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Experiment and Analysis of Rolling Bearing Performance against Variations in Load and Rotational Speed

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Abstract— *Rolling bearings are important components in mechanical systems that function to reduce friction and support radial and axial loads. This study aims to evaluate the performance of radial ball-type rolling bearings against variations in load and rotational speed. The test method was carried out using a bearing test rig with variations in load of 50 N, 100 N, and 150 N and rotational speed of 500 rpm, 1000 rpm, and 1500 rpm. The parameters analyzed include operating temperature, vibration, and wear level. The results show that increasing load and rotational speed are directly proportional to increasing temperature and vibration, which has an impact on accelerating bearing wear. This study provides a deeper understanding of the operational characteristics of rolling bearings under dynamic conditions, which is important for optimizing industrial rotational systems.*

Keywords— *Rolling bearings, temperature, vibration, wear, load, rotational speed*.

I. Introduction

Rolling bearings are essential components in mechanical systems because they minimize friction and bear radial and/or axial loads, facilitating relative movement between parts. Their use is very wide, ranging from household appliances to heavy industrial systems and aircraft [1]. The efficiency and reliability of mechanical systems are highly dependent on bearing performance, so understanding bearing behavior under dynamic working conditions is crucial in equipment design and maintenance.

Rolling bearing performance is affected by various factors, such as load type, rotational speed, lubrication, temperature, component material, and environmental conditions. In real operating environments, bearings often experience variable loads and high rotational speeds, which can cause increased temperature, vibration, and wear, ultimately leading to premature component failure [2][3].

Several previous studies have identified that increased load significantly accelerates bearing wear due to increased contact pressure between rolling elements and raceways. Guo et al. [4] reported that high contact pressure at moderate speeds causes micropitting and lubricant degradation, which accelerates the failure rate. In addition, the effect of rotational speed on operating temperature has been studied by Cao et al. [5], who found that temperature increases non-linearly with increasing speed, especially under limited lubrication conditions.

In the context of developing condition monitoring systems, vibration and temperature measurements have become the main approaches for early detection of bearing failures. According to research by Li et al. [6], vibration patterns at certain frequencies can indicate defects in rolling elements or raceways. In addition, operating temperature trends can be used as early indicators of lubricant degradation or increased internal friction [7].

In addition to experimental observations, numerical approaches and computer simulations have also been widely developed. For example, Lin et al. [8] developed a dynamic thermal model to predict the temperature distribution in ball bearings by considering speed, lubricant viscosity, and friction. Although simulations provide good theoretical insights, experimental validation is still needed to ensure the accuracy of the model.

The majority of current research, though, continues to concentrate on a single variable or on static load circumstances. The combined effects of simultaneous load and speed variations on bearing performance are still less systematically explored. In fact, in real mechanical systems such as industrial gearboxes or electric motors, dynamic and fluctuating operating conditions are common.

Therefore, this study aims to experimentally examine the effect of a combination of load variations and rotational speed on rolling bearing performance parameters, namely operating temperature, vibration, and wear. A deeper understanding of the relationship between these parameters will contribute to the design of more reliable bearings and the implementation of data-based predictive maintenance strategies.

II. Methodology

2.1. Bearing Specifications

The type of bearing used is a deep groove ball bearing type 6204ZZ (inner diameter 20 mm, outer diameter 47 mm, width 14 mm).

2.2. Tools and Materials

- Bearing test rig with 1 HP electric motor
- K-type thermocouple temperature sensor
- Accelerometer for vibration measurement
- Analytical balance for wear mass measurement
- Shear load 50 N, 100 N, 150 N
- Lubrication using lithium-based grease

2.3. Testing Procedure

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1. The bearing is mounted on the test rig.
2. The load is given in stages (50–150 N).
3. The motor rotation is set at 500 rpm, 1000 rpm, and 1500 rpm.
4. The test is carried out for 30 minutes for each combination of variables.
5. The data of temperature, vibration and mass of the bearing before and after testing are recorded.

III. Results and Analysis

Tests were conducted on 6204ZZ type rolling bearings with variations in loads of 50 N, 100 N, and 150 N and rotational speeds of 500 rpm, 1000 rpm, and 1500 rpm. Parameters observed included operating temperature, RMS vibration, and mass wear. Each test was conducted for 30 minutes under constant lubrication conditions.

3.1. Bearing Operating Temperature

With increasing load and speed, the highest bearing temperature was found to rise. The increase in temperature is caused by increased internal friction due to higher contact pressure and friction of the lubricating fluid at high speeds.

Figure 1 shows the relationship between load in Newton and operating temperature in °C on rolling bearings tested at three rotational speed levels: 500 rpm, 1000 rpm, and 1500 rpm. It can be seen that at each load level (50 N, 100 N, and 150 N), an increase in rotational speed causes an increase in operating temperature. At a load of 50 N, the temperature increases from about 38.2°C at 500 rpm to about 51.8°C at 1500 rpm. The same trend is evident at loads of 100 N and 150 N, where the highest temperature is always reached at 1500 rpm, indicating that increasing load and rotational speed contribute significantly to the increase in temperature due to friction and energy dissipation in the bearing. This shows that both load and rotational speed have a direct effect on the thermal performance of bearings, which is important to consider in the design of rotating machinery systems.

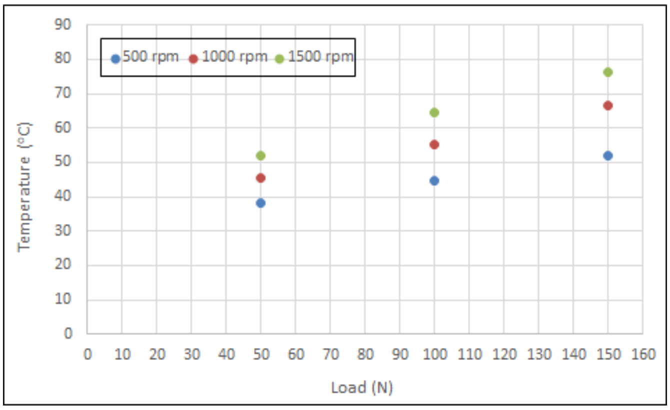

Figure 1. Operating temperature versus load

3.2. RMS Vibration

The vibration measurement in RMS (Root Mean Square) unit shows that the vibration increases significantly with increasing rotational speed. High vibration indicates an increase in unbalance and dynamic forces, as well as the onset of wear on the rolling elements and raceways. The vibration spectrum increases drastically at the highest load and speed combination. The RMS value of vibration increases from 0.2 g at light conditions to 0.7 g at heavy conditions.

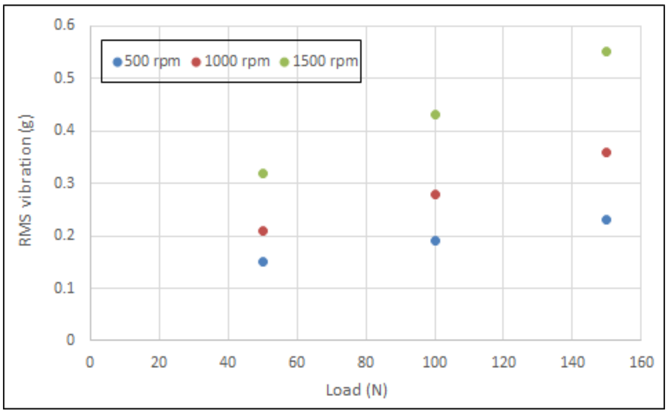

Figure 2. RMS vibration against load

The relationship between load in Newton (N) and RMS (Root Mean Square) vibration in g (earth gravity) on rolling bearings tested at three rotational speed levels: 500 rpm, 1000 rpm, and 1500 rpm as shown in Figure 2. It can be seen that at each load level (50 N, 100 N, and 150 N), increasing rotational speed tends to increase the RMS vibration value. At a load of 50 N, the vibration value increases from around 0.15 g (500 rpm) to 0.32 g (1500 rpm), while at a load of 150 N the vibration value reaches a maximum in the range of 0.55 g at 1500 rpm. This shows that the higher the speed and load, the vibration that occurs in the bearing also increases significantly. This increase in vibration can be caused by dynamic imbalance, increased centrifugal force, and increased internal friction which causes greater mechanical vibration [9]. This analysis is important to understand the safe operating limits of the bearing so that it does not experience premature damage due to excessive vibration.

3.3. Bearing Mass Wear

Bearing wear is calculated from the difference in mass before and after the test. The results show that wear increases linearly with load, although slightly affected by speed. Table 3 presents wear data at a constant speed of 1000 rpm. Increasing the load causes greater contact pressure and accelerates the mechanical wear of the contact surface.

Figure 3 shows the relationship between load in Newton (N) and bearing mass wear in grams (gr) at three rotational speed levels: 500 rpm, 1000 rpm, and 1500 rpm. It is clear that both increasing load and rotational speed have a significant impact on increasing bearing mass wear. At each load level (50 N, 100 N, and 150 N), wear increases with increasing speed. For example, at a load of 150 N, mass wear increases from about 0.012 g at 500 rpm to about 0.024 g at 1500 rpm. This indicates that the friction and contact forces between the rolling elements and their tracks increase progressively with speed and load, thereby accelerating surface degradation [10]. This trend emphasizes the importance of controlling load and speed in bearing applications to maintain component life, and demonstrates the tribological performance of bearings under extreme conditions.

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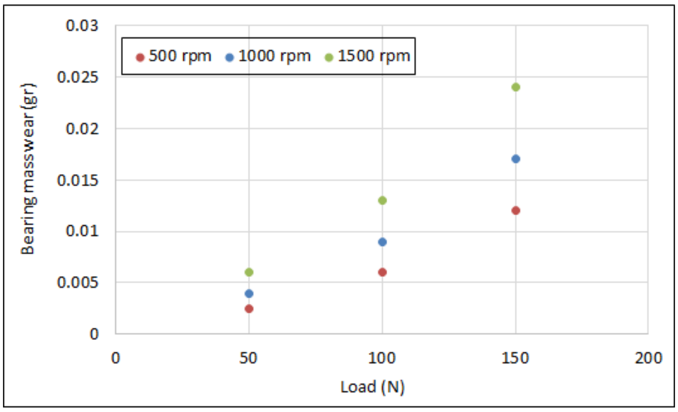

Figure 3. Mass wear against load

IV. Conclusion

This study shows that increasing load and rotational speed significantly affect the performance of rolling bearings, especially in terms of operating temperature, vibration, and wear. These results can be used as a basis for designing more reliable mechanical systems, as well as developing predictive maintenance strategies. Further research can focus on the effects of lubricant types, variations in bearing materials (such as ceramics), and the application of real-time monitoring technology for condition-based maintenance.

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