SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

# Characterization of Lazy S Feature in 2024 Aluminum Friction Stir Welds Made Using a Self-Reacting Tool

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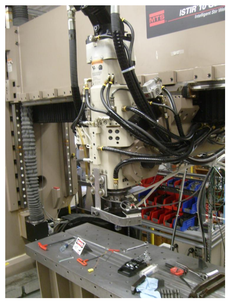


## Objectives

•Produce welds exhibiting Lazy S feature in different sizes and/or shapes

• Determine composition and origin of Lazy S feature

• Test tensile strength of each weld

• Correlate any variations in tensile strength with the shape and/or size of the Lazy S feature

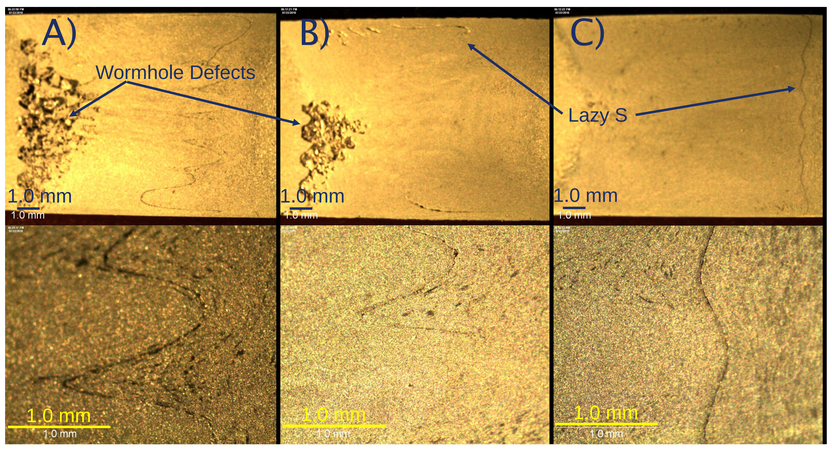
## Procedures

•Material
- 2024-T4 Aluminum, mill finished
- 3/8” x 3” x 8” sections, welded along long edge

•Weld Parameters
- Weld 3: 230 RPM, centered
- Weld 4: 200 RPM, centered
- Weld 5: 230 RPM, offset to advancing side by 3/32”

•Polishing and etching of samples
- Polished to 1 micron mirror finish
- Pre-etched in 10% NaOH solution
- Re-polished with 1 micron cloth
- Etched with Keller’s reagent

•Feature Length measured using image processing software with segmented line approximation




Macrographs of weld cross-sections (top) and micrographs of Lazy S features (bottom): A) Weld 3, B) Weld 4, C) Weld 5.
(Advancing sides are at the left, retreating sides are to the right.)

## Results

•Lazy S feature located in welds, shown on left.
- Shape appears to be related to the pin geometry
- Similar shape in all welds, with varied overall length/distortion

•Tensile Tests performed on same welds
- Welds 3 and 4 failed due to brittle fracture along advancing edge of stir zone
- Weld 5 failed along Lazy S, at retreating edge of nugget

•Average tensile test results, show far lower strength in Weld 5

| Weld | Spindle Speed | Offset (Adv. Side) | Modulus | Stress At Yield | Feature Length |
|---|---|---|---|---|---|
| I. D. | RPM | in. | ksi (avg.) | ksi (avg.) | in. |
| | | | | | |
| SRT-3 | 230 | - | 5197 | 30 | 1.2 |
| SRT-4 | 200 | - | 5273 | 33 | |
| SRT-5 | 230 | 0.094 | 5364 | 17 | 0.4 |

## Conclusions

The Lazy S feature appears to result from incomplete stirring of the faying surface. The oxide layers from the original surface are pushed to the retreating side of the weld, rather than being stirred into the nugget effectively. This effect is accentuated in welds offset to the advancing side.

The Lazy S only seems to have an impact on the tensile strength of the weld when its total path length is comparatively short. This allows the original oxide to be concentrated sufficiently to form a complete barrier across the nugget.

## Impact

Self-reacting tools are a relatively new development in friction stir welding. They produce full thickness welds, and allow material to be welded without requiring complex support structures to react the forge forces involved. This cuts costs and improves energy efficiency.

Currently, self reacting tools are most likely to be used in aerospace and naval applications. Characterization of potential defects in SRT welds could help promote the use of this technology to drastically cut production costs, potentially reducing the cost of transportation for the public in the long run.

## Future Work

- Produce additional samples for a more complete data set
- Vary surface preparation in an attempt to adjust feature thickness
- Examine feature’s effects on fatigue strength
- Expand test matrix to include different material thicknesses

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