Endoscopic Fluorescent Penetrant Inspection (FPI)

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Abstract

Traditional endoscopic inspections sometimes do not allow to determine the nature and threat of an indication. There are suspicious indications like black marks, scratches, blade impact or residual crack after blending operation. To resolve the doubt, Snecma, in association with EFER Endoscopy company, developed various technologies allowing to apply a FPI operation inside the reactor to bring out discontinuities in the blades surface.

Keywords: aerospace, fluorescent penetrant inspection, endoscopy, reactor, blades, suspicious indications

1. Introduction

The endoscopic Fluorescent Penetrant Inspection (FPI) is a technique arising from two different NDT methods: FPI and Endoscopy.

- FPI: applying a range of chemicals allowing detection and localization of surface or open discontinuities
- Endoscopy: inspection method allowing to view and examine surfaces which are not directly visually accessible

Endoscopic FPI is a high-sensitivity FPI process carried out in-situ and performed through provided dedicated endoscopy ports.

2. Endoscopy FPI

2.1 Benefits of Endoscopic FPI

Traditional endoscopy does not always allow determining the actual nature or threat of an indication.
Indeed there are suspicious indications like black marks, scratches, impacts or residual cracks after blending.

Figure 1. Leading edge of High Pressure Compressor blade (stage 7) after blending white light illumination
Thus this innovation allows:

- to resolve any doubts by determining in-situ the threat posed by an indication;
- to guarantee material health after blending;

![Figure 2 & 3. Before blending: Crack length estimated at 5mm max](image1)

![Figure 4 & 5. After blending: No crack](image2)

- to limit the number of engine disassemblies: 68 engine removals avoided out of 75 inspections since 2006
- to contribute to flight safety;
- to lower the engine operating costs:

<table>
<thead>
<tr>
<th>Engine Disassembly Cost</th>
<th>Blending + Endo FPI cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine removal</td>
<td>1.4%</td>
</tr>
<tr>
<td>Engine rental</td>
<td>0.6% per day</td>
</tr>
<tr>
<td></td>
<td>(varies with overall rental time)</td>
</tr>
<tr>
<td>LPT removal and installation</td>
<td>4.7%</td>
</tr>
<tr>
<td>Engine repair</td>
<td>93.3%</td>
</tr>
<tr>
<td>(LPT module servicing)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
</tr>
<tr>
<td><strong>6.2 to 7.8%</strong></td>
<td></td>
</tr>
</tbody>
</table>

![Figure 6. Cost comparison of Endoscopic FPI + Blending / Engine Disassembly: CFM56 Low Pressure Turbine](image3)
2.2 Endoscopic FPI technologies developed

SneCMA and Efer Endoscopic developed a portable spraying and inspection allowing to apply an Endoscopic FPI:

- UV and white light source for endoscope
- FPI chemicals stowage and spraying case

- Endoscope according to application:
2.3 Endoscopic FPI in-situ implementation

Although the FPI is relatively easy to carry out, its implementation inside a non-disassembled engine is a delicate task.

Implementation:

- Part cleaning using acetone
- Application of S4 high sensitivity fluorescent penetrant
- Excess cleaning using water
- Application of emulsifier
- Part cleaning with water and drying
- Developer application

![Figure 7. Spraying of the various FPI chemicals on inspected zone](image1)

- Visualize under UV lighting

![Figure 8. Observation and decision under UV illumination](image2)
2.4 Endoscopic FPI training

Both equipment operation and endoscopic FPI procedure require preliminary theoretical and practical training of operators. This training is provided by the Snecma Center for Industrial Competences in NDT (CCI CND). Prerequisite for attending the training is a level 2 COSAC FPI certification, or equivalent. Training duration is 5 days and organised as such -

<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory course « The keys to endoscopy »</td>
<td>Practical course « The keys to endoscopy »</td>
<td>Practical endoscopic exercises on test boxes using the different kits</td>
<td>Trials on engine using the different kits</td>
<td>Trials on engine using the different kits</td>
</tr>
<tr>
<td>Endoscopy Test Practical course « The keys to endoscopy »</td>
<td>Film projection Instructions manual &amp; qualification file review Equipment presentation (rigid and flexible kits)</td>
<td>Practical endoscopic FPI exercises on test boxes using the different kits</td>
<td>Trials on engine using the different kits</td>
<td>Trials on engine using the different kits Endo FPI Test</td>
</tr>
</tbody>
</table>

Figure 9. Training description

At the end of this training, and upon review by the Snecma trainer, a certificate covering Endoscopic FPI will be issued to the trainee.

2.5 Operational experience

Endoscopic FPI is applied to all engine types in service or under development:

- Commercial
- High power
- Military
- Spatial
This technique is also applicable to modules and airframes with difficult access:

- TIG welds on reheater bracket

![Weld inspection](image1)

![Crack viewed under UV](image2)

- APU turbine impeller

![Application of products](image3)

![UV light observation](image4)

![Crack viewed under UV](image5)
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