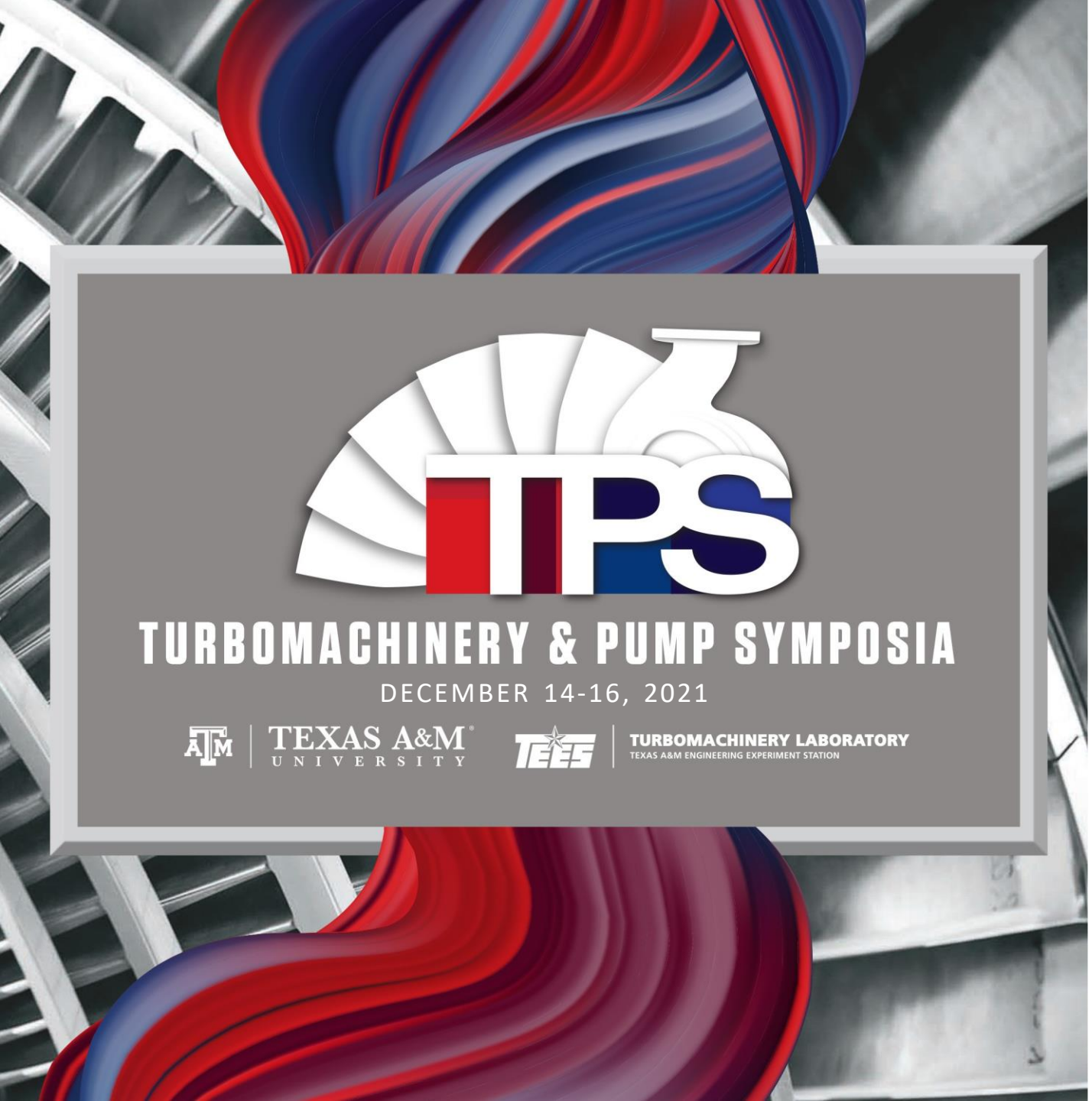

The Use of Online Condition Monitoring in The Identification of Gas Compressor Rotor Damage

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Author Bios

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Author Bios

Joanne Blackburn received her Master's degree in Aeronautical Engineering in 2013 from Loughborough University . She began her professional career as a Rotating Equipment Engineering graduate for the oil and gas company BG Group. Here she supported late life operations of North Sea assets ahead of spending a year overseas overseeing commissioning and performance test of an LNG site. Through company merger she spent a year at Shell working in engineering projects before joining bp in 2017. She has spent the last four years working as the Rotating Equipment Engineer in the North Sea.

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Abstract

Investigation and management of a rotordynamic issue affecting a production-critical centrifugal gas compressor. Following a restart of the compressor after a plant trip, radial vibration at the non-drive end of the shaft increased gradually over a period of six months.

Using a cause map to guide the investigation in conjunction with vibration analysis and physical bearing inspection resulted in a diagnosis of a mechanical issue with the rotor. Under close monitoring, the compressor was safely operated in this condition for six months whilst the outage was planned and optimised to reduce the production impact.

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Problem Statement

Upon restart of a critical gas export compressor continuously rising vibration was observed on the NDE over a period of 6 months.

Quick Background

* Machine tripped twice in 2019 due to plant upsets
* The Compressor surged severely during plant upsets
* Production loss - approx 30% of plant throughput

Incentive/Path Forward

Due to the criticality of this compressor the issue warranted a prompt and thorough investigation to identify and resolve the problem while minimizing production loss.

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Root Cause Failure Analysis

- Problem statement:

  "Rising Synchronous Shaft Displacement on HP Compressor"

- RCFA map with 32 possible causes
  - Mechanical change / Vibration Analysis
  - Measurement error / Dimensional Analysis
  - Process change / Influence on vibration

- Methodical gathering and evaluation of evidence to close out theories

Vibration Analysis

- Increasing vibration compressor NDE and DE (to a lesser extent)
- Stable bearing temperatures, shaft centerline and axial position
- The orbit timebase was circular in shape but continuously increasing in amplitude on NDE

Vibration Analysis

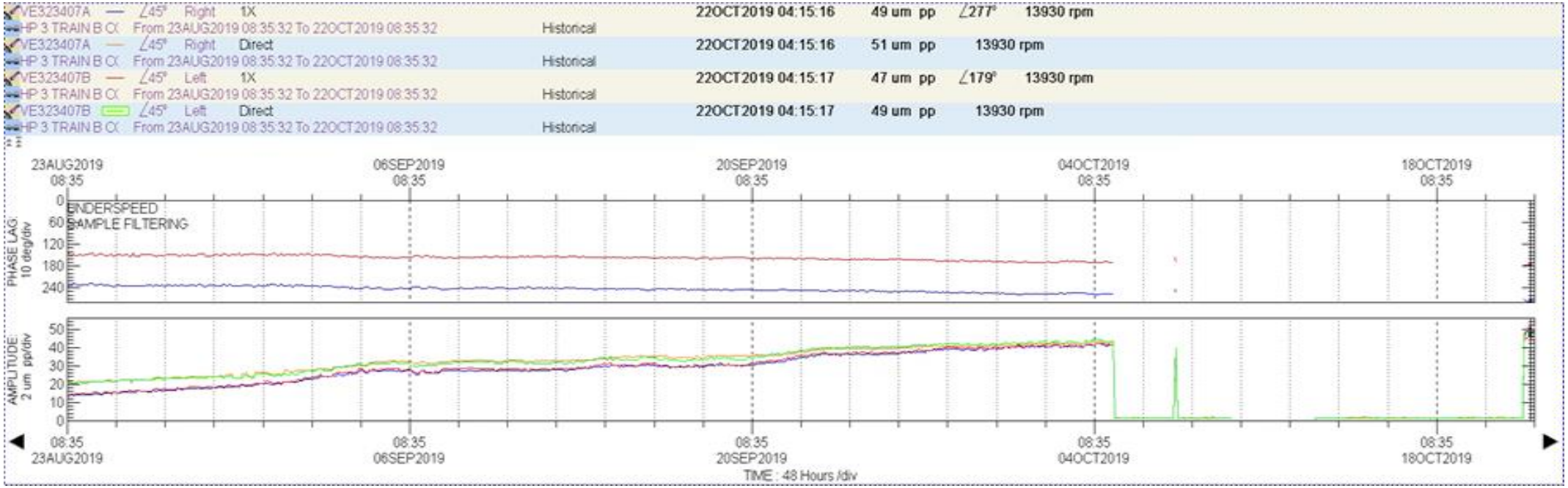

Figure 2 – Compressor DE/NDE Direct & 1x Trend (System 1)

Outcome - recommended additional measurements and transient data analysis

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Additional Measurements

- Bearing housing vibration measurements
- Lube oil temperature checks
- Effect of changing compressor load

- **Outcome** – No apparent issues

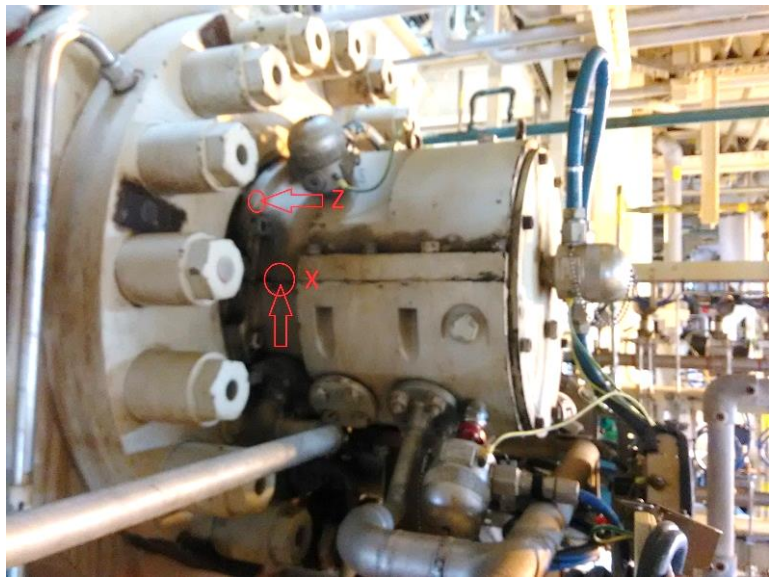


Figure 3 – Offline Bearing Housing Measurements

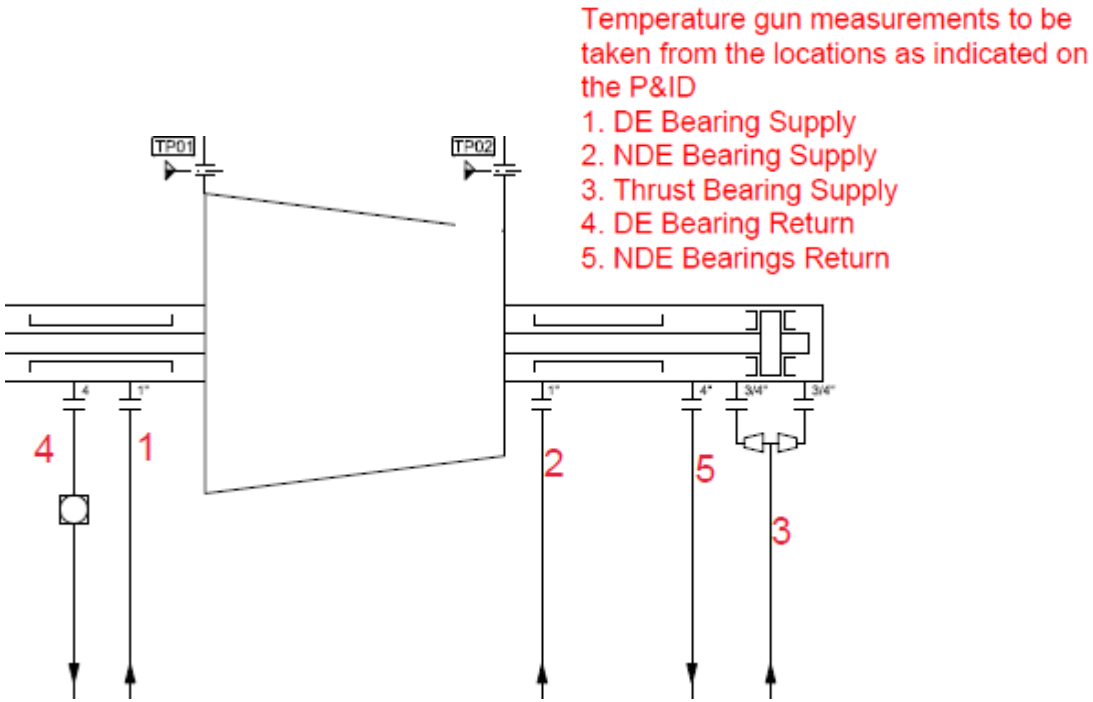


Figure 4 – Lube Oil Temperature Gun Checks

Bearing Inspection (NDE)

- Radial and thrust bearing clearances within tolerance
- Bearing crush within tolerance (no evidence of looseness)
- Tilting pads in good condition
- **Outcome** – no issues found bearing recommended for continued operation

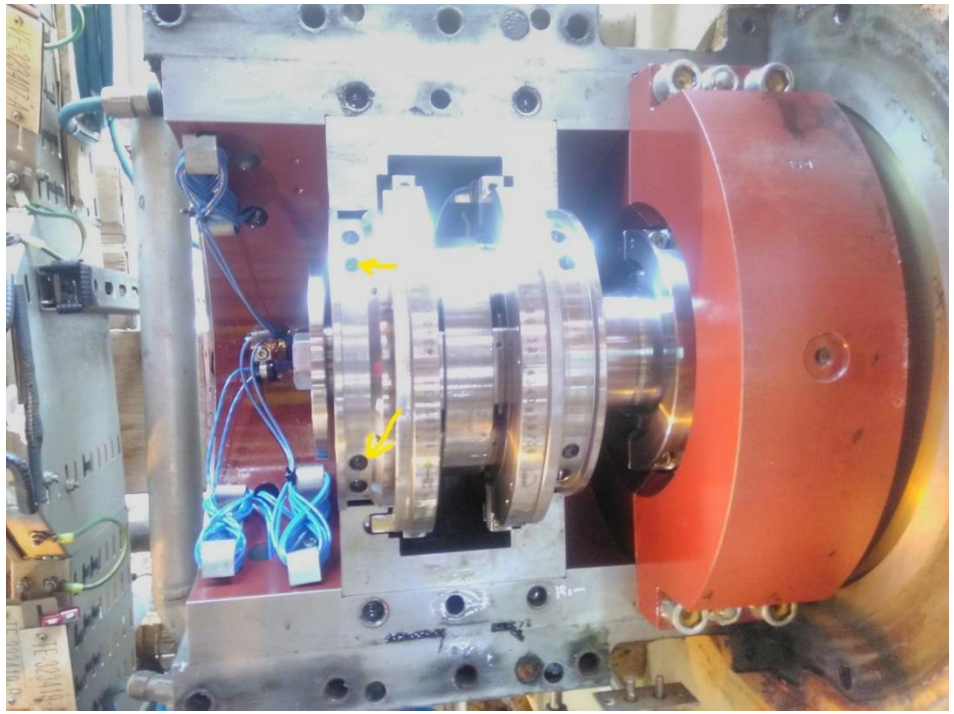


Figure 5 – NDE Bearing Inspection

Transient Data

- No evidence of change in the **critical speed**
- Changes to the **heavy/high spot** location and rotor response passing the first **balance resonance**
- Evidence of an abnormal **unidirectional 1X change** in rotor response and it's **repeatable** for different start-ups.

- **Outcome** – Issues of concern, recommended rotor inspection

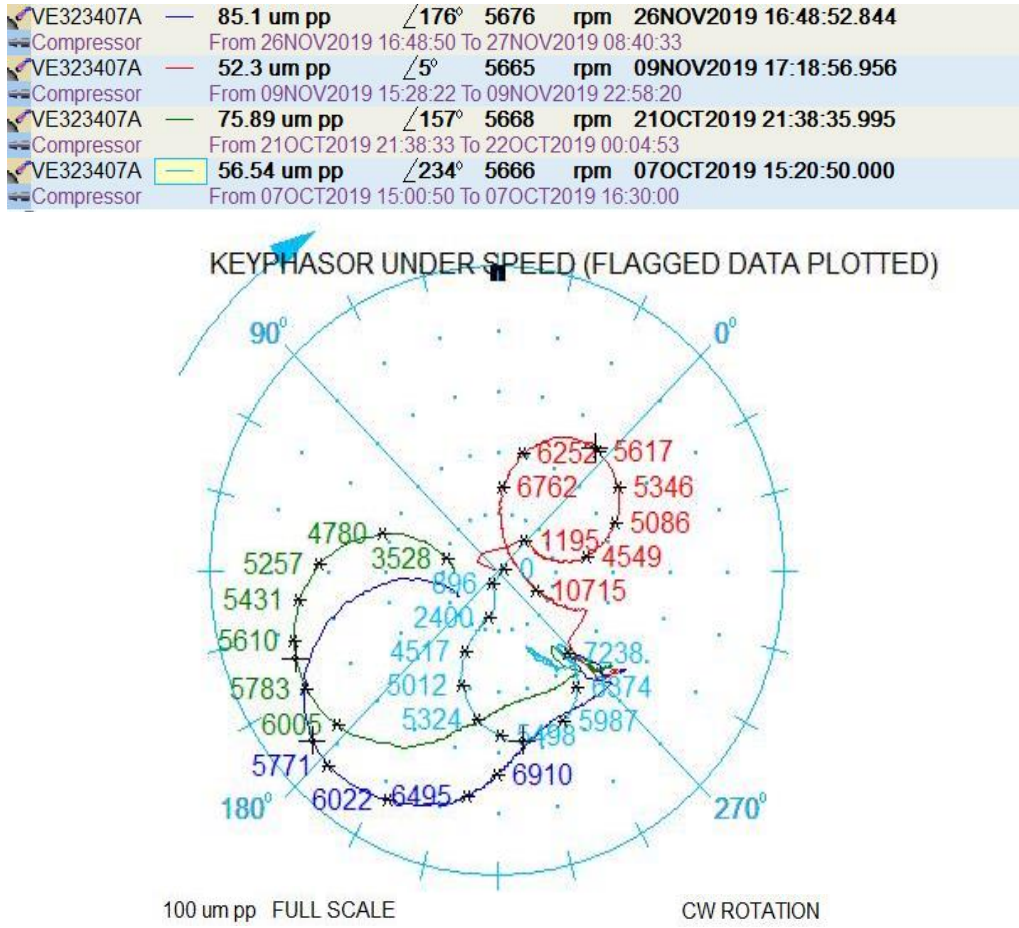


Figure 6 – Compressor NDE Start Up Comparison Polar Plot (System 1)

Removal from Service

Remove from Service - Options/Considerations:

- Risk assessment to prolong run-time
- What should be monitored
- Limits for shut down
- Planning for a possible outage
- Remove from service/not?

Outcome:

- Raise the vibration trip limits from 67um to 82um
- Expand monitoring parameters - Bearing temperature/bearing lube/axial position/etc
- Inspect NDE bearing
- Remove from service at revised Trip Limits

Strip and Inspect

- OEM accommodated a “virtual strip”
- Light corrosion on shaft – preservation?
- A fine film of dirt towards discharge side – not an issue
- Some minor scores on sealing surfaces – not cause of vibration
- Clean and in good condition

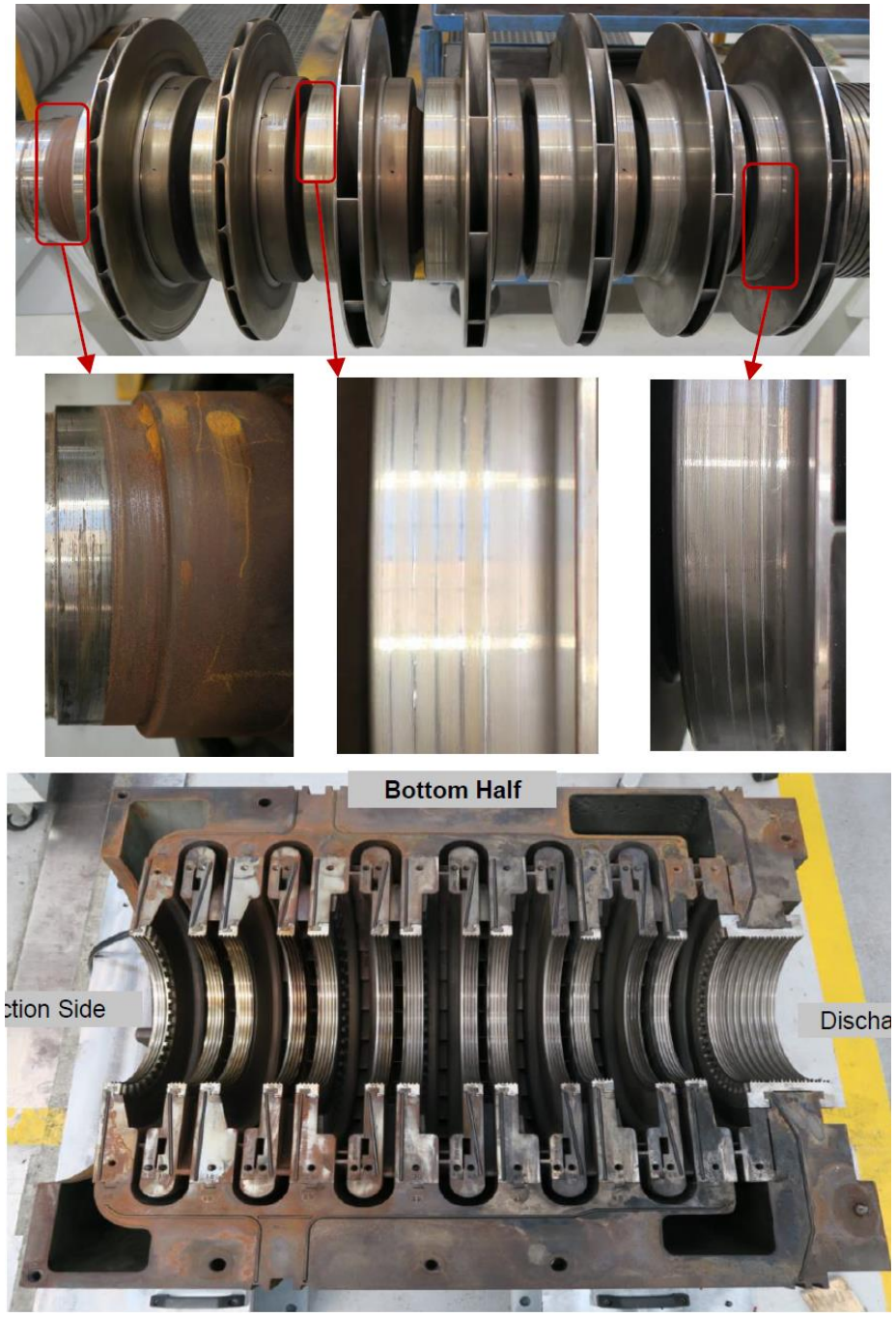
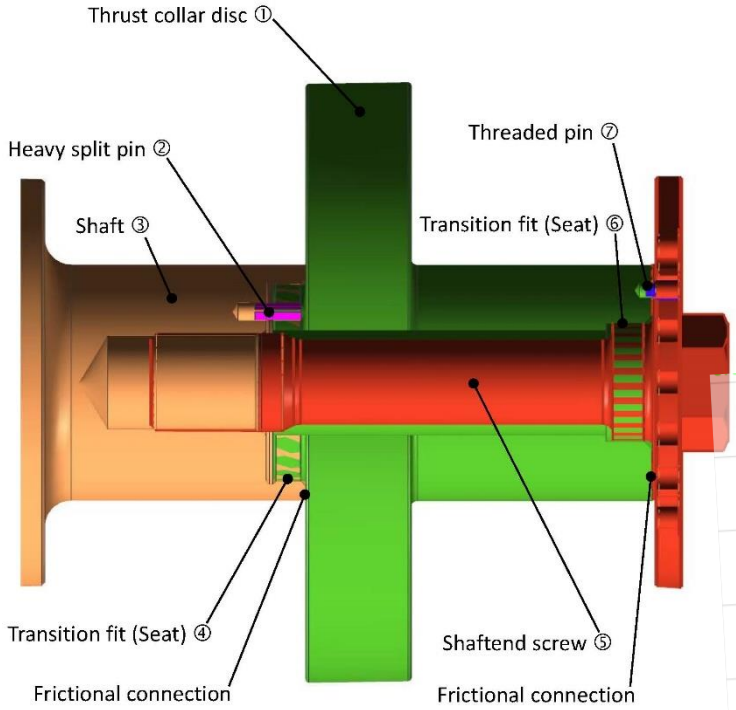


Figure 8 – Compressor Strip Down

Thrust Collar Design / Inspection



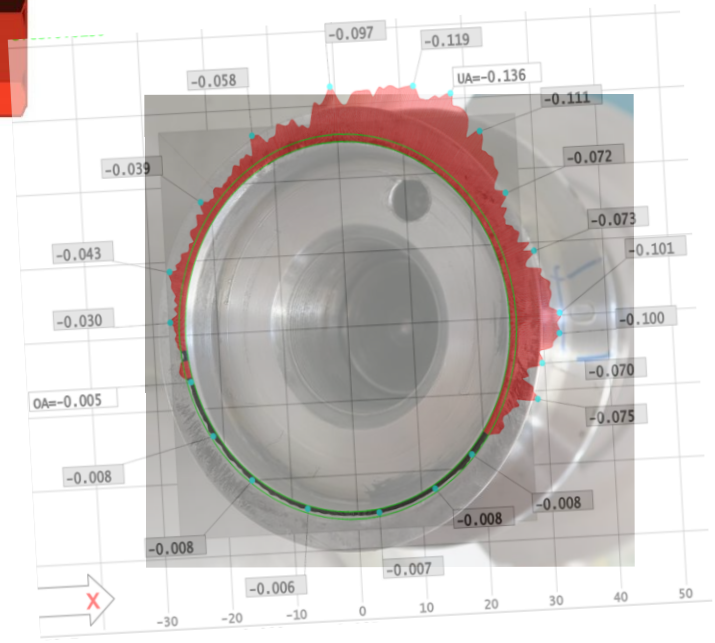


Figure 9 – Thrust Collar Design and Inspection

- Thrust collar is bolted arrangement
- Thrust collar-shaft transition fit **visually worn**
- Heavy split pin (radial positioning) **deformed**
- Shaft measurements highlighted that the **fitting diameter** is worn and **unacceptable**

Root Cause Findings

- Heavy split pin location hole is out of position and oversized
- The positioning pin is deformed/ bent
- Severe surge contributed to the pin deformation and subsequent parts wear
- The increase wear led to thrust collar eccentricity
- The unbalance caused by thrust collar eccentricity resulted in the increasing NDE vibration

	All values in mm Bore diameter	All values in mm Radial bore Position
Position	D1	R1
Value	5.7	20.45
Acceptable Y / N	N	N

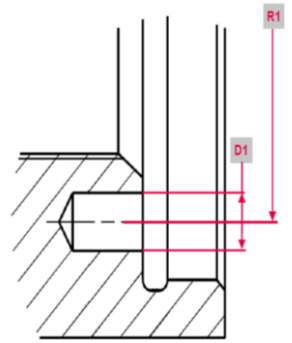


Figure 10 – Locating Hole Measurement Check

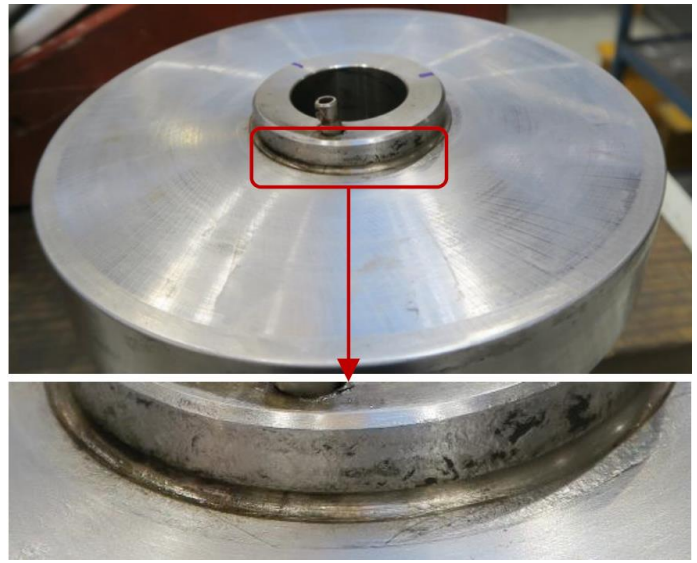
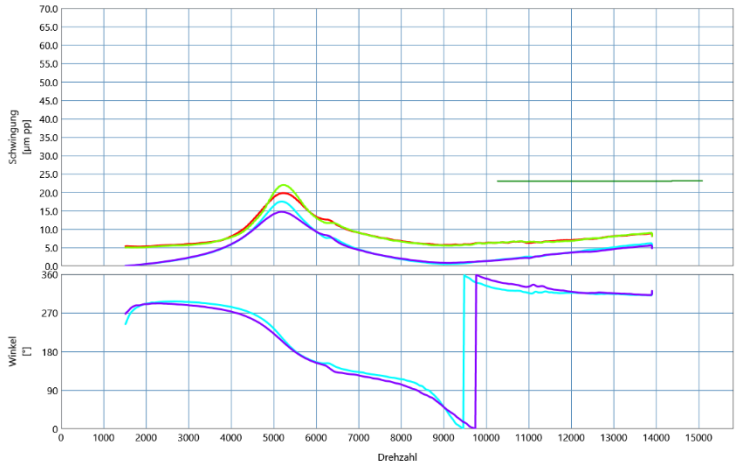


Figure 11 – Damaged Thrust Collar

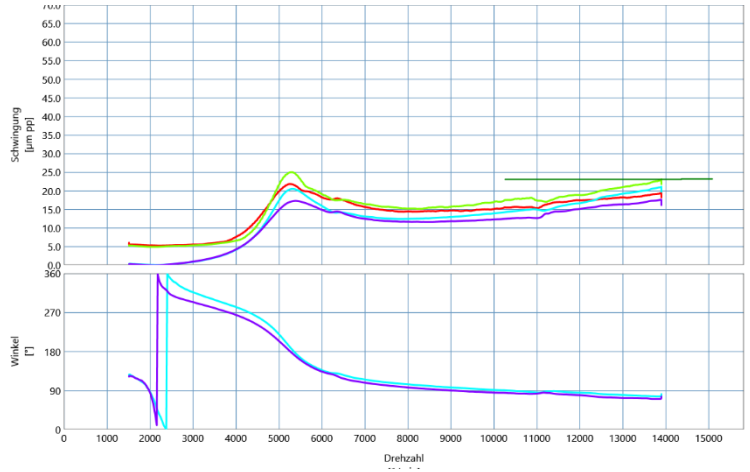
High Speed Balance NDE Vibration

Figure 12 – HSB Results - Shaft Vibration NDE(OEM)



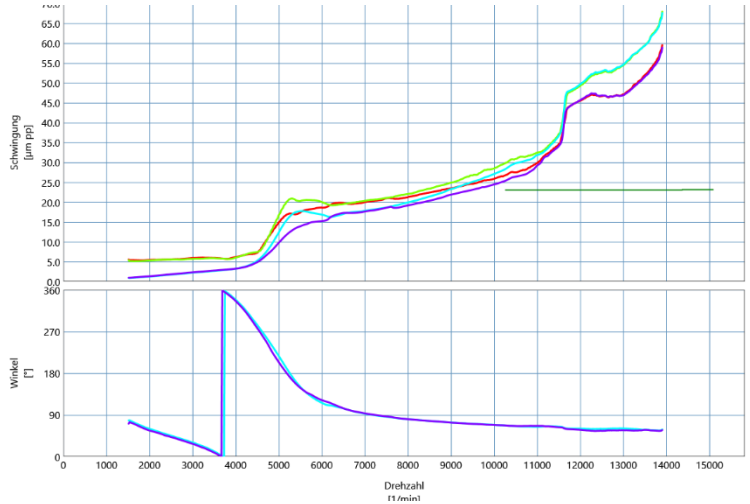
Run 1 – Thrust Collar assembled towards sound centring.

DE/NDE - 7/10um-pp



Run 2 – Thrust Collar assembled towards worn centring.

Runout - 0.12mm
DE/NDE - 8/22um-pp
Unbalance - 378gmm



Run 3 – Thrust Collar assembled towards worn centring. (Pin Reversed)

Runout - 0.25mm
DE/NDE - 21/68um-pp
Unbalance - 788gmm

Findings & Solution

- The drilling of the locating hole for the pin was done manually which compromise the collar assembly
- Post build quality checks did not include locating hole measurement and the issue was missed
- The end user will request the locating hole measurement check after future overhauls on the operated fleet
- The primary means of identifying this defect will be online vibration monitoring
- **Outcome** - The OEM acknowledged the problem and changed the drilling process from a manual to a machining activity

Credit

- Nicolas Péton – Bently Nevada
- Paul Yingst – bp
- Dr. Peter Popaleny – Bently Nevada
- Patrick Ashley – Bently Nevada
- Niall Ewart – bp
- Clive Woolsey - bp
- Ajay Khetarpal – bp/Harbor Energy
- Bill Foiles – bp

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Questions?

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