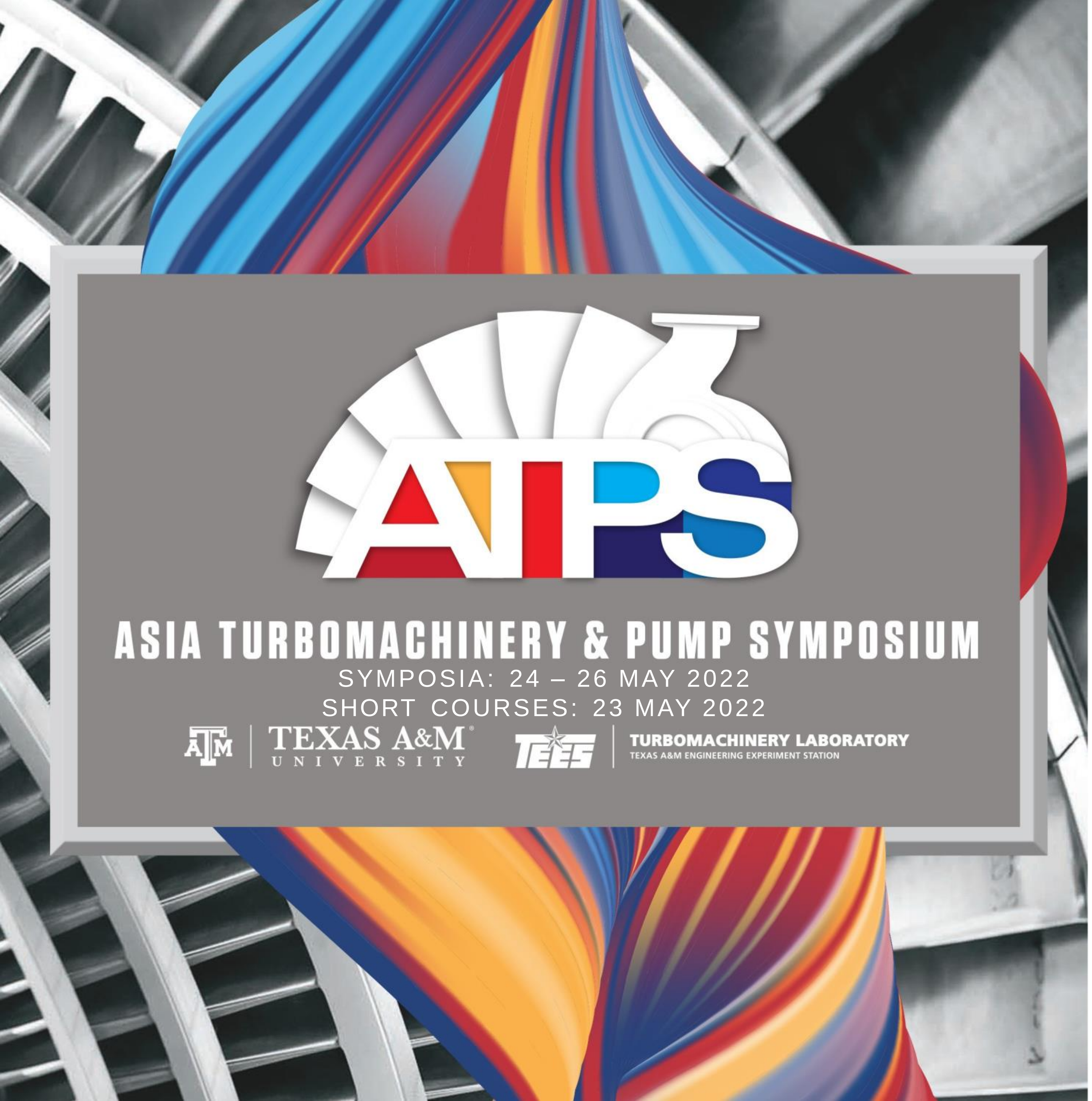

Vibration Diagnostic of Steam Turbine Intermittent Rubbing

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Abstract

A special purpose steam turbine has started to experience intermittent radial vibration spikes. The turbine is used to drive a Hydrogen Recycle Gas Compressor in Aromatics unit. No abnormality observed on the compressor end. ADRE 408 external data acquisition and diagnostic system was used to collect vibration data during steady state operation. Detailed vibration diagnosis was performed to evaluate overall rotor dynamic behavior of the machine train, assess vibration levels against the OEM set-points and ISO 7919-3 standards, troubleshoot potential mechanical malfunctions that leads to intermittent vibration spike and provide recommendations for safe operation of the unit. From the analysis, the cause of high vibration was determined to be intermittent light rubbing of the steam turbine rotor with the bearing housing oil baffle (seal).

Temporary mitigation actions were implemented: (i) increase vibration alarm limit from 30um to 42um and; (ii) commission sealing air to both DE and NDE bearing housing oil baffle, which was later on found to be clogged with oil carbonization. The intent of the mitigation actions is to reduce the probability of tripping the machine. However, it was not adequate and deemed to be too late to prevent the force outage.

After the trip, both DE and NDE bearing housing were opened for inspection. Severe oil carbonization was observed on the NDE bearing housing oil baffle which has close clearance and the sealing air port was plugged. The oil carbonization was cleaned without removing the steam turbine rotor (extensive work) in order to minimize the turbine downtime. Top halve oil baffle was completely cleaned while bottom halve oil baffle was cleaned to the best effort due to access constraint. The turbine was restarted successfully. No significant vibration spikes observed after 2 months of running. Proper visual cue (signage) was implemented to ensure sealing air supply valve is opened at all time when turbine is in operation.

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Agenda

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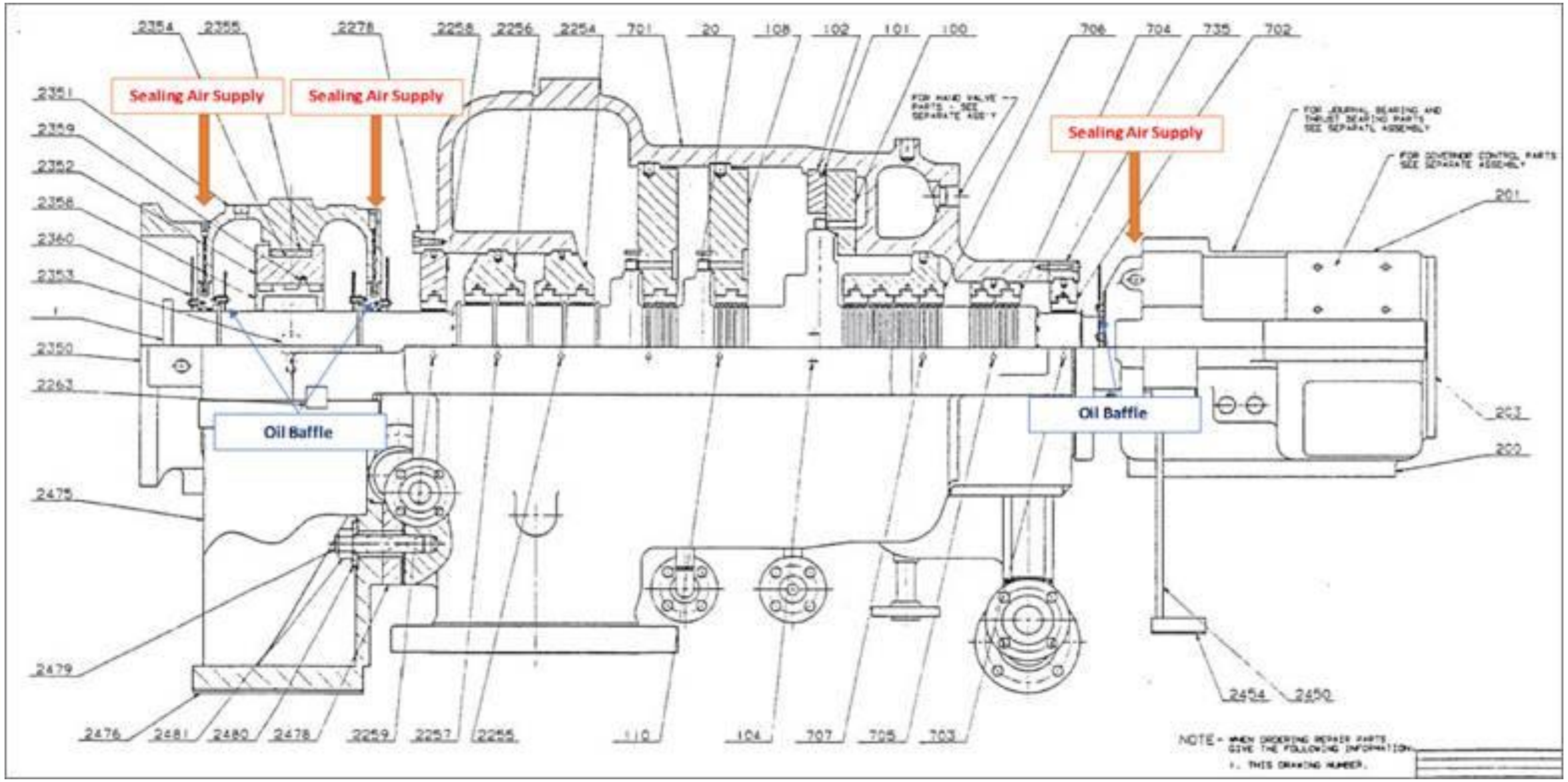
Equipment General Info



Steam Turbine Details

Type:	Back pressure turbine
Rating:	1.2MW (3 stages)
Inlet:	4,000kpag; 400degC
Exhaust:	1,200kpag; 215degC
Flow:	18,000 kg/hr

Rated Speed:	9,500 RPM
Max. Speed:	11,550 RPM
Min. Gov.:	6,050 RPM
1st Critical:	5,000 RPM
Trip Speed:	12,705 RPM

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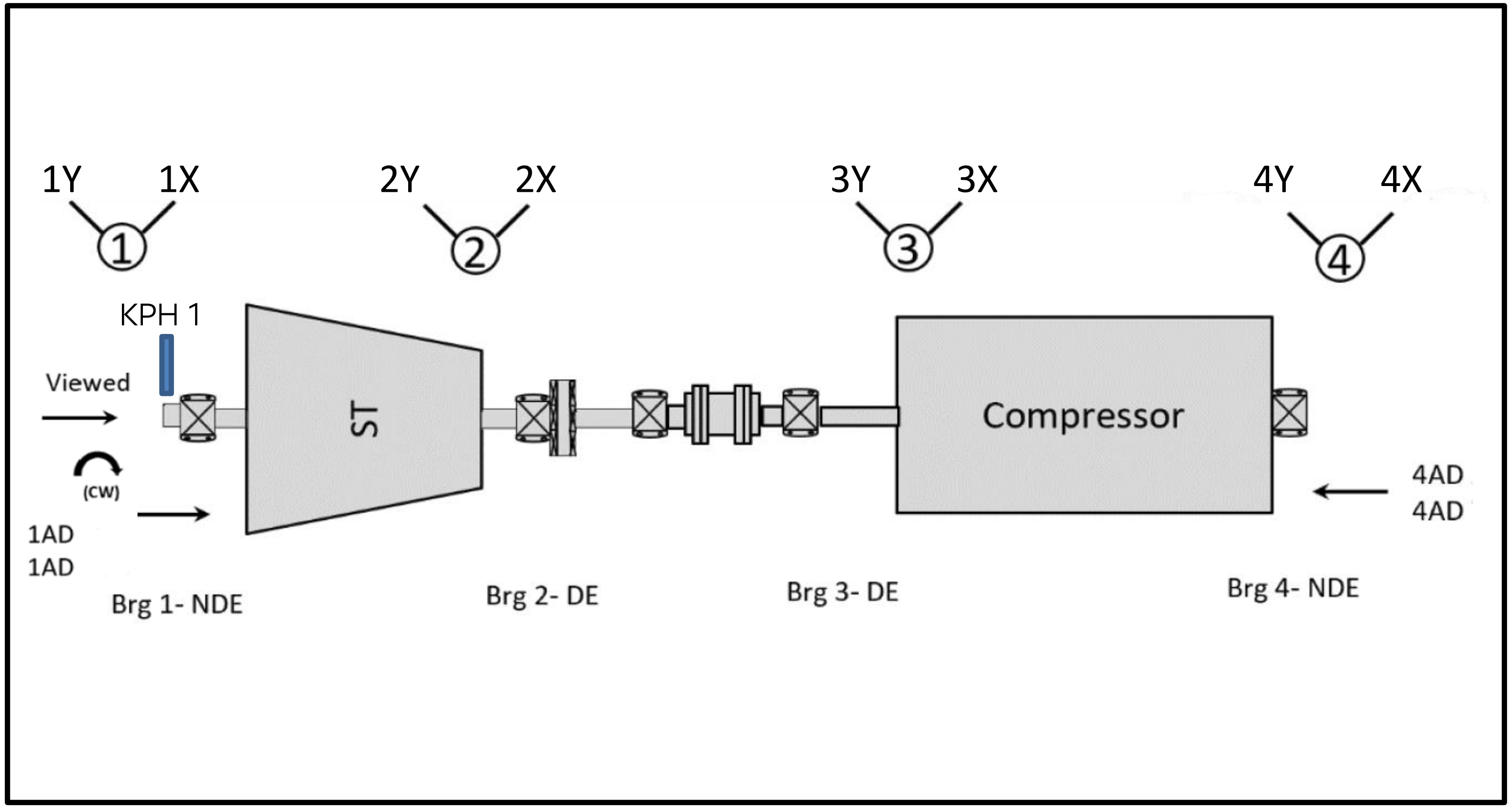
Equipment General Info

Steam Turbine Probe Orientation



Probe Orientation				
Tag#	Equipment	Bearing	X/Y	Key Phasor
1Y	Turbine NDE	1	45° Left	KPH 1
1X	Turbine NDE	1	45° Right	
2Y	Turbine DE	2	45° Left	
2X	Turbine DE	2	45° Right	
3Y	Comp DE	3	45° Left	
3X	Comp DE	3	45° Right	
4Y	Comp NDE	4	45° Left	
4X	Comp NDE	4	45° Right	

Alarm set point: 30 μm
Trip set point: 48 μm

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Problem Description

- The steam turbine was last overhauled in April 2019. The turbine typical overhaul interval is between 12 – 15 years. Rotor, bearings, casing and inter-stage seals were replace with new. Internal clearances were restored back to within OEM design limits. Turbine vibration was healthy and stable during commissioning.
- After about 1.5 years of operation, the turbine started to experience intermittent vibration spikes. The amplitude of spikes on steam end were consistently observed to be higher than exhaust end.
- The increase in vibration amplitude was observed to be gradual, and return to ‘normal’ level every time the vibration peaks.

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Analysis

1. ADRE 408 external data acquisition and diagnostic system was used to collect the steady state vibration data for further troubleshooting.

2. Dominant 1x peak during vibration spike , with clear reverse component observed on full spectrum.

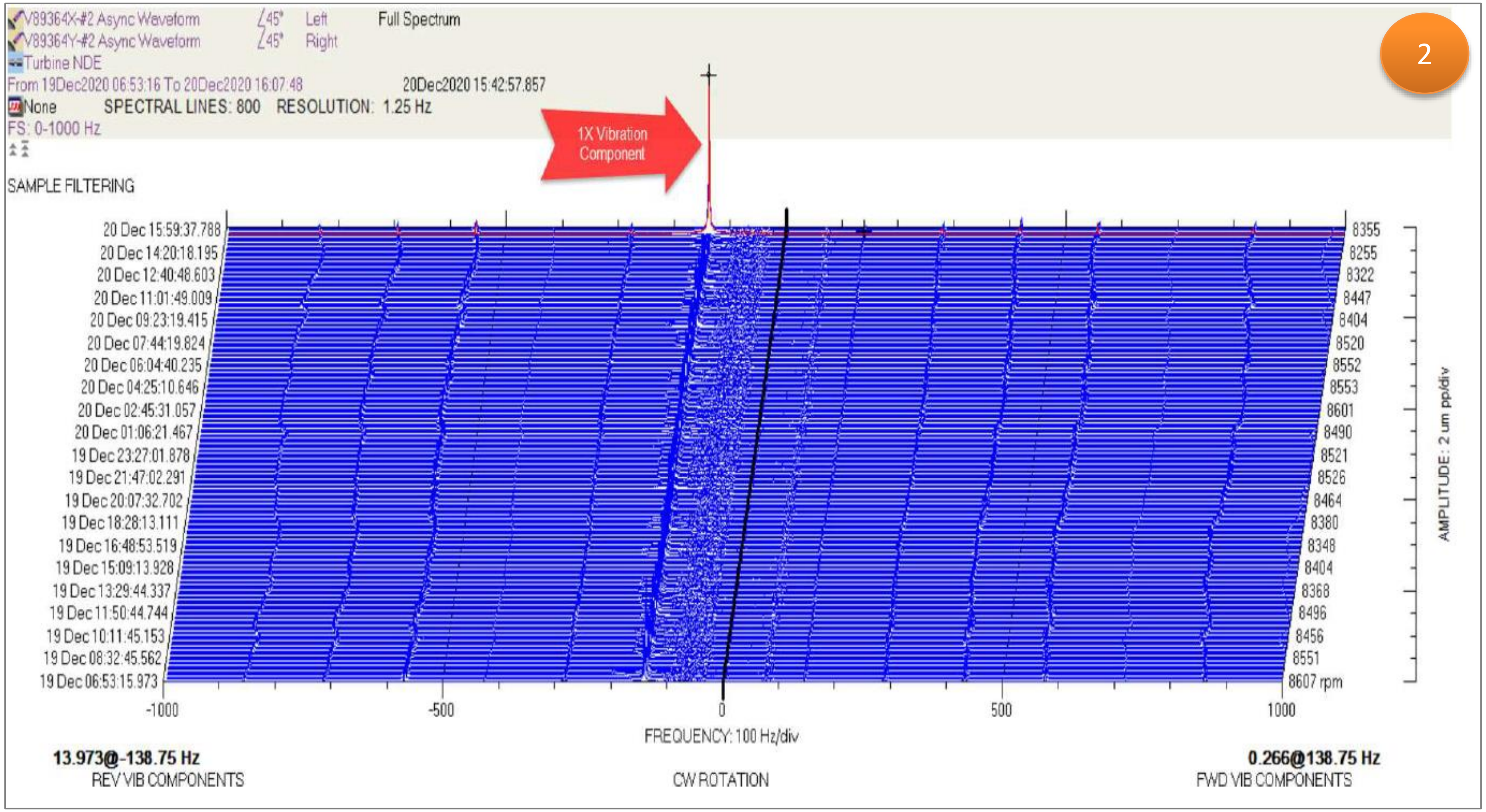

Fig. 2: Full spectrum during vibration spike

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Analysis

3. Significant phase angle change observed during vibration spike indicating a shift of rotor heavy spot. Reverse precession (vs. direction of shaft rotation) was observed on orbit plot.

4. Polar plot shows random shift of phase angle during vibration spike event.

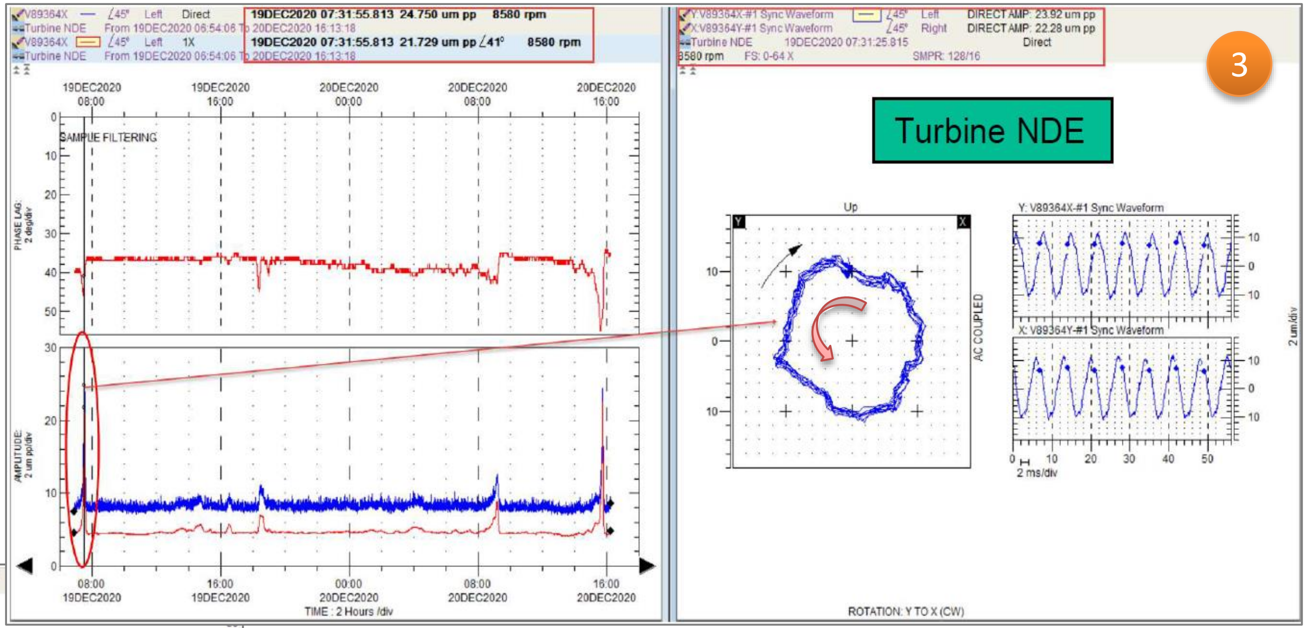

Fig. 3: Phase angle change in Bode and reverse precession in orbit observed

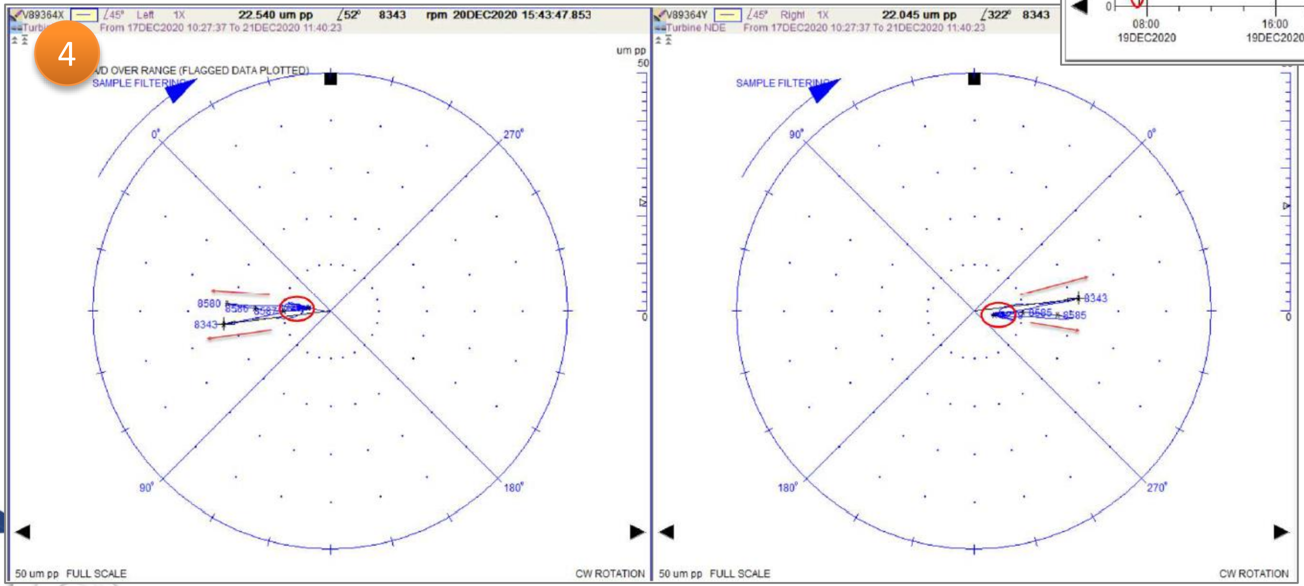

Fig. 4: Polar plot with phase shift during vibration spike

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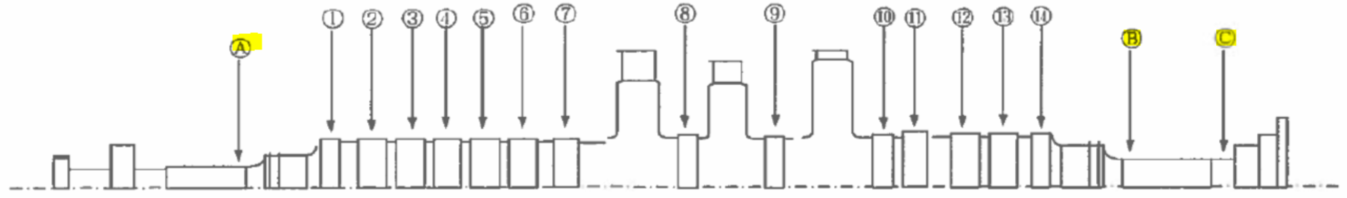
Analysis

- Base on vibration data analysis, it is highly suspected the cause of intermittent vibration spike is due to **light or partial rubbing** of rotor.
- Rubbing is not a machinery malfunction; but rather a secondary indicator that there are other primary cause(s) that led to the rub.
- Last overhaul QA/QC record indicates the location of tightest clearances is at the bearing housing oil baffle (A, B and C with design clearance of 0.001" – 0.003")
- Site check revealed that the sealing air supply to oil baffle was not commissioned post turbine restart in 2019.
- *Lack of sealing air => Oil migration to oil baffle => Oil carbonization (high temp.) => Smaller clearances => Rotor rubbing*

Internal Labyrinth Clearance (*W)

Date: 9/3/2019



	Position	Design	As Found	As Left (Final)		Position	Design	As Found	As Left (Final)
A	Oil Baffle	0.025-0.076	0.09	0.0254	8	2nd stage Laby		Damaged	0.5330
1	Outer Laby		0.62	0.5330	9	3rd stage Laby		Damaged	0.5330
2	Mid Laby		0.60	0.5330	10	Inner Laby		0.60	0.5330
3	Mid Laby		0.65	0.5330	11	Inner Laby	0.483-0.584	0.58	0.5330
4	Inner Laby	0.483-0.584	Damaged	0.5330	12	Mid Laby		0.58	0.5330
5	Inner Laby		Damaged	0.5330	13	Mid Laby		0.55	0.5330
6	Inner Laby		Damaged	0.5330	14	Outer Laby		0.55	0.5330
7	Inner Laby		Damaged	0.5330	B	Oil Baffle	0.025-0.076	0.09	0.0254
					C	Oil Baffle	0.025-0.076	0.09	0.0254

IMMEDIATE ACTION:

To reduce the probability of tripping,

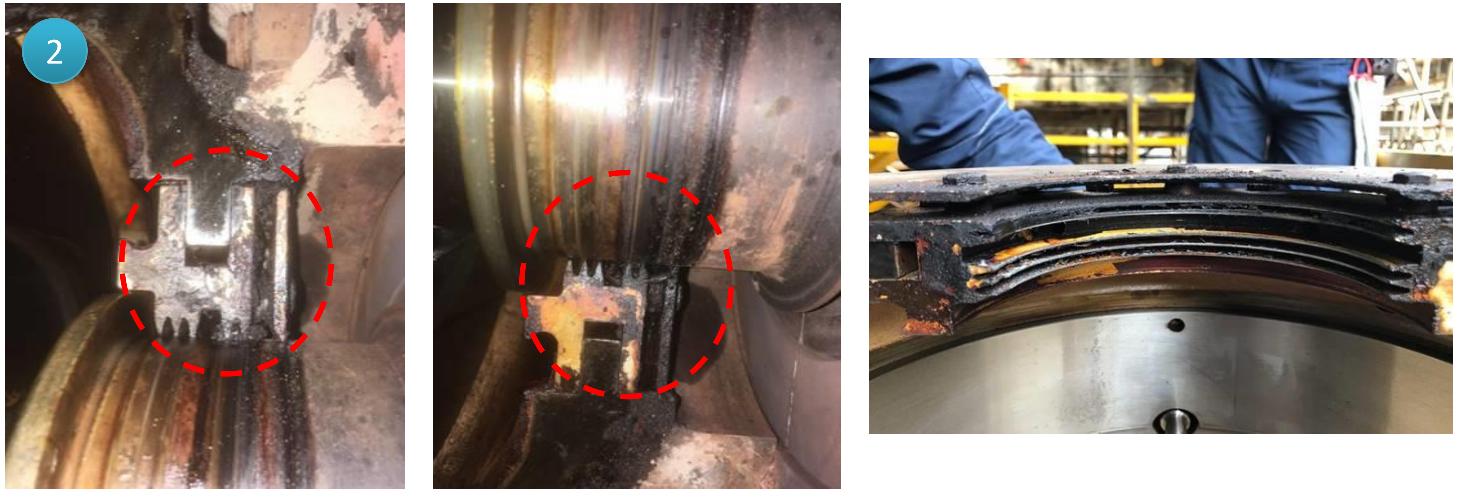
1. Recommission the sealing air supply to air baffle
2. Review and increase vibration alarm set point

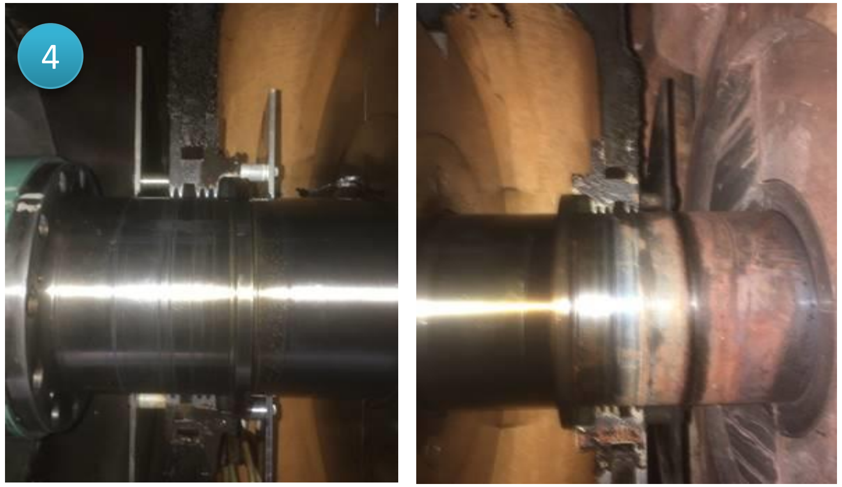
Unfortunately, it was too late and the turbine eventually tripped on NDE (Steam end) VAHH in Feb 2021

Open

Findings & Mitigation

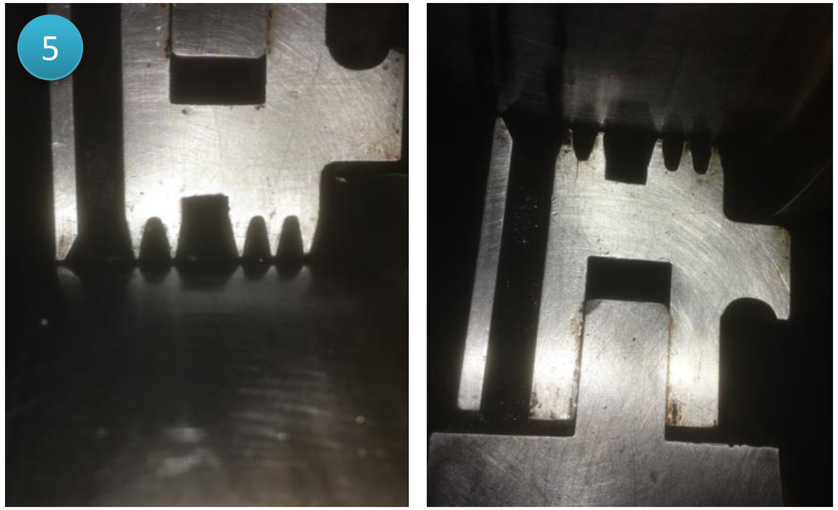
1. After the trip event, the turbine bearing housing was opened for inspection.
2. Steam end bearing housing oil baffle was badly clogged with carbonized oil. Clear rubbing sign on turbine shaft.
3. The sealing air injection port was also fully plugged which explain the reason why recommissioning of sealing air does not help to prevent the trip.
4. Exhaust end bearing housing oil baffles were significantly cleaner as they were exposed to much lower temperature; hence no carbonized oil.
5. All oil baffle were cleaned before reassembling of the bearing housing.





DE oil baffle – coupling end

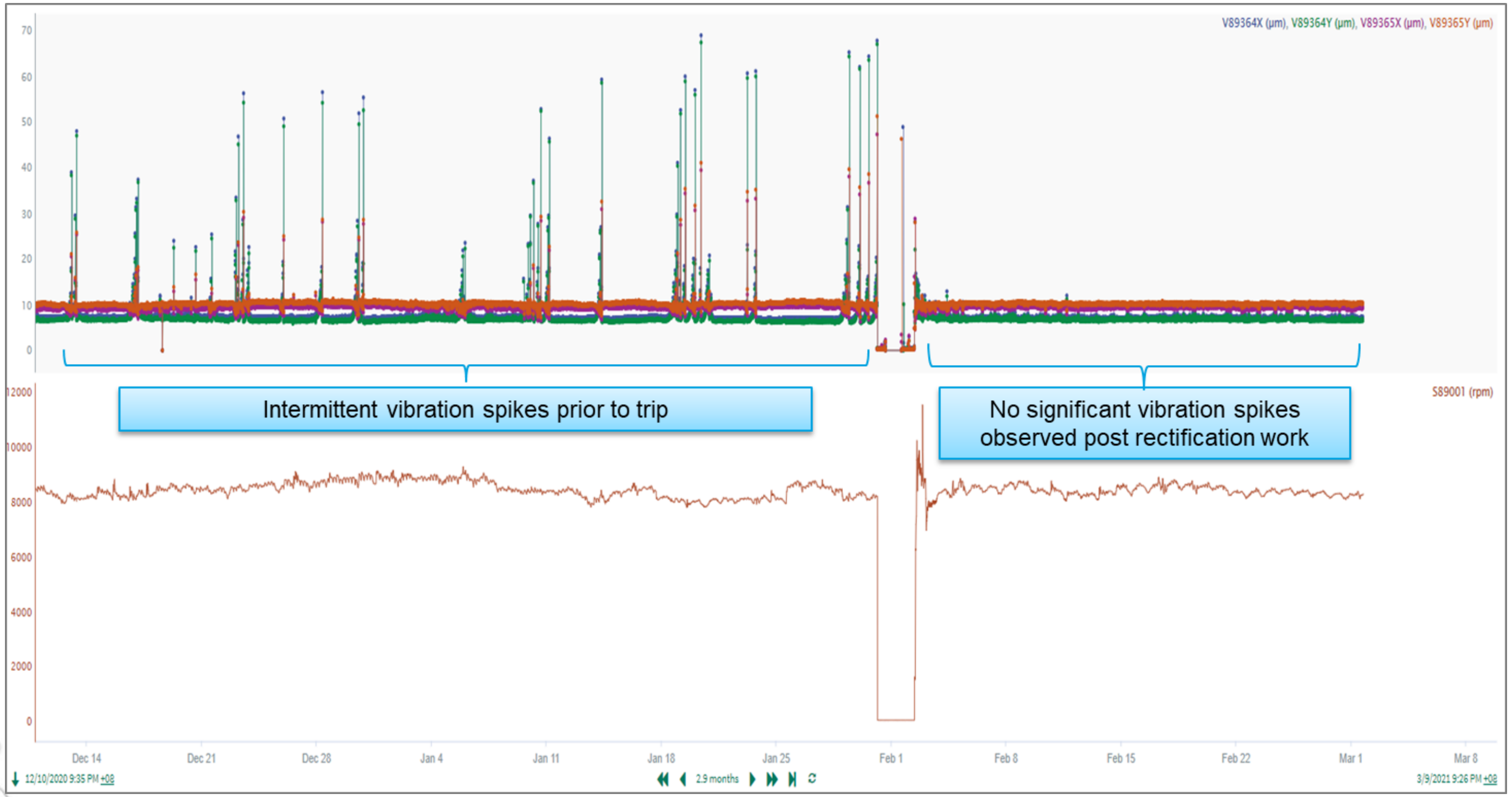
DE oil baffle – exhaust end



Steam end (NDE) oil baffle post cleaning

Mitigation & Results

- As the vibration analysis and troubleshooting was completed prior to the trip event, the total downtime was significantly reduced to only 2 days (including unit restart). Targeted rectification work can be performed immediately after the trip.
- Post restart, the vibration trend was healthy and stable. No vibration spikes observed.
- Site visual cue / signage was put up to remind operators the importance of commissioning the sealing air to the bearing housing oil baffle.
- Similar "Caution" remarks was updated into the turbine start-up procedure for long term sustainability.



IMPORTANT NOTICE

Sealing air to bearing housing oil baffle need to be commissioned prior to starting the oil system to prevent oil carbonization at oil baffle.

Note:
1. DE Oil Baffle Coupling End (Gate valve 2.5 turn opening)
2. DE Oil Baffle Exhaust End (Gate Valve 2.5 turn opening)
3. NDE Oil Baffle Steam End (Gate Valve full open; needle valve 3 turn)

Procedure Steps:

Initial/Date

A) Preparation:

1. Walk through the line-up of the process lines and drain any liquids from all low points. ______
2. Drain any liquids from the compressor casing drains. ______

B) Starting the Lube Oil System:

CAUTION:

Sealing air to bearing housing oil baffle need to be commissioned prior to starting the oil system to prevent oil carbonization at oil baffle.

Note:
1. DE Oil Baffle Coupling End (Gate valve 2.5 turn opening)
2. DE Oil Baffle Exhaust End (Gate Valve 2.5 turn opening)
3. NDE Oil Baffle Steam End (Gate Valve full open; needle valve 3 turn)

1. Check the lube oil reservoir level and de-gassing tank level. ______
2. Check the lube oil and seal oil line-up. ______
3. Ensure governor oil level is sufficient. ______

Key Learnings

1. Vibration data collection and diagnostic is an important tools for machinery troubleshooting.
2. In this case, it has helped to reduce equipment downtime by identify the risk and required rectification scope in advance prior to the trip. In many other cases, it can even prevent an unplanned shutdown.
3. The importance of sealing air was not fully understood and underestimated. It is crucial in preventing oil leakage through the oil baffle, forming carbonized oil when exposed to the radiant heat from steam turbine casing. Besides, the continuous flow of air will directionally cool down the surround temperature of the oil baffle.

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End of Presentation
Questions?

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