

# **You Can't Spot Weld Aluminum or Magnesium.... or can you?**

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# Why Weld Aluminum and Magnesium?

- **Light weight structures need low density materials**
  - **Low carbon steel**            **7.85**        **grams/cc**
  - **Aluminum alloys**            **2.50-2.80** **grams/cc**
  - **Magnesium alloys**            **1.75-1.90** **grams/cc**
- **Aluminum alloy structures can weigh a third and magnesium alloy structures a fourth that of steel structures, if heat-treated to similar strengths**
  - **Improved gas mileage of automobiles**
  - **Longer flight range of aerospace structures**
- **Welded structures are commonly less expensive, so the weldability of these materials is important**



# Aluminum structures are not commonly welded



- **These aircraft wings and flat-bed truck bodies are riveted**
  - **Welding them would save millions of dollars in manufacturing costs**
  - **But, aluminum alloy welds presently lower load-bearing ability and are not durable in fatigue or corrosion**



# Aluminum car manufacturers typically spot weld and adhesively bond body parts



Photo Ref.  
Aluminum  
[matter.org/UK](http://matter.org/UK)

- **Aluminum car body manufacturers typically find spot welding or adhesive bonding unreliable.**
  - They spot weld through an adhesive and
  - Bake in an oven to adhesively bond in addition! (Expensive!)
  - Spot weld fumes are not environmentally friendly!!



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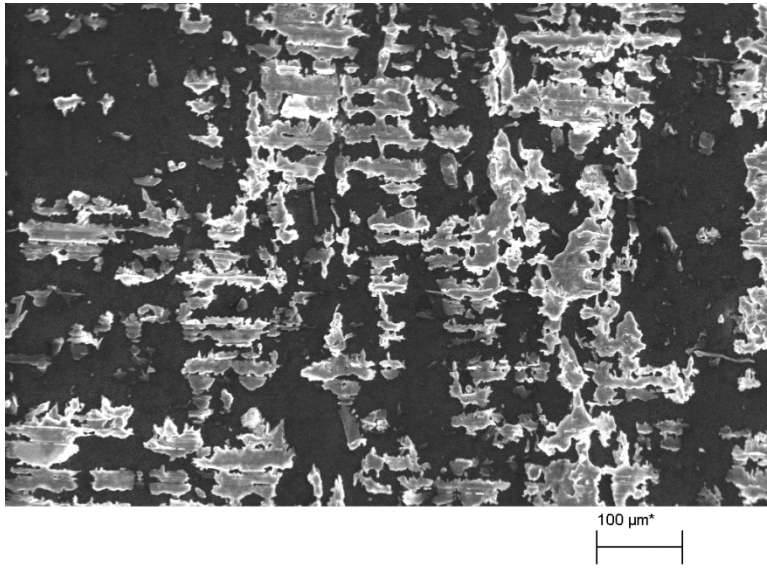
# Typical Aluminum alloy spot welds are not factory-friendly

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- ❑ Lower the strength of the heat-affected zone and the welded structures by nearly 50%
- ❑ Weld electrodes need frequent dressing due to diameter mushrooming and aluminum oxide pick up
- ❑ High strength alloy weld nuggets crack while solidifying
- ❑ Sheets thicker than around 5 mm and thick-thin combinations are very difficult to spot weld
- ❑ Weld quality very sensitive to part cleanliness



# Spot welding magnesium alloys can be hazardous



**Fine spatter dust (commonly finer than 0.1 mm in size) on the surface of a spot welded magnesium alloy part**

**Fine magnesium-alloy spatter-dust generated typically at the spot weld electrode-to-metal interface can be a serious fire hazard**

**it is commonly very difficult to spot weld magnesium alloys without this spatter dust**



# How do we effectively spot weld these two important alloy families?

- Use large water-cooled copper alloy electrodes in contact with parts welded
  - Low electrode wear and aluminum pick-up
  - Stronger welded structures
    - Effective cooling of the HAZs during and after welding
  - No dust or spatter from the electrode-metal interface



Typical 75 mm diameter water cooled copper alloy electrodes for spot welding 6.25 mm thick aluminum alloy plates to result in a spot weld diameter of nearly 20 mm

**IWSL Patent-pending**



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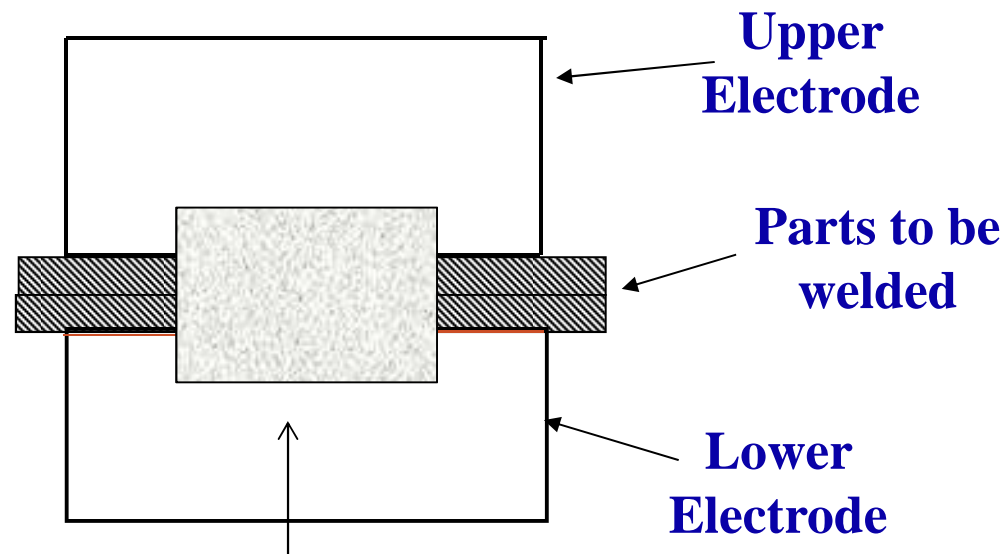
# Focus the weld current to an order of magnitude higher current density

Focused Current  
Resistance Welding  
(FCRW)

aka

*Strong-Al* Welding

**IWSL Patent-pending**



IWSL proprietary mechanism for :

1. **Focusing the weld current** with an order of magnitude higher current density than at the electrode-metal interface
2. **Containing molten metal** expulsion away from the weld joint
3. **Enabling the forging of weld metal** as it solidifies



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# ***Strong-Al (FCRW) spot welds:*** **Much stronger than aerospace quality spot welds**

**Aerospace Quality Spot Welds**

***FCRW Strong-Al Spot Welds***



**6061 T6 Aluminum alloy sheets(1.5 inches \* 0.060 inch)**

- **Very sensitive to surface cleaning prior to welding**
- **Weld strength 700-1300 pounds in a tensile-shear test**
- **Production Quality in a factory is unstable due to electrode wear**

- **Weld quality and strength not sensitive to cleaning prior to welding**
- **Weld strength nearly 50% higher for the same weld size (>2300 pounds)**
- **Stable electrode surfaces and production quality**



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# High Quality thick-thin aluminum alloy welding is enabled



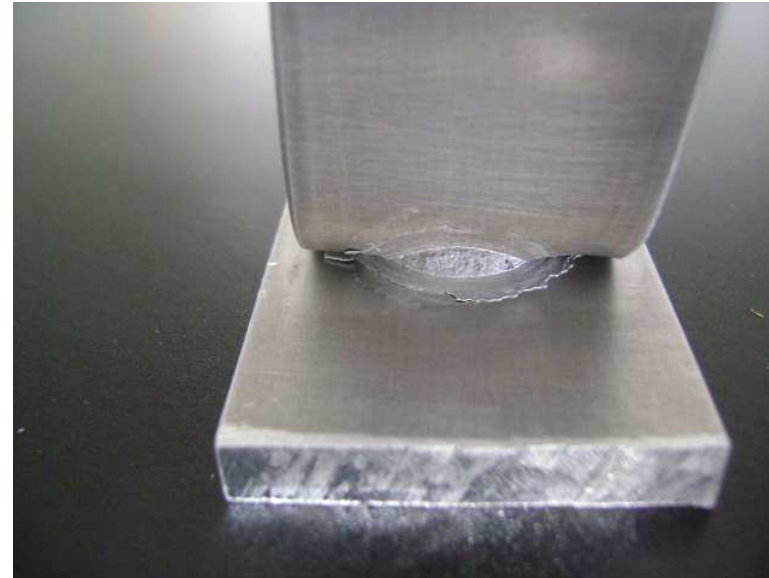
Thin sheet is not thinned during *Strong-Al* welding in a 15% current range and retains 85% of its original hardness versus less than 50% with conventional welding processes



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# Thick aluminum alloy effectively spot welded

Ideal for a crash-resistant Aluminum Impact Bar



The *Strong-Al* weld nugget diameter is around 20 mm  
The weld is very close to the edges in a 6.25 mm thick part  
**New paradigms for a light-weight structure designer!**



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***Strong-Al (FCR) welds are durable:  
Pass fatigue test specified by a flatbed manufacturer***



**6.25 mm  
thick 6061 T-  
6 alloy plate  
FCR welded  
to a 6.25 mm  
thick 5454 H-  
34 alloy plate**



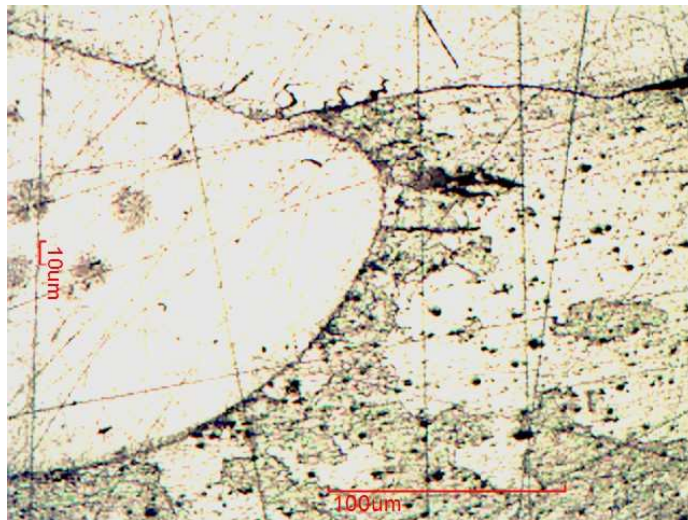
**Pictures of a Strong-Al (FCRW) weld that passed fatigue test requirements of a flatbed manufacturer ( 0 to 1700 pounds @ 1 cycle/sec for 30,000 cycles)**



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# Defect-free Strong-Al weld microstructures in a 5000 series alloy

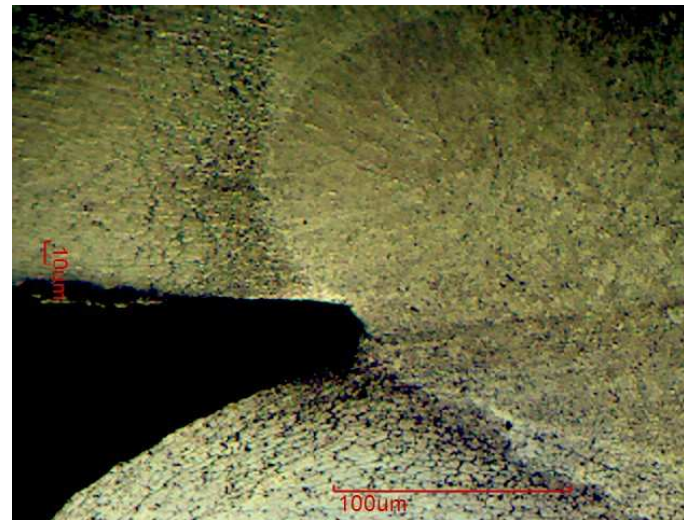
## Conventional Spot Welds



Typical defect-like Indications  
along grain boundaries in the  
HAZ



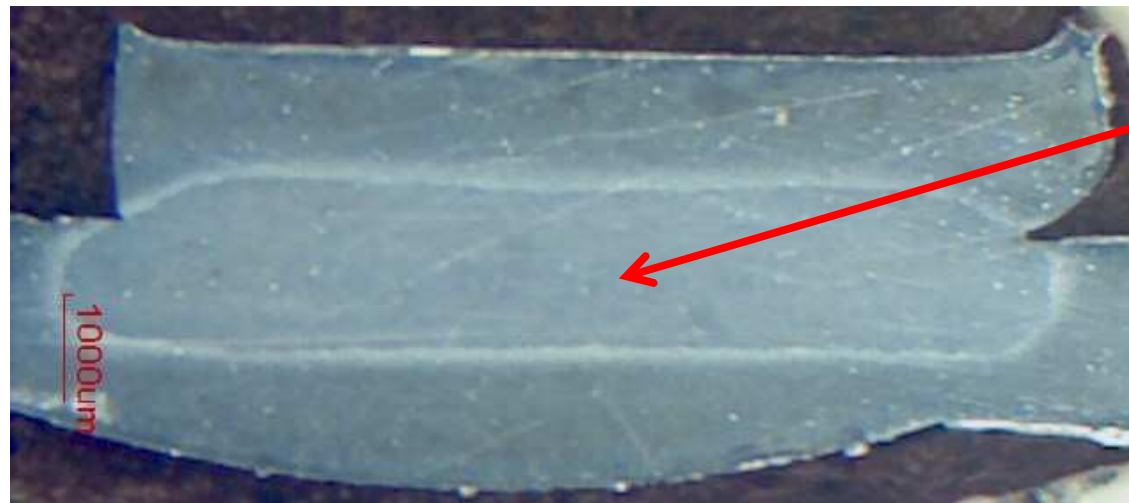
## Strong-Al Spot Welds (FCRW)



Better HAZ microstructures  
and properties as seen from  
peel tested *Strong-Al* weld

The *Strong-Al* weld is  
free from  
crack-like  
indications in  
the HAZ

# *Strong-Al* weld microstructures show non-melted outer surfaces



Weld nugget

Peel tested *Strong-Al* spot weld of 6061-T6 alloy (0.063 inch or 1.6 mm thick)

*Strong-Al* Weld microstructure shows:

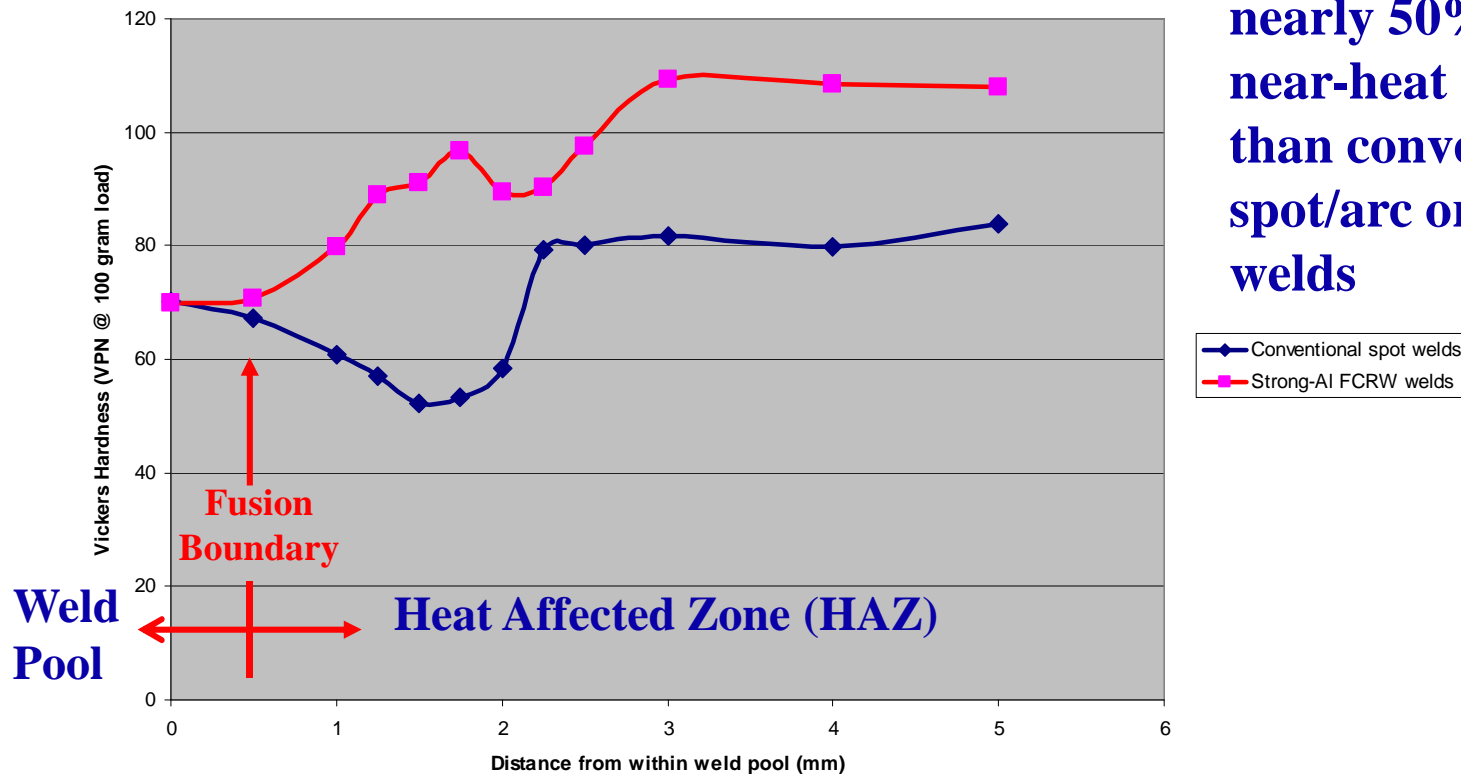
1. Large weld nugget (10 mm diameter) in a thin sheet (1.6 mm)
2. Non-melted outer surfaces **improve the strength and corrosion resistance** of the welded structure



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# Strong-Al welds have higher HAZ hardness resulting in higher strength of the welded structure

Microhardness Traverses Across Strong-Al and Conventional Spot Welds



*Strong-Al Welds are nearly 50% harder in the near-heat affected zone than conventional spot/arc or friction-stir welds*



# ***Strong-Al* spot welding stabilizes high quality**

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- **Stable production conditions in a welding factory through low electrode wear**
  - **Weld electrode contact areas are at least twice the weld nugget areas projected on to the electrodes**
- **Welded structures are nearly 50% stronger for the same weld size and structure design**
  - **The heat-affected zone (HAZ) is cooled during and after welding by a water-cooled copper alloy**
  - **50% harder HAZ microstructures**





## ***Strong-Al* spot welds enable new designs**

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- **Manufacturing or factory-friendly**
  - **Little or no sensitivity to the surface cleanliness of the parts welded**
  - **Weld current ranges of more than 15% without weld metal expulsion**
- **Thick-thin combinations readily weldable**
- **Thick parts (6-8 mm thick) readily weldable**



## **Good *Strong-Al* welds in difficult-to-weld alloys**

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- **Forging during solidification helps reduce weld defects**
  - **High strength aerospace alloys such as 7075 become spot-weldable**
  - **Large nuggets are possible in thin sheet metal**
    - **Nugget diameter to nugget thickness ratios of around 10 readily possible**
  - **Forging further enhances cooling rates enhancing weld structure strength and durability**



# Industrially Safe welding of Magnesium alloys by FCRW

- Coupons welded with **no production of fine dust**
  - AZ 31 Magnesium alloy of thickness 2.0 mm



**Dust-Spatter-free  
and flash-free  
welding in a 15%  
current range**



**Peel tests show  
failure in the parent  
metal; The weld is  
intact**



**Tensile tests show  
parent metal failure  
at a load of 2000  
pounds per spot**



# Conclusions

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- **New method of welding aluminum alloys changes the paradigms in designing light weight structures**
  - **Large volume welding with stable high quality enabled**
  - **Welded structures have significantly improved strength and durability**
  - **Combinations of thicknesses and materials previously not weldable are now readily weldable**
- **Industrially safe welding of magnesium alloys is also enabled**
- **Institutions interested in working with us may look up our website for contact information**

