To Review on Crack Detection in Centrifugal Pump using Vibration Analysis

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ABSTRACT
Centrifugal pumps play a vital role in many critical applications and these are the largest single consumer of power in industry. This means that faulty pumps cause a high rate of energy loss with associated performance degradation, high vibration levels and significant noise radiation. This paper focuses on a problem of vibration-based condition monitoring and fault diagnosis of centrifugal pumps. Time index parameter is applied as fault indicator and the power spectrum analysis is used as a frequency domain analysis. The amplitude of the impeller passing frequency and the vibration time index are increased as the blade crack size is developed, which can be used as indicator for fault severity. A test ring method used to the analysis the vibration in the pump.

Keyword---- Monitoring, Performance Pump, Vibration, fault

I. INTRODUCTION
Centrifugal pumps are utilized widely in the oil and chemical industry. Great attention has been paid to the condition monitoring and fault diagnosis of the centrifugal pump by the field engineers and technicians. 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 [1]. The monitoring of the centrifugal pumps is necessary to ensure high-performance safety operations of pumps. Therefore, many studies have been conducted in recent years with more advanced data analysis methods applied to the vibration of the pump.

Saeid Farokhzad [2] presented an adaptive network fuzzy inference system (ANFIS) to diagnose the fault type of the pump. The pump conditions were considered to be healthy, broken impeller, worn impeller, leakage and cavitations. These features are extracted from vibration signals using the FFT technique. The features were fed into an adaptive neurofuzzy inference system as input vectors. Performance of the system was validated by applying the testing data set to the trained ANFIS model. 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 [3].

II. VIBRATION SOURCES OF A CENTRIFUGAL PUMP
2.1 Working mechanism of a centrifugal pump
A centrifugal pump consists of the rotating elements (e.g. pump impeller and shaft) and stationary elements (e.g. electrical motor and associated cooling fan, casing box and bearings). The vibration of the working pump is generated by both mechanical and hydrodynamic sources. The mechanical sources are invariably generated by rotation of unbalanced masses and friction in the bearings. Hydrodynamic vibration is due to fluid flow perturbations and interaction of the rotor blades particularly with the volute tongue and guide vanes.

2.2 Vibration sources
All machinery with moving parts generates mechanical forces during normal operation. As the mechanical condition of the machine changes because of wear, changes in operating environment, load variations etc. The vibration profile that results from motion is the result of a force imbalance – there is always some imbalance in real-world applications [4]. Causes of vibrations are of major concerns because of the damage to the pump and piping that generally results from excessive vibration. Excessive vibration in a pump may be a result of improper installation or maintenance,
incorrect application or hydraulic interconnections with the piping system [5]. Vibration can be defined as simply the cyclic or oscillating motion of a machine or machine component from its position of rest. Forces generated within the machine cause vibration. These forces may:
1. Change in direction with time, such as the force generated by a rotating imbalance.
2. Change in amplitude or intensity with time, such as the unbalanced magnetic forces generated in an induction motor due to an unequal air gap between the motor armature and stator.
3. Result in friction between rotating and stationary machine components in much the same way that friction from a bow causes a violin string to vibrate.
4. Result from impacts, such as the impacts generated by the rolling elements of a bearing passing over flaws in the bearing raceways.
5. Result from randomly generated forces such as flow turbulence in fluid-handling devices such as fans, blowers and pumps; or combustion turbulence in gas turbines or boiler. [6]

2.3 Vibration changes with operating conditions
With a worn impeller the loss in discharge pressure is associated with a loss of pump efficiency, therefore the power consumed by the pump will either remain the same, or increase as wear occurs. With wear, operational records will indicate a gradual change in performance over some period of time. Partially blocked pathways will usually be evidenced by a pump that delivers full discharge pressure at shut-off, with a sharp drop in discharge pressure as flow is increased. The drop in discharge pressure is often accompanied by increased vibration as the flow restriction starts to cause cavitations. If vibration is also present at shut-off the blockage may be in the impeller causing a physical imbalance [7].

III. VIBRATION ANALYSIS

3.1. Machine Vibration Index (VI)
It is a time domain parameter namely Vibration Index (VI) which correlates the vibration amplitudes ($V_{i}$) in three directions, vertical (Y), horizontal (H) and axial (Z), with the present and the severity of the fault and defined by Harihara and Parlos (2008):

$$V_I = \sqrt[3]{\sum_{i=1}^{N} \left[ \sqrt{\sum_{j=1}^{3} V_{i,j}^{2}} \right]}$$

3.2 Power Spectrum (PS)
It is the power of the spectrum measured in decibel (dB) and given by:

$$PS(dB) = \frac{1}{2\pi} \int_{-\infty}^{\infty} |F(w)|^2 dw$$

Where, $F(w)$ is the Fourier Transform (FT) of vibration signal.

The spectrum analysis as it reduces the unwanted noise or distortion and focus more on the feature signal. By using power spectrum analysis the machinery fault could be diagnose even with its severity. The presence and severity of the impeller crack impeller cause a clear increment in the amplitude of the spectrum at the impeller passing. If the crack size increases more, the harmonics of impeller frequency will be introduced. With more crack size a sidebands of the impeller frequency at the impeller rotational speed and its harmonics will appear in the frequency spectrum.[8]

IV. EXPERIMENTAL SETUP
The pump test rig consists of a centrifugal pump, electric motor and close-loop piping water system for water circulation, which is schematized in Fig4.1. The pump model is a F32/200A series standardized to DIN 24255. It is a single suction, single stage, end/top discharge, closed impeller and closed-coupled centrifugal pump, which can deliver water at a rate of 250 l/min m at a head of up to 55 m. A variable-speed electric motor is used to control the speed of the centrifugal pump by adjusting the supply to the three phase induction motor of 4 kW at 2900 rpm.

<table>
<thead>
<tr>
<th>Type</th>
<th>Accelerometer (piezoelectric)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>YD3-8131</td>
</tr>
<tr>
<td>Frequency</td>
<td>2Hz-15kHz</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>1.51 mv/ms-2</td>
</tr>
<tr>
<td>Range</td>
<td>&lt; 2000 ms-2</td>
</tr>
<tr>
<td>Temperature range</td>
<td>&lt; 250°C</td>
</tr>
</tbody>
</table>

Table1. Specification of the accelerometer

![Fig4.1. Schematic of test system](image)
addition, the rotational speed of the pump is measured by a shaft encoder at the free end of the motor. A flow sensor was installed in the discharge line for flow rate measurement. Two pressure sensors are installed in the suction and discharge lines respectively for pump delivery head measurement [9].

The predicted characteristics between the NPSHa and NPSHr for this system were obtained by throttling the valve in the discharge line progressively, the relation between NPSHa, NPSHr and flow rate. NPSHr (from pump head) increases with flow rate and increases rapidly above 220 l/m. The measured NPSHa decreases with flow rate and the NPSHa- NPSHr intersection occurs at a flow rate of approximately 320 l/m and head 5.75(m) [10].

![Figure 4.2. Pump performance](image1)

V. RESULT

The results for all tests show that the vibration level increases with increased of flow rate and with different readings, this is due to a different type of defect on each impeller. The vibration index increases as the impeller blades cracks increases. At healthy condition, the index vibration is 0.793 while with crack 9 it reaches to 1.341 which shown in fig.

![Fig. Machine Vibration Index Response](image2)

There are three peaks at frequencies of 1655Hz, 3310Hz and 4965 Hz, with different amplitudes. The 2nd and 3rd frequency peaks are equals to the multiples of the first peak (harmonics). The first peak amplitude is rises as the blade crack size increases and it is proportionally increases with crack size until it reach until it reaches to maximum value at crack 9.

![Fig. The time domain signal and the corresponding power spectrum for cracked impeller](image3)

Power consumption is higher for the faulty condition particularly for flow rates higher than 250 l/m. Vibration acceleration is generally greater for the faulty condition for flow rates between 100 l/m and 320 l/m, as can be seen from the blue and red lines in Fig.

![Fig. power vs flow rate](image4)

The vibration acceleration for the faulty pump is almost linearly proportional to flow between 50 to 220 l/m and then increases rapidly up to 320 l/m flow rate after which it decreases rapidly. The vibration acceleration for the healthy pump increases almost linearly between flow rates of 50 and 275 l/m then increases rapidly.

![Fig. Vibration acceleration vs flow rate](image5)
VI. CONCLUSION

Based on a general understanding of vibration characteristics of pumps, experimental studies have been carried out on a centrifugal pump for developing effective diagnosis features for incipient impeller defects. This paper investigated the centrifugal pump impeller cracks diagnosis using vibration analysis. The vibration index is applied as a time domain fault indicator and power spectrum at specified frequencies as a frequency fault indicator. It is concluded that the vibration index increases as impeller crack size increases. By using power spectrum analysis, as the impeller crack size increases, the fundamental frequency (impeller frequency) increases. The vibration level increases with increased of flow rate and with different readings, this is due to a different type of defect on each impeller. The experimental study has shown that data obtained from impellers with different gaps are different. The pump faults may then be identified using these data/features.

REFERENCE


