New Test Part for Ultrasonic Welding Characterization

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Agenda

- ISTeP Description
- I-Beam Description
- DOE
- Test results and analysis
- Summary
- Future improvements
- Dukane iQ Servo Welder overview
- WELDED ASSEMBLIES -

- COVER -
  - NOMINAM WALL 3/32"
  - SHOT SIZE .20 CU/IN
  BOTH PARTS

- BODY -
  - NOMINAM WALL 3/32"
  - SHOT SIZE .40 CU/IN
  BOTH PARTS

SECTION A-A

DETAIL A
SCALE 8.000
.017

.76

90°

.030

.015 E.D. HEIGHT

SECTION A-A

DETAIL B
SCALE 8.000
AWS I-Beam

Figure 5—Energy Director Butt Joint Welding

Figure 6—Double Shear Joint Welding
AWS I-Beam

AWS G1.2M/G1.2:1999

Notes:
1. All dimensions mm (in.)
2. Tolerances: ±0.2 (0.008)
   ±0.05 (0.002)

<table>
<thead>
<tr>
<th>Profile</th>
<th>A</th>
<th>B</th>
<th>Ref. C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Energy Director</td>
<td>0.61 (0.024)</td>
<td>0.30 (0.012)</td>
<td>90°</td>
</tr>
<tr>
<td>Large Energy Director</td>
<td>0.81 (0.032)</td>
<td>0.51 (0.020)</td>
<td>77°</td>
</tr>
</tbody>
</table>
Dukane Announces ISTeP – an Advanced Test Part!

- Dukane Corporation has taken a significant step to improve the ultrasonic industry’s standard test part. We are calling it the ISTeP – Industrial Standard Test Part.
- It is two-piece cylindrical part used to test a variety of welded parts’ characteristics. With ISTeP ultrasonic weld quality can be determined with enhanced confidence.
- **Outside the I-Beam** – By rethinking the design of the existing industry standard part (I-Beam) currently used for testing, it became clear there was room for improvement. Consider ISTeP’s cylindrical shape.
ISTeP

• Dukane’s investment in the development of a better industry standard test part included a fresh part design and also production of a quality injection mold. The ISTeP team created the mold so that gates and knits insured a uniform mold fill, especially in the joint area. There are three joint design options – 60° or 90° energy directors, and a standard shear joint. In addition, the mold has inserts for the joint area. These allow for additional options manufacturers and designers may bring in the future that are unique to their weld joint specifications.

• **Pressure/Burst/Leak Testing** - An integral port in ISTeP’s lower portion makes it easy to insert an air tube for a variety of checks that can be made.
ISTeP

- **Pull Testing** is simplified by the use of ISTep’s unique tabs, three on the top piece, and three on the lower portion. The tabs help reduce time spent assembling the test part into its pull test fixture.
  - Bond strength of different plastic resins can be compared - polycarbonate vs. ABS as an example.
  - When parts come apart under testing, they will do so avoiding the so-called “zipper effect” that was previously common.
ISTeP

Testing Weld Processes and Features – Welding methods each have their distinct advantages. To find which combination of process and features work best, ISTeP could be used with pneumatic and servo welders, using features such as amplitude profiling or Melt-Match® technology, for instance. Dukane’s enhanced *iQ Series* generators and software are available to provide even more versatility and possibility to make the testing process complete and comprehensive.

Mold Availability – ISTeP’s injection mold is available from Dukane for firms interested in obtaining test parts molded in their resin of choice. Dukane Corporation offers expertise and know-how for your application.
The same 20 kHz iQ Servo Driven Press system is used
O-Ring Booster and Resonant mount Boosters were tested
Horns for I-Beam and ISTeP have similar gain – amplitude for both parts was very close
Same weld set-up parameters were used to weld both part in sets 1, 2 and 3. Deeper collapsed distance was used for ISTeP in set # 4 to accommodate part’s taller Energy Director
Parts were measured before and after the weld and the difference was calculated (actual collapsed distance). This value was then compared against the welder readings
The same pull test fixture was used with part holders that were made to match ISTeP and I-Beam respectively
ISTeP – Lexan12R; I-Beam – Lexan141 – similar properties
ISTeP Energy Director

Photo from a microscope
Ultrasonic Welding Joints

Energy Director

<table>
<thead>
<tr>
<th>Dimension</th>
<th>General Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Wall Thickness</td>
</tr>
<tr>
<td>B</td>
<td>Energy Director Base Width</td>
</tr>
<tr>
<td>A</td>
<td>Energy Director Height</td>
</tr>
<tr>
<td>E</td>
<td>Energy Director Angle</td>
</tr>
</tbody>
</table>
Unwelded End of E/D

Typical Energy Director Unwelded
Typical Energy Director Welded
DOE – ISTeP Pull Test Fixture
DOE – I-Beam Pull Test Fixture
DOE – I-Beam Welding Setup
DOE – I-Beam Height Measurement Fixture
DOE – ISTeP Welding Setup
DOE – Welding Setup Parameters
I-Beam Set # 1, 2

Servo Press
With O-Ring Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 92.161 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.300 mm
Enable Melt Detect Enabled After Force Drops By 10 %
Weld Motion Control Speed 10.000 mm/s
Weld Amplitude 100 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 12.700 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 96.268 mm
DOE – Welding Setup Parameters

ISTeP Set # 1, 2

Servo Press
With O-Ring Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 88.682 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.300 mm
Enable Melt Detect Enabled After Force Drops By 10 %
Weld Motion Control Speed 10.000 mm/s
Weld Amplitude 100 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 12.700 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 96.268 mm
DOE – Welding Setup Parameters

I-Beam Set # 3

Servo Press
With O-Ring Booster
Trigger Type Force
Force 250.0 N
Sensing Start
Position 36.805 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.250 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 42.265 mm
DOE – Welding Setup Parameters

ISTeP Set # 3

Servo Press
With Resonant Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 63.006 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.250 mm
Enable Melt Detect Enabled After Force Drops By 5%
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90%

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 71.151 mm
DOE – Welding Setup Parameters

I-Beam Set # 4

Servo Press
With Resonant Booster
Trigger Type Force Trigger Force 250.0 N
Sensing Start
Position 41.542 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.250 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 45.564 mm
DOE – Welding Setup Parameters

ISTeP Set # 4

Servo Press
With Resonant Booster
Trigger Type Force
Trigger Force 250.0 N
Sensing Start
Position 62.940 mm
Sensing Speed 1.270 mm/s

Weld Settings
Weld Method Distance 0.305 mm
Enable Melt Detect Enabled After Force Drops By 5 %
Weld Motion Control Speed 2.000 mm/s
Weld Amplitude 90 %

Hold Settings
Dynamic Hold Method Distance 0.050 mm
Hold Constant Speed 5.000 mm/s
Max Hold Time 1.000 s
Static Hold Method Time 0.500 s
Travel Limit 71.151 mm
## ISTeP vs. I-Beam Weld Results Summary

<table>
<thead>
<tr>
<th>ISTeP_Set 1 (mm)</th>
<th>Computer Data</th>
<th>Difference Measured</th>
<th>Pull Strength</th>
<th>ISTeP_Set 2 (mm)</th>
<th>Computer Data</th>
<th>Difference Measured</th>
<th>Pull Strength</th>
<th>ISTeP_Set 3 (mm)</th>
<th>Computer Data</th>
<th>Difference Measured</th>
<th>Pull Strength</th>
<th>ISTeP_Set 4 (mm)</th>
<th>Computer Data</th>
<th>Difference Measured</th>
<th>Pull Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Welding</td>
<td>After Welding</td>
<td>Difference</td>
<td>mm</td>
<td>Before Welding</td>
<td>After Welding</td>
<td>Difference</td>
<td>mm</td>
<td>Before Welding</td>
<td>After Welding</td>
<td>Difference</td>
<td>mm</td>
<td>Before Welding</td>
<td>After Welding</td>
<td>Difference</td>
<td>mm</td>
</tr>
<tr>
<td>Average</td>
<td>19.923</td>
<td>19.662</td>
<td>0.261</td>
<td>352</td>
<td>0.091</td>
<td>712</td>
<td>19.615</td>
<td>19.410</td>
<td>0.206</td>
<td>0.352</td>
<td>-0.147</td>
<td>1529</td>
<td>19.615</td>
<td>19.401</td>
<td>0.217</td>
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<tr>
<td>Std. Dev</td>
<td>0.007</td>
<td>0.004</td>
<td>0.007</td>
<td>0.001</td>
<td>102</td>
<td>0.043</td>
<td>0.026</td>
<td>0.032</td>
<td>0.001</td>
<td>306</td>
<td></td>
<td></td>
<td>79</td>
<td>0.040</td>
<td>0.026</td>
</tr>
</tbody>
</table>

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### Average Pull Strength

- Before Welding: 19.923 mm
- After Welding: 19.662 mm
- Difference: -0.261 mm

###STD Dev

- Before Welding: 0.007 mm
- After Welding: 0.004 mm
- Difference: 0.003 mm

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**Note:** The table above summarizes the results of weld test comparisons between ISTeP and I-Beam welds. The table includes data for four sets of welds, with columns for Before and After welding, difference in pull strength, and a set's average and standard deviation. The results highlight the effectiveness and consistency of ISTeP in weld testing compared to I-Beam methods.
## ISTeP vs. I-Beam
### Weld Results Summary Set # 4

<table>
<thead>
<tr>
<th></th>
<th>Force at Trigger</th>
<th>Weld Time</th>
<th>Weld Energy</th>
<th>Weld Peak Power</th>
<th>Weld Peak Force</th>
<th>Weld Distance</th>
<th>Hold Distance</th>
<th>Weld + Hold Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISTeP</td>
<td>Average</td>
<td>250.733</td>
<td>0.235</td>
<td>195.503</td>
<td>2255.187</td>
<td>919.133</td>
<td>0.308</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>Std. Dev</td>
<td>0.691</td>
<td>0.008</td>
<td>10.604</td>
<td>50.147</td>
<td>16.152</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Std. Dev %</td>
<td>0.28%</td>
<td>3.27%</td>
<td>5.42%</td>
<td>2.22%</td>
<td>1.76%</td>
<td>0.57%</td>
<td>3.42%</td>
<td>0.21%</td>
</tr>
<tr>
<td>I-Beam</td>
<td>Average</td>
<td>250.167</td>
<td>0.192</td>
<td>103.113</td>
<td>1446.490</td>
<td>567.867</td>
<td>0.254</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>Std. Dev</td>
<td>0.379</td>
<td>0.006</td>
<td>5.837</td>
<td>74.153</td>
<td>122.471</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Std. Dev %</td>
<td>0.15%</td>
<td>3.38%</td>
<td>5.66%</td>
<td>5.13%</td>
<td>21.57%</td>
<td>0.64%</td>
<td>3.38%</td>
<td>0.22%</td>
</tr>
</tbody>
</table>
ISTeP vs. I-Beam
Weld Results Summary

• Height Measurements
  – The ISTeP height measurements showed very consistent average and standard deviation from set to set.
  – The I-Beam have showed less consistent averages from set to set and increasingly better standard deviation.
  – In the set 1 the pre-welding height’s standard deviation for the I-Beam parts were 4 times greater than for the ISTeP, in the last set it was only double. We believe that our operator has improved his consistency of assembling the I-Beam. This means that the I-Beam measurements have greater dependency on operator skill and are less accurate for short runs.
  – The ISTeP showed consistently lower standard deviation for both pre and post weld measurements.
ISTeP vs. I-Beam
Weld Results Summary

- Weld Depth
  - In sets 1 & 2 both parts were measured to have less weld depth than was programmed (high compressibility in the O-Ring booster).
  - In sets 3 and 4 the I-Beams had a greater measured weld depth than programmed. Both sets were welded with lower velocity, but set 3 used O-Ring and set 4 used Resonant booster.
  - In sets 3 and 4 the I-Beams showed a closer correlation to programmed weld depth than the ISTeP parts.
  - The ISTeP parts showed the best match to the programmed weld depth in set 3. Set 4 had deeper weld, and therefore larger force and larger deflection in the booster.
ISTeP vs. I-Beam
Weld Results Summary

• Pull Strength
  – The I-Beam parts consistently showed greater pull force
  – The ISTeP parts broke the part rather than the weld in many of the last set of samples
    • Perhaps the pull features of the part should be modified?
  – The ISTeP parts showed a standard deviation of pull force of 20%, the I-Beams had 34%

• Peak Power and Peak Force during welding
  – The ISTeP had much more consistent results for sets 3 & 4, and higher average results
    • Perhaps the weld strength would be greater if the pull features of the test part were modified?

• Weld Energy
  – The ISTeP had greater values, but standard deviation was the same for both part styles.
ISTeP vs. I-Beam
Weld Results Summary

20 kHz Servo-2 - I-Beam - Part Count 37
15 Apr 2013

DISTANCE [mm] vs. FORCE [N]
ISTeP vs. I-Beam

Weld Results Summary

20 kHz Servo-2 - ISTeP - Part Count 30
15 Apr 2013

DISTANCE [mm]

FORCE [N]
ISTeP vs. I-Beam
Weld Results Summary

• Our conclusion is that the ISTeP is a much more accurate and consistent part but we may need to improve the pull feature design to make it perform even better.
ISTeP vs. I-Beam
Future Development

• We will consider running similar tests with additional plastic materials
• We will consider optimizing ISTeP’s pull features to make it perform even better
• We will investigate optimization of the weld parameters
• We will promote the usage of this parts by the industry and academia
## Ultrasonic Welding Process Optimization

<table>
<thead>
<tr>
<th>Welder Control Features</th>
<th>BASIC</th>
<th>GOOD</th>
<th>BETTER</th>
<th>BEST</th>
</tr>
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<tbody>
<tr>
<td>Trigger</td>
<td>Spring</td>
<td>Spring</td>
<td>Force xdcr</td>
<td>Force xdcr</td>
</tr>
<tr>
<td>Single Pressure</td>
<td>X</td>
<td>X</td>
<td>Force xdcr</td>
<td>X</td>
</tr>
<tr>
<td>Dual Pressure</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Time</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Energy</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Distance</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electronic Pressure</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Pressure Profile</td>
<td></td>
<td>X</td>
<td></td>
<td>Servo Weld speed profile</td>
</tr>
<tr>
<td>Hydraulic Weld Speed Control</td>
<td></td>
<td>X</td>
<td>X</td>
<td>Servo Weld speed profile</td>
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<tr>
<td>Servo Speed Control</td>
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<td></td>
<td></td>
<td>Servo Weld speed profile</td>
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<tr>
<td>Servo Speed Profile</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Hold by Distance</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Static Hold</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Move after Force Drop (Melt-Detect)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
iQ Servo Models
FDA compliant

- Simplified Validation Servo vs. pneumatic
- No operator controls - eliminates unauthorized machine adjustments
- All mechanical adjustments require tool.
Developed and Manufactured by Dukane
St. Charles, IL

• System Patents

#7,475,801 - iQ Generator
#7,819,158 – Servo packaging and velocity/force profiling
#8,052,816 – Servo with delayed motion
Earlier Experiment

Common ultrasonic shear joint design.
Comparison of Collapse Distance Repeatability For Pneumatic and Servo Welders (round filters Polycarbonate parts)

<table>
<thead>
<tr>
<th></th>
<th>Pneumatic</th>
<th>Servo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Collapse (in.)</td>
<td>0.0179”</td>
<td>0.0172”</td>
</tr>
<tr>
<td>Standard Deviation (in.)</td>
<td>0.0004”</td>
<td>0.0001”</td>
</tr>
</tbody>
</table>
## Comparison of Pull Strength Repeatability
For Pneumatic and Servo Welders
(round filters Polycarbonate parts)

<table>
<thead>
<tr>
<th>Normalized Data to compensate for uneven Collapse Distance</th>
<th>Pneumatic</th>
<th>Servo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Pull Strength per Inch of Weld Depth (Collapse Distance) (lb./in.)</strong></td>
<td>56,730</td>
<td>57,610</td>
</tr>
<tr>
<td><strong>Standard Deviation (lb./in.)</strong></td>
<td>8600 (15.2%)</td>
<td>1140 (2.0%)</td>
</tr>
</tbody>
</table>
References


References


Questions?