Design of Machines and Structures, Vol. 8, No. 1 (2018), pp. 45–51.

METHODS FOR THE DETECTION AND ANALYSIS OF BEARING FAILURES

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Abstract: Bearings have a very important role in almost all rotating machine. Their operating properties impact the function of the whole machine. Failures of bearings can cause machine malfunction or even lead to catastrophic accidents. In order to prevent these events, continuous failure detection is necessary. This paper focuses on the methods for detection of bearing failures.

Keywords: *bearing failures, analysis techniques, signal processing*

1. INTRODUCTION

Bearings can be found extensively in domestic- and industrial applications. Their usage means risk for almost all forms of rotating equipment, such as pumps, machine tools, generators, electric motors, starters etc. These frequently used components have special importance in the course of investigations because their failure can cause big damages. The success of bearing life prediction depends on precise defect detection.

2. BEARING FAILURES

Even if bearings are being used under excellent conditions, sooner or long after material fatigue will befall. Besides other things unfavourable operating environment, contaminated or peculiarly moist areas and improper handling practices induce premature failures. Commonly the service life of bearings is expressed either as a period of time or as the total number of rotations before the incidence of failures in the outer ring, inner ring or rolling element because of rolling fatigue, as a result of repeated stress. When bearing defect is found, even if it is insignificant, it is necessary to examine the phenomenon to determine causes. In this case not only the bearing but also the shaft, housing, and lubricant used with the bearing should be exhaustively investigated [1].

Every bearing failure creates its own characteristic damage. Defects can be divided into primary or secondary ones in many cases. Primary defects are for example the smearing, wear, corrosion, indentations, surface distress and the passage of electric current. Even these defects may lead to scrapping the bearings in consequence of noise, low efficiency, vibration and so forth. Secondary failures such as flaking and cracks are rooted in primary ones. A wrong bearing generally indicates a combination of secondary and primary failure [2]. *Table 1* contains the most common bearing failures and parts in which they occur.

Table 1
Often occurring bearing damages [1]

Bearing failure	**Bearing ring, Rolling element**			**Bearing ring**	**Cage**	
	·Raceway surface ·Rolling surface	*·Roller guide surface ·Cage guide surface ·Roller end face*	*·Others*	*·Fitting surface*	*·Pocket surface ·Guide surface*	*·Rivet*
Smearing	□	□	–	–	–	–
Wear	□	□	□	□	□	×
Corrosion	□	□	□	□	□	□
Fretting	□	–	–	□	–	–
Cracks	×	×	×	×	×	×
Chips	×	×	□	×	×	×
Brinelling	□	□	□	□	–	–
Nicks	□	□	□	□	□	□
Flaking	×	–	–	–	–	–
Scratches	□	□	□	□	□	□
Scuffing	□	□	□	□	–	–
Seizure	×	×	×	×	×	–
Rust	□	□	□	□	□	□
Pear skin	□	–	–	–	–	–
Creep	–	–	–	□	–	–
Electric pitting	□	□	–	–	□	–
Failure of cage	–	–	–	–	□	×

Where × means that in principle, not reusable; □ signifies that reusable in accordance with seriousness of failure, by repairing or meeting required conditions; – means that no failure of this part [1].

The aforementioned failures eventually will be resulted in the endurance of the surface. Nevertheless, the total lifetime of a bearing is meant to be the number of revolution until the first indication of the surface endurance appears. If investigate some similar bearing under the same condition, it is apparent, that the obtained lifetimes may diverge. The one most common bearing failure is the outer ring defects, whereas in most cases the outer ring comprises and the load invariably affects the same point of the outer ring through on the rollers.

3. ANALYSIS METHODS

Condition monitoring is one possibility of preventive maintenance program. The collected data can be used to locate machinery problems and corrective activities can then be implemented. Different techniques are used for the perception of bearing condition. Such methods are noise analysis, acoustic measurements, temperature monitoring, wear debris detection, vibration analysis etc.

3.1. Temperature monitoring

Bearing distributed defects generate excessive heat in the rotating parts. Bearing manufacturers have long been aware of the connection of heat to bearing life and have designed formulas to accurately calculate safe operating temperatures. The results indicate a temperature band in which both lubricants and bearings will operate at top performance with the least stress. As soon as outside the optimal temperature range, they will degrade at an accelerated rate. *Figure 1* shows the temperature range of a typical rolling element bearing. The red zone (No. 3) represents the critical section, the yellow zone (No. 2) symbolizes the decreasing lubricant and bearing life, the green zone (No. 1) expresses the optimal place for bearing and lubrication temperature [3].

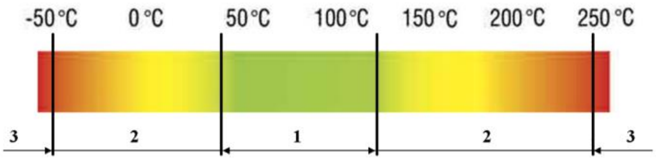

Figure 1. Thermal ranges [3]

Exist several temperature bands for distinct combinations of bearing and lubricant, but they will have the identical general trend regarding the optimal operating temperature and its effect on accelerated failure and wear. Thermal imaging empowers real-time temperature monitoring and localization of temperature increases. Moreover, it allows a spatial visualization of heat propagation in monitored areas [4].

3.2. Wear debris detection

The wear progress of a machine is commonly the result of many distinct, simultaneous wear mechanisms, each of which has its own way of affecting to the machine's operating environment and the changes that occur in it. If the poor operating conditions persist, the wear could either inflict parts of the machine to break or disturb the machine's operation. To allow detection at an untimely phase and control of the wear process, the size, amount and appearance of wear debris particles in the machine's lubricating oil must be monitored [5]. In this method, the presence of metallic particles in the lubricant is detected by sensitive sensors. Furthermore, the spectrographic analysis of the dissimilar metallic elements in the lubricant could facilitate the location of the defect [6].

3.3. Acoustic measurement

Acoustic measurement is receiving increasing significance in condition monitoring of bearings. The most efficient acoustic-based bearing health monitoring is acoustic emission. This is a transient impulse generated by the rapid release of strain energy in solid material under mechanical or thermal stress. The perception of cracks is the main application of acoustic emission. Therefore, this method can be used as a device for condition monitoring of bearing failures and shaft cracks. The acoustic emission is not disturbed or influenced by other mechanical defects and noise in rotating machinery, such as unbalance and misalignment, which cannot be eliminated entirely and lightly. So the acoustic emission based methods are superior in certain areas, especially for early fault detection in bearings. The acoustic emission progress is capable of detecting defects forming deep inside the material, even before it would propagate out to the surface. The measurement of a machine's sound can also be employed for diagnosing damages in bearings. Usually, the precision of these methods depends on sound intensity data and sound pressure [7].

3.4. Noise analysis

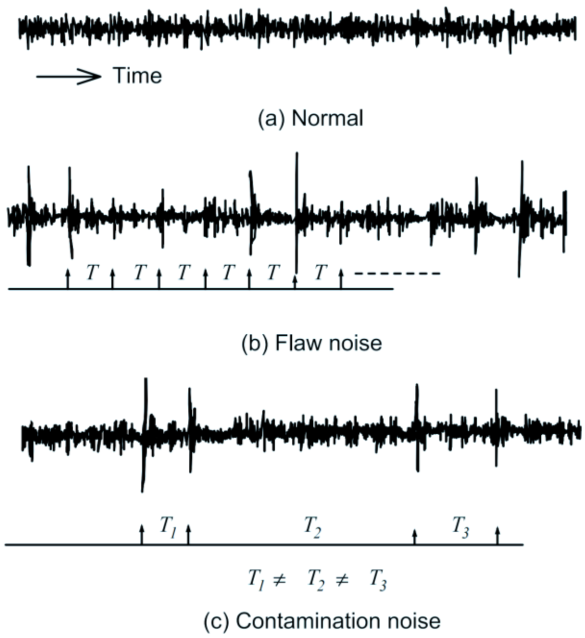

Figure 2. Waveform of noise due to contamination and flaw [8]

Even though the most modern manufacturing technology is used, sound still befall obviously in bearings. As the noise emitted by bearings is composed of all types of faults developed during the working time of the bearings and the manufacturing process, the effective values of certain noise quantities enable precise and quick examination [8]. Flaw noise has unique generation cycles or intervals if compared to other types of noise (*Figure 2*).

3.5. Vibration analysis

Vibration signals collected from bearings have affluent information on machine health conditions. Since the irregular vibration of rotary machines is the first sensory effect of rotary component failure, vibration analysis is widely spread in the industry. Vibration analysis can be applied for the diagnosis of almost every type of faults even localized or distributed. These methods benefits are accurate results, specific information and low-cost sensors. Several vibration analysis techniques available to analyse the bearing vibrations. Condition monitoring using vibration measurement can be classified into frequency domain, time domain, time-frequency domain and other techniques. The time-domain features are got from the raw vibration signal through the statistical parameters. Many stochastic indexes (like skewness, RMS value, peak-to-peak value, kurtosis etc.) use to characterize the status of bearings. Generally, the indexes of a damaged bearing tend to be bigger than the values of a normal bearing [9].

Frequency domain techniques are one of the most effective approach for the interpretation of bearing failures. The frequency domain involves to parse or display of vibration data based on the frequency. One main advantage of the method is that the repetitive nature of the vibration signals is exactly displayed as peaks in the frequency spectrum at the frequency where the repetition takes place. Time domain vibration signals are processed into the frequency domain by the adaptation of Fourier transform, typically in the shape of fast Fourier transform (FFT) algorithm. FFT is an algorithm to calculate the discrete Fourier transform and its inverse [6]. In a frequency spectrum *(Figure 3)* the horizontal axis is generally the frequency and the vertical axis is the amplitude of displacement, velocity or acceleration.

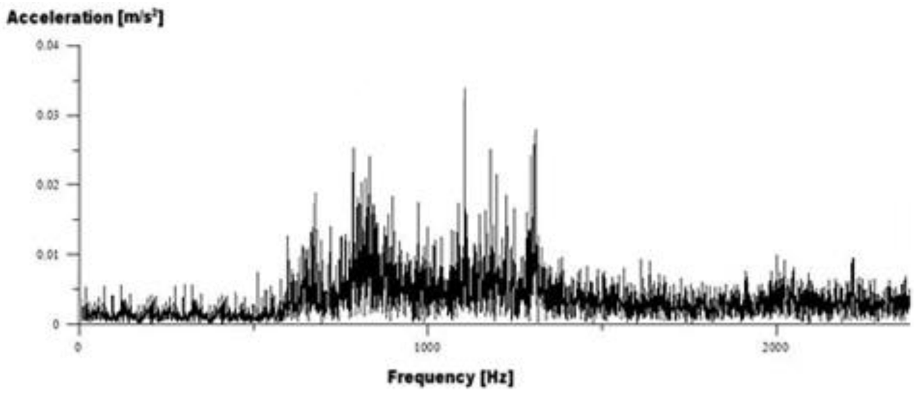

Figure 3. Frequency spectrum

Time–frequency domain analysis can manifest the signal frequency components, identifies their time variant features. These techniques have facility to handle both, stationary and non-stationary vibration signals. This is the one serious advantage over frequency domain techniques [10].

4. Conclusion

Many different methods have been evolved for monitoring and diagnosing of bearings in the past decades. Vibration based monitoring methods are advantageous tools in the field of predictive maintenance and efficacious in detecting defects in the bearings. Acoustic emission is receiving increasing attention as a complementary method for condition monitoring of bearings, as acoustic emission is enough sensitive to initial defects. Temperature monitoring of bearing is an effective method for fault perception in rotating machines.

Acknowledgement

This research was supported by the ÚNKP-18-3 New National Excellence Program of the Ministry of Human Capacities.

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