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Steam Turbine Seal Rub

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Vibration data helps to identify a steam turbine seal rub.

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Executive Summary

This case history describes how the vibration data provided by System 1* software helped to identify an appropriate course of action following severe vibration events experienced by a Steam Turbine driver of a recycled gas compressor in an oil refinery owned by Hellenic Petroleum SA in Thessaloniki, Greece.

A few months after its commissioning, the turbine instrumentation began to indicate brief periods of elevated vibration. These spikes in high vibration gradually appeared with increasing frequency and increased observed amplitudes. In August 2012, the observed vibration closely approached turbine trip limits. Based on the measurements shown by System 1, the operations and maintenance staff decided to wait until the next plant shut down for troubleshooting. The turbine was in operation for another six months, with occasional periods of high vibration noted.

In February 2013, the turbine was disassembled and inspected. The findings indicated that the reason for the peaks was oil in the vacuum chamber, which touched the turbine shaft from time to time. The oil had leaked through the oil labyrinths, which had worn unevenly because of misalignment.

Steam Turbine Nameplate Data & Construction

- Power at shaft, rated / normal : 1485 / 1150 kW
- Shaft speed, rated/normal : 9250 / 9466 rpm
- Steam flow, rated/normal : 24020 / 18660 kg/h
- Steam inlet pressure / temperature : 40 barg @ 380 ^{o}C
- Steam exhaust pressure / temperature : 10 barg @ 250 ^{o}C

The drawing in figure 1 shows a cross section of the non-drive end (NDE) of the turbine. The bearing lubrication oil is contained by the oil labyrinth. Any oil leaking past the lip seals of the oil labyrinth normally flows to the drain. Any evaporated oil fumes are evacuated from the space between the oil and steam labyrinth by the vacuum separation system.

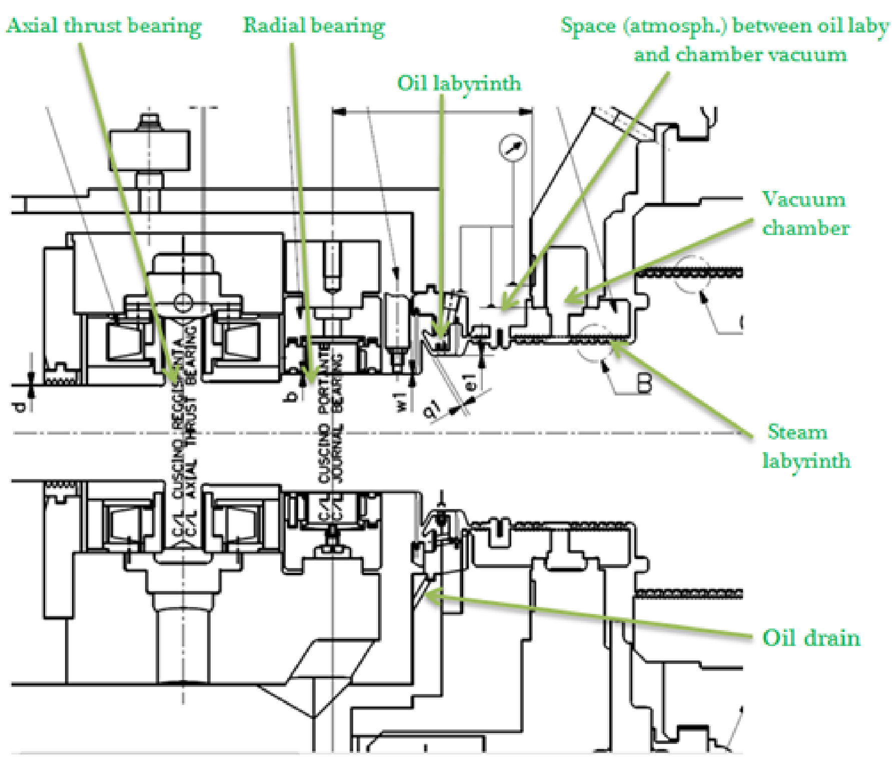

Figure 1: *Turbine cross-section drawing –Non-Drive End*

The vacuum chamber therefore collects flow suctions from two directions: the steam leaking from the steam labyrinth seal and the evaporation, if any, of the oil leaking from the oil labyrinth seal. A similar arrangement exists on the drive end (DE) of the turbine.

Vibration Instrumentation

Figure 2 shows a System 1 view of the steam turbine monitoring instrumentation. In addition to temperature and Keyphasor* (speed and phase reference) monitoring, there are proximity probes – VE-14375X/Y and VE-14376X/Y – that measure the horizontal and vertical distance between the inner surface of DE and NDE bearings and the shaft. These non-contacting proximity transducers measure the vibration of the turbine rotor within the clearance of its oil-film bearings.

Figure 2: *Steam turbine vibration instrumentation communicating with System 1 software*

Sequence of Events

The steam turbine was commissioned in January 2011 and started normal operation in September 2011.

From initial startup to February 2012 turbine operation was smooth. Vibration levels were consistently low and no high-amplitude spikes were observed. Levels were measured in the five to 15 micron range, which was well within the normal operating parameters of the machine. The alert alarm was set at 63 microns and the danger alarm was set at 85 microns.

Intermittent High Vibration Observed

From February 2012 to the end of August 2012 brief periods of high vibration were observed, with peaks levels reaching as high as 40 microns. On August 30 and 31, and again on September 2, the observed peaks climbed as high as 83 microns, almost reaching the trip setpoint of 85 microns (Figure 3). A review of vibration data revealed that 90% of the observed high vibration could be attributed to 1X (synchronous) vibration.

Figure 3: *System 1 vibration trend, showing occasional spikes of high vibration that occurred over a period of two weeks. Note: The alert alarm set point (57 microns) is indicated with a dashed line.*

A closer evaluation showed that the brief recurring periods of high vibration started at normal levels of 10 to 15 microns, climbed quickly to a peak value as high as 50 to 80 microns, and then rapidly dropped back down to normal levels. Each event lasted from about five to 15 minutes (Figure 4). The peaks appeared at intervals ranging from eight hours to three days. During some of the high vibration occurrences, operators who were near the turbine reported that they could feel and hear significant increases in machine vibration.

Figure 4a: *This System 1 plot show the phase and amplitude (both unfiltered and 1X-filtered) trends. The orbit plot shows the behavior of a typical brief period of high vibration. In this example, vibration amplitude rose from normal levels (eight microns) to a peak value of 74 microns in about four minutes – and then back down to normal again in about the same amount of time.*

Figure 4b: *The orbit plot on the left shows the overall broadband amplitude, while the orbit on the right indicates its 1X-filtered constituent, which more than 90% of the overall vibration.*

Initial Investigation and Actions

Defects such as misalignment, imbalance and looseness can often produce low-frequency vibration corresponding to running speed of the rotor (1X). However, these defects were ruled out because they would have caused constant vibration rather than the observed intermittent periods of high vibration. The orbit plots were then reviewed (Figure 5). The shape of the orbits indicated the presence of a light intermittent rub, which can sometimes occur with the buildup of carbonized oil on rotor shaft seals.

***Figure 5:** The orbit plots during the intermittent vibration peaks show changing phase angles, a classic indication of rub caused by thermal bow with a wandering hot spot.*

The next plant shutdown was not planned for another six months, when an outage was scheduled to occur. In order to minimize the potential for damage caused by continued operation with an intermittent seal rub, we decided on the following steps:

1. Evaluate lubricating oil for possible replacement: The oil was analyzed and found to be in good usable condition. No replacement was needed.
2. Perform maintenance and cleaning of the oil clarifier: This routine maintenance was performed with no major findings.
3. Check oil pressure upstream of flow-control orifices: Oil pressure was checked and verified to be normal.
4. It had been noted that pressure in the vacuum chamber was slightly higher than specified. The pressure was reduced to match the specification.

No noteworthy change in the vibration was noted after these actions were completed. After consulting with GE specialists, it was agreed that it would be acceptable to operate the turbine with an intermittent light rub until the planned outage, provided that vibration indications remained within the previously observed ranges.

Turbine Maintenance & Findings

In February, 2013 the steam turbine was disassembled for general inspection during the scheduled outage.

Inspection Results

- Unusually high misalignment was found among the turbine bearing supports (offsets of up to 1 mm).
- Carbonized lubricating oil had built up in the seal vacuum chamber and was coming in contact with the turbine rotor (Figure 6).
- One-sided wear of the oil labyrinth rings was discovered (Figure 7).
- No significant damage had occurred to the rotor shaft, steam labyrinths or bearings.

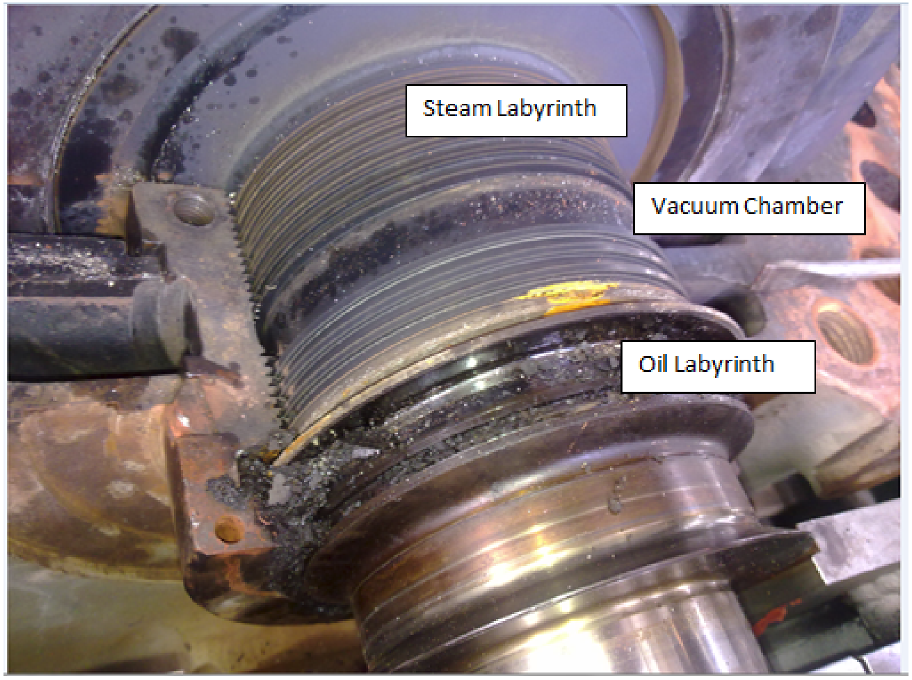

Figure 6: *Carbonized oil is visible in the vacuum chamber.*

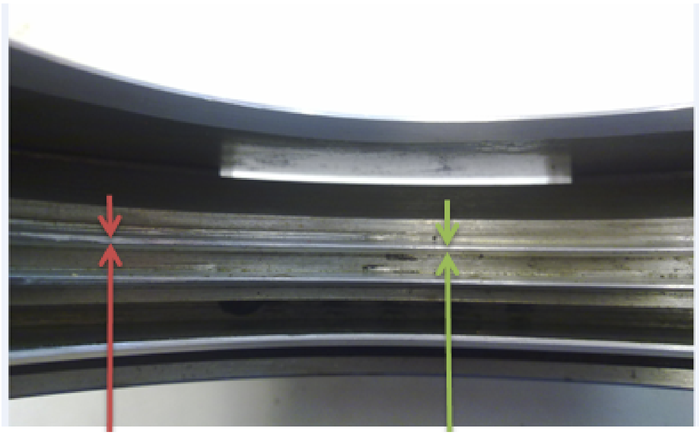

Figure 7: *This photo shows uneven (one-sided) wear of oil labyrinth rings*

Conclusions and Further Actions

Based on the inspection results, the original diagnosis of an intermittent light rub was verified. The most probable failure scenario was summarized:

- Misalignment caused uneven wear on one side of the oil labyrinth rings.
- Excess oil leaked into the space between the oil rings and the vacuum chamber.

- The oil vapor mixed with high temperature steam in the vacuum chamber.
- The oil heated until it formed hard, carbonized “coke,” which built up until a rub occurred.
- Within a few minutes, the carbon deposits were abraded away through the rubbing action until the rub disappeared. But the leaking oil would form more coke and the cycle would eventually repeat itself.

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