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Resolve 60 MW LMZ Steam Turbine Trip Issue During Cooling Water Pump Changeover

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Abstract: ***Steam turbine reliability depends upon the combined stability of the steam path, condenser system, lubrication system, rotor-bearing dynamics, and protection system. A trip of a 60 MW condensing steam turbine occurred during a routine cooling water (CW) pump changeover operation. Initial investigation identified condenser vacuum may deterioration following temporary reduction in cooling water flow. However, detailed analysis of turbine vibration trends revealed a delayed increase in rear bearing vibrationreaching 4.5 mm/s approximately three minutes after before unit trip.***

Subsequent inspection during outage revealed excessive top oil clearance in the rear journal bearing and a 0.46 mm shim installed at the bearing parting plane. The investigation concluded that the condenser disturbance acted as an initiating event, while degraded bearing dynamic characteristics amplified the rotor response, leading to turbine protection operation.

This paper discusses the event chronology, rotor dynamic behaviour, bearing stability analysis, root cause determination, reliability implications, and preventive measures.

I. INTRODUCTION

In modern thermal power plants, steam turbines operate as highly integrated thermo-mechanical systems. Any disturbance occurring in one subsystem can propagate through multiple systems before ultimately affecting machine reliability.

The condenser is one of the most critical auxiliaries connected to the steam turbine. It establishes and maintains the low exhaust pressure necessary for efficient energy conversion. Even a short reduction in cooling water flow can rapidly increase condenser pressure and adversely affect turbine performance.

Historically, many turbine trips associated with condenser disturbances have been attributed solely to vacuum loss. However, operating experience has shown that process disturbances frequently expose latent mechanical weaknesses already present within the machine.

The present case represents such a situation, where vibration 4.5 mmof rear bearing ultimately causing a turbine trip. The below DCS trend show the event:-

II. PLANT AND TURBINE DESCRIPTION

1.	Make :-	LMZ Rassia
2.	Model No:-	K-60-9.3
3.	Rated capacity, MW:-	60
4.	Turbine Type:-	Condensing cum Extraction
5.	Rotational Speed, RPM:-	3000
6.	No. of Stages:-	22
7.	Main Steam Pressure (Kg/Cm^2):-	93.1
8.	Main Steam temperature (degree C):-	530
9.	Main Steam Flow (TPH):-	251.6
10.	Cooling water temperature (degree C):-	33
11.	Feed water temperature :-	219
12.	Condenser Pressure (Kg f/Cm^2):-	0.079
13.	Cooling water flow, m^3/hr:-	12000

The rear journal bearing supports the LP rotor section and is responsible for maintaining rotor stability under varying operating loads.

III. NORMAL OPERATION

Prior to the event:
1) Unit operating at approximately 58 MW.
2) CW Pump-A & B running.
3) CW Pump-C on standby.
4) Condenser vacuum stable.
5) Bearing vibrations normal.
6) No abnormal alarms present.

IV. AS PART OF ROUTINE OPERATION

1) Standby CW Pump-C was started.
2) Transfer of condenser cooling duty was initiated.
3) Existing CW Pump-A or B was prepared for shutdown.
4) Rear Bearing Vibration = 4.5 mm/s
5) Time Delay = Approximately 3 Minutes

If vibration were caused directly by pump switching, it would appear immediately.This confirms a secondary mechanism rather than an instantaneous excitation source.

V. BEARING INSPECTION FINDINGS

A small piece of shim was observed on the bearing parting plane after dismantling

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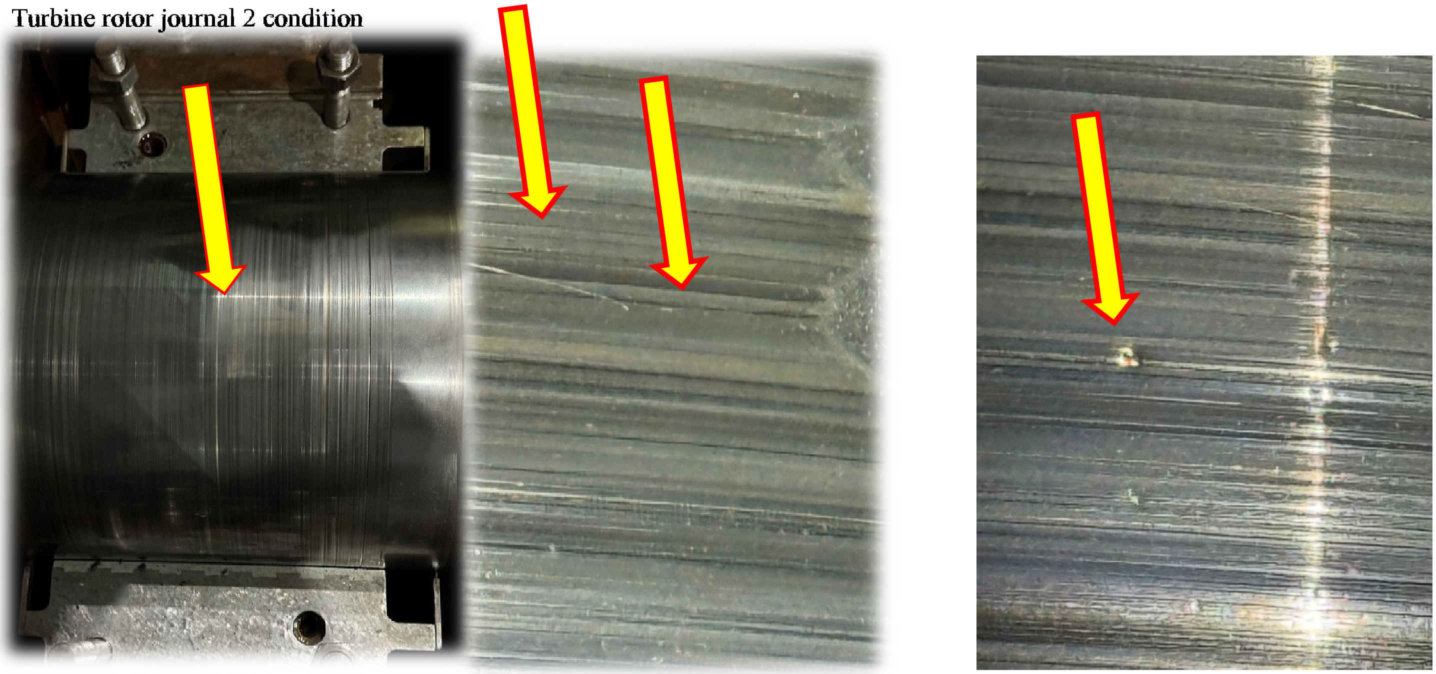
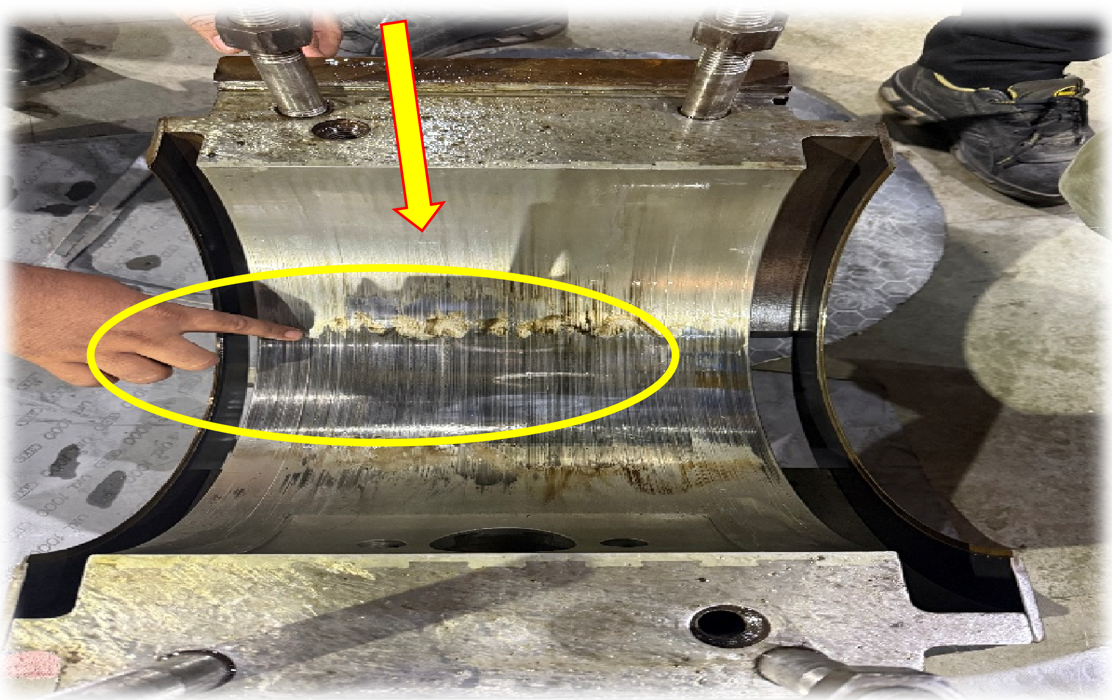
Turbine rotor journal 2 condition



Bearing no 2 bottom porting (Babbit material dislodged)



Heavy scar and dent mark lines were observed on the journal, and rubbing was also noted on the bottom half of the bearing. Additionally, the RTD position was found to be slightly below the babbitt material level. The bearing measurements after dismantling are as follows: -

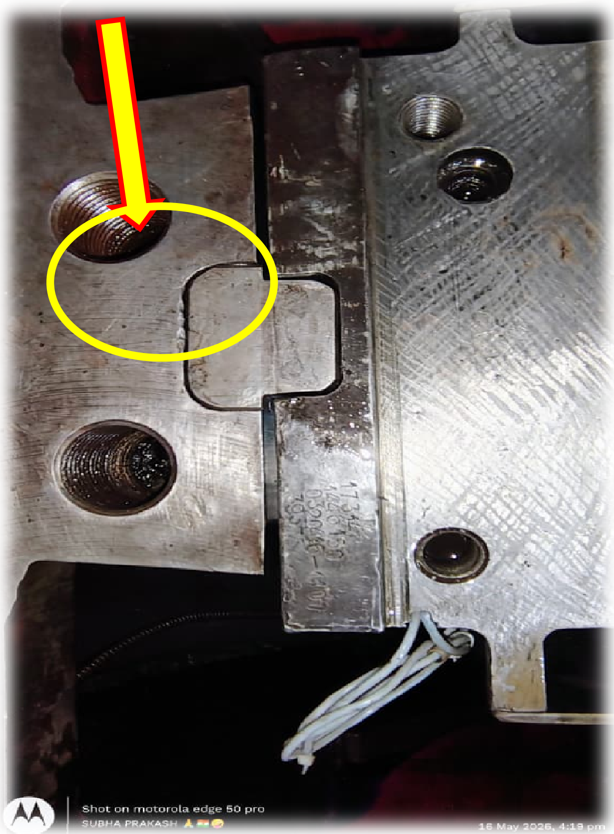
Bearing 2 clearances measurement: -

Journal diameter 359.56 mm (360 mm as per designed)

Bearing Top oil clearance 0.80/0.85/0.75mm (0.60 to 0.675 mm as per designed)
Bearing side oil clearance 0.60mm (0.60 mm as per designed)
Bearing ID 360.25 mm

The existing bearing was replaced with a refurbished spare bearing, with the measured Total Oil Clearance (TOC) found to be 0.70 mm. Furthermore, journal polishing was performed using coir rope& fine emery belt to improve maximum surface finish and ensure proper bearing performance.

Another observation was that the bearing lock thickness was 9 mm higher. After machining the lock was used during box up of bearing 2.



VI. BEARING THEORY AND DYNAMIC STABILITY

A journal bearing supports the rotor through a pressurized oil film.

Functions include:

- Load support
- Rotor cantering
- Vibration damping
- Dynamic stabilization

A healthy bearing behaves like:-

Spring with Damper

The oil film provides: -

- Stiffness
- Damping

These properties prevent excessive shaft motion.

VII. EFFECT OF INCREASED BEARING CLEARANCE

As bearing clearance increases:

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Oil Film Thickness ↑ (increased)
Stiffness ↓ (decreased)
Damping ↓(decreased)
Rotor Motion ↑ (increased)
The rotor becomes increasingly sensitive to:

- Load changes
- Steam force variations
- Thermal distortion
- Pressure disturbances

In such conditions, even a relatively small process disturbance can generate significant vibration.

VIII. EFFECT OF PARTING PLANE SHIM

The presence of a 0.46 mm shim significantly alters bearing geometry.
Potential consequences:-Increased Effective Clearance
Additional shim separates upper and lower halves.
Result:

- Increased top clearance
- Modified oil wedge

Reduced Oil Film Stiffness:-Hydrodynamic pressure generation decreases.
Uneven Load Distribution:-Journal no longer operates under optimum geometry.
Reduced Stability Margin:-Rotor becomes vulnerable to transient disturbances.

IX. ROOT CAUSE ANALYSIS

Immediate Cause:-Temporary reduction in CW flow during pump transfer.
Mechanical Cause:-Excessive rear bearing clearance.
Latent Cause:0.46 mm shim altering bearing geometry and dynamic characteristics.
Fundamental Root Cause:Insufficient rotor-bearing stability margin due to degraded bearing condition.

X. WHY VIBRATION INCREASED AFTER 3 MINUTES

This question became central to the investigation.
The delayed increase can be explained by

1) *Thermal Effects*

Increased exhaust pressure raised LP casing temperature.
Thermal gradients developed gradually.

2) *Oil Film Response*

Oil film characteristics changed progressively.

3) *Rotor Repositioning*

Rotor centreline shifted as steam loading changed.

4) *Stability Threshold*

The bearing remained stable initially.
As loading increased, the stability threshold was crossed, resulting in rapid vibration growth.
This explains the three-minute delay.

XI. RELIABILITY IMPLICATIONS

Potential consequences include:

- Bearing wiping
- Journal scoring
- Oil whip development
- Rotor rub

- LP blade damage
- Extended outage
- High repair cost

The trip therefore prevented more severe damage.

XII. RECOMMENDATIONS

Mechanical

- Restore OEM bearing clearances.
- Review necessity of 0.46 mm shim.
- Inspect journal condition.
- Verify rotor alignment.

Reliability

- Bearing clearance audit during every overhaul.
- Dynamic stability assessment.
- Historical modification review.

XIII. LESSONS LEARNED

- Process disturbances and mechanical defects frequently interact.
- Bearing condition significantly influences turbine response.
- Excessive bearing clearance can remain hidden until transient loading occurs.
- Historical modifications such as shimming require periodic engineering review.
- Integrated analysis of process and mechanical data is essential for accurate root cause determination.

XIV. CONCLUSION

The cooling water pump changeover initiated resulting rotor dynamic loading acted upon a rear bearing already operating with excessive clearance and modified geometry due to a 0.46 mm parting-plane shim.

The degraded bearing condition amplified rotor motion, causing vibration to increase to 4.5 mm/s approximately three minutes after the condenser disturbance. The event demonstrates how latent mechanical weaknesses can transform a manageable process upset into a turbine trip.

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