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Condition Monitoring for Inner Raceway Fault of Induction Motor Ball Bearings

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Abstract

In recent years, induction motors are becoming the most important equipment in industry. Induction machines play a polar role in industry and this motivates for their reliable and safe operation. Motor failures often happen when they are needed the most. In some industries this can't be abide because it leads to losses in production time, cost of repairing, and it spoils the safety conditions of the industry. Faults and failures of induction machines can increase downtimes and generate large losses in terms of maintenance and lost revenues, and this motivates the condition monitoring. In general, detection and diagnosis of inchoate faults is desirable for good product quality and improved operational efficiency of induction motors running off the power supply mains. This paper presents a method for detection of faults in ball bearing. Different kinds of actual faults have been acquired in real time from a test platform and a signal of a fault in an early stage has been created In this paper a fault identifying system is developed for induction motors ball bearing using vibration signal analysis methods.

Keywords: Induction motor, condition monitoring, bearing fault, vibration signal.

Introduction

Bearings play an important role in the reliability and performance of induction motor. The results of various studies show that motor faults are typically related to core components such as rotor, stator and bearings. These components account for 88% of motor failures.[1] Rolling element bearings are one of the most common components in rotating machinery including induction motors. According to Albrecht [2] and many others, about 40% of failures of electric motors are caused by bearings.

Therefore, bearings play the most important roles in condition monitoring. Faults in any part of bearing will generate unique frequency components in the measured machine vibration and other sensor signals. The frequencies produce by bearing faults are function of the bearing geometry and the running speed.[3]. Bearing faults can also cause rotor eccentricity [4].Failure of bearing increases the rotational friction of the rotor of induction motor. Thus, detection and diagnosis of mechanical faults in rolling element bearings is very crucial for the reliable operation of an induction motor. In many situations, vibration monitoring methods are utilized to detect the presence of an incipient bearing failure. Vibration monitoring is a reliable tool for bearing failures. The vibration data contains fault signatures and salient fault features because of the direct measurement of the critical signal and placement of the vibration sensor.

Bearing components

Ball bearings support and locate rotating shafts in machines. The main components of ball bearings are as shown in figure 1.

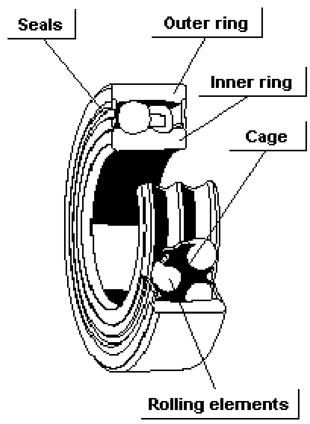

Figure 1: components of the rolling bearing

Inner ring

The inner ring is mounted on the shaft of the machine and is the rotating part. The bore can be cylindrical or tapered. The raceways against which the rolling elements run have different forms such as spherical, cylindrical or tapered, depending on the type of rolling elements.

Outer ring

The outer ring is mounted in the housing of the machine and in most cases it does not rotate. The raceways against which the rolling elements run have different forms depending on the type of rolling elements. The forms of the raceways may be spherical, cylindrical or tapered.

Rolling elements

The rolling elements may have different forms as shown in Figure 1. The forms of the rolling elements may be balls, cylindrical rollers, spherical rollers, tapered rollers or needle rollers. They rotate against the inner and outer ring raceways and transmit the load acting on the bearing via small surface contacts separated by a thin lubricating film. The rolling elements are made of carbon chromium steel, also called bearing steel.

Cage

The cage separates the rolling elements to prevent metal-to-metal contact between them during operation that would cause poor lubrication conditions. In many bearing types the cage holds the bearing together during handling. Cages are made from cold rolled steel strip.

Seals

Seals are essential for a long and reliable life of the bearing. They protect the bearing from contamination and keep the lubricant inside the bearings.

Bearing fault types

Almost 40%–50% of all motor failures are bearing related. Basic vibration signal processing [3] has got several advantages over its contemporary methods like [6-7]. The main reason of failure of ball bearings are manufacturing errors; improper assembly, loading, operation, or lubrication; or because of too harsh an environment. However, even if a bearing is perfectly made, assembled, etc. it will eventually fail due to fatigue of the bearing material. Most failure modes for ball bearings involve the development of irregularities on the bearing raceway or on a rotating element. With time, the discontinuities spread and, if the bearing survives long enough, it may eventually be worn smoother.

The bearing consists mainly of the outer and inner raceway, the balls and the cage which assures equidistance between the balls. The different faults occurring in a ball bearing can be classified according to the affected element and are:

- Outer raceway defect
- Inner raceway defect
- Ball defect
- Cage defect

Vibration analysis

Condition monitoring of ball bearings in induction motor using vibration analysis is a very well established method. It offers the advantages of reducing down time and improving maintenance efficiency[3]. The vibration produced by a healthy, new bearing is low in level and looks like random noise.

As a fault begins to develop, the vibration produced by the bearing changes: Every time a rolling element encounters a discontinuity in its path a pulse of vibration results. The resulting pulses of vibration repeat periodically at a rate determined by the location of the discontinuity and by the bearing geometry. These repetition rates are known as the bearing frequencies, more specifically:

- Ball passing frequency of the outer race (BPFO) for a fault on the outer-race
- Ball passing frequency inner race (BPFI) for a fault on the inner-race
- Ball spin frequency (BSF) for a fault on the ball itself
- The fundamental train frequency (FTF) for a fault on the cage.

This paper considers ball bearings with a geometry shown in Figure 2 The bearing frequencies can easily be calculated from the bearing geometry using the following formulae

For outer race defects

$$fBPFO = \frac{N}{2} fr(1 - \frac{db}{dm} Cos \propto) \quad (1)$$

For inner race defects

$$fBPFI = \frac{N}{2} fr(1 + \frac{db}{dm} Cos \propto) \quad (2)$$

For ball defects

$$fBSF = \frac{dm}{db} fr(1 - (\frac{db}{dm} Cos \propto)^2) \quad (3)$$

For cage defects

$$fFTF = \frac{1}{2} fr(1 - \frac{db}{dm} Cos \propto) \quad (4)$$

In above formulae N= No. of ball, fr=relative rev. /s between inner and outer races

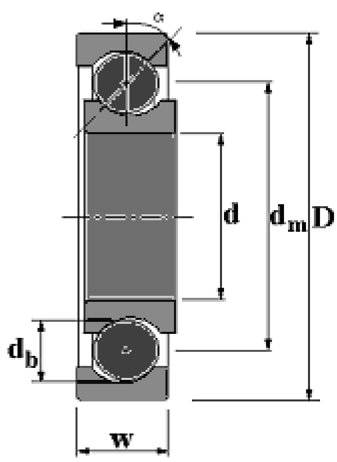

Figure 2: Geometry of ball bearing

Experimental results

A test setup has been developed with a fault on inner raceway of ball bearing as shown in figure 3. The vibration signal is analyzed with assuming contact angle β equal to zero degrees and motor operating without load (f_r= 25.13 Hz), the characteristic inner raceway frequency is calculated from equation (2) to be 137 Hz. A logarithmic plot of the vibration spectrum with healthy bearing and damaged bearing condition is shown in figure 4&5. The characteristic frequency of the inner raceway defect f_i and its multiples $2f_i$ are the components with the largest magnitude. No. of tests with different load levels permitted to observe slight variations of the characteristic vibration frequency according to equation (2). Some more components due to other mechanical effects and a general rise of the vibration level can also be observed on the vibration spectrum.

Figure 3: Developed test setup

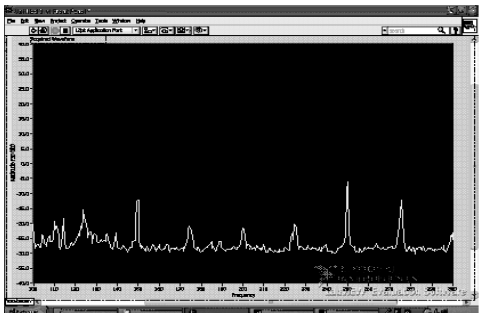

Figure 3: Vibration spectrum of unloaded healthy machine

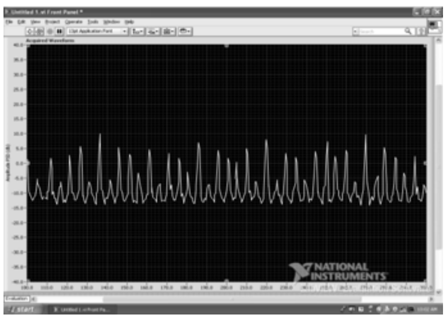

Figure 4: Vibration spectrum of unloaded machine with inner raceway defect.

Conclusion

This paper presents a method for detection of ball bearing fault on inner raceway in induction motors by vibration analysis. An experimental study has been conducted on a test rig with faulty bearings, measuring vibrations. The spectral analysis shows the characteristic vibration frequencies. Monitoring of these frequencies fault on bearing of induction motor can be detected.

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