2013 UTSR Fellowship

August 7, 2013
Shelby Hayes

Industrial Turbomachinery Systems

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Primary Summer Projects

UNS N08020 Research and Weld Trials

EB Weld Development

Spray Angle Characterization
UNSW N08020 Project Overview

- **Tasks:**
  - Research
  - Engineering Report
  - Project Day Presentation
  - Weld Trials

- **Material Introduction**
  - UNS N08020 is austenitic steel that is a chromium-nickel alloy designed for excellent corrosion resistance.
  - Superior properties for withstanding gas turbine combustors compared to 300 series stainless steels.
  - Less costly than other high nickel alloys such as Hast X or Inconel 625.

- **Project Support:** Derek Polaikis, Mike Hackenberg, Ann Kreutziger, Scott Litaker
# Material Characteristics

**• Chemical**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Ni</th>
<th>Cr</th>
<th>Cu</th>
<th>Mo</th>
<th>Mn</th>
<th>Nb</th>
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<tbody>
<tr>
<td>316</td>
<td>10-14</td>
<td>16-18</td>
<td>0-0.75</td>
<td>2-3</td>
<td>0-2</td>
<td>-</td>
</tr>
<tr>
<td>8020</td>
<td>32-38</td>
<td>19-21</td>
<td>3-4</td>
<td>2-3</td>
<td>0-2</td>
<td>0-1</td>
</tr>
<tr>
<td>Hast X</td>
<td>49-50</td>
<td>21-22</td>
<td>-</td>
<td>9</td>
<td>0-1</td>
<td>-</td>
</tr>
<tr>
<td>Inc 625</td>
<td>58-61</td>
<td>20-23</td>
<td>-</td>
<td>8-10</td>
<td>0-0.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>

**• Mechanical**

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Density (lbs/in³)</th>
<th>Modulus of Elasticity (Msi)</th>
<th>Ultimate Strength (ksi)</th>
<th>Yield Strength (ksi)</th>
<th>Melting Point (F)</th>
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</thead>
<tbody>
<tr>
<td>316</td>
<td>0.29</td>
<td>29</td>
<td>75</td>
<td>30</td>
<td>2500-2650</td>
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<tr>
<td>8020</td>
<td>0.28</td>
<td>28</td>
<td>80</td>
<td>35</td>
<td>2525-2630</td>
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<tr>
<td>Hast X</td>
<td>0.30</td>
<td>30</td>
<td>110</td>
<td>56</td>
<td>2300-2470</td>
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<tr>
<td>Inc 625</td>
<td>0.31</td>
<td>30</td>
<td>120</td>
<td>60</td>
<td>2350-2460</td>
</tr>
</tbody>
</table>
## Material Characteristics

### Thermal

<table>
<thead>
<tr>
<th>Thermal Expansion</th>
<th>Expansion Coefficient ($10^{-6}/^\circ\text{C}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C to:</td>
<td>316</td>
</tr>
<tr>
<td>100</td>
<td>16.5</td>
</tr>
<tr>
<td>350</td>
<td>17.5</td>
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<tr>
<td>900</td>
<td>19.3</td>
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</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Thermal Conductivity (W/m·K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(°C)</td>
<td>316 SS</td>
</tr>
<tr>
<td>50</td>
<td>14.6</td>
</tr>
<tr>
<td>200</td>
<td>17.2</td>
</tr>
<tr>
<td>400</td>
<td>20.1</td>
</tr>
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</table>
Machining

- **UNS N08020** requires more power than carbon steels to machine.
  - *Machine tools should be rigid* and used to no more than 75% of their rated capacity.
  - Tools, either high speed steel or cemented carbide, *should be sharp*, and reground at predetermined intervals.
  - Feed rates should be high enough to *ensure that the tool cutting edge is getting under the previous cut* thus avoiding work-hardened zones.
  - Lubricants, such as sulfur-chlorinated petroleum oil, are suggested. Such lubricants may be thinned with paraffin oil for finish cuts at higher speeds.
Welding

• **Cleanliness of the weld materials is critical.** Expressed by Siemens as well.

• **Minimize dilution in the weld fillers.**
  - ER320LR filler metal for TIG welding
  - AWS ERNiCrMo-3 for TIG welding to other metal alloys such as 316, C276 and Alloy 22

• **The nickel alloy weld filler used with UNS N08020 gives a more viscous weld pool than with conventional stainless fillers.**

• **Minimize heat input, and the interpass temperatures should be kept below 100°C.**
Current Weld Trials

• Manual TIG weld Samples 1 and 2, PN Joint 15: UNS N08020 to SS 304.

• Sample 1 had visible cracking because Alloy was being welded to a dissimilar material.

• Sample 2 was welded with a gap and eliminated the visible cracks.
**Development Schedule**

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Finish</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>PILOT NOZZLE DEVELOPMENT</td>
<td>Tue 10/29/13</td>
</tr>
<tr>
<td>2</td>
<td>Coupon Design and Release</td>
<td>Mon 6/3/13</td>
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<tr>
<td>3</td>
<td>RFQs and Review</td>
<td>Mon 6/10/13</td>
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<tr>
<td>4</td>
<td>PO Placement</td>
<td>Mon 6/17/13</td>
</tr>
<tr>
<td>5</td>
<td>Component Fabrication and Delivery</td>
<td>Tue 7/16/13</td>
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<tr>
<td>6</td>
<td>Joint 12; EBW Alloy20 to Inco625</td>
<td>Fri 8/23/13</td>
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<tr>
<td>10</td>
<td>Joint 15; TIG Manual Alloy20 to 304</td>
<td>Wed 9/4/13</td>
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<td>14</td>
<td>Joint 8; EBW Alloy20 to 321</td>
<td>Thu 9/19/13</td>
</tr>
<tr>
<td>18</td>
<td>Joint 3; EBW Alloy20 to 321</td>
<td>Tue 10/29/13</td>
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<td>22</td>
<td>Customer Review</td>
<td>Tue 10/29/13</td>
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<td>24</td>
<td>DF42 NOZZLE DEVELOPMENT</td>
<td>Wed 2/19/14</td>
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<tr>
<td>25</td>
<td>Coupon Design and Release</td>
<td>Tue 7/23/13</td>
</tr>
<tr>
<td>26</td>
<td>RFQs and Review</td>
<td>Fri 7/26/13</td>
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<tr>
<td>27</td>
<td>PO Placement</td>
<td>Mon 7/29/13</td>
</tr>
<tr>
<td>28</td>
<td>Component Fabrication and Delivery</td>
<td>Mon 8/19/13</td>
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<tr>
<td>29</td>
<td>Joint 5mm Wall; TIG Alloy20 to HastX</td>
<td>Fri 9/20/13</td>
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<td>33</td>
<td>Joint 7.2mm Wall; EBW Alloy20 to Alloy20</td>
<td>Wed 10/30/13</td>
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<td>37</td>
<td>Joint 3mm Wall; TIG Alloy20 to 304L</td>
<td>Tue 12/3/13</td>
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<tr>
<td>41</td>
<td>Joint 3mm Wall; TIG Alloy20 to 316L</td>
<td>Thu 1/16/14</td>
</tr>
<tr>
<td>45</td>
<td>Joint 3mm Wall; EBW Alloy20 to 321</td>
<td>Wed 2/19/14</td>
</tr>
<tr>
<td>49</td>
<td>Customer Review</td>
<td>Wed 2/19/14</td>
</tr>
</tbody>
</table>

- Schedule dependent on resource availability.
- Purpose of the project is to familiarize Woodward with UNS N08020.
Spray Angle Project Overview

• **Purpose:** Determine the optimal method for measuring the spray angle of atomizers.
  - Accuracy
  - Precision
  - Repeatability
  - Time

• **Methods**
  - Hand
  - Picture
  - Habco System
  - Production (not included in study)

• **Project support:** Dan Burke, Bruce Harrar, Scott Litaker
Methods

Hand

Habco

Picture
HOLE SIZE MAY VARY TO MEET FLOW REQUIREMENTS.

2. SPRAY ANGLE TO BE 80°-100°. FLOW TO BE 198,3-210,5 PPH @ 100 PSI USING MIL-PRF-7024 II D CALIBRATION FLUID.
Definition of Spray Angle

- Angle formed by two straight lines drawn from the discharge orifice and cut at specified distance from the atomizer face.
  - Distance from discharge orifice
  - Spray density
  - Curved boundaries
Method Comparison

- **Hand**
  - Tedious Work (without good precision)
  - Operator Dependent
  - Errors
  - Visual Fatigue
  + Alignment

- **Habco System**
  - Requires a Master
  + Consistent
  + Quick
  + Ability to Quantify Lighting
  + Potential for Production Applications

- **Photos**
  - Time Consuming
  - Camera Settings Vary
  - Operator Dependent
  + Consistent Specific Procedure
  + Visualize Lighting Variations
Method Comparison

- The data recorded by the Habco vision system is more condensed and more repeatable.
Time Comparison

- Significant time decrease when using the Habco system.
- Data most consistent with 3 to 5 center lights.

- When the light is in the center, the experiment set-up is much quicker and more straightforward.
Effect of Lighting Intensity

- Data is more linear with 3 or 4 lights.
- The variation in angle measurements increases as the light source gets further from the exit orifice.
- Recommendations:
  - Light source should not be further than 12 inches away.
  - Conduct a similar study with a master.
Future Actions and Recommendations

• **Recommend using the Habco vision system for DF42.**
  - A master for each atomizer design would have to be set-up to determine the optimal distance of the light to the exit orifice and light intensity.
  - Develop light fixtures that enable flexibility.
  - Design a fuel recycle tube to reclaim atomized fuel.
  - Dan Burke is already developing more robust fixtures to accommodate for the Habco vision system.
EB Weld Development Project Overview

• **Problem**: Tail-out cracks when EB welding Hast-X to SS have been a reoccurring problem.
  - Both Siemens and GE require the use of Hast-X in the nozzle.

• **Project Goal**: Optimize weld and process parameters such that microcracking in the tail-out section of the weld is eliminated.
  - Initial goal for the summer was to identify key input variables.

• **Benefits**: Reduce costs and increase the value added.
  - No Wasted Material
  - No Rework Procedures
  - Competitive Advantage

• **Project Support**: Antione Ford, Derek Polaikis
# Lean Six Sigma Project Charter

**Project Name:** HAST-X TO 300 SERIES WELD DEVELOPMENT  
**Project Type:** Six Sigma  
**Leader Name:** MARK DIERINGER  
**Business Unit:** ATS  
**Plant Location:** Greenville  
**Champion:** MARK DIERINGER  
**BB Mentor:** JOE CONWAY

### Problem Description
EB WELDING HAST-X (AMS 5754) TO 300 SERIES STAINLESS STEEL YIELDS MICROCRACKING IN THE TAIL-OUT SECTION OF THE CIRCUMFERENTIAL WELD. CONSEQUENTLY, THE PRESENCE OF MICROCRACKS IN THE WELD FAILS NDT (FPI INSPECTION).

### Goal / Objective
THE GOAL IS TO OPTIMIZE WELD AND PROCESS PARAMETERS SUCH THAT MICROCRACKING IN THE TAIL-OUT SECTION OF THE WELD IS ELIMINATED THUS PASSING SCRUTINY OF NDT METHODS (FPI INSPECTION).

### Business Benefit(s)
AT PRESENT WOODWARD’S ONLY COUNTERMEASURE IS TO ADD EXTRA MATERIAL (COST) LOCALLY AT THE JOINT PREP THAT GETS, SUBSEQUENTLY, MACHINED (REWORK) TO A FINAL DIAMETER. IN EFFECT THE MICROCRACKING IS STILL PRESENT BUT IS MACHINED AWAY DURING A TURNING OPERATION.

### Team Members
<table>
<thead>
<tr>
<th>Name</th>
<th>Job Function</th>
<th>Metric</th>
<th>Baseline</th>
<th>Goal</th>
<th>Status Key</th>
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<tbody>
<tr>
<td>Craig Tucker</td>
<td>Program Manager</td>
<td>TAILOUT CRACKS</td>
<td>ADDED MAT’L AT PREP</td>
<td>NO ADDED MAT’L AT PREP</td>
<td>Green</td>
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<tr>
<td>Jack Bardolph</td>
<td>Process Engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tom Austin</td>
<td>Manufacturing Engineer</td>
<td></td>
<td></td>
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<tr>
<td>Antione Ford</td>
<td>Project Engineer</td>
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<tr>
<td>Shelby Hayes</td>
<td>Engineering Intern</td>
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<tr>
<td>Derek Polaikis</td>
<td>Process Engineer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Status Key:**  
- Green: On-Track  
- Yellow: Completed  
- Red: Needs Attention  
- Dark Red: Needs Urgent Attention
Why do we have tail-out cracking when welding Hast-X to SS 304?
Redefine Summer Goal

• Current measurement abilities of Woodward is Pass or Fail the NDT (FPI).
  ▪ Past records of welding samples were not helpful, because the samples failed but we did not have any information on the procedure.
  ▪ No indication of the results improving, maintaining or declining.

• Need an advanced measurement system that can quantify the cracks.
  ▪ Useful to know length, crack density, depth and location.
Measurement

- **Equipment and Software Upgrade**
  - Cost: High initial cost
  - Time: 1 day

- **M&P**
  - Cost: $886/sample
  - Time: 5-10 days

- **ATS**
  - Cost: $150/sample
  - Time: 3-5 days

- **Recommendation:** Upgrade the measurement system. Derek Polaikis would be able to use the upgrades on various applications and it will add to the effectiveness of Woodward.
Skills and Lessons Learned

• **Company Methods**
  - Six Sigma
  - Culture into Action

• **NPI Processes**
  - Assemblies
  - Quality Inspections
  - Braze Processes
  - Pressure Testing
  - Lathe
  - SMD Testing
  - Laser Marker

• **Production Processes**
  - EB Welding
  - FPI
  - CMM
  - Flow Test
  - Collar Press Fit

• **Customer and Supplier Interaction**
  - GE Tour
  - Phone and Email Correspondence
  - M&P Face-to-Face

• **Welding**
  - TIG
  - Laser Tacking
  - Spot/Resistance Tacking
  - Microscope Inspection

• **Project Management**
  - Wedding Planning/Delegation Proficiency