Project Data

Title & Goal

☑ Cooperative ☐ Proprietary **Project# :** FF-LIFT-021617-B-001 **Date#:** Start Date **Company:**

Title: Automated One-Sided Joining of Dissimilar Materials Utilizing Hybrid Rivet Weld Process

Goal: Reliable and Robust Joining of Dissimilar Materials for Automotive Body Assembly

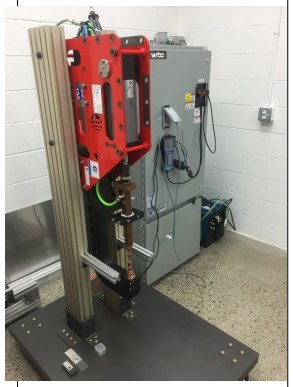
Potential Industry: Automotive, other industries **Potential Company:** **Contact:**

Project Scope / Solution

Project Scope

Auto companies are trying to reduce weight in their body structures with a mixed material strategy but do not have a reliable joining process for dissimilar materials (steel, UHSS, aluminum, magnesium, composites) due to joint integrity impacts from imperfections in intermetallic interface, corrosion propagation, etc. Our interest is to demonstrate an advanced joining processes that combines riveting with resistance spot welding technologies to cost effectively join steel to aluminum materials for auto body in white (BIW) assembly processes. The project will demonstrate a highly automated, one sided joining process ideal for automotive body assembly. The project is specifically joining roof sheet aluminum 6000IHEDT or 6451 with material gage 1.2mm to A Pillar support hot stamped sheet steel 1500 also at 1.2mm. Our system uses existing capital equipment (transformers, robots) found in auto body assembly plants w/ limited investment in unique weld gun & custom rivets.

Figure 1



Deliverables

- DFMEA for one-sided hybrid joining system design
- PFMEA for one-sided hybrid joining system design
- Design/engineer customized rivet and one sided weld gun
- Design/engineer automated rivet feeding system
- Integrate customized weld gun, rivet feeder, weld controller, robot
- Algorithm development to support process
- Demonstrate customer part run off with integrated system

Target Technology

- ☑ JOINING & ASSEMBLY
- ☐ COATINGS
- ☐ NOVEL/AGILE PROCESSING
- ☐ THERMO-MECHANICAL PROCESSING
- ☐ POWDER PROCESSING
- ☐ MELT PROCESSING

Deliverables

Resources

Sponsor :

Pillar Leader:

Team Leader:

Team Members :

Measures

Measures of Success:

- Ability to create robust joints of dissimilar material samples
- Ability to simultaneously control riveting and RSW in one mfg. step within automated one second tact time
- Ability of system to provide multiple orientation one sided joining
- Ability to ensure a repeatable process over 1,000+ samples

Project Data

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Project TimeLine

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Design/Simulation	Design Proto Tools	Build Proto Tools	Integrate System	Parts Run-Off	Testing /Validation

Approach / Solution Summary

Proposal / Solution

The OPT Rivet Weld joining of dissimilar materials process combines self pierce riveting and resistance spot welding in one manufacturing step allowing auto OEM's to switch out heavier materials (steel) with lighter materials (aluminum, magnesium) in the BIW architecture thereby saving weight on each vehicle while not significantly adding to their operating cost. The process uses proprietary software algorithms to precisely control the weld current and force to ensure a reliable joining of mixed materials. Signals are sent to the weld controller to alter weld current and force to pre-heat the rivet allowing for ease of penetration in top joining material. Weld temperature is controlled to ensure weld nugget growth is encapsulated within the rivet as an extra measure of joint robustness (Figure 1). The process is designed to reduce weld imperfections, reduce splatter, and contain brittle intermetallic weld nugget encapsulated in our customized hollow rivet (Figures 2). The weld nugget is encapsulated within the rivet where it is protected from humidity, moisture, air intrusion. Previous samples with cross section microscopic images have verified our ability to control the weld nugget and create a barrier between the rivet and the weld nugget (Figure 3). CTE delta is controlled by algorithms and low weld current and force to reduce occurrence of thermal expansion of materials. We are using specialized metallic coatings matched to base Al and steel materials to avoid galvanic reactions followed by an insulating polymer based sealer with <1 mils thickness adequate on both the rivet and joined metal surfaces which we have verified with our customers to be suitable for most body assembly applications. The process requires galvanic pre-treatments to the joined materials surfaces and the rivet. We are planning to use a robust polymer sealer that performs as a nonabsorbent insulation barrier between the dissimilar materials. The polymer sealer has additives to resist fracture, scratch and deformation during the riveting process. The coatings/sealers are designed to withstand high temperatures to avoid degradation during welding process. The coatings and sealing agents we are planning to use have been used in similar operations with success however we have yet to validate on our rivet weld system, that is one of the purposes of the demonstration.

Figure 1

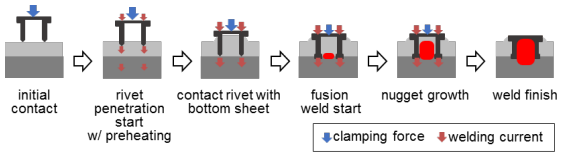


Figure 2

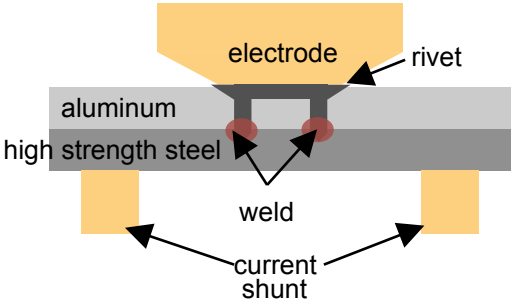
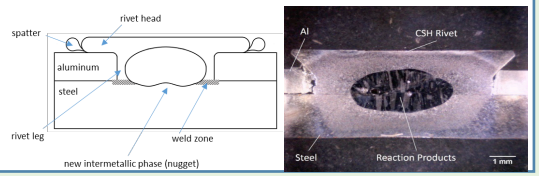


Figure 3



Project Data

Title

☑ Estimate ☐ Fixed TPV $400K MRL Level: MRL 5

Title: Automated One-Sided Joining of Dissimilar Materials Utilizing Hybrid Rivet Weld Process

Solution

Technical Approach / Readiness of Technology

The OPT hybrid “Rivet Weld” technology has been proven using a variety of steel to aluminum alloys in a lab demo setting (MRL5). We have demonstrated very accurate control of the weld melt temperature of the different alloys to regulate the precise temperature individually of both the steel and aluminum side to ensure a perfect bond while simultaneously riveting the structures to encapsulate the weld spot. We have proven this in our labs in a controlled operating environment joining steel to aluminum including sheet to sheet, sheet to a tube structure, and sheet to a casting. We have demonstrated the process using auto OEM provided material samples. Our auto OEM partners (FCA and SF Motors) would like us to now demonstrate a repeatable demonstration using a one sided highly automated robotic solution that would be suitable for auto body assembly operations. This will enable auto OEM’s to lightweight their vehicles by introducing a mixed material strategy on the BIW with the confidence that these dissimilar materials can be joined in a repeatable method in a highly automated assembly line and with a robust joint that will prove durable in harsh auto duty cycle operations. The proposed project is to demonstrate the Rivet Weld system as a one sided joining process suitable for a highly automated manufacturing process. OPT will work with our partners Milco and Arnold Fastening Systems to finalize a DFMEA and PFMEA. OPT will develop a FEA model to perform analysis to optimize the rivet shape for the process. Because the proven OPT rivet weld system’s has the ability to utilize low weld current and force, this allows us the unique ability to employ a indirect welding system. The project will involve Milco to design and engineer a customized indirect weld gun with an off-set backstop in parallel with the electrode to allow for one sided joining. The project will involve Arnold Fastening Systems to support manufacturing feasibility of custom rivet design as well as fabrication of the rivets for the demo. The project requires the integration of a automatic rivet feeding system (Arnold) and weld gun on a robotic arm (Milco). The automated system will demonstrate the ability to produce robust joints on dissimilar materials suitable for an auto body assembly plant that allows for joining at different orientations in a second or less tact time. If we can prove this process, we can expect our system to be specified into Body-In-White (BIW) manufacturing joining operations first on a aluminum roof application. Additional auto BIW joining applications include sheet to sheet aluminum roof to A, B, C steel pillars; sheet to casting aluminum A pillar to cast iron shock tower casting, sheet to tube aluminum B pillar to high steel tube rocker. The project FCA has asked us to demonstrate is on the BIW, specifically joining roof sheet aluminum 6000IHEDT or 6451 with material gage 1.2mm to A Pillar support hot stamped sheet steel 1500 also at 1.2mm. See diagram on slide 4 provided by FCA (confidential). FCA is planning an aluminum roof for their Jeep Wagoneer (confidential) and plans within the next month to assembly 6-7 bodies with mixed material strategy as a demonstration at their joining tech center in Auburn Hills. They have invited us to bring our newly developed rivet weld system to demonstrate on these bodies. SF Motors is finalizing their mixed material strategy for their S306 high performance full battery electric vehicle.

Project Data

Title

Proprietary Project# : FF-LIFT-021617-B-001

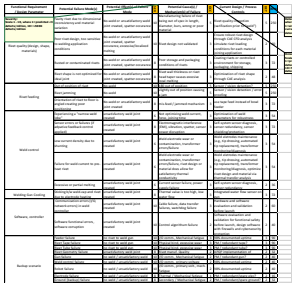
Title: Automated One-Sided Joining of Dissimilar Materials Utilizing Hybrid Rivet Weld Process

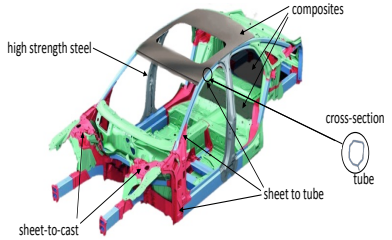
Solution

Technical Approach / Readiness of Technology

Project Proposed Scope of Work:

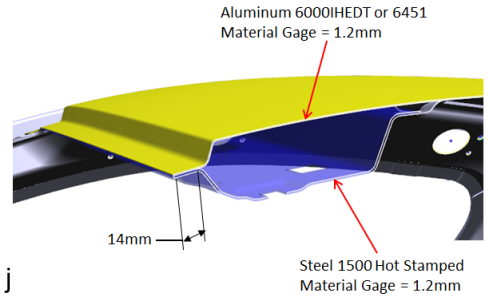
- Finalize DFMEA for one-sided hybrid joining system design
- Develop PFMEA for one-sided hybrid joining system design
- CAE model development and analysis to optimize rivet design
- Manufacturing validation of optimized rivet design
- Design/engineer customized one sided weld gun
- Design/engineer automated rivet feeding system
- Integrate customized weld gun, rivet feeder, weld controller, robot
- Algorithm development to support integrated process
- Demonstrate customer part run off with integrated system, join customer provided samples:
  - Auto BIW, specifically joining roof sheet aluminum 6000IHEDT or 6451 with material gage 1.2mm to A Pillar support hot stamped boron sheet steel 1500 also at 1.2mm.





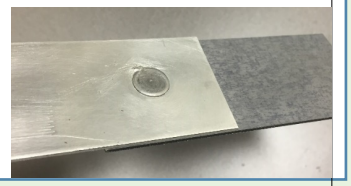
Deliverables:

- Custom rivet design optimized for hybrid joining process
- Manufacturing method for custom rivet
- Custom indirect weld gun optimized for one-sided automated joining process
- Automated rivet feeding system
- Integrated robotic hybrid joining system with customized weld gun, rivet feeder, weld controller
- Customer material sample run-off demonstrations to validate process for specific automotive BIW j



Measures of Project Success:

- Ability to create robust joints of dissimilar material samples
- Ability to simultaneously control riveting and RSW in one manufacturing step within automated one second tact time
- Ability of system to provide multiple orientation one sided joining required of BIW assembly operations
- Ability to ensure a repeatable process over 1,000+ samples
- Ability to avoid corrosion and galvanic reactions typically associated with joining dissimilar materials
- Ability of samples to pass required automotive testing hurdles (e.g., strength, shear, vibration, corrosion)
- Ability to reach cost parity with other joining of dissimilar materials processes (e.g., spot welding or drill flow screws combined with structural adhesives) while minimizing change over in auto body assembly operations.



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Solution

Technical Approach / Readiness of Technology

The proposed demonstration project ask is designed to take us from MRL 5-9. We plan to build an automated rivet weld joining system with low rate production demonstrated with the capability in place to begin full rate production. The demonstration is designed to ensure major system design features are stable and proven in test and evaluation and materials are available to meet planned rate production schedules while addressing high volume production risks.

The roadmap for this project to move from MRL5 to MRL 9 include…

- Major system design features are stable and proven in test and evaluation – we plan to demonstrate that the rivet is able to feed automatically without issues, that the weld nugget is controlled each time within hollow rivet diameter, that the indirect weld gun can provide appropriate weld current and force to repeat a perfect weld each time, that the system on a robotic arm can join at different orientations without impacting off center rivet penetration into the materials
- Materials are available to meet planned rate production schedules – we plan to demonstrate that our one step rivet weld system can meet a tact time of one second or less reliably with a repeatable joint without voids or imperfections, with rivet flush to surface and not exceeding over 1mm above material.
- Manufacturing processes and procedures are established and controlled to three-sigma or some other appropriate quality level to meet design key characteristic tolerances in a low rate production environment. We have developed a draft of the DFMEA and plan to finalize the DFMEA and PFMEA with our partners and customers as a result of this project. We also plan to employ a Certified Product Development Process (CPDP) and Advanced Product Quality Planning (APQP) process for this new production viable rivet weld process. OPT will develop Process Flow Diagrams, PFMEA and Control Plans for each part number down to the component level. The PFMEA will be utilized to assess risk at the system level including component, sub assembly, and the assembly level.
- Production risk monitoring ongoing. Low Rate Initial Production (LRIP) cost goals met, learning curve validated – we plan to demonstrate at high sample rates (1,000+ joints) how well the system operates without need for maintenance in order to gain a reasonable degree of confidence as to whether the system actually performs to the agreed-upon requirements before we can expect our customers to provide contracts for mass production.
- Actual cost model developed for Full Rate Production environment, with impact of Continuous improvement – we plan to demonstrate the cost viability of our system including capex, tooling, consumables; provide a per joint cost estimate; and calculate a cost trade off analysis for our customers of using our system vs. their other joining techniques as requested. The tooling cost of the rivet for cold forming is roughly $7,000 with production expected to be 3-4 cents/rivet. The rivet feeding system is roughly $30,000 at prototype and $1,000-2,000 at production. The indirect one-sided weld gun is $70,000 at prototype and $18,750 at production. The entire high volume one-sided rivet weld production system unit deployment including plant support & evaluation is approximated at a investment of $37,500 for a auto body assembly operation.