Initial Evaluation of a Spring-Opposed Shoulder Retractable Pin Tool for Friction Stir Welding

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Friction Stir Welding

- Solid state process
- Rotating tool provides frictional heat
- Shoulder of tool retains stirred material

[TWI, 1991]

[1]frictionstirlink.com, Friction Stir Link Inc.
Why FSW?

- Maintain parent material strength (alloy dependent)
- No fumes, arcs, or spatter
- High repeatability
- No weld post-processing
Q: Why a Retractable Pin?
A: Exit Material Without Defects

- Closed Contours (e.g. cylinders, spheres)
Other Closed Contour Methods:

Figure: ‘Start and park’ method in the welding of cylinders without a RPT [2.]

Keyhole Defect

Method: Stop traverse and remove tool

Result: Void left by pin
Run-out Defect

Method: Weld over material boundary

Result: Material fails
- Pin traverse forces
- Proximity of FSW influenced zone
- No edge material containment
Tapered Retraction: Conventional FSW Tool

- Gradually remove pin during weld traverse
Tapered Retraction with a Conventional Tool

- Lack of shoulder pressure results in defect
Retractable Pin Tool: Tapered Retraction

- Gradually remove pin during weld traverse while applying shoulder pressure
Goals:

- Maintain shoulder/work contact while inserting & retracting pin.
- Maintain significant shoulder force on work during insertion & retraction to prevent flash.
- Leave no hole when welding cylinders or closed contours.
Stack of 10 Disc Springs Forces Shoulder into Contact

- Compact
- Concentric
- High Capacity
- Shoulder keyed to shaft
- Entire apparatus spins as a whole
- Replaceable pin tool
- Press fit
- Backed by a channel to aid in removal.
- Outer boss further constrains discs
- Retaining washer allows application of preload condition in discs
Elliptical mating for smooth actuation.
RPT placed in series with Dynamometer.
Static Welding Trials: Axial Force Calibration and SSRPT Validation

Goals:

• Discern axial force component in pin and in shoulder.

• Verify theoretical axial shoulder force as pin depth varies.

Methods:

• Incrementally plunge RPT without traverse.

• Incrementally plunge a dimensionally equivalent conventional tool without traverse.
Conventional Tool Pin Plunge (1/4-20 right hand threading) spun 2000rpm CCW.

1/4"-20 pin force relationship:
\[ y = mx + b = 22570 \text{ N/in.} \cdot \text{plunge}'' + 2650 \text{ N} \]
\[ = 5080 \text{ lb./in.} \cdot \text{plunge}'' + 600 \text{ lb.} \]
Spring-opposed Shoulder RPT

Total Axial Force:

Subtracting the experimentally determined pin force yields an indirect measure of the experimental spring constant for the device which can be compared to the theoretical value for a stack of 12 spring washers.

$\Rightarrow$ Experimental:
\[ k_{\text{shoulder}} = 6188 \text{ lb/in.} \]

Theoretical:
\[ k_{12\text{stack}} = 5859 \text{lb/in.} \]
Tapered Retraction Welding Trials
Initial Results: Retraction Zone

- Retract pin at 0.12 in/min
- Weld quality maintained through 40% of retraction
How can quality be improved?

• Adjust traverse rate and/or spindle speed during retraction
• Vary retraction rate over length of retraction
• Adjust force relationship of shoulder
Tool: ¼” diameter pin, 0.7” diameter shoulder
Parameters: 2200rpm, 10ipm, 0.06” pin depth
Retraction Parameters: 2200rpm, 5ipm, 0.12”/min retraction rate
Weld Parameters: 2200rpm, 10ipm, 0.03” pin depth, smooth pin
Retraction Parameters: All 2ipm, 0.12”/min retraction rate

2200rpm retraction:

1900rpm retraction:

2500rpm retraction:
2800rpm retraction:

→ 2500rpm is best, try slowing retraction rate to 0.06”/min:
2500rpm, 0.06”/min retraction rate:
Weld Parameters: 2200rpm, 10ipm, 0.03” pin depth, smooth pin
Retraction Parameters: 2500rpm, 2ipm, 0.12”/min retraction rate
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