Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles

Donald J Spinella – Principal Investigator

Sandeep S. Karwa – Principal Investigator

Project ID: Mat133

2018 Annual Merit Review

June, 2018

ARCONIC
Innovation, engineered.

THE OHIO STATE UNIVERSITY

HONDA
Honda R&D Americas, Inc.

Overview

Timeline:

- Start Date: October 1, 2016
- End Date: September 30, 2019
- 40% complete

Barriers:

- Combinations of dissimilar materials with fasteners can cause galvanic corrosion.
- Joining of multi-material systems requires new technologies that may require billions in capital.
- Many existing fasteners are incompatible with UHSS/AHSS or require additional process steps.

Budget:

- Total project funding: $2,395,295
  - Govt. share: $1,764,330
  - Partner share: $630,965
- Funding in FY2017: $742,878
- Funding for FY2018: $1,017,972

Partners:

- Arconic Inc. – Lead
- Honda R&D Americas Inc.
- The Ohio State University

Relevance

Project Objectives:

- Develop weld process parameters and produce joints between Al, AHSS, and CFRP to establish confidence in RSR process robustness.
- Evaluate extent of galvanic corrosion and identify corrosion mitigation strategies.
- Demonstrate RSR implementation on a robotic system exploring process boundaries such as joint gaps, angularity, adhesives, and flange width variations.

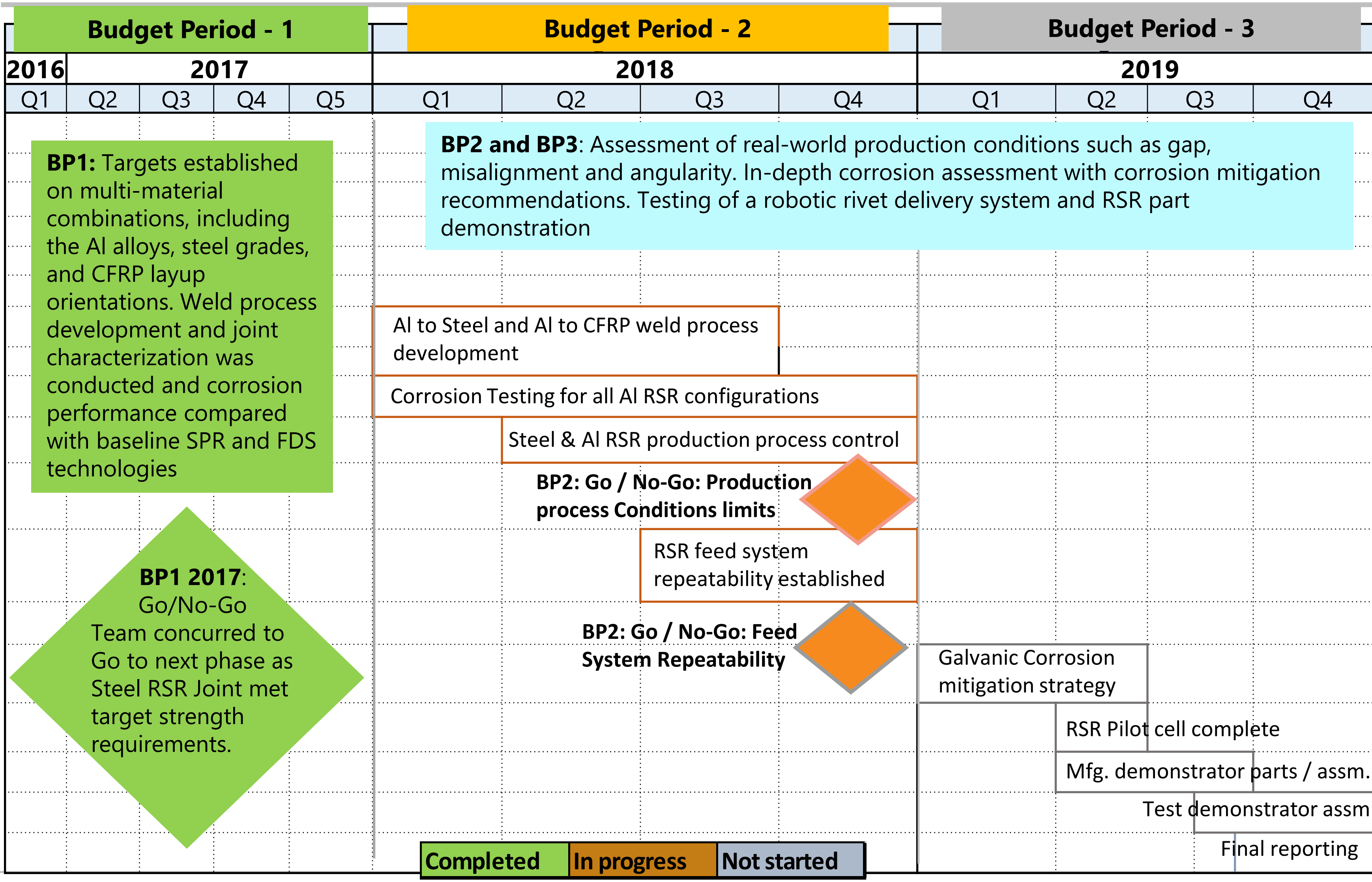
Impact:

- Provide high performance multi-material joining (Al to Steel and Al to CFRP) with the existing resistance spot welding infrastructure and knowledge base, offsetting billions in capital other technologies would require.
- Increase the flexibility of the existing infrastructure by allowing spot welding of like materials in sequence along with dissimilar material joining by simply not feeding a rivet to the tips.
- Enable an additional 10-20% weight reduction over high strength steel-only designs, providing a 1.5 - 3% total improvement in fuel efficiency for vehicles that incorporate RSR for multi-material joining.

Milestones

	BP1					BP2				BP3			
	2016	2017				2018				2019			
Milestones and Go / No-Go points	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Define preliminary material & part and testing requirements	100%												
Steel RSR piloted & self-piloted weld process developed		100%											
Al RSR piloted weld process developed		100%											
Assessment of rivet material and coating selection on corrosion performance for Al to St and Al to CFRP joints		100%											
Mechanical property assessment for Steel RSR				100%									
Corrosion assessment for Baseline SPR and FDS joints				100%									
Go/No Go: Steel RSR Joints meet targets					100%								
Al to Steel RSR piloted weld process developed						In Process (50%)							
Al to CFRP RSR piloted weld process developed							In process (15%)						
Corrosion Testing Completed for All RSR Configurations						In Process (25%)							
Steel & Al RSR production process condition limits established													
Go/No Go: Establish production condition limits													
RSR feed system repeatability established													
Go/No Go: Establish feed system repeatability													
Determine production galvanic corrosion mitigation strategies to improve corrosion performance													
RSR pilot cell complete													
Manufacture demonstrator parts and assemblies													
Test demonstrator assemblies													
Final Reporting													

Approach / Strategy

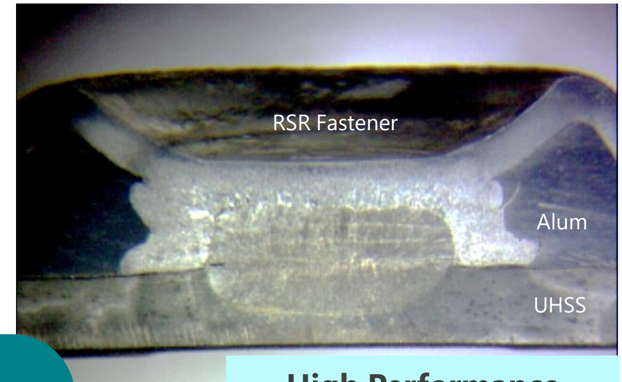


ARCONIC

Arconic RSR™ (Resistance Spot Riveting)

A new technology being developed by Arconic leveraging existing RSW infrastructure for high performance joining in current and future material combinations

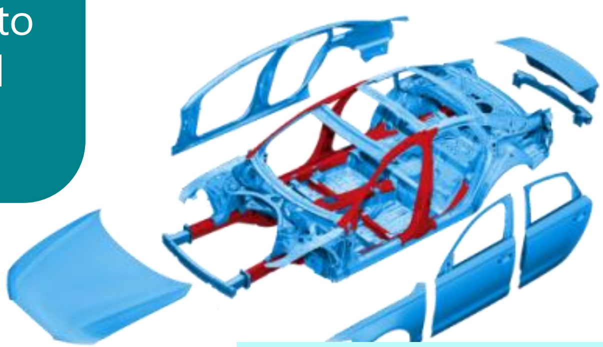
Engineered Fastener Family and Installation Equipment



High Performance Multi-material Joints

Goal: BIW weight savings due to multi-material combinations enabled by RSR, yielding1.5% to 3% total improvement in fuel efficiency

Conventional RSW Infrastructure



Applications include structures, interiors, closures

Current & Future Multi-material Vehicles

RSR™ Process Videos and Joint Combinations

RSR Offers flexibility for wide variety of material combinations

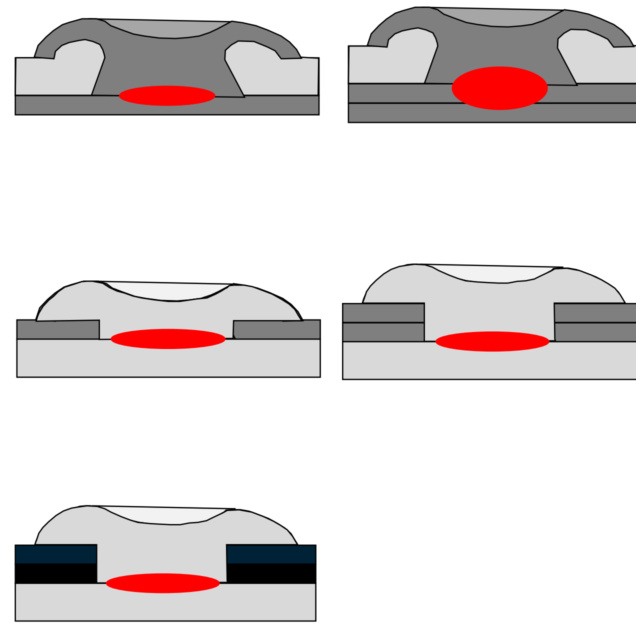
Piloted RSR™

2 Thickness | 3 Thickness

Al to St
St RSR

St to Al
Al RSR

CFRP to Al
Al RSR



Aluminum | Steel | CFRP

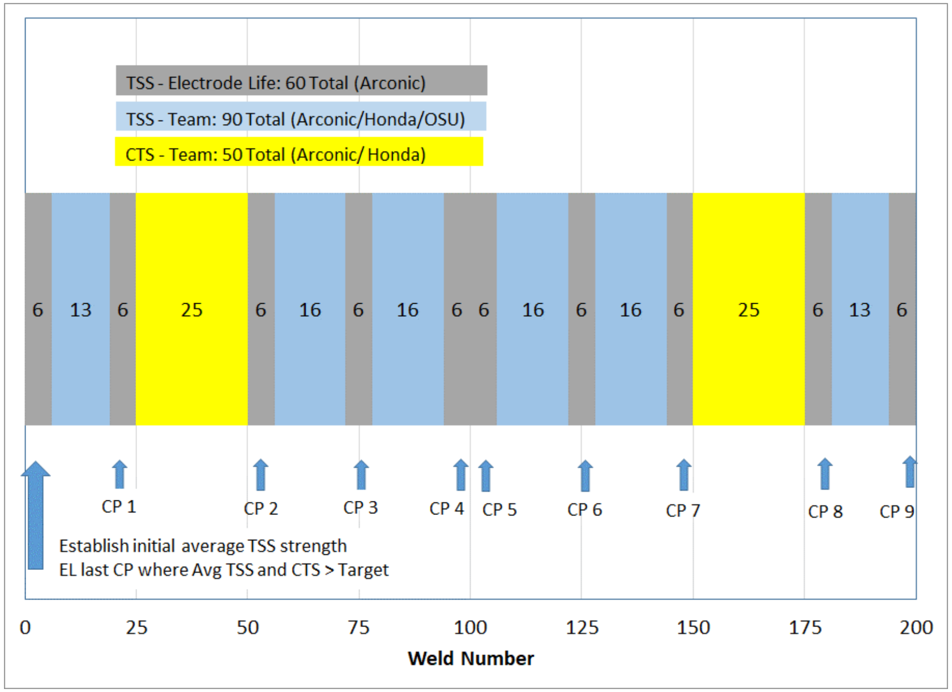
Technical Accomplishments and Progress

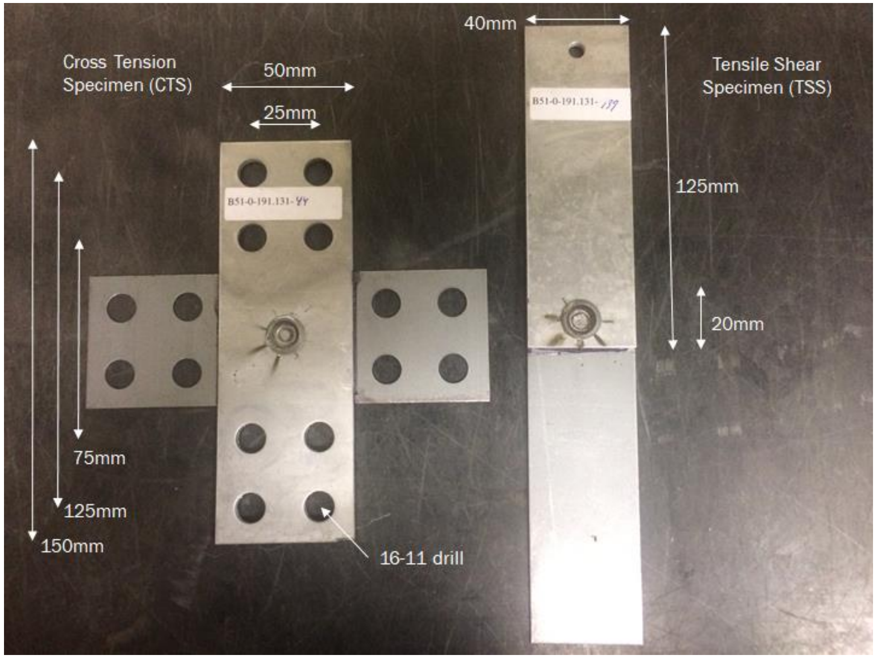
Test Plan Matrix for Preliminary EL, Mechanical, and Corrosion Test

Joint Stackup Description							Team Member Test Type			Budget Period	Samples Manufactured
Rivet	Pilot	Top	Adh*	Mid	Adh*	Bottom	Arconic	Honda	OSU		
St RSR	Y	AURAL2 3.0mm	Y			JAC 980 1.2mm	E	C	C	1	Yes
	Y	AURAL2 3.0mm	N			JAC 980 1.2mm	M		C	1	Yes
	Y	AURAL2 3.0mm	Y	JAC 980 1.2mm	N	JAC 980 1.2mm	E	C	C	1	Yes
	Y	AURAL2 3.0mm	N	JAC 980 1.2mm	N	JAC 980 1.2mm	M		C	1	Yes
	N	MMHF-T4 1.0mm	Y	USIBOR 1500 1.2mm	Y	JAC 980 1.2mm	E	C	C	1	Yes
	N	MMHF-T4 1.0mm	N	USIBOR 1500 1.2mm	N	JAC 980 1.2mm	M		C	1	Yes
	Y	AA6013-T4 2.0mm	N			JAC 980 1.2mm	M		C	1	Yes
	Y	AA5754-O 2.0mm	N			JAC 980 1.2mm	M		C	1	Yes
	Y	AA7055-T76 2.0mm	N			JAC 980 1.2mm	M		C	1	Yes
	Y	AA6013-T4 2.0mm	N			JAC 590 1.2mm	M		C	1	Yes
Al RSR	Y	JAC 980 1.2mm	Y			AURAL2 3.0mm	E	C	C	2	Yes
	Y	JAC 980 1.2mm	N			AURAL2 3.0mm	M		C	2	Yes
	Y	JAC 980 1.2mm	N	JAC 980 1.2mm	Y	AURAL2 3.0mm	E	C	C	2	Yes
	Y	JAC 980 1.2mm	N	JAC 980 1.2mm	N	AURAL2 3.0mm	M		C	2	Yes
	Y	JAC 980 1.2mm	Y	USIBOR 1500 1.2mm	Y	MMHF-T4 1.0mm	E	C	C	2	Development
	Y	JAC 980 1.2mm	N	USIBOR 1500 1.2mm	N	MMHF-T4 1.0mm	M		C	2	Development
	Y	Semi-Iso CFRP 4.0mm	Y			AA6013-T4 2.0mm	E	C	C	2	Development
	Y	Semi-Iso CFRP 4.0mm	N			AA6013-T4 2.0mm	M		C	2	Development
	Y	Semi-Iso CFRP 4.0mm	Y			AA6013-T4 3.0mm	E	C	C	2	Development
St SPR Baseline	N	JAC 590 1.2mm	Y			AA6013-T4 2mm	M		C	1	Yes
	N	JAC 590 1.2mm	N			AA6013-T4 2mm	M		C	1	Yes
St FDS Baseline	Y	JAC 980 1.2mm	Y			AA7055-T76 2mm	M		C	1	Yes
	Y	JAC 980 1.2mm	N			AA7055-T76 2mm	M		C	1	Yes
Adh* - Adhesive between sheets					Test Code	Electrode Life	Mechanical Testing		Corrosion		

Technical Accomplishments and Progress

Target Conditions for Go/No Go, Electrode Life Testing Protocol and Coupon Geometries



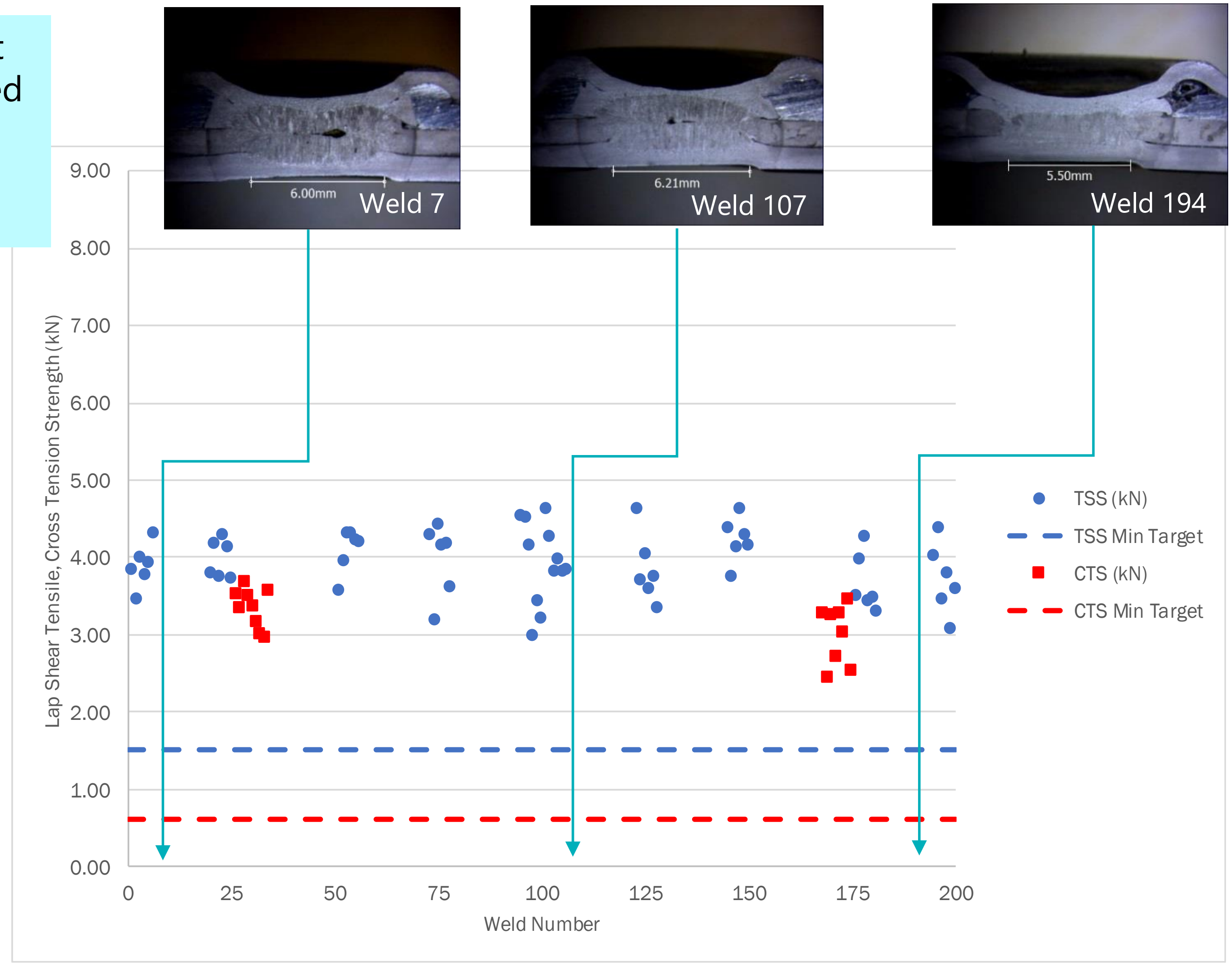


- CTS and TSS specimens align with ASTM and JIS standards.
- Electrode Life (EL) testing was a combination of CTS and TSS coupons.
- Half of the EL coupons slated for corrosion testing at the OSU and Honda.

Technical Accomplishments and Progress

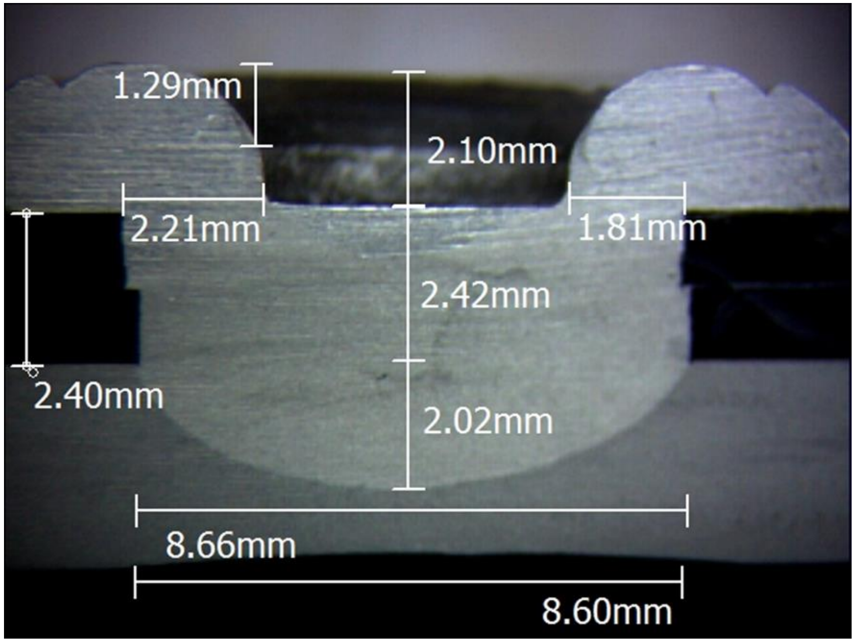
Steel RSR EL Results: 1.2mm 980 MPa to 1.2mm Usibor® 1500 to 1.0mm MMHF through Dow 5055-C with R4-3GA

- 3T Self-Pilot Joint
- CTS, TSS exceeded minimum target strength through 200 welds

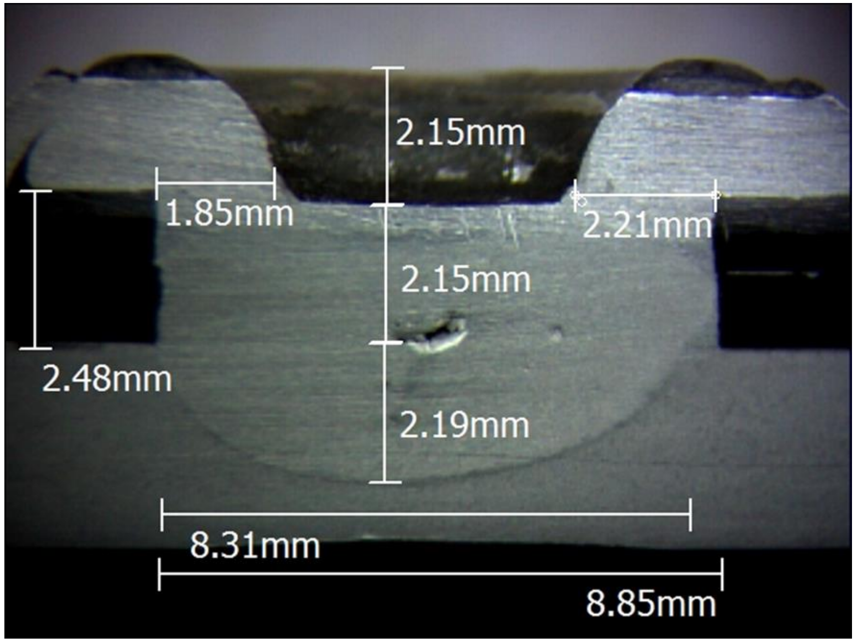


Technical Accomplishments and Progress

Aluminum RSR EL 3T Testing – 2 Sheets of 1.2mm 980 MPa (9mm dia. pilot) to 3.0mm Aural 2 with F7-5



3mm Aural2-T7 to Two Sheets of 1.2mm 980MPa (no adhesive)



3mm Aural2-T7 to Two Sheets of 1.2mm 980MPa through Dow 5055 Adhesive

RSR-F7-5V employed with conventional schedules (upslope + weld) and 9mm pilot hole in steel

Technical Accomplishments and Progress

BP1 Go / No-Go Target Criteria versus Actual Results

EL Joint Stack-up Description							TSS Minimum, kN		CTS Minimum, kN		EL, # Welds	
Rivet	Pilot	Top	Adh	Mid	Adh	Bottom	Target	Measured	Target	Measured	Target	Measured
St RSR	Y	AURAL2 3.0 mm	Y			JAC 980 1.2 mm	3.38	5.57	1.35	1.61	100	200
	Y	AURAL2 3.0 mm	Y	JAC 980 1.2 mm	N	JAC 980 1.2 mm	3.38	6.08	1.35	4.79	100	200
	N	MMHF-T4 3.0 mm	Y	USIBOR 1500 1.2 mm	Y	JAC 980 1.2 mm	1.51	2.99	0.60	2.46	100	200

Color Code	Target	Below Target	Met Target	Above Target

Technical Accomplishments and Progress

RSR and Baseline Technologies Undergoing 4 Different Types of Corrosion Testing

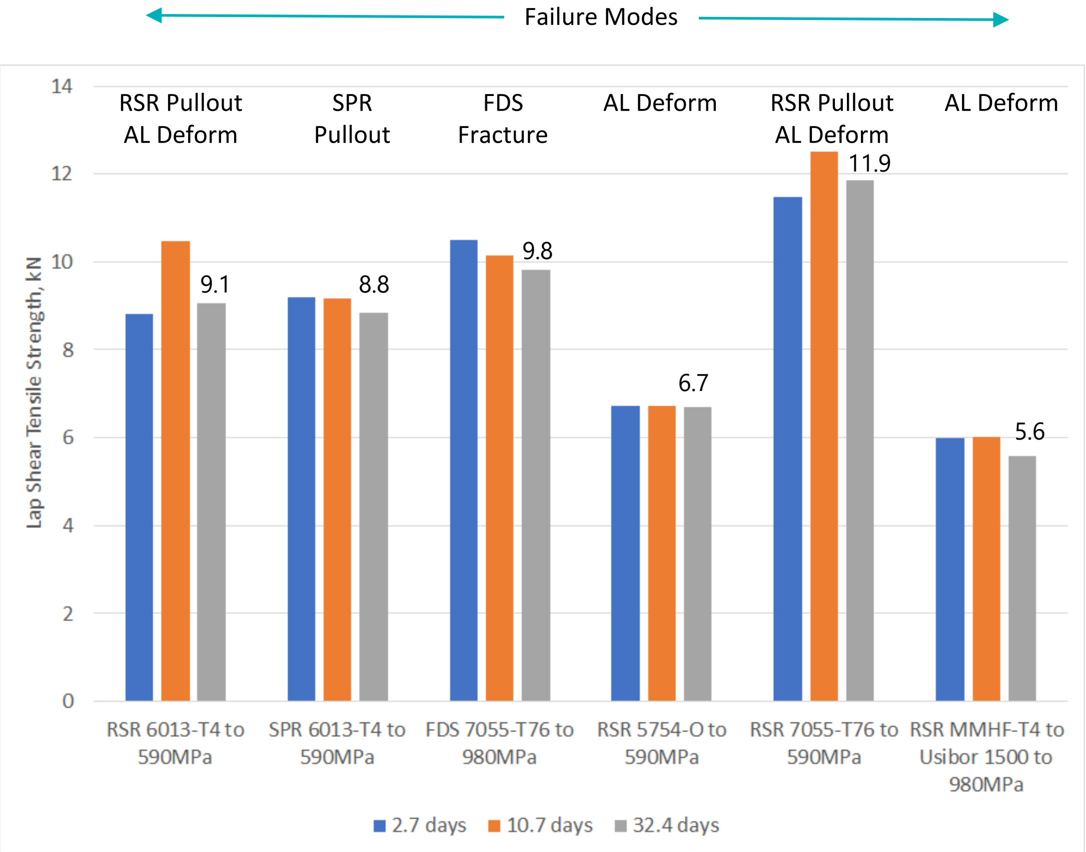
Test Code	Adhesive	Top Plate Material	Middle Plate Material	Bottom Plate Material	B117 (continuous neutral salt spray)	ASTM G85 (acidified salt spray with wet and dry cycles)	Nissan Underbody (wet and dry cycles with ?pH salt spray)	Received Prepared In Progress Standard 3 Exposures Complete All Exposures Complete Micro. cell	Serial polishing
AL to SP									
B51-0-191.131-	Y	AURAL2 3.0mm	-	JAC 980 1.2mm	15	15	15	3	2
A51-0-191.131-	N	AURAL2 3.0mm	-	JAC 980 1.2mm	10*	10	10	3	2
B51-0-191.191.131-	Y	AURAL2 3.0mm	JAC 980 1.2mm	JAC 980 1.2mm	15	15	15	3	2
A51-0-191.191.131-	N	AURAL2 3.0mm	JAC 980 1.2mm	JAC 980 1.2mm	10	10	10	3	2
B52-0-191.230.150-	Y	MMHF-T4EX 0.9mm	USIBOR 1500 1.0mm	JAC 980 1.2mm	15	15	15	3	2
A52-0-191.230.150-	N	MMHF-T4EX 0.9mm	USIBOR 1500 1.0mm	JAC 980 1.2mm	10	10	10	3	2
A51-0-191.40-	N	6013-T4 2.0mm	-	JAC 980 1.2mm	10	10	10	3	2
A52-0-191.40-	N	6013-T4 2.0mm	-	JAC 980 1.2mm	10*	10	10	3	2
A51-0-191.140-	N	5754-O 2.0mm	-	JAC 980 1.2mm	10*	10	10	3	2
A51-0-191.160-	N	7055-T76 2.0mm	-	JAC 980 1.2mm	10*	10	10	3	2
A51-0-171.40-	N	6013-T4 2.0mm	-	JAC 590 1.2mm	10*	10	10	3	2
SP to AL									
B53-0-131.191-	Y	JAC 980 1.2mm	-	AURAL2 3.0mm	15	15	15	3	2
A53-0-131.191-	N	JAC 980 1.2mm	-	AURAL2 3.0mm	10	10	10	3	2
B53-0-131.191.191-	Y	JAC 980 1.2mm	JAC 980 1.2mm	AURAL2 3.0mm	15	15	15	3	2
A53-0-131.191.191-	N	JAC 980 1.2mm	JAC 980 1.2mm	AURAL2 3.0mm	10	10	10	3	2
B53-0-150.230.191-	Y	JAC 980 1.2mm	USIBOR 1500 1.0mm	MMHF-T4EX 1.0mm	15	15	15	3	2
A53-0-150.230.191-	N	JAC 980 1.2mm	USIBOR 1500 1.0mm	MMHF-T4EX 1.0mm	10	10	10	3	2
CFRP to AL									
B53-0-40.300-	Y	Semi-Iso CFRP 4.0mm	-	6013-T4 2.0mm	15	15	15	3	2
A53-0-40.300-	N	Semi-Iso CFRP 4.0mm	-	6013-T4 2.0mm	10	10	10	3	2
B53-0-41.300-	Y	Semi-Iso CFRP 4.0mm	-	6013-T4 3.0mm	10	10	10	3	2
SPR									
B54-0-40.171-	Y	JAC 590 1.2mm	-	6013-T4 2mm	15*	15	15	3	2
A54-0-40.171-	N	JAC 590 1.2mm	-	6013-T4 2mm	10*	10	10	3	2
EJOT FDS									
B55-0-160.191-	Y	JAC 980 1.2mm	-	7055-T76 2mm	15*	15	15	3	2
A55-0-160.191-	N	JAC 980 1.2mm	-	7055-T76 2mm	10*	10	10	3	2

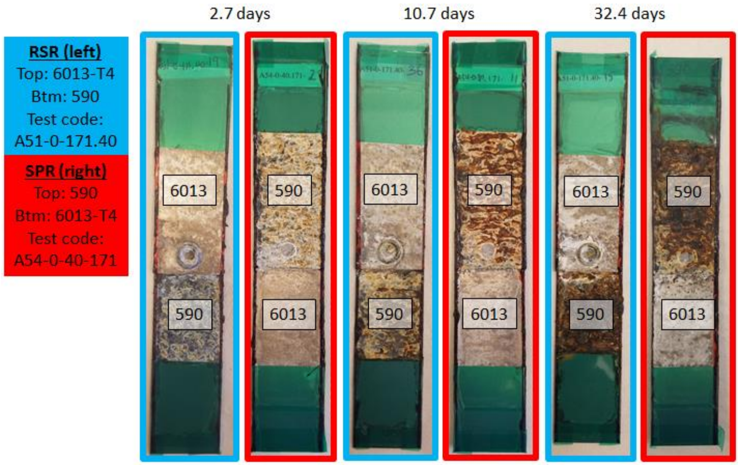
*Mechanical testing performed on samples

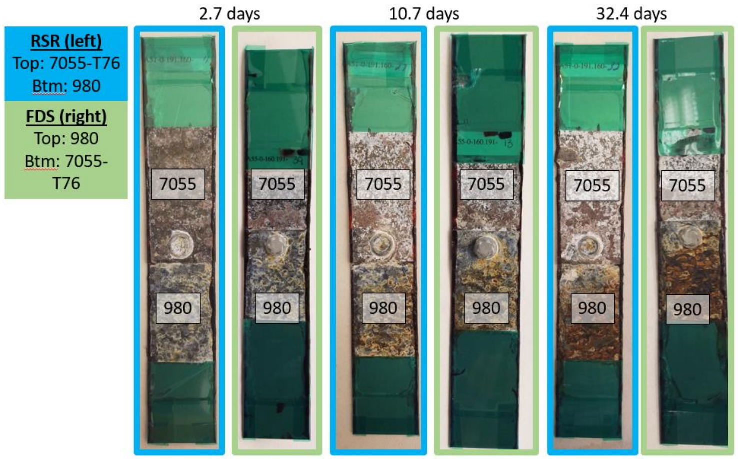
ARCONIC

Technical Accomplishments and Progress

RSR versus Baseline SPR and FDS after ASTM B117 Exposure of 2.7, 10.7 and 32.4 days



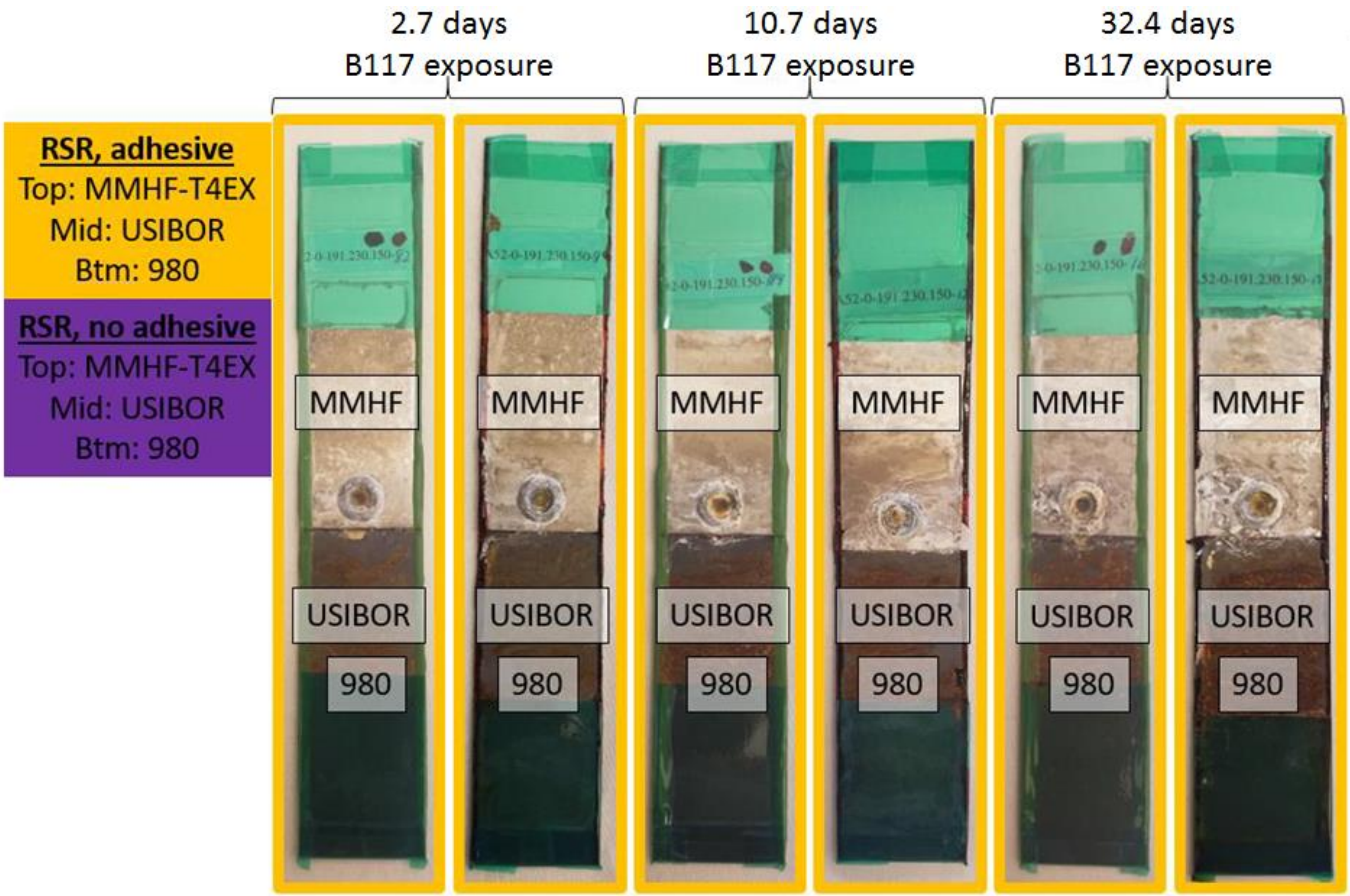




RSR showed similar corrosion strength versus other technologies and across alloy families

Technical Accomplishments and Progress

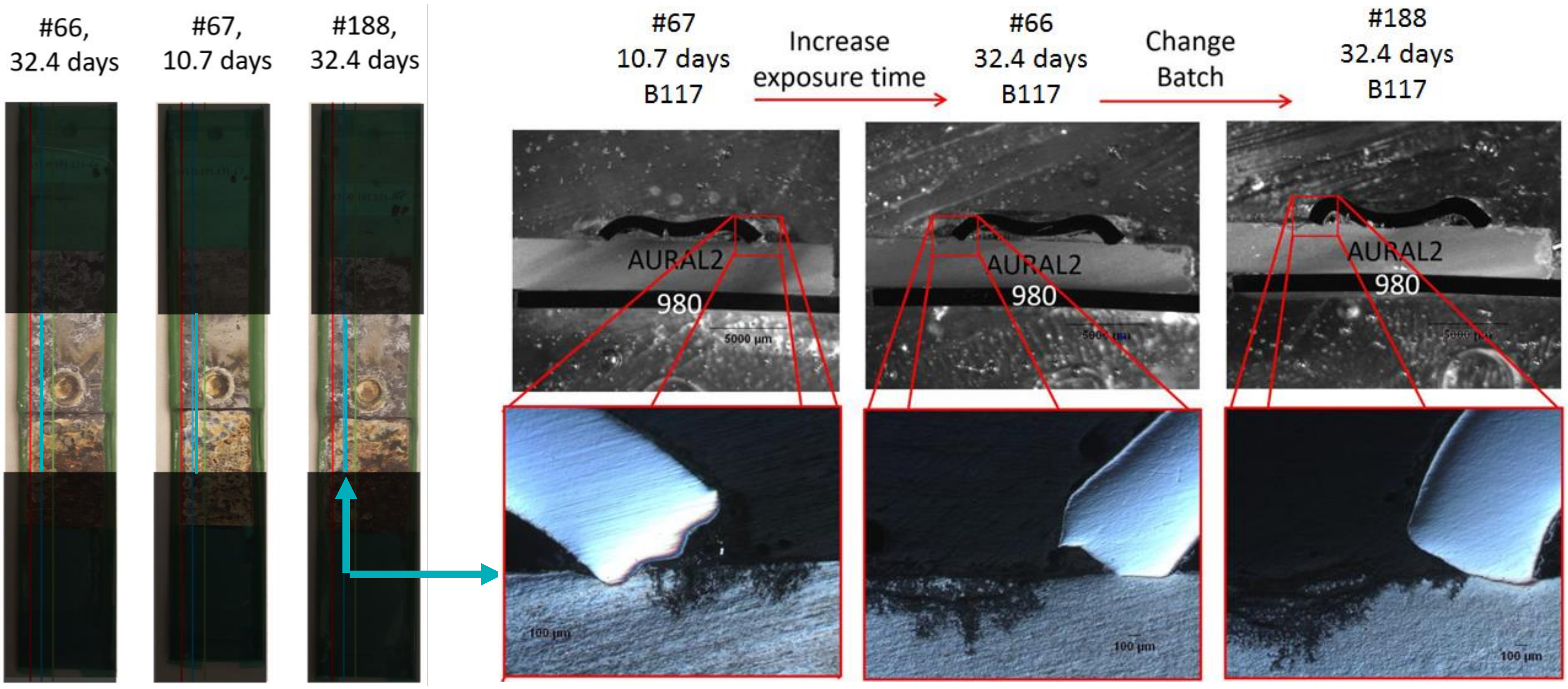
Steel RSR Corrosion Specimens 3T Electrode Life Specimens in the Self-Pilot Mode



No observable difference in corrosion performance noted with and w/out adhesive

Technical Accomplishments and Progress

Serial Cross Sectioning of RSR Joints to Understand the Depth and Morphology of the Corrosion Attack



Developing fundamental understanding on corrosion versus location surrounding the RSR for various material combinations

Collaboration and Coordination with Other Institutions

Arconic will oversee project management. Arconic will produce the RSR samples for mechanical and corrosion testing and later produce the demonstration assemblies. Arconic will integrate the rivet delivery system to a robotic pilot cell to demonstrate production capability. Arconic will explore production variations such as joint gaps, angularity, flange length variations and stack thickness variations.

Honda R&D Americas, Inc.

Honda will develop specification requirements for related coupon testing that will be conducted by Honda, industry, and the Ohio State University. Honda will also provide support with specification development for the joining process and equipment requirements. Honda will judge the functional performance of the component in comparison to the baseline hot stamped UHSS application.

The Ohio State University will characterize and quantify the galvanic corrosion resistance of RSR joints of aluminum to steel and aluminum to CFRP and the ability of adhesives, pre joining surface coatings, and e-coat/paint/sealant packages to protect the RSR joint against galvanic corrosion.

Remaining Challenges and Barriers

- Conventional resistance spot-welding of Al to steel has low joint strength, fatigue and corrosion performance.
- Currently, there is no way to join CFRP to Al using resistance spot-welding equipment.
- Confidence in the RSR process robustness must be established for production applications. EL of the process must be in line with existing tip-dressing frequency to be viable.
- Confidence in the RSR process for high-volume manufacturing. RSR has only been demonstrated on a stationary pilot station.
- Corrosion behavior of other multi-material joining technologies are well understood. RSR needs to have a baseline established to compare to other technologies, and if necessary, improve the corrosion performance to meet end-customer needs.

We will address these items in our future work

Proposed Future Research

FY18 – FY19 proposed Work will Include:

1. Al to Steel and AL to CFRP RSR weld process development
2. Corrosion Testing for All RSR Configurations at OSU and Honda
3. Develop and establish Steel & Al RSR production process condition limits
4. Go/No Go: Establish production condition limits
5. Develop and establish RSR feed system repeatability
6. Go/No Go: Establish feed system repeatability
7. Determine production galvanic corrosion mitigation strategies to improve corrosion performance
8. Develop and install RSR pilot cell
9. Manufacture demonstrator parts and assemblies
10. Test demonstrator assemblies
11. Final Reporting

Summary

- Defined materials, stackup combinations and performance targets for RSR and baseline joints.
- Weld process parameters for the steel-based RSR with and without adhesives were developed and ~950 coupons were manufactured as part of the EL and corrosion assessments.
- EL testing on the steel-based RSR was conducted on three different material combination conditions and all static strength (both TSS and CTS) and EL targets were achieved.
- Weld process parameters for the aluminum-based RSR with and without adhesives are in development and ~300 coupons were manufactured as part of the EL and corrosion assessments. An additional ~1200 coupons will be manufactured in BP2.
- Baseline multi-material technologies (SPR and FDS) were manufactured for corrosion assessment. OSU began corrosion testing (ASTM B117 continuous neutral salt spray) on baseline SPR and FDS in addition to steel-based RSR. Visual corrosion assessment showed RSR performed similar to baseline technologies.
- Teamed reviewed the EL and mechanical properties for steel RSR joint and corrosion test performance on RSR, SPR and FDS joints in November 2017 and agreed results met the "GO" criteria

ARCONIC

Innovation, engineered.