NEEDS

Project Data

Title & Goal

☐ Production ☑ R&D Development **Project#:** FF-LIFT-020717-B-002 **Date#:** **Company:**

Title: Development of A Friction Stir Riveting Device

Goal: A Low Cost, Reliable Friction Stir Riveting Device

Problem / Needs

Business Case

Impact

A Low Cost, Reliable Friction Stir Riveting Device is crucial for joining light metals such as Al and Mg alloys and dissimilar light metals. It provides the customers a new means of joining light metals at a fraction of the cost of current devices, and a much higher strength than any existing joining techniques.

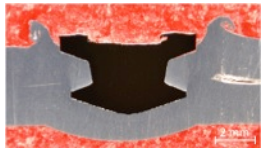
Problem/Statement

Friction Stir Riveting has been developed at the University of Toledo for several years but has yet to be implemented in production due to limited in-house machine capability and other resources. Excellent results have been achieved on joining Al to Al and Al to Mg alloys. The strength of joints (peak load) is consistently beyond 7,000 N which is higher than resistance spot welding and self-piercing riveting.

This project will optimize the joining parameters and produce a commercial device compatible with potential customers' needs.

Figure 1

Figure 2



Deliverables

Financials

Estimated cost impact for aerospace is $XXXX annually
Estimated sales for SMEs is $XXXX annually

Deliverables

A production device which can be used in robotic applications.

Project Data

Title & Goal

☑ Cooperative ☐ Proprietary **Project# :** FF-LIFT-020717-B-002 **Date#:** March 1, 2017 **Company:**

Title: Development of A Friction Stir Riveting Device

Goal: A Low Cost, Reliable Friction Stir Riveting Device

Potential Industry: Automotive, Aerospace **Potential Company:** GM, Fiat-Chrysler, Boeing **Contact:**

Project Scope / Solution

Project Scope

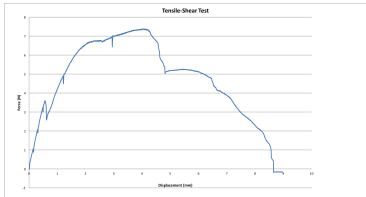
The goal of this project is developing an industrial device of friction-stir riveting. The following will be performed to achieve this goal:

1. Design and build a prototype of friction-stir riveting device;
2. Optimizing rivet design and process parameters of riveting

The following is not included in this project:

1. Industrial trials of the device;
2. Robotic application of the process.

Figure 1



Deliverables

- An industrial prototype of friction-stir riveting device
- An optimized rivet design
- A riveting feeding system
- Optimized riveting process parameters

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

1. Cycle time
2. Joint strength
3. Reliability of the system including feeding, clamping, riveting, and tool life

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Title

☑ **Cooperative** ☐ **Proprietary** **Project# :** FF-LIFT-020717-B-002 **Date#:** March 1, 2017 **Company:**

Title: Development of a Friction Stir Riveting Device

Project TimeLine

Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7
Rivet Design/Data Collection	Prototype Design	Building Prototype	Prototype Building/ Testing	Testing/Improvement	Testing /Improvement	Validation

Approach / Solution Summary

Proposal / Solution

Background

Light metals have been extensively used in the aerospace industry, and have been introduced to the automotive industry for weight reduction in the last two decades. As the enabling technology, joining of these metals is a critical issue for the adoption of such materials. Resistance spot welding, the most common joining method in the sheet metal industry, of aluminum alloys has proven difficult mainly because of their volatile physical properties. The high electrical conductivity of such alloys requires the use of low-alloyed copper for electrodes which is usually soft with low wear resistance. In addition, the high electrical conductivity, together with the high thermal conductivity of aluminum, requires the use of high electric current in a short period of time in order to concentrate the Joule heating in the weld area. Consequently, welding aluminum alloys generally suffers short electrode life and inconsistent weld quality, and is inadequate for certain large volume productions. In general, welding aluminum requires much tighter process control than welding steels, and it is often augmented with adhesive bonding, which complicates the welding process. Alternative joining methods to welding aluminum alloys have been developed, and the most noticeable is probably friction-stir welding, which has been fairly successful in joining aluminum and other metals. However, friction-stir welding requires rigid fixture and allows for little flexibility in the welding process, making it difficult to apply in sheet metal assembly. A special friction-stir welding process is friction-stir spot welding (FSSW), which is more versatile, yet the strength of FSSW is significantly lower than other joining techniques. Another alternative to welding, self-piercing riveting, has been adopted in certain applications. In this process a joint is formed by pressing a semi-tubular rivet into the sheets supported on a die, forming a mechanical interlock between the sheets. It has achieved limited successes in joining aluminum alloys and mild steels, but it has proven inadequate for joining magnesium alloys, and its strength is usually lower that that of resistance spot welds.

Figure 1

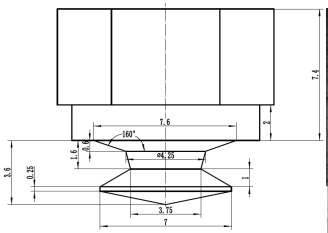


Figure 2

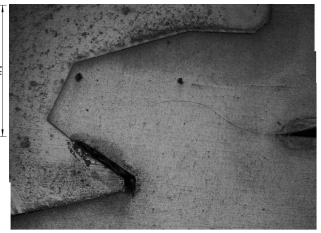
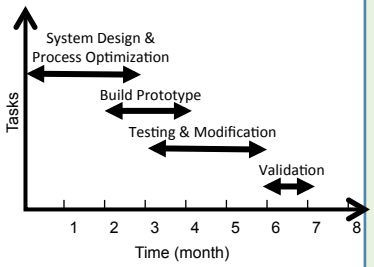


Figure 3

Figure 4



Project Data

Title

☑ Estimate ☐ Fixed TPV $252K MRL Level: 6

Title: Development of a Friction Stir Riveting Device

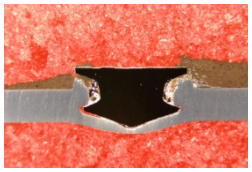
Solution

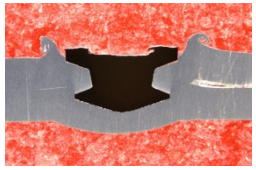
Technical Approach / Readiness of Technology

Solution

Developing a practical and reliable joining method is an essential step in enabling the use of light metals in the sheet metal industry. Dr. Zhang's research group's efforts in self-piercing riveting and friction-stir spot welding have led to the development of an innovative joining process driven by a similar mechanism as in a friction-stir spot welding.

Friction-stir riveting consists of spinning and pushing a solid rivet into the layers of materials to be joined. A progressive view of the riveting process through the intermittent steps of the rivet entering the aluminum sheets is illustrated in the following figure, by the three specimens representing the beginning, middle, and end of riveting. At beginning the rivet extrudes into the top sheet softened by the spinning action. The first batch of the extruded metal goes out of the surface of the top sheet, and the subsequently squeezed metal curls into the opening on the backside of the rivet head. The thrust force exerted by the rivet also pushes the sheets into the die cavity underneath the bottom sheet. This extrusion process continues as the rivet penetrates through the top sheet and enters the bottom one, and a mixed zone is formed behind the rivet head. Compressed by the rivet tail, the stirred metal is squeezed into the openings around the rivet trunk. A reasonable joint is formed as the rivet settles at a designated depth, with a compacted mixed zone.





The strength of a friction-stir riveted joint comes from three sources: the mixed zone formed by the advancing rivet between the sheets, the solid rivet which provides a mechanical interlocking, and the solid bonding between the sheets at the faying interface formed under the combination of heating and pressure. Therefore, an ideal riveting process should generate sufficient strength in each of these three categories.

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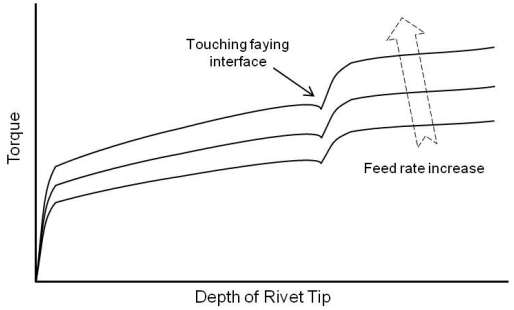
Solution

Technical Approach / Readiness of Technology

In this project, three major tasks are planned:

1. Rivet Modification. The current rivet design has a large head for the ease of holding the rivet for driving the rivet into the workpieces. This large head portion will be reduced, and an alternative holding mechanism will be introduced.
2. Design and build a prototype friction-stir riveting device which can be integrated with a light metal production environment. It consists of the following:
   a) Select appropriate hardware for the application
      - An electric motor for providing a variable torque
      - An electric motor for providing a variable thrust force
      - A programmable digital control unit for controlling the spindle speed and feed rate
      - A feeding unit for transporting the rivets to the driver tip
      - A clamping unit

   b) Build a prototype
3. Optimize the process parameters.
   a) Conduct a design of experiments to understand the process parameters such as the clamping force, spindle speed, and feed rate on the joint quality
   b) Optimize the process parameters. One example is as shown in the figure below, in which variable spindle speed and feed rate can be used to control the heat generation/input, in order to maximize the mixed zone with the minimum amount of time.



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Solution

Technical Approach / Readiness of Technology

Cost Sharing & Budget Justification

A. *Senior Personnel.* Dr. Hongyan Zhang will be paid by the University of Toledo, not this project, for the entire project period of seven months.

B. *Other Personnel*.
One *PhD student*, two *MS students* and two *undergraduate students* are needed to conduct optimization of driving mechanism, and design, analysis, manufacturing, and testing of the friction stir riveting device.
One technician at the College of Engineering's machine shop will spend 20% of his time working with the students and be paid by the university.

The amount of funding request is $125,000. Cost sharing by the University of Toledo is $126,343.

Requested funding will be used to cover the following expenses:

Stipends for 1 PhD student, 2 MS students, and 2 undergraduate students:	$39,600
Fringe benefits of the students:	$7,010
Travel/shipping cost:	$3,000
Materials & supplies:	$30,000
Machining cost:	$5,136
Indirect cost (47.50%):	$4,0254
Total Budget Request:	**$125,000**

Cost sharing by the University of Toledo:

Dr. Zhang and technician's salary:	$40,357
Dr. Zhang and technician's fringe benefits:	$12,147
Students' tuition:	$48,900
Indirect cost (47.50%):	$24,939
Total Cost Sharing:	**$126,343**