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VIBRATION ANALYSIS TECHNIQUES FOR ROLLING ELEMENT BEARING FAULT DETECTION

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Abstract: Unexpected rolling element bearing failures can cause machine breakdown and might even lead to catastrophic accident or even human casualty.In order to prevent these accidents, continuous failure detection is necessary. The following paper focuses on different rolling bearing defect detection methods based on vibration signal analysis.
Keywords: *rolling element bearing failures,vibration signal, time-frequency domain techniques*

1. Introduction

Rolling element bearings can be found extensively in industrial and domestic applications. These frequently used components have special importance in the course of investigationsbecause their failure can cause enormousdamages.The success of bearing life prediction depends onprecise defect detection and assessment.

2. Bearing failures

Even when bearings are being used under optimal conditions, sooner or later material fatigue will occur.Among other thingspoor operating environment, contaminated or peculiarly moist areasandimproper handling practices induce untimely bearing failures.Each failure creates its own typical damage. Thus, defects can be divided into primary or secondary ones in several cases. Primary failures are for example the corrosion,smearing, wear, indentations, surface distress and the passage of electric current.Even these defects may lead to scrapping the bearings in consequence of noise,low efficiency, vibrationand so forth. Secondary defects such as flaking and cracks are rooted in primary ones. A defective bearing often indicates a combination of secondary and primary failure [1].

The above mentioned failures eventually will be resulted in the endurance of the surface.Accordingly, the total lifetime of a bearing is meant to be the number of revolution until the first indication of the surface endurance appears.When examine some similar bearing under the same condition, it is apparent, that the obtained lifetimes may diverge.When examine some analogous bearings under the identical condition, it is apparent, that the obtained lifetimes may diverge.

The most common rolling element bearing failure is the outer ring defects, whereas in most cases the outer ring comprisesand the load always affects the same point of the outer ringthrough on the rollers. Figure 1 shows smearingat the outer ring.



Figure 1. Outer ring defects

3. Vibration analysis techniques

Vibration signals collected from rolling element bearings carry affluent information on machine health conditions.Hence, the vibration-based methods have received thorough study during the past few decades.Various vibration analysis techniques exist to analyse the bearing vibrations. Condition monitoring utilizing vibration measurement can be categorized into time domain, frequency domain, time-frequency domain and other techniques.

3.1. Time domain techniques

One of the fastest detection and diagnosis approaches is to analyse the measured vibration signal in the time domain.The time-domain features are extracted from the raw vibration signal through the statistical parameters.Several stochastic type indexes widespread use to characterize the health of bearings.Some important statistical parameters are given in Figure 2.

Peak Value	$\frac{1}{2}\left(max(x_i) - min(x_i)\right)$
Root mean square	$\sqrt{\frac{\sum_{i=1}^{N}(x_i)^2}{N}}$
Crest Factor	$\frac{\text{Peak Value}}{\text{RMS}}$
Skewness	$\frac{\sum_{i=1}^{N}(X_i - \bar{X})^3}{(N-1)S^3}$
Kurtosis	$\frac{\sum_{i=1}^{N}(X_i - \bar{X})^4}{(N-1)S^4}$
Impulse Factor	$\frac{Peak\ Value}{(\sum_{i=1}^{N} x_i)/N}$
Shape Factor	$\frac{\sqrt{\frac{\sum_{i=1}^{N}(x_i)^2}{N}}}{(\sum_{i=1}^{N} x_i)/N}$
Energy in time Domain	$\left(\frac{\sum_{i=1}^{N}\sqrt{\lvert x_i\rvert}}{N}\right)^2$
Clarence Factor	$\frac{Peak\ Value}{\left(\frac{\sum_{i=1}^{N}\sqrt{\lvert x_i\rvert}}{N}\right)^2}$
Standard deviation	$\sqrt{\frac{\sum_{i=1}^{N}(x_i - x_m)^2}{N-1}}$

Figure 2. Time domain features with calculation formulas [2]

Where $\bar{X}$ is the mean value of the discrete time signal,x_i is the ith sample, N is the number of discrete points and represents the signal from every sampled point.

Peak-to-peak value can measures in the time domain or frequency domain. Peak value is the disparity between the maximum positive and the maximum negative amplitudes.Root mean square (RMS) measures the comprehensive level of a discrete signal.Crest factor is the proportion of peak acceleration over RMS.This quantity perceives acceleration bursts even if signal RMS has not changed.Kurtosis value is another relevant parameter.This metric is compromise measure between the intensive lower moments and other susceptible higher moments [3].

Crest factor, Kurtosis value, Impulse factor and Clearancefactor are non-dimensional statistical indexes. Kurtosis andCrest factor valuehave comparable effects likeClearance andImpulse factors.Crest factor,theImpulse factor, Kurtosis value, and Clearance factor are all susceptible to initial fatigue [3].

3.2. Frequency domain techniques

The frequency domain analysis can reveal some information that cannot be found in time-domain.The frequency domainimplies to the analysis or display of the vibration data based on the frequency.Frequency domain techniques are the most popular approach for the interpretation of bearing failures.One principal advantage of the method is that the repetitive nature of the vibration signals is precisely displayed as peaks in the frequency spectrum at the frequency where the repetition takes place.The time domain vibration signal is typically processed into the frequency domain by the adaptation of Fourier transform, generally in the shape of fast Fourier transform (FFT) algorithm.A FFT is an algorithm to calculate the discrete Fourier transform (DFT)and its inverse.Afrequency spectrumis illustrated in Figure 3.

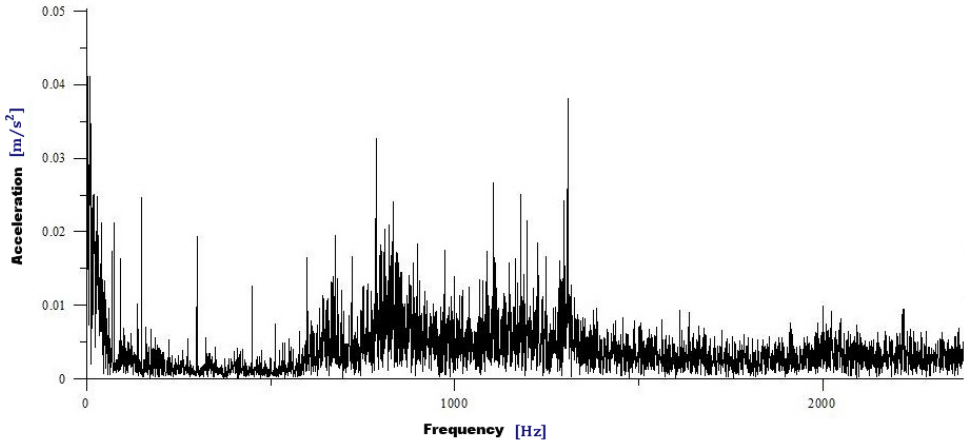


Figure 3. The trend of a frequency spectrum

In a frequency spectrum the horizontal axis is usually the frequency and the vertical axis is the amplitude of displacement, acceleration or velocity. The major benefit of frequencydomain techniques over time-domain techniques is that it has ability to easily ascertain the certain frequency components of interest.

3.3. Time-frequency domain techniques

Several time-frequency domain techniques have been generated whichshow possibility for detecting and diagnosing bearing problems in some of the more complicated rotating machines where the noise to signal ratio is low and a large number of frequency elements are present.

Time–frequency analysis can display the signal frequency components, identifies their time variant features.Time-frequency domain techniques have facility to handle both, non-stationary and stationary vibration signals. This is the one main advantage over frequency domain techniques.These methodsfor instancethe Wavelet transform, the short time Fourier transform and the Wigner-Ville distribution [3].

One of the most widely used time-frequency techniques is the short time Fourier transform(STFT).STFT distributes the original signal into segments with short-time window and then apply the Fourier transform to each time segment to ascertain the

frequencies that existed in that segment. The Wavelet transform (WT) is a favoured method to diagnosis bearing faults.One advantage of WT over the STFT is that it can achieve high frequency resolutions with sharper time resolutions.

The Wigner-Ville distribution (WVD) not applies any window function so it is free from the interference between time localization and frequency resolution. Figure 4 shows the WVD in a non-stationaryoccurrence.Asterisks signalize instantaneous frequency measurements [4].

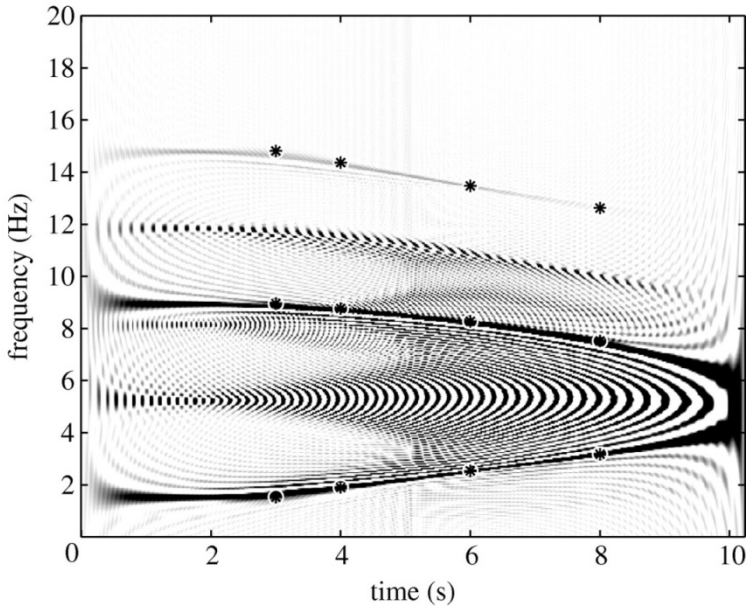


Figure 4. Wigner–Ville distribution in a non-stationary case [4]

3.4. Other Techniques

Some other techniques apply to diagnosis of rolling element bearing failures for example fuzzy logic systems, artificial neural networks (ANNs), Singular Spectrum Analysis (SSA) and so on. One advantage of ANNs that can detect bearing faults using short data length [3].

4. Conclusion

The vibration based monitoring methods are useful tools in the field of predictive maintenanceand efficacious in detecting the defects in the rolling element bearings.The present paper dealt with rolling element bearing failures and classifiedfrequent vibration analysis techniques.

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