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Comparative Study of Spectrogram, Cepstrum and Mel-Frequency Analysis for Bushing Fault Diagnosis using Sound Signal.

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Abstract

This research paper aims to present the Comparative Study of Spectrogram, Cepstrum and Mel-Frequency Analysis for Bushing Fault Diagnosis using Sound Signal, have three case of condition testing for shaded pole motor. This research used shaded pole motor from Table Fan to testing. The Spectrogram were detected for bushing of shaded pole motor are healthy, but this method difficult to separate normal and crack on bushing because can be distracted by ambient noise, Cepstrum confirmed that the faulted on bushing and easy than Spectrogram to separate normal and crack on bushing because can be reduce ambient noise and Mel Frequency Analysis confirmed that the faulted on bushing and easy than Spectrogram to separate normal and crack on bushing of shaded pole motor with a slightly damaged front sliding bushing. The spectrogram, Cepstrum and Mel Frequency Analysis confirmed that the sound signal effects changed.

Keywords: Spectrogram, Cepstrum, Mel Frequency and Bushing Fault,

1. Introduction

At present electric motors and gear motors most popular are used in a broad range of industrial, commercial, and residential, applications. Lower 1 hp to 100,000 hp of electric motors are available to meet any industrial need. Examples of applications include industrial fans, blowers, pumps, machine tools, power tools, turbines, compressors, alternators, ships, rolling mills, paper mills, movers, and other special applications. With the electric motor, every machine could be powered by its own electric motor and provide easy control at the point of use. This improved power transmission efficiency and increased safety and ease of setting up production.

Rolling element bearings or bushing constitute a major part of almost every rotating machine. There are number of mechanisms that can trigger bearing damage and eventually failures, including mechanical damage, crack, wear, lubricant deficiency, corrosion and plastic deformation. When the smooth rolling contact surfaces are marred, higher stress conditions imposed on the contact surfaces which reduce bearing life significantly. As a fatal defect is detected, it is common to shut down

the machinery as soon as possible to avoid catastrophic damages. Performing such an action at which usually occurs at inconvenient times typically results in substantial time and economical losses. Thus, the ability to detect bearing faults at an early stage is a major concern. The use of sound and vibration signals is quite common in the field of condition monitoring. These signals usually reflect the working condition of rotating machines. Energy levels of sound and vibration signals increase due propagation of faults in machine elements.

By comparing the signals of a machine running in normal and faulty conditions, detection of faults like mass unbalance, rotor rub, shaft misalignment, gear failures and bearing defects is possible. These signals are also used to detect incipient failures of machine components through online monitoring systems to reduce the possibility of catastrophic damage resulting in downtime [3] Lot of research articles have been published on the applications of sound and vibration monitoring and analysis techniques to detect faults in rotating machines [1-3]. Conducted experimental investigations to study the effect of surface irregularities in rolling and sliding contacts on noise generation. The results showed that there is an increase in overall noise level of the system with increase in roughness. When a fine surface wears, noise level increases and when a rough surface wears, noise level reduces; hence monitoring of overall noise level and discrete frequency patterns provide an indication of the surface condition of contacting pair [3].

Reported investigations carried out on the application of sound pressure and vibration signals to detect defects in rolling element bearings using statistical parameter estimation method. The well-established statistical parameters such as crest factor and the distribution of moments including kurtosis and skewness, as well as other parameters obtained from beta distribution functions were utilized in this study [3-6].

Spectrogram using Matlab Programming was study to detection on bushing fault are confirmed [7]. In our research, we used Python NumPy to provide an environment that is an effective open-source alternative for MatLab and Librosa: a python package for music and audio analysis, Matplotlib: a python library for plotting.

In this research, the technique and solution of Spectrogram, Cepstrum and Mel-Frequency Analysis are implemented with Python Programming to comparative any technique and solution for diagnosis of bushing fault. The fault diagnosis and detection solution with suitable for on bushing, bearing and shaft of electric motor and gear motor in industrial was developed to easy and low-cost technique [9].

Fig. 1. Shows Table Fans are used shaded pole motor for driving blade of three speed table fan using for experimental in this research.

Fig. 1 Shaded Pole Motor

2. Experimental Setup

Fig. 2. Shows the test system of shaded pole motor. The power supply used Variac, 0–230 VAC, 2A, 500 W for three speed shaded pole motor 40 W 220 VAC. 50 Hz. Sony TX650 digital voice recorder TX series used for audio recorder.

Testing condition for shaded pole motor was present. Case 1: Normal Bushing, Low Speed, Medium Speed and High Speed

Case 2: One crack on Bushing, Low Speed, Medium Speed and High Speed

Case 3: Four crack on Bushing, Low Speed, Medium Speed and High Speed

Voltage from power supply are fixed at 220 VAC in every case and measuring current, power and r.p.m. for compare. The audio was recording in 60 sec. Electrical current data result of shaded pole motor isn't different. This diagnosis can be used [2–3]. The microphone can capture more information (frequency bandwidth) than the shaded pole motor. Ultrasounds and acoustic signals (20–20,000 Hz) are often used in industry [1].

Fig. 3. Shows the normal and Crack on bushing of shaded pole motor. The crack on bushing make from flat-blade screw driver for assume as crack in condition to testing

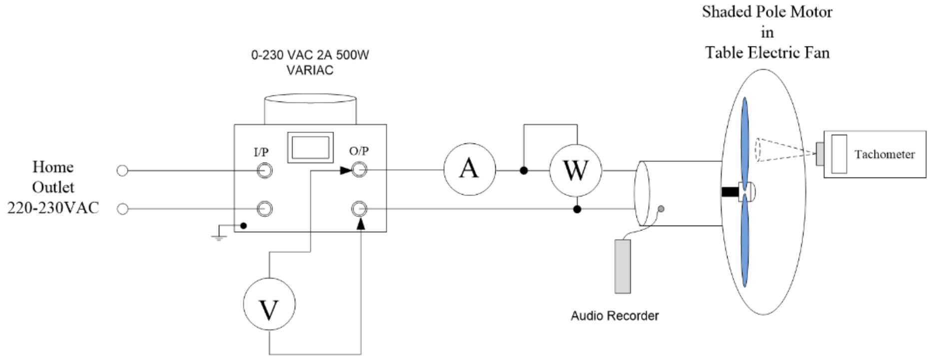

Fig. 2 Diagram of Experimental Setup

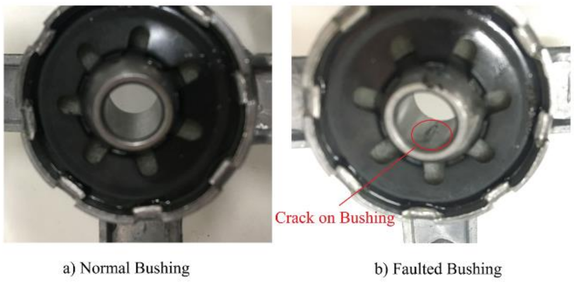

Fig. 3 Normal and Crack Bushing

3. Result and Discussion

Results of sound signal are innovative for automatic fault diagnosis was confirmed. [8] According this research using sound signal for diagnosis fault with Spectrogram, Cepstrum and Mel-Frequency Analysis

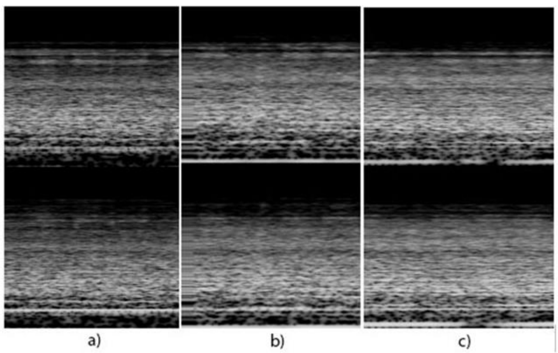

Fig. 4 Spectrogram of under faulted bushing condition

From Fig.4 [7] difficult for diagnosis because these results are black and white tone and none scaling.

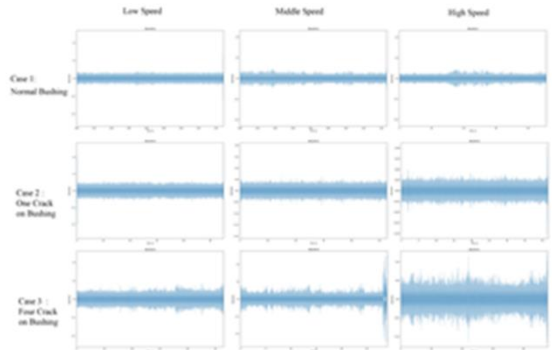

Fig. 5 Waveform of Case 1, Case 2 and Case 3

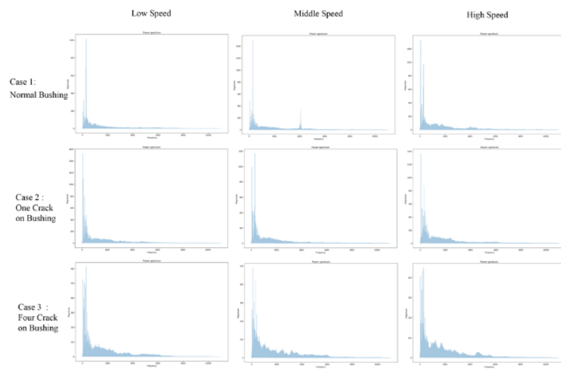

Fig. 6 Cepstrum of Case 1, Case 2 and Case 3

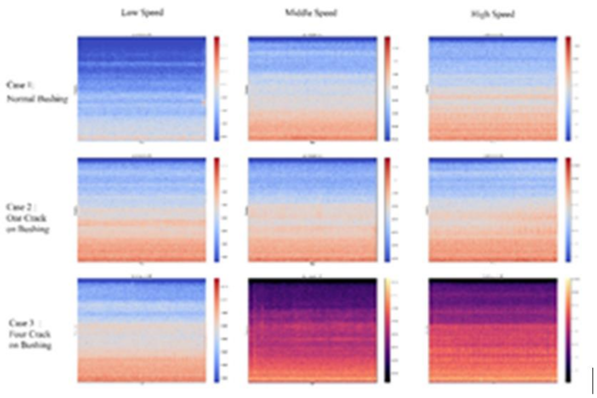

Fig. 7 Mel-Frequency of Case 1, Case 2 and Case 3

Fig. 5. Shows results of waveform using Python Programming, and electrical data are 220, 0.093 A, 15 W, 410 r.p.m. of shaded pole motor in normal bushing at low speed, 220 V, 0.188 A, 30 W, 850 r.p.m. of medium speed and 220 V, 0.25 A, 40 W, 1100 r.p.m. at high speed.

Fig. 6. Shows results of Cepstrum using Python Programming, and electrical data are 220, 0.093 A, 15 W, 410 r.p.m. of shaded pole motor in one crack on bushing at low speed, 220 V, 0.188 A, 30 W, 850 r.p.m. at medium speed and 220 V, 0.25 A, 40 W, 1100 r.p.m. at high speed.

Fig. 7. Shows results of Mel-Frequency analysis using Python Programming, and electrical data are 220, 0.093 A, 15 W, 410 r.p.m. of shaded pole motor in one crack on bushing at low speed, 220 V, 0.188 A, 30 W, 850 r.p.m. at medium speed and 220 V, 0.25 A, 40 W, 1100 r.p.m. at high speed.

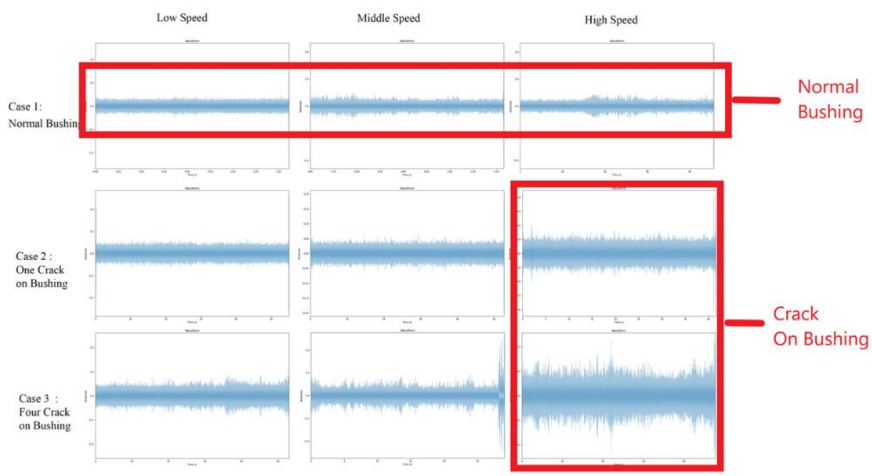

Fig. 8 Waveform and diagnosis with Python Programming

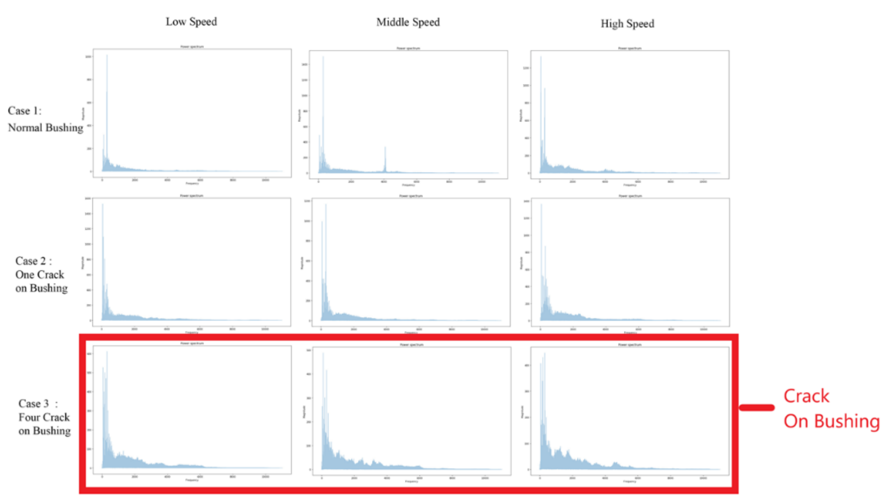

Fig. 9 Cepstrum and diagnosis with Python Programming

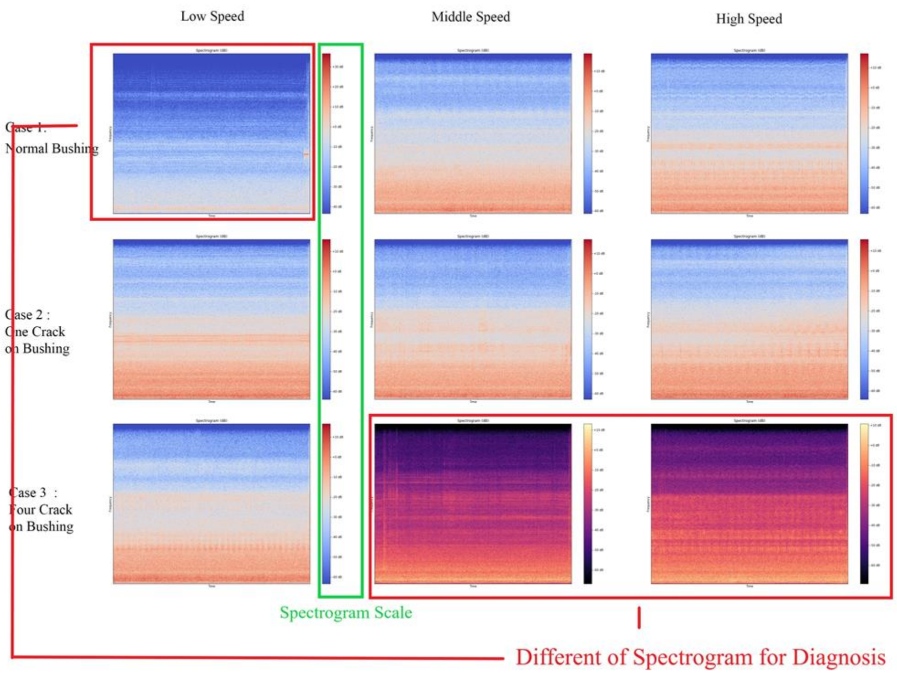

Fig. 10 Mel-Frequency Analysis and diagnosis with Python Programming

From Fig. 8 The waveform are difficult for diagnosis because this results at low speed on normal bushing and middle speed and high speed on four cracks on bushing case have a different.

From Fig. 9 Cepstrum are easy for diagnosis because this results at have a different of peak and intensity of peak.

From Fig. 10 Mel-Frequency Analysis are very easy than implement spectrogram and cepstrum for diagnosis because this results at have a many different of peak and intensity of peak on normal bushing and faulted on bushing.

That results use smart technique for analysis sound signal in below step [9-12].

Step 1: Audio input and data preprocessing

In this step, the data pre-processing of the audio data has three main steps:

1) data input by recording audio in normal, one crack, and four crack bushing with low, medium, high speed.

2) load the audio file with Librosa and

3) generate the audio waveform from full-length recording audio which is in a WAV format audio file. The waveform shows how a signal changes with time (time-domain graph).

Step 2: Power Spectrum generating

Firstly, split the full-length recording audio into frames and apply the FFT. The frame is transformed from the time domain waveform to the frequency domain audio waveform. Second, calculate absolute value on complex numbers to get magnitude. Third, create frequency variable and take half of the spectrum and frequency. Finally plot Power spectrum.

Step 3: Spectrogram generating

After waveform pass FFT, we apply logarithm to cast amplitude to Decibels and display spectrogram.

Step 4: Mel-frequency Cepstral Coefficients

(MFCCs) Mel spectrum is computed by passing the Fourier transformed signal through a set of band-pass filters known as Mel-filter bank. A Mel is a unit of measure based on the human ears perceived frequency. The DCT is applied to the trans-formed Mel frequency coefficients produces a set of cepstral coefficients.

5. Conclusion

In experimental condition to diagnosis of faulted bushing of shaded pole motor possible successfully performed by developed innovative techniques of fault diagnosis using sound signal. These results were comparative studies to find the optimization point to bushing fault detection of shaded pole motor with Spectrogram, Cepstram and Mel frequency Analysis.

The Spectrogram confirmed that the faulted on bushing but this technique are difficult to separate normal and crack on bushing because can be distracted by ambient noise [2].

The Cepstrum confirmed that the faulted on bushing and easy than Spectrogram to separate normal and crack on bushing because can be reduce ambient noise [11-12].

The Mel Frequency Analysis confirmed that the faulted on bushing and easy than Spectrogram to separate normal and crack on bushing because can be reduce ambient noise [11-12].

However, we can combine Spectrogram, Cepstram and Mel frequency Analysis to confirmed bushing fault and develop to automation [8].

Future more the solution and method were developed to detect fault on bearing and rotor shaft of rotating machine and gearbox of rotating machine.

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