Friction Stir Welding on the External Tank

FSW

Implementation on the Space Shuttle's External Tank

Manufacturing Problem Prevention Program

June 6, 2001

David Hartley
Friction Stir Welding on the External Tank

Objective

Increase the Safety, Reliability, & Producibility of the ET by Implementing the FSW Process

LO2 Barrel Welds
4 Each 8'-Feet Long
Tapered Thickness

LH2 Barrel 1 (Longeron Welds)
4 Each 15-feet Long
Tapered Thickness

Barrel Welds
8,000 Inches
Out of
36,000 Total Inches

LH2 Barrels 2, 3 and 4 Welds
24 Each 20-feet Long
22 Each Constant Thickness
2 Each Tapered Thickness

LH2 Barrel 1 Welds
6 Each 15-feet Long
Constant Thickness
Friction Stir Welding on the External Tank
FSW Process Overview

- The base material is clamped to a backing anvil
- A FSW pin tool consists of a concave shoulder and a pin with a length approximately equal to the material thickness
- The pin tool is rotated and plunged into the material until the shoulder penetrates below the top surface
  - Frictional heating from the rotating tool plasticizes the material between the anvil and the shoulder. The rotating tool is then traversed along the weld seam, generating a combination of extrusion and forging between the tool shoulder and the anvil resulting in a ductile, high strength, solid state weld.
# Friction Stir Welding on the External Tank

## FSW/Fusion Process Comparison

<table>
<thead>
<tr>
<th></th>
<th><strong>FSW</strong></th>
<th><strong>Fusion</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weld Set Up</strong></td>
<td>Schedule Selection</td>
<td>Tungsten Position</td>
</tr>
<tr>
<td></td>
<td>Pin Tool Selection</td>
<td>Tungsten Size/type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wire Alloy and Diameter</td>
</tr>
<tr>
<td><strong>During Welding</strong></td>
<td>Plunge Depth/load</td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td>Rotation Speed</td>
<td>Voltage</td>
</tr>
<tr>
<td></td>
<td>Speed Travel</td>
<td>Travel Speed</td>
</tr>
<tr>
<td></td>
<td>Centerline Position</td>
<td>Wire Feed Rate</td>
</tr>
<tr>
<td></td>
<td>Pin Length (Tapers)</td>
<td>APC/AVC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reverse Current</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plasma Gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shield Gas and Flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Back Side Purge Gas and Flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pulse Frequency/Duty Cycle</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arc Gap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oscillator Width (Cover Pass)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oscillator Dwell (Cover Pass)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Oscillator Speed (Cover Pass)</td>
</tr>
</tbody>
</table>

---

*Friction Stir Welding Vastly Reduces and Simplifies Process Variables*
Friction Stir Welding on the External Tank

FSW Process/ET Benefits

- Increased Margin Through:
  - Improved Strength
  - Improved Toughness (CIFS)
  - Improved Cryogenic Enhancements
  - Reduced Peaking and Mismatch
  - Reduced Rework and Repairs
Friction Stir Welding on the External Tank

FSW Process/ET Benefits

- Process Enhancements
  - No filler material or shielding gases required
  - Fewer variables to control
  - Low residual stresses and distortion

- Manifest Supportability
  - Reduced weld defect rate will result in improved cycle time
  - Two new universal tools will improve throughput
  - Weight savings through elimination of weld wire

- Cost Reductions
  - Reduction in labor associated with process improvements
  - Fewer consumables required
  - Reduced manufacturing steps

- Other Safety Improvements
  - Reduced personnel exposure to hazardous operations

FSW Will Improve ET Safety, Reliability and Producibility
Friction Stir Welding on the External Tank
Implementation Status - Development Work

- Full Scale Barrel Demonstration
- Orthogrid 2195 SLWT Panels
- FSW Longitudinal Welds

- Retractable Pin Tool Demonstrated
- Close-out/Repair Welds
- Variable Thickness Welds

NASA and LMSSC are Bringing this Technology to the “Next Level”
Friction Stir Welding on the External Tank
Implementation Status - Process

- **Trades Completed**
  - Anvil Material
  - Pin Material & Configuration
  - Pin Measurement Errors
  - Process Envelope for constant thickness welds

- **Key Issues Resolved**
  - Pin Breakage on Thicker Welds
  - Anvil Material and Heat Sink
  - Allowables/Characterization Test Plan
Friction Stir Welding on the External Tank

Project Status - Development (In Work)

- **Process Mapping**
  - Determine effect of process variables on IPM vs. RPM process map
  - Process maps include strength, microstructure, NDE results, flash, and pin fracture

![Example of Process Map](image_url)
Friction Stir Welding on the External Tank
Implementation Status - Today's Fusion Tooling

Existing Short Barrel Weld Tool

*Vertical VPPA welding of LH2
Barrel 1 and LO2 Barrel*

Existing Long Barrel Weld Tool

*Horizontal SPA welding of LH2
Barrels 2, 3 & 4*
**Friction Stir Welding on the External Tank**

**Implementation Status - Tomorrow’s FSW Tooling**

**Mechanical**
- Universal Tool that handles all Barrel Configurations
- Utilizes Retractable Pin Tool for Tapered Welds
- Provides Access to entire barrel
- Integral Test Fixture
- Reacts clamp and force loads
- Accommodates facility hook height

**Electrical Controls**
- Complete Automatic Operations
- Process Observation Cameras
- Automatic Seam Tracking
- Touch Screen Operation
- Process Data Acquisition and Archival
Friction Stir Welding on the External Tank
Implementation Status - FSW Tooling

• Tooling Status

  – Contract Awarded to General Tool Company (GTC)
  – Prototypes Demonstrated
    ~ Clamping
    ~ RPT Measurement
    ~ Force Control
  – Design Complete
    ~ Production Tool
    ~ Development/Trainer
    ~ Platforms
  – Fabrication in work

Tool Design is Complete and Fabrication Started
Friction Stir Welding on the External Tank

Implementation Status - Production Tooling
Friction Stir Welding on the External Tank

Implementation Status - Production Tooling

ET Barrel
Anvil
Friction Stir Welding on the External Tank
Implementation Status - Trainer
Friction Stir Welding on the External Tank
Implementation Status - Facility Modifications

- Facilities Modifications
  - Pit to Accommodate Hook Height
  - Pit Designed to Accommodate Louisiana Soil Conditions
  - Both Tools in Single Pit

- Modification Status
  - Test Pilings driven to verify No ET Production Impacts
  - Contract Awarded
  - Foundation Started
    - piles complete
    - excavation complete
  - On target for July completion

Facility Modifications are Ahead of Schedule
Friction Stir Welding on the External Tank

Summary

- FSW Is a Significant Safety Benefit for Shuttle Program
- FSW Is a Major Process Improvement for the External Tank
- Project Is Fully Staffed using NASA/Contractor Integrated Process Teams
- Tool Design is Complete and Fabrication Underway
- Facilities Modifications Nearing Completion
- Project Is on Target to Weld Flight Hardware in July of 2002
- Flight Hardware Projected to Fly in 2005

FSW Improves ET Safety Margins, Reliability and Producibility