Improving Electromotor Process in Water Pump by Using Power Spectral Density, Time Signal and Fault Probability Distribution Function

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ABSTRACT: *Condition monitoring based on the vibration signal analysis was often based on the Fast Fourier Transform (FFT). In order to overcome performance limitations of FFT such as disability of describing non-stationeries vibration signal that introduced by faults, Power spectral density (PSD) technique is very effective. Exponential distribution function was used for calculating an electromotor fault probability .The objective of this paper was to investigate the correlation between vibration analyses, fault diagnosis, Fault Probability Distribution Function (FPDF), Time signal and PSD of an electromotor of process water pump. We were calculated* G_{rms} *(Root-Mean-Square Acceleration) and PSD of DE of an electromotor before and after repair. Also before repair probability of fault was calculated. The results of this paper have given more understanding on the dependent roles of vibration analysis and PSD in predicting and diagnosing machine faults and by using FPDF we can determine the amount of fault probability before repair.*

Keywords: Condition Monitoring, Power Spectral Density, Electromotor of Process water pump, Time signal, Fault probability

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1. Introduction

Structural damage detection of industrial machinery can considerably increase safety and reduce maintenance costs [1]. Vibration analysis is a very powerful condition monitoring technique which is becoming more popular and common practice in industry. The amplitude of the vibration signature gives an indication of the severity of the problem, whilst the frequency can indicate the source of the defect [2]. By analyzing the frequency spectra, and using signal processing techniques, both the defect and natural frequencies of the various structural components can be identified [4, 3].The vibration signal analysis was often based on the Fast Fourier Transform (FFT) [5, 6].In order to overcome performance limitations of FFT such as disability of describing non-stationeries vibration signal that introduced by faults, Power spectral density is reported in several research works (Gibson, 1972; Norton and Karczub, 2003)[7, 8].This paper focuses on vibration-based condition monitoring and fault diagnosis of an electromotor of process water pump by using Power spectral density (PSD) and Fault Probability Distribution Function.The objective of this paper was to investigate the correlation between vibration analyses, fault diagnosis, Fault Probability Distribution Function (FPDF) andPSD.Density data produced by vibration analysis. We were calculated G_{rms}(Root-Mean-Square Acceleration),PSD and fault probabilityof DE of an electromotor before and after repair (unhealthy and healthy situations).The results of this paper have given more understanding on the dependent roles of vibration analysis and PSD in predicting and diagnosing machine faults and by using FPDF we can determine the amount of fault probability before repair.

2. Materials and Method

The test rig used for the experimentation was the electromotor of process water pump. Details of the electromotor were given in table 1.

Electromotor	Description
Type of motor	M2BA 315SMA 4
Power (kW)	110
Motor driving speed (rpm)	1500

Table 1. Detail of the electromotor

The experimental procedure for the vibration analysis consisted of taking vibration readings at Driven End (DE) of the elevator electromotor. The electromotor was running under healthy and unhealthy situations. The Vibration data were collected on a regular basis after the run in period. Vibration measurements were taken on the input shaft casing of electromotor using an Easy-Viber (VMI was the manufacturer). Spectra Pro4 software was used for acquisition the vibration spectrum based on the Fast Fourier Transform (FFT) at frequency domain between 0 to 850 Hz.

2.1 Power Spectral Density (PSD)

Power spectral density (PSD) function shows the strength of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are strong and at which frequencies variations are weak (Irvine, 1998) [9].

$$X(f) = \int_{f_1}^{f_2} x(t) e^{-2\pi i f t} dt \qquad (1)$$

If x (t) is expressed in units of (m/s2), X (f) is expressed in units of (m/s2)/Hz. From the complex spectrum, the one-sided power spectral density can be computed in (m/s2)2/Hz as Below:

$$PSD(f) = \frac{2\,|x(f)|^2}{(t_2 - t_1)} \qquad (2)$$

Where the factor 2 is due to adding the contributions from positive and negative frequencies.

The PSD divides up the total power of the vibration. To see this, we integrate it over its entire One-sided frequency domain (0, F) [5]:

$$\int_0^f PSD(f)\, df = \frac{\int_{f_1}^{f_2} |x(t)|^2\, dt}{(t_2 - t_1)} \qquad (3)$$

2.2 Probability Distribution Function (PDF)

A mathematical function can be used to model the frequencies and probabilities of occurrences over time. The probabilities of a continuous random variable are modelled using continuous distribution functions, also known as probability density functions (PDF's) [10, 11].

2.3 Probability density function

The probability density function (PDF) f of a random variable X gives a natural description of the distribution of X and allows probabilities associated with X to be computed [12].

$$P(a < X < b) = \{\int_a^b f(x) d(x)\} \qquad (4)$$

The probability density function (PDF) of an exponential distribution has the form

$$f(x;\lambda) = \begin{cases} \lambda e^{-\lambda x}, x \geq 0 \\ 0 \quad\quad , x < 0 \end{cases} \quad (5)$$

Where $\lambda > 0$ is a parameter of the distribution, often called the rate parameter. The distribution is supported on the interval $[0, \infty)$. If a variable has this distribution, we write $X \sim$ Exponential (λ) [13].

3. Results and Discussion

The experimental results of the overall vibratory velocity of DE of the electromotor are shown in figure 1. According to ISO TC108, 1963 standard, the warning and critical reference value of overall vibratory velocity level is 2.8 and 4.5 mm/s, respectively. Vibratory velocity level of DE of the electromotor is on warning status at first and fourth measurement.

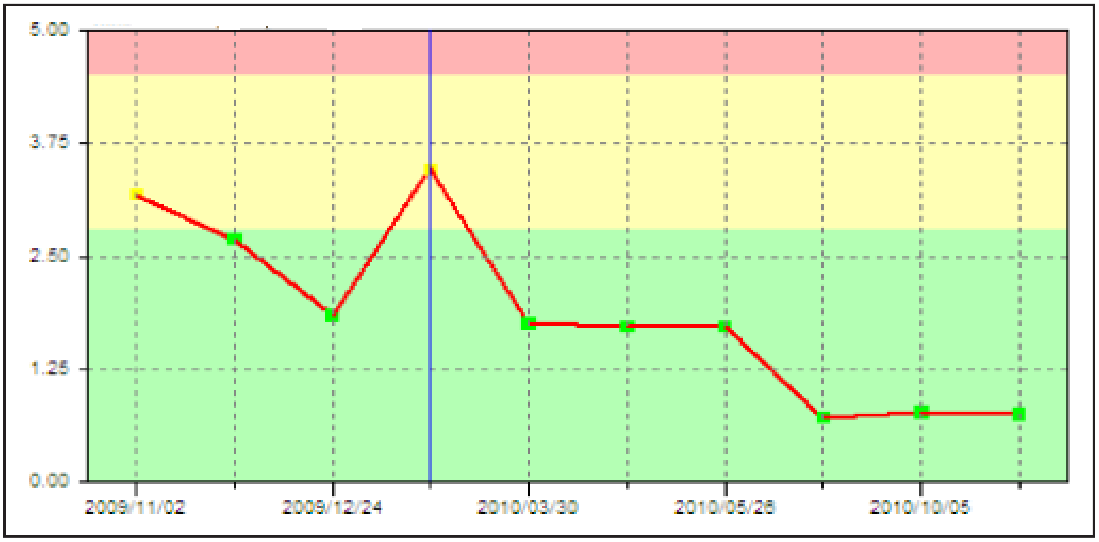

Figure 1. Overall vibrations of DE of the electromotor

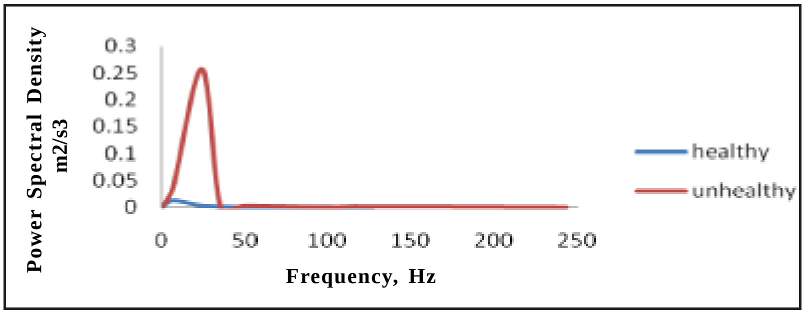

Figure 2. Power Spectral Density result of the DE of the electromotor on healthy and unhealthy situations

We measured frequency spectrum of electromotor but it is obviously difficult to diagnose faults by using spectrum of vibration signals alone. By using of frequency spectrum result, we calculate PSD of electromotor in different situation. Figure 2 shows the PSD curves of DE of the electromotor in healthy and unhealthy situations.

Vibration signals carry information about exciting forces and the structural path through which they propagate to vibration transducers (Williams, 1994) [14].Time signal plots (figure 3 and 4) recorded during the operation of DE of the electromotor on healthy and unhealthy situations respectively.

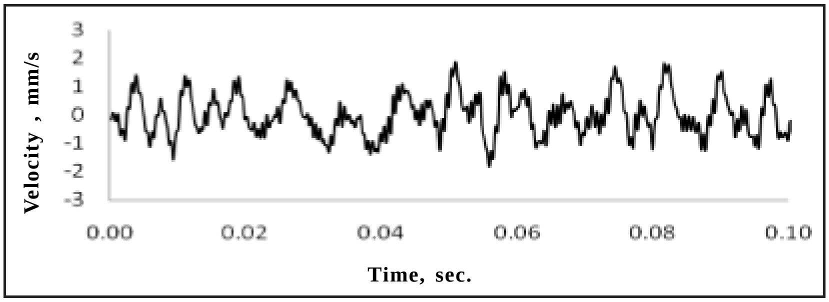

Figure 3. Time signal result of DE of the electromotor on healthysituation

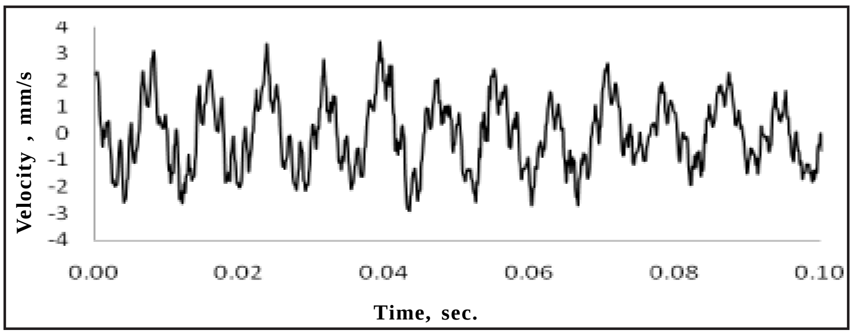

Figure 4. Time signal result of DE of the electromotor on unhealthy situation

The results showed that by using the fault probability distribution function we can find the specific frequency and the exact value of fault probability as soon as possible. Figure 5 shows fault probability distribution function of DE of the electromotor of process water pump before repair.

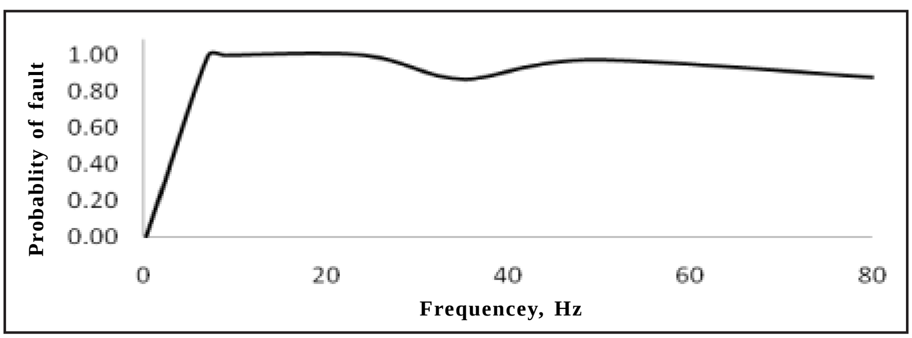

Figure 5. Fault probability result of DE of the electromotor before repair

4. Conclusions

The results showed that area under PSD carves were indicated a problem. The more area below PSD curve showed the faults were deeper. Integration of vibration condition monitoring technique with Power Spectral Density analyze could indicate more understanding about diagnosis of the electromotor. Vibration analysis and Power Spectral Density could provide quick and reliable information on the condition of the electromotor on different situations. By comprising of unhealthy and healthy situations, we can understand that the different between modulation of electromotor before and after repair. In unhealthy situation the results of time signal showed that we had more unshaped signal and also modulation and the overall of time signal in this situation was over than healthy situation. The results showed that by using the fault probability distribution function we can find the specific frequency and the exact value of fault probability as soon as possible.

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