Vibration Signals Analysis and Condition Monitoring of Centrifugal Pump

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ABSTRACT: Centrifugal pumps are widely used in a variety of applications. In many applications the role of centrifugal pump is critical and condition monitoring is essential. The objective of this study is to investigate the correlation between vibration analysis and fault diagnosis of centrifugal pump. This was achieved by vibration analysis and investigating different operating conditions of centrifugal water pump. This pump coupled to the electromotor that was run under of speed 1450 RPM. The pump conditions were considered to be normal pump, broken impeller and leakage faults with the aim of fault detection. Vibration data was collected from the inspected pump and compared with vibration spectra in normal condition of healthy machine. The results from this study have given more understanding on the dependent roles of vibration analysis in predicting and diagnosing machine faults.

Keywords: Vibration Signals, Fault diagnosis, Centrifugal pump

INTRODUCTION

Centrifugal pumps are one of the most important elements in almost all industries. They play an important role in industries and it requires continuous monitoring to increase the availability of the pump. The pumps are the key elements in food industry, waste water treatment plants, agriculture, oil and gas industry, paper and pulp industry, etc (Azadeh et al., 2010; Sakthivel et al., 2010). Therefore, monitoring of pumps is necessary to prevent a decrease in their efficiency. Condition monitoring of rotating machinery is important in terms of system maintenance and process automation (Schoen et al., 1995). Vibration analysis has been used in rotating machines fault diagnosis for decades. By measuring and analyzing the vibration of a machine, it is possible to determine both the nature and severity of the defect, and hence predict the machine’s useful life or failure point (Marcal et al., 2000; Laggan., 1999). Usually, vibration signals are acquired from accelerometers mounted on the outer surface of a bearing housing. The signals consist of vibrations from the meshing gears, shafts, bearings, and other components. The useful information is corrupted and it is difficult to diagnose a pump from such vibration signals (Hongkaia et al., 2006). Vibrations externally measured on a pump have been used to monitor the operating condition of the pump and diagnose the fault, if there is any, without interfering with the normal operation. The most common method employed for examining mechanical vibration is spectral analysis. Condition monitoring and fault diagnostics is useful for ensuring the safe running of machines (Peng and Chu., 2004). Vibrations signals are often used for fault signals diagnosis in mechanical systems since them often carry dynamic information from mechanical elements. These mechanical signals normally consist of a combination of the fundamental frequency with a narrowband frequency component and the harmonics. Most of these are related to the revolutions of the rotating system since the energy of vibration is increased when a mechanical element is damaged or worn. Some of the conventional techniques used for fault signals diagnosis include power spectra in time domain or frequency domain, and they can provide an effective technique for machinery diagnosis provided that there is the assumption that the signals are stationary(Ren et al., 2006). By measuring and analyzing the vibration of a machine, it is possible to determine both the nature and severity of the defect, and hence predict the machine’s useful life or
The main advances in vibration analysis in recent years are the development in signal processing techniques, for vibration diagnostics of gearing systems (Laggan., 1999). The development of the Fast Fourier Transform (FFT) in 1965 (Cooley and Tukey., 1965) allowed the development of commercial real-time spectral analyzers and, as the use of these analyzers become more widespread, a number of authors describe the vibration effects of various machine faults and how these could be diagnosed using spectral analysis (Minns and Stewart., 1972; Farokhzad et al., 2012; Swansson., 1980).

**Experimental Setup**

The main objective of the study is to find whether the centrifugal water pump is in good condition or in faulty condition. If the pump is in faulty condition then the aim is to segregate the faults into seal fault and impeller fault. Referring to figure (1), the experimental setup to collect dataset consists of centrifugal water pump (made by Pumpiran company, pump model: 40-250(Ø220)1450), an electrical motor with one speed that driven the system, a triaxial accelerometer and an data acquisition. Test-bed was designed and constructed to install pump and electromotor. The location of accelerometer shown in figure (2).

![Experimental setup](image1)

**Figure 1. Experimental setup.**

![Location of accelerometer](image2)

**Figure 2. Location of accelerometer.**

This pump coupled to the electromotor that was initially run under normal operating conditions and its speed was at 1450 RPM. Two different configurations were tested broken impeller and leakage (seal faulty) conditions (figure (3)). All vibration signals were collected from the experimental testing of pump using the
accelerometer which was mounted on the In-Bearing of input shaft of the pump. The signals from the accelerometer were recorded in a data acquisition.

Gear sets generate tones known as the gear mesh frequency. The gear mesh frequency is calculated via equation 1.

\[ GMF = \text{No.of Teeth} \times \text{RPM} \]  

The corresponding spike at this frequency generally amplifies as gear damage increases (Andy et al., 2003), according to we used from this theory to calculate the impeller mesh frequency. The impeller mesh frequency calculated via equation 2.

\[ IMF = \text{Number of blade} \times \text{RPM} \]  

RESULTS AND DISCUSSION

The most basic form of vibration analysis is called an overall vibration measurement. This reading provides a single number that describes the total amount of vibration energy being emitted by a machine. The idea is that more vibration indicates a problem. Signal data was acquired for machine conditions, including: a normal pump, broken impeller and leakage of the pump at operating speed of 1450 RPM. The experimental results of the overall vibratory velocity level of pump have shown in figure (4). The warning and critical reference value is 2.8 and 4.5 mm/s, respectively. It's obvious from figure (4) that the overall vibratory velocity level of the in-bearing of pump was on critical level at several measurements. The typical vibration spectrum of the in-bearing of pump has shown in figure (5), that shows the measured vibration spectra and the arrows show main vibration peaks.

CONCLUSIONS

The results clearly indicate a significant variation in vibration trend as a function of operating conditions. The experimental results demonstrated that the vibration monitoring rig modeled various modes of machine failure was indeed capable of both independently and simultaneously generate common machine faults. In this research we have been made an experimental test system that we were able to perform practical tests on the constructed rig to confirm the expected theoretical frequencies that we needed. This research was offered complementary strengths in root cause analysis of machine failure, and natural allies in diagnosing machine condition. It reinforces indications correlation between vibration condition monitoring and fault diagnosis for centrifugal pump. Both amplitude of the dominating peak and its location along the frequency axis changes in various conditions of pump.
The data indicate that it is not possible to conclude that the cause of real world machinery malfunction is fault pump just by looking at a single vibration spectrum at an operating condition. A careful examination is essential to differentiate fault pump from other sources of vibration. The corresponding stress will depend upon the stiffness of the machine structure. The frequencies of peak vibration amplitude, set locations and directions were inconsistent even with speed and coupling held constant. For predictive maintenance applications where the goal is machinery health monitoring, it is sufficient to realize that the problem is complex. One can routinely trend the vibration spectra until it becomes severe. But for root cause analysis, one must exercise caution and perform a detailed analysis. Obviously, the rules provided in training courses and wall charts are doubtful at best.

Figure 4. Comparison of overall vibrations of pump in healthy, broken impeller and leakage condition.

Data analysis required comparing the plots obtained for each test condition to those expected for the specific machine faults simulated. Prominent frequency spikes determined from the time and frequency domain graphs were also compared to the theoretical vibration fault signatures. The results showed that the RMS values for healthy pump at 1450 rpm were on acceptable status. The results showed that the RMS values for the broken impeller were on critical status.

Table 1. Fundamental impeller damage frequency.

<table>
<thead>
<tr>
<th>Shaft Speed (rpm)</th>
<th>Theoretical Frequency (Hz)</th>
<th>Experimental Central Frequency(Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1450</td>
<td>169.16</td>
<td>295.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Impeller Broken Sealed Faulty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>159.13</td>
</tr>
</tbody>
</table>

Figure 5. Frequency spectrum of the different conditions of pump.
Measurement values and mean of them were higher than the RMS value of pump in healthy condition. Figure (4) showed the overall vibrations of impeller broken and leakage condition in comparison with healthy condition. As can be seen in figure, the prominent frequency peak occurred with high accuracy near the predicted value of impeller mesh frequency, as shown in Table 1.

REFERENCE


Minns H, Stewart RM. 1972. An introduction to condition monitoring with special reference to rotating machinery, Workshop In On-Condition Maintenance, Section 8, Institute of Sound And Vibration Research, University of South Ampton.


