4.6</td>
<td>5.1</td>
<td>5.6</td>
<td>7.1</td>
</tr>
<tr>
<td><strong>Weld Time</strong></td>
<td>Number of 60Hz Cycles</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DC Welding Current kA RMS</strong></td>
<td>As Received Surface</td>
<td>20</td>
<td>22</td>
<td>23</td>
<td>26</td>
<td>30</td>
<td>32</td>
<td>35</td>
<td>37</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Mechanical and/or Chemically Cleaned Surface</td>
<td>21</td>
<td>24</td>
<td>25</td>
<td>27</td>
<td>31</td>
<td>33</td>
<td>36</td>
<td>38</td>
<td>41</td>
<td>51</td>
</tr>
</tbody>
</table>

Ref: AA T10, Table 7
TSS Performance of AL Resistance Spot Welds

![Graph showing the relationship between MINIMUM SHEAR TENSION STRENGTH (kN) and THICKNESS (mm).]

- 386 MPa and above
- 240 MPa to 385.9 Mpa
- 135 MPa to 239.9 Mpa
- Below 135 Mpa

**Typical Auto Alloys**

AWS D17.2:2007 Aluminum Tensile Shear Strength
Gas Metal Arc Welding - GMAW

- Wire feed rolls
- Consumable electrode wire
- Shielding gas
- Arc plasma
- Weld metal
- Base metal
GMAW – Advantages and Disadvantages

Advantages
- Can be used manually and automatically
- Suitable for welding most joint types
- Applicable to joining various thicknesses \((\geq 1.5\ \text{mm})\) and thickness combinations
- Lends itself to automation with mechanized straight-tracks and robots
- Good travel speeds - 0.5 to 1.5 m/min

Disadvantages
- Sensitive to variations in joint gaps and lateral positioning of the joint edges, relative to the welding torch
- More prone to formation of weld porosity than GTAW
- Can be used in the flat downward, horizontal, vertical, overhead and intermediate welding positions
- Not as “fine” to control as GTAW
- May require parts to be cleaned of lubricants and contaminants
Laser Beam Welding - LBW

- Laser beam
- Plasma
- Filler material
- Processing gas
- Vapor capillary
- Workpiece
- Melt
- Weld track

$V_s$
Laser Beam Welding – Advantages and Disadvantages

**Advantages**

- Higher welding speeds of travel on thin sections
- High penetration/width ratio of welds
- Strong welds with UTS joint efficiency >90% in some alloys
- Precise heat input which leads to narrower weld beads, heat-affected zones and distortion
- Welds Lap-Penetration and Square-Butt joints
- Can maximize system utilization by switching between continuous and stitch welding modes
- Can be readily automated using robot or gantry systems
- Ready beam-sharing between different stations and/or use with Hybrid welding processes (e.g., GMA/Laser) of 6xxx

**Disadvantages**

- Certain alloys will require a filler alloy
- Joint fitup and precision
- Capital costs
Solid-State Welding – Key Characteristics

- Surface oxides must be removed / displaced / dispersed so that parent metals come into direct contact
- Combinations of heat, pressure & time
- Deformation may be present
  - Plasticized materials displace oxides, pressure allows intimate contact resulting in metallurgical bonding
- Temperatures below material’s melting point
  - Allows dissimilar material combinations (AL to ST, AL to CU) since intermetallics are not generated
  - *If temperatures above melting*, molten metals and intermetallics must be expelled for good properties.
Solid-State Joint Configurations

- **Butt**
  - Cold
  - Area <0.5in²
  - Single Weld
  - Various shapes
  - Area <30in²
  - Single or Continuous
  - Various shapes
  - Area <60in²
  - Single Weld
  - Round shapes
  - Area <2in²
  - Single or Continuous
  - Various shapes
  - Friction
  - Friction Stir
  - Magnetic Pulse
  - Ultrasonic
  - Explosion
  - Area >100ft²
  - Single Weld
  - Various shapes

- **Lap (Spot or Seam)**
  - Diam <0.25in
  - Single or Continuous
  - Various shapes
  - Diam <0.25in
  - Single or Continuous
  - Various shapes
  - Area <0.5in²
  - Single Weld
  - Various shapes
  - Area <30in²
  - Single or Continuous
  - Various shapes
  - Area <60in²
  - Single Weld
  - Round shapes
  - Area <2in²
  - Single or Continuous
  - Various shapes
  - Various shapes

Advancing each generation.
Ultrasonic Welding Process

Ultrasonic Welding – Advantages and Disadvantages

**Advantages**

- Low # Process Inputs
- Low heat distortion
- Low heat-affected zone
- Weld through lubricants
- Surface preparation not critical
- Excellent electrical joint properties
- Low energy joining process
- No arcs & fume emissions (clean)
- 2 to 3 second cycle times
- Bimetallic combinations
- No water cooling or filler materials

**Disadvantages**

- Thickness limited to approx. < 3mm
- Difficult for deep parts (throat depth)
- Requires good workpiece alignment

**Applications**

- Electrical Wiring
- Light gauge sheet joining
- Sheet to wire joints
- Bimetallic, multi-material joining
- Products in consumer, industrial, auto, defense, and aero
Ultrasonic Process Variables and Mechanical Performance

- Major Process Variables
  - Vibration Amplitude (Microns), Force (Pressure), Time, Tool Geometry
- Weld Energy = Power * Time = (Amplitude * Force) * Time
  - Increased Power or Time necessary with part contamination or tool wear

Advantages

- Good mechanical properties
- Minimal weld induced distortion
- Full or partial penetration from one side
- Square butt & lap-penetration type joints
- High quality welds involving fewer repairs and rejects
- No filler alloy addition & shielding gas
- Very simple to operate and maintain
- Welds aluminum alloys normally considered non-fusion weldable (e.g., 7050, 7075)

Disadvantages

- Requires good fitup and clamping systems
FSW Joint Types

Retreating Side

Advancing Side

Ideal for FSW

Square-Butt

Challenging

Lap-Penetration

Highly specialized

Lap-Fillet

Part A

Part B
FSW versus GMAW Property Comparison: 6061-T6

Mechanical Property

Strength (ksi) or elongation (%)

Tensile Strength  |  Yield Strength  |  % Elongation

Base Metal  |  Friction Stir Weld  |  GMA Weld

Strength (ksi):
- Base Metal
- Friction Stir Weld
- GMA Weld

Elongation (%):
- Base Metal
- Friction Stir Weld
- GMA Weld
Friction Stir Spot Welding

Advantages

- Replaces RSW and mechanical fastening joints
- Minimal weld induced distortion
- Stitch and refill variants
- Low consumable & infrastructure costs (low electricity, no chilling water)
- Welds aluminum alloys normally considered non-fusion weldable (e.g., 7050, 7075)

Disadvantages

- Cycle time for thick stackups
- Switching between different stackups and material combinations

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Arul et. al., “Effects of Surface Treatment (Lubricant) on Spot Friction Welded Joints Made of 6111-T4 Aluminum Sheets”, SAE Paper 2007-01-1706
Friction Spot Welding Fatigue Performance – 0.94mm 6111-T4

Friction Welding Process - Direct Drive

Position, Clamp, & rotate parts

Advance non-rotary part, start pressure

Heating

Forge / Upset

Single part rotates to desired speed

Force pushing parts, increasing frictional heat

Rotation and force applied for a specific period

Flash-off

High forging force applied
Friction Welding – Advantages & Disadvantages

**Advantages**
- Low Number Process Inputs
- Low heat distortion
- Good joint properties (low heat-affected zone)
- Weld through lubricants
- Surface preparation not critical
- Excellent joint properties
- Low energy joining process
- Clean process - no arcs and fume emissions
- Fast second cycle times
- Bimetallic combinations
- No water cooling or filler materials required

**Disadvantages**
- Equipment may be capitally intensive
- Requires good workpiece alignment

**Applications**
- Automotive driveshafts
- Suspension rods, axles
- Bimetallic joining
- Products in Auto, Defense, Aero
Mechanical Fastening: SPR – Self-Piercing Rivet

Factors for SPR Joint Design

- Total Stack-Up Thickness
  - Determines rivet length
- Flange or Overlap Width
- Edge Distance
- Tool Clearance
- Materials being Joined
  - Aluminum
  - Steel
  - Multi-Materials (Hybrids)

Stack-up / Orientation

- Softer (top) to Harder (bottom)
- Thick to thin, thin should be no less than 1/3t of the thicker

Rivet Diameter

- 3 mm or 5 mm
  - Joint strength
  - Robustness of joint
  - Access

Rivet Length

- 3 mm rivet, 1.5 - 3.0 mm > than stack
- 5 mm rivet, 2.0 - 4.0 mm > than stack
Mechanical Fastening: SPR – Self-Piercing Rivet

6111-T4 Alloy

Lap Shear Tensile Strength, N,

1 mm to 1.5 mm Material

1.5 mm to 1.5 mm Material
1. FLOW DRILLING SCREW (FDS) is applied to surface with medium thrust and spindle rotation.
2. As friction and heat increases, the surface plasticizes and begins to “flow“.
3. Material begins to form the extended threading are behind the application.
4. As the flow phase ends the ‘thread rolling‘ phase begins with lower RPM on the spindle.
5. The screw now begins to act like a normal fastener and is driven to a torque.
6. The fastener is seated as it would be in any normal torque strategy. As the materials cool it also contacts around the threads for added joint integrity.
TOX Clinching Process

Material Stack-up / Orientation
- Preferable to have thicker or harder material on punch side
- Minimum single sheet thickness of 0.3 mm (depend on TOX diameter)
- Maximum combine thickness is 8 mm (depend on TOX diameter)
- Total stack-up of 2 to 4 layers possible

TOX diameters
- Available in 3, 4, 5, 6, 8, 10, and 12 mm button diameters
Mechanical Fastening: TOX Mechanical Clinch

TOX Joint Strength

Effect of Button Diameter
1mm : 1mm 6111-T4 Joints

- Pull Strength
- Shear Strength

Effect of Alloy
with 8 mm TOX

- Pull Strength
- Shear Strength

Alloy / Gauge Combination
1mm:1mm 6111-T4
1mm: 2mm 5754-0
Aluminum Automotive Joining Applications
Friction Stir Welded Suspension Link for Lincoln Town Car

www.aluminum.org

6061 Extrusions
Jaguar XJ

- Pretreated aluminum sheet
- 40% lighter, 60% stiffer than previous steel-body XJ

Stamped sheet panels assembled with adhesive bonding in combination with self-pierce riveting

Audi A2

http://www.autoaluminum.org/

• 30 meters of laser welds


Aluminum Association’s Aluminum Welding Seminar, 2003
Automotive Closure Panel RSW Applications

Ford Explorer
AL hood and fenders
www.ford.com

General Motor’s Yukon
AL liftgate
www.gm.com

Nissan Altima
AL hood and decklid
www.nissanusa.com

Acura MDX
AL hood
www.acura.com

DaimlerChrysler Pacifica
AL hood
www.chrysler.com
Automotive Closure Panel Mechanical Fastener

Chrysler Concord
AL hood (SPR, TOX)

www.chrysler.com

GM U-Van (Venture)
AL hood (TOX)

www.gm.com

Plymouth Prowler
SPR body and panels

www.chrysler.com
Mazda RX-8 – Friction Stir Spot Weld
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Advancing each generation.