

DIAGNOSTICS AND ANALYSIS OF DIFFERENT TYPES OF ROLLER BEARING FAILURE: AN EXTENSIVE STUDY

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ABSTRACT: Antifriction bearing failure is a major factor in the failure of rotating machinery. As a fatal defect is detected, it is common to shut down the machinery as soon as possible to avoid catastrophic damages. Performing such an action, which usually occurs at inconvenient times, typically results in substantial time and economic losses. It is, therefore, important to monitor the condition of antifriction bearing and to know the details of the severity of defects before they cause serious catastrophic consequences. This report highlights the work done by various researchers for bearing fault detection describes the suitability of different cause of failure. Time domain analysis, frequency domain analysis, and wavelet transform analysis has been focused to identify different defects in bearing. The conclusion has been made depending on the suitability of each one of these technologies to detect progressing and defects in roller the bearing.

KEYWORDS: Condition monitoring, Fault diagnosis, Roller Bearing, Failure Analysis

I. INTRODUCTION:

A bearing is a mechanical element that allows relative motion between two objects, with minimum friction. It used in many applications, which include rotating component. The functions of the bearing are to ensure free rotation of the shaft or the axle with minimum friction supports the shaft or the axle and holds it in exact position holds up the forces that act on the shaft or the axle and transmits them to the frame or the foundation. The term “rolling bearing” includes all forms of roller and ball bearing which allow rotary motion of a shaft. The rolling contact bearing has a low starting friction and thus it offers low friction hence also called anti-friction bearings. A complete ball bearing includes inner ring, outer ring, rolling element (balls or rollers) and the cage which separates the rolling element from each other. Rolling bearings are high accuracy, low cost but commonly used in all kinds of rotary machine. Mostly the ball and roller bearing failures are caused by Interference of the lubricant supply to the bearing or inadequate delivery of the lubricating oil to the raceway contact [1, 2]. Bearing temperature are many critical parameters, such as the lubricant viscosity, load-carrying capacity, load distribution and power loss. Many researchers are working on thermal analysis of journal bearings [3,4]. Ball and roller bearing failures are caused by interference of the lubricant supply to the bearing or inadequate delivery of the lubricating oil to the raceway contact. The preliminary types of roller bearings are cylindrical, needle, tapered, and spherical roller bearing. Figure1 shows the component of ball bearings and roller bearings [5, 6]. At extreme condition of heavy loading, very high speed, and very high or low operating temperature leads to early bearing failure and reducing bearing life [7, 8]. The service life of bearings [9] is expressed either as a period of time or as the total number of rotations before the occurrence of failures in the inner ring, outer ring or in rolling element (ball or roller) because of rolling fatigue, due to repeated stress. Bearing failure increase maintenance cost.

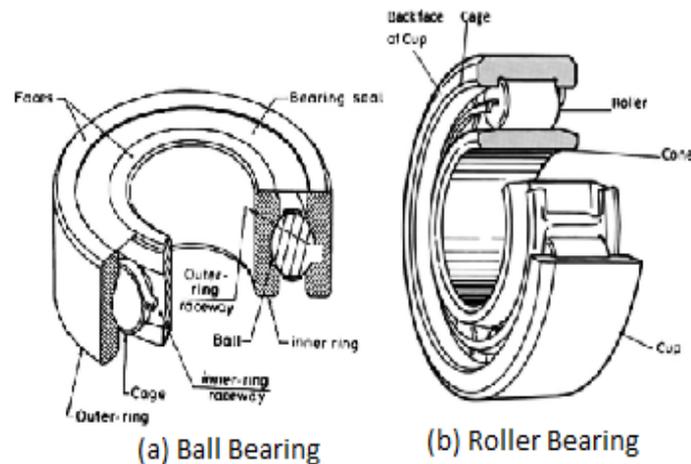


Figure1 Component of (a) Ball and (b) Roller Bearing

2. LITERATURE REVIEW:

Eschmann et al (1958) stated that one of the reason fatigue failure begins with smaller scissure between raceway and rolling elements and it's propagate gradually with continues operation .it's also generate vibration and increasing noise levels [10].

Riddle (1995) stated that bearing failure is occurred due to contamination, improper lubrication and dirt particles. Improperly installed bearing are also reason of failure due to forcing bearing on shaft and housing and its causes physical damage as brinelling [11].

R.K Upadhyay stated that due to cyclic stress rolling contact fatigue occurs, to reduce this kind of problem we have to increase angle of oscillation to secure roller overlap to drag fresh lubricant in to area so surface of raceway and balls are separate d by lubricant and reduce friction [12].

Jafar Takabi et al (2015) stated that first type is thermal failure of rolling bearings that can occur at high rotational speeds and large radial loads, and the second type deals with spindle bearings of high-speed machine tools. The results of dynamic simulations for the first type of thermal failure show that the unstable motion of the cage can lead to an ultimate bearing seizure because o f the cage failure due to the large rollers/cage contact forces and high wear rate of the cage. Second type of thermal failure of rolling element bearings, the simulation results reveal that the minimum film thickness at the raceways. Severe surface damage and wear occur at the raceways contact surfaces and eventually the bearing fails. The cause of this failure is the thermal seizure of the spindle bearing due to the rapid rise of the thermally-induced preload inside the bearing assembly with no sign of cage instability [13, 14].

Aditya et al (2014) tested cylindrical roller bearing in order to investigate its tribological properties. Initially, wear rates are very small and constant over a period of time. This wear is further responsible for fatigue failure of the bearing. Due to increase in wear, lubricant film is not capable to form a hydrodynamic film between roller and inner race. scanning electron microscope of the inner race and rollers have revealed the presence of pits, cracks at the contact surface and wear debris due to surface contact fatigue. An increase in bearing temperature reduces the lubricant film thickness. The lubricant film between the roller and inner race could not be effectively formed due to increase in bearing temperature, which results in direct contact between two metal surfaces and thus wear takes place [15].

First linear model of vibration in shaft bearing system was proposed by Yhland in 1992[16] due to bearing imperfection like radial and axial waviness [16].

3. SERVICE LIFE OF BEARING:

The service life of bearings is expressed either as a period of time or as the total number of rotations before the occurrence of failures in the inner race, outer race or in rolling element (ball or roller) because of rolling fatigue, due to repeated stress. Rated life of bearing expressed as the period at which material or machine element fails under the stated condition of use given by its manufacturing company. The service life of bearing differs from various rated life, where bearing failure may cause by poor lubrication, misalignment, observation and mounting damage before its actual life.

Rated Service Life of Rolling Bearing:

$$L = (C_r/P)^p, L_h = 10^6 / 60n * (C_r/P)^p$$

Where L: rated service life, 10^6 rotations;

L_h : rated service life, h; C_r : basic dynamic load rating, N; P: dynamic equivalent load rating, N; n: rotational speed, min^{-1} ; p: 3 for ball bearing; 10/3 roller bearing.

4. CAUSES OF FAILURE:

CAUSES	FAILURE RATE IN %
Dirt	45.4
Misassembly	12.8
Misalignment	12.6
Insufficient Lubrication	11.4
Overloading	8.1
Corrosion	3.7
Other	3.2

The Above table lists is the major causes of premature bearing failure, along with percentage figures which indicate prime contributor to a bearing's destruction. In many cases a premature bearing failure is due to a combination of several of these causes [17, 18].

4.1 Misalignment: Misalignment can be detected on the running track of the no rotating ring by a ball wear path that is not parallel to the running track edges if misalignment exceeds 0.001 in. we can expect an abnormal temperature rise in the bearing and housing and heavy wear in the cage ball pockets. The most common causes of misalignment are: bent shaft, burrs or dirt on shaft or housing shoulders. Fig.2a and fig.2b show the shaft misalignment and housing misalignment. To overcome this problem we have to take corrective action and follow the proper alignment.

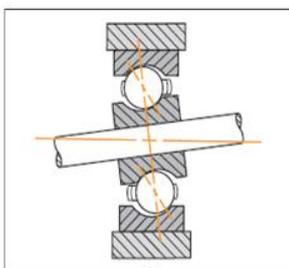


Fig.6(a)

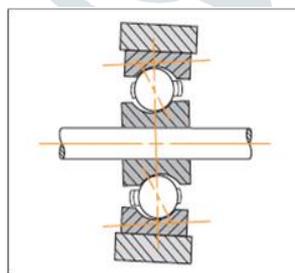


Fig. 6(b)

Figure 2(a) & 2(b): Misalignment of shaft

4.2 Contamination: Contamination symptoms are denting of the bearing raceways and balls resulting in high vibration and wear [19, 20]. Contamination is mainly caused by impurities present into bearing lubricants. These include dirt, abrasive grit, and dust, steel chips from contaminated work areas and dirty hands or tools.

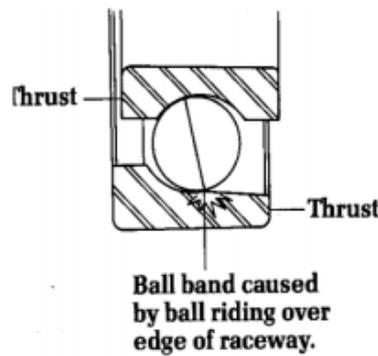


Figure 3 Contamination

4.3 Brinelling: Brinelling basically occurred due to improper mounting, incorrect assembly, and high impact load. Brinelling increases vibration noise and causes premature failure. As shown in figure 3 incorrect removals of bearing and correct mount or dismount of bearing by applying force on a tightly fitted raceway.

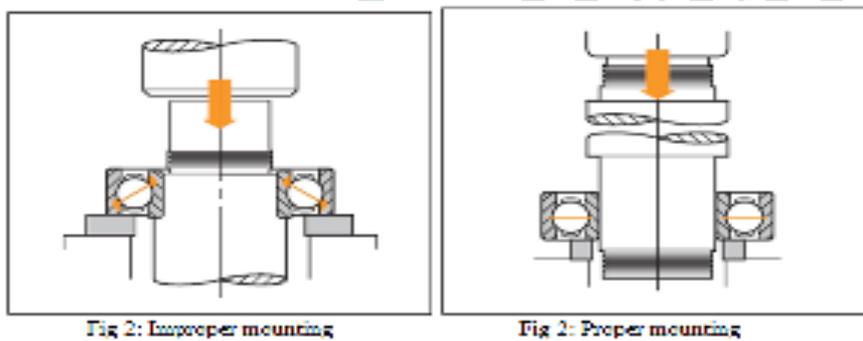


Figure 4 Brinelling Process

4.4 Overheating: Overheating is generally the result of heavy operating temperatures and improper lubrication. High temperatures cause grease to bleed (purge the oil), which effect on the lubricant's efficiency. In upraised temperature conditions, oxidation can lead to the loss of lubricating oils from the grease, leaving a dry, crusty soap that can seize the bearing. High temperatures also reduce the hardness of the metal, causing early failure.

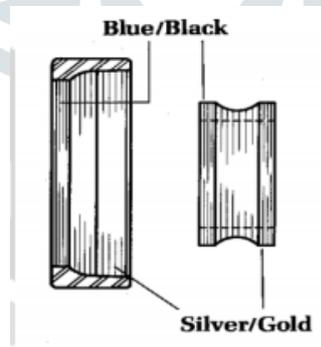


Figure 5 Overheating

4.5 Fatigue failure: Failures are typically are caused by restricted lubricant flow or excessive temperatures that degrade the lubricant's properties. In supreme cases, corrosion can initiate early fatigue failures. When the environment is particularly aggressive, the use of external seals in addition to integral seals should be considered. After a certain time, a bearing that is subjected to loading fails due to fatigue of the material. If a bearing is also catastrophically preloaded or overstressed, after a shorter operating time, it will also stop working due to fatigue damage. Fatigue increases faster if the bearing is overloaded, over speeding, or oil starving. These factors severely reduce the service life of bearings and they are normal occurrences in all bearings.

If a bearing fails due to fatigue sooner than its predicted time, the failure can generally be traced to either overloading or bad installation or maintenance.



Figure 6 Fatigue failures on inner race

5. BEARING FAULT DIAGNOSTIC TECHNIQUES:

1. Time-domain analysis
2. Wavelet Technique
3. Frequency-domain analysis

5.1 Times-Frequency Domain Analysis: Rolling element bearings (REBs) are the most important components in rotating machines and are often expected to carry heavy loads and operate at high efficiency and reliability. An unexplored failure can cause consequential damage to the machine and human casualty as well. Countless methods have been developed to detect faults in rolling element bearings. Maximum research on bearing diagnosis can be categorized in a time domain and frequency domains. Recently RMS, crest factor, probability density moments (skewness, kurtosis) are the most popular statistical time domain parameter for bearings. In the frequency domain analysis, the enveloping method, also known as demodulation or HFRT (High-Frequency Resonance Technique), is among the most popular technique for detection of localized bearing defects. In low-speed machine condition monitoring, conventional techniques involving vibration acceleration may not be able to detect a growing fault due to the low impact energy generated by the relative moving components. As an alternative to accelerometers, Acoustic Emission (AE) has also been used nowadays, especially for the detection of incipient bearing defects.

Application of AE technology has been use in machine tool wear monitoring, structural health monitoring, machinery bearings condition monitoring and tribological process monitoring. Mba and Rao [21] provided a review on the state-of-the-art of AE technology in machine condition monitoring. Yoshioka [22] have shown that AE technique can detect defects before they appear in the vibration acceleration range and can also identify possible sources of AE generation during a fatigue life test of thrust ball bearing. Shiroishi et al [23] compared acceleration signal and AE technique for the detection of different sizes of localized defects using an ALE (Adaptive Line Enhancer) and HFRT (High Frequency Resonance Technique). They concluded that the acceleration was comparable to or better than the AE at detecting the different types of defect. However, the results by Shiroishi are problematic in low speed situations.

5.2 Wavelet Technique: Time-frequency analysis, including the wavelet transform, is the most important and powerful tools in the value field of structural health monitoring using vibration analysis. Basically use of signal analysis techniques, based on spectral approaches such as the fast Fourier transform, are powerful in diagnosing a variety of vibration-related problems in rotating machinery.

Wavelet transformation:

The continuous wavelet transformation of a finite energy signal $s(t)$ with the analyzing wavelet $\psi(t)$ is the convolution of $s(t)$ with a scaled and conjugate wavelet [24]:

$$W(\alpha, b) = \alpha^{-1/2} \int_{-\infty}^{\infty} s(t) \psi^* \left(\frac{t-b}{\alpha} \right) dt$$

The wavelet coefficient $W(\alpha, b)$ measures the similarity between the signal $s(t)$ and analyzing wavelet $\psi(t)$ at different scales as defined by the parameter α , and different time positions as defined by the parameter b . The factor $\alpha^{-1/2}$ is used for energy preservation. That equation indicates that the wavelet analysis is a time-frequency analysis, or, more properly termed, a time-scale analysis. The wavelet transform can be also considered as a special filtering operation. The frequency segmentation is obtained by translation can be also considered as a special filtering operation. The frequency segmentation is obtained by translation and dilution of the analyzing wavelet. At consequently larger scales, the frequency resolution improves and the time resolution decreases.

Wavelet technique is used as a powerful diagnostic method for the detection of incipient bearing failures via stator current analysis. This method has several advantages over Fourier analysis.

5.3 Frequency domain analysis: Now a day's maintenance of modern rotating machinery is highly related to the preservation of bearings, due to the relative commonality of their faults. That's why most of the circumstances occurring in the bearing assemblies of motors are in some way represented as motor vibration, which is one of the most important signals to consider in most motor fault detection plan. Properly identifying bearing vibration in a motor system is highly cost-effective. To minimizing motor vibration properly action is required. Signals measured by vibration sensors are generally compared to reference signals in order to explain the bearing condition. Methods to analyze these signals include frequency-domain signal analysis, time-domain signal analysis, probabilistic analysis, and waveform analysis. Among these, the frequency domain signal analysis approach, which is also the basic tool used in some of the other approaches, such as probabilistic analysis, is the most popular method due to the availability of the Fourier Transform technique. In the motor fault diagnostics process, the sensors collect time domain vibration signals. The Fast Fourier Transform (FFT) technique is then employed to convert the time domain signals into frequency domain signals, which can provide major features for the diagnosis of the bearing condition. The diagnostic expert then uses time domain and frequency domain signals to explain the conditions of motor operation and determine what defects are present in the motor.

This frequency domain analysis technique is also most important method to detect bearing fault.

Apart from all of this there are so many method of analysis to identify bearing failure such as, Empirical mode decomposition method (EMD), Kurt gram method and Local mean decomposition (LMD).

6. CONCLUSION: After review all type of bearing failure and its causes and cures we have to take some corrective action to resolve above failure and most of them due to lubrication, misalignment and contamination .Other failures that is not directly affected to the bearing, such as unacceptable operating conditions, storage, transport and handling represent 6% of premature bearing failures. Among other indirect causes, the worst operating conditions are over-speeding, excessive vibrations, overloading, electrical discharge and high temperature. This paper has been presented on the basis of previously done experiment by different authors all over the world. Hence it has been understood that there is no competitive technique except vibration analysis for detection of fault occurring or going to occur in different parts of roller bearing. It is also found that time domain wave form can best give the sensitivity of vibration in defective parts, while frequency domain spectrum enables to understand the location of defects whether on inner race, outer race or the rollers the bearing. Wavelet transform technique has its advantage on case of application with microprocessor with better sensitivity and consistency.

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