JOINING MAGNESIUM ALLOYS TO CARBON FIBER REINFORCED POLYMERS

Darrell Herling

Pacific Northwest National Laboratory
DOE-VTO AMR

Project ID # MAT-139

OVERVIEW

Timeline

- Start: FY18
- Finish: FY20
- 22% Complete

Barriers

- Magnesium (Mg) to carbon fiber reinforced polymer (CFRP) joints are limited by:
  - Galvanic corrosion, joint strength
  - Process time

Budget

- Total Project – $1.8M
- 50/50 PNNL/ORNL
  - FY18 - $600K
  - FY19 - $600K
  - FY20 - $600K

Partners

- Pacific Northwest National Laboratory
- Oak Ridge National Laboratory
- BASF
- POSCO

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RELEVANCE

- **Project Goals:**
  - Develop new techniques for joining Mg sheet/castings to CFRP
  - Improve joint performance compared to existing dissimilar joining techniques
  - Enable widespread use of Mg-CFRP joining technologies for automotive lightweighting

- **Challenges and Barriers:**
  - Lack of advanced technologies for joining metals to composites
  - Limited scientific understanding of metal to composite joints
  - High corrosion potential between Mg and CFRP

APPROACH

- **Investigate four joining technologies that involve mechanical interlocking**
  - Task 1: Friction Stir Interlocking — PNNL Lead
  - Task 2: Bolting and Friction Self-Piercing Rivet — ORNL Lead
  - Task 3: Magnesium Overcasting — PNNL Lead
  - Task 4: Ultrasonic Joining — ORNL Lead
- **Materials to be investigated**
  - **Magnesium:** AZ31 sheet, AZ91 and AM50 casting
  - **CFRP:** Thermoset and thermoplastic
- **Milestone: Down-select most promising technologies for continued development (Sept. 2018)**

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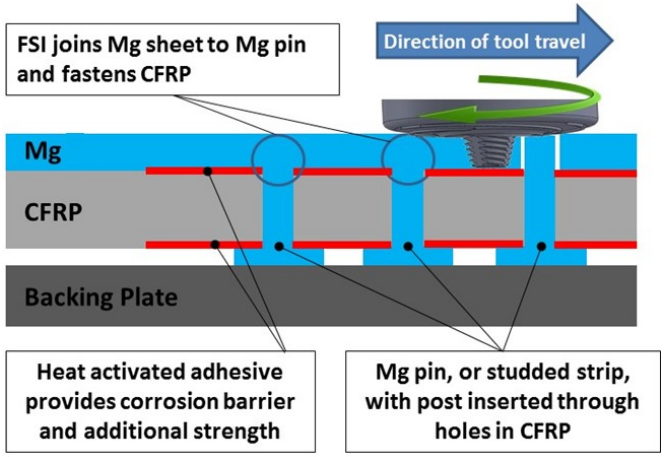
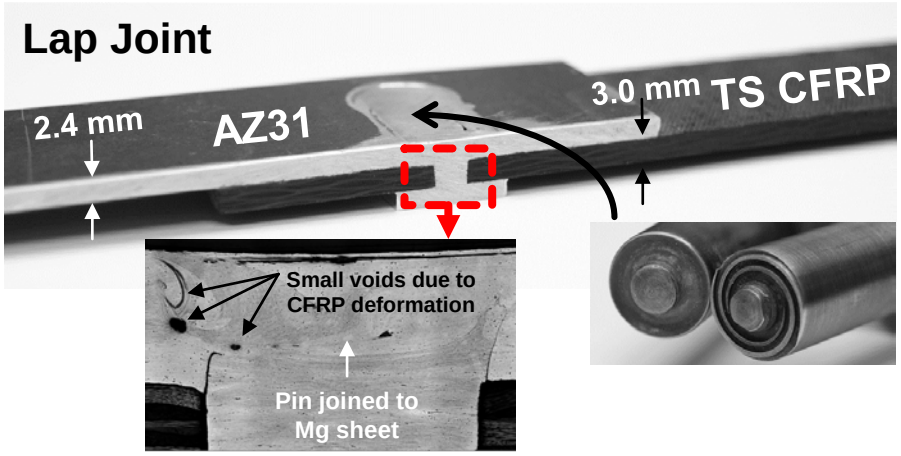
ACCOMPLISHMENTS: TASK 1
FRICTION STIR INTERLOCKING

Approach



- Multiple interlocks formed quickly in curvilinear pattern
- Mg inserts can be embedded during CFRP fabrication
- Compatible with weld-based manufacturing backbone

Accomplishments



- Proof-of-concept for Mg to TS-CFRP
- Lessons learned for tool design and process parameters
- 2.0 kN load capacity and 100 MPa strength for 5mm Mg pins in lap shear

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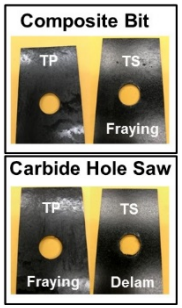
ACCOMPLISHMENTS: TASK 2
BOLTING AND FRICTION BIT JOINING

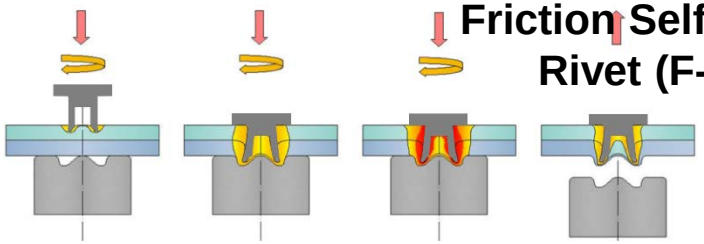
Approach

- Explore effects of hole drilling method on generation of defects
- Investigate potential for self-healing
- Incorporate method for corrosion mitigation

Conventional Bolting



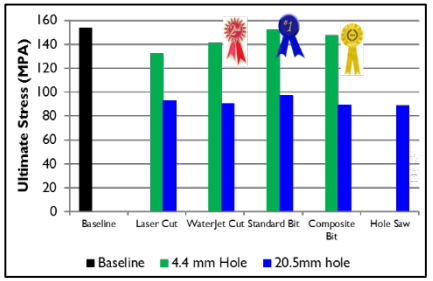
Friction Self-Piercing Rivet (F-SPR)



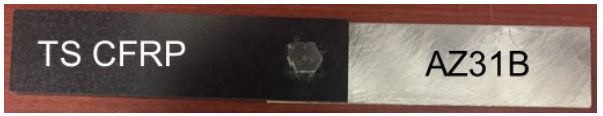
- Localized frictional heating reduces cracking often associated with SPR for low ductility alloys (e.g. Mg alloys)

Accomplishments

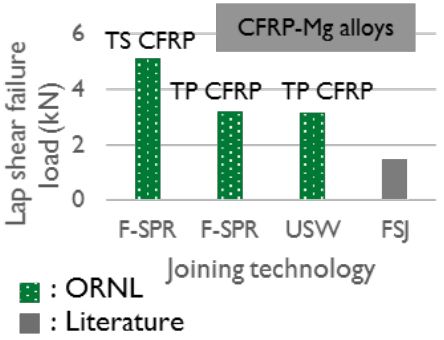
Tensile strength of TP-CFRP coupons with holes drilled by various methods



Mg to TS-CFRP lap coupons made using F-SPR



- Load carrying capacity for TS/TP-CFRP compares favorably to friction spot joining



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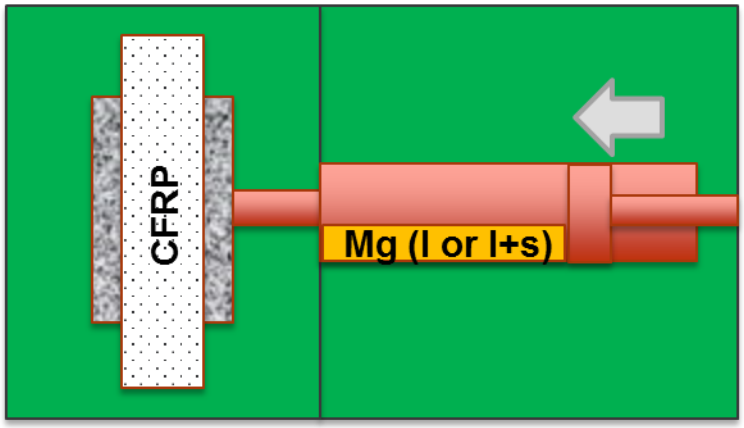
ACCOMPLISHMENTS: TASK 3 MAGNESIUM OVERCASTING

Approach

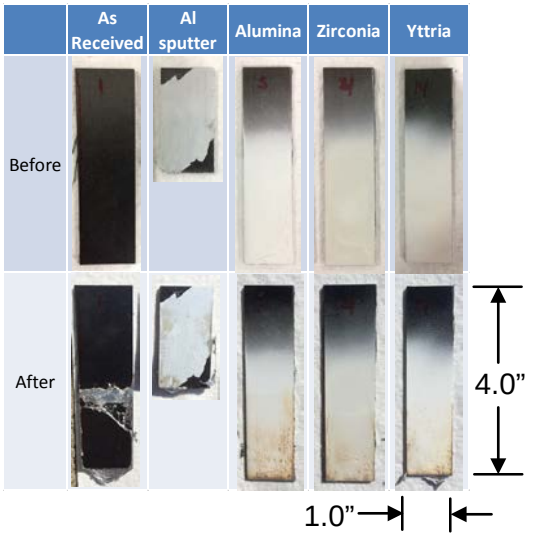
Die-casting/ Squeeze casting



- Use high pressure die-casting over CFRP to mechanically interlock with engineered features and potentially bond to carbon fibers
- Exposure time must be very short to minimize degradation of CFRP

Accomplishments

TS-CFRP with various coatings exposed to molten Al



- Scoping study with Al and TS-CFRP demonstrates composites survive if contact with molten metal is <~10 s
- Influence of surface coatings have been evaluated for protection and wetting

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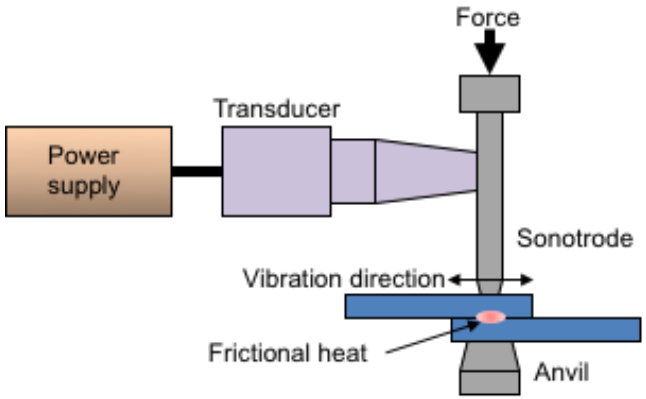
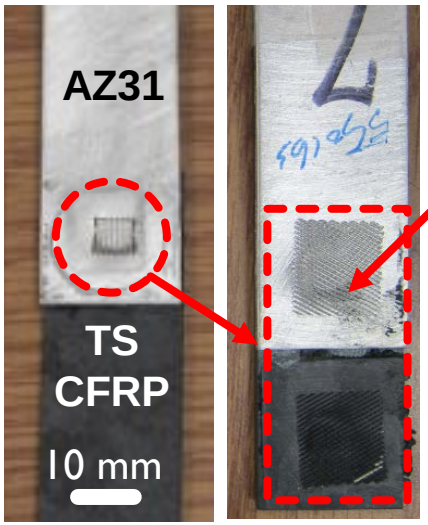
ACCOMPLISHMENTS: TASK 4 ULTRASONIC JOINING

Approach

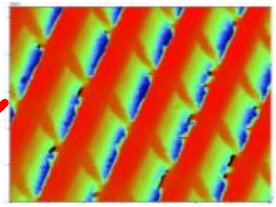


- Use ultrasonic vibrations to achieve chemical bonding between Mg and CFRP resin and fibers
- Incorporate interfacial features that enhance mechanical interlocking
- Process is low energy, fast, clean and can be highly automated

Accomplishments



Achieved ultrasonic joining of Mg to TS-CFRP



Surface Features

- Design surface features via mod/sim that improve joint strength
- 3.2 kN load capacity compares favorably to friction spot joining

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ACCOMPLISHMENTS – RESPONSES TO PREVIOUS YEARS REVIEWERS' COMMENTS

- Project is a new start in FY18

COLLABORATION AND COORDINATION

- Pacific Northwest National Laboratory
  - Scott Whalen (Task 1 Lead), Piyush Upadhyay, Md. Reza-E-Rabby
  - Aashish Rohatgi (Task 3 Lead), Jens Darsell, Jung-Pyung Choi
- Oak Ridge National Laboratory
  - C. David Warren (Task 2 and 4 Lead), Yong Chae Lim, Jian Chen
- BASF – Thermoplastic plaques provided
- POSCO – Magnesium sheet provided

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REMAINING CHALLENGES AND BARRIERS

- Develop Mg-CFRP joining technologies to a level that will allow for meaningful comparison and down-select
- Increase joint strength and load carrying capacity
- Prevent corrosion between Mg and CFRP

PROPOSED FUTURE WORK

- Establish criteria for evaluating, comparing, and down-selecting joining technologies for continued development beyond FY18
- Mature joining technologies to inform down-selection criteria
- Perform down-select before end of FY18
- Incorporate corrosion barrier technologies into most promising joining techniques

Future work is subject to change based on funding levels

TECHNOLOGY TRANSFER ACTIVITIES

- Project is a new start in FY18
- PNNL patent application submitted for “Friction Stir Interlocking” 15/794,687

SUMMARY

- The goal of this project is to develop advanced techniques for joining Mg sheet/casting to TS/TP CFRP
  - Friction Stir Interlocking
  - Conventional Bolting and Friction Self-Piercing Riveting
  - Magnesium Overcasting
  - Ultrasonic Joining
- Rapid progress is being made toward maturing these four technologies
- Technology down-select will occur in Sept. 2018 to determine which approaches will continue being developed in FY19-20.