Table of Contents

LIST OF FIGURES

Executive summary

This project is about using Acoustic Emissions technique for developing a fault detection monitoring system for monitoring valves. Through that process quality and saving maintenance costs can be achieved.

This System can be developed through an extensive study on valves responses through acoustic emissions monitoring, this is carried on by attaching a sensor to the body of both a healthy and unhealthy valve and analyzing the responses of each.by the end of the study the software is hoped to be implemented on any valve in a process plant and detect the efficiency of that valve. The study will take place on a test grid which is specially built for that purpose.

In this progress report current progress in the research is presented and discussed, the healthy valve was tested on two types of sensors in order to determine which is the best sensor to operate on in the next phase .they are differential sensor and resonance sensor.

Chapter 1

1.1 Introduction

Process plants consist of thousands, of control loops all networked together to produce a product. Each of these control loops is designed to keep some important process variable such as pressure, flow, level, temperature, etc. within a required operating range to ensure the quality of the end product.

Each of these loops receives and internally creates disturbances that detrimentally affect the process variable, and interaction from other loops in the network provides disturbances that influence the process variable.

To reduce the effect of these load disturbances, sensors and transmitters collect information about the process variable and its relationship to some desired set point. A controller then processes this information and decides what must be done to get the process variable back to where it should be after a load disturbance occurs. When all the measuring, comparing, and calculating are done, some type of final control element must implement the strategy selected by the controller. The most common final control element in the process control industries is the control valve.

In this study of project, monitoring system for early detection of fault in control valve is greatly highlighted. By knowing the abnormal operating conditions, it can reduce the negative effect on the control valve which might lead to unplanned shutdown which will cause unnecessary losses. Through monitoring system, the fault can be detected and resolved at the early stage. There are many techniques to encounter control valve fault detection at the beginning stage. One of them is using Acoustic Emission (AE) technique by measuring and analyzing the sound wave originate from the leakage flow. Besides collecting data, another focus is on development of diagnostic software. The purpose of this software is to detect fault automatically without spending much time analyzing the data. Hence, there are two focus of the background study that is fault detection and analysis of control valve as well as development of diagnostic software.

1.2 Problem Statement

Control valve life cycle starts from Installation, Commissioning, Preventive Maintenance, Corrective Maintenance and Replace New Valve. Replacement of control valve requires high expenses and same goes to corrective maintenance where shutdown of the plant has to be done if the discovery of the fault is only done after some error occurs. For that reason, if a fault can be detected at early stage before the control valve has reached its maximum tolerable limit and broke down, the plant can be guaranteed to have smooth production besides spending a large sum of money to replace the whole valve. In this project, Acoustic Emission (AE) technique is used as a monitoring system to detect fault at early stage to extend the life span of a control valve.

1.3 Objectives

The objectives of this project are as follow:

a) To be able to analyze data output from the test rig on healthy valve.

b) To be able to analyze data output from the test rig on healthy valve.

c) To achieve precise data that can be used to build the diagnostic software

1.4 Scope of Study

The scope of study is to utilize Acoustic Emission technique to capture the data of healthy and unhealthy valve. For the case of unhealthy valve, this project is going to focus on stem and plug problem. The data generated is used for analysis and comparison in order to predict possible cause of fault detected before any downtime of the control valve. This project is divided into two semesters. The main task for the first semester focuses on research and testing the test rig to sustain efficient results with clear data on both healthy valve and unhealthy valve.

While on the second semester, the data generated beforehand will be employed to develop diagnostic software that is able to detect type of faults of any valve. The types of faults proposed for this project are plug and stem problem which will be discussed in the theory.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Control valves have been used extensively in process control loop. The valve is selected based on factors such as cost, minimum maintenance, use the least of energy and compatibility which will keep the plant cost to the lowest. In fact, control valves are considered the most important component which needs much attention for the well-being of the process. Failure of any control valves during process is fatal to the process and might cause unnecessary losses. Therefore, proper and timely maintenance is vital. Manufacturers should take notice on the maintenance part which is gradually becoming priority of consideration for control valve by users. However, in the past, maintenance part is not highly emphasized when a control valve encountered a defect. On the other hand, replacement concept is being carried out where the whole valve is being replaced by a new one. The reason is to save time from finding the cause of the failure. This method had increased the cost of production whenever a control valve broke down due to spare parts problem which can be solved instantly besides replacing the valve.
Nowadays, maintenance programs are scheduled along the life time of the valve, which requires shutting down the process in order to maintain and overhaul ,this increases the maintenance cost in a needless way .Maintenance is divided into four categories which are warranty, planning, safety, and instruction. Warranties are issued to ensure functionality of the valve. If there is any defect, the company has to provide maintenance for free. Maintenance is planned during installation so that control valves are operating without fail. Thirdly, safety is greatly emphasized especially before any attempts are made to service a valve. Lastly, instructions are provided along with purchase of every control valve.

A study reported that the cost of performing predictive maintenance on valves can be up to five times less expensive than preventive maintenance and ten times less expensive than corrective maintenance even before the cost of downtime is configured.[1]

Another study, performed by Soloman Associates at more than 100 olefin plants at North America, found that overall plant reliability is best performed in plant that has highest level of working and effective process control.[2]

The loss of production due to reliability issues range from 2% of plant capacity in the best facility to about 16% in the worst plants. Control valves are the key components in any control systems. Abnormal operating conditions can adversely affect the performance of a control valve and can sometimes seriously damage the valve. Therefore, fault detection in control valve at the early stage is very crucial for industrial plant to prevent unexpected shutdown that can be very costly. Through condition monitoring system, any fault encountered by the control valve can be detected and the performance of the control valve can be maintained [3]. So that project is of a great significance to the field of maintenance of control valve

2.2 Theory

2.2.1 Control Valve

2.2.1.1 Definition and Working Principle

In simple term, control valve acts like a water tap which is to control the flow of water flowing out accordingly. Being related to industrial applications, it is a final controlling element used to control conditions such as pressure, flow, temperature and level by responding to the signals or the set point provided. The figure below shows the explode view of a typical control valve. Control valve has two (2) major components that are Body and Actuator. Generally, Body is used to let fluid to pass through while Actuator functions to control the movement of stem.

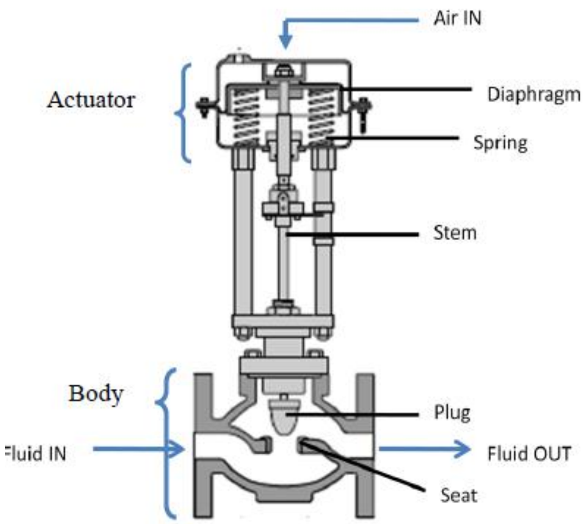


Figure 1: Explode View of Control Valve

Figure 1 globe valve

For valve closing, the air is injected onto Diaphragm in Actuator which creates force to push the Stem downwards. That will cause the Plug to approach the Seat slowly.

Throughout the process, the flow is regulated by the moving of Plug towards the Seat. When the Plug and Seat are fully touched, then the valve is considered fully close. On the other hand, in order to open the valve, remove or reduce the air from Actuator and the Stem with Plug will moves upwards slowly, leading to valve opening. This is because the spring below diaphragm is returning back to its original position, since there is zero pressure exerted on the Diaphragm.

2.2.1.2 Faults Detection

When a control valve breaks down, the faulty part will produce sound wave and generate random frequencies and amplitudes which can be detected in the structure of the control valve. The main supply in the process plant contains a flow of control valve as liquid. The vibration, axial displacement, accelerometer and velocity signals are quite common in the field of condition monitoring system.

Normally, the control valve faults can be detected and identified by comparing the signals generated from the healthy and unhealthy control valves

2.2.3 Acoustic Emission theory

It refers to the generation of transient elastic waves produced by a sudden redistribution of stress in a material. When a structure is subjected to an external stimulus (change in pressure, load, or temperature), localized sources trigger the release of energy, in the form of stress waves, which propagate and are recorded by sensors. With the right equipment and setup, motions on the order of picometers (10 -12 m) can be identified. Sources of AE vary from natural events like earthquakes and rockbursts to the initiation and growth of cracks, slip and dislocation movements,Leakage, melting, twinning, and phase transformations in metals.

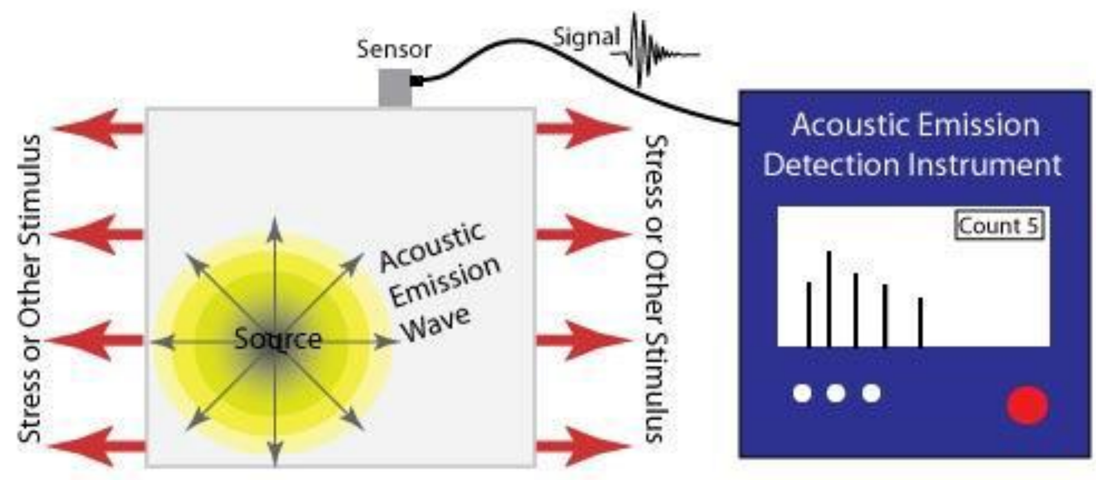


Figure 2 Acoustic emission technique

Material emit at places were the local stress is high enough to cause fresh, permanent deformation. Often this happens at stress concentrations, places where the stress is raised by local geometry, stress concentrations exist at weld details, changes in section and structural discontinuities in general they also exist around cracks and flows. The stress concentrations at weld details are the reason why fatigue cracks initiate at these locations.

2.2.4 Acoustic emissions analysis

The heart of any AE system is its data analysis capability. The basic objective of data analysis is to identify signals of interest while rejecting non-interesting signals (noise). Another objective is to be able to perform the data analysis in real time while the test is being conducted. A compromise must always be made between too little data analysis and too much, especially when real time analysis is being done. If there is too little data for analysis, then a lot of uninteresting "noises" will contaminate the test results, possibly confusing the operator about the integrity of the structure. If there is too much data for analysis, then there are many periods when the system is "dead" and not able to acquire any more data, be it interesting signals or uninteresting "noise".

There are multiple levels of signals processing which can be applied to AE signals. The simplest of these is frequency filtering, which consists of passing only those signals falling within a selected band width. This concept is identical to the manner in which a specific radio station is selected from among the many in the RF spectrum. The next level of signal processing consists of special filtration, which consists of passing only those signals originating within a selected area on the structure. This concept is identical to the manner in which an underground nuclear test in a certain location can be differentiated from earth quakes in other locations. Special filtration can be made more complete using "guard" sensors. In this scheme the sensors closer to the region of interest are called data sensor, the "guard" sensors are placed outside of the both the data sensors and the region of interest. Acceptance of an AE signals will occur if and only if the data sensors receive the signal before the guard sensor. If the signal is received by the guard sensor first, it is classified as noise and rejected. Special filtration technique is applied when the AE signals are in an analog form, thus they are inherently fast.[4]

As a study performed earlier on acoustic emissions analysis detection of defective manufactures in press process, it says that the interpretation of the AE signals can be classified into the activity method represented by the excess of the acoustic emission and the method of the waveform analysis that relates to the shape of the signal. A method by the acoustic emission activity evaluates variables including the event number, the ring-down count, the peak amplitude and energy, and etc. And there is a direct relation with the size and frequency of the acoustic discharge source.

The method by the waveform analysis compares how the waveform of the acoustic emissions was drawn. There are variables, used in this case, such as the rise time, the event duration, the rising slope and frequency spectrum etc. The example of the evaluation using Event and ring-down count observes the Kaiser effect, and the Felicity ratio and creep phenomenon. The Kaiser effect (Kaiser 1953) has been applied as to know the initial stress condition of rock materials.

Based on the Kaiser effect, T. Fowler proposed the Felicity ratio, which can show the damage quantitatively in tank structures. The Felicity ratio was established because of the following fact. The Kaiser effect can only hold in the stable condition of the materials. As to progress the internal instability, the Kaiser effect is gradually breaking down, As a result, AE activity starts to be observed even under lower stress than that of the maximum stress experienced . The development of creep along with the uniform event increase or the uniform ring-down count increase can occur in the test piece under constant stress. And in this case, it can estimate that the advance of damage is taking place in the test piece. The rise time, the event duration, and a slope and frequency spectrum can be used in the observation of the waveform characteristics, based on the idea that the acoustic emission occurred from the special deformation mechanism has the special waveform characteristics. And it is possible to verify the special failure mechanism by processing these parameters statistically. As the parameters used for signal characteristics, not only the variables used in the specialized equipment for acoustic emission signal analysis but also the various variables which could be regarded as even a feeble feature of the generated signals are being used [13].

Another case studies were performed earlier about the different methodologies of analysis of acoustic emission waves for monitoring reinforced concrete structure, it shows that there are many techniques have been developed to interpret and to analyze the AE data. The most appropriate approach for any AE testing situation is dependent on a number of factors. Those include the suitability of the AE analysis for the particular selected material, size of the specimen, type of loading would be applied, purpose of the monitoring, and so forth. Two modern AE analyses (Wavelet analysis and b-value analysis) have been discussed in the research, at the point wavelet analysis have been focused on in our research

2.2.4.1 Wavelet analysis

A. Wavelet Analysis wavelet transform analysis has been developed from the previous numerical method known as a Fast Fourier Transform (FFT). The characteristic of the FFT method similar with the wavelet transform which is finding the frequency of signal components, but this traditional method can only extracted from the complete duration of a signal. However the wavelet analysis is well suited technique to detect and analyze AE events occurring to different scales of signal according to the duration of time. Furthermore, Wavelet transform has been proven the ability to defeats many of the limitations of the widely used Fourier transform (FT). Upon that matter, it has gained the popularity as an efficient of the signal processing in monitoring system [7] .Basically, wavelet transform analysis can be defined as a time frequency or discrete (digital) signal and also reported that, wavelet analysis is a mathematical function that cut up data into different frequency of AE waveforms [7] .

Due to the modern developments of AE analysis technique in concrete structure, wavelet transforms has recently been consume and perfect tool technique of analysis for concrete structure damage detection and also in structural health monitoring.

- Significant of the Analysis:

This type of analysis is significantly important due to the development raise new problem of cases and therefore, analytical techniques such as wavelet analysis are highly demand to solve the current problem. This owing to the high of AE signal rates and events at relative high frequency from 20kHz up to several MHz Mostly, this was occurred during the extremely damage in concrete structure such as, building due to earthquake loading and bridge owing to increase traffic loading. According to, the main objective of this method is to develop the analytical method of AE signal analysis based on the rate of damage for ensuring the safety of structural integrity during the severe environmental loading. In addition, wavelet Transform analysis also significant in the AE signals waveforms as an AE filter technique to avoid and reducing the noise from the signal. The design of wavelet filters to enhance the signal to noise ratio in the AE signal analysis. The elimination of low frequency noises by using the wavelet algorithm show the satisfy result during analysis of AE signal. The Paper Concluded that, this type of analysis is effectives and useful for detecting the damage of the concrete structure due to the AE signal waveforms. This was proved by the previous researchers about the application in the AE signal for concrete structure. Therefore, wavelet analysis has the potential of becoming an effective tool for detection of damage mechanisms and health monitoring of structure for the natural frequencies are irregularly changing [8].

Another Study was performed on Vibration and Acoustic emission analysis of defect rolling bearings , this study managed to detect the defect using vibration analysis and acoustic emission analysis successfully [9]. The study concluded that measurement of acoustic noise can be used for the detection of defects in rolling element bearings. These measurements are normally carried out in two modes: sound pressure and sound intensity. Sound pressure generated by good bearings has been studied by several researchers, but very little literature is available on sound measurements as a defect detection technique. Researches have shown the usefulness of sound pressure measurement for the detection of defects in axially loaded ball bearings. The role of surface irregularities in the production of noise in rolling contact has been studied with the help of sound pressure measurement [10].

Sound intensity measurement, a comparatively recent technique, has also been tried successfully for the detection of defects in rolling element bearings. Sound intensity is defined as the time-averaged rate of flow of sound energy through unit area. Unlike sound pressure, it is a vector quantity and the two-microphone intensity probe has directional characteristics. Sound intensity in the frequency domain can be obtained from the imaginary part of the cross-spectrum between the signals of two closely spaced microphones. A special two microphone probe is used for intensity measurements. The imaginary part of the cross-spectrum can be obtained directly using a dual-channel FFT analyzer.

Tandon and Nakra [11] have shown the usefulness of sound intensity measurement as a bearing diagnostic technique and have concluded that, for this purpose, it is more effective than sound pressure measurement. Spectral analysis of demodulated signals received by a sound meter has been suggested as a monitoring tool for wayside detection of railroad roller bearing defects [12].

The detectability of defects by sound measurement may be affected by sources other than bearing noise unless adequate precautions are taken to isolate the latter. A partial or full acoustic enclosure lined with sound absorbing material is usually constructed around the test bearing for this purpose.

The paper has concluded that Acoustic emission measurements have also been used successfully for detecting defects in rolling element bearings. Some studies indicate that these measurements are better than vibration measurements and can detect a defect even before it appears on the surface. Demodulation of AE signals for bearing defect detection has also been suggested

.

2.2.4.2 Statistical Analysis

Statistical analysis is one of the commonly used methods to analyze data. Kurtosis, standard deviation, maximum amplitude and root mean square (RMS) are the examples of statistical analysis. The randomness in the generation of Acoustic Emission (AE) signal requires a statistical analysis of AE signals.

Kurtosis is any measure of the peaks of the probability distribution of a real-valued random variable. It is among the sensitive parameters for machines diagnosis. Standard deviation is a measurement of variability or diversity used in statistics and probability theory. It basically shows how much variation or dispersion there is from the mean value.

A high standard deviation indicates that the data is spread out over a large range of values while a low standard deviation indicates that the data is closer to the mean. Maximum amplitude can be found by referring to maximum peak of graph in time domain. It can be easily observed during receiving the data from AE sensor.

Root mean square (RMS) is a statistical measure of the magnitude of a varying quantity. The RMS value of a set of values is the square root of the arithmetic mean of the squares of the original vales. Based on past study [3], a healthy control valve should possess values as in Table 1. Any values that are not within the range will be considered as unhealthy control valve.

Table 1 Statistical analysis standards

Statistical Anal. method	**Value**
Kurtosis Standard Deviation Maximum Amplitude Root Mean Square (RMS)	< 3 < 0.5 < 2 < 2

2.2.4.3 Power spectral density analysis

Power spectral density function (PSD) shows the strength of the variations (energy) as a function of frequency. In other words, it shows at which frequencies variations are strong and at which frequencies variations are weak. The unit of PSD is energy per frequency(width) and you can obtain energy within a specific frequency range by integrating PSD within that frequency range. Computation of PSD is done directly by the method called FFT or computing autocorrelation function and then transforming it.

This method will be tried during our research to identify the frequency width of the healthy valve and unhealthy valve signals. The mathematical equation representing the power spectral density is as follows:

$$P_{\mathrm{AR}}(f) = \frac{\sigma^2}{|A(f)|^2} = \frac{\sigma^2}{\left|1 + \sum_{k=1}^{p} a_k \exp(-\mathrm{j}2\pi f k \Delta t)\right|^2}$$

Where σ^2 is the variance of input data.

CHAPTER 3: METHODOLOGY

3.1 Analysis Technique

3.1.1 Literature Review

Further elaborating in this section, literature review is discussed in terms of the experimental setup, diagnostic software, and hardware needed to conduct the experiment.

3.1.2 Experimental Setup

In this project, a specifically built test rig for this purpose will be tested to perform experiments on control valves. The test rig includes main components such as control valve, pressure transmitter, level transmitter, pump, water tank and others. experiments are being conducted on the control valve to collect data for healthy and unhealthy valve. During the experiments, then acoustic emission is attached to valve body supported by adhesive tapes and the other end is connected to preamplifier. Next, it is connected to filter followed by amplifier. The setup is used to collect data and analysis and comparison.

3.1.3 Diagnostic Software

Upon collecting needed data, an extensive comparison between the data collected from the healthy valve and the unhealthy valve is performed. MATLAB graphical interface unit will be used as a powerful tool to analyze the data[6], then hopefully by the end of the second semester the software can be developed to diagnose and analyze the functionality of operating valves in any plant .

3.2 Materials and equipment

Equipment required to conduct this project is divided in two types which are hardware and software.

3.2.1 Hardware

a) Experimentation equipment includes Acoustic Emission Sensor, Filter, Amplifier, DAQ card, Computer

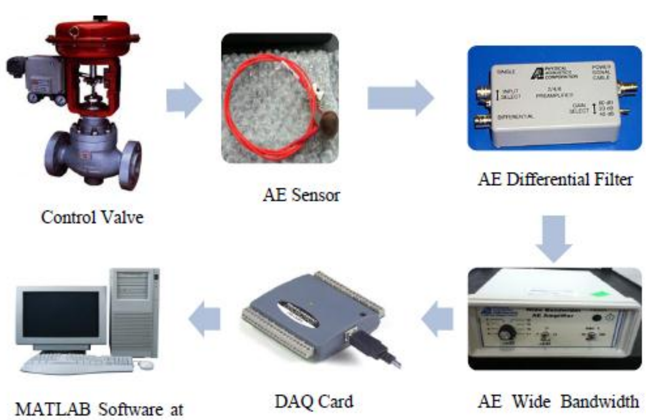


Figure 3 Experimental equipment

b) Test Rig includes Control Valve, pressure transmitters, orifice plates, Pump, Calibration water tank and a buffer tank

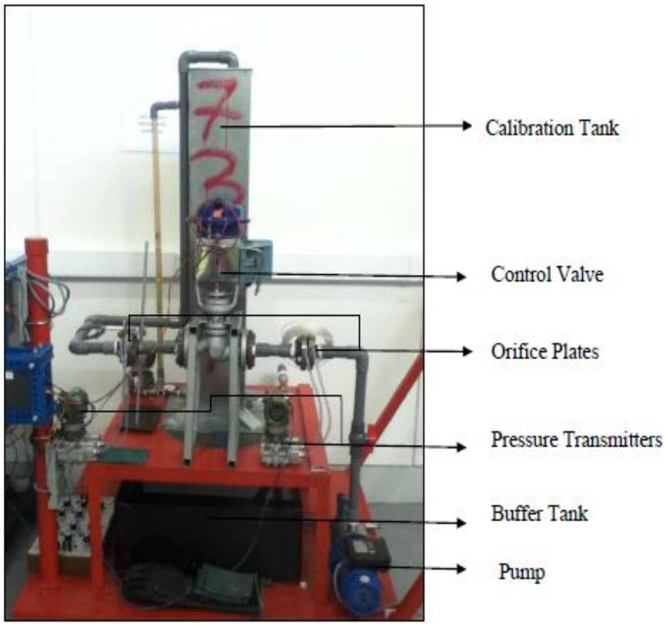


Figure 4 Test Rig

3.2.2 Software

a) MATLAB

b) INSTACAL (MCC DAQ)

3.3 Execution flow chart

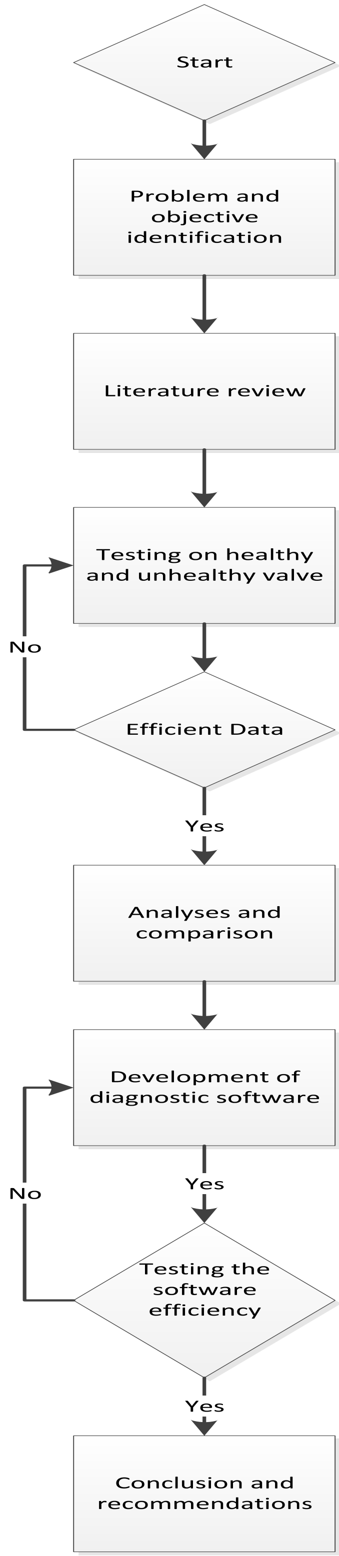


Figure 5 Execution flow chart

Chapter 4: Results and discussion

This project started off with Problem and Objective Identification. The problems of control valve are identified in order to find out the objectives of the project. The objectives are the aims of the project which are intended to be achieved to solve the problems that were encountered. In Literature Review, detailed preparations are important to ensure clear understanding on the subject. Reading related journals, articles and reference books are one of the ways to assist in this project. Next, the project proceeds technically by experimenting on the Test Rig. The purpose of the test rig is to perform experiments firstly on healthy valve followed by unhealthy valve. Experiments are performed on healthy valve using Acoustic Emission (AE) technique. If the data gathered is efficient enough, the experiments will be continued on unhealthy valve.. After that, the data that is collected will be analyzed and compared between the healthy and unhealthy valve. The data should be organized to assist the next procedure. The most important procedure is development of diagnostic software. The diagnostic software is used to analyze and detect types of fault that a control valve is facing. Tentatively, MATLAB Graphical User Interface will be used to build the software by utilizing the data that was collected and analyzed.

4.1 Test rig

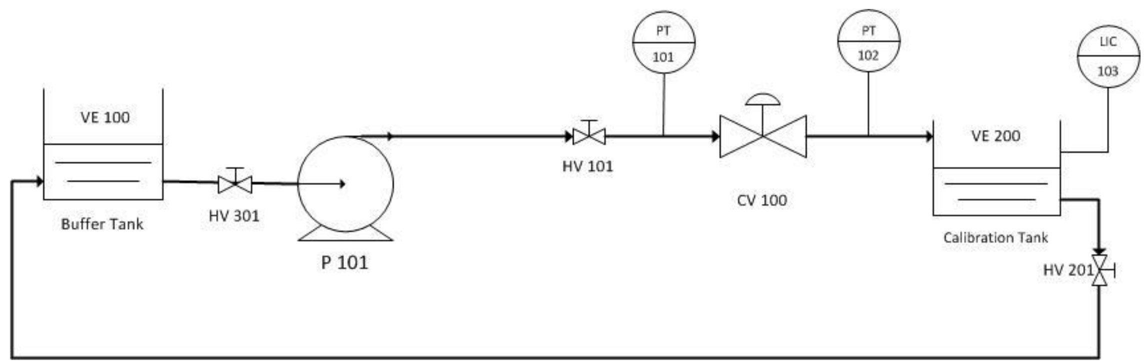


Figure 6 P&ID of test rig

The detailed specifications for each instrumentation can be found in Appendix C. As shown in the figure, the test rig consists of a control valve (CV-100) which is the main subject to be studied on. A pump (P-101) to exert force for the 21
water to flow through the pipelines. Two tanks which are Buffer Tank (VE-100) and Calibration Tank (VE-200) to hold water alternatively. Two pressure transmitters (PT-101 and PT-102) to measure pressure drop at Orifice plates. And also pressure transmitter which acts as a level transmitter (LIC-103) to monitor and control the level of water in Calibration Tank (VE-200). There are three Hand-valves (HV-101, HV-201, HV-301) to determine the presence of water by turning it on or off. The process kicked start when water is pumped from Buffer Tank (VE-100) into the pipe to flow through Control Valve (CV-100). The Orifice plates are installed at the inlet and outlet of the body of Control Valve to measure the differential pressure of the flow. Then, the water is fed back to Calibration Tank where level of tank not only can be monitored but controlled by the controller. Water from Calibration Tank will flow into Buffer Tank where the process will be repeating until the pump is stopped manually.

4.2 Controller testing

Undeniably, controller is essential in this process loop since it is used to control the level of Calibration Tank. In other word, the level can be set at the point that the user wanted it to be which is called Auto Mode. This test focused on collecting data from level transmitter (LIC-103) which is connected to Data Acquisition System (DAQ) card. The test was done by adjusting the Set Point (SP) of the level of tank at 0, 25, 50, 75 and 100% at the controller. The range of water level in the tank is 0-800 mmH20. The graphical result is observed in MATLAB software in computer where DAQ card function's plays an important role. The exact result of the testing is shown in the Table 1.

Table 2 Waterlevel and the theoritical voltage response

Water Level @ SP (%)	Voltage (V)
0	1
25	2
50	3
75	4
100	5

The result from the experiment that is performed is as follow:

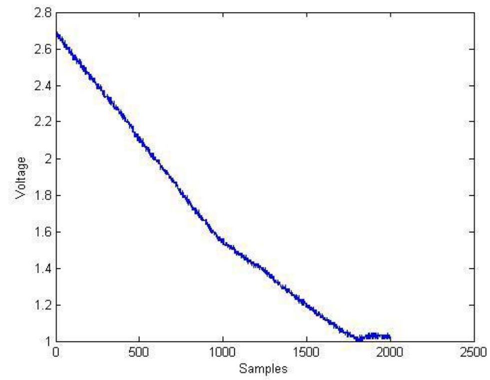


Figure 7 Set point at 0 %

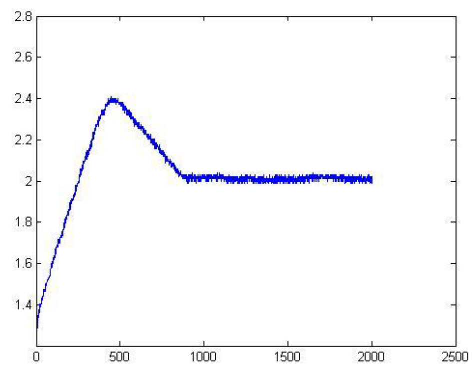


Figure 8 Set point at25 %

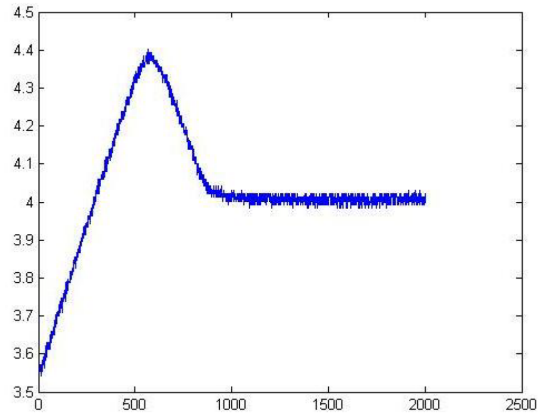


Figure 9 Setpoint at 75 %

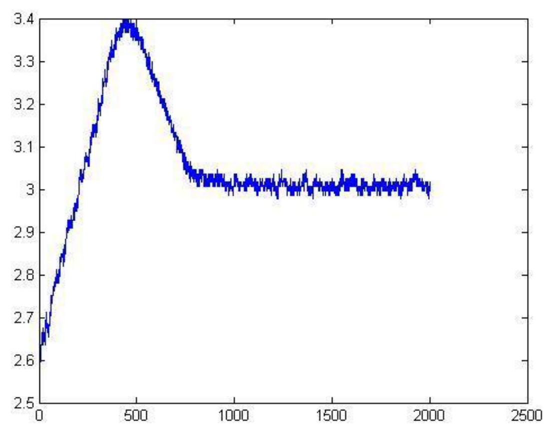


Figure 10 Setpoint at 50 %

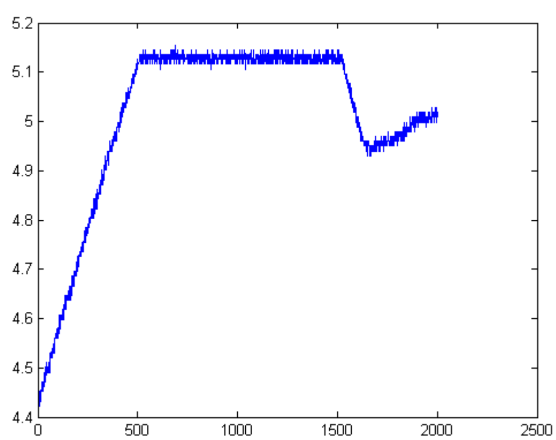


Figure 11 Setpoint at 100 %

AS from the resulted graphs when SP is at 0%, the graph does not show any complication and the voltage sent from transmitter to DAQ card is 1V which is same as the exact result that is wanted. By looking at the graphs resulted when SP is at 25% 50% and 75%, there is a similarity where there is a slight overshoot. It is because the Manipulated Variable (MV) of the control valve had increased more than enough when it wanted to arrive at the Set Point given. Although it increased more than the value set, it managed to return to its original value. As for SP at 100%, the voltage had an overshoot of 0.1V at the beginning and it decreases around 0.2V. Finally, the voltage shows 5V. This is because when the water level had passed the SP, the controller will play its role by decreasing the MV so that the voltage generated will be 5V. As a conclusion for testing of controller, it can be concluded that the controller performed excellently for the test rig in controlling the water level in the tank when it is in Auto Mode.

4.3 Healthy valve testing

In this section, the testing of the healthy valve fixed on our test rig was performed , the purpose of the test is not merely proving the healthiness of the valve as it was determined to be before, the purpose is to :

1- Interpret the output data in order to keep as a reference for the next phase of the project which is testing on an unhealthy valve
2- Comparing the performance of the acoustic emission sensors available which are of two types, Resonance sensor and differential sensor
3- Determining which sensor will be more appropriate for the data collection and comparison in both phases

In order to achieve the mentioned three objectives the experimentation was performed on both sensors at both modes of the controller , manual and automatic, ,at different levels of the tank and at different openings of the valve .

Through literature review it shows that the healthy valve acoustic emission should not be higher than 2 V in amplitude , and that will be our main reference in our experimenting.

4.3.1Testing on Resonance sensor:

The first phase on testing the sensor is to have the proper software setup for it, so using matlab a pickup signal is designed to process and maintain the right values of the AE sensor, the pickup signal diagrams is as follows:

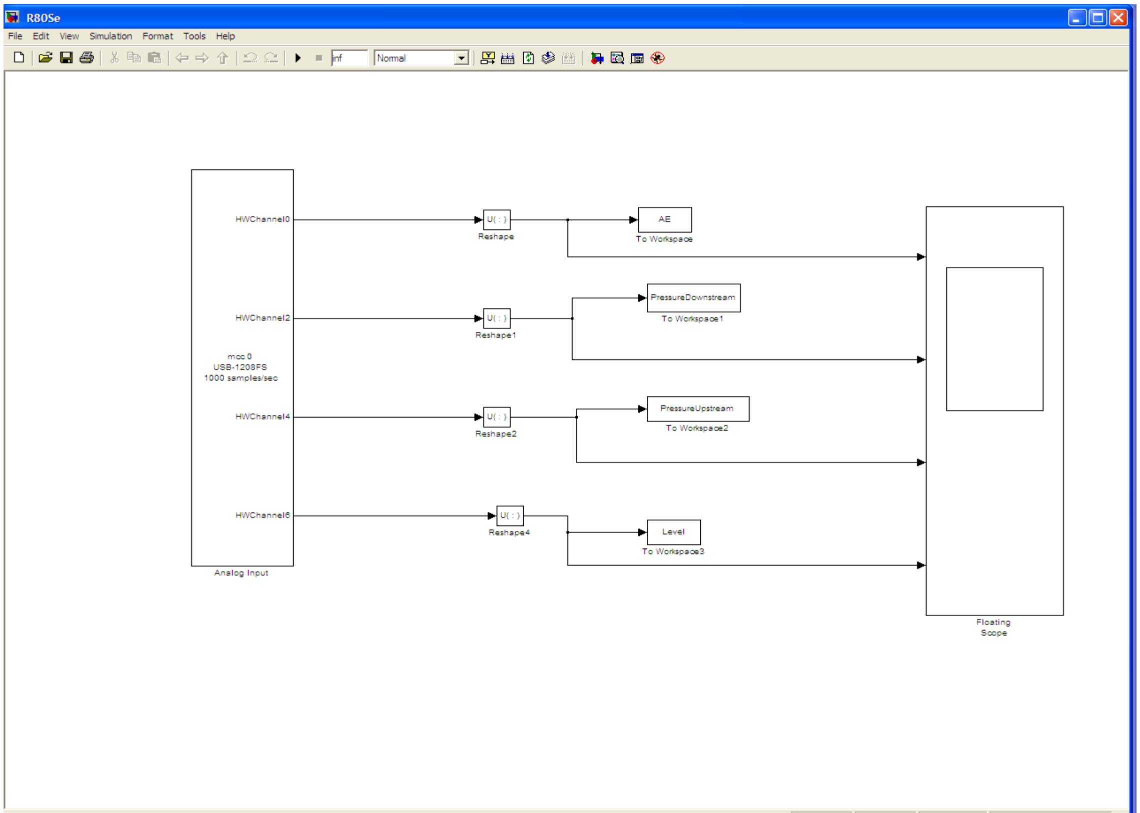


Figure 12 Simulink Pickup Signal for Narrowband sensor

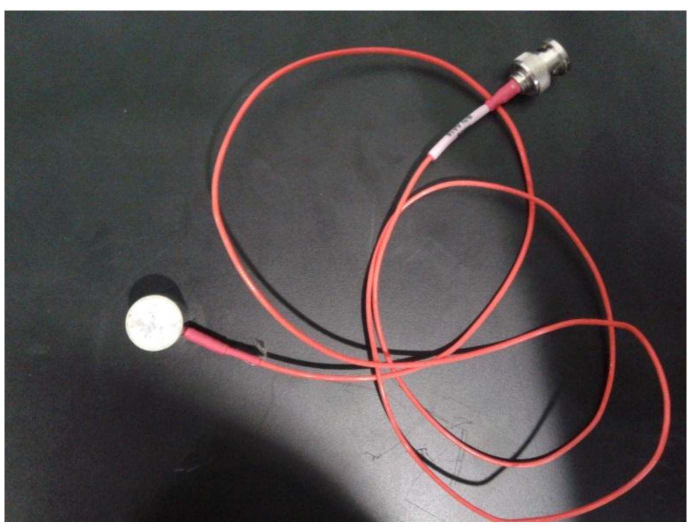


Figure 13 Resonance (narrow band) sensor

-Firstly we experiment on the automatic mode, by sitting the set point of the controller to Empty the tank and maintain it at 0% level

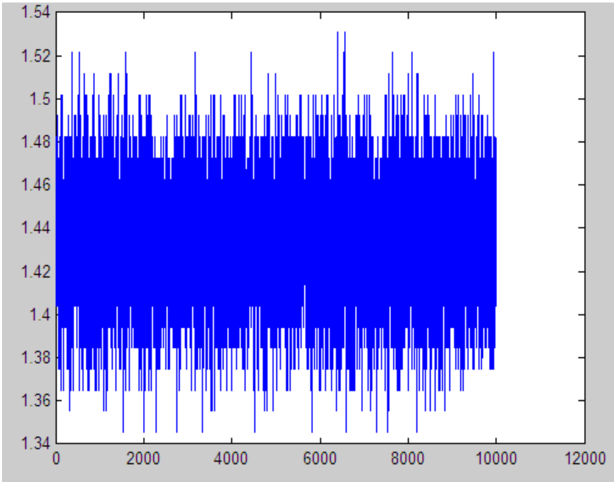


Figure 14: AE at 0% of the tank

Then at 25 %

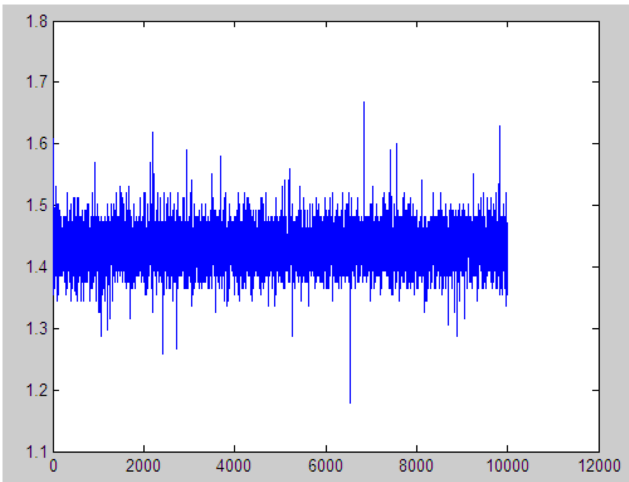


Figure 15 AE at 25% of the tank

Then at 50%

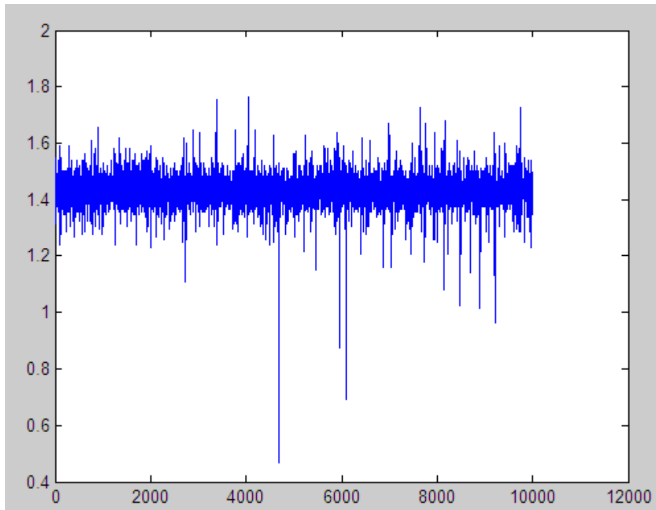


Figure 16 AE at 50% of the tank

Then at 75%

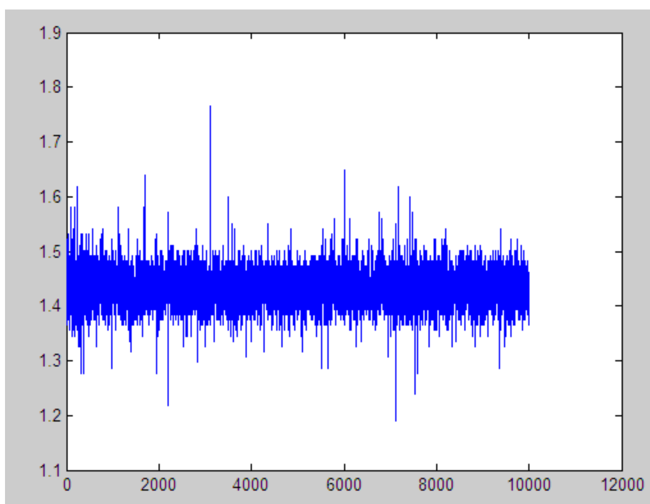


Figure 17 AE at 75% of the tank

Then at 100%

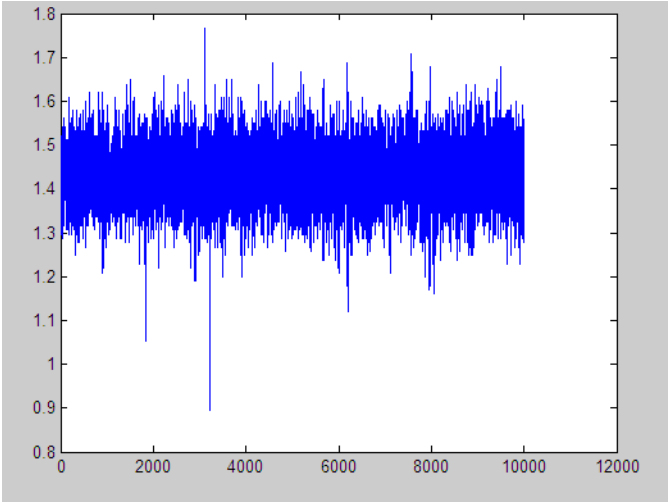


Figure 18 AE at 100% of the tank

-Upon collecting the results from last phase, it’s shown that the project is heading in the right direction, so next phase on resonance sensor testing was performed on manual mode ,by maintaining the opening of the valve and collecting the AE signal until the tank reaches its maximum level .

First. At 25% opening of the valve

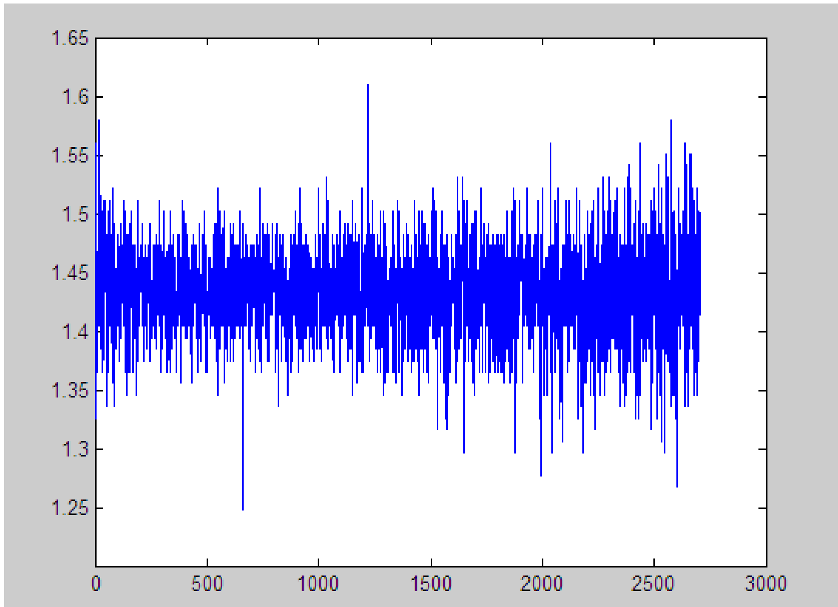


Figure 19 AE at 0% of the tank (Manual mode)

Then at , 50% opening

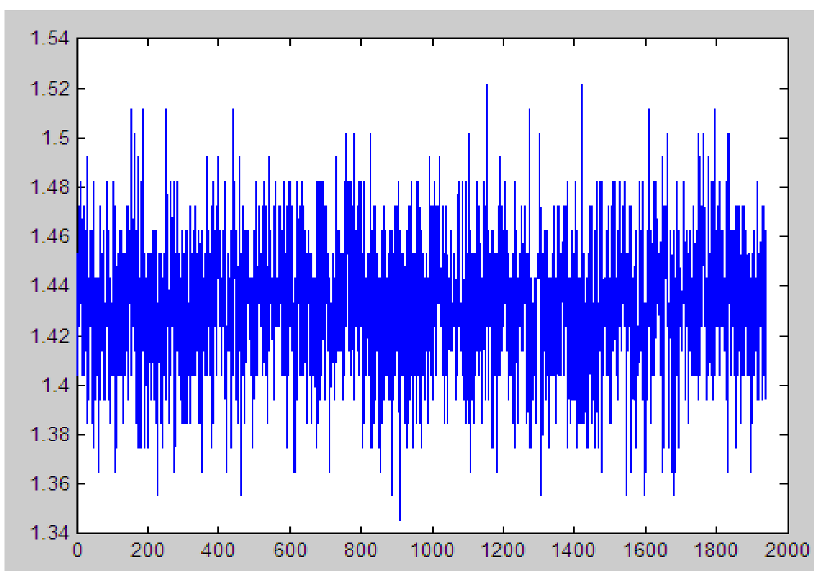


Figure 20 AE at 25% of the tank (Manual mode)

Then at 75%

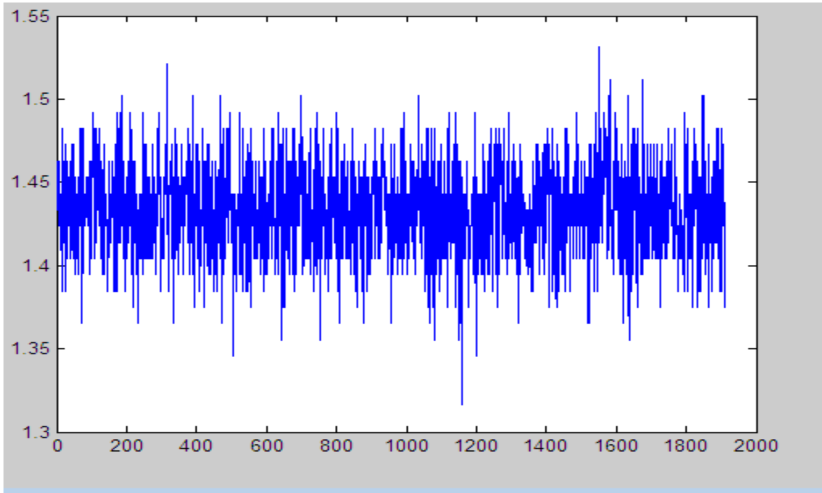


Figure 21 AE at 75% of the tank (Manual mode)

Finally at 100% opening

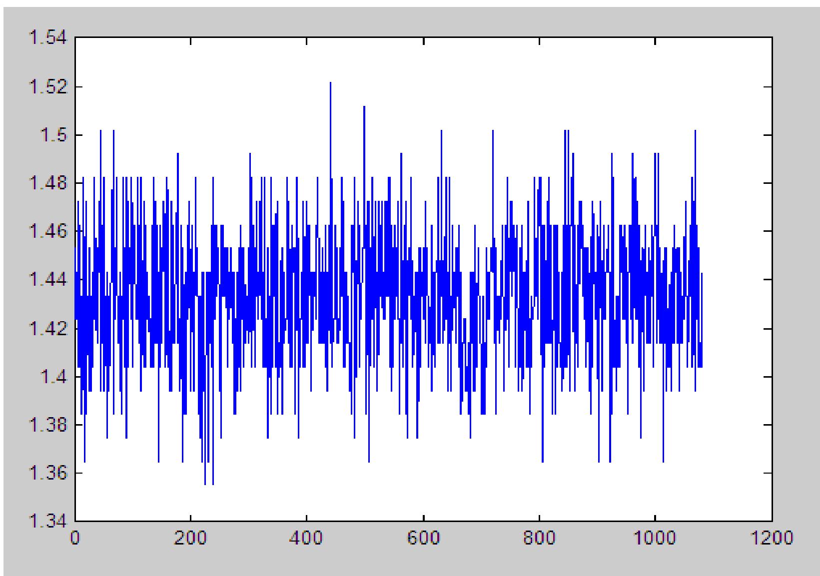


Figure 22 AE at 100% of the tank (Manual mode)

4.3.2 Testing on a differential (wideband) sensor

Using the differential sensor gives output over a wide range of frequencies. So tests on automatic mode were performed to test its performance. The pick up signal designed for that sensor using MATLAB is as follows :

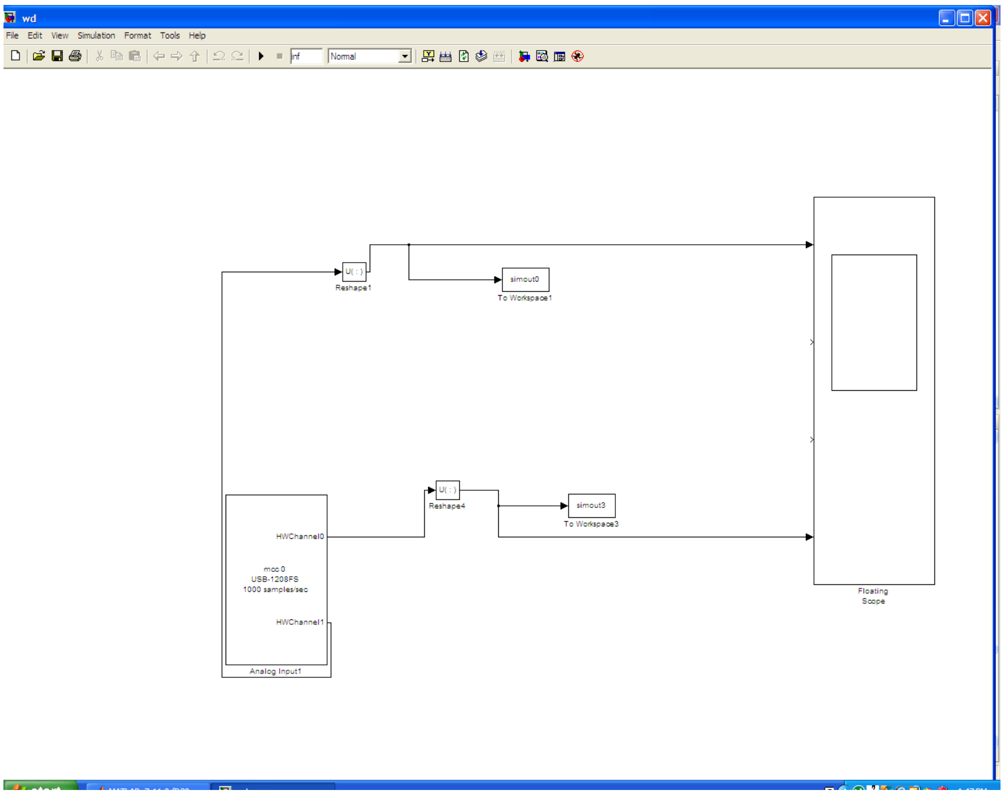


Figure 23 Differential (Wide band) sensor pickup signal

Figure 24 AE wideband (Differential) sensor

So, testing on 0% level of the tank :

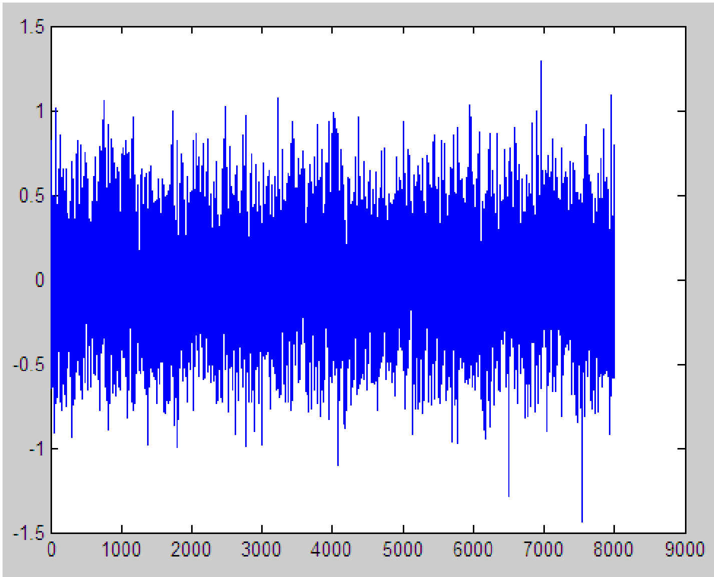


Figure 25 Wide band signal with set point at 0%

Testing on 25%

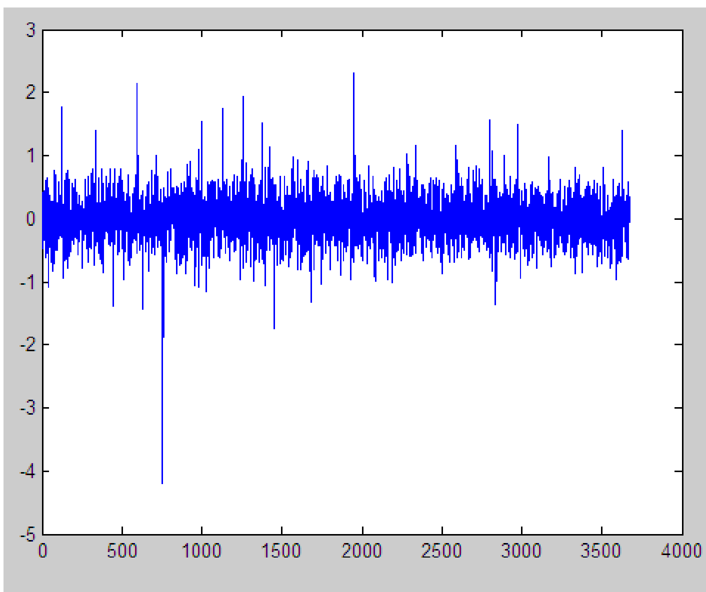


Figure 26 Wide band signal with set point at 0%

Testing on 50 %

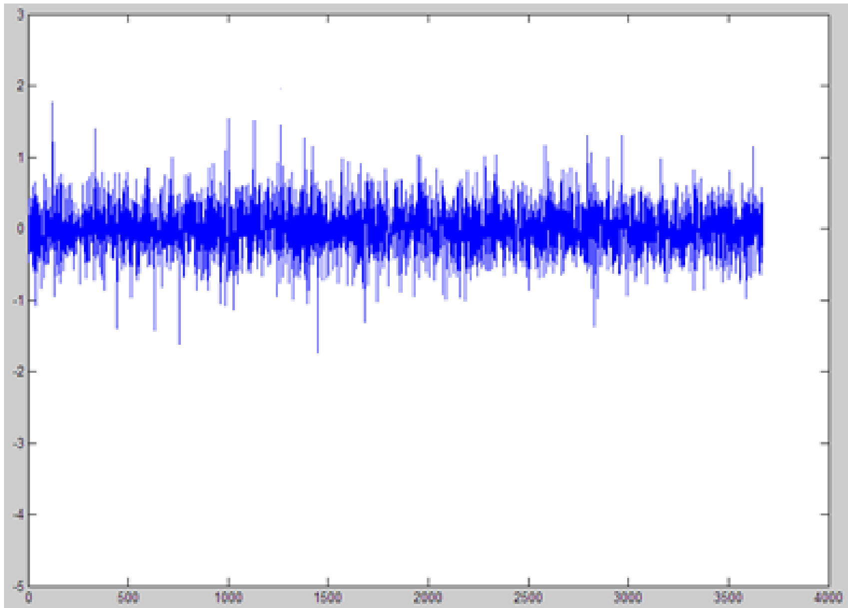


Figure 27 Wide band signal with set point at 50%

Then on 75 %

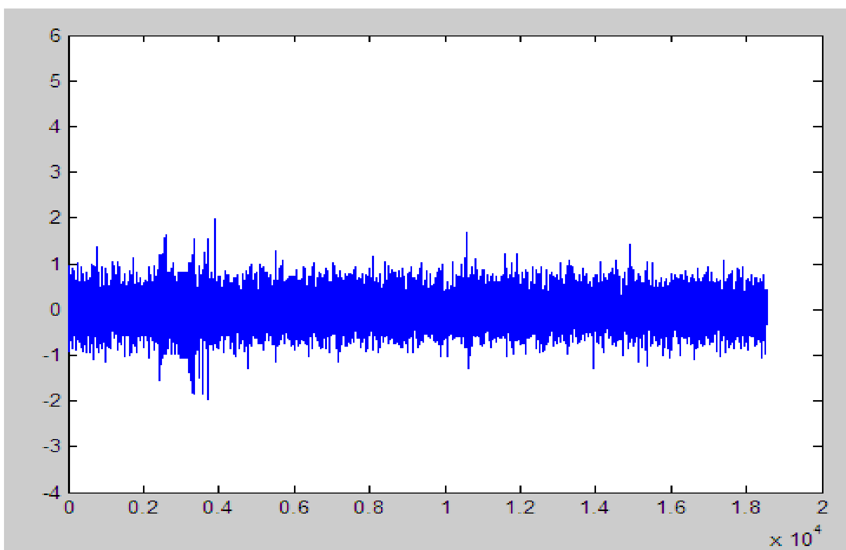
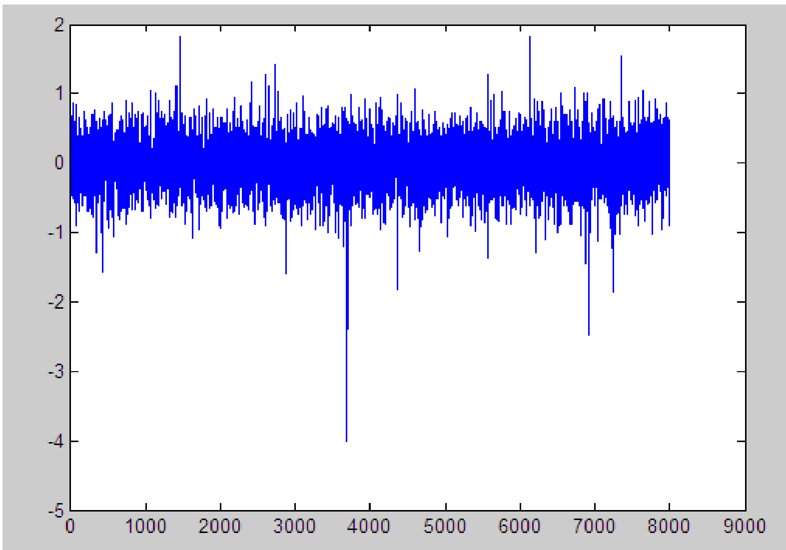


Figure 28 Wide band signal with set point at 100%

Then at 100%



4.3.3 Resonance vs. Differential sensors

Through the AE signals shown above, Two types of acoustic emission sensors have been used in order to determine the adequate acoustic emission sensors for detecting the globe valve failures later on. One type is a narrow band (resonance type) sensor that is highly sensitive to about a 60 kHz frequency and can cover the 30–100 kHz range.

The other type is a wide band sensor that covers the 100–1000 kHz range and is less sensitive to a particular frequency. The sensor positions are determined by the most effective area on the valve body where the propagation of waves will be at its highest.

As the literature review indicates, the healthy valve AE signal should not exceed the amplitude of 2 V in the resonance type and should be between -2 V and 2 V in the differential type.

Yet through the results shown above, the resonance type has indeed supported the right indications, yet the differential results were also good but providing minor overshoots along the experiment.

This result is perfectly normal, and proves even more that the valve being tested is a healthy valve. This is due to the high reliable sensitivity of the resonance sensor over the small range frequencies which a healthy valve will omit, as the wideband sensor is to be of a less sensitivity and a higher range of frequency, that’s why it it’s expected that in the next phase of the research , both sensor will be used and that wideband sensor will have the capability to detect mechanical failures over the resonance sensor.

4.4 Statistical analysis

As discussed in the literature review, statistical analysis is a powerful method to analyze the behavior of the valve, and it has been proven before that a healthy valve will omit certain values to prove its healthiness, this method includes 4 techniques they are kurtosis analysis, standard deviation, maximum amplitude and root mean square, so as discussed the healthy valve should give an approximate value near to those values for the analysis

Table 3 Statistical Analysis Standards for healthy valve acoustic emission respons

Statistical Anal. method	**Value**
Kurtosis	< 3
Standard Deviation	< 0.5
Maximum Amplitude	< 2
Root Mean Square (RMS)	< 2

4.4.1 Kurtosis analysis

The table below highlights the results obtained for Kurtosis analysis

Table 4 Kurtosis Analysis

Trial	Percentage of Valve Opening (%)				
	0	25	50	75	100
1	2.9887	2.7967	3.1823	2.8098	2.7432
2	2.9088	2.7656	3.0281	2.8540	2.5378
3	2.7933	2.9757	2.7842	2.8320	2.9075
4	2.7508	2.8723	2.7594	2.7072	2.6691
5	2.4366	2.8283	2.9983	2.7201	2.7188
6	2.8990	2.5934	2.8061	2.6666	2.5475
7	2.7391	2.6430	2.8059	2.8585	2.6921
8	2.7076	2.7038	2.7812	2.7228	2.6835
9	2.6025	2.6439	2.5813	2.5588	2.5859
10	2.7928	2.5256	2.6178	2.7335	2.688

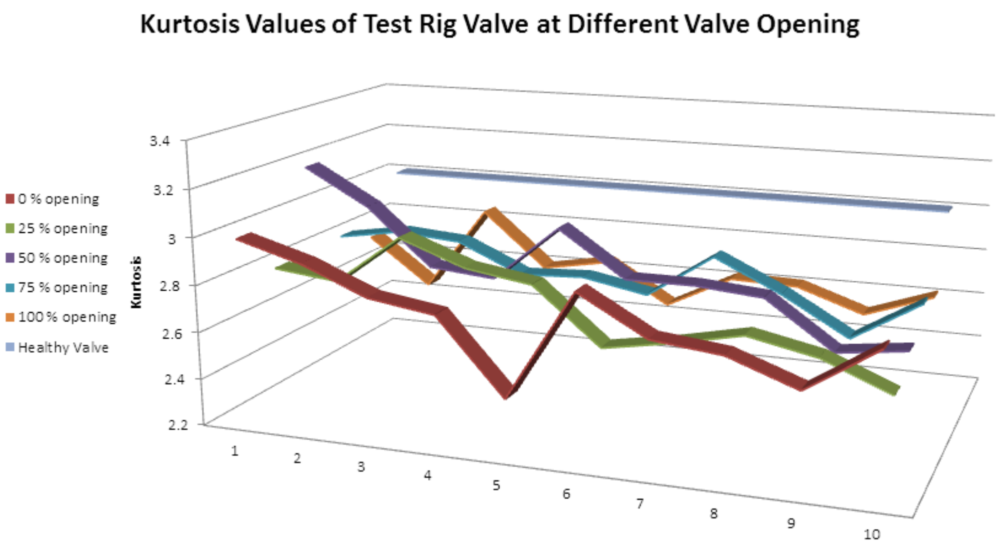


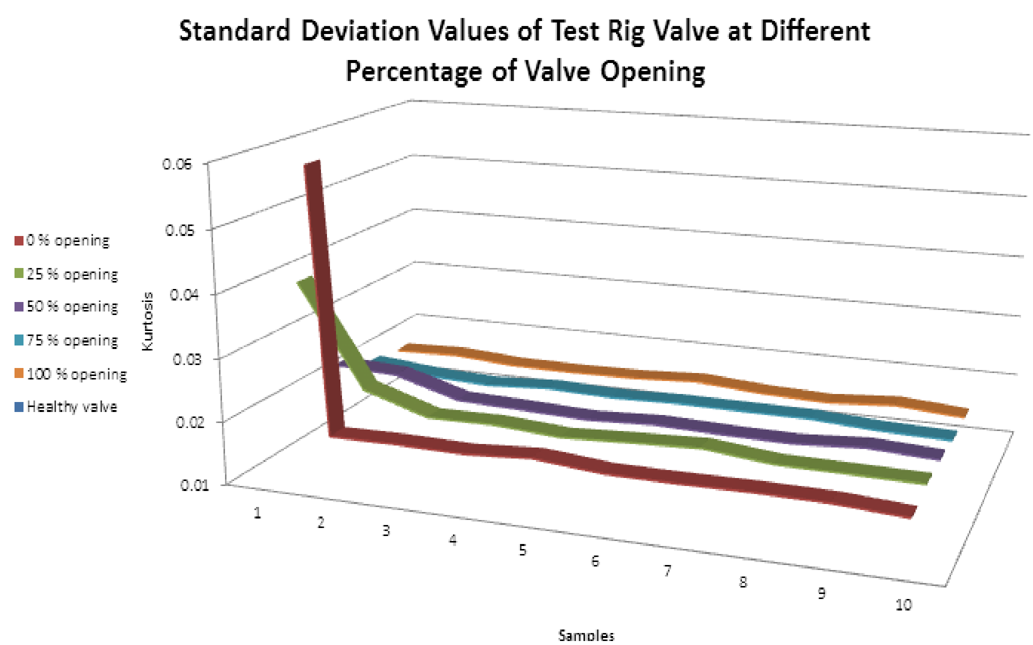
Figure 29 Kurtosis analysis graph

As the results obtained from the table shows, kurtosis analysis turned out to be a success and a first confirmation that the project is heading on the right track, as the values obtained are below 3 which achieves the criteria of the healthy valve, if those values were above 3 that will mean that the valve is not healthy or the measurements taking during testing were not precise.

4.4.2 Standard deviation

The table below contains the result obtained from the standard deviation analysis.

Trial	Percentage of Valve Opening (%)				
	0	25	50	75	100
1	0.20950	0.03898	0.02237	0.01955	0.01870
2	0.01861	0.02269	0.02182	0.01855	0.01901
3	0.01873	0.01938	0.01879	0.01807	0.01828
4	0.01856	0.01952	0.01848	0.01867	0.01820
5	0.01925	0.01881	0.01808	0.01834	0.01837
6	0.01831	0.01933	0.01859	0.01861	0.01892
7	0.01827	0.01979	0.01829	0.01856	0.01813
8	0.01840	0.01869	0.01816	0.01853	0.01779
9	0.01831	0.01863	0.01886	0.01789	0.01857
10	0.01766	0.01854	0.01832	0.01765	0.01780



As shown in the table the values obtained are all below 0.5 which means that this is the second confirmation that the valve is healthy and that this method can be used in the next phase of the project to differentiate the healthy valve from the unhealthy valve.

4.4.3 Maximum amplitude

The table below shows the maximum amplitude analysis obtained from the experiments performed on the healthy valve.

Table 5 Maximum amplitude analysis

Trial	Percentage of Valve Opening (%)				
	0	25	50	75	100
1	1.521	1.58	1.512	1.512	1.482
2	1.492	1.531	1.502	1.482	1.482
3	1.482	1.502	1.492	1.482	1.492
4	1.482	1.482	1.482	1.482	1.482
5	1.482	1.492	1.502	1.482	1.482
6	1.482	1.482	1.482	1.482	1.482
7	1.482	1.502	1.482	1.482	1.482
8	1.492	1.492	1.482	1.482	1.482
9	1.482	1.502	1.482	1.482	1.482
10	1.482	1.482	1.482	1.482	1.482

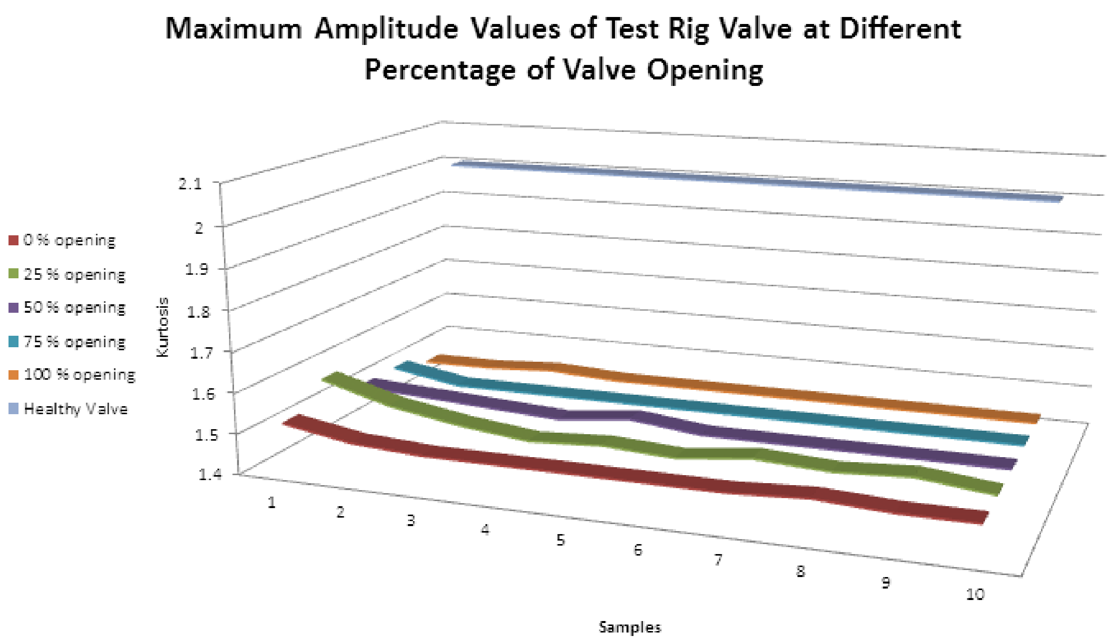


Figure 30 Maximum amplitude analysis graph

As shown in the table it is obvious that all the values obtained are below 2, means that the maximum amplitude of the waves are acceptable and that they indicate a healthy valve.

4.4.3 Vrms

Table 6 Vrms analysis

Trial	Percentage of Valve Opening (%)				
	0	25	50	75	100
1	1.4318	1.4319	1.4343	1.4330	1.4328
2	1.4322	1.4324	1.4330	1.4321	1.4345
3	1.4319	1.4321	1.4327	1.4325	1.4325
4	1.4332	1.4328	1.4320	1.4328	1.4324
5	1.4340	1.4329	1.4337	1.4329	1.4335
6	1.4317	1.4342	1.4321	1.4336	1.4332
7	1.4326	1.4329	1.4333	1.4325	1.4335
8	1.4331	1.4334	1.4330	1.4331	1.4331
9	1.4334	1.4337	1.4336	1.4340	1.4329
10	1.4339	1.4338	1.4334	1.4340	1.4329

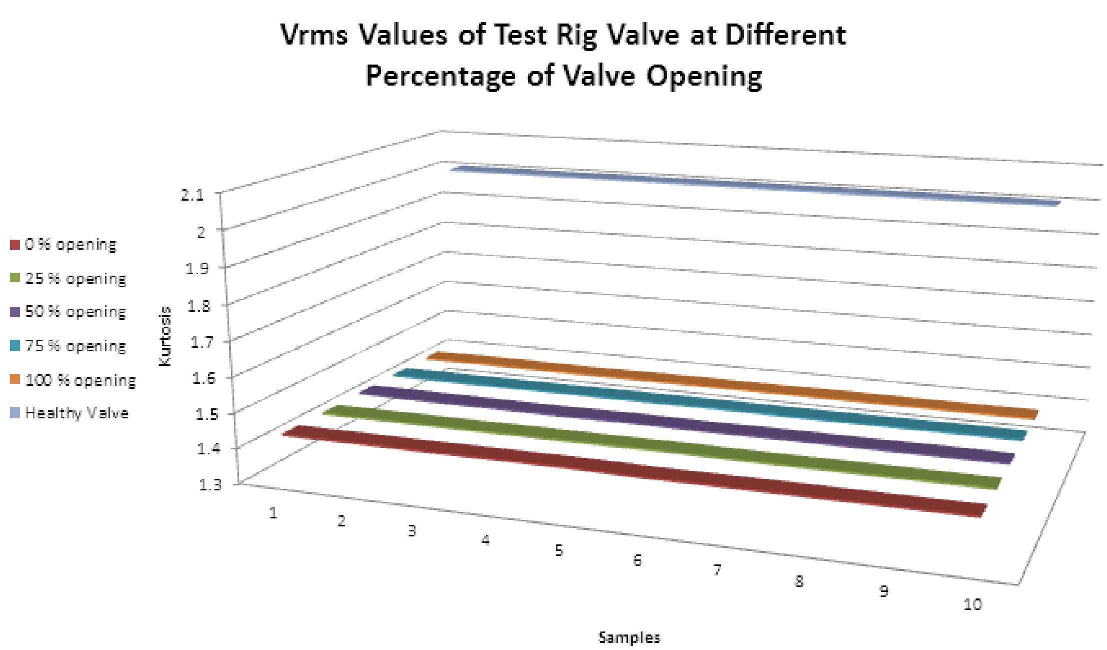


Figure 31 Vrms values graph

As shown from the root mean square analysis, all the values are below two which gives us healthy indications for the valve. This is the last step of the statistical analysis and it shows that all the specifications needed for a healthy valve are met, which makes it a strong candidate to be used to differentiate between healthy and unhealthy valve.

4.5 Power spectral density analysis

Power spectral density was tried also during our data analysis, yet applying the normal preset functions using matlab does not supply us with precise calculations in terms of the frequency width .

This is due to that the frequency spectrums of the acoustic emission sensors with the FFT analysis are unclear and hard to analyze based on the fact that there are no reference points that the research can refer to make sure of that the right data was obtained .

So ,the research continued ,by performing another type of analysis which is wavelet analysis, this analysis is much more precise than power spectral analysis, but it requires building an algorithm to identify the behavior of the waves ,that algorithm is in progress and will be carried in further development of the project .

The Fourier transform code was processed as follows :

```
a=AE


subplot(211), plot(AE)
grid on
ylabel('Voltage(V)')
xlabel('Sample')
title('Time domain')
Fs = 100000;
n = length(AE);
xfft = abs(fft(AE, n));
mag = 20*log10(xfft);
mag = mag(1:floor(n/2));
f = (0:length(mag)-1)*Fs/n;
f = f(:);
subplot(212),plot(f,mag)
grid on
ylabel('Magnitude (dB)')
xlabel('Frequency (Hz)')
title('Frequency domain')
[ymax,maxindex]= max(mag);
maxfreq = f(maxindex)
[ymax,maxindex]=max(mag);
maxmag=mag(maxindex)
fthresh = 5.0e+003;
index=find(f <= 5.0e+003);
```

Figure 32 Fourrier transform code

And the power spectral density code was processed as follows:

```
Fs=10000;

%# of samples in the data
datasize=size(simout3);
numsample=datasize(1);

%Windowing
H=hann(numsample);
W=H.*(simout3(:,1));

%Fourier Transform
FFTX=fft(W,numsample);

%Power: magnitude^2
X=FFTX(1:floor(numsample/2)).*conj(FFTX(1:floor(numsample/2)));

%Bandwidth
BW=1.5*Fs*numsample;

%PSD=magnitude^2/bandwidth
PSD=X/BW;

%Computing the corresponding frequency values
Omega=Fs*(0:numsample-1)/numsample;
Omega=Omega(1:floor(numsample/2));


%Plot PSD
H=plot(Omega,PSD);
set(H,'Color','BLACK');
```

Figure 33 PSD code1

This code resulted in inaccurate presentation that cannot be relied on.

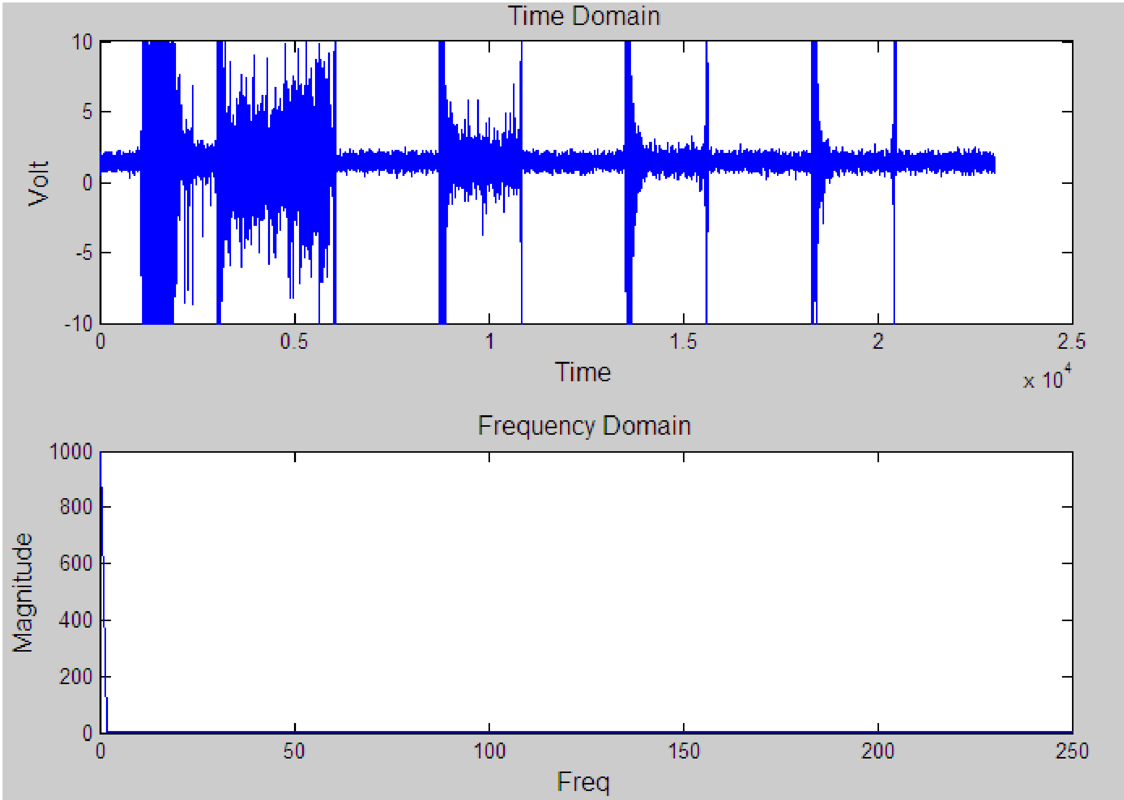


Figure 34 PSD response1

Another coding approach was used as follows

```
Fs = 10000;
  t = 0:1/Fs;
       randn('state',0);
       x = AE+randn(size(t));
       h = spectrum.periodogram('rectangular');
       hopts = psdopts(h,x);
       set(hopts,'Fs',Fs,'SpectrumType','twosided','CenterDC',true);
       psd(h,x,hopts)
    hpsd = psd(h,x,hopts);
       avgpower(hpsd)
```

The result is as follows:

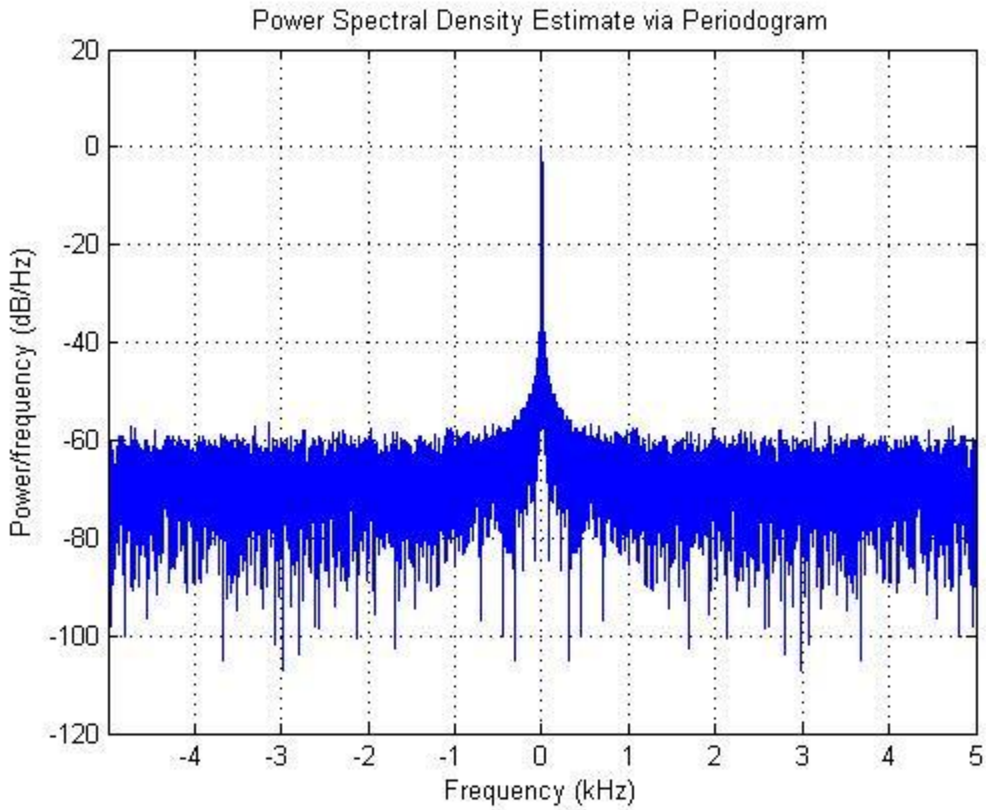


Figure 35 PSD response 2

This code is proved to be in efficient which leads us to think of a more efficient way which is wavelet analysis, but this way needs an algorithm to build which is the current process that the project is still at in terms of software development as discussed before.

4.5 Unhealthy valve experimental setup

This phase is to test an unhealthy valve on our test rig, but that requires an unhealthy valve to perform the experiment on and collect the output data, it was planned on the research to experiment on an unhealthy valve that will be sent from Petronas plant PFK , this valve was so important to our progress since it was a real life fault that was going to be tested ,however after two months waiting for Petronas to permit the release of the valve. The procedure was not completed.

That put the research in the situation of creating a substitute to that valve, so planning started to purposely create a fault in the same healthy valve that was used in the previous phase.

So since the research done states that different faults have different responses interms of frequency and amplitude which will be shown in statistical analysis and wavelet analysis.

The plan is to start first by creating different classes of corrosion to the valve, with having the valve tested every time the corrosion level increases.

The valve was dipped in highly concentrated sulphuric acid as proposed by chemical department; the reaction is still under development up to date.

As follows pictures of the up to date status of the valve in the chemical reaction process.

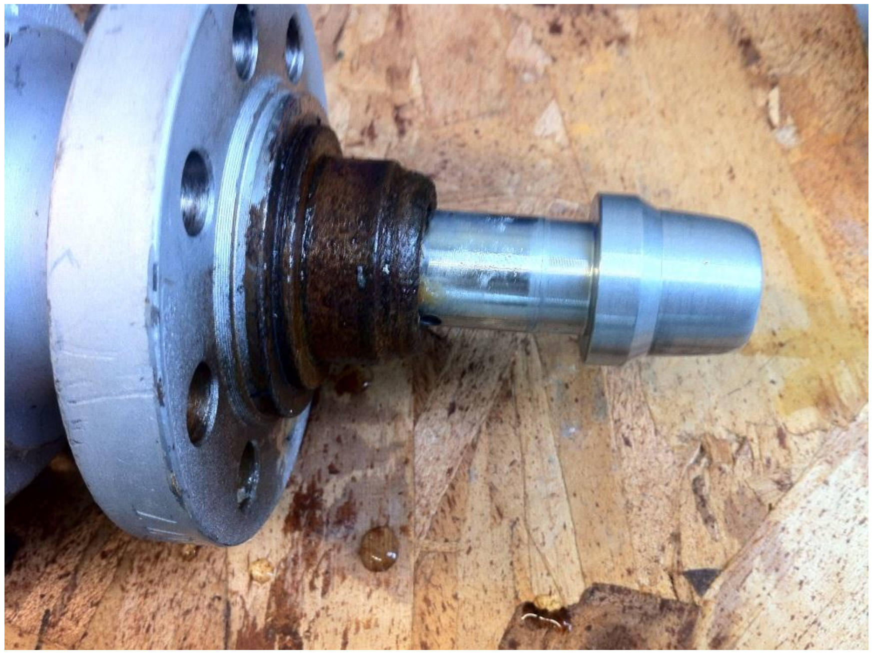


Figure 36 Valve corrosion progress in 2 days

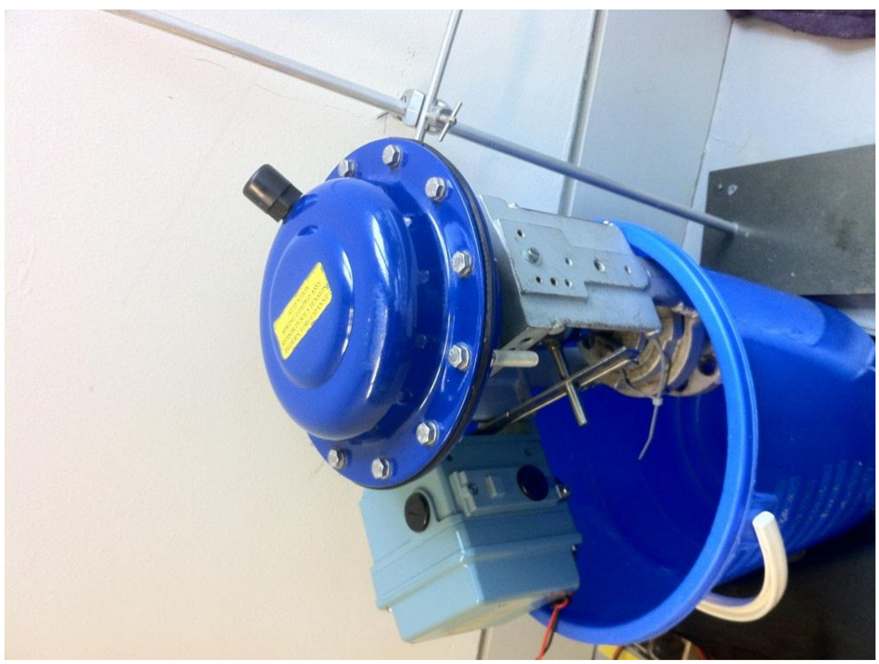


Figure 37 Chemical reaction process setup

Figure 38 Valve body with a thin corrosion layer

As shown in the figures above the chemical reaction is taking process in the lab ,as shown In figure 36 the valve plug is starting to get a thin layer of corrosion ,yet the process is very slow due to the valve's anti corrosive layer, steps might be taken later on to fasten the process, yet the process has to be slow and taken slightly step by step, as it is very advisable that the data gets collected as the valve will be experimented on at different levels of corrosion.

Chapter 5

5.1 Conclusion

This project targets to cut maintenance costs while increasing the efficiency of process plants by developing a software that targets on evaluating the condition of operating control valves as detecting leakage.

This is done using acoustic emissions technique over the control valves; both healthy and unhealthy valves are tested in this experiment in order to reach a high efficiency analysis level that enables us to develop the software.

Testing phase on the healthy valve has already been done using two types of acoustic emission sensors wideband (differential) and narrow band (resonance) sensor, resonance sensor has proven to be more effective in this phase yet, differential sensor is expected to be more effective in detecting the faults in the next phase.

Analysis on the collected data was done in many ways, statistical analysis were performed and conceived a huge success proving the healthiness of the valve.

Power spectral analysis were also performed but did not achieve a high accuracy due to the complexity of the coding required so another way is being approached which is the wavelet analysis method.

Unhealthy valve was awaited to be received from Petronas PFK site, but was not delivered yet, so the research took a path into creating our own fault in many grades and testing on each state.

Corrosion testing started first and is taking place at the moment, once corrosion occurs testing will be followed on immediately.

As a conclusion in this phase of the project we aimed to attain efficient results from the experiment, compare and analyze them and once achieved the second phase is targeted which is to develop the diagnostic software aimed.

5.2 Recommendations

This project has cut through major milestones in the path of the research, yet further phases has to be done in order to meet the final query as in the Diagnostic software to be built.

Wavelet analysis algorithm has to be done in order to obtain certain results in order to be used in the diagnostic software.

Testing on the unhealthy valve has to be carried on, then once obtained achievable results the diagnostic software can be built using the pattern recognition software via MATLAB.

References

[1] Thompson G. and G. Zolkiewski, “An Experimental Investigation into the Detection of Internal Leakage of Gases through Valves by Vibration Analysis”, Proceedings of the Institute of Mechanical Engineers, Vol. 21 I, Part E, 1997,

[2] M.A. Shariff and R. I. Grosvenor, “Internal Valve Leakage Detection using an Acoustic Emission Measurement System”, Journal of Institute of Measurement and Control, December 1998, Vol. 20, No.5233-242, pp.

.

[3] Rosdiazli bin Ibrahim, 2011 “A Study on Control Valve Fault Incipient Detection Monitoring System Using Acoustic Emission Technique, , IEEE

[4] A. Masjedian Jazi, H. Rahimzadeh, “Detecting Cavitation in Globe Valves by Two Methods: Characteristic Diagrams and Acoustic Analysis”, 1440-1445

[5] Seda Postalcioglu Ozgen, 2009, “Graphical User Interface Aided Online Fault Diagnosis of Electric Motor-DC Motor Case Study”, 12-17

[6] Dong Hun Kim, Won Kyu Lee, Sok Won Kim, 2009, “Analysis of Acoustic mission Signal for the Detection of Defective Manufactures in Press Process”, World Academy of Science, Engineering and Technology

[7] Nesvijski, E. and M. Marasteanu (2001). "Wavelet Transform and Its Application to Acoustic Emission Analysis of Asphalt Cold Cracking."

[8] Khamedi R., Fallahi A., Refahi Oskouei A.,(2010) “Effect of Martensite phase volume fraction on acoustic emission signals using wavelet packet analysis during tensile loading of dual phase steel”

[10] Anantapadmanaban T, Radhakrishnan V, 1982, “An investigation of the role of surface irregularities in the noise spectrum of rolling and sliding contacts”.

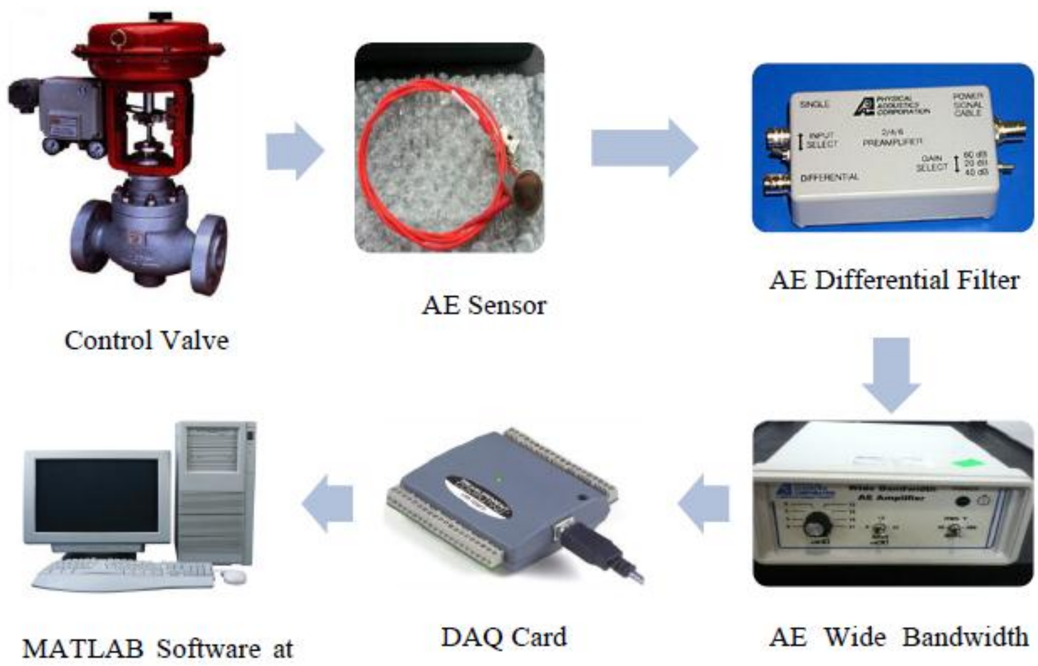
[11] Tandon N, Nakra BC, 1990, “The application of the sound intensity technique to defect detection in rolling element bearings. Appl Acoust “

[12] Florom RL, Hiatt AR, Bambara JE, Smith RL, 1987, “ Wayside acoustic detection of railroad roller bearing defects”. ASME Paper 87.

[13] Christian U. Grosse, Masayasu Ohtsu, 2008, “Acoustic Emission Testing”, Springer Verlag, pp.45-47

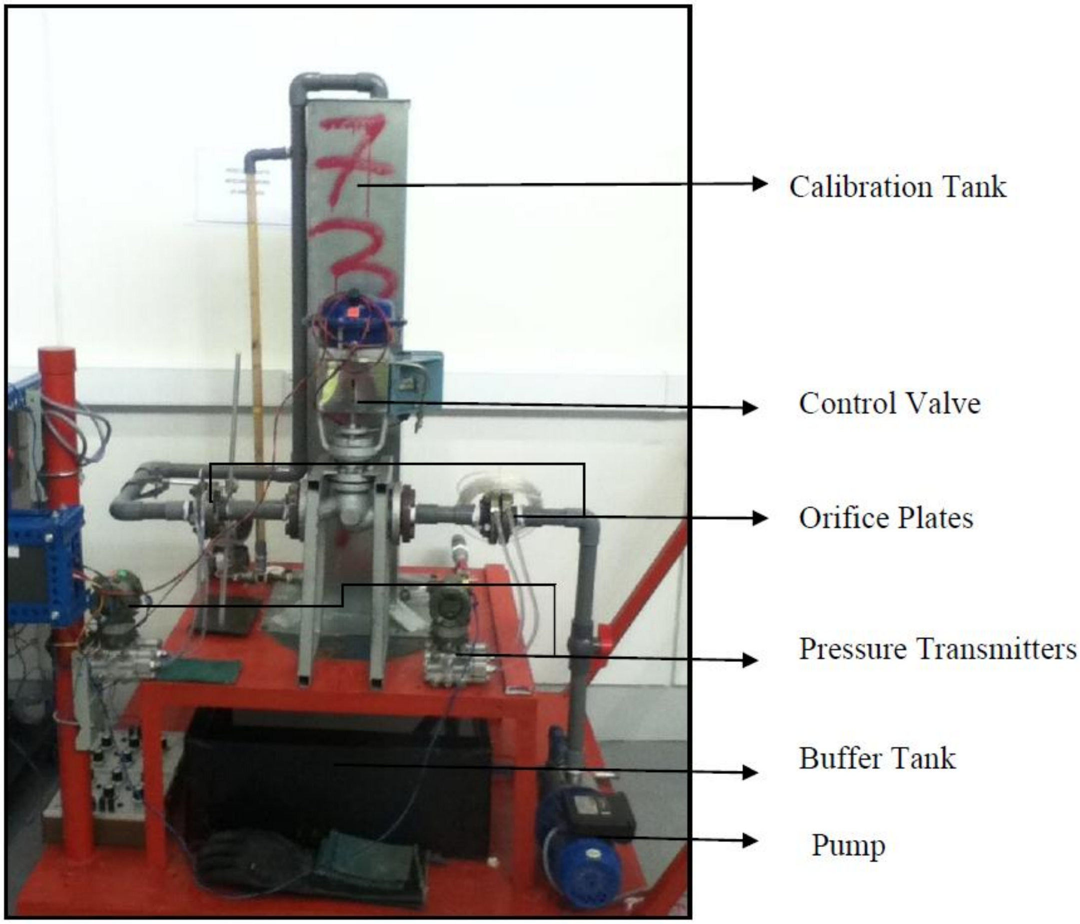
APPENDICES

Appendix A: Experimental Setup

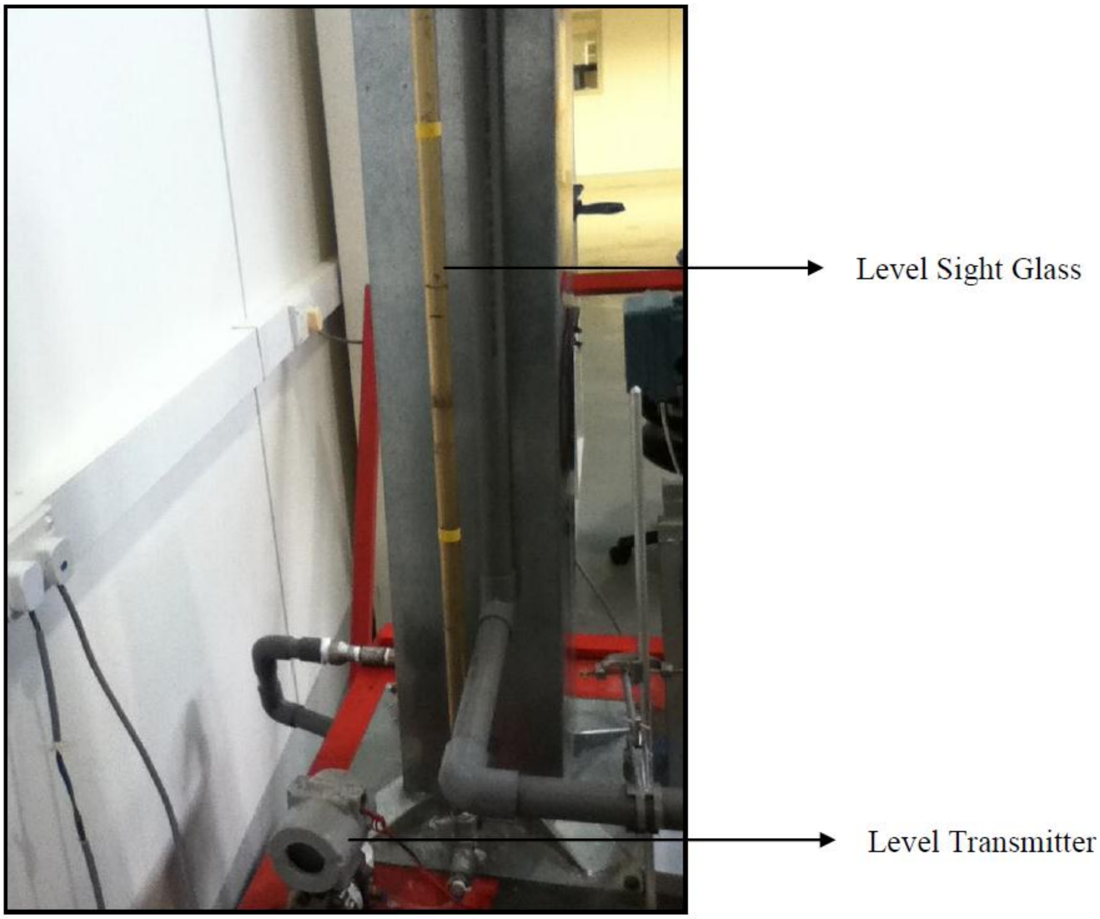


Appendix B: Test rig

Front View:



Side View:

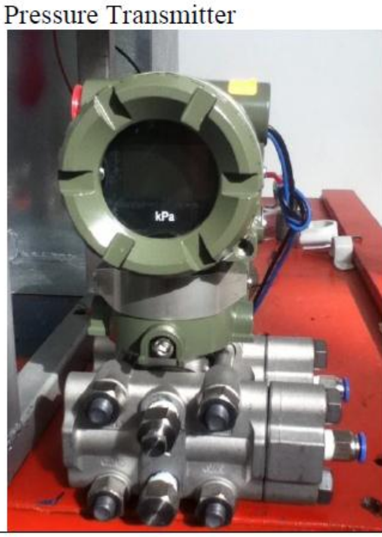


Appendix C: Gantt chart for FYP 1 and FYP2

Week Number/Title	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of project title														
Research on Acoustic Emissions														
Finalizing proposal														
Experimentation														
Analysis and comparison of data														
Interim report submission														

Week Number/Title	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Testing on resonance sensors														
Testing on differential sensor														
Data analysis														
Progress report														
Testing on unhealthy valve														
Project Viva, submission of final report and technical paper														

Appendix C: Equipment Specifications

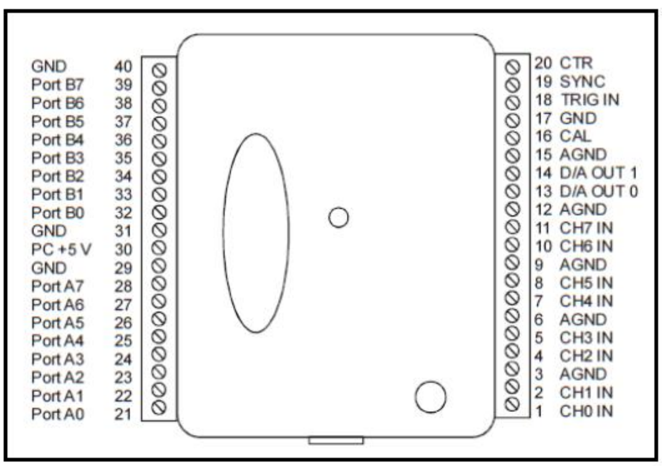
No.	Equipment & Purpose	Specifications	Actions
1	Control Valve 	To control flow of water Brand : Foxboro	Overhauled
2	Pressure Transmitter 	To obtain differential pressure by measuring from both sides of control valve Brand : Yokogawa	Calibrated

3	Pressure (Level) Transmitter 	To measure level of water in the tank Brand: Smar	Calibrated Range:0-800mmH20
4	Controller 	To control water level in the tank To control opening of control valve Brand: Yokogawa	Calibrated
5	Pump 	To pump water into test rig Brand: Ebara Flow rate: 5-45 l/min HP: 0.5	Inspected

Appendix D: DAQ card Specifications

Model: USB-1208FS

Main connector and pin out for 8-channel single-ended mode



8-channel single-ended mode

Pin	Signal Name	Pin	Signal Name
1	CH0 IN	21	Port A0
2	CH1 IN	22	Port A1
3	AGND	23	Port A2
4	CH2 IN	24	Port A3
5	CH3 IN	25	Port A4
6	AGND	26	Port A5
7	CH4 IN	27	Port A6
8	CH5 IN	28	Port A7
9	AGND	29	GND
10	CH6 IN	30	PC+5V
11	CH7 IN	31	GND
12	AGND	32	Port B0
13	D/A OUT 0	33	Port B1
14	D/A OUT 1	34	Port B2
15	AGND	35	Port B3
16	CAL	36	Port B4
17	GND	37	Port B5
18	TRIG_IN	38	Port B6
19	SYNC	39	Port B7
20	CTR	40	GND