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Survey of Fault Detection in Motor Ball Bearing

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ABSTRACT: -Bearings are one of the critical components in rotating machinery. Most of the failures in oil-lubricated journal bearings are related with instabilities produced by bearing wear or lubrication system problems, and effect in increased shaft vibration. Therefore, monitoring of the journal bearing condition in the field mainly relies on analysis of accelerometer signals or proximity probe. However, not all motors with journal bearings are equipped with such mechanical sensors due to cost or environmental restrictions. The need of an effective and easy fault diagnosis technique has headed to the increasing use of motor current signature analysis (MCSA). The objective of this paper is to study about different methods to detect faults (outer race fault) in a mechanical system.

KEYWORDS: Lubrication, babbitt surface, deformation, corrosion, acoustic, wear debris and signature analysis

I. INTRODUCTION

The bearing is one of the most important mechanical components in an electric motor that minimizes the friction between the rotating and stationary elements. In a rolling element (or anti-friction) bearing, rolling elements such as balls or rollers 'roll' between the outer race fixed to the end shield and the inner race fixed to the rotating shaft to minimize friction. In oil-lubricated journal (sleeve) bearings, the shaft load is supported by the oil film pressure between the shaft (journal) and bearing (sleeve) for minimizing friction [1]. The shaft forms a stable and fixed rotating orbit lifted from the bottom position by the oil pressure, as shown in Fig. 1.

Despite the benefits of journal bearings, they are limited to large motors and some special small motor applications. The majority of motors rated above 500 kW employ journal bearings since the physical diameter and shaft peripheral speed begin to exceed the design limits of rolling element bearings.

Lubrication system failure can cause bearing failure in a short period of time since insufficient or loss of lubrication results in extreme heating and journal or bearing surface damage. Irregular bearing clearance due to journal or bearing surface damage can be caused by contamination, frequent starts/stops, cavitation, shaft currents, or corrosion, as shown in Fig. 2.

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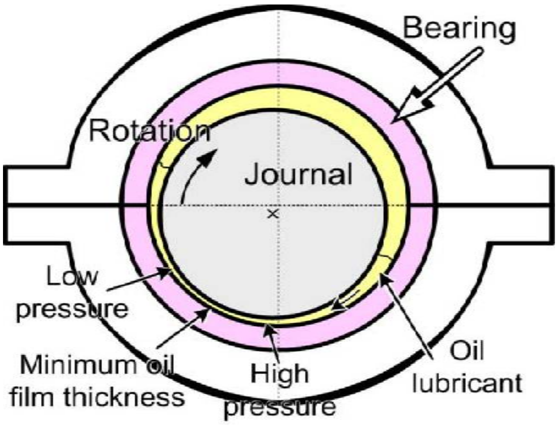
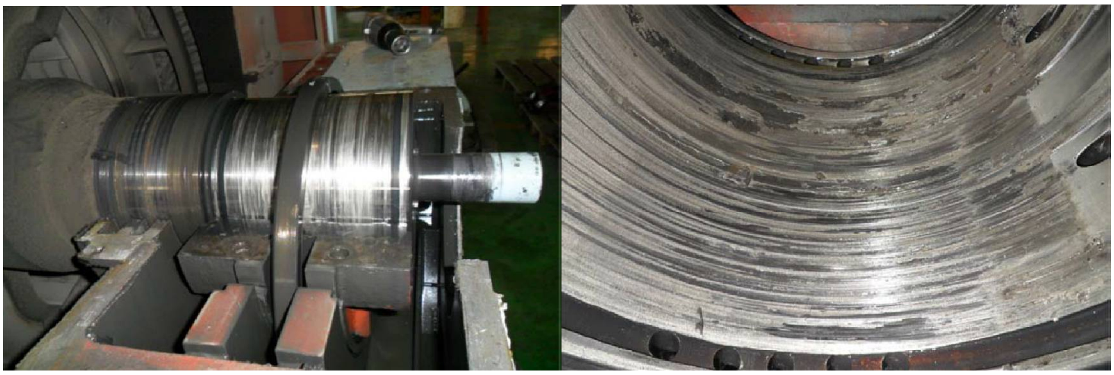


Fig. 1. Schematic of oil-lubricated journal (sleeve) bearing [1]

This can result in mechanical instabilities in the shaft rotation such as oil whirl, oil whip, looseness, or journal and bearing contact, etc., leading to increased vibration and bearing failure. Mechanical stress due to mechanical instabilities, misalignment, unbalance, bent shaft, external vibration, or excessive/cyclic loading can also cause fatigue damage on the bearing babbitt surface.



(a) (b)

Fig 2. 6.6 kV, 3.4 MW induction motor journal bearing inspection; (a) shaft and lower half of bearing; (b) bearing babbitt surface damage[1]

On-line monitoring based on thermal or mechanical measurements, and off-line oil analysis have been studied and applied in the field over the years for preventing journal bearing failure [2]-[10]. Since many of the failures are associated with mechanical instabilities, in-service monitoring of journal bearing faults in the field mainly relies on the analysis of mechanical measurements such as acceleration or displacement. However, not all medium-high voltage motors with journal bearings have mechanical sensors installed due to cost and environmental limitations.

For the low voltage seal less pump- and compressor motors with journal bearings, most of them do not have dedicated sensors installed for condition monitoring purposes. Vibration analysis with portable equipment can also be difficult for motors operating in a harsh environment. Therefore, it is desirable to develop a remote, cost-effective solution for monitoring the journal bearing condition without using a mechanical sensor.

MCSA has come up as with an important software in the area of fault diagnosis in past two and half decades. Vibration-based diagnostics has always been considered easy and reliable to use. Although, different techniques used for fault detection are acoustics emission (Zhan and Makis, 2006), vibration monitoring (Ruqiang and GAO, 2006),

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temperature monitoring (Nandi and Toliyat, 1999), wear debris analysis (Ebersbach et al., 2006). MCSA has emerged as a highly sensitive, selective and cost-effective tool. Some of the applications of MCSA are in the area of petrochemical refineries, offshore oil and gas production platforms, mining industry, paper mills and car industry.

The organization of the paper in the subsequent sections is as follows. In Section II, the details of bearing fall model is described followed by available methods of monitoring technique in Section III presents a brief introduction. In Section IV, advantages of current signals and the different stages of the proposed technique have been discussed. Section V presents the conclusions.

II. BEARING FALL MODELS

The service life of a rolling element bearing rotating under load is firm by material fatigue and wear at the running surfaces. Premature bearing failures can be caused by a large number of factors, the most common of which are wear, fatigue, corrosion, plastic deformation, brineiling, poor lubrication, faulty installation and incorrect design. Common modes of bearing failure are discussed below [11]:

A. Fatiguedamage initiates with the creation of minute cracks below the bearing surface. As running continues, the cracks growth to the surface where they cause material to break in the contact areas. The actual failure can manifest itself as spalling, pitting or flaking of the rolling elements or bearing races. If the bearing lingers in service, the damage will blowout in the locality of the defect due to stress concentration [11].

B. Wear is another cause of bearing failure. It is caused mainly by foreign particles and dirt entering the bearing through inadequate sealing or due to polluted lubricant. The abrasive foreign particles roughen the surfaces giving a rough appearance. Severe wear changes the raceway and changes the rolling diameter and element profile, increasing the bearing clearance. The rolling friction increases significantly and can lead to high levels of skidding and slip, the end result of which is complete breakdown [11].

C. Plastic deformation contacting surfaces can be the outcome of a bearing subject to excessive loading whileundergoing small or stationary movements. The result is indentation of the gutter as the excessive loading cause's localized plastic deformation. In operation, the deformed bearing would rotate unevenly producing excessive vibration and would not be suitable for further service [11].

D. Corrosion damage occurs when acids, water or other contaminants in the oil enter the bearing segment. This can be caused by damaged seals, condensation or acidic lubricants which occurs when bearings are cooled down from a higher operating temperature in very humid air. The result is rust on the successively surfaces which produces noisy and uneven operation as the rust particles interfere with the smooth rolling action and lubrication of the rolling elements [11].

E. Brinelling manifests itself spaced indentations distributed over the entire raceway circumference, corresponding in shape to the Hertzian contact area. Three possible origins of brinelling are,
   (1) Static overloading which leads to plastic distortion of the raceways,
   (2) When a stationary rolling bearing is subject to vibration and shock loads and
   (3) When a bearing forms the loop for the passage of electric current [11].

F. Inadequate lubrication is one of the most common causes of impulsive bearing failure as it leads to slip, skidding,heat generation, sticking and increased friction. At the highly frazzled region of Hertzian contact, when there isdeficient in lubricant, the contacting surfaces will rub together, only to be torn apart as the rolling element moves on.The three acute points of bearing lubrication the roller-race interface, fall at the cage-roller interface and the cage raceinterface [11].

G. Faulty installation can contain such effects as undue preloading in either axial or radial directions, loose fit, misalignment or damage due to extreme force used in mounting the bearing components [11].

H. Incorrect design can involve underprivileged choice of bearing size or type for the required operation, or insufficient support bythe coupling parts. Incorrect bearing selection can effect in any number of problems subjected on whether it includes lowload carrying competency or low speed rating. The end outcome will be reduced premature failure and fatigue life [11].

III. BEARING CONDITION MONITORING TECHNIQUES

There are two types of defects: Distributed Defects, Localized Defects. Distributed defects include surface waviness, roughness, misaligned races and off-size rolling elements [12]. Localized defects include pits spalls and cracks on the rolling surfaces. Condition monitoring systems are of two types: permanent and periodic. In a permanent monitoring system (also called an on-line CMS), machinery vibration is observed continuously at particular points of the machine and is constantly matched with suitable levels of vibration. The permanent monitoring system can be costly, so it is usually used only in perilous applications [12]. In a periodic monitoring system (also called an off-line CMS), machinery vibration is observed (or detailed and later analyzed) at pre define time intervals in the field; then an analysis is done either in the laboratory or in the field. Different methods are used for the analysis of bearing defects. The methods are generally classified as current and temperature monitoring, acoustic measurements, wear debris detection, and vibration analysis [13].

A. Temperature Monitoring
Bearing scattered defects generate too much heat in the rotating components. Monitoring the temperature of a bearing lubricant or housing is the modest method for fault detection of rotary machines [13].

B. Acoustic Measurement
The most nominal acoustic-based bearing health monitoring is acoustic emission. It is aephemeral impulse generated by the prompt release of strain energy in solid material under thermal or mechanical stress. The revealing of cracks is the key application of acoustic emission; therefore, this method can be used as anapparatus for condition monitoring of shaft cracks and bearing faults. The depth of a machine's sound can also be engaged for detecting faults in bearings. Typically, the accuracy of these technique depends on sound intensity and sound pressure data [13].

C. Electrical Motor Current Monitoring
The functional conditions of a motor can be monitored by investigating the continuum of the motor current. The fluctuations in the electric background noise are allied with the changes in the mechanical apparatuses of the machine; therefore, fault signatures can be spotted by motor current signal processing techniques [13].

D. Wear Debris Analysis
In this analysis, the presence of metallic elements in the lubricant is identified by sensitive sensors. Furthermore, the spectrographic investigation of the dissimilar metallic elements in the lubricant can simplify the location of the error/fault [13].

E. Vibration Measurement
Since the unusual vibration of rotary machines is the initially sensory outcome of rotary component failure, vibration analysis is extensivelyengaged in the industry. The fault vibration signal engendered by the interaction between a rolling surface and a smashed area occurs regardless of the defect type. Consequently, a vibration analysis can be employed for the diagnosis of all types of burdens, either distributed or localized. Furthermore, low-cost sensors, simple setups, accurate results, specific information on the damage location, and comparable rates of damage are other benefits of the vibration measurement method [13].

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IV. MOTOR CURRENT SIGNATURE ANALYSIS

Electrical Signature Analysis is the way of capturing a motor's voltage & current signals and analyzing them to spot various faults. Current monitoring, Current Park's vector, and current signature analysis, fall under the class of electrical analysis. This technic use stator current to detect different kind of machine faults. Currents signals can be used to be examined for detection of faults inside the motor. Certain signal are called a diagnosis media, and the output of the analysis applied to the selected diagnosis media is called a signature. Each strong motor gives a certain signature and that signature is unnatural when faults occur inside the motor. By comparing signatures in the course of motor operation with its original strong signature, faults can be detected at early stage. Hence judgments can be taken whether to linger or to break the motor operation.

Why Current signature analysis?

- Electrical signals are simpler, easier, and cheaper to be stored and measured.
- Manual access to motor itself is not required and signals can be observed from control panels.
- Online fault monitoring can be achieved with the running operation of the motor. [14]
- Faults can be detected at an early stage before becoming unadorned. Hence, sudden break down of motor are avoided, and maintenance cost is reduced.

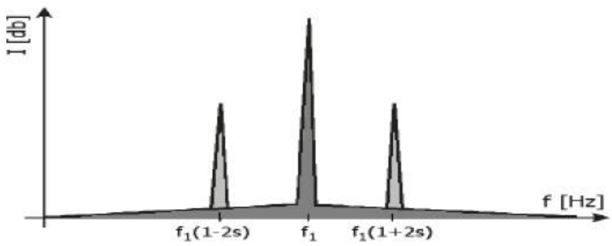

Fig. 3. Idealized current spectrum [7]

Motor Current Signature Analysis (MCSA) is a method used to determine the operating condition of AC induction motors without disturbing production. MCSA is detect an electrical signal that contains current components. MCSA detect the faults at an early stage and avoid the impairment and complete failure of the motor. By using MCSA, exact analysis of fault is possible. An idealized current spectrum is shown in Fig.3. Usually a decibel (dB) versus frequency spectrum is drawn in order to give a wide dynamic range and to spot the exclusive current signature patterns that are distinctive of different faults.[15] Motor Current Signature Analysis (MCSA) is based on current observing of induction motor therefore it is less expensive. The MCSA uses the spectrum of current machine for locating the fault frequencies. When a fault is detected, the frequency spectrum of the line current changed from strong motor. Motor Current Signature Analysis (MCSA) based methods are used to diagnose the most regular faults of induction motor such as short winding fault, broken bar fault, load fault and bearing fault.

The current monitoring techniques consist of following stages. The fig 4. Shows the block diagram of current monitoring techniques.

A) Sampler
Key purpose of method is to monitor a current of single-phase stator. The single-phase current is pick up by using Current Transformer and produces the signal proportional to it. The analog signal provided to analog to digital (A/D) converter. The filtered current is sampled by analog to digital converter at determined sampling rate. This is sustained for a sampling period which is enough to achieve required FFT.

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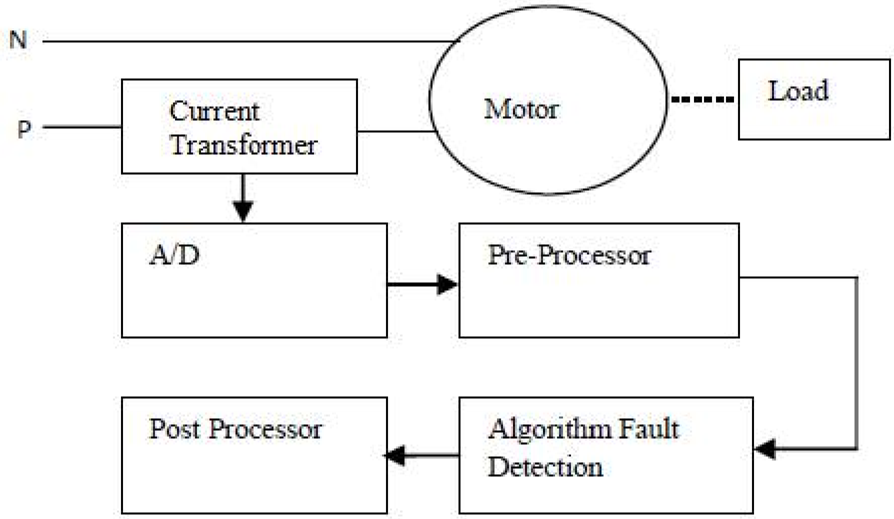

Fig. 4. Block diagram of current monitoring techniques [7]

B) Pre-Processor

It transforms the sampled signal to the frequency domain using an FFT algorithm. The produced spectrum includes only the scale information about each frequency element. Noise that is existent in the spectrum is suppressed by averaging a determined number of produced spectra. This can be completed by using either spectra calculated from various sample sets or spectra calculated from multiple fixed sections of a single large sample set. Because of the frequency ROI and the preferred frequency resolution, several thousand frequency components are produced by the processing section.

C) Fault Detection Algorithm

In order to reduce the huge amount of spectral data to a usable level an algorithm, that is frequency filter, removes those modules that provide no valuable information. The algorithm saves only those modules that are of specific interest because they specify individual frequencies in the current spectrum that are known to be tied to particular motor faults. Since the slip is not continual during normal operation, some of these modules are bands in the spectrum where the width is determined by the maximum variation in the motor slip. [16]

D) Postprocessor

Since a fault is not a specious event but continues to reduce the motor, the postprocessor diagnoses the frequency modules and then classifies them (for each specified fault).

V. CONCLUSION

Electrical machinery is the powerhouse of the modern industry. Failures of induction motors cause production downtime and may generate large losses in terms of maintenance and lost revenue. Timely detection of incipient motor faults is hence of great importance. Developing motor faults have its counterparts in waveform and harmonic content of the motor supply current. MCSA can be applied everywhere in industry where induction motors are used enabling non-intrusive on-line (even remote) analysis of motor supply current and detects faults while motor is still operational and without interrupting its service. It can be efficiently applied to detection and the localization for variety of motor faults. As such it is important contribution to tools for condition monitoring of induction motors.

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In this paper we have discussed about different methods of fault detection in section III that are temperature monitoring, acoustic measurement, electrical motor current monitoring, wear debris analysis and Vibration Measurement. In section IV, we have briefly studied about motor current signature analysis, how its work, why it's necessary and different stages of current signature analysis.

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