Fault Diagnosis in Electromotor Pumps using Vibration Analysis

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ABSTRACT: *Power Spectral Density (PSD) refers to the amount of power per unit of frequency as a function of the frequency. The PSD describes how the power (or variance) of a time series is distributed with frequency. In this research, we calculated Grms (Root-Mean-Square Acceleration) and PSD of NAJI fire pump on healthy and unhealthy situations. In addition, we calculated Grms and PSD of NAJI fire pump electromotor on healthy, misalign and looseness situations. The results showed that different situations showed different PSD vs. frequency. With calculating PSD, we could find some fault and diagnosis of pump and electromotor as soon as possible. The results of this paper have given more understanding on the dependent roles of vibration analysis and Power Spectral Density carve in predicting and diagnosing of the pump and the electromotor faults.*

Keywords: Vibration, Power Spectral Density, PSD, Pump, Electromotor, Fault Diagnosis

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1. Introduction

Vibration signals carry information about exciting forces and the structural path through which they propagate to vibration transducers [1]. Vibration characteristics can be distinctively divided into two types: forced vibration and free vibration. Typical forced vibration relates to problems such as misalignment and excitation of electrical or mechanical nature. Free vibration is a self-excited phenomenon that is dependent on the geometry, mass, and damping of the system, and typically caused by structural, acoustic resonance, and by aerodynamic or hydrodynamic excitation. Byrne and his co-worker showed that condition monitoring had a good application in industrials [2]. Vibration analysis in particular has for some time been used as a predictive maintenance procedure and as a support for machinery maintenance decisions [3]. In this research, density data produced by vibration analysis was compared with previous data. Numerical data produced by PSD were compared with power spectral density in healthy situation of pump and electromotor of NAJI fire pump in order to quantify the effectiveness of the power spectral density technique [4, 5 and 6].We were calculated Grms and PSD of pump and electromotor of NAJI fire pump in different situation. It was shown that PSD provides a good and rapid method to show faults of pump and electromotor. The objective of this research was to investigate the correlation between vibration analysis, PSD and fault diagnosis.

1.1 Calculating G_{rms}

It is very easy to describe the G_{rms}(sometimes written as GRMS or Grms or grms or g_{rms})value as just the square root of the area under the ASD vs. frequency curve, which it is. But to physically interpret this value we need to look at G_{rms} a different way. The easiest way to think of the G_{rms} is to first look at the mean square acceleration. Mean-square acceleration is the average of the square of the acceleration over time. Those is, if you were to look at a time history of an accelerometer trace and were to square this time history and then determine the average value for this squared acceleration over the length of the time history, that would be the mean square acceleration. Using the mean square value keeps everything positive. Below is presented the method to calculating the G_{rms} response from a random vibration ASD curve [4, 5]. Figure 1 shows a bandwidth of 10 Hz, which will be used as an example for calculating Grms [4, 5].

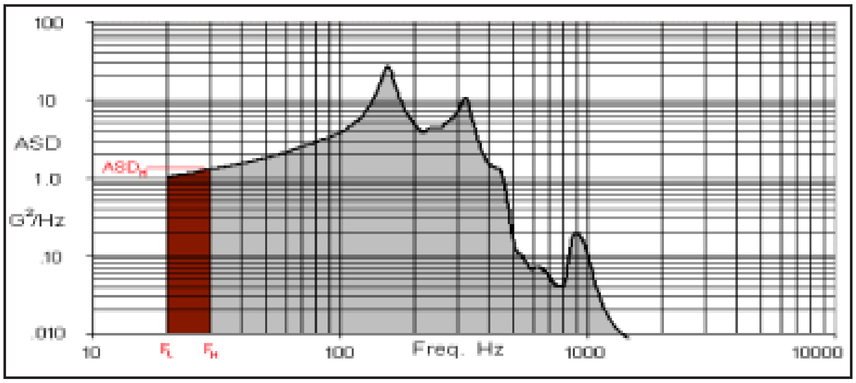

Figure 1. A bandwidth of 10 Hz [5, 6]

We can calculate the number of octaves from (1).

$$\#Octaves = \frac{log(F_H / F_L)}{log(2)} \tag{1}$$

The dB value calculates by equation number 2.

$$dB = 10log(ASD_H \, / \, ASD_L) \tag{2}$$

The slope, m can calculate by (3).

$$m = dB \, / \, \#Octaves \tag{3}$$

For calculating, the area under the curve between the frequencies FL and FH , we can use by (4)

$$\left[A = 10\log(2)\frac{ASD_H}{10\log(2)+m}\left[F_H - (F_L)\left(\frac{F_L}{F_H}\right)^{m/10\log(2)} \right]\right] \tag{4}$$

NOTE - The above equation is invalid if the slope m = -10log (2) because you would be dividing by zero.

If m = -10log (2), use (5) for the area [4,5]:

$$\mathrm{A} = ASD_L \times F_L \times In\left(\frac{F_H}{F_L}\right) \tag{5}$$

(L'hôpital's Rule is used to solve the equation as the limit of [1 + m/(10log2)] goes to zero -- or some such nonsense.) The G_{rms} value takes from the square root of the area that shows in (6).

$$g_{rms} = \sqrt{\mathrm{A}} \tag{6}$$

In order to calculate the G_{rms} value for the entire curve, sum up all the areas (A1 + A2 + A3 + ... + An = A) and take the square root of the sum [4, 5].

1.2 Power Spectral Density (PSD)

Most random vibration testing is conducted using Gaussian random suppositions for both measurement and specification purposes. With Gaussian assumptions, there is no definable maximum amplitude, and the amplitude levels are measured in RMS (root-mean-squared) values [3, 4]. Random vibration can be thought of as containing excitation at all frequencies within the specified frequency band but no excitation at any specific single frequency [4, 7]. An acceleration spectrum is normally specified in terms of its' acceleration density using the units of g^2 per Hz. Acceleration density is defined as (7) [4,7]:

$$g_d = \lim a^2 / \Delta f / \Delta f \geq 0 \tag{7}$$

Where: g_d = acceleration density, a = rms acceleration, • f = bandwidth

2. Experimentation and Testing

The test rigs used for the experimentation were the pump and electromotor. The Pump was running under healthy and unhealthy situations. The electromotor design incorporated an unbalance, a coupling disk system to impose shaft misalignment, and looseness. The coupling discs system was used to create an angular misalignment. The power of electromotor was 16 KW, three phase, variable speed. The Vibration data were collected on a regular basis after the run in period. The experimental procedure for the vibration analysis consisted of taking vibration readings at one location over the pump and taking vibration readings at one select location over the electromotor. Vibration measurements were taken on the input shaft casing of pump and on the DE of electromotor using an Easy-Viber (VMI was the manufacturer). We were fixed our pump on healthy and unhealthy situations and we were fixed our electromotor on different faults and measured the overall vibration and calculated Grms and PSD on that situation.

3. Results and Discussion

Figure 2 and 3 showed frequency spectrum result of input shaft casing of the pump in healthy and unhealthy respectively. The frequency spectrum of each fault was different and overall vibration values also were different at the same frequency.

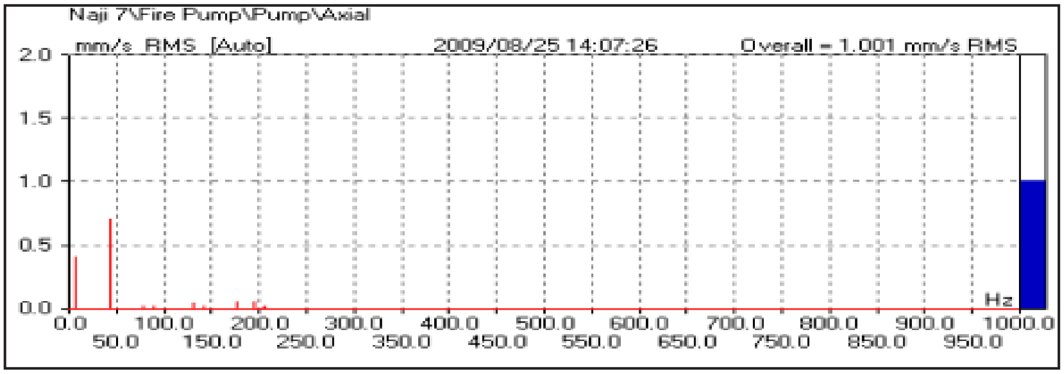

Figure 2. Frequency spectrum result of input shaft casing of pump on healthy situation

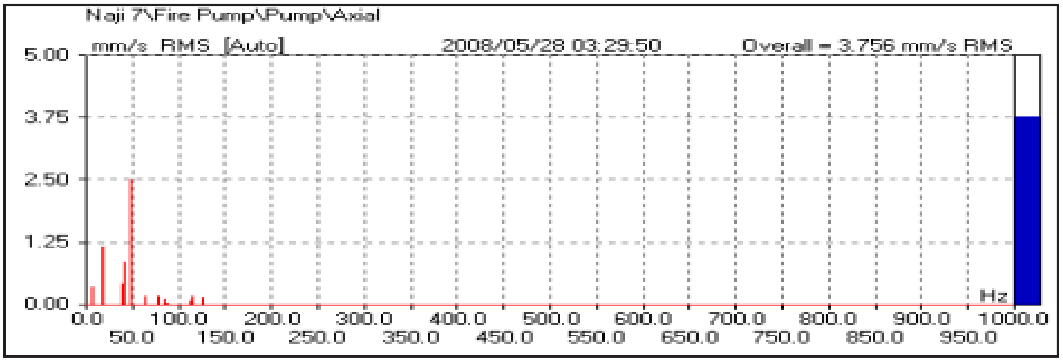

Figure 3. Frequency spectrum result of input shaft casing of pump on unhealthy situation

Figure 4 and 5 show the power spectral density of input shaft casing of pump in different situation. There was big different between PSD of healthy and unhealthy situations. The results showed that different situations were showed different PSD vs. frequency. The results showed that with calculating PSD we could find some fault and diagnosis of pump as soon as possible.

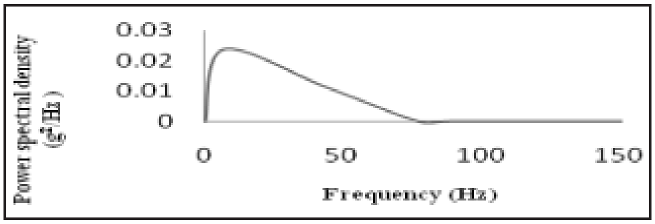

Figure 4. Power Spectral Density result of pump on healthy situation

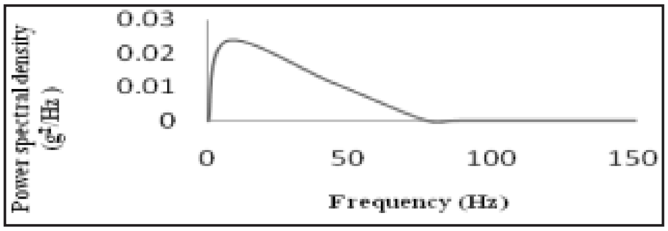

Figure 5. Power Spectral Density result of pump on unhealthy situation

Figure 6 until 8 showed frequency spectrum result of DE of electromotor in healthy, misalign and looseness, respectively.

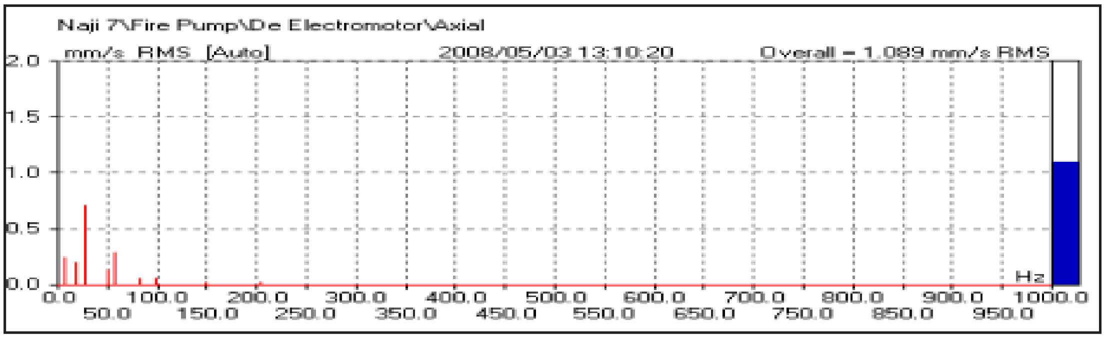

Figure 6. Frequency spectrum result of DE of electromotor on healthy situation

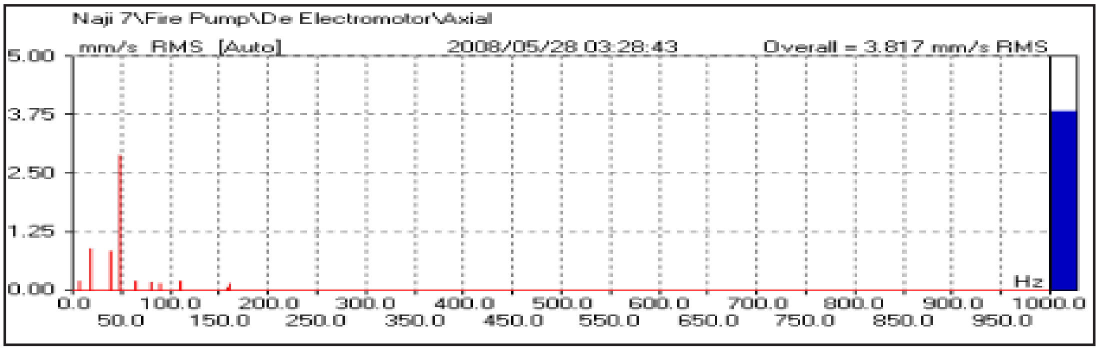

Figure 7. Frequency spectrum result of DE of electromotor on misalign situation

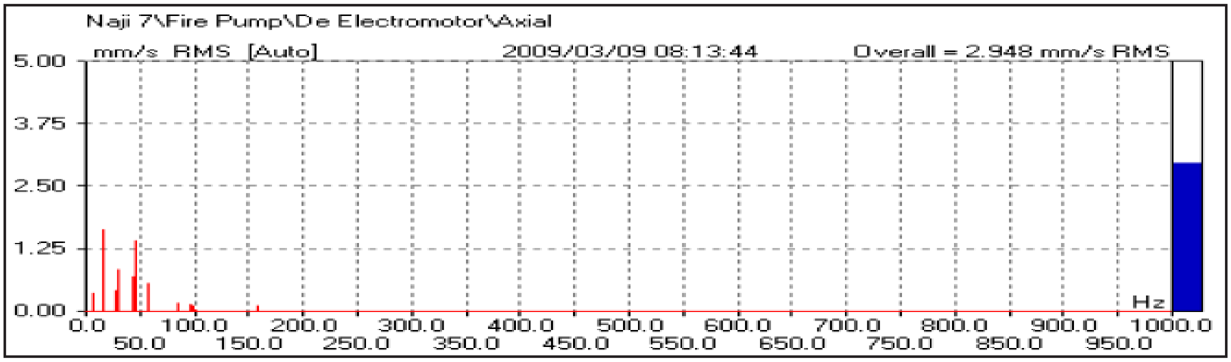

Figure 8. Frequency spectrum result of DE of electromotor on looseness situation

The results showed that area under PSD carves were indicated a problem. The Fig.9 until 11 shows the PSD of DE of electromotor in different situation. There was big different between PSD of looseness fault and other faults. Results showed that when we had deeper faults such as looseness the area under PSD carves was grown.

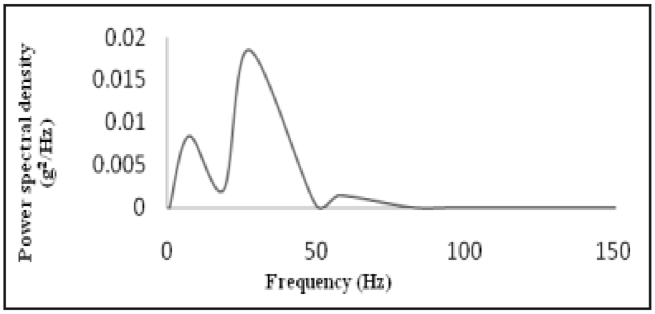

Figure 9. Power Spectral Density result of electromotor on healthy situation

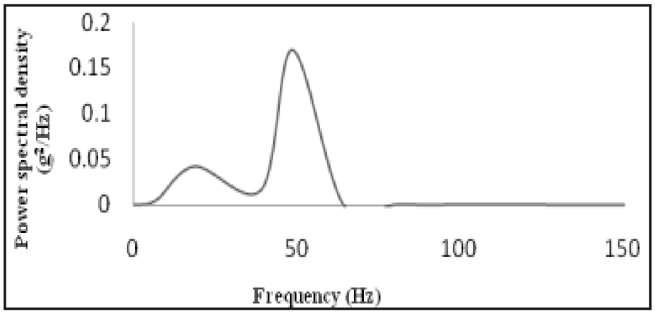

Figure 10. Power Spectral Density result of electromotor on misalign situation

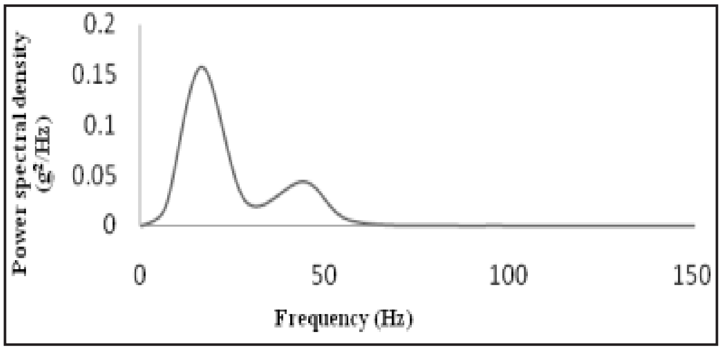

Figure 11. Power Spectral Density result of electromotor on looseness situation

Results showed that vibration condition monitoring and Power Spectral Density technique could detect fault diagnosis of the pump and electromotor. Vibration analysis and Power Spectral Density could provide quick and reliable information on the condition of the pump and electromotor on different situations. Integration of vibration condition monitoring technique with Power Spectral Density analyze could indicate more understanding about diagnosis of the pump and electromotor.

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