Control Valve Fault Detection by Acoustic Emission: Data Collection Method

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***Abstract*—Control valves are essential components in process control industry. They are the final control elements that play an important role to regulate flow rate. The condition of control valves affect the whole cycle of process. Therefore, information about their health would be useful to plant personnel during maintenance. This project proposes acoustic emission (AE) technique for control valve fault detection. This paper discusses two methods used for data collection. Data acquisition system (DAQ) was used for retrieving data in time domain while spectrum analyzer was used for frequency domain data.**

***Index Terms*—acoustic emission, control valve, fault detection**

I. Introduction

Control valve is a power operated device which regulates the fluid flow rate in a process control system. Basically, it consists of a plug and stem. The stem is manipulated by air pressure and the plug alters the orifice area in the flow path. The change of valve position is in response to a signal from the controlling system.

There are two actions of pneumatic control valve; air to open and air to close. Air to open means the control valve opening gets larger linear to air supply. If air supply fails, this type of control valve will be in fully close. The concept is opposite in air to close type, where air is supplied to close the valve. During air failure, the control valve will be in fully open. The suitable action is chosen based on the safety requirement of the process.

Number of plugs also differentiates control valves. Control valve would be either single-seated or double-seated. Single seated control valve has one plug while double seated has two plugs. Normally, single seated control valve is used in application that needs the control valve to be closed tightly. Whereas if the process does not expect fully closed condition, double seated valve is recommended. Fig. 1 shows the difference of single-seated and double-seated control valve.

The last feature that classifies control valves is flow characteristics. It gives the relationship between stem movements with flow rate. Three types of control valve commonly found are quick opening, linear and equal percentage. These characteristics can be identified by plug shapes. This is shown in Fig. 2. However, these flow characteristics are true only when the pressure drop across control valve is constant.

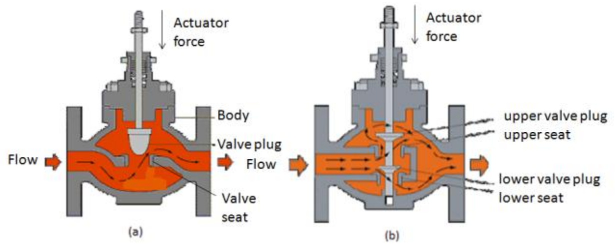

Figure 1. Single seated control valve (b) Double seated control valve

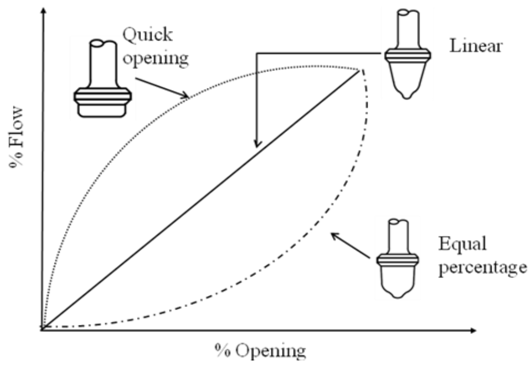

Figure 2. Control valve characteristics

A. *Acoustic Emission*

Acoustic emission (AE) is a nondestructive testing (NDT) method used in a wide area of applications. This method was well accepted and commonly found in industries for the reason that it is simple and easy to use. Acoustic emission is an energy emitted in the form of transient elastic wave or sound wave within material. The signal is obtained using AE equipment after the sound wave has been detected and processed electrically**.**

Examples of current application of AE technology are detecting tool wear in turning process, detecting defects

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such as pitting and crack in gears and bearings [1], assessing surface integrity of rail-track, detecting cavitations and determining Best Efficiency Pump (BEP) in centrifugal pump [2]. It was also applied on gear fault detection and bridge inspection in civil infrastructure study [3]. AE is also widely used for locating leaking of liquids or gases in pressurized or evacuated components or systems as a result of pressure differential [4].

Using AE, the entire structure to be monitored can be covered in a single inspection. Compared to other non-destructive techniques, the initial cost for AE is similar. However, the operational cost of AE is much cheaper. Moreover, AE can implement online monitoring for the entire structure or any part of it [5].

The elastic waves heard by AE were produced by a sudden redistribution of stress in a material. For example, when a structure experience cracks, energy is released in the form of stress waves, which propagate to the surface and are recorded by sensors.

AE sources are from macroscopic, microscopic and pseudo sources. Examples of macroscopic source are deformation and fracture while microscopic AE sources are commonly found in civil engineering such as beginning and spreading of cracks, formation of bubbles, dislocation motion, and slip formation. Pseudo sources do not release the AE directly within the material, but from external mechanisms, such as friction from rotating bearing and leakage of gas or liquid. For defects in equipments, AE can be detected from leaks, cavitations, friction in rotating equipments, and growth or alignment of magnetic domains [5], [6], [7].

In this project, fluid leakage in control valve is a type of pseudo source. AE detects leak by hearing the “noise” when a medium flows through leak orifice. This noise is the turbulent flow that leaks through a small orifice [8], [9]. The turbulence energy represents AE activity. Commonly, AE is found at high frequency. Tamutus and Ternowchek [10] stated that turbulence that cause AE at over 100 kHz while Hellier [11] believe AE frequencies are between 150 kHz and 300kHz.

II. Experimental Setup

Common instruments needed in collection of AE data are AE sensor, amplifiers and signal processing instrument that could collect the data. This project has done two methods for data collection, one AE data in time domain using DAQ and another in frequency domain using spectrum analyzer.

AE sensor used has frequency range of 100-1000 kHz and resonance frequency from 100-800kHz. The sensor’s task is to measure the peak amplitude is utilized to capture the AE signal that emitted from the control valve. The sensor was attached at control valve body using adhesive tape and it was connected to the preamplifier.

The signal was amplified using 60/40/20 dB AE Preamplifier. It was accompanied by PAC AE5A post amplifier which is a high performance AE system that amplifies and filters incoming AE signals. Then, the amplified signal was connected to either a DAQ or spectrum analyzer. All data were collected when the control valve was in fully closed condition.

A. Data Acquisition System (DAQ)

The output of AE analog signal output was interfaced to computer using the Measurement Computing Data Acquisition System (DAQ MCC USB-1208FS). InstaCal software was use to configure the DAQ. When the DAQ software is successfully installed into the computer system, the transmitted signals will be analyzed using MATLAB software.

Several experiments were carried out on two control valves, healthy and unhealthy globe type control valve available in the laboratory. Fig. 3 shows the experimental setup for data collection using DAQ. This method collected data in time domain.

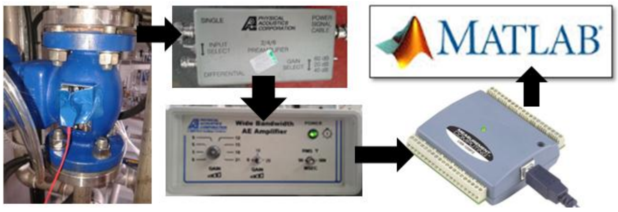

Figure 3. Experimental setup with DAQ

B. Spectrum Analyzer

In this method DAQ was replaced with R3131A spectrum analyzer. The specification states that it could show signal from 9 kHz up to 3GHz. It was used to sample the data and display the signal spectrum in frequency domain. Fig. 4 shows the experimental setup of the system.

Experiments were done on one globe before and after damage. The control valve plug was damaged intentionally to obtain leakage fault. Frequency domain data were obtained from spectrum analyzer in the form of data logging. Saved data were transferred into computer for further analysis.

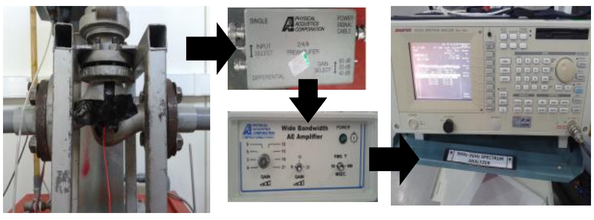

Figure 4. Experimental setup with spectrum analyzer

III. Results

Some data has been collected at healthy and unhealthy control valves. The raw data from both methods will be discussed.

A. Data Acquisition System (DAQ)

The time domain and frequency domain data are plot using Matlab to see basis of the signal behaviour. Fig. 5 and Fig. 6 show the time domain signal for healthy and unhealthy control valves.

Comparison between both plot shows that AE amplitude are higher at damaged control valve. For further analysis, the time domain signals were transformed into frequency domain. However, it was found that the frequency component obtained was at low frequencies. This was due to the DAQ which has sampling rate up to 50kS/s only. Discussion by [10], [11], [8] found that on faulty valve, AE was found at frequency over 100kHz. Therefore, we are not sure the signals captured are AE or outside disturbance since the signals obtained from DAQ could not show AE behavior after 50kHz.

The DAQ used in this method was unable to sample to high frequency. It could not provide enough information in the case of damaged control valve. Therefore, spectrum analyzer was proposed for the next part to enable us to see the higher frequency components of the signal.

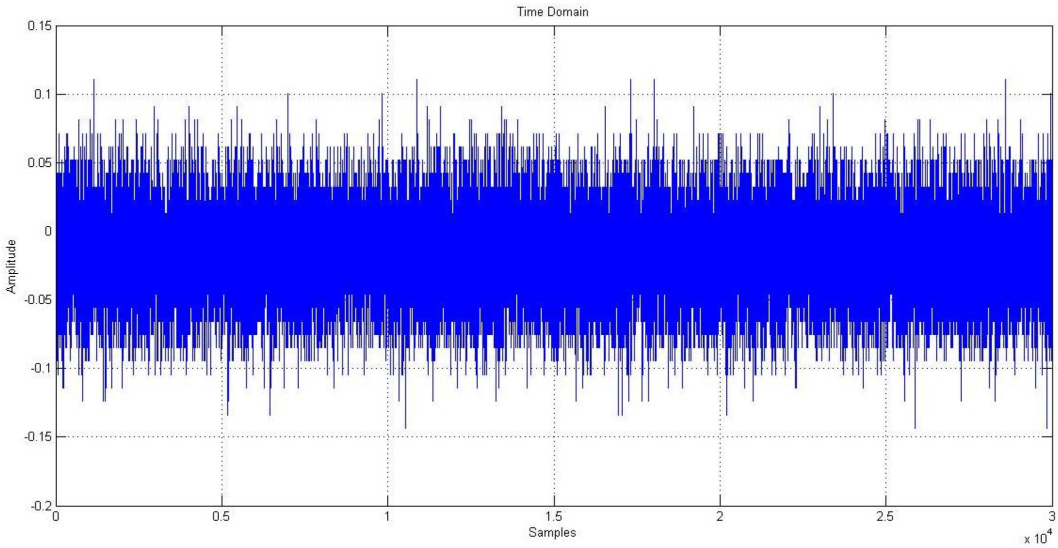

Figure 5. Time domain for healthy control valve

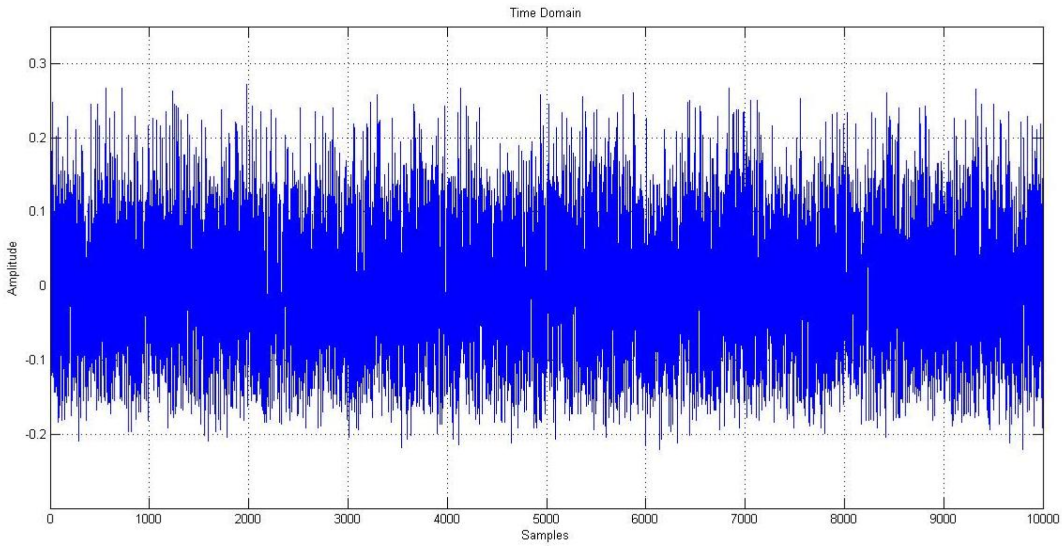

Figure 6. Time domain for unhealthy control valve

B. Spectrum Analyzer

The raw signal obtained from spectrum analyzer shows the AE peak at higher frequency. Fig. 7 shows AE amplitude for healthy control valve while Fig. 8 shows AE for damaged control valve.

From these graphs we can see that the maximum amplitude of AE is high when control valve is damaged. The peak is found at frequency around 100kHz. AE peak shoots up when control valve experience damage. However they are only based on the raw data. These data need to be analyzed to give better interpretation of the signals. The selection for analysis method must be suitable for these data which are already in the frequency domain. Further research need to be done since most signal processing method are using data in time domain form.

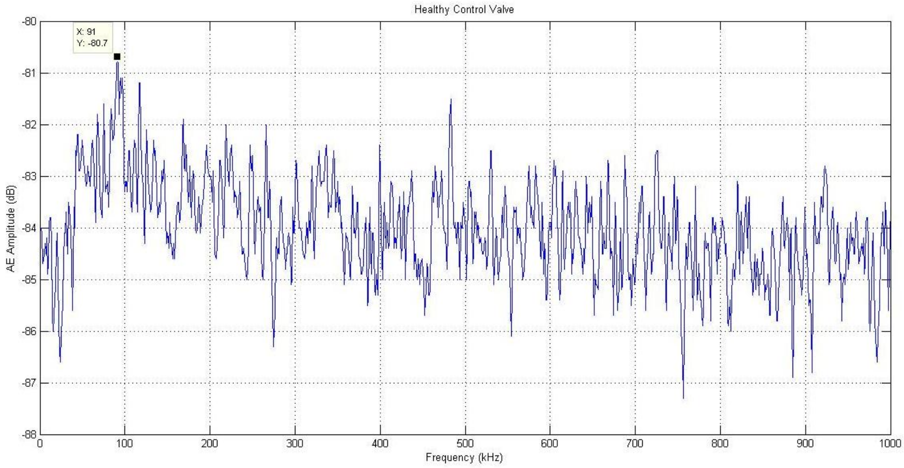

Figure 7. Frequency spectrum of healthy control valve

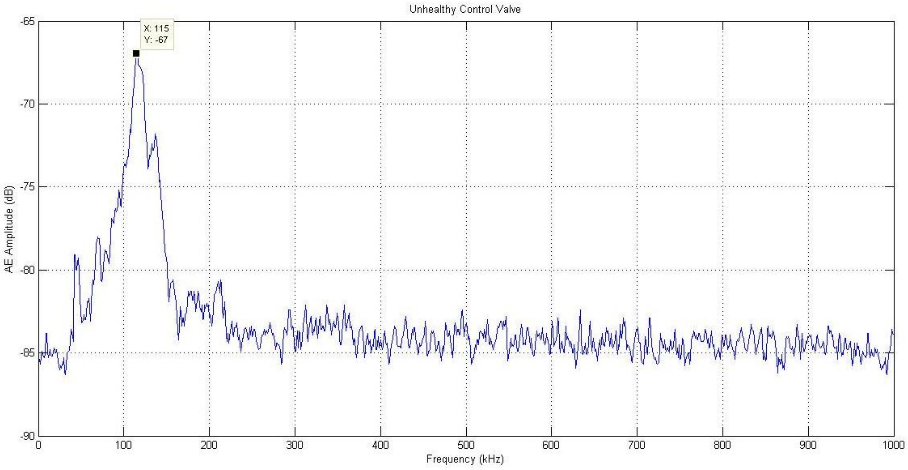

Figure 8. Frequency spectrum of damaged control valve

IV. SUMMARY

This paper discuss about two methods done for collecting AE data from control valve which is in good condition and damaged control valve. It is found that the DAQ used for this purpose was not suitable because the specifications limit data to be sampled up to 50 kHz only. DAQ with higher ability of sampling rate would be better for future work. On the contrary, spectrum analyzer helps us to view AE signal behaviour directly in frequency domain even at high frequencies. However, the signal shown was only raw data which need further analysis. Frequency domain type of data is unfamiliar to renowned signal processing method such as Fourier Transform and Wavelet. The pro and con of these methods could be taken into account for future work.

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