

Correlation between Lube Oil Condition & Bearing Temperatures

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Abstract

High-speed rotating equipment, such as compressors, rely on fluid film bearings—including tilting pad journal (TPJ) bearings and equalized (Kingsbury style) thrust bearings—for precise rotor support and positioning. Maintaining the rotor position within a 10th of a millimeter of oil is crucial for efficient and reliable operation. A key monitoring tool for these systems is temperature trending, which involves continuously monitoring bearing temperatures using sensors like thermocouples or resistance temperature detectors (RTDs) mounted on the bearing housing. By plotting this data over time, significant changes or gradual increases in temperature can be identified, indicating potential issues such as inadequate lubrication, misalignment, overloading, or impending bearing failure.

This paper investigates the correlation between bearing temperature behavior and lubricant condition in fluid film bearing systems. It explores how degradation mechanisms—particularly oxidation and shear-induced stress—alter lubricant chemistry, which in turn affects film thickness, deposit formation, and thermal transfer efficiency. Drawing on case studies from turbine and compressor applications, as well as tribological modeling and field diagnostics, the study illustrates how localized varnish and shear-stress deposits drive temperature instability and bearing degradation.

By integrating oil analysis, mechanical inspection, and thermal monitoring data, this research underscores the value of condition-based lubrication strategies. The findings highlight the importance of correlating lubricant degradation with thermal response to enhance predictive maintenance and extend the operational reliability of high-speed rotating equipment.

1. Introduction

In fluid film bearings, a stable lubricating film is crucial for load support and thermal management. Deviations in temperature or vibration patterns often precede catastrophic bearing failure. As such, monitoring these indicators provide insight into changes in lubricant condition and mechanical integrity. Particularly in high-speed rotating systems like centrifugal compressors and gas turbines, lubricant degradation manifests as increased bearing temperatures and vibrations.

Varnish in both journal and thrust bearings occur in the minimum oil film region, as can be seen in Fig. 1.

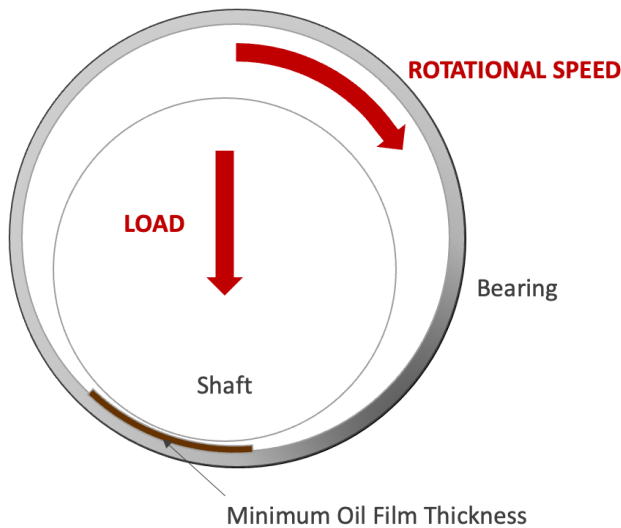


Figure 1: Varnish forms in the minimum oil film thickness region, lowering bearing clearances.

2. Lubricant Degradation Mechanisms

Lubricant degradation is often driven by oxidation, thermal stress, and mechanical shear. In compressors, localized shear-induced degradation creates high temperatures at microscopic interfaces, leading to insoluble deposits (shear-stress varnish) that traditional MPC analysis may not detect. These deposits form at the minimum oil film region, coinciding with areas of high load and temperature.

In parallel, oxidation accelerates in the presence of air and high temperatures, leading to soluble and insoluble byproducts. Insolubles tend to precipitate and form hard deposits on bearing surfaces, increasing friction and altering load distribution.

By understanding how these degradation mechanisms occur, we can use tools to predict their formation leading to their presence in these systems. It is also critical to note that there are differences in the types of deposits formed by each mechanism.

3. Impact of Varnish on Bearings

The first impact of varnish on bearings is the reduction in film thickness. It is common to see this measured real-time by observing the rotor position. As can be seen in Fig. 2, the shaft of the bearing increases with bearing temperature,

suggesting that the film of varnish is vertically shifting the rotor.

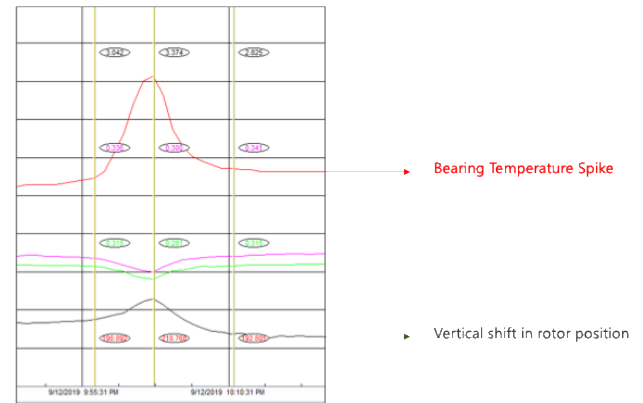


Figure 2: Correlation between the vertical positioning of the rotor and bearing temperature spikes.

The reduced bearing clearance increases the pressure on the oil film, reduces load carrying capacity and decreases the critical speed of the bearing. This creates dynamic instability in the bearing increasing its vibration and temperatures. These are summarized in Fig. 3.

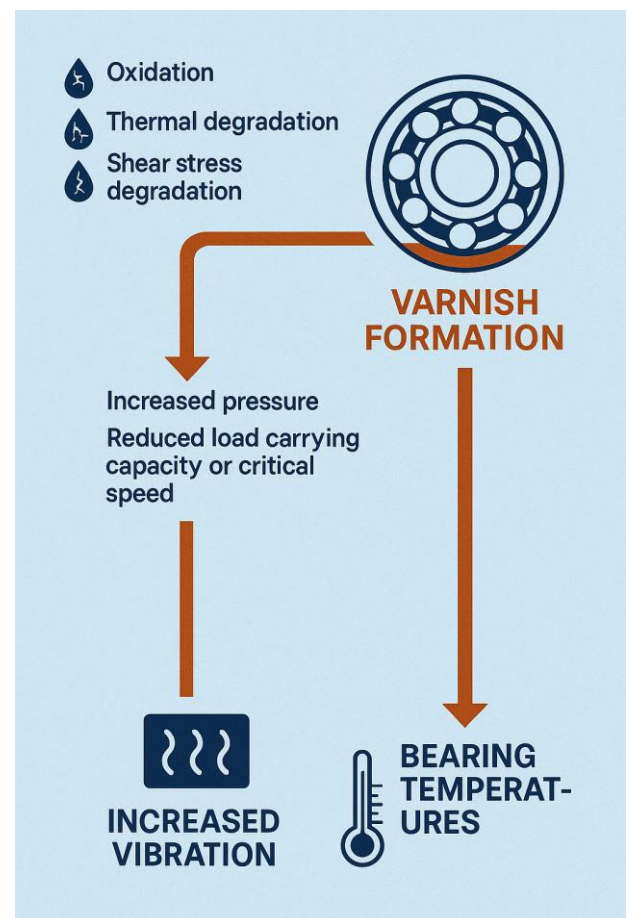


Figure 3: Impact of varnish in bearings

4. Why bearing temperatures are a concern

Babbitt alloys, commonly used as a soft lining in journal and thrust bearings, have a creep temperature threshold around 132°C. At or above this temperature, the babbitt material can begin to plastically deform under load, a phenomenon known as creep. This deformation alters bearing clearances, which leads to loss of hydrodynamic film, metal-to-metal contact, and rapid wear or seizure, threatening the production of the turbine or compressor. Typical bearing alarms are set at 110°C where trip temperature is usually 120°C. An overview of these temperatures can be viewed in Fig. 4.

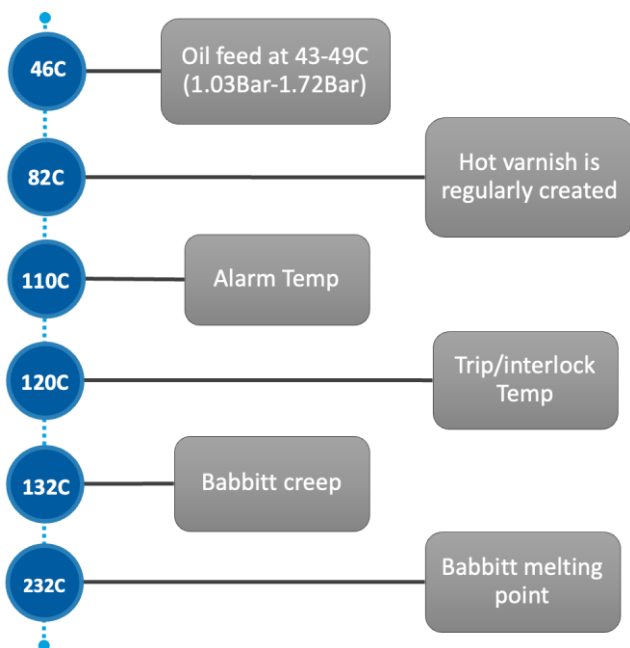


Figure 4: Some notable bearing temperatures, some of which are highlighted in API 670.

5. Experimental and Field Observations

In a centrifugal compressor case study by Shin et al (2025), oil varnish accumulation over four years led to a 300% increase in rotor vibration, rising from 6 μm to 18 μm . Following disassembly, varnish was observed on bearing pads. Replacing the oil and removing varnish restored normal vibration levels.

Similarly, bearing temperature behavior exhibited a cyclical pattern of rapid spikes

followed by gradual cooling. Temperature excursions ranged from 7°C to 17°C above baseline, correlating with varnish presence and shifting journal load angles induced by changes in inlet guide vane (IGV) position. These findings were corroborated by thermohydrodynamic (THD) simulations. A summary of the impact that varnish has bearing pressure and temperature compared to eccentricity can be seen in Fig. 5.

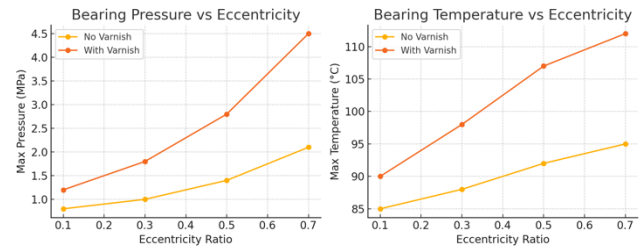


Figure 5: In THD simulations, varnish increases pressure, temperature and eccentricity.

The trend of both bearing and vibration temperatures resembles an increasing sawtooth graph, as can be seen in Fig. 4.

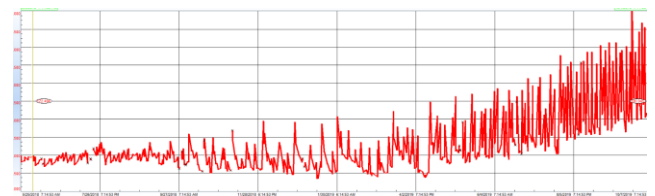


Figure 6: An example of varnish-induced bearing temperature excursions resembling a sawtooth pattern.

Varnish also acts as an insulator. We see evidence of this in heat transfer applications where the reduction of varnish has a direct effect on the efficiency of heat transfer.

This has not yet been modeled in bearings, but it is believed that this insulating effect increases the overall temperature trend in bearings.

6. Modeling Varnish Effects on Bearing Performance

Jang et al. (2024) developed a THD model to simulate the impact of varnish on journal bearings. Results showed that varnish thicknesses as low as 20% of bearing clearance reduced minimum film thickness significantly and raised maximum bearing pressure and temperature. Additionally, the critical speed of the rotor-bearing system dropped by up to 17% due to changes in stiffness and damping coefficients.

Figure 7 illustrates the coordinates system for dynamic coefficients for a two-grooved journal bearing. The mathematical model was based on these variables.

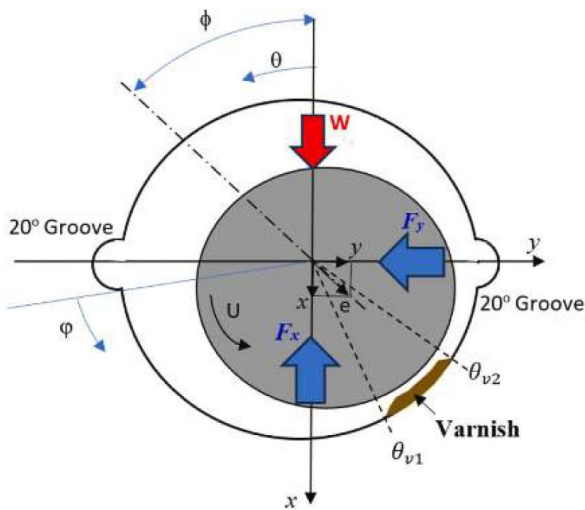


Figure 7: Dynamic coefficients for a two-grooved journal bearing.

Dimensional and dimensionless stiffness and damping coefficients were calculated using a modified Reynolds equation and the Elrod-Adams cavitation algorithm. Simulations demonstrated that varnish deposits localized near the minimum film region led to large increases in bearing pressure (up to 8.9 MPa) and temperatures (exceeding 112°C).

7. Discussion

Both field and modeled data consistently show that varnish compromises film integrity and

contributes to dynamic instability. Reduced bearing clearance amplifies stiffness and decreases logarithmic decrement (log-dec), a key stability parameter.

Key correlations identified include:

- Varnish → Reduced clearance → Increased stiffness → Rotor vibration
- Varnish → Increased viscosity → Elevated bearing temperature
- IGV-induced journal load angle shifts → Transient thermal spikes

Integrating temperature trending with oil analysis (e.g., viscosity, MPC, FTIR) and vibration monitoring can thus provide a predictive toolkit for early varnish detection.

Interestingly enough, we may also be able to monitor the critical speed of the rotor bearing system as there has been a noted decrease due to the presence of varnish. However, none of these factors can be taken into isolation as they must all contribute to the matrix of condition monitoring techniques which indicate the presence of varnish in a system.

8. Conclusion

Oil varnish and shear-stress deposits are potent contributors to rotor vibration and bearing temperature instability in high-speed rotating equipment. Through a combination of modeling and empirical data, this paper confirms that these degradation products impact bearing dynamics by altering clearance, stiffness, and thermal behavior.

Therefore, when implementing condition monitoring strategies, it is important to note that oil analysis alone may not provide all the information needed to determine the presence of varnish in these systems.

Condition-based maintenance strategies that incorporate real-time temperature and vibration monitoring, along with comprehensive lubricant

analysis, are critical for mitigating varnish-induced failures and extending equipment life.

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