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Application of Zhao-Atlas-Marks Transforms in Non-Stationary Bearing Fault Diagnosis

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Abstract

Rolling element bearings (Ball Bearings) are the main rotating element in mechanical engineering applications such as Thermal Power plants, Nuclear power plants, Aviation and Chemical industries. The defects in the rolling element bearings may arise due to reasons such as overloading, fatigue, improper design and manufacturing of the bearing, misalignment of bearing races, etc. Depending on the application, the speed and load conditions of shaft may cause some failures which leads to non-stationary operating conditions. Since early fault detection can save emergency maintenance cost, the bearing fault diagnosis is important in monitoring applications. This paper is attempt to analyze the effectiveness of the new time-frequency distributions called the Zhao-Atlas-Marks (ZAM) distribution to enhance non stationary vibration signal analysis for fault diagnosis in bearings. Also the performance of ZAM with Short Term Fourier Transform (STFT) is discussed in this paper.
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Keywords:*Bearing fault, Short Term Fourier Transform (STFT), Zhao-Atlas-Marks (ZAM), Time-Frequency analysis.*

1. Introduction

Rolling element bearing comes under the critical component in many rotating machineries. Ball bearings are important components in many industrial and transportation applications. Condition-based maintenance (CBM) of such machines is gaining importance in industries because of the need to increase reliability and to decrease possible loss of production due to machine breakdown.

CBM is a decision-making strategy based on real time diagnosis of impending failures and prognosis of future equipment health. The condition of a system is quantified by obtaining data from various sensors in the system periodically or even continually. The detection of failures in components can be done by comparing the signals of a

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machine running in normal condition and faulty condition [1]. In order to predict and overcome wear related damage progression in bearings, various condition monitoring techniques have been developed [2, 3] in past literature. There are several vibrational analysis techniques for analyzing the bearing vibrations. These techniques are classified into time domain analysis, frequency domain analysis and time frequency domain analysis. In time domain analysis, various parameters such as Root Mean Square (RMS), Peak, Kurtosis, Crest Factor, Standard Deviation etc., have been considered in order to analyze the various defects [4, 5].

In frequency domain analysis, the time domain vibrational signals are converted into discrete frequency components using Fast Fourier Transform (FFT).Spectrum analysis is the FFT of log of a vibration Spectrum in which frequency of our interest can be identified easily [6]. Since the FFT analysis is most suitable to stationary signal analysis and in order to combine the advantages of both time domain and frequency domain analysis, the time frequency domain analysis was introduced by many researchers in the fault diagnosis using vibration signals. Time frequency domain analysis is the 3D time, frequency and amplitude representation of the signal, it has the capability to handle both stationary and non-stationary vibration signals. A number of time frequency analysis methods such as Short Time Fourier Transform (STFT), Wagner-Ville Distribution (WVD), Wavelet Transform, Zhao-Atlas-Marks (ZAM), and Bessel's, etc. [7]. The ZAM distribution of fault diagnosis is applied in gear fault diagnosis [8]. Although various time frequency analysis is applied for the bearing fault diagnosis, the ZAM distribution of bearing fault analysis is not attempted.

Hence In this work, the bearing fault diagnosis is done using sophisticated signal processing technique called ZAM transform. The ZAM is used to present the time frequency analysis and the comparison of normal and faulty signal is done. Also the performance of ZAM is discussed with STFT (spectrogram). The vibration response of the bearing under normal and faulty conditions such as faults in inner race and outer race are considered for the analysis.

2. Time-Frequency Representations

This paper discusses on time-frequency representations like STFT and ZAM for fault diagnosis which have been explained in detail in this section.

2.1. Short Time Fourier Transform (STFT)

Fourier atoms were introduced to measure the "frequency variations" of sound. The WFT of a function *f (t)* is given by [9]

$$f(t,\xi)=\int_{-\infty}^{+\infty} f(t)g(t-u)e^{-i\xi t}dt \tag{1}$$

Where *g(t)* is a real and symmetric window translated by *u* and modulated by the frequency ξ, *t* is the instantaneous time. The transform is called the STFT because the multiplication by *g (t - u)* localizes the Fourier integral in the neighborhood. The resolution in time and frequency of the WFT depends on the spread in time and frequency of the selected window type (Rectangle, Blackman, Hamming, Gaussian, Hanning etc.). This spread is the smallest in the Gaussian window defined as follows [10]

$$g(t)=e^{-18t^2} \tag{2}$$

The WFT can be implemented digitally and efficiently in real time using discrete Fourier transform (DFT). The energy density possessed by the WFT is called a spectrogram denoted by $P_s f$

$$p_s f(t,\xi)=|sf(t,\xi)|^2=|\int_{-\infty}^{+\infty} f(t)g(t-u)e^{-i\xi t}dt|^2 \tag{3}$$

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