Cavitation detection of centrifugal pump using Time – Domain method

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Abstract— This paper studies cavitation detection of centrifugal pump using Time –Domain method. Centrifugal pump is the most popular pump which is widely used in the world. The centrifugal pump may face many problems, one of these is cavitation. Cavitation is formation of bubbles or cavities in liquid that is developed when there is low pressure around the impeller. Cavitation can lead to failure of pump housing, impeller damage and decreased flow and pressure. So, this project is to detect the cavitation fault using time domain method and particularly using parameters such as; Kurtosis, RMS, Mean and Peak. The vibration signals were collected from different positions, namely, vertical, horizontal and axial, and all results were compared for healthy and cavitation conditions. The results were plotted as graphs using MATLAB and tables were also provided.

Keywords— Centrifugal pump, Cavitation, Time domain, Root Mean Square, peak, Mean and kurtosis.

INTRODUCTION

The most popular pumps used in the world are centrifugal pumps. There are various applications for the centrifugal pumps in industries such like; water pumping from lower level to higher one, and to transfer different liquids . The important two parts of this type of pumps are the impeller and the volute. The impeller part can be either open, semi-open or closed, and its purpose to imparting kinetic energy by rotation to the incoming fluid. The second part is volute which is used to redirect the fluid from the impeller and channels to be in a single direction. The main purpose of the pump is to increase the pressure of the incoming fluid and channel and make it in the desired direction [1].

Cavitation is the formation and collapse of vapor bubbles inside the pump. Cavitation occurs when the absolute pressure on the liquid is less than the liquid vapor pressure. The sound can be heard when the vapor bubbles collapse occur, this sound like some rocks are moving inside the pump. If the energy of the vapor bubbles collapse is enough, they can affect on the internal casing and remove metal from it. If the cavitation occurs, the efficiency of the pump will reduce. Also the pressure and flow may have a sudden change at the output discharge.
The cavitation produces vibration and noise. When the pump works under cavitation condition for a period of time (enough time) may leading to such following problems:

- Pitting on the casing wall and impeller.
- Failure early.
- Break the shaft.
- Mechanical seal failure early.

There are five types of cavitation which are vaporization cavitation, internal re-circulation cavitation, vane passing syndrome cavitation, air aspiration cavitation and turbulence cavitation.
There are many methods which have been used for cavitation fault detection. Al Hashmi, 2013 [2], used a method that called statistical analysis of acoustic signal for cavitation detection and Mckee et al, 2012 [1], applied a method based on statistical parameters for a centrifugal pump to indicate cavitation signal. Kristoffer et al, 2015 [3], used method based on the spectral and statistical of cavitation vibration and Chudina,2002., [4] studies the noise as an indicator of cavitation in a centrifugal pump.

There are two methods to display the dynamic signal; one is called time domain method and another known as frequency domain method. Figure 1 shows the time domain, the *y* axis represents the amplitude of the signal and the *x* axis represents the time. Time domain representation is known as amplitude over time trend and is shown in Figure 1 [5].

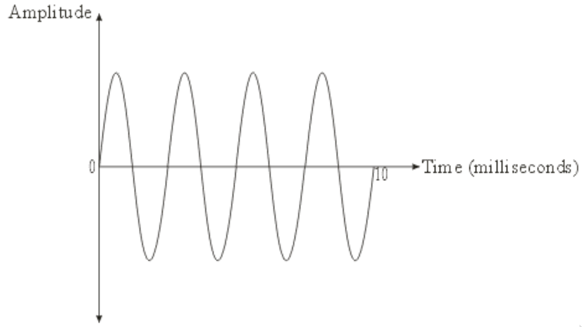

Figure 1: Time Domain [5]

There are different parameters in the time domain that can be used to describe the signal like Peak, Peak to Peak and RMS. By looking at the graph which represents the change of the signal with respect to time can easily understand the peak and peak to peak.

The vibration signal contains power, to measure this power use RMS. To calculate RMS use [6]:

$$\mathrm{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2} \quad (1)$$

Where N is Signal length, Xi is signal values and xi is Mean

$$\boldsymbol{\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i} \quad (\mathbf{2})$$

Kurtosis Factor ‘KF’ is the measurement of distribution flatness. It is used as an indicator of major peaks in a set of data [6].

$$K = \frac{1}{N}\sum_{i=1}^{N}\frac{(x_i - \bar{x})^2}{RMS^4} \quad (3)$$

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

EXPERIMENTAL WORK AND METHODOLOGY

The tests were carried out on the dynamic laboratory at the Caledonian college of engineering. The experimental setup is a test rig as shown in Figure 2 which contains a centrifugal pump with specifications as; 2HP (1.5kW), 3000 RPM, discharge 1"*1" and the capacity 9.5 m3/h. Also it has a tank with volume 0.0716391m3 (19 Gallon), and two pressure gauges, one with range from -1 to 4 bar (-15 to 60 psi), and other with range from 0 to 7 bar (0 to 100 psi). The diameters of the Pipeline delivery is 1" and this pipeline contains two valves.

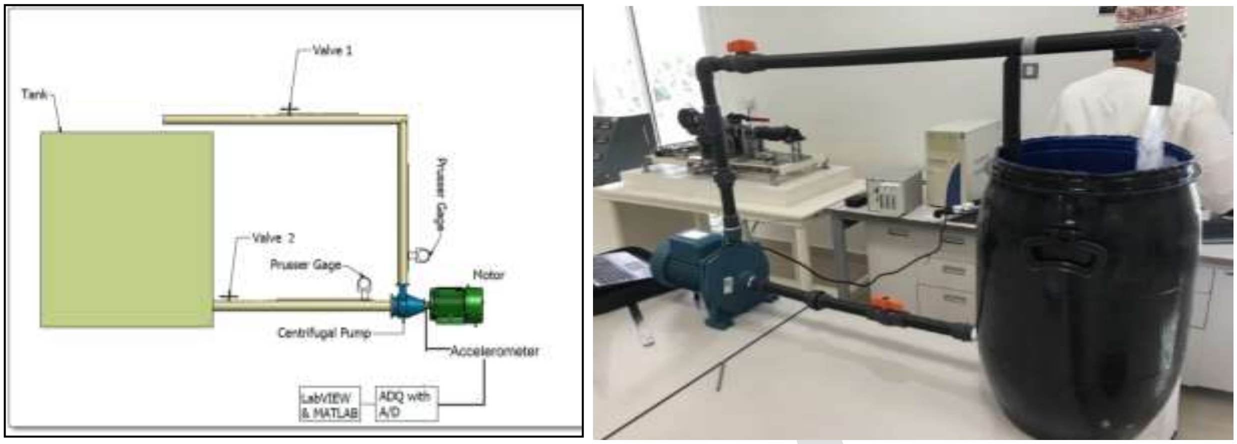

Figure 2: Experimental setupTest Rig

This study is based on collecting and analyzing of vibration data. The vibration signals obtained from a test rig by an accelerometer sensor located on the suction eye. The DAQ (Data Acquisition system) used to amplify and filer the signals at a proper sampling rate with the A/D card (analog to digital converter) to convert the analog signals which are obtained by the accelerometer sensor to the digital signal. LABVIEW software was used to capturing the signals, and MATLAB used for the further processing and analysis of the data.

The vibration data was collected and analyzed in two conditions; with cavitation condition and then with healthy condition. Centrifugal pump was running under healthy condition and cavitation condition by adjusting suction valve. MATLAB was utilized for the analysis of the obtained signals using time domain method with parameters such as mean, peak, root mean square and kurtosis.

RESULTS AND DISCUSSION

This study has investigated the application of time domain as an indicator for the centrifugal pump condition and particularly to distinguish between healthy and cavitation conditions. The time domain signal was plotted using MATLAB software and some parameters like RMS, Peak, Mean, and Kurtosis are calculated for each signal at both conditions. A histogram was also measured and plotted using MATLAB. Frequency domain was used to confirm the presence of each condition.

Figure 3 shows the time domain, histogram and frequency domain for axial position in healthy condition.

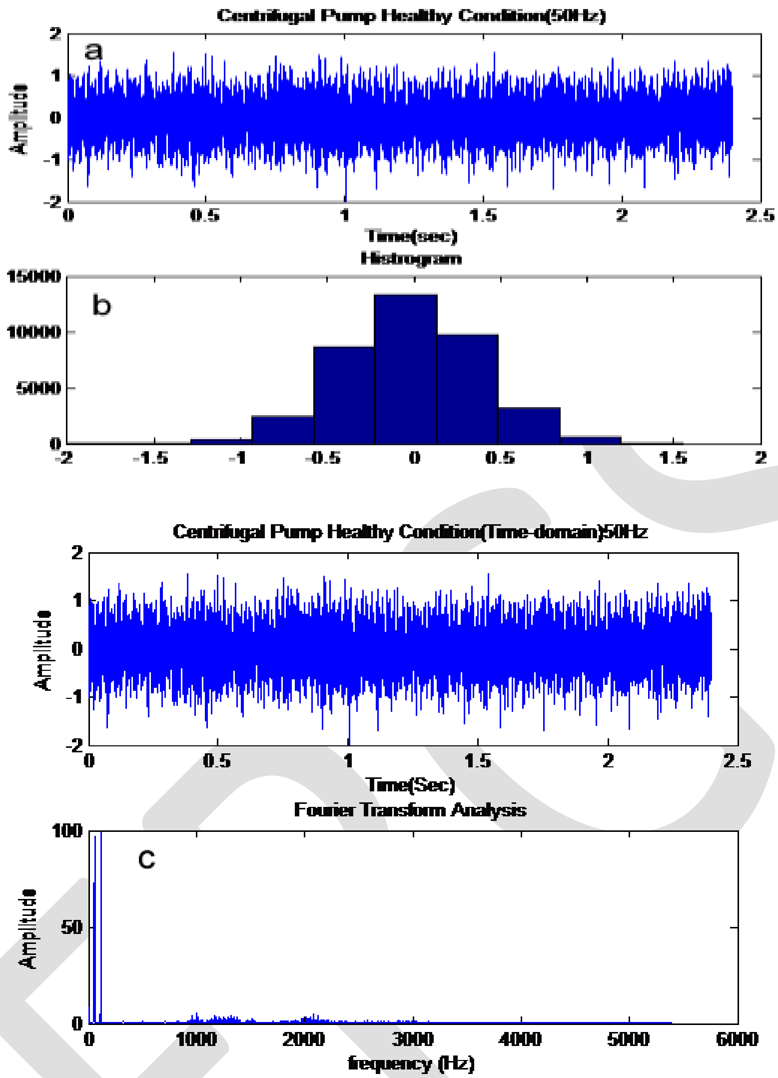

Figure 3: (a) Time domain, (b) histogram and (c) frequency domain of pump at healthy axial reading.

The graph shows the time domain, histogram and frequency domain for axial position in cavitation condition.

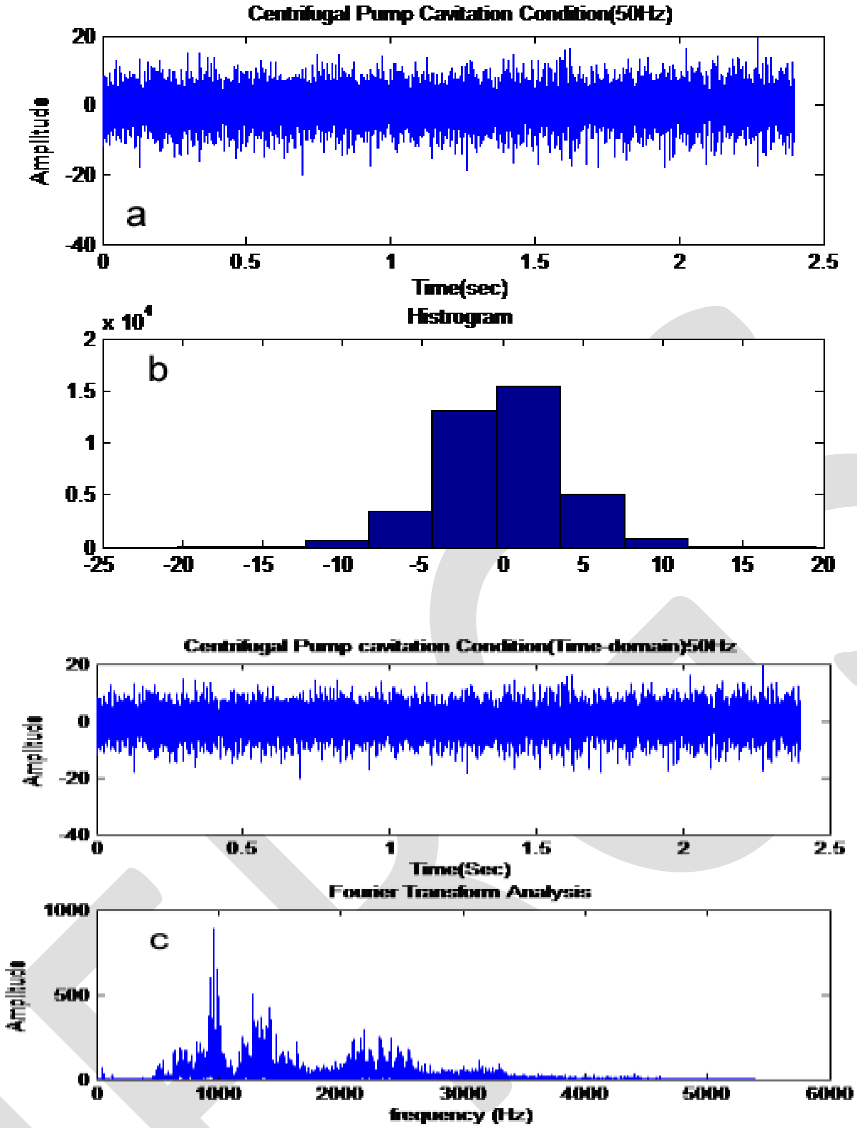

Figure 4: (a) Time domain, (b) histogram and (c) frequency domain of pump cavitation axial reading

By comparing between a healthy condition and cavitation condition, can observe there is different in the distribution of histogram and by looking to the frequency domain, at the healthy condition the amplitude is very low after 1000Hz but at the cavitation condition the amplitude after 1000Hz is high and it remains irregular high up 3000Hz. Vibration and frequency at cavitation condition were found as random and at broadband or higher frequencies. Also by comparing the parameters for both condition, found there are different in peak and RMS value. The value of RMS and peak at cavitation condition value is greater than of healthy condition.

Time domain can be used as an indicator for the centrifugal pump condition and particularly as for this work, it was obviously observed that parameters like RMS and Peak can easily show higher values with cavitation condition compared the values of healthy condition. Kurtosis parameter is also a good indicator but not effective compared the parameters of RMS and Peak. Comparative graph in Figure 4 and 5 shows the values difference between healthy and cavitation conditions for the RMS and Peak parameters respectively.

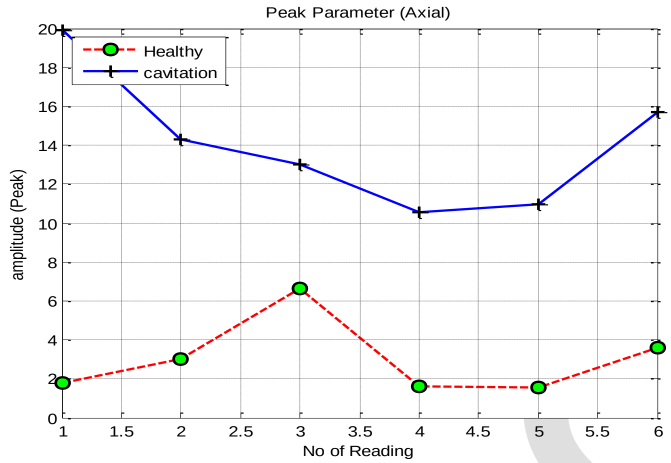

Figure 5: Comparatives Peak parameters for Healthy and cavitation condition.

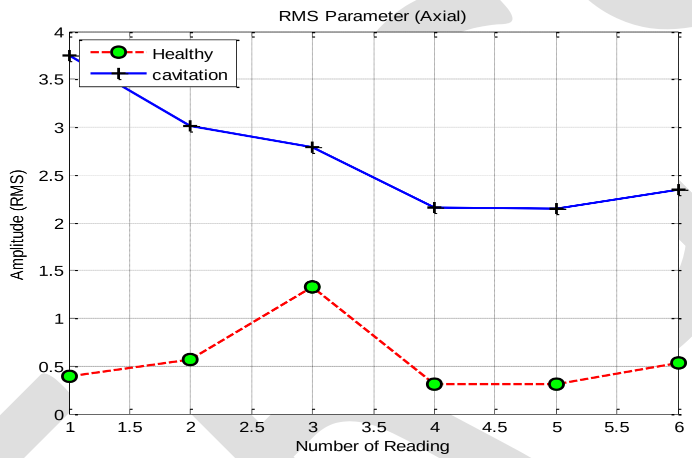

Figure 6 : Comparatives RMS parameters for Healthy and cavitation condition

CONCLUSION

The paper has been done successfully throughout collection of the reading (vibration signals) from centrifugal pump test rig and use time domain as an indicator for the centrifugal pump condition and particularly to distinguish between healthy and cavitation conditions. Moreover, the results were plotted as graphs using MATLAB and parameters were given in tables. The results have shown that the time domain can be used as an indicator for the centrifugal pump condition and particularly RMS and Peak values were found to be the best parameters of time domain to detect the cavitation. Moreover, the best position of accelerometer sensor is axial from suction location. Finally, it is clearly has been observed that cavitation has random vibration in which its detection is required more attention.

REFERENCES:

[1] Mckee, KK, Forbes, G, Mazhar, I, Entwistle, R, Hodkiewicz, M & Howard, I 2012, 'A single cavitation indicator based on statistical parameters for a centrifugal pump'. inWCEAM World Congress of Engineering Asset Management. vol. 8, South Korea, pp. 6pp, A single cavitation indicator based on statistical parameters for a centrifugal pump, 1 January.

[2]Al-Hashmi, S., 2013. Statistical Analysis of Acoustic Signal for Cavitation Detection. International Journal of Emerging Technology and Advanced Engineering, 3(4), pp.55-66.

[3]Kristoffer , M., Forbes, G., Mazhar, I., Entwistle, R., Hodkiewicz, M. and Howard, I., 2015. A vibration cavitation sensitivity parameter based on spectral and statistical methods. Expert Systems with Applications, 42 , pp.67-78.

[4]Chudina, M., 2002. Noise as an Indicator of Cavitation in a Centrifugal. *ACOUSTICAL PHYSICS*, 49(4), pp.463-74.

[5]Mitchell, J.,1993. Introduction to Machinery analysis and Monitoring. second edition edition. Tulsa: PennWell Publishing Company.

[6]Al-Tubi, M. & Al-Raheem, K., 2010. Rooling Element Bearing Faults Detection. Caledonian journal of Engineering, 6(1), pp.44-48.