Turbine Outage Lessons Learned and GT Maintenance Case Studies

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ITC – Contract Turbine Experts

Turbine Services - Technical

- **Turbine Field Engineers (Steam, Gas, Generator)**
- **Outage Client Representation (Owner's Engineer)**
- Outage Planning/Scheduling
- Vibration Data Acquisition and Analysis
- Borescope Engineering Review
- Turbine Maintenance Training (ITC/HPC)
- Troubleshooting and Root Cause Analysis (RCA)

Lessons Learned

"Those that fail to learn from history are doomed to repeat it." – Winston Churchill

Every outage has lessons to learn:

- Things that went great and should be repeated,
- Things that went terrible and should be avoided,
- Things that were not ideal, but with a few tweaks could be made better.

All these lessons should be recorded to remind ourselves in the future of the valuable experiences learned from a previous outage.

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Common Topics for Lessons Learned

- Communication
- Experience Deficit & Technical Errors
- Planning and Scheduling
- Logistics
  - Scaffolding
  - Site Access
- Operations
- LOTO
- Labor Quality
  - Tooling
  - Rigging
  - Precision Measurement
- Contingency Planning
- Vendor Quality
- Reporting
- Safety

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Common Lessons from Multiple Outages

#1 - Communication

- A worklist prepared for the oncoming shift.
- An effective shift change meeting with all stakeholders present.

#2 - Experience Deficit & Technical Errors

- An experience deficit exists in both technical field engineers and craft labor, resulting in avoidable errors. Recent examples include:
  - Improper casing bolting and doweling – damage and leaks
  - Improper rigging
  - Precision measurement error
  - Flange leaks

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More Lessons - from Multiple Outages

LOTO

- LOTO is all over the map, with little standardization between sites.
- Great variation exists on “temporary lifts” for systems such as lube and lift oil.

Logistics

- Logistical items are low-hanging fruit but can become major delays when missed or inadequate.
  - Welding gasses
  - Toilets
  - Internet
  - Electricity
  - Scaffold needs
  - Parts Storage
  - Tooling rentals (Hytorc and Riverhawk)
  - Office space, tables, and chairs
  - Air Compressors
  - Light Plants
  - Fuel services
  - Forklift

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And Still More - Lessons from Multiple Outages

Planning & Scheduling

- Outages are being scheduled based on a best-case duration and unit condition.
  - With increased maintenance intervals, unexpected findings are more common.
  - The result - Outages are often longer than planned.
- Outages are being planned at the last minute, creating resource deficits at peak times with Turbine Field Engineers, Millwrights, Tooling, and Shop availability.
- Contingency Planning is not occurring.

Lighting

- Inadequate lighting is common, in dark compartments, and especially on night shift.
- Improved lighting can greatly improve work quality, productivity, and safety.

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Best Practices – Lessons Learned Document

- Make a Lessons Learned Document for every outage.
- Review prior outage lessons learned docs:
  - When *planning* the next outage
  - When *starting* the next outage

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GT Maintenance & Case Studies

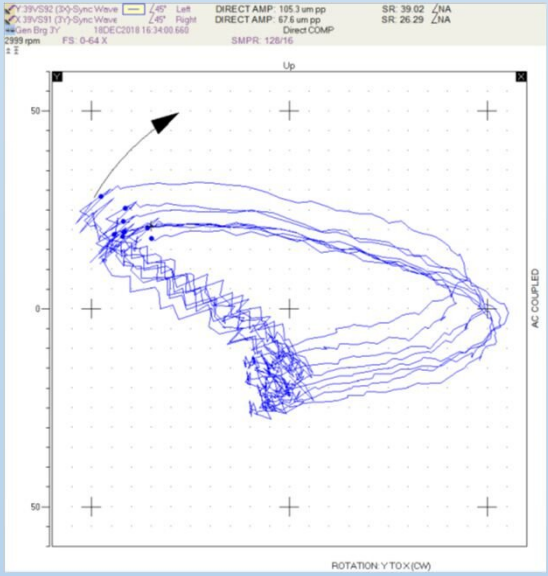
Case Studies

- 9FB Turbine Generator Alignment
- 7EA Compressor Casing Bore Misalignment
- S17 Blade Migration
- 9E Reverse Flow in Fuel Nozzles
- 7EA Increase Nox after HGP
- Vibrating Generator after Major Inspection

Case Study #1

Incorrect Generator Alignment

- A turbine owner reported a 2-year problem with a 9FB generator vibration issue. Owner has a LTSA with the OEM.
- A consulting engineer was brought in for a second opinion, and identified several problems, including:
  - Internal rubs within the generator bearing based on vibration orbit data,
  - Potential soft feet under the generator.



Result

- Consulting engineer was brought on site to troubleshoot and solve vibration issue.
- Root cause was identified that the OEM factory alignment drawings had an error, where a “plus” was a “minus” on the drawing, causing field engineers to align the generator incorrectly.
- Generator was found misaligned by 0.063”. The tolerance is plus or minus .001”.
- Upon correction, the unit is now running smoothly.
- The OEM paid to correct the misalignment under warranty.

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Case Study #2

Compressor Casing Bore Steps

- A 7EA turbine owner reported great difficulty with operating the turbine since the last major inspection, and significant vibration events after the prior major.
- A consulting engineer was brought in to direct the next major inspection.
- Several compressor issues were identified, including:
  - Heavy rubs at the compressor horizontal joints on only one casing half,
  - Upon reassembly, half-shell clearances were very tight in this area,
  - Upon installing casing with dowels, a significant step was still present at the inner casing bore adjacent to blade tips.

Result

- The Root Cause of the bore misalignment was yielded dowel holes, resulting in dowels that did not align casings as expected.
- The misaligned dowel holes were caused by heavy handed dowel installation that yielded casing dowel holes, and resulted in casing join steps.
- To correct, upper and lower casing bores were aligned under pressure to eliminate steps, then doweled and bolted in place to align the bores.
  - A recommendation was made to align and re-establish new larger dowel holes at a subsequent outage.
- The result – The unit started up with no vibration issues or rubs, and the unit has been running smoothly and safely for several years.

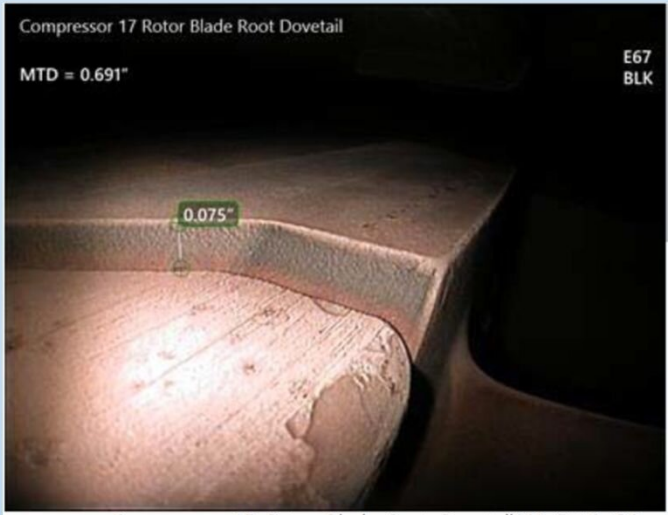
Case Study #3

S17 Blade Migration

- A seasonal borescope inspection was performed on a 9FB, finding a 3rd reoccurrence of S17 blade migration.
- Several of the rotor stakes were undersized, cracked, or pushed flat, allowing blade to migrate axially downstream.
- Both axial staking and flowpath wheel staking were performed previously and failed.

Result

- Stakes were upgraded to flowpath staking -Rev2, where stakes are placed on the vane platform OD.
- Great difficulty was encountered by the OEM in finding consistent staking tooling, procedures to make a consistent stake, and personnel that could perform stakes that would not fail. Multiple tools were used, many personnel applied, and several new blades were scrapped once a stake cracked.
- Each stake had to be inspected, measured, and confirmed to be of adequate quality – 100% stake inspection was required to maintain quality.
- Result: Unit was placed back in operation and is running reliably with no further migration issue reported.



Compressor_17_Rotor_Blade_Root_Dovetail001-FLAG.JPG

Compressor_17_Rotor_Blade_Root_Dovetail006-FLAG.JPG

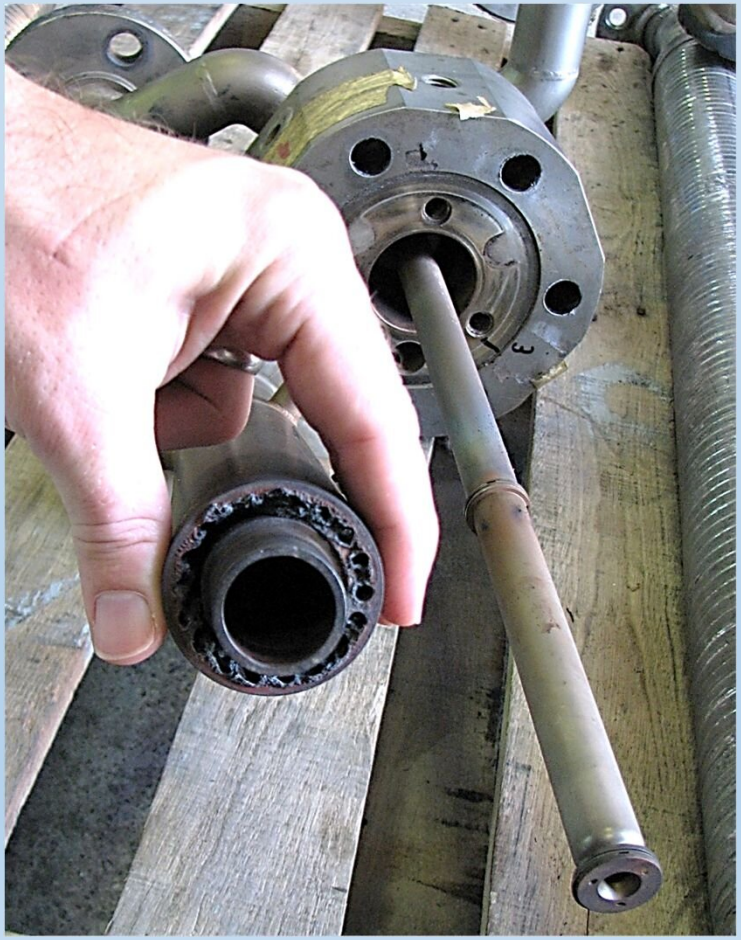
Case Study #4

9E Fuel Nozzles Burning Up

- A Turbine owner in Argentina reported burning-up a second set of 9E DLN1 combustion hardware after a repeated combustion inspection.
- A consulting engineer was brought in to troubleshoot, and identified several problems, including:
  - Melting of fuel nozzles on the INSIDE of the fuel nozzle passages,
  - Problems with the installation, design, and condition of the DLN purge valves.

Result

- During subsequent outage, consulting engineer was brought on site to troubleshoot and solve the burning fuel hardware issue.
- Root cause was identified:
  - The DLN-1 purge valves were incorrectly bleeding off combustion gases during operation, pulling the flame back inside the fuel nozzle,
  - The purge valves were determined to be installed backwards, causing the valve disk to be pushed off the valve seat during operation.
- After correction, the unit is now running well.



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Case Study #5

7EA NOx Emissions elevated after an outage

- After a HGP outage, a 7EA was unable to reach base load with acceptable emissions. The unit had to be detuned 15% to stay under NOx limits.

Root Cause:

- The Dilution holes in the newly installed sets of liners had a significant change from the removed liner set to the installed set.
  - Removed Set: 2.100” Dilution holes
  - Installed Set: 2.300” dilution holes

Recommendations:

- ALWAYS VERIFY DILUTION HOLE SIZES
- Install liners with the same dilution hole size.
- Flow Test Liners when they are refurbished

Result

- Due to schedule considerations, the removed set was refurbishment was expedited, and reinstalled into the unit.
- After correction, the NOx emissions excursion issue was fully resolved, and unit reached base load without issue.

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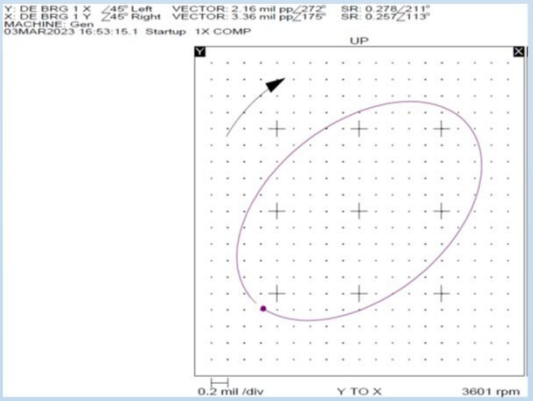
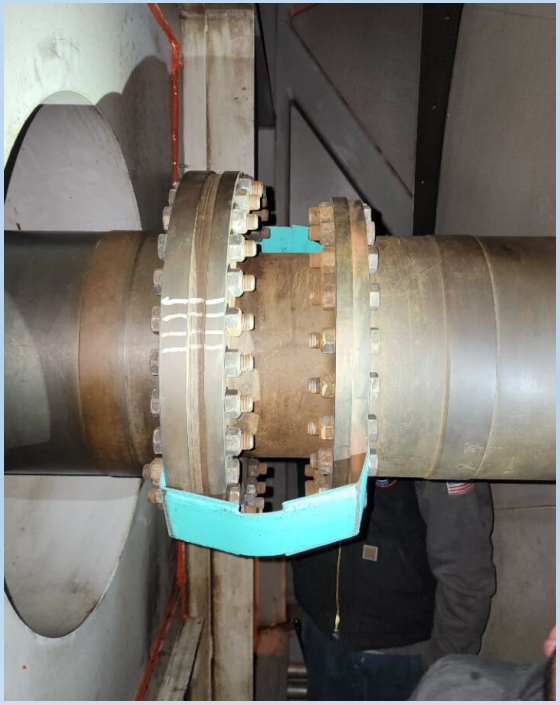
Case Study #6



Vibrating Generator after major inspection

- After an LM6000 / Brush BDAX7 major inspection with rotor high speed balancing, generator vibration levels increased from 1 mil to 3.5 mils. A specialist was called in for a balance shot on the generator.
- ADRE Vibration Data was taken, data indicated a clear mass imbalance problem.
- Prior to installing the requested generator balance shot, the consultant requested all covers to be remove for visual inspection of the coupling area.



Result

- Upon visual inspection, the temporary coupling braces were found still attached the to rotor. 3 bolts were left out of one side, and 1 bolt out of the other.
- The temporary coupling braces were removed, all bolting installed, and the unit restarted for a new set of vibration data.
- After correction, the unit is now running at 1 mil on all bearings.

Questions?

Thank You!

Please stop by the ITC exhibitor booth
and meet our speaker, chief engineer, and management team.