Dissimilar Resistance Spot Welding Optimization

Shailen Patel - Olentangy Orange High School

Advisors: Rakhi Bawa, Dr. Antonio J. Ramirez – The Ohio State University

MANUFACTURING & MATERIALS JOINING INNOVATION CENTER

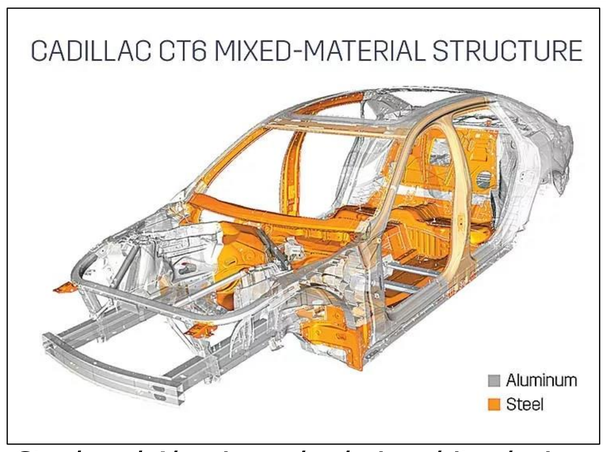
Background

RSW in automotive manufacturing

Source: ResearchGate, "Robots are commonly used for spot welding and arc welding in the automotive industry," 2018

Resistance Spot Welding (RSW) is a fast, automated, and cost-effective method widely used in manufacturing. Expanding RSW to join dissimilar metals like steel and aluminum could enhance lightweight production and manufacturing flexibility.

- Dissimilar RSW benefits automotive, aerospace, and manufacturing industries
- Lightweight vehicle demand drives steel-aluminum RSW adoption
- RSW provides automation, consistency, and scalability
- Brittle intermetallic compounds (IMCs) at dissimilar weld interface reduce joint strength
- Adhesives and mechanical fasteners avoid IMCs but add weight and complexity
- Interlayer foils help but still yield weak joints
- Solving IMC issues would enable strong, lightweight, automated assemblies



Steel and Aluminum body-in-white design

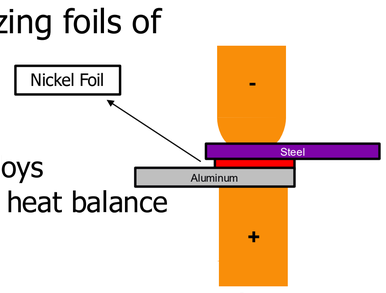
Source: MotorTrend, "Cadillac CT6 Mixed-Material Structure," 2015.

Objective

The goal of this research is to be able to join steel and aluminum efficiently and effectively utilizing RSW technology. The weld should minimize intermetallic morphology and create a strong bond. This will enable primarily automotive manufactures to be able to simultaneously use high strength steels and aluminum for body-in-white designs.

Approach

1. MATERIAL APPROACH: 25µm, 40µm, 70µm brazing foils of different Nickel alloys for interlayer material
   - All foils were hand placed between sheets
   - Same welding parameters maintained for each trail
   - Foil sheets of different thickness were of different alloys
   - Strategic electrode-material orientation designed for heat balance

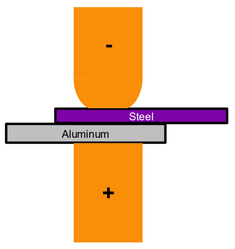


2. PROCESS APPROACH: MF-FC technology to increase current and shorten time for a shorter weld time
   - Tested in multiple different trials

Applied Clamping Force (kN)

Impulse Level (% nominal)	2.45 kN	2.7 kN	3.11 kN	4.7 kN
70 %			47.3	
75 %			50.2	
80 %		50.7	52.4	52.5
85 %		53.3		
90 %	55.0	54.7		
95 %	56.5	56.6		
98 %	57.3	53.6		

Table entries: Peak Current (kA)



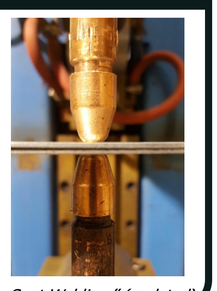
Strongest welds highlighted

Conclusions

1. IMC formation was successfully suppressed by separating steel and aluminum via brazing foils
2. Microstructures of aluminum changed due to brazing foil, while the steel microstructure stayed relatively the same
3. MF-FC technology showed no significant improvements in mechanical properties, but samples over 90% impulse level experienced the strongest mechanical properties

Future Work

1. Find a brazing foil material that increases mechanical strength while preventing IMC formation
2. Include possibly more than 1 interlayer in the dissimilar RSW
3. Cross-sectional analysis of MF-FC welds to investigate microstructures and see if IMCs were formed
4. Evaluate adhesives between dissimilar RSW to test strength and IMC levels

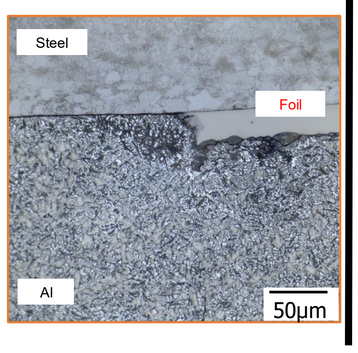


Source: Huys Industries, "Resistance Spot Welding," (undated)

Results & Discussion

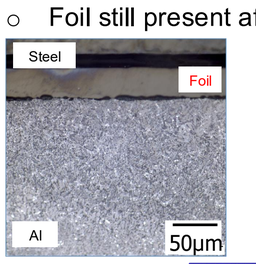
25µm foil

- No improvement in mechanical properties
- Intermetallic phase morphology present in Al nugget
- Foil mixed fully with aluminum
- St relatively unchanged



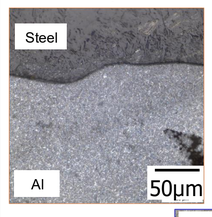
40µm foil

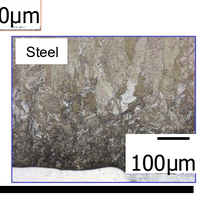
- Intermetallic-fingerlike morphology present in al nugget
- IMC-like microstructure near interface on al
- St grain sizes smallest
- Martensite more apparent in St
- Foil still present after weld

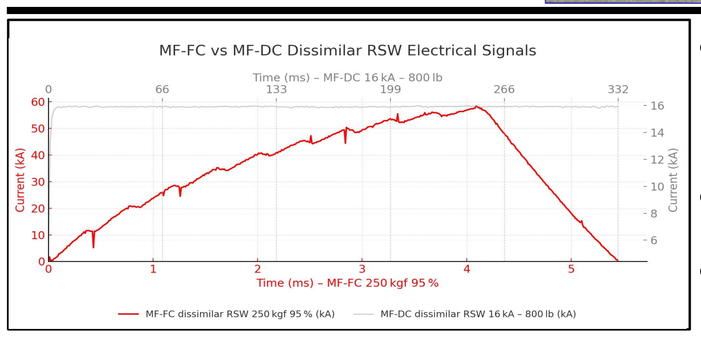


70µm foil

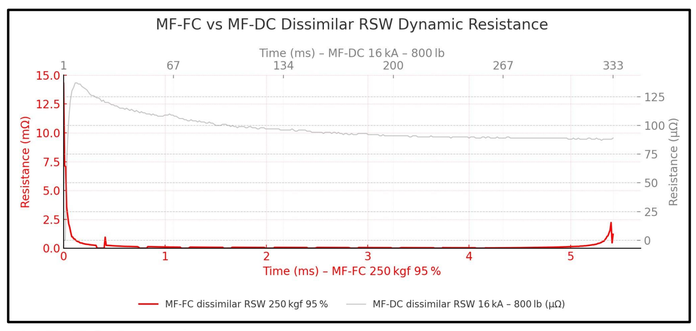
- IMC phase morphology not present
- Bright/Shiny phase appears in aluminum
- St near interface shows formation of martensite
- St in the middle of the nugget is same as seen in 25µm foil







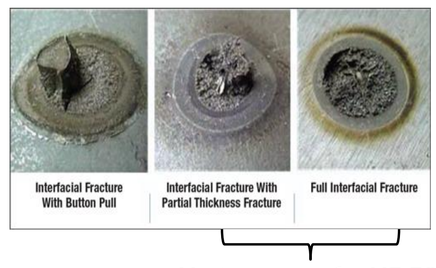
- Current for MF-FC is less stable than MF-DC and therefore welds are less robust
- Time for weld in MF-FC is significantly less than MF-DC
- Current on MF-FC is notably greater than MF-DC



- Greater current values decrease resistance much faster in MF-FC
- Resistance plateaus for MF-DC, helping to maintain stable heat in the weld

MF-FC Results

- Had no significant boost in mechanical properties
- All trails below 90% split at the interface from a drop at chest level
- Button pull out was insignificant



Most common for MF-FC

Source: AHSS Insights, "Resistance Spot Welding Automotive AHSS," 2021

<u>Materials Approach: Brazing Foil</u>

- Reduced IMC formation
- Did not improve mechanical properties
- Differing foil materials may have caused differing microstructures between samples
- Foil **did** prevent St and Al from mixing

<u>Process Approach: MF-FC technology</u>

- No improvement in mechanical properties
- Cross sectional analysis unavailable
- Multiple pulses need to be tested as MF-DC was welded with pulses

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