GREAT DESIGNS IN STEEL

AHSS/UHSS Alternative Joining Fatigue Performance

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Project Team Members

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Background

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A/SP Joining Team – J#4: Alternative Joining Team

Purpose:

Identify joining technologies that can provide advantages in UHSS and 3rd Gen AHSS materials compared to Resistance Spot Welding (RSW)

Approach

- Identify developing alternative joining processes competitive with resistance spot welding (RSW)
- Identify joint combinations of interest to current and emerging vehicle applications
- Create lap shear and cross tension coupons from viable joining processes
  - Phase I: Quasi-Static Testing (Presented at 2022 GDIS)
  - Phase II: Fatigue Testing
- Compare performance of joints using alternative joining processes with RSW.
- Create a comparative tool to enable joining specialists to select viable joining technologies for material stack-ups of interest

Value Proposition:

Enable A/SP OEM and Tier 1 members to more quickly and confidently implement the use the highest performance steel grades that are suitable for their respective manufacturing footprints and business models.

Project Details

Phase 2 (2021-2023)

Project Goal

Evaluate the fatigue performance of alternative joining processes evaluated in Phase I.

Project Objectives

Fatigue test lap shear coupons from viable technologies tested in Phase I.

Compare fatigue performance of alternative joining technologies against baseline RSW steel joints

Deliverable

Provide a comparative tool to facilitate comparison and guide joining specialist in the selection of viable alternative joining technologies

Results Summary

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Fatigue Strength

Joint ID	Top / Bottom [Baseline]	RSW No Adh.	RSW Adhesive	A-TAC No Adh.	A-TAC Adhesive	A-MCL No Adh.	A-MCL Adhesive	C-TAR No Adh.	C-TAR Adhesive
Joint 1	CR04 (0.7) / PHS1800 (1.4) [PHS1300 (1.5)]	[green]	[green]	[green]	[green]	[gray]	[gray]	[green]	[green]
Joint 2	PHS1300 (1.2) / PHS1800 (1.4) [PHS1300 (1.5)]	[green]	[green]	[green]	[green]	[gray]	[gray]	[green]	[red]
Joint 3	DP590 (1.2) / PHS1800 (1.4) [PHS1300 (1.5)]	[green]	[green]	[green]	[green]	[gray]	[gray]	[green]	[green]
Joint 4	CR04 (0.7) / MS1700 (1.0) [MS1500 (1.2)]	[green]	[green]	[red] *	[orange] *	[gray]	[gray]	[green]	[green]
Joint 5	MS1700 (1.0) [MS1500 (1.2)] / PHS1300 (1.5)	[green]	[green]	[green]	[red]	[gray]	[gray]	[green]	[orange]
Joint 6	MS1700 (1.0) [MS1500 (1.2)] / DP780 (1.9)	[green]	[green]	[green]	[orange]	[gray]	[gray]	[green]	[red]
Joint 7	RA980 (1.1) [DP780 (1.4)] / DP590 (1.5)	[green]	[green]	[green]	[red]	[green]	[green]	[green]	[red]
Joint 8	CR04 (0.7) / RA980 (1.1) [DP780 (1.4)]	[green]	[green]	[green]	[green]	[red] *	[green] *	[gray]	[gray]
Joint 9	RA980 (1.1) [DP780 (1.4)] / PHS1300 (1.5)	[green]	[green]	[green]	[red]	[gray]	[gray]	[green]	[gray]
Joint 10	RA1180 (1.2) [PHS1300 (1.2)] / PHS1300 (1.5)	[green]	[green]	[green]	[red]	[gray]	[gray]	[green]	[red]
Joint 11	CR04 (0.7) / RA1180 (1.2) [PHS1300 (1.2)]	[green]	[green]	[green]	[green]	[red] *	[green] *	[green]	[green]
Joint 12	DP590 (1.0) / RA1180 (1.6) [PHS1300 (1.5)]	[green]	[green]	[red] *	[green] *	[red] *	[green] *	[gray]	[gray]

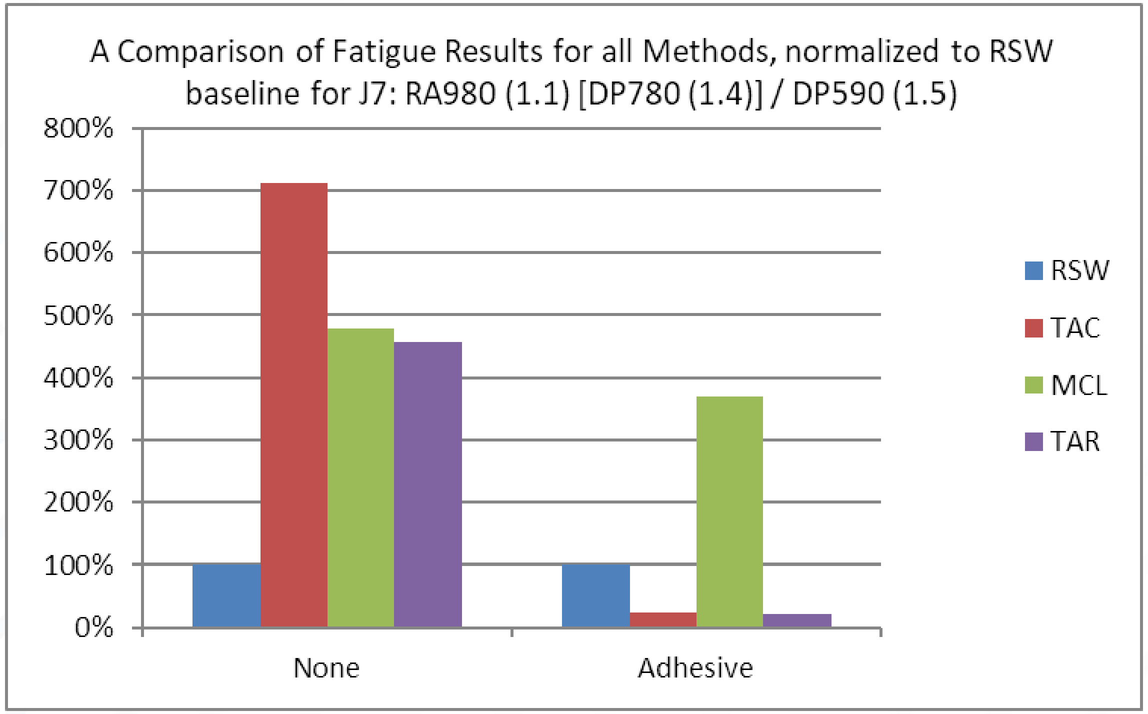
Observations
- Fatigue life with adhesive is higher than without, meaning a green result for adhesive represents a higher test load than a green result without adhesive. →
- Results without adhesive were generally better than results with adhesive
- Thermally Assisted Clinching (TAC) and Thermally Assisted Self-Piercing Riveting (TAR) were both able to successfully produce (10) of (12) joints without adhesive
- TAC was able to successfully Produce (5) of (12) joints with adhesive, (1) additional without thermal assist
- TAR was able to successfully produce (4) of (12) joints with adhesive

Fatigue loads normalized to 100k cycles for RSW, R=0.1, 20hZ
- Mean load without Adhesive = 3.1 kN
- Mean load with Adhesive = 14.9 kN

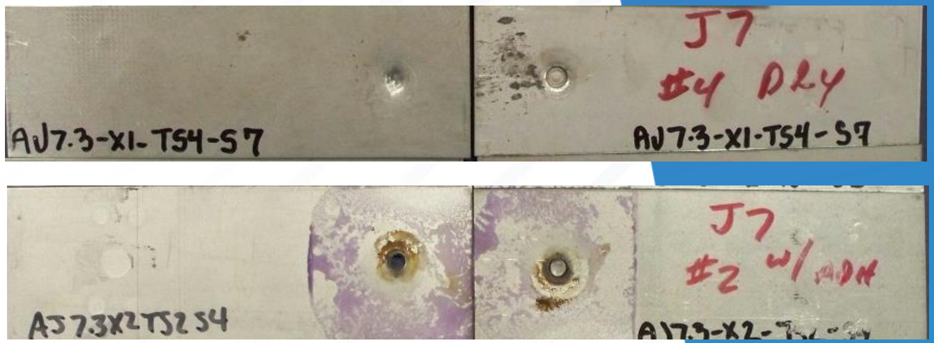
Versus RSW Baseline
[green] >=100%
[yellow] >=80%
[orange] >=60%
[red] <60%
[gray] No Data

* Joint deemed unfeasible based on non-adhesive test results, excluded from later calculations

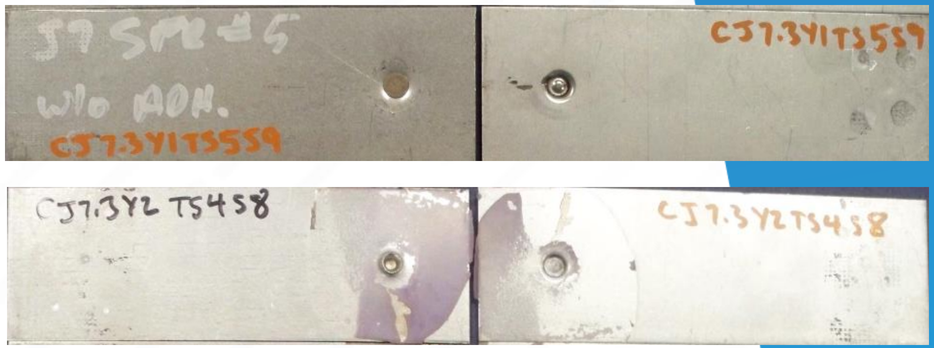
Close-Up View



Thermally Assisted Clinch (TAC)
No Adhesive (Top)
With Adhesive (Bottom)



Thermally Assisted SPR (TAR)
No Adhesive (Top)
With Adhesive (Bottom)



RSW Baseline
No Adhesive (Top)
With Adhesive (Bottom)

Average Performance across all joints (J1 through J12)

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All Joint Average	No Adhesive	With Adhesive
TAC	512%	133%
MCL*	480%	370%
TAR	594%	143%

- Joints indicated as unfeasible on slide #5 are not included in the above numbers
- On average, all (3) methods out-performed Resistance Spot Weld (RSW) without adhesive
- With adhesive, results were not statistically better than RSW for either thermally assisted process
  - Clinching without thermal assist (MCL) is shown for comparison, *but only successfully produced (1) of the (12) test joints

Conclusions

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Thermally Assisted Clinching (TAC) and Thermally Assisted Self Piercing Riveting (TAR) are capable of producing a wide variety of joints in recent AHSS/UHSS grades such as PHS1800, MS1700, 3rd Gen 980 and 3rd Gen 1180

Phase 1:

- Quasi-static strength is generally not improved versus RSW in these grades

Phase 2

- Fatigue properties without adhesive are generally better than RSW
- Fatigue properties with adhesive are inconsistent and not statistically better than RSW
- TAC or TAR without adhesive are not direct replacements for RSW with adhesive because target loads are much higher for joints designed with adhesives

Next Steps

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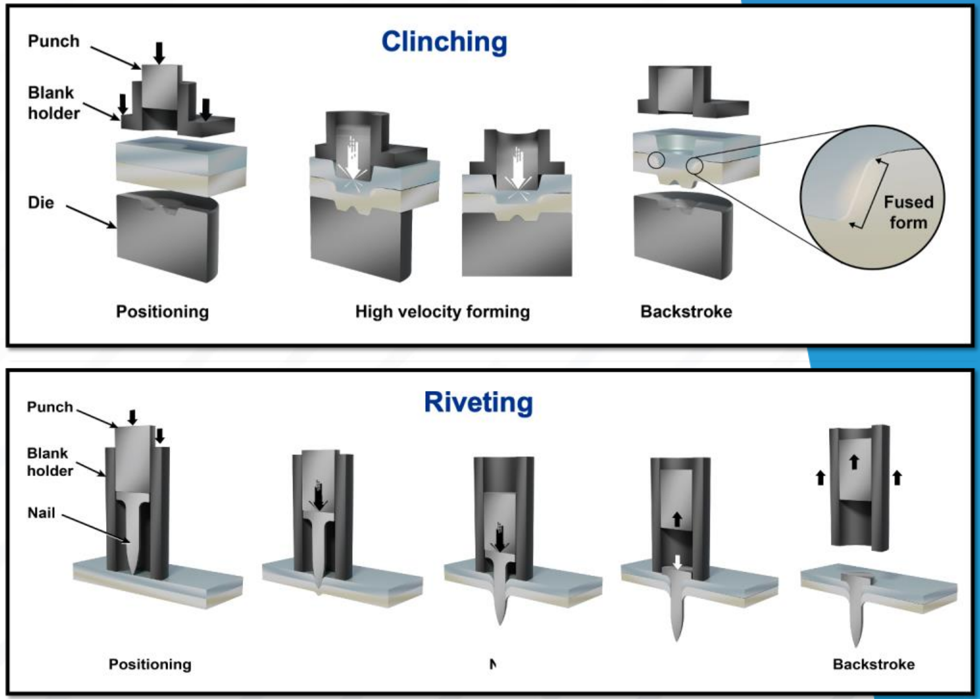
Phase 3

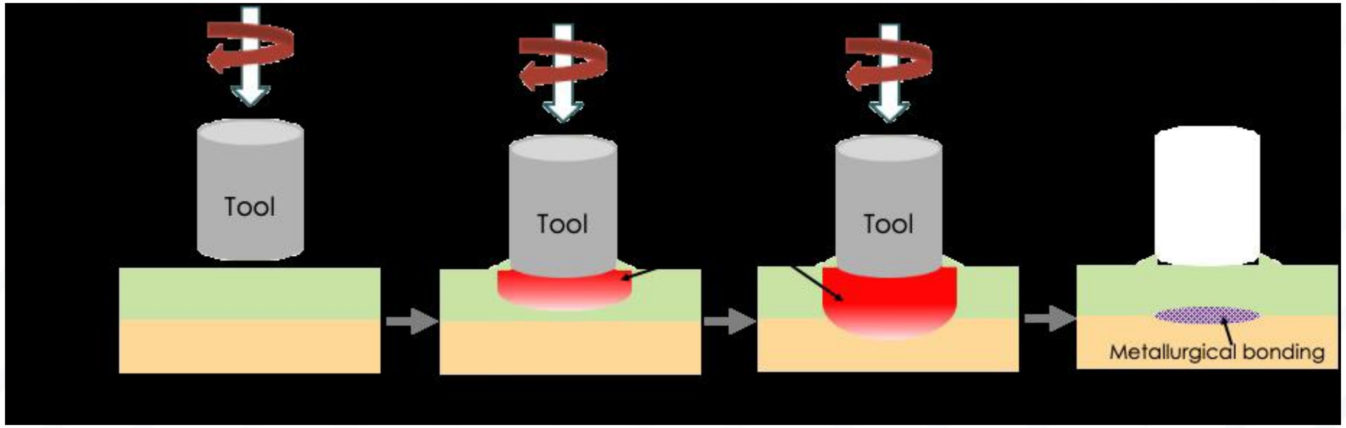
- Test different heat sources for TAC and TAR to assess effects on adhesive performance
- Test thermally assisted single-sided joining

- Other Alternative Joining Initiatives:
  - Evaluate High Velocity Joining (HiVe) - PNNL
  - Evaluate Friction Pressure Welding - ORNL

High-Velocity Joining



Friction Pressure Welding



For More Information

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- Publications:
  - 2024 Automotive Circle, B. Macek (Phase II)
  - 2023 Automotive Circle, B. Macek (Phase I)
  - 2022 GDIS, B. Macek (Phase I)

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