Common Damage Modes and Preventive Measures for Steam Turbine Bearing Bushes

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Abstract: This article introduces several common damage modes of steam turbine bearing bushes and presents corresponding preventive and corrective measures.

Keywords: Steam Turbine; Bearing Bush; Damage; Prevention

Overview & Background

The bearing bush is an essential component of a steam turbine. Steam turbine bearing bushes are categorized into two types: radial bearing bushes and thrust bearing bushes. The function of the radial bearing bush is to support the weight of the rotor, withstand additional loads caused by rotor unbalance, asymmetrical steam admission, aerodynamic forces, and mechanical vibration/shocks, while ensuring radial alignment of the rotor relative to the stator. According to the oil wedge formed during operation, radial bearing bushes can be classified into cylindrical, elliptical, and three-wedge configurations.

The function of the thrust bearing bush is to withstand the axial load of the rotor, balancing the axial steam thrust acting on the rotor during operation and fixing the axial position of the rotor to maintain proper axial clearances between stationary and rotating parts. Most thrust bearings used in steam turbines are Mitchell-type bearings, which utilize 8–12 sector-shaped thrust pads to establish a pressurized oil film against the turbine's thrust collar, thereby balancing the operational axial forces.

Because bearing bushes operate under high loads and high journal rotational speeds, steam turbine bearings utilize hydrodynamic sliding bearings founded on liquid friction theory. By leveraging the hydrodynamic pressure created by the high-speed rotation of the journal, a stable oil film is established to isolate direct surface contact of the friction pair and provide hydrodynamic lubrication, balancing external loads.

Steam turbine bearing bushes feature a bimetallic dual-layer structure composed of a steel backing (shell) and an alloy lining. Tin-antimony bearing alloy (also known as tin-based Babbitt metal) is widely used for the alloy layer due to its excellent compatibility and run-in characteristics. Its base metal is tin, combined with specific proportions of antimony and copper. Cubic crystals of tin and antimony serve as hard points uniformly distributed within the tin matrix, while needle-like copper-tin compounds form a spatial framework that prevents segregation during alloy crystallization. To enhance the performance of Babbitt metal—especially its high-temperature resistance—small amounts of nickel, cadmium, and arsenic are added. Nickel and cadmium improve strength and hardness, whereas arsenic refines grain structure, enhances alloy fluidity, and reduces hardness drop at elevated temperatures.

In practical operation, radial and thrust bearing bushes typically experience damage modes such as abnormal wear, fatigue, corrosion, debonding (shell separation), and porosity/slag inclusions.

1. Abnormal Wear

1.1 Scratches and Score Marks

Pits, circumferential linear scratches, or gouges form on the bearing bush or journal surface. This is mainly a form of non-uniform wear caused by hard mechanical debris/particles suspended in the lubricating oil.

Recommended Corrective Measures for Scratches:

- Scrape and dress the damaged bearing surface to remove foreign particles and dirt, maintaining a smooth surface finish.
- Thoroughly clean the oil system, increase the mesh rating (fineness) of the oil filters, strictly control lubricant quality, and replace with new oil or install a new bearing bush if necessary.

1.2 Localized Wear

Axis misalignment during installation or insufficient rigidity of the bearing bush and rotor shaft can cause eccentric loading, resulting in severe localized wear on the bearing surface. In severe cases, this leads to overheating and thermal damage of the bearing bush.

Recommended Corrective Measures for Localized Wear: Analyze the root cause of eccentric loading and adjust the installation to eliminate misalignments. Refer to the scratch troubleshooting recommendations. Furthermore, when the chromium content of the shaft journal material is ≥12%, journal wear becomes highly sensitive; metal fragments worn off the journal can embed into the Babbitt alloy surface. These hard fragments act like cutting blades, expanding wear on both journal and bearing surfaces until failure occurs.

1.3 Adhesion and Galling (Wiping)

Galling is a form of adhesive wear. In severe cases, it causes seizure between the rotating shaft and the bearing bush.

1.3.1 Bearing Bush Overheating

Excessive temperature rise in the bearing bush reduces the mechanical strength of the alloy, causing softening, surface galling, and thermal cracking.

- **Recommendations:** Corrective Measures: Analyze the cause and lower the maximum operating temperature; optimize the bearing bush design, and replace with a new bush if necessary.

1.3.2 Surface Flow (Wiping / Metal Run)

During unit startup or shutdown, inadequate bearing clearance, poor oil inlet conditions, excessive oil viscosity, overloading, or eccentric loading can cause oil film breakdown and severe friction. The resulting rapid temperature spike melts low-melting-point phases (tin matrix) in the alloy, causing the molten metal to flow along the direction of shaft rotation—a phenomenon known as surface flow or wiping.

For high-capacity units coasting down to low speeds, if the high-pressure jacking oil system fails or provides insufficient pressure to lift the rotor, surface wiping is highly likely to occur.

Recommended Corrective Measures for Surface Flow:

- Optimize bearing bush design by enlarging oil inlet clearances to ensure sufficient oil supply and improve lubrication under low-speed, heavy-load conditions.
- Improve the reliability of the high-pressure rotor jacking oil system.
- Polishing and smooth the affected journal surface to remove foreign materials. Lightly scrape wiped areas on the bearing surface; re-use after evaluation, or replace with a new bush if wiping is severe.
- Enhance the overall reliability of the lubricating oil system to guarantee uninterrupted oil delivery.

2. Fatigue Damage

Mechanical fatigue is caused by repeated stress cycling or reverse loading, typically manifesting on the bearing working surface as pitted or cavernous spalling. The primary cause is alternating stresses—such as shaft vibration and dynamic impacts—exceeding the fatigue limit of the alloy material.

Variations in dynamic oil film pressure subject the bearing surface to compound tensile, compressive, and shear stresses. Shear stresses in particular induce micro-cracks on the surface, which in severe cases lead to localized spalling of alloy chunks.

Recommended Corrective Measures for Fatigue Damage:

- For minor fatigue damage, clean the bearing bush to remove debris, scrape the surface, and verify that critical parameters (such as clearance) meet design specifications. If cracking has developed, replace with a new bearing bush and consider appropriately increasing clearance to ensure ample oil flow.
- Improve dynamic balancing accuracy of the rotor to reduce vibration induced by unbalance; re-check shaft alignment and coupling conditions according to design standards.
- Perform on-site vibration spectrum analysis to ensure the absence of sub-synchronous whirl (half-speed whirl) and oil whip phenomena.
- Verify that the bearing pedestal and foundation possess sufficient structural stiffness. Ensure the natural frequency of the rotor-bearing-foundation system avoids the operating speed range with adequate safety margin.

3. Debonding Failure (Shell Separation)

Debonding occurs due to poor adhesion between the Babbitt alloy layer and the steel backing. The main root causes are incomplete surface cleaning of the base metal prior to casting, leaving oxide films, dust, or grease on the interface. Additionally, if the steel backing material has a high carbon content, poor weldability/bonding with the bearing alloy can also lead to debonding.

Corrective Measures: Refine the casting procedure for bearing lining to minimize residual casting stresses at the bond interface, and strictly prevent defects such as blowholes, gas pores, and slag inclusions within the alloy layer.

4. Corrosion

Corrosion in sliding bearings is primarily caused by chemical reactions between environmental media (such as atmospheric moisture, fuel, or lubricating oil) and the bearing working surface, resulting in the formation of oxide films and reaction products on the bearing face.

4.1 Electrolyte Corrosion

Exposure to acidic, alkaline, or saline aqueous solutions dissolves the surface metal or forms a hard, brittle oxide layer. Under operational load, this brittle layer crumbles and peels off, resulting in surface pitting.

4.2 Shaft Current Electrical Corrosion

Experimental tests and field practice demonstrate that when the shaft current density in a turbo-generator set exceeds 0.2 A/cm^2, electrical erosion can occur on both journal and bearing alloy surfaces. Mild electrical corrosion causes loss of metallic luster on journal and bearing alloy surfaces; burned oil may create black deposits, and Babbitt alloy powder appears in the lube oil. Under severe conditions, electrical pitting transforms journal and bearing surfaces into a dull, greyish-white pitted texture.

Recommended Corrective Measures for Shaft Current Corrosion:

- Polish the shaft journal to eliminate electrical erosion marks.
- Eliminate the root cause of electrical currents; inspect and maintain insulation on electrical components, thermocouple wiring, and water pipe connections.
- Inspect bearing bush insulation to ensure no stray currents pass through the bearing, and verify proper shaft grounding.
- Conduct rigorous insulation testing following the installation of new bearing bushes.

5. Cavitation Erosion

Under heavy loads and high rotational speeds, if localized oil film pressure drops below the saturation vapor pressure of the lubricating oil, microscopic vapor bubbles form within the oil film. As these bubbles travel into higher-pressure zones or as oil pressure recovers, the bubbles collapse rapidly. Surrounding lubricant rushes violently into the void, generating high-velocity micro-jets that strike the adjacent bearing surface. Although each micro-jet acts on a tiny area, their vast quantity subjects the bearing surface to severe cyclic hydraulic impacts. This causes plastic deformation, alters surface stress distribution, elevates working stresses, and ultimately leads to localized spalling of the bearing surface.

Recommended Corrective Measures for Cavitation Erosion:

- Bearing bushes with mild cavitation erosion can be re-used after careful scraping and surface dressing.
- Remove entrained water and dissolved gases from the lubricating oil.
- Eliminate or mitigate dynamic impact loads.
- Where feasible, moderately increase oil supply pressure, smooth and optimize bearing oil grooves for unobstructed flow, reduce bearing clearance, and ensure full oil supply.

- Utilize bearing lining materials with higher hardness.

6. Conclusion

The mechanisms underlying bearing bush damage are complex. However, if damage is detected prior to a catastrophic failure, the root cause can usually be determined clearly. Conversely, after a major failure or failure cascade occurs, root cause analysis becomes significantly more difficult. Bearing damage can be discovered during routine machine overhauls, or detected early by analyzing abnormal data trends from online monitoring instrumentation measuring oil pressure, bearing temperature, and shaft vibration.