Best Practices for Fluorescent Penetrant Inspection of Drum Rotors and Deep Well Spools

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Best Practices for Fluorescent Penetrant Inspection of Drum Rotors and Deep Well Spools

• Work in Progress

• Many contributors to date

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• B. Griffiths RR - UK
• T. Dreher RR - US
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• W. Rummel - Consult.
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• B. Stevens - United
Drum Rotor FPI Best Practice

Motivation

• Drum Rotors are:
  – Critical Pieces of Rotating Hardware
  – Typical in modern compressor design
  – Challenging to inspect – especially with FPI-compared to bolted rotors
  – Unique practices at engine shops
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*Benefits of Industry Best Practice*

- Compliance Straight-forward (compromise solutions not necessary)
- Less variability across the industry
- Improved inspection sensitivity and reliability
# Drum Rotor FPI Best Practice

## Observations

<table>
<thead>
<tr>
<th>O/H Shop</th>
<th>Cleaning</th>
<th>FPI Process</th>
<th>FPI Fixturing</th>
<th>Viewing</th>
<th>Viewing Fixture</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>aqueous alkaline cleaner</td>
<td>Ultrahigh Sensitivity; Hydrophilic Emulsifier</td>
<td>Sling</td>
<td>Video System</td>
<td>Yes</td>
</tr>
<tr>
<td>B</td>
<td>aqueous alkaline cleaner</td>
<td>Ultrahigh Sensitivity; Hydrophilic Emulsifier</td>
<td>Sling</td>
<td>UV Scope</td>
<td>No - Sling</td>
</tr>
<tr>
<td>C</td>
<td>aqueous alkaline cleaner</td>
<td>Ultrahigh Sensitivity; Hydrophilic Emulsifier</td>
<td>Modified Sling</td>
<td>Video System</td>
<td>Yes</td>
</tr>
<tr>
<td>D</td>
<td>aqueous alkaline cleaner</td>
<td>Ultrahigh Sensitivity; Hydrophilic Emulsifier</td>
<td>Sling</td>
<td>Mirror and UV source</td>
<td>No - Sling</td>
</tr>
<tr>
<td>E</td>
<td>aqueous alkaline cleaner</td>
<td>Ultrahigh Sensitivity; Hydrophilic Emulsifier</td>
<td>Sling during emulsification. Fixture during penetrant application.</td>
<td>Mirror and flex UV light guide</td>
<td>Yes</td>
</tr>
</tbody>
</table>
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Approach

• Augments existing shop processes
  – Consistency across stages
  – Addresses blind areas
• Performance-based vs. Equipment-based
• Assurance of complete viewing
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2 Primary Sections to Best Practice

• FPI Processing

• Viewing System Requirements
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**FPI Processing Key Elements**

- Ultrahigh Sensitivity Penetrant System
- Processing Chemistry / Times Consistent with Individual Facilities
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**FPI Processing Key Elements**

- Fixturing
  - Safe, Smooth Manipulation
  - Addresses areas obscured by fixturing
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**FPI Processing Key Elements**

- Tighter control on emulsification time
  - 10% on shop specific emulsifier contact time
  - Stop bath recommended
  - Pumping or siphoning
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FPI Processing Key

Elements

• Drying
• Developer
  – Manual Wand Required
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**FPI Processing Key Elements**

- Viewing System Requirements for
  - Resolution – Fluorescing gage
  - UV intensity (max and min) – To be amended in AMS 2647
  - White light contamination limits (AMS 2647)
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Part Holding Fixture for Viewing
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FPI Processing Key Elements

• User Establishes Key Usage Parameters
  – Stand off distance
  – Field of View
  – Index Size
  – Process to assure full viewing
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• Field of View Determination

\[ \alpha = \tan^{-1}\left( \frac{R_1}{H_1} \right) \]

\[ R_2 = \tan(\alpha) \cdot H_2 \]
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- Standoff Distance
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• Index / Overlap

\[ I_D = 1.8 \cdot R \]
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- Drum Rotor FPI Probability of Detection
  Fixture Design and Fabricated
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Data Collection

- Processing performed on production FPI line
- Data collected in lab environment
  - Technicians accustomed to looking for small cracks typically produce 0.04” – 0.05” 90/95 on this set
  - Production facilities typically produce ~0.060” 90/95 on this set
  - Data included in this presentation were generated in lab with technicians
  - Approximately 8 hours required to complete inspection in drum rotor inspection with borescope. Development time controlled to within limits of specification (developer applied with bulb as inspection progressed.)
- Variables Tested With POD Fixture
  - Emulsification Time (1 min when processed as web vs. 5 min when processed as drum)
  - Mirror vs. Viewing System
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Data Collection

• Definitions
  – Drum – panels installed in “webs” and “webs” installed in drum rotor fixture
  – Borescope – UV borescope used inside drum rotor fixture
  – Mirror – UV light guide attached to shop mirror used in drum rotor fixture
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• Results - All values 90% POD / 95% CL
• Results are from laboratory environment in a controlled setting

<table>
<thead>
<tr>
<th>Processing / Viewing*</th>
<th>Processing – Webs$^1$</th>
<th>Processing – Drum$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewing as Webs with no visual aids</td>
<td>X</td>
<td>0.050”</td>
</tr>
<tr>
<td>Viewing as Drum with Borescope</td>
<td>0.078”</td>
<td>0.091”</td>
</tr>
<tr>
<td>Viewing as Drum with Mirror</td>
<td>X</td>
<td>&gt;0.150”</td>
</tr>
</tbody>
</table>
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• Next Steps
  – Address within SAE Committee K
  – Finalize Best Practice
  – Potential for separate document or attachment to AMS 2647
Conclusions

• Fixtures for FPI processing and viewing are a necessity for inspection of drum rotors
  – Control the process parameters and to assure coverage and overlap
• POD estimates were generated in a laboratory environment under controlled conditions and may not be representative of production POD values
  – Inspection of drum rotor took 8 hours using fixtured borescope
• Repeat of the POD study in overhaul environment would be beneficial in supporting fleet management objectives