STRESS CORROSION FAILURE OF A LOW PRESSURE DISK FROM A 800 MW STEAM TURBINE

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Stress corrosion cracking is known to be a function of stress, material and environment. However, a fourth variable that is often overlooked is operating time. Maintaining steam chemistry within OEM and industry guidelines is not sufficient to prevent stress corrosion cracking in high stress locations such as the blade attachments of older low pressure turbine disks. Resulting stress corrosion failures occur without warning and generally result in significant secondary damage and unit downtime. Non-destructive examination has been used to identify stress corrosion cracking however, many blade attachment designs are not conducive to inspection without complete removal of blading.

This case study discusses the root cause analysis of a recent stress corrosion failure of a low pressure disk from an 800 MW steam turbine. Turbine disk modifications to prevent future stress corrosion cracking are detailed.
Background

- Tandem Compound Steam Turbine Generator
  - Arrangement
    - High Pressure Turbine
    - Double Flow Intermediate Pressure Turbine
    - Two Double Flow Low Pressure Turbines
  - Design Rating: 800 MW
  - Inlet Temperature: 1000°F/1000°F
  - Speed: 3600 RPM
  - Operating Time: 24 Years
Severe Vibration Encountered During Overspeed Test

- Unit Tripped
- Coast Down was Less than 2 1/2 Minutes
- External Damage was Extensive
  - Exciter Shaft and Generator Shaft Fractured
  - Pedestals Torn from Foundation
  - Casing Bolts Sheared Off
One L-1 Low Pressure Turbine Disk had Fractured Circumferentially and Radially through Multiple Finger Pinned Blade Attachments
  - Approximately 60% of Blades Missing
  - Imbalance Estimated at 1500 lbs.

Remaining Three L-1 Disks Exhibited Stress Corrosion Cracks in Finger Pinned Blade Attachments

Significant Internal Damage to all Turbine Modules
Teardown Observations

Fractured L-1 Disk
Teardown Observations
RCA Findings

- L-1 Disk Fractures Due to Caustic Stress Corrosion
  - Initiated at Pin Holes and Finger Ledges
- Steam Chemistry Within OEM Requirements
- No Material Anomalies
- No “Abnormal” Operating Conditions
RCA Findings

FRACTURES THROUGH FINGERS

SCC CRACKS AT LEDGES AND PIN HOLES
RCA Findings

INTERGRANULAR FRACTURE

CRACK BRANCHING
RCA Findings

- Blade Attachment Design Requires Blade Removal for Non-Destructive Examination of Disk Fingers
  - Limit on Number of Times Blades may be Removed
Stress Corrosion Cracking

- Variables
  - Material
  - Stress
  - Environment
  - Time
Stress Corrosion Cracking

- Operating Time Affects Stress Corrosion Cracking
  - Concentration of Precipitates in Crevices
    - Shut Down/Start-Up
    - Partial Loading
  - Initiation and Propagation
Post Event Repairs

- New 12Cr Stainless Steel L-1 Low Pressure Turbine Disks Installed
- Disk/Blade Geometry Modified
  - Reduce Stress Concentrations
- Finger Pinned Root Attachments Shot Peened after Final Machining
“Good” Steam Chemistry Does Not Insure Against Stress Corrosion Cracking of Low Alloy Disks

Stress Corrosion Cracking a Function of Operating Time and Start-up/Shutdowns
  - Older Units at Greater Risk

Non-Destructive Inspection Crucial

For Repairs/Retrofits, 12 Cr Stainless Steel and Shot Peening Significantly Improve SCC Resistance