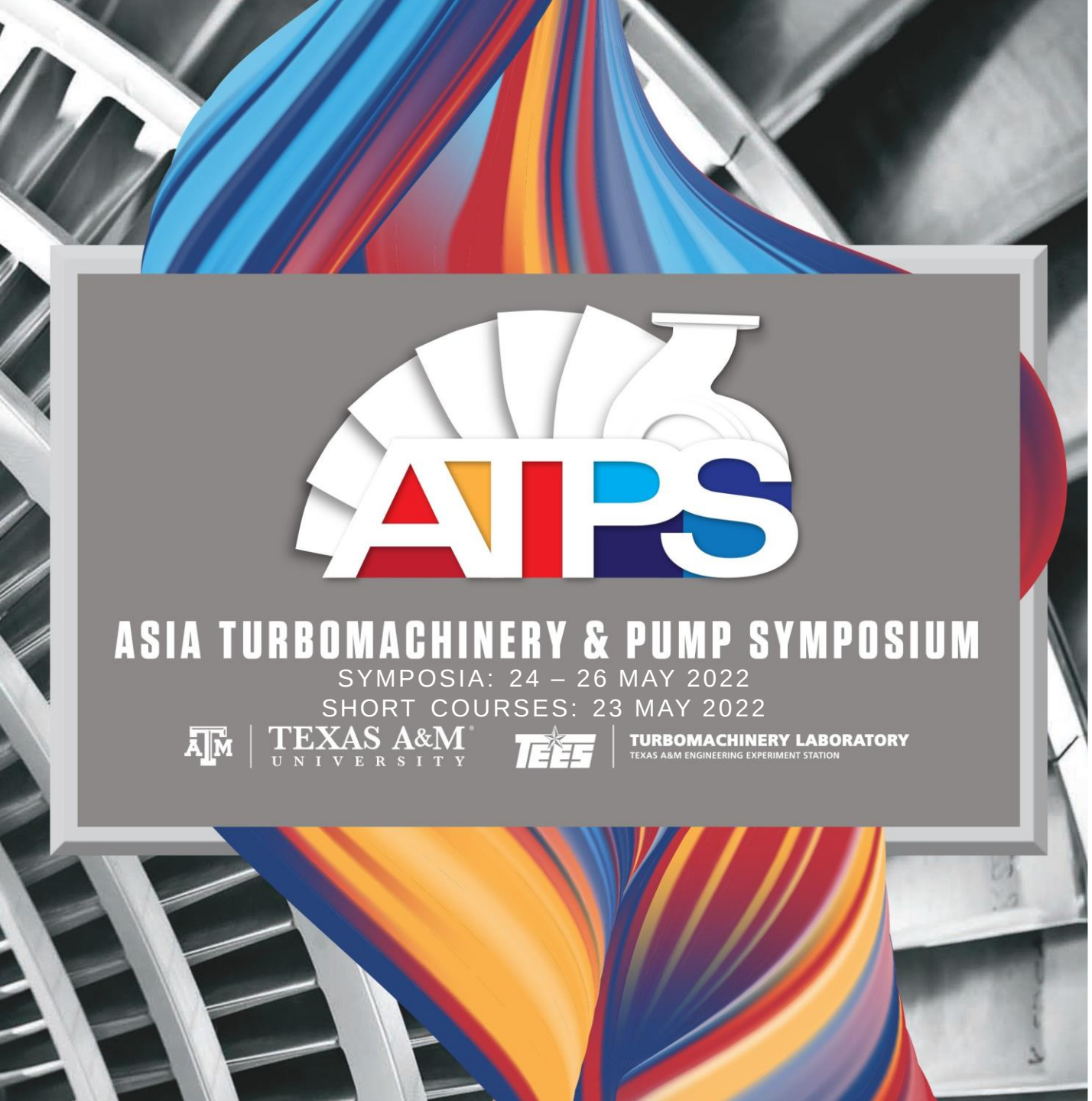

Application of Polycrystalline Diamond (PCD) Bearing for Reactor Circulation Pump

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ABSTRACT

The axial flow loop reactor pump installed in a polymer unit facilitates slurry circulation in the reactor. The pump is installed with triple mechanical seal having API seal flushing plans 32, 53C and 52. The seal cartridge contains a radial bearing for shaft support to ensure stability on the cantilevered pump design.

There have been multiple failures in the past with low seal MTBF. The failure analyses conducted indicate similar failure mechanism- seal support bearing failure leading to primary seal leak and subsequent shutdown. The failure mechanism has been attributed to skidding and sliding wear on one of the rows of rollers in the bearing. The skidding/sliding is caused by the insufficient load on one of the rows of rollers caused by axial misalignment between the inner and outer race. This misalignment can happen during transients when thermal growth differences require outer race to slide inside the seal housing fit.

The lubrication of the bearing and sliding joint can be further impacted by seal oil contamination stemming from seal face geometric instability allowing reverse flow of process across seal face. This process contamination and viscosity loss can cause rapid deterioration of the bearing due to poor lubrication.

To address these vulnerabilities, a Polycrystalline Diamond (PCD) bearing is installed to replace existing spherical roller bearing for the rotor support system inside the mechanical seal cartridge. Also due to PCD bearing design, the bearing is less sensitive to lubrication issue caused by C3 ingress into seal oil.

This article presents a summary of investigation around the root cause of multiple seal failures in a specialty pump application and ‘fit for purpose’ mitigation taken as a result of investigation along with the capabilities of PCD bearing technology to tackle a design with inherent vulnerability.

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Background

Equipment Details

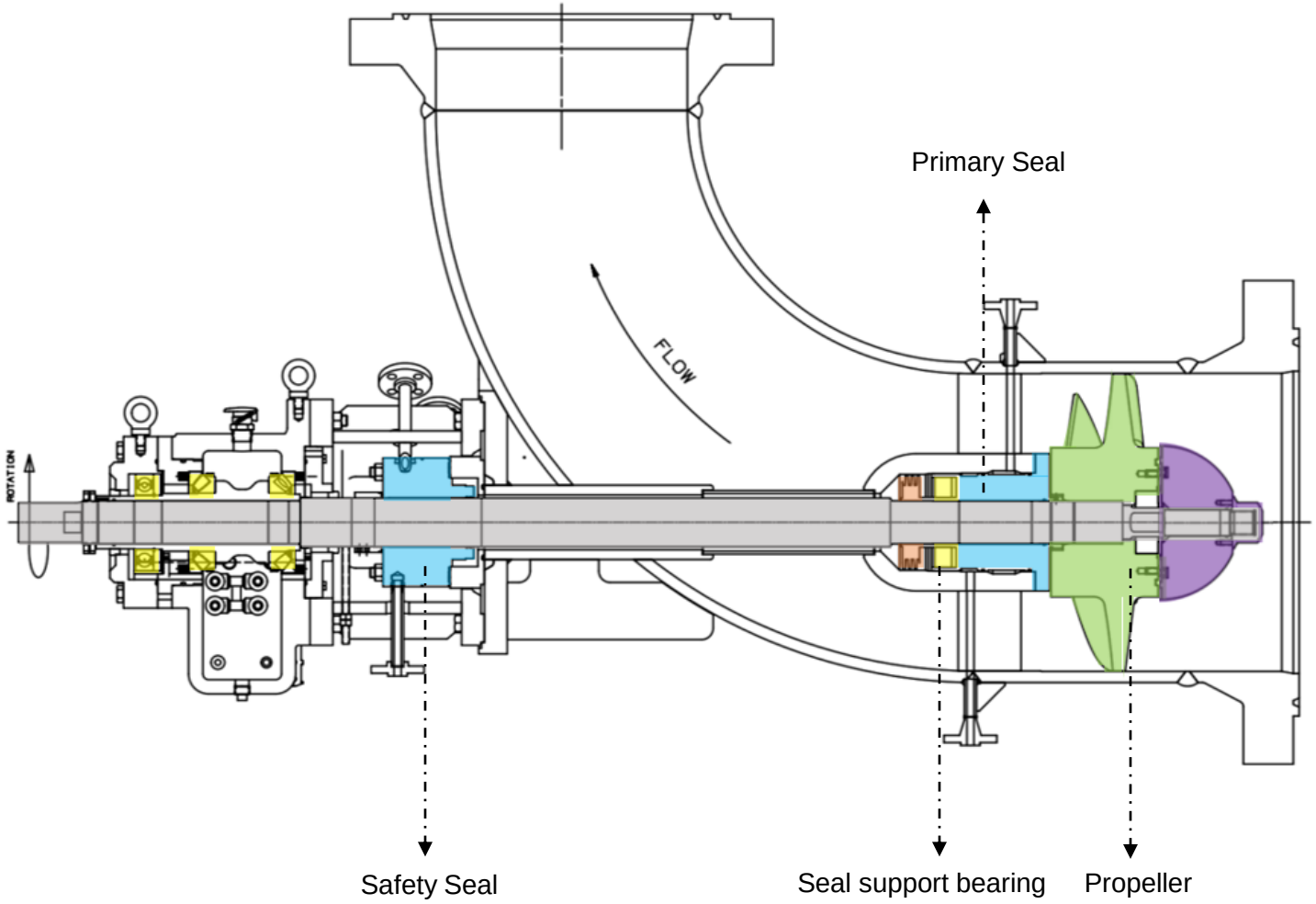
Single stage axial flow pump
Service: Reactor Slurry
Flow: 6000-8000 m3/hr
Differential Pressure: 200KPaG
Pumping Temperature: 70°C

Motor power: 750 kW
Revolution: 1500 rpm

Impeller type/mounting:
Axial Propeller/Overhung

DE Bearing: Deep goove ball bearing/Spherical roller thrust bearings

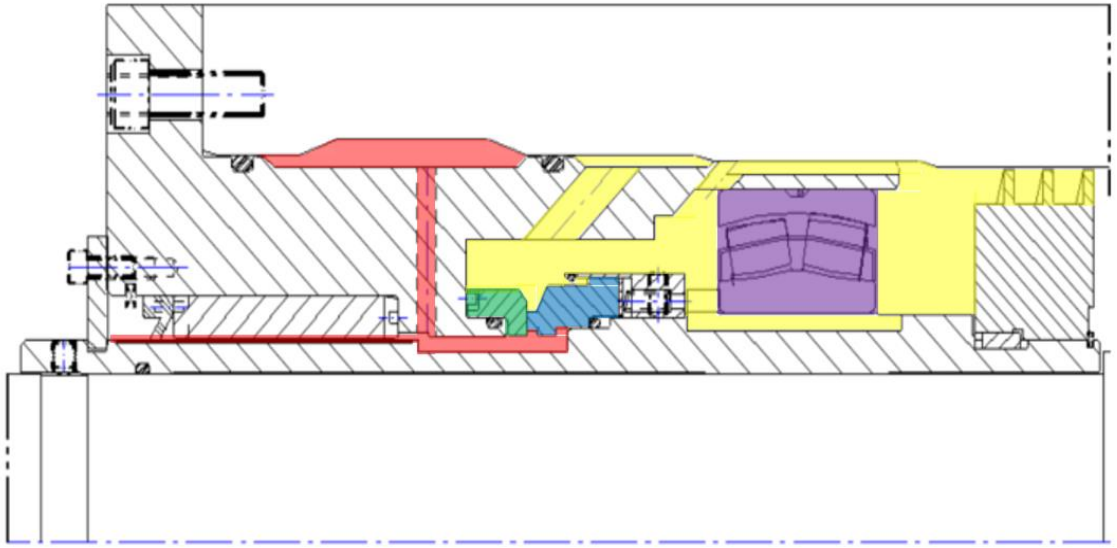
NDE Bearing: Spherical Roller Bearing

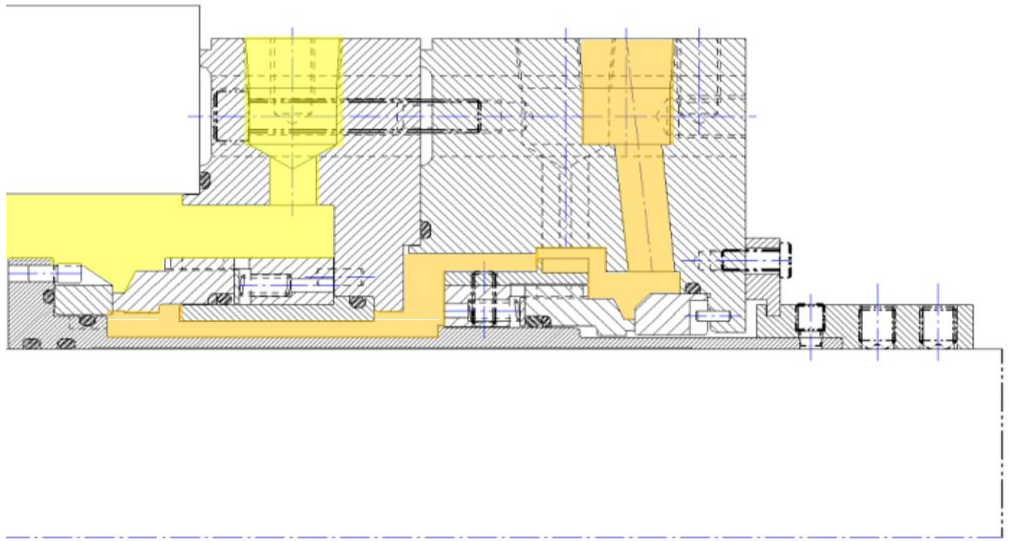


Background

Mechanical Seal details:

- Triple Seal with Rotating Pusher on Primary
- Primary seal face combination: TC/SiC
- API Plan: 32/53C/52
- Heat generation: 0.97KW (Primary) + 2.84KW (Load) + 0.59KW (Safety)
- Balance ratio: 0.86
- Bearing: Spherical Roller Bearing





Background

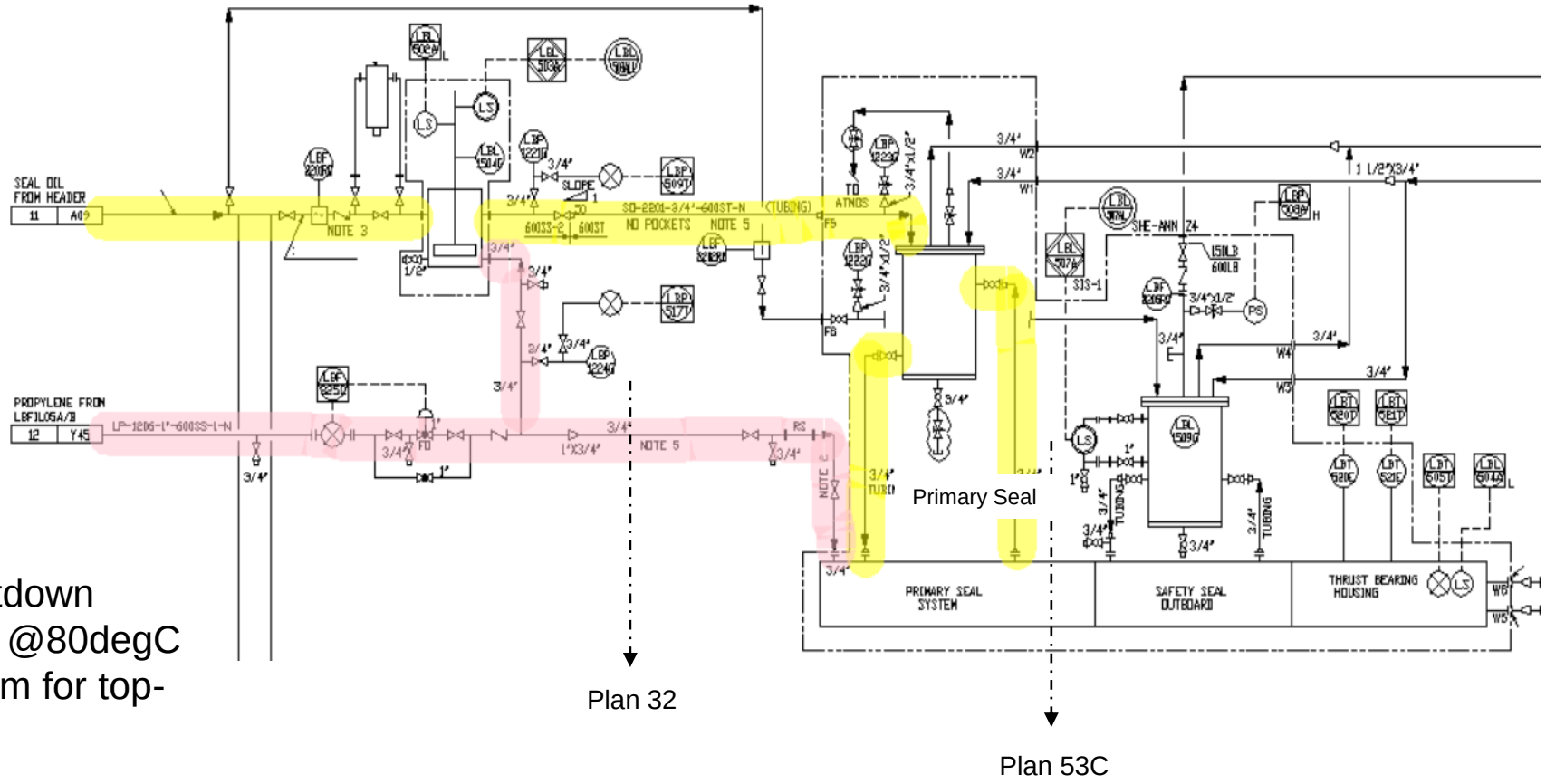
Seal Oil P&ID

API Plan 32:
Fluid: Process fluid

Barrier:
Fluid: ISO VG-68 mineral oil
Pressure: Plan 32 + 10%
Seal oil filter: 5micron

Pump protection:

Pump high amps e-seq, initiate shutdown
Pump outboard bearing temp alarm @80degC
Primary seal oil piston level low alarm for top-up



Problem Description

Multiple seal failures with low mechanical seal life (~3years)

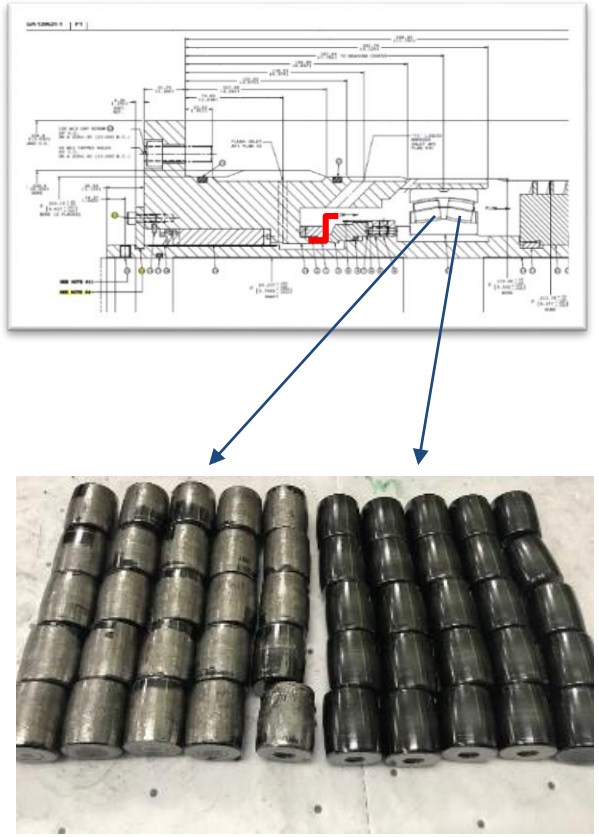
Seal support bearing failure leading to primary seal leak and subsequent shutdown

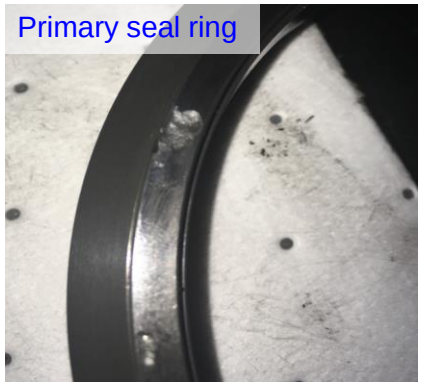
Loss of bearing lubrication because of seal oil viscosity reduction due to process ingress

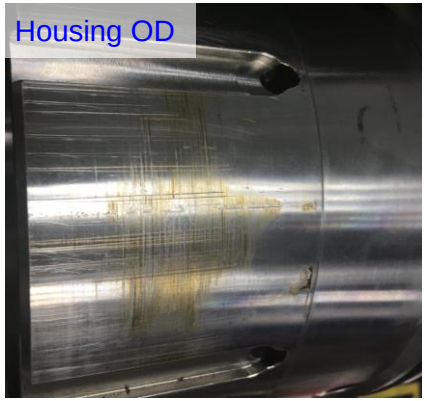
The bearing failure mechanism is attributed to skidding and sliding wear on one of the two rows of rollers in the bearing

Chipping on primary seal ring SiC face at multiple locations with excessive wear marks

One sided wear on the sleeve OD and bind mark on the housing OD and gland housing ID







Analysis

Existing spherical roller bearing design is oversized operating at less than the required minimum load for bearing

Thus the bearing is vulnerable to skidding of rolling elements

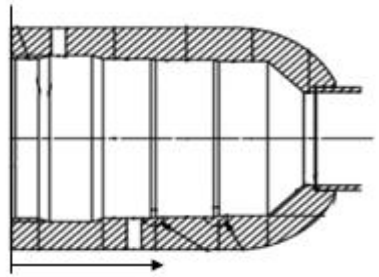
The skidding / sliding is caused by insufficient load on one of the rows of rollers caused by axial misalignment between the inner and outer races

The misalignment can happen during transients when thermal growth differences required the outer race to slide inside the seal housing fit

Outer race unable to slide due to less than adequate stuffing box geometry

Inadequate stuffing box concentricity can lead to uneven seal face loading and result in C3 ingress

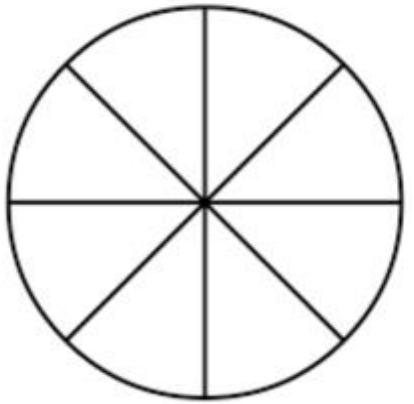
Install bronze bushing. Measure and record concentricity between shaft and stuffing box at various locations (Mark locations on diagram. All dimensions in mm)



Point	Distance from stuffing box face
A	197.65
B	116.40
C	13.10

Point	Reading	
A	+0.00	(+0.00)
B	+0.00	(+0.00)
C	+0.00	(+0.00)

Point	Reading	
A	+0.23	(+0.32)
B	+0.23	(+0.58)
C	+0.19	(+0.38)



Point	Reading	
A	+0.00	(+0.23)
B	+0.03	(+0.16)
C	-0.04	(-0.11)

Point	Reading	
A	+0.08	(+0.42)
B	+0.23	(+0.47)
C	+0.12	(+0.32)

Mitigation

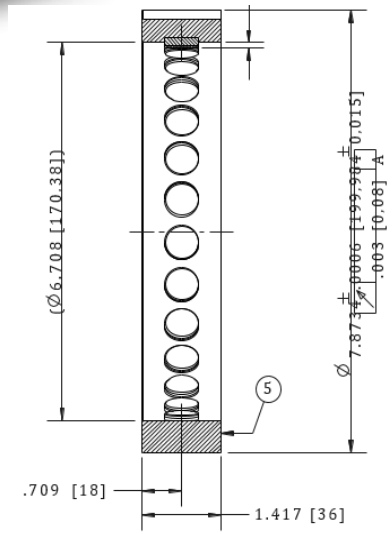
Spherical roller bearing is susceptible to skidding and experiences rapid deterioration because of C3 ingress into the seal oil

To address these vulnerabilities, a PCD bearing is selected for this application

The outer race is fixed with snap rings and thermal growth is accommodated between the inner and outer race PCD elements

Also, the bearing is less sensitive to lubrication issues caused by C3 ingress into the seal oil

PCD radial bearing set includes a rotating and stationary bearing ring opposing each other with the PCD surface



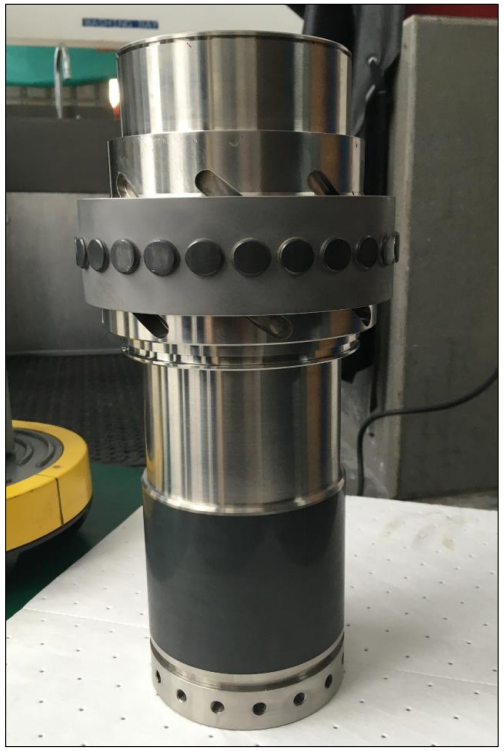
Background

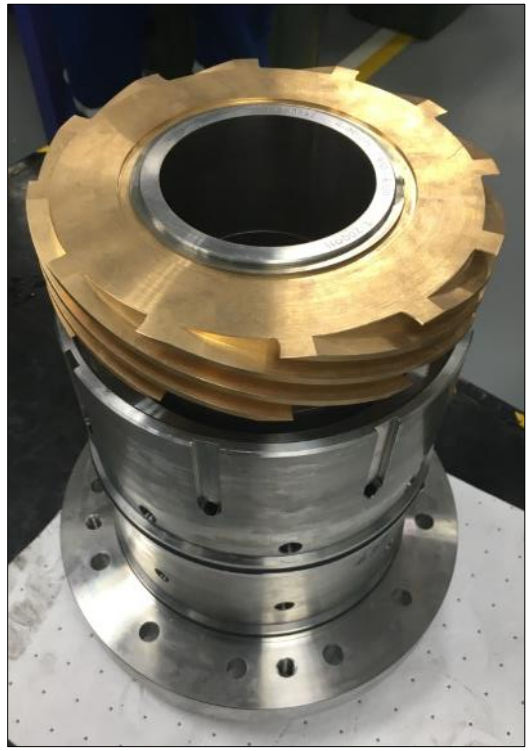
PCD bearing can accommodate 0.4 deg of angular misalignment when compared to the required max misalignment capability of 0.04 deg based on worst case scenario of tolerance stack-up

Heat generation of PCD bearing after ‘break-in’ run would be 0.9KW when compared to 4.3KW for spherical roller bearing

The primary seal configuration changed to stationary pusher design to accommodate stuffing box concentricity issue

The primary seal faces are applied with ‘diamond coating’ for lower heat generation





Results

The seal was upgraded in 2020 and current health status of the pump based on assessment looks stable and healthy

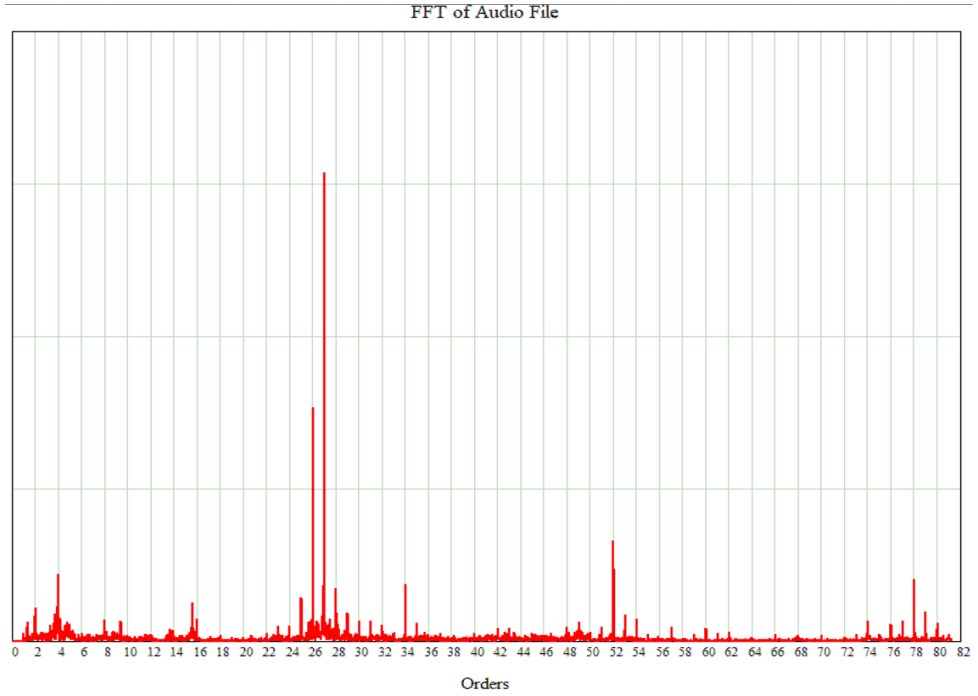
Pump casing vibration is at baseline and seal oil analysis did not indicate any abnormality with respect to particle count and metal constituents

Seal oil VOC (Volatile Organic Compound) is at baseline with steady trend over the past 1year

Seal leakage rate and motor amps stable

Higher than usual noise level observed. The noise file converted to frequency domain indicates dominant peak at total number of pucks

Acoustic insulation applied on the casing to reduce the overall noise level within the acceptable levels



Key Learning

- Seal oil analysis is significant for the comprehensive health assessment of the pump (specially for product lubricated bearing)
- This is a special case wherein the same lube oil is used to lubricate seal faces and bearings making it challenging application
- PCD bearing comes as an effective alternative to tackle viscosity related issues in seal oil
- Stuffing box geometry is significant for seal performance
- PCD bearing can be applied to wide range of applications like vertical vessel agitators, centrifugal pumps, specialty applications, conveyors etc
- Significant work required with specialist vendors (in this case ChampionX) for development of PCD bearing for specific applications

End of Presentation
Questions?

ASIA TURBOMACHINERY & PUMP SYMPOSIUM