Diagnosis of Centrifugal Pump's Impeller Condition Using Frequency-Domain Analysis

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Abstract: This paper studies condition monitoring of the centrifugal pump impeller and the influence of the damaged impeller on centrifugal pump vibration behaviors using vibration analysis of frequency – domain method. A centrifugal pump setup is used to study both conditions of healthy impeller and damaged impeller. Impeller consists of six blades where one blade is removed and vibration forces are monitored using frequency-domain analysis. Vibration data would be acquired from two locations, namely, bearing housing and pump discharge. The acquired signals would be analysed and plotted into graphs, where the condition of centrifugal pump with conditions of normal and damaged impeller can be compared.

1. Introduction

The Centrifugal pump is known for its industrial widely preferred machine due to its major applications such as food processing and water or sewage transference. Failures of the centrifugal pumps have to be well monitored as it could lead to catastrophic damage and causes interruption for the production. Such pump failures can be classified as hydraulic and mechanical ones [1]. Vibration analysis can be used as a good method for the pump fault detection, where for the certain mechanical or hydraulic vibration forces would be certain frequencies [1-3]. Impeller plays a major role in pump operation where the type and specifications of impeller have to be carefully selected as they affect the pump performance. Condition of impeller has to be well monitored as well as it can experience different types of damage due for instance to cavitation [1,2].

Many of earlier researchers have done many investigations and examinations in this field. University of Strathclyde (2003) [4] has proposed a computer system to analyse and detect the fault of centrifugal pump, they have remarked high level of vibration at impeller blade passing frequency and its harmonics. Zouari, et al. (2004) [5] used the artificial neural network to diagnose the centrifugal pump and particularly diagnosing the faults of (misalignment, partial flow and air injection). Nordmann and Aenis (2004) [6] built a software to identify and detect crack, also based on the measurement of the system output if can be diagnosis the centrifugal pump.

Fast Fourier Transform (FFT) algorithm computes the discrete Fourier transform (DFT) of a sequence, or it’s inverse. Fourier analysis converts a signal from its original domain (time-domain) into frequency-domain. An FFT effectively calculates such transformations by factorizing the DFT matrix into a product of sparse (mostly zero) factors. There are many different FFT algorithms in mathematics, from simple complex-number arithmetic to group theory and number theory [7].

The below following equation is for Fast Fourier Transform (FFT):

\[ X(f) = \frac{1}{M} \sum_{m=0}^{M-1} F[x(\tau)] e^{-2\pi j t M} dt \]

X (f): is the Fourier Transform.

x (t): is the time signal.

j: is a complex number.

This paper is divided into four parts including introduction. Part 2 presents experimental setup and methodology. Part 3 illustrates results and discussion. Finally, a conclusion with remarks is given in part 4.

2. Experimental Setup and Methodology

This work conducted using a centrifugal pump test rig as shown in Figure 1 and it includes the following components:

A DC motor is used to rotate the centrifugal pump. Shaft which is used to connect the DC motor and the centrifugal pump and used to rotate the centrifugal pump. Coupling is used to fitting the shafts together. Centrifugal pump is used to convert the rotating energy to the fluid. Pressure gauges are used to measure the pressure of water. Flow meter is
used to measure the flow of water. Pipes which are used to transfer the fluid from centrifugal pump to the tank and from the tank to the centrifugal pump. Accelerometer sensor is used to capture the signal from the centrifugal pump. DAQ with A/D card are used to convert the signal from analog to digital. A computer is provided with LABVIEW software and MATLAB software. Digital tachometer is used to measure the speed of the shaft (RPM).

An accelerometer sensor is used to collect the vibration signals at different conditions. Such readings are sent to DAQ where have to be amplified and filtered out and at a proper sampling rate, a A/D converts the analog signals to digital ones. LABVIEW software is used to capture the signals. Finally, signals are further processed using MATLAB and particularly with frequency domain. Diagnosis of impeller condition would be tested and confirmed by Fast Fourier Transform (FFT) based on a developed MATLAB code.

3. Results and Discussion

The vibration signals of both healthy and faulty impeller were acquired and first displayed in LABVIEW. Then an FFT code was developed in MATLAB software and results were analysed based on the followings:

Speed of the centrifugal pump was 3000 RPM.

\[
\omega = \frac{2 \pi n}{60} = 50 \text{Hz (Frequency)}
\]

And LABVIEW has shown some harmonics (Multiples) like;

50=1X, 100=2X, 150=3X, 200=4X

Create damage on blades in the impeller of the centrifugal pump as shown in Figure 2, there are 6 blades, one blade was removed.

Results have been obtained through different accelerometer mounting positions which are vertical, horizontal and axial. Such vibration signals were also acquired from both discharge and bearing housing locations. Generally, vibration signals were processed and analyzed using frequency-domain and particularly using Fast Fourier Transform (FFT).

Figures 3 and 4 below describe the healthy condition of the impeller.

![Figure 3. (a) Time domain, (b) Frequency domain of centrifugal pump normal axial reading at discharge.](image-url)
By comparing the three mounting positions (axial, horizontal and vertical) for healthy condition, all are shown healthy behaviors. It is found the best position to take the reading at discharge is the axial position because the frequency is clear with low noise, and Figure 3 is very clear. Although the other one is also shown healthy behavior with normal and low vibration and it is shown that the best position to take the reading at bearing housing is the axial position because the frequency is clear with low noise, and Figure 4 is very clear. Although the other one is also shown healthy behavior with normal and low vibration.

Figures 5 and 6 below describe the faulty condition of the impeller.

**4. Conclusion**

This work was completed successfully starting from the stage of acquiring the signals from test rig and then processing these signals through MATLAB software. The ability of FFT in detecting impeller condition has been tested and confirmed. The results were compared between normal and faulty conditions, and the frequency domain of healthy signals were found to be smooth and with low noise, and with faulty condition, signals were found noisy.
ones and corresponding with (BPF) with its harmonics. Impeller damage was created by removing one blade from the six blades of impeller. Axial direction from both locations of bearing housing and discharge were found to have the best results.

5. References


