Self-Reacting Friction Stir Welding for Aluminum Alloy Circumferential Weld Application

Friction stir welding is an innovative weld process that continues to grow in use, in the commercial, defense, and space sectors. It produces high quality and high strength welds in aluminum alloys. The process consists of a rotating weld pin tool that plasticizes material through friction. The plasticized material is welded by applying a high weld forge force through the weld pin tool against the material during pin tool rotation. The high weld forge force is reacted against an anvil and a stout tool structure. A variation of friction stir welding currently being evaluated is self-reacting friction stir welding. Self-reacting friction stir welding incorporates two opposing shoulders on the crown and root sides of the weld joint. In self-reacting friction stir welding, the weld forge force is reacted against the crown shoulder portion of the weld pin tool by the root shoulder. This eliminates the need for a stout tooling structure to react the high weld forge force required in the typical friction stir weld process. Therefore, the self-reacting feature reduces tooling requirements and, therefore, process implementation costs. This makes the process attractive for aluminum alloy circumferential weld applications. To evaluate the application of self-reacting friction stir welding for aluminum alloy circumferential welding, a feasibility study was performed. The study consisted of performing a fourteen-foot diameter aluminum alloy circumferential demonstration weld using typical fusion weld tooling. To accomplish the demonstration weld, weld and tack weld development were performed and fourteen-foot diameter rings were fabricated. Weld development consisted of weld pin tool selection and the generation of a process map and envelope. Tack weld development evaluated gas tungsten arc welding and friction stir welding for tack welding rings together for circumferential welding. As a result of the study, a successful circumferential demonstration weld was produced leading the way for future circumferential weld implementation.

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12/9/02
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Aeromat 2003

XX June 2003

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Overview

- Introduction
- Thin Gage 2XXX/2XXX Weld Development
- Tack Weld Development
- Ring Fabrication
- Circumferential Weld Demonstration
- Conclusions
Introduction
SR-FSW for Aluminum Alloy Circ. Weld Application

Introduction
SR-FSW for Aluminum Alloy Circ. Weld Application

Thin Gage 2XXX/2XXX Weld Development

- Process Map – Preliminary Pin Tool Design

![Diagram showing relationship between Weld Travel Rate (ipm) and Spindle Rotational Speed (rpm) with zones for Symmetrical Weld Nugget, Asymmetrical Weld Nugget, and Excessive Flashing.](image-url)
SR-FSW for Aluminum Alloy Circ. Weld Application

Thin Gage 2XXX/2XXX Weld Development

- Process Map – Preliminary Pin Tool Design

![Diagram showing process map with weld nugget, excessive flashing, and spindle rotational speed.](image-url)
SR-FSW for Aluminum Alloy Circ. Weld Application

Thin Gage 2XXX/2XXX Weld Development

- Process Map – Preliminary Pin Tool Design

Weld Travel Rate (ipm)

Spindle Rotational Speed (rpm)

Symmetrical Weld Nugget

Asymmetrical Weld Nugget

Excessive Flashing
SR-FSW for Aluminum Alloy Circ. Weld Application

Thin Gage 2XXX/2XXX Weld Development

- Process Map – Preliminary Pin Tool Design

![Diagram showing weld map with labels for symmetrical and asymmetrical weld nuggets, and excessive flashing.}

Spindle Rotational Speed (rpm)

Weld Travel Rate (ipm)

Symmetrical Weld Nugget

Asymmetrical Weld Nugget

Excessive Flashing
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Thin Gage 2XXX/2XXX Weld Development

- Process Map – Optimized Pin Tool Design

![Diagram showing the relationship between weld travel rate (ipm) and spindle rotational speed (rpm) with various weld defects and optimal regions indicated.]

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Thin Gage 2XXX/2XXX Weld Development

- Process Map – Optimized Pin Tool Design
SR-FSW for Aluminum Alloy Circ. Weld Application

Thin Gage 2XXX/2XXX Weld Development

- Process Map – Optimized Pin Tool Design
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Thin Gage 2XXX/2XXX Weld Development

- Process Map – Optimized Pin Tool Design

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Thin Gage 2XXX/2XXX Weld Development

- Process Envelope – Optimized Pin Tool Design

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Tack Welding Development

- "No tack" welding
- Gas tungsten arc (GTA) tack welding
- Friction stir welding
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Tack Weld Development

- "No Tack" Welding

Butt Joint Opened Up

Closed up at end
SR-FSW for Aluminum Alloy Circ. Weld Application

Tack Weld Development

- Tack Weld Layout

- Drilled Thru-Hole for Start
- Tack Welds (3)
- 4" Long 10" Centers

Weld Start
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Tack Weld Development

- GTA Tack Welding

No Panel Separation

Crown Side

Root Side
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Tack Weld Development

- Friction Stir Tack Welding

No Panel Separation

Crown Side

Root Side
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Ring Fabrication – Thin Gage 2XXX/2XXX Friction Stir Welding

Ring Segments

Chopped/High Heat Input

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Ring Fabrication – Machining of Friction Stir Welded Ring
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Loading Rings Into Circumferential Weld Tool
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Friction Stir Tack Welding of Rings
SR-FSW for Aluminum Alloy Circ. Weld Application

Ring Welding

- Data Acquisition
  - Spindle Rotational Speed (rpm)
  - Travel Rate (ipm)
  - Reaction Force (lbs)
  - Torque (ft-lbs)
  - Plow Force (lbs)
  - Plunge Force (lbs)
SR-FSW for Aluminum Alloy Circ. Weld Application

Welded Rings

Crown Side

Root Side
Conclusions

- Friction stir tack welding was able to be performed without the use of an anvil

- During SR-FS welding, friction stir tack welding along with basic fusion weld tooling held the rings together.

- The selected SR-FS weld pin tool design did not fail during the fourteen-foot diameter circumferential weld.
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