GE 6001 User's Group

Rotor End of Life Assessment
Rotor Life Assessment vs. Extension

- These terms are loosely used and often interchanged when describing something that needs to be done, or something that needs happen to a gas turbine rotor as it reaches its published end of life.

- They DO NOT mean the same thing.

- Two facts remain about life assessment and life extension
  
  - According to OEM published technical literature, rotors can’t run forever
  
  - End users are concerned about how to better judge the condition of a rotor as it nearing the published limits
OEM Recommendations

- Released in 2007 with Compliance Code S (safety) and Timing Code 5 (at scheduled part repair or replacement)

- Establishes life management recommendations and methodology

- “Exceeding the serviceable life of the rotor system can lead to a wheel failure that causes extensive damage to the gas turbine. This event can also potentially lead to substantial damage to adjacent equipment and serious injury to any nearby personnel.”

- Possible life extension of up to 100,000 hours for frame 3 and 5 and up to 50,000 hours for E-class units that have not passed the 5000 starts limit.
What Do User’s Need?

- It is clear that end users are concerned about the life expectancy of their rotors, as well as their insurers.
- Unfortunately life extensions are usually a costly procedure due to down time.
- Most end user groups, leading independent consultants, and insurers agree that the most sensible thing to do is:

  Thoroughly Inspect  Evaluate Risks  Take Mitigation Measures

This is where Sulzer can help!
What does Sulzer Provide?

- **Rotor Life Assessment**
  - This term refers to the thorough inspection and testing performed on rotors in order to characterize their overall and current condition, and to detect any flaws within the components of the rotor.
  - This inspection is coupled with specialized equipment, strictly designed for the inspections involved with Rotor Life Assessment.
  - Critical personnel to hold quality assurance and completion of the assessment as well as evaluate any findings that might arise during the assessment.
What does Sulzer Provide?

Thoroughly Inspect

- Sulzer has developed testing procedures and tooling to offer a comparable level of evaluation that OEMs perform and recommend; followed by (2) ASNT Level III Inspectors
- If needed, less than two week turnaround on Rotor Life Assessment
- To perform such thorough testing, a rotor must be unstacked. Sulzer utilizes (2) stacking pits for increased availability.
- In addition, Sulzer has the capability of unstacking, servicing (coating), re-stacking and balancing rotors all under one roof.
Life-Limiting Factors

- Material degradation
- Low-cycle fatigue / Thermomechanical fatigue
- Environmental attack
- Wear and impact
- Growth of original defects
Life-Limiting Factors

- Material Degradation
  - Spheroidization, carbide coarsening, etc.
  - Embrittlement
  - Creep
Life-Limiting Factors

- Low-cycle fatigue / thermomechanical fatigue
- High-cycle fatigue
Life-Limiting Factors

- Environmental attack
Life-Limiting Factors

- Wear and impact
Life-Limiting Factors

- Growth of original defects
“One good test result is worth a thousand expert opinions”
## Inspection Methods

<table>
<thead>
<tr>
<th>NDE Procedure</th>
<th>Part to be Qualified</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness</td>
<td>Turbine wheels, turbine spacers, compressor wheels, distance piece</td>
<td>Compressor blades not tested</td>
</tr>
<tr>
<td>Magnetic Particle</td>
<td>Turbine wheels, turbine spacers, compressor wheels, distance piece</td>
<td>On all ferromagnetic components</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Turbine wheels, turbine spacers, compressor wheels, through-bolts</td>
<td>All components tested</td>
</tr>
<tr>
<td>Boresonic</td>
<td>Turbine and compressor wheels</td>
<td>Bore must be honed/polished to required surface finish</td>
</tr>
<tr>
<td>Phased Array Ultrasonic</td>
<td>Turbine and compressor wheels, spacers</td>
<td>Requires wide/flat area</td>
</tr>
<tr>
<td>Eddy Current</td>
<td>Turbine and compressor wheels, spacers</td>
<td>Specifically the rabbet fit areas and wheel bores</td>
</tr>
<tr>
<td>Array Eddy Current</td>
<td>FA class turbine wheels</td>
<td>Requires probes for root profiles</td>
</tr>
<tr>
<td>Dye Penetrant</td>
<td>FA class turbine wheels/spacers</td>
<td>Used on any non-ferromagnetic components</td>
</tr>
<tr>
<td>In-situ Metallography and Replication</td>
<td>Turbine and compressor wheels, distance piece</td>
<td>Tested on only the fwd. side of part</td>
</tr>
<tr>
<td>Chemical analysis</td>
<td>Turbine wheels &amp; spacers, compressor wheels</td>
<td>Shavings from drilled balance holes or direct analysis</td>
</tr>
</tbody>
</table>
Inspection Methods

STG. 3 TURBINE WHEEL
FROM FWD. SIDE

15th STG. COMPRESSOR
WHEEL (FWD. SIDE)

IN-SITU METALLOGRAPHY
AND REPLICATIONS
(FWD. SIDE ONLY)

BORESONIC TEST
BORE DIMENSION

HARDNESS TRAVERSE

EDDY CURRENT
(ESPECIALLY CORNERS & RADII)

PHASED ARRAY ULTRASONIC

BORE DIMENSION
BOERSONIC TEST

IN-SITU METALLOGRAPHY
AND REPLICATIONS
(FWD. SIDE ONLY)
Inspection Methods

- Visual
  - Corrosion
  - Erosion
  - Oxidation
  - Galling/Fretting
  - Impact/Dings
Inspection Methods

- Magnetic Particle
  - Magnetic alloy
  - Near-surface
  - Narrow cracks
Inspection Methods

- **Ultrasonic**
  - Straight/longitudinal beam
  - Flat accessible areas are also inspected by phased array
Inspection Methods

- Phased Array Ultrasonic Testing

Conventional UT inspections use a probe that sends a narrow beam of ultrasonic energy into the part under test. This technique can miss indications located away from the beam axis. A more advanced test method is the Phased Array Ultrasonic Technology. A phased array beam is accomplished by using multiple “probes”, which are timed to produce a wider, sweeping beam. This wider beam allows detection of indications which may be located at different angles to the tested surface (away from the beam axis).
Inspection Methods

- **Eddy Current Testing**

  Eddy Current Testing (ET) uses an alternating current passing through a coil to produce a magnetic field. When the coil is placed near a conductive test piece, the changing magnetic field causes current flow in the material. These are called eddy currents. These eddy currents can be measured and used to find flaws in the test piece.
Inspection Methods

- Eddy Current
Inspection Methods

- Eddy Current
Inspection Methods

- Array Eddy Current

  For non-magnetic turbine wheels (Frame 6FA), Sulzer has developed a proprietary probe which uses numerous coils to check for indications in the root area. During the scan of each root area, the design of the probe also detects indications at both the cooling holes and the lock wire tab.
Inspection Methods

- Boresonic
  - Uses longitudinal and transverse ultrasonic waves to inspect the bore
  - Because surface roughness can interfere with data acquisition, the bore must be honed/polished
  - Automated probe is used to scan the bore for inclusions, cracking, or any relevant defect
Inspection Methods

- Hardness Measurement
  - Performed on wheels, spacers, distance piece from the bore to the rim
  - Two methods
    - Ultrasonic Contact Impedance
    - Rebound
Inspection Methods

- **Metallography / Replication**
  - Performed on the forward face of the wheels
  - The replica is examined using an optical microscope and SEM to detect deterioration of the microstructure.
Inspection Methods

- Alloy Composition Verification
  - The chemical composition of all rotor components is verified using x-ray fluorescence and optical emission spectrometry.
Documentation

Sunombre Cogeneration

Rotor Evaluation
GE 6001 B

Project 125185

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**NDT Report**

Component: 1ST STAGE TURBINE DISK

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### RESULTS

**Standard NDT inspections**

- All of the components had high to moderate utility, especially in the root area. The shafts and root have a Hi N of the matrix for high carbon detection in the matrix. General groups also have moderate wear and signs.

**Material Property Summary**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>3.20 g/cm³</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td>200 GPa</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>350 MPa</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>500 MPa</td>
</tr>
</tbody>
</table>

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**Conclusions and Recommendations**

- The inspectors noted no indications of significant defects or material degradation. However, some areas of the components show signs of wear and tear, which may require additional monitoring.

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**Microstructural Observation**

The material properties of the electrodes depend on the temperature and strain. The inspection revealed no significant defects or material degradation.

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<table>
<thead>
<tr>
<th>Component</th>
<th>Inspection Method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaft 1</td>
<td>Ultrasonic Testing</td>
<td>Good</td>
</tr>
<tr>
<td>Shaft 2</td>
<td>Magnetic Particle</td>
<td>Good</td>
</tr>
<tr>
<td>Shaft 3</td>
<td>Radiographic</td>
<td>Good</td>
</tr>
<tr>
<td>Shaft 14</td>
<td>Ultrasonic Testing</td>
<td>Good</td>
</tr>
<tr>
<td>Shaft 17</td>
<td>Magnetic Particle</td>
<td>Good</td>
</tr>
</tbody>
</table>

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**TABLE 1: ULTRASONIC TESTING PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Amplitude</td>
<td>5 Vpp</td>
</tr>
</tbody>
</table>

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**SULZER**

Date: April 22, 2013

**Recommendation**

- Additional monitoring and inspection are recommended for the components shown in the report.

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**SULZER**

Date: April 22, 2013

**Signature**

[Signature]

[Position]
“Upon successful completion of the Rotor Life Assessment, Sulzer Turbo Services evaluates and confirms that examined components are suitable for continued service up to the ultimate end of life published by the original equipment manufacturer.”

Wayne Greaves  
Senior Materials Engineer / Lab Manager  
Rotating Equipment Services  
Sulzer Turbo Services Houston Inc.  
[www.sulzer.com](http://www.sulzer.com)
Sulzer’s Offering for Rotor Life Assessment

- Sulzer has developed the capability to unstack, service and inspect rotors following the same testing protocols suggested by industry leading experts and OEMs.

- This approach is Sulzer’s response to the end user’s need to be able to thoroughly inspect, detect, and mitigate the risks affecting their rotors.

- In addition, to support the end user fleet, Sulzer is developing the manufacturing capabilities to provide new compressor discs, turbine discs, and spacers.