Training Session 5: Gas Turbine Repair

By
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Why do we need to Repair?

- Maintenance after fuel is the main operating cost over the life cycle of a GT
- Spare part replacement and repairs of hot section components represent the major cost portion of all maintenance
- Typically component repairs cost 10% to 30% of the replacement new part cost
- Repairs represent main cost savings opportunity to the engine operator
When do we need to Repair?

- Meet OEM recommended schedules
- Based on condition – vibration or borescope inspection
- Before a part fails
- Before the part is damaged beyond repair
- When an engine performance limit is reached
- At the same time as other parts to match maintenance cycles
What do we need to Repair?

- Acceleration Expansion
- Deceleration Contraction
- Thermal Mechanical Fatigue Cracks

- BOW
- TWIST
- LEAN
What do we need to Repair?
What are the Materials?

Compressor
- Some 300SS
- 403, 410, 422, 450 Stainless
- IN718
- Ti64 titanium

Combustor
- 300SS
- Hastelloy-X, RA-33
- IN-600, IN-617
- Nimonic 75, Nimonic 263
- Haynes 230

Compressor Casings
- Grey Cast Iron
- Carbon Steel
- Aluminum

Turbine Shells
- Ductile Cast Iron
- Stainless Steel
- Nickel Alloy

Compressor Wheels/Disks
- Ni-Cr-MO-V Forging

Turbine Wheels/Discs
- Ni-Cr-MO-V Steel
- Cr-Mo-V Forging
- 12Cr Stainless
- Discalloy
- A286
- IN718

Turbine Rotating

Turbine Stationary
- 300SS, 400SS, C242, C1023
- N-155, M509, HS-188, L605
- X-40, X-45, FSX-414, ECY-768
- IN738, R80, GTD222, GTD444

Combustor
- 300SS
- Hastelloy-X, RA-33
- IN-600, IN-617
- Nimonic 75, Nimonic 263
- Haynes 230
What are the Materials?
Where do we Repair?

Industrial Frame Gas Turbine

Disassembled in Field

Repair Vendor

Assembled in Field
Where do we Repair?

- Aero Derivative Gas Turbine
  - Removed from Berth
  - Disassembled at Overhaul Shop
  - Repair Vendor
  - Assembled at Overhaul Shop
  - Returned to Berth
How do we Repair?
Repair Process

- Incoming Inspection
- Clean & Strip Coatings
- Post Coating Inspection
- Geometry Repair
- Machine/Finish Geometry
- Heat Treatment
- Pre-Coating Inspection
- Coating
- Final Inspection
Incoming Inspection

• Triage
  – Is the component repairable?
  – What is the expected level of the repair

• For higher technology components Metallurgical Life Analysis is required
Life Analysis

- Looking beyond what external inspections can see
- Causes of material loss
- Internal cracking
- Internal coating quality
Life Analysis
Incoming Inspection

- Internal Geometry
Incoming Inspection

- Cooling System Inspection
  - Qualitative and Quantitative
Clean and Strip Coatings

• Internal Cleaning using thermal and chemical processes is necessary before stripping
• Internal deposits and oxides limit the effectiveness of the stripping process
Clean and Strip Coatings

- Acid mix and temperatures based on materials and coatings
- Internal strip requires careful control of acid
- External only stripping possible with masking
Post Strip Inspection

• Fluorescent Penetrant Inspection
  – Find cracks and porosity

• Dimensional Inspection Key Features
  – Blades: Tip height, wall and TE thickness, airfoil geometry, assembly features, deformation
  – Vanes: Wall and TE thickness, deformation, airfoil geometry, assembly features
Geometry Repair

Stage 1 Bucket
Geometry Repair

Weldability of Superalloys

Difficult to Weld
High Welding Costs

Weldable
Low Welding Costs
Geometry Repair

Blade after First Service

Repaired Blades
Geometry Repair

• Development of welding alloys with the following attributes:
  – Melting temperature below the incipient melting temperature of base alloys
  – Wide solidification range
  – Sufficient ductility to accommodate welding stresses by plastic deformation within weld beads
  – Strength equal to or greater than conventional repair materials.
  – Cyclic oxidation resistance equal to or greater than that of the base alloy.
Geometry Repair

- Microstructure of the weld
  - Low porosity
  - Excellent fusion
  - No heat affected zone (HAZ) cracking

weld deposit (silicon modified)

base alloy (GTD 111)
Geometry Repair

- The strength and ductility of the modified weld filler meets or exceeds that of the standard weld filler at low and high temperature

<table>
<thead>
<tr>
<th>Material</th>
<th>Temperature (°F)</th>
<th>Yield Stress (ksi)</th>
<th>UTS (ksi)</th>
<th>Elongation (%)</th>
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<tr>
<td>Standard Weld</td>
<td>70</td>
<td>120</td>
<td>145</td>
<td>5</td>
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<tr>
<td></td>
<td>1800</td>
<td>39</td>
<td>47</td>
<td>13</td>
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<tr>
<td>Standard Weld + Silicon</td>
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<td>137</td>
<td>146</td>
<td>6</td>
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<tr>
<td></td>
<td>1800</td>
<td>50</td>
<td>55</td>
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</tbody>
</table>
Geometry Repair

Incoming → Blending → Green LPM™ → Heat Treated & Blended

- Low Melt
- High Melt
- Consolidated

Green → Sintered → Infiltrated → Diffused
Geometry Repair

- Incoming Damage: Burned LE & TE, deteriorated braze joint, hot corrosion damage
- Previously considered scrap
Geometry Repair

- LPM high strength alloy as-applied to leading edge, mid airfoil, and trailing edges
- LPM material after high temperature vacuum heat treatment to "cast" material to the airfoils
Geometry Repair

- Airfoils machined to original contours, all cooling holes re-established by EDM machining, airfoils re-coated, and shrouds coated with TBC coatings.
- NVGs fully restored for continued service
Geometry Repair

- Significant missing material on leading edge due to FOD
- To maintain cooling design internal geometry must be recreated during repair
Geometry Repair

- Form casting process allows LPM to be formed to match internal geometry
- LPM applied over form and onto base alloy
Geometry Repair

- Part returned for repair after 24,000 hours
- Inspection revealed no indications or material loss
Geometry Repair

- Incoming seal segments distorted (out of round), seal slots misaligned, backing plates thin due to oxidation – parts were previously declared scrap and replaced with new
Geometry Repair

- Panel replacement
Geometry Repair

- Reconstruction repair
Geometry Repair

- Reconstruction repair
Heat Treatment

- FSR™ Full Solution Rejuvenation™

Service

as-manufactured condition

service run: before heat treatment

Rejuvenation

rejuvenation heat treatment

Heat Treatment

conventional heat treatment
Heat Treatment

- Time and temperature parameters unique to alloys
- Multiple aging cycles used to form a duplex microstructure
Heat Treatment

Liburdi Turbine Services Heat Treatment Development Timeline

IN700, IN738, IN792, U500, U520, X45, X750
N155, M252, Nim115, Rene 80, Rene 77
310 SS
Nim108, MarM002, GTD111
IN939, C1023
MarM247
A286, FSX 414, Nim80A
Nim90
Nim105
HastX, Nim263, C242
416 SS, C8Y, IN617
GTD222
Coating

- Selection of Coating System
Coating

TBC Being Applied to Upper Hot Gas Case
Questions?

- Why?
- When?
- What?
- Where?
- How?