A Case Study in Reshoring Through Robotics
From Product Planning through Manufacturing Performance Tracking

Digital Bridge 2018
DoubleTree Hilton Pittsburgh-Cranberry
November 1, 2018

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Product

- Compact heat exchangers (HEX), specifically radiators and charge-air coolers used in the below industrial applications:
  - Generators
  - Aerial platforms
  - Wood chippers
  - Irrigation pumps
  - Welders
Dominant Industrial HEX Technologies in 2010

• Copper brass tube and fin
  • More durable
  • More expensive

• Aluminum tube and fin
  • Less durable
  • Less expensive

LME Aluminum and Copper Pricing [USD/MT]
# Aluminum HEX Problems and Solutions

<table>
<thead>
<tr>
<th>Problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>Pressure cycling causes thin stamped tanks to crack</td>
<td>Used thick cast tanks</td>
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<tr>
<td>Thermal cycling causes tube to header failures</td>
<td>Used isolators between sidebrackets and headers</td>
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<tr>
<td>Repetitive shock causes tube to header failures</td>
<td>Sidebrackets link tanks together though isolators</td>
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<td>Offshore tank/ connection/ core production generates long lead-times</td>
<td><strong>Reshore!</strong></td>
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<td>and requires high inventory levels</td>
<td><strong>Robotic welding!</strong></td>
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<td>Increased US labor costs make manual welding of HEX cost prohibitive</td>
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HEX Design

• Inverted header
• Isolator pockets hold isolators mounting to robotic tooling
• Awarded US Patents 8,561,679 8,561,678 and 9,316,449
Durability Test Results

Compared Al replacement (36000002) with excellent CuBr radiator (69000351)
- Over 3x the performance in pressure cycle (2.5 to 23.5 psi) durability test
- Nearly identical thermal cycle (0 C to 100 C) durability of 5,500 cycles
- Comparable repetitive shock test results
- 91% burst test performance. (Al burst at 86 psig; CuBr burst at 94 psig)
Cast Tank Path and Current State

- Outsourced design and manufacture of tank molds
- Insourced mold design and outsourced machining
- Insourced mold design and machining
- Changed the material to EDRO P1-FM™ Free Machining Holder Steel
- Incorporated Carnegie, PA based Superbolt tensioners to counteract thermal strains and keep molds closed
Robot Tooling

• Version 1: Laser cut supports and round slide
• Version 2: Aluminum extrusions and linear bearings
• Version 3: Increased stiffness to weight ratio
• Version 4: Moved connection to tank welds off of the core
Traditional MIG Welding Robot [2010]

- Panasonic TA-1900 Arm, G3 TAWERS Series Controller, WG-350 Power Supply
  - Traditional MIG welding
  - Repeatable positioning

- Positioners with Coordinated Motion
  - Allowed rotation of the fixture to be coordinated with robot motion

- Touch Sensing
  - Location can be measured by having weld wire touch the part. Sensitive to wire casting.

**Reduced weld time from 105 to 15 minutes!**
Cold Metal Transfer Welding Robot [2014]

- Motoman MA 1900 Arm, DX 100 Controller, Fronius TPS 4000 CMT Advanced Power Supply
  - Traditional MIG and
  - Cold Metal Transfer (CMT) welding
    - Improved weldability which reduced scrap and rework
- Positioners with Coordinated Motion
  - Allowed rotation of the fixture to be coordinated with robot motion
- AccuFast Laser Point Switch
  - To measure a point in space, robot is moved so that the switch is made
  - Changing focal lengths required frequent calibration
Challenges

• Brazing of cores caused skew and other inconsistencies [4 mm]
• Each HEX required patching
• Each side of each robot for each core had a unique program
• Each new program took 4 to 6 hours to create
• Removal of tank flash caused inconsistent seam locations
Advanced Weld Trials

• Calibrated tool center point
• Calibrated point at laser focal length
• Standardized programming
• Created database to store results
• Overcame 4 mm position variance!
• 99/100 connection success!
• 19/20 seam success!

• Problems
  • 6 minutes to measure part
  • Missed measurements were common
Profilometer Integration [2018]

- Keyence LG-V7200 Laser Displacement Profiler
- Keyence LG-V7001P Laser Displacement Profiler Controller
- Reduced measurement time from 6 minutes to 1 minute
- Minimized missed measurements
- Reduced programming time from over ½ shift to 15 minutes!
Profilometer Calibration

- Define user frame relative to fixture
- Set each rotation parallel with fixture
- Find one point
Manufacturing Performance Tracking

- SN generated at robot
- Barcode printed at robot
- Program, cell, measurements, etc. entered into database
- Visual inspection and leak test results entered into database
- Real time WIP tracking
Future Integration

• Automatically feed MRP system
• Generate reports
  • Average WIP
  • Inventory turns
  • Throughput
  • Utilization
  • Yield
• Contribute to interconnection, information transparency, technical assistance and decentralized decisions – Industry 4.0!