Development and Application of the Ultrasonic Stir Welding Process

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Presentation will cover ...

- Describe the ultrasonic stir weld (USW) process
- Background study of US friction reduction
- Prototype USW system
- Advanced USW system
Basic Friction Stir Welding Process

- Tool Shank
- Tool Shoulder
- Tool Pin
- Threads
- Down force provides material constraint
- FSW Tool
- Travel Direction
- Weld Joint
- Rotational Direction
- Shoulder
- Pin
- Advancing Side
- Stir Zone
- Retreating Side
Concept for Ultrasonic Stir Weld System

- Existing Ultrasonic Drill Unit
- US Stir Weld Tool
- Actuators
- Force Plate
- Induction Heating Source
- US Transducer & Transmission Line
- Parts
- Containment Plate
- Stir Weld Tool Tip

Seek reduced friction between CP and parts

Improve effectiveness of weld stir tool
Friction Reduction at Containment Plate

- Strip draw test permitted US friction reduction to be evaluated
Figure 15. Example data from tests 52022 – No. 10,11,12. Clamping force, 400lbs. – without ultrasonics (No. 10) and at 40% amplitude (No. 11, 12).
NASA friction reduction tests

2008 Experimentation at MSFC
Leased EWI twist drill system

FRICCTION REDUCTION

PLUNGE FORCE REDUCTION
USW Prototype System

US Power Supplies (1 of 2)

Z-axis Drive

Spindle Motor

Stir Tool Transducer

Stir Tool

Induction Heating Coil

Containment Plate

Base Plate for Test Plates

Moving Table

CP Transducer, Curved Transmission Line
# Early Weld Data

## Weld # 13

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Settings/Readings</th>
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<tbody>
<tr>
<td>Plate Material</td>
<td>Al 2219</td>
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<tr>
<td>Weld Type</td>
<td>Weld Plates</td>
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<tr>
<td>US Stir Tool PS Setting &amp; Power</td>
<td>65%, 1043W</td>
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<tr>
<td>US CP PS Setting &amp; Power</td>
<td>90%, Overload</td>
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<tr>
<td>Stir Tool RPM</td>
<td>600</td>
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<tr>
<td>CP Force</td>
<td>3000 lb.</td>
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<tr>
<td>Table Speed</td>
<td>10 ipm</td>
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<tr>
<td>Weld Depth Setting</td>
<td></td>
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<tr>
<td>Induction: Setting/Output</td>
<td></td>
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</tbody>
</table>

Despite discontinuities, early results seen as positive
Advanced USW System

- Overall system
Ultrasonic Components

- US Transducer
- Case
- Booster
- Stir Tool
- Transmission Line
- Containment Plate
US Stir Tool Details

Transducer

Booster

Stir Tool
Containment Plate Details

Transducer

Transmission Line

Containment Plate
Load Cell – measure US FSW forces/torques

\[ F_P = \text{Plunge Force} \]
\[ F_T = \text{Transverse (Drag) Plunge} \]
\[ F_S = \text{Side Force} \]
\[ T = \text{Torque} \]
Data file contains information on

- Machine Parameters (Command & Actual)
  - Execution Time, Distance, Weld Operation, Spindle Speed, Path Max. Force Limit, Plunge Depth, Travel Speed, Plunge Speed, Laser Height Sensor Data, Induction Power,
- Process Feedback
  - Forces: Path Force, Cross Path Force, Plunge Force, Torque
  - Ultrasonic Frequency, Power and Amplitude
  - Ultrasonic Containment Plate Force
  - Individual outputs from each of the charge amplifiers

Sampling Rate of 20 samples per second.

Usually Plotted vs. Time or Distance

- Plotted vs. Time includes plunge data
- Plotted vs. Distance for direct weld comparison
USW Data Files

- Created as a .txt file that is opened by Microsoft Excel.
Columns can be selected to ‘drill down’ into parameters of interest.

These are usually plotted as an X-Y Graph.
Capabilities Summary

• Ability to “pulse” US energy on/off; adjust parameters real-time (travel speed, spindle RPM, US amplitude, X and Z axis position, plunge and pin axis force)
• Force, torque measurement
• Record US power versus time
• Head deflection control - two laser height sensors.
• Linear encoder to better control tool penetration
• Ultrasonic energy integrated into stir rod and containment plate.
• Maximum 600 RPM, maximum Z force 15,000 pounds.
• Independent control of heating capability via induction technology.
Initial NASA Tests

Increasing force with decreasing US

$T_{ult} = 46.65 \text{ ksi}$
$T_{yld} = 31.16 \text{ ksi}$

$T_{ult} = 33.91 \text{ ksi}$
$T_{yld} = 31.12 \text{ ksi}$
FUTURE WORK

• Begin induction coil pre-heat
• Characteristics of hot weld versus cold weld
• Pulse ultrasonics on/off
• Determine upper limit of CP amplitude
• Faster travel rates
• Develop parameters for heat resistant alloys
Goal ...
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