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Failure Analysis of Cylindrical Roller Bearing using Morphological Study and FTIR Spectroscopy

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ABSTRACT:

Cylindrical roller bearings are widely used in high-speed and heavy-load applications such as machine tools, steel mills, and aircraft transmission systems. This study investigates the progressive failure of cylindrical roller bearings under varying load conditions using morphological analysis (SEM) and Fourier Transform Infrared (FTIR) Spectroscopy. An experimental setup was designed and fabricated to apply stepwise dynamic loading, and changes in surface wear, crack development, and lubricant degradation were systematically recorded. SEM analysis revealed increasing severity of surface damage, such as cracks and pitting, with increasing loads, while FTIR analysis confirmed degradation of grease through additive breakdown and oxidation. The combined findings emphasize the critical role of proper lubrication and load management in bearing life and failure prediction.

Keywords: Cylindrical Roller Bearing, FTIR Spectroscopy, SEM analysis, Bearing Failure.

1. Introductio:

Cylindrical roller bearings are critical components in many mechanical systems due to their ability to handle high radial loads and precision operations. However, they are prone to wear and failure due to combined effects of loading, lubrication failure, and surface fatigue. This study aims to analyze the morphological and chemical degradation of these bearings under controlled experimental conditions using SEM and FTIR spectroscopy.

2. Methodology:

A custom experimental test rig was developed using a 3 HP induction motor, 25 mm shaft, and cylindrical roller bearings mounted on pedestal blocks. A spring balance and power screw applied loads of 40 kg, 60 kg, 80 kg, and 100 kg to the bearing system. After specified run times, the bearings and grease were analyzed.

- **SEM** was used to identify surface wear, cracks, and pitting.
- **FTIR** was applied to compare fresh and used grease samples to detect chemical breakdown and formation of acidic byproducts.

3. Result and Discussion:

3.1 Morphological Observations(SEM)

- At 40 kg load: No visible damage, surface remained smooth.
- At 60–80 kg: Progressive surface roughness, minor to moderate cracks, and debris formation were observed.
- At 100 kg: Severe damage, including deep cracks and pitting; lubricant film was fully broken down.

3.2 Chemical Degradation (FTIR)

- FTIR spectra showed a clear breakdown of base oil and additives at higher loads.
- Presence of oxidation products and acid peaks confirmed grease deterioration.
- Comparison of fresh and used grease spectra illustrated the role of heat and mechanical stress in lubricant failure.

3.3 Additional Observations

- The wear particles generated under higher loads acted as abrasive agents, worsening the surface condition.
- Grease temperature increased due to load-induced friction, reducing its viscosity and film thickness.
- SEM micrographs provided evidence of both adhesive and abrasive wear mechanisms.

4. Conclusion:

This study demonstrates that bearing failure is not only a result of mechanical stress but also significantly influenced by lubricant performance under thermal and dynamic conditions. Key findings include:

- Increasing load leads to accelerated fatigue, wear, and degradation of bearing surfaces.
- FTIR spectroscopy is an effective tool for identifying lubricant deterioration at a chemical level.
- SEM analysis provides visual confirmation of failure mechanisms like surface fatigue, crack propagation, and pitting.
- The integration of both techniques helps in early diagnosis and condition-based maintenance planning.

5. Future Work :

- **Advanced Lubricant Studies:** Analyze synthetic, biodegradable, and nano-lubricants for performance under harsh conditions.
- **Temperature and Speed Analysis:** Study combined effects of temperature, speed variation, and vibration on bearing performance.
- **Sensor-based Predictive Maintenance:** Use vibration and temperature sensors with machine learning to detect failure patterns.
- **Material Improvements:** Experiment with ceramic hybrid bearings or surface-coated components to increase lifespan.
- **Long-Term Life Testing:** Simulate real-world operating hours and develop fatigue life prediction models.
- **Tribological Simulations:** Use finite element analysis (FEA) and computational fluid dynamics (CFD) to model bearing behavior under dynamic conditions

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