A LOW-COST AIR LEAKAGE MONITORING TECHNIQUE FOR INDUSTRIAL COMPRESSED AIR PIPING SYSTEM USING ACOUSTIC EMISSION SENSOR

Kittipob Aurreethum

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Technology
Graduate School
Thai-Nichi Institute of Technology
Academic Year 2015

Thesis Title	A Low-Cost Air Leakage Monitoring Technique for Industrial Compressed Air Piping Systems using Acoustic Emission Sensor
By	Kittipob Aurreethum
Field of Study	Engineering Technology
Advisor	Asst. Prof. Dr. Wimol San-Um

The Graduate School of Thai-Nichi Institute of Technology has been approved and accepted as partial fulfillment of the requirements for the Master's Degree

………………………….……………….. Dean of Graduate School
(Assoc. Prof. Dr. Pichit Sukchareonpong)
Month.…..…..… Date…….. , Year………..

Thesis Committees

………………………….……………….. Chairperson
(Dr. Surapong Pongyupinpanich)

………………………….……………….. Committee
(Asst. Prof. Dr. Warakorn Srichavengsup)

………………………….……………….. Committee
(Dr. Kanticha Kittipeerachon)

………………………….……………….. Advisor
(Asst. Prof. Dr. Wimol San-um)

KITTIPOB AURREETHUM : A LOW-COST AIR LEAKAGE MONITORING TECHNIQUE FOR INDUSTRIAL COMPRESSED AIR PIPING SYSTEM USING ACOUSTIC EMISSION SENSOR. ADVISOR: ASST. PROF. DR. WIMOL SAN-UM, 40 PP.

This thesis presents Non-Destructive Inspection (NDI) of industrial compressed air piping system using Acoustic Emission (AE) sensing technique. The purpose of this paper is to implement a cost-effective AE sensing system for industrial application where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. The experiment utilizes a steel pipeline with a diameter of 0.5 inches to model the industrial compressed air pipelines, completely including a 90o-Degree Elbow (ELL), a T-Shape Elbow (TEE), and blank-end. The air compressor with an electric regulator provides air pressure with four cases, i.e. 4 to 6 Bars. The AE sensor is attached to various points on the steel pipeline using grease. The AE signal is amplified with 20 dB prior to an analysisin Labview through National Instrument (NI) DAQ board. The signal characterization was performed through a magnitude in frequency response diagram. The results reveal that the AE signal with no-leak and leak conditions can be inspected accurately. The flaw signatures at different source of leakage can also be observed. This paper presents an alternative potential for a cost-effective AE characterization methods in industrial applications.

Graduate School Student's Signature……….…………….…….

Field of Engineering Technology Advisor's signature……..…..………………

Academic Year 2015

Acknowledgements

The author wishes to express his profound gratitude and respectfully dedicate this work to his parent and family members for their endless encouragements, love and sacrifices. The author is most grateful to his advisor, Asst.Prof.Dr.Wimol San-um, for his valuable supervision, support and encouragements throughout the study. In addition, grateful acknowledges are made to Asst.Dr.Surapong Srichavengsup, Asst. Prof. Dr.Warakorn Srichavengsup and Dr.Kanticha Kittipeerachon members of thesis committee, for their valuable suggestions and comments. The authors are grateful to Research and Development Division of Thai-Nichi Institute of Technology for research fund supports.

Kittipob Aurreethum

Table of Contents

Table of Contents (Continued)

List of Table

List of Figures

Chapter 1
Introduction

1.1 Introduction

This chapter gives a background of a research approaches, involving Acoustic Emission phenomena of pipeline when have leaking and fluid dynamics It also includes the motivation, statement of problem, research scope, research objective, expected outcomes and definition of technical terms.

1.2 Background

Pipeline transport is the transportation of goods or material through a pipe. Pipelines in various stages of construction. Liquids and gases are transported in pipelines and any chemically stable substance can be sent through a pipeline. Pipelines are useful for transporting water for drinking or irrigation over long distances when it needs to move over hills, or where canals or channels are poor choices due to considerations of evaporation, pollution, or environmental impact. Pneumatic tubes using compressed air can be used to transport solid capsules.

Oil pipelines are made from steel or plastic tubes which are usually buried. The oil is moved through the pipelines by pump stations along the pipeline. Natural gas (and similar gaseous fuels) are lightly pressurised into liquids knows as Natural Gas Liquids (NGLs). Natural gas pipelines are constructed of carbon steel. Highly toxic ammonia is theoretically the most dangerous substance to be transported through long-distance pipelines, but accidents have been rare. Hydrogen pipeline transport is the transportation of hydrogen through a pipe. District heating or teleheating systems use a network of insulated pipes which transport heated water, pressurized hot water.

Pipelines conveying flammable or explosive material, such as natural gas or oil, pose special safety concerns and there have been various accidents. Pipelines can be the target of vandalism, sabotage, or even terrorist attacks. In war, pipelines are often the target of military attacks.

Figure 1.1 Pipeline use to transport material

From above to see that Pipelines usually involve work to be executed under difficult circumstances. Pipelines typically span long distances and can cross extremely rugged terrain such as hills, lakes, rivers, mountains, and even domestic areas. It is crucial that pipelines are tested for integrity, are corrosive or leak because when occur leaking will significantly the environmental damages and human and financial losses of any accidental.

In present Various technologies and strategies have been implemented for monitoring pipelines, from physically walking the lines to satellite surveillance. The most common technology to protect pipelines from occasional leaks is Computational Pipeline Monitoring takes information from the field related to pressures, flows, and temperatures to estimate the hydraulic behavior of the product being transported. Once the estimation is completed, the results are compared to other field references to detect the presence of an anomaly or unexpected situation, which may be related to a leak. But there research that apply the acoustic emission technology to Source signal and location leaking of replica steel pipe .The Acoustic Emission (AE) signal is a transient elastic wave generated by the rapid release of energy from localized source within a material.

This thesis therefore studies the application of the AE sensor for Analysis of leakage in air pressure steel pipeline of using acoustic emission method.AE signal is transmitted to personal computer for signal analysis in both time and frequency domains.

1.3 Motivations

The motivation of this thesis is to find between signal leak or not leak location with AE sensor from transient elastic wave and rapid release of energy from localized source within a material shall be used in this thesis as it is a new technique for leak detection that receives much research attention.

1.4 Statement of Problem and Hypothesis

Leakage detect as one of the most important problem in air pipeline can lead to financial losses as well as reverse human an environmental impacts. Acoustic emission (AE) is a non destructive testing technique which is used to leak detection and stress-wave process arising from local energy release within the material, such as those cause by impact crack propogation and fluid flow thought confined space. These wave are propagated through the ppe wall and recorded by using acoustic sensor installed on the pipe wall.

1.5 Objectives

1.5.1 To study and analysis the relationship between the AE signal and leak in air pressure steel pipeline in both time and frequency domains.

1.5.2 To design and apply acoustic emission sensor for detecting anomalies leaking and compare signal between signal not leak and leak.

1.6 Research Scopes

1.6.1 Study and Analysis the relationship between the AE signal and leak in air pressure steel pipeline in both time and frequency domain.

1.6.2 Design and apply Acoustic emission sensor for detecting anomalies leaking and compare signal between signal not-leak and leak.

1.7 Expected Outcomes

1.7.1 To achieve the relationship between the AE signal and leak in air pressure steel pipeline in both time and frequency domains.

1.7.2 To achieve the relationship between the AE signal and leak in air pressure steel pipeline in both time and frequency domains.

1.8 Definitions

1.8.1 Acoustic emission (AE) is the class of phenomena radiation where transient elastic wave in solids are generated by the rapid release of energy from localized source within material that occurs when a material undergoes irreversible changes in its internal structure, for example as a result of crack formation or plastic deformation due to aging, temperature gradients or external mechanical forces. In particular, this results in small surface displacements of a material produced by elastic or stress waves generated when the accumulated elastic energy in a material or on its surface is released rapidly. The waves generated by sources of AE are of practical interest in methods used to capture AE in a controlled fashion, for study and/or use for inspection of structural integrity, quality control, system feedback, process monitoring, and others.

1.8.2 Analog-to-digital conversion is a device that converts a continuous physical quantity (usually voltage) to a digital number that represents the quantity's amplitude. The conversion involves quantization of the input, so it necessarily introduces a small amount of error. Instead of doing a single conversion, an ADC often performs the conversions ("samples" the input) periodically. The result is a sequence of digital values that have been converted from a continuous-time and continuous-amplitude analog signal to a discrete-time and discrete-amplitude digital signal.

1.8.3 Compressed air is air kept under a pressure that is greater than atmospheric pressure. It serves many domestic and industrial purposes.

1.8.4 Nondestructive testing or Non-destructive testing (NDT) is a wide group of analysis techniques used in science and industry to evaluate the properties of a material, component or system without causing damage. The terms Nondestructive examination (NDE), Nondestructive inspection (NDI) and Nondestructive evaluation (NDE) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product evaluation, trouble shooting, and research. Common NDT methods include ultrasonic, magnetic-particle and low coherence interferometry.

1.9 Conclusions

This chapter has introduced the background of Acoustic emission Phenomena and Non-destructive testing (NDT) for new technic. This chapter also summarized the objectives as well as the expected outcomes of the research. Some basic definitions of technical terms are also defined.

Chapter 2
Related Theories and Literature Reviews

2.1 Introduction

Chapter 2 present a synthesis of the related theory, particularly a key concept of AE principle and its parameters and analog-to-digital converter. The literature review are also studied, focusing on the applications, techniques and characteristics of AE sensor for pipelines leak detection in which the knowledge from theries and literature review are synthesized and applied for this research.

2.2 Related Theory

2.2.1 Acoustic Emissions

It can tell that material you can "listen" to the sounds of cracks growing, fibers breaking and many other modes of active damage in stressed materials, enerally speaking these breaking sounds are refer to as “Acoustic Emission” (AE): ”AE refers to the generation of transient elastic waves during the rapid release of energy from localized sources within a material. The source of these emissions in metals is closely associated with the dislocation movement accompanying plastic deformation and the initiation and extension of cracks in a structure under stress. Other sources of Acoustic Emission are: melting, phase transformation, thermal stresses, cool down cracking and stress build up”.

Acoustic emission testing has become a recognized nondestructive test (NDT) method commonly used to detect and locate faults in mechanically load structure and components. AE can provide comprehensive information on the origination of a discontinuity (flaw) in a stressed component and also provide information pertaining to the development of this flaw as the component is subjected to continuous or repetitive stress. Discontinuities in components release energy as the component is subjected to mechanical loading or stress. This energy travels in the form of high-frequency stress wave. These wave or oscillations are received with the use of sensor (transducers) that in turn convert the energy into a voltage .This voltage is electronically amplified and with the use timing circuits is further processed as AE signal data. Analysis of the collected data comprises the characterization of the received voltage (signals) according to their source location, voltage intensity and frequency content.

This make Acoustic emission testing particularly interesting for applications that require constant monitoring of certain strucres, e.g. signal that show for pipeline leak. Often, this method is used to detect material failure at a very early stage of damage and before the structure fails completely.

2.2.1.1 Sensor Technology

AE signal are often being capture with piezoelectric sensors. These sensor are directly attached to the surface of the material sample under test converting dynamic motions at the surface into an electrical signal. When using piezoelectric sensors, it must be considered that they are normally operate at resonance and Therefore do not allow broadband detection of AE signals nevertheless, the frequency ranges of the expected signals are often fairly well known, making it possible to choose the right sensor before the experiment. Thus, their case of use as well as their high sensitivity makes piezoelectric sensors the instrument of choice for many AE applications, even though more sophisticated AE sensor conceots exist (e.g.sensor based on laser or on fiber optics). Figure 2.1shows the structure of Piezoelectric AE

Before A/D conversion, the electrical signal at the output of a piezoelectric sensor normally needs to be filtered and amplified. This process is also known as “signal conditioning”. It is abvious, that these components of an acquisition system are very sensitive and heavily influence the overall measurement quality. The conditioned signal is then sampled and all further processing is then performed digitally. Figure 2.2shows the AE data acquisition process

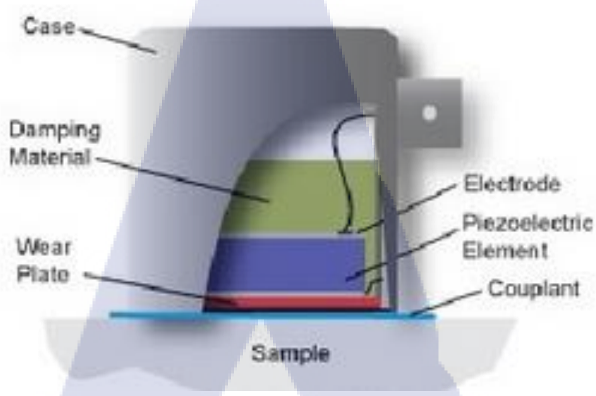


Figure 2.1 The structure of Piezoelectric AE sensor.

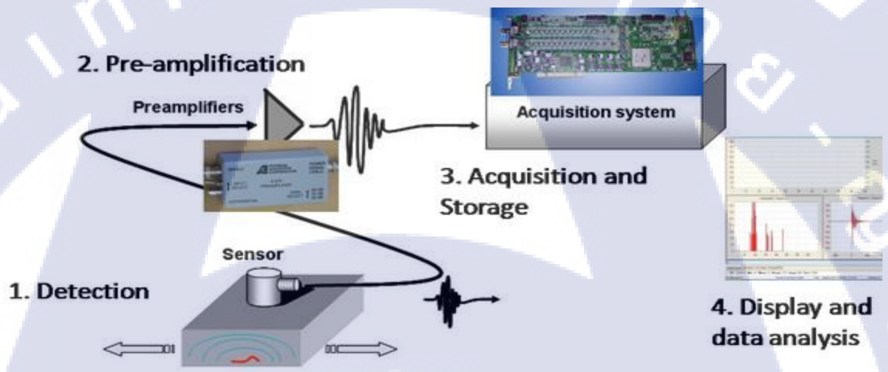


Figure 2.2 The AE data acquisition process

2.2.1.2 Data Processing and Signal Parameter Analysis

In present will that people Try to find system at advanced, fast, and accurate. Which AE can detect from signal, processing and characterization show in the digital domain. AE activity normally occur rapidly and randomly, resulting indistinct "pulses" of oscillation in the measured AE signal. With the equipment configured and setup complete, AE testing may begin. The sensor is coupled to the test surface and held in place with tape or adhesive. An operator then monitors the signals which are excited by the induced stresses in the object. When a useful transient, or burst signal is correctly obtained, parameters like amplitude, counts, measured area under the rectified signal envelope (MARSE), duration, and rise time can be gathered. Each of the AE signal feature shown in the Figure2.3 Show characteristic of AE parameters and described at below.

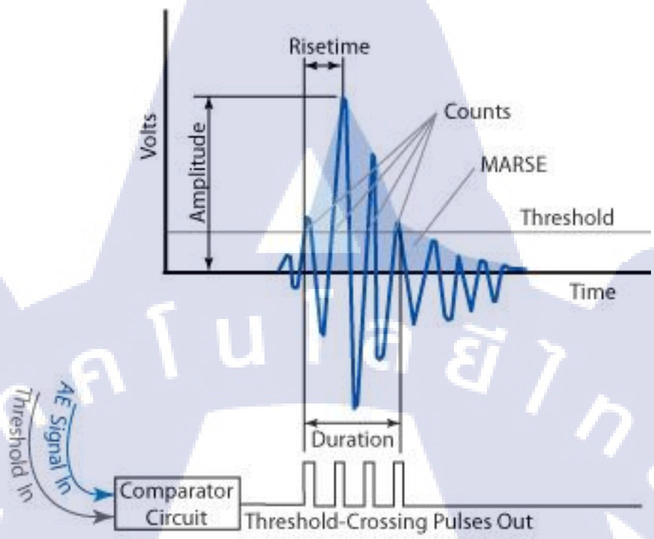


Figure 2.3 Characteristic of AE parameters

2.2.2 Operation Amplifier

Operation amplifier (Op Amps) is optinal integrated circuit or IC .The type of circuit is linear Integrated Circuit. Which has bring to the application use various tasks extensively. Operation amplifier be the first designed in1948 to help with the math laboratory in analog computer monitor. Therefore, it is called Operational Amplifier which means the circuit operation.

In addition Op Amps be used in the application of the many various operations. Is due to expand this circuit Expansion Differential Amplifier with a rate. Expansion is very high and the design and analysis of circuits with a Op Amps it can be easy to use.

Application used Op Amps be found in circuit tester, Display circuit and circuit electronic in process control, integrated tuner, integrated communications, alarm systems, electronic circuits of medical , scientific and the computer system etc. It is seen that the op amp been used extensively. Figure2.4 show the symbol of the op amps.

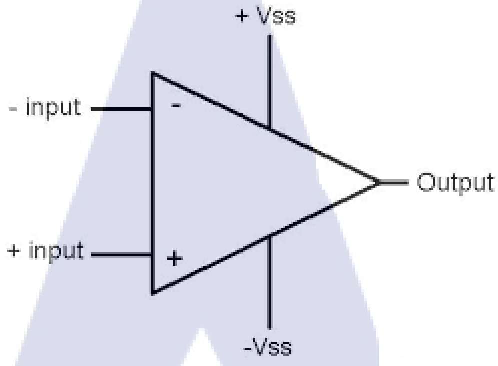


Figure 2.4 The symbol of the op amps.

The sources used function of the source DC is $+V_{ss}$ and $-V_{ss}$ Payment with Op-Amp which mainly uses not exceed ± 15 V input way have 2 terminal are Positive input and negative input . Figure2.5 show the compatible with the characteristics of the op amp

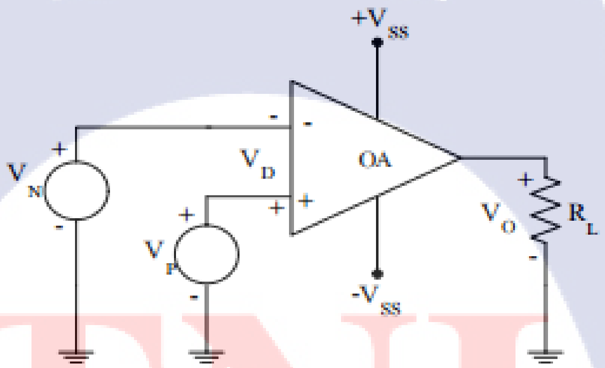


Figure2.5 The compatible with the characteristics of the op amp

Figure 2.5 shows that output V_o out of Op Amp passes resistor R_L in grounded, positively input represent the a pole of. V_p, negative input represent the apole of V_N. The difference between V_p and V_N is V_D.

$$V_D = V_p - V_N \qquad (1)$$

The op amp is ideal we find the growth rate (μ) from

$$\mu = \frac{V_0}{V_D} \qquad (2)$$

2.2.3 Theory of flow in a pipe

Physical properties some aspects of fluid viz Pressure, density, speed, number, Ray Reynolds (Reynolds' number), these values are correlated to the flow, which will be discussed further.

Pressure is related to the force-sectional area.so When have change the cross-sectional area to make change pressure. We can apply to use to calculate the velocity of fluid flow from the equation of Bernoulli which is for the flow Steady, incompressible, inviscid and usage Specific flow only.

Density used to calculate the pressure of the fluid at any point indicates the density. Mass per unit volume

Speed is the variable that determines the behavior of fluid flow that is going on. Any manner that is, when the average velocity of the fluid is moving slowly. We will call this flow is Laminar flow. Shown in Figure 2.6 can be see that area around diameter of the pipe. The flow of area around diameter velocity is greater than the area Away and speed is of more value to a certain level to cause turbulent flow. Shown in Figure 2.6 show the flow behind this is seen as the most incidentally low. The sculpture will be a turbulent flow with model uncertainties.

Reynolds Number is the index number indicating the phenomenon. Fluid flow which is proportion of inertia / viscous Ray Reynolds numbers are charged depending on the flow viscosity. Pipe diameter and density we could have written such a relationship is.

$$Re = \frac{\rho V D}{\mu} \qquad (3)$$

When Re Reynolds Number

V Flow velocity (m / s)

D Diameter of the pipe (m)

ρ Density of the liquid (kg/m3)

μ The viscosity of the fluid, (kg/ms)

Reynolds numbers without units. And a very important this is a number that used to determine the pattern of fluid flow as any. Such as

Re in the range 0 - 2000 state of flow is Laminar Flow.

Re in the range of 2001 - 4000 state of flow is a flow Transition Zone. Transition Zone is two models (Laminar + Turbulent).

Re over 4000 state of flow is Turbulent Flow.

Figure 2.6 show Velocity Profile of flowing

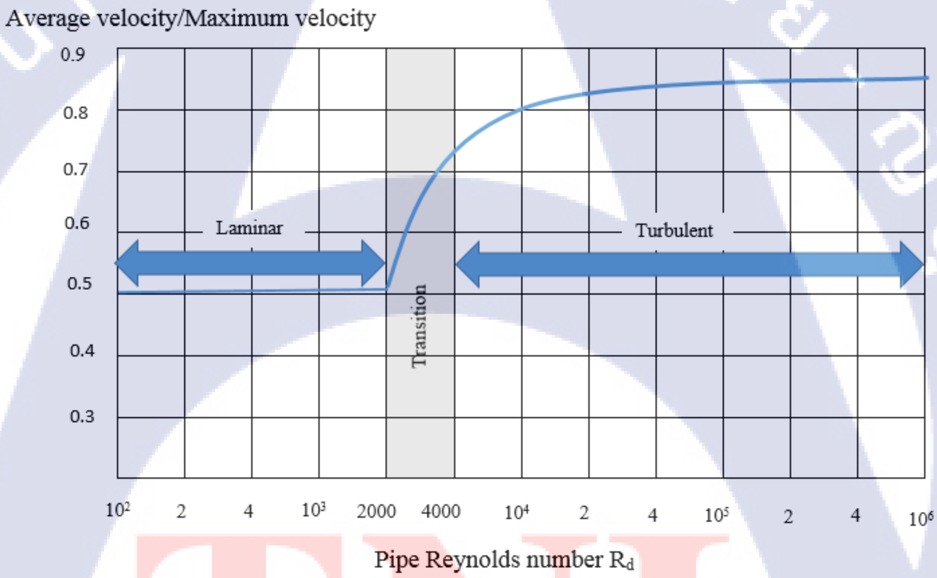


Figure2.6 Velocity Profile of flowing

If the fluid the inlet pipe flow Uniform flow is shown when considering the effect of viscosity found. In this case, the fluid viscosity the effect of shear. Boundary layers, which causes the flow in the class will be divided into two distinct parts, we call the distance the fluid. Influx as the Entrance length, after this period, the flow is changed to fully developed flow during which the speed will not be changed with distance along the flow (x). Figure2.7 Show Entrance region, developing flow and fully developed flow in a pipe.

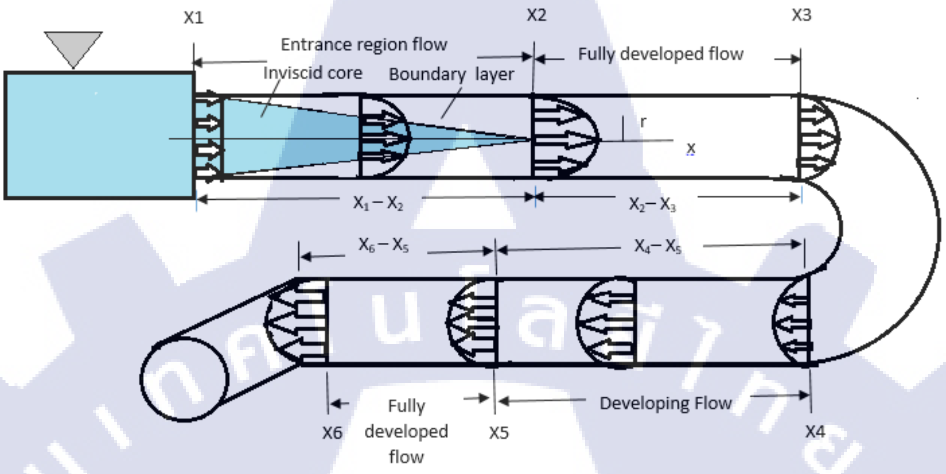


Figure2.7 Entrance region, developing flow and fully developed flow in a pipe

To calculate the length of the fully developed flow is calculated using the following equation.

$$\frac{le}{D} = 0.06\,Re \qquad \text{; Laminar flow} \qquad (4)$$

$$\frac{le}{D} = 4.4(Re)^{1/6} \qquad \text{; Turbulent flow} \qquad (5)$$

In order to achieve the fully developed flow $X_3 - X_2 >$ le or $X_5 - X_4 > X_6 - X_5$

When *le* is Distance of Entrance length (m)

D is Diameter of pipe (m)

2.2.4 Fast Fourier transform (FFT)

Algorithms have computational complexity O ($n \log n$) instead of $O(n^2)$. If n is a power of 2, a one-dimensional FFT of length n requires less than $3n \log_2 n$ floating-point operations (times a proportionality constant). For n = 220, that is a factor of almost 35,000 faster than $2n$.

When using FFT algorithms, a distinction is made between the *window* length and the transform length. The window length is the length of the input data vector. It is determined by, for example, the size of an external buffer. The transform length is the length of the output, the computed DFT. An FFT algorithm pads or chops the input to achieve the desired transform length. The following figure illustrates the two lengths.

The execution time of an FFT algorithm depends on the transform length. It is fastest when the transform length is a power of two, and almost as fast when the transform length has only small prime factors. It is typically slower for transform lengths that are prime or have large prime factors. Time differences, however, are reduced to insignificance by modern FFT algorithms such as those used in Labview version 2013 Adjusting the transform length for efficiency is usually unnecessary in practice.

2.3 Literature reviews on Existing Acoustic Emission Method

2.3.1 Related Publication

Table 2.1 Summary of related publications with proposed scheme.

Author	Year	Proposed Schemes
P. Davis and J.Brockhurst [1]	2015	Subsea pipe infrastructure monitoring: A frame work for technology review and selection
D. Ozevin and J. Harding [2]	2012	Novel leak localization in pressurized pipeline networks using acoustic emission and geometric connectivity
S. L. Ying et al. [3]	2012	Comparison of Magnetic Flux Leakage (MFL) and Acoustic Emission(AE) Techniques in corrosion Inspection for Pressure Pipelines
S. Li et al. [4]	2012	Leak Detection and Location for Gas Pipelines Using Acoustic Emission Sensors
D. Feng et al. [5]	2011.	Leakage-Detection System in a Liquid Pipeline
L. Sun et al. [6]	2010	Active Defects Detection and Localization Using Acoustic Emission Method
R. Wu et al.[7]	2008	Wavelets application on Acoustic Emission signal detection in pipeline
A. J. Brunner and M. Barbezat[8]	2007	Acoustic Emission Leak Testing of Pipes for pressurized Gas using Active Fiber Composite Elements as Sensors
T. Kaewkongkal and J. Lim [9]	2007	Statistical estimated parameter for pipeline condition monitoring using acoustic emission

Table 2.1 Summary of related publications with proposed scheme. (cont.)

Author	Year	Proposed Schemes
M. A. Jeed and C. R. L. Murthy[10]	2001	A model with nonzero rise time for AE signals

Table 2.1 summarizes related publications with proposed scheme. As shown in Table 2.1, P. Davis and J.Brockhurst [1] present a framework to assist in the identification and prioritization of emerging inspection technology using subsea pipeline and component. To inspector priority technology for further investigation and field trialling based on their perceive value. Use for any technical detection for inspection therefore Acoustic emission detection, Electromagnetic acoustic transducer, Fiber optic sensing and Computed tomography scanning.

D.Ozevin and J.Harding [2] present damage occur propagate all though the structural thickness and cause leaking. The leak in pressurized pipelines causes turbulent flow at its location, which generates solid particles or gas bubble impacting on the pipeline material. Analysis leakage source 2D using 1D source of leakage. Using multi-dimension space is identified in an effective approach using an array sensors spread on the pipeline network. The experimental design includes a pipeline system made from PVC pipes and orifice simulation leak to use air intake 3 different of pressure Levels by use pressure. The leak simulation was repeat from two joint locations and use 3 unit piezoelectric AE sensors. To display Wave from recorded 2 source from 2 sensor. And summary to use cross correlation of two waveforms and arrival time difference and To show Pipeline network and AE sensor for leak location display ASL distributions of three sensors due to leak near sensor and the corresponding matrices for the source location (units as meter for j and s matrix).

S.L.Ying et al. [3] present about Non-Destructive Testing (NDT) is the application of measurementtechniques in order to identify damage and irregularities in materials. MFLPIG navigates the pipeline, a strong magnetic field is applied to the pipe wall from permanent magnets coupled beneath wear brushes that provide protection againstdebris and damage inside the pipe. Acoustic Emission (AE), according to ASTM, is generally understood as the generation of transient elastic waves during the rapid release of energy from localized sources within a material. The most common inspection method for measuring corrosion in pressure pipes uses MFLPIG (Magnetic Flux Leakage detector .Accurately measure the three dimensional vector of the leakage field. Using two AE sensors are mounted on the two ends of the pipe. As an acoustic emission event occurs somewhere on the pipe, the resulting stress waves will propagate in both directions at the same constant velocity and arrive the two sensors. And Comparison of Magnetic Flux Leakage and Acoustic Emission for all factor of leakage.

S. Li et al. [4] present about AE is commonly defined as transient elastic waves within a material, caused by the release of localized stress energy. It is sound waves produced when a material undergoes stress, as a result of an extemal force. The position of a leak is easily determined using a simple algebraic relationship among the time delay r, the distance between two sensors and the acoustic wave speed c in a gas pipeline. Using to 2 AE sensor are installed on the outer surface of the pipeline and special data acquisition programs have been designed using Labview to process the leak acoustic signals picked up by the AE sensors. Find Spectrum of a leak signal and a background noise. Comparison of spectral for leak signal with different detection distance, leak signal with different pressure and leak signal with different leakage aperture. To show display Spectrum of a leak signal and a background noise. and Showing comparison of spectral for leak signal with different detection distance, leak signal with different pressure and leak signal with different leakage aperture.

D. Feng et al. [5] proposes Finding method for detection leakage from water and oil etc.in order that Method response to those emerging social demands will require, as one measure ,the development of a monitoring system that can estimate the health of pipeline system from the viewpoint of high-efficiency operation pipeline safety ,resource saving and environment protection. To development of system to monitor Leakage-Detection System in a Liquid Pipeline. To source location from position leakage and failure. The contracted system consists of an acoustic Emission inspection system using acoustic emission (AE) sensors and a system for checking pressure using pressure sensor.

L. Sun et al. [6] proposes acoustic emission (AE) can detect the active defects of the pressurized pipeline in real time, such as crack extension and corrosion. Stress wave may be excited by the pipeline defects, and the wave carrying defect source information will propagate along the pipeline. Crack is one of the most common defects in the pipeline, and it is usually caused by material flaw of the pipeline. Nielsen-Hsu Pencil Lead Break method was used to simulate crack in the pipeline in AE experiments.The expanding and cracking process of the crack is a discontinuous stochastic processes As a result, burst AE signals are a series of discrete random pulses with different amplitude. During the expanding process of the micro cracking, a large amount of AE signals will be released. With the analysis of the acquired AE signal, the location and hazard level of the defects can be judged.

R. Wu et al [7] present AE techniques are used to observe and monitor these invisible events. Previous studies showed that the amplitude of AE signals is proportional to the released energy, and the frequency distribution is related with the size of the defect. To use time-domain and frequency domain. Wavelet Transform (WT) is a time-scale-frequency technique with adaptable precision, which does better features extraction and details detection. And STFT uses small windows to localize a signal in time domain, and applies Fourier transform in this small range to get the corresponding frequency distribution.

A. J. Brunner and M. Barbezat [8] present potential acoustic emission (AE) applications for piezoelectric activefiber-composite (AFC) sensor elements made from piezoelectric fibers, a model experiment for leak testing on pipe segments has been designed. A pipe segment made of aluminum with a diameter of 50 mm has been operated with compressed air (gaseous medium) for a range of operating pressures (between 400 and 800 kPa). Leaks have been simulated by use of screws with holes of various diameters (between 0.1 to 1.2 mm). One AFC sensor has been mounted directly on the pipe surface, complemented by two conventional AE sensors mounted on waveguides. AE signal parameters and waveforms were recorded at different pressures with and without simulated leaks. The experiments to date show distinct differences in the power spectra obtained from fast Fourier transform of the AE waveforms depending on whether a leak is present or not.

T. Kaewkongkal and J. Lim [9] present about acoustic emission natural phenomenon of stress wave generation and propagation spontaneously when a material is subjected under stress. Defect mechanisms will generate the transient elastic stresses or acoustic emission waves that propagate along the pipeline. And using Gaussian distribution of mathematically for acoustic emission signals collected from different machine operating conditions.

M. A. Jeed and C. R. L. Murthy [10] Acoustic emission (AE) signals are conventionally modelled as damped or decaying sinusoidal functions. A major drawback of this model is it’s negligible or zero rise time. This paper proposes an alternative model, which provides for the rising part of the signal without sacrificing the analytical tractability and simplicity of the conventional model. Signals obtained from the proposed model through computer programs are illustrated for demonstrating their parity with actual AE signals. Analytic expressions for the time-domain parameters, viz., peak amplitude and rise time used in conventional AE signal analysis, are also derived. The model is believed to be also of use in modelling the output signal of any transducer that has finite rise time and fall time.

2.4 Conclusions

This chapter has provided information for related theory including key concepts of acoustic Emission, NDI Testing and stress wave generation from pipeline leak. The literature reviews of ten papers on acoustic emission leak testing were also included.

Chapter 3
Research Methodology

3.1 Introduction

This chapter presents research methodology, including research process and research tool that uses in this thesis.

3.2 Research Processes

3.2.1 Study theory of the Control system, Acoustic emission sensor, Data Processing and Theory of flow in a pipe, Fast Fourier transform (FFT) and Labview version 2013.

3.2.2 Study the operation and properties of Acoustic emission sensor, Data Processing and Theory of flow in a pipe, Fast Fourier transform (FFT)Non-destructive testing (NDT) and Labview version 2013 Block diagram.

3.2.3 Design pipeline air piping system, block diagram of control system leakage pipeline and condition in leakage pipe line.

3.2.4 Run the condition leak and non-leakage tests using acoustic emission sensor and show at signal of at acoustic emission signal at Labview version 2013 software by signal is Fast Fourier transform (FFT) signal.

3.2.5 Design the hash algorithms with minimum number of chaotic map, but high potential in all kinds of attacks.

3.2.6 Perform the analysis of hash function performances.

3.3 Research Tools

In this thesis, research tool is Labview version 2013, Steel pipeline, Acoustic Emission Sensor Air Compressor

3.4 Conclusion

This chapter has presented research methodology, including research process, and research tool that uses in this thesis.

Chapter 4

Experimental Results

4.1 Introduction

This chapter presents the NDI of industrial compressed air piping system using AE sensing technique. The major objective is to implement a cost-effective AE sensing system for industrial applications where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. Focusing on AE signal features in frequency domain as a tool, characteristics of a leakage detection system will be experimentally clarified through normal and faulty conditions

4.2 Mathematical Models of AE signal

The AE sensing techniques typically counts on a propagating transient wave generated by sudden stress-strain change in a material. According to the standard ASTME 1316 the two categories of AE signals are a burst AE signal considered as a qualitative measure of a discrete signal related to an individual emission event, and a continuous AE signal considered as a qualitative measure of the sustained signal level. The burst AE signal defined as Vburst(t) for single frequency f0 is idealized in order to include the arrival time factor into the formulation as follows

$$V_{burst}(t) = V_0 \sin(2\pi f_0 t)\{(1 - e^{-(t-t_{arrival})/t_{rise}}) \in 0\ldots1\} x e^{-(t-t_{arrival})/t_{decay}} H[t - t_{arrival}]$$

Where the term {(1-[exp (t-tarrival)/trise])ε0…1} indicates the rise time function normalized to be in the range of 0-1, trise is rise time, the term exp (t-tarrival)/tdecay indicates the decay time with tdecay, the term H[t-tarrival] is Heaviside function indicating the waveform arrival to the sensor at tarrival The continuous AE signal v continuous (t) for single frequency f0 is idealized in as follows;

$$V_{continuous}(t) = \sin(2\pi f_0 t)\sum_{i=1}^{\infty} V_i \{(1 - e^{-(t-t_{arrival})/t_{rise}}) \in 0\ldots1\} x e^{-(t-t_{arrival}(i))/t_{decay}(i)} H[t - t_{arrival}(i)]$$

4.3 Research Metodology

The research methodology in this study is a measure of AE signal in time-domain prior to a conversion to the subsequent frequency-domain using FFT analysis. Fig.4.1 shows a steel pipeline with a diameter of 0.5 inches that model the industrial compressed air pipelines. The steel pipeline completely includes a 90o -Degree Elbow (ELL), a T-Shape Elbow (TEE), and Blank-end. The air compressor with an electric regulator provides air pressure with three generally used cases, i.e. 4, 5, and 6 Bars. The AE sensor is attached to only one point at the air in-let on the steel pipeline using grease. The detected AE signals are amplified with a gain of 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. Note that the gain of 20 dB since signal swing is less than the power supply of 5 V. Fig.4.2 shows the experiment equipment, involving the designed pipeline, the air compressor with a regulator, the AE sensor model R80α, and the preamplifier with three variable gains of values 20dB, 40dB, and 60dB. The inspection procedures are performed at four particular points (LP1-LP4), focusing on the joints that vulnerable to air leakage. Fig.4.3 illustrates the four leak points in the experiments. The results will be obtained through the comparisons of no-leak and leak conditions.

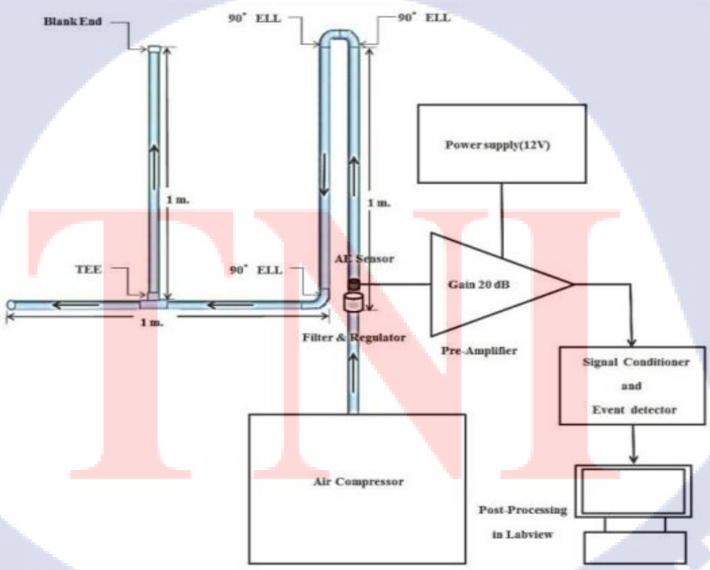


Figure 4.1 A steel pipeline with a diameter of 0.5 inches that model the industrial compressed air pipelines.

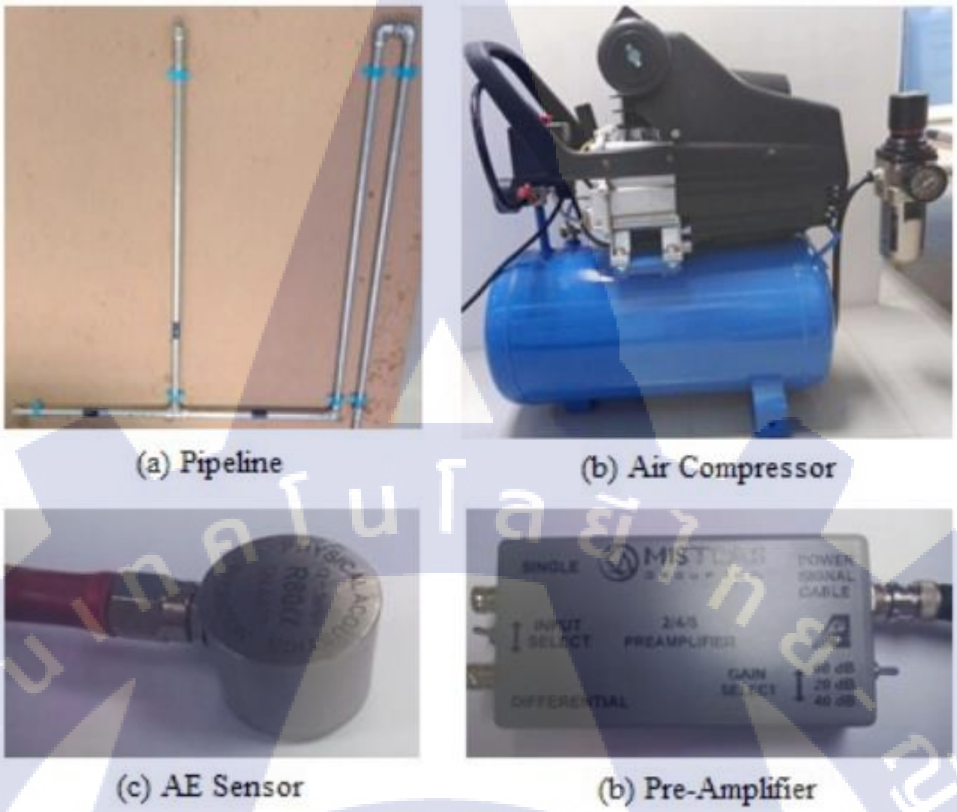


Figure 4.2 Experiment equipments, (a) Pipeline, (b) Air compressor, (c) AE sensor, and (d) Pre-Amplifier.

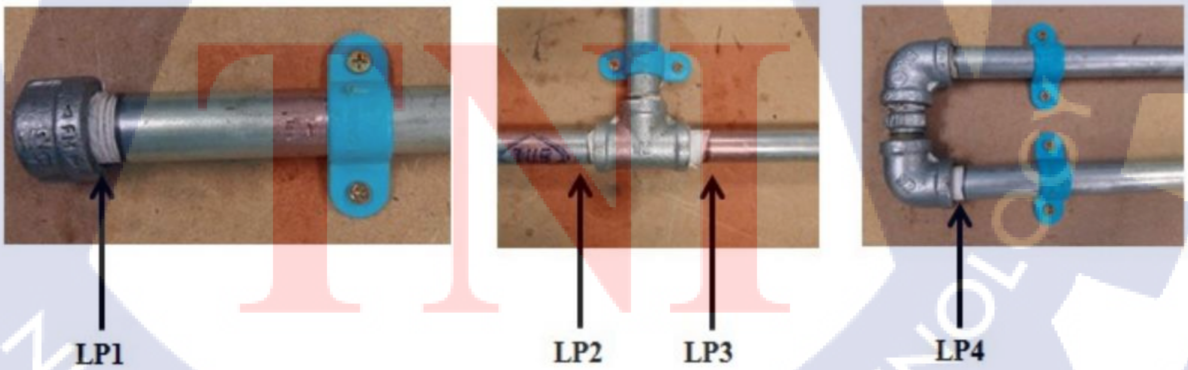


Figure 4.3 Four Leak Points (LP1-LP4) focusing on the joints of the air compressed steel pipeline.

4.4 Experimental Result and analysis

According to the experiment methodology, the results have been achieved through Labview program. For no-leak conditions, Figure 4.4 shows the frequency responses of measured time-domain AE signals at different pressure values of 4, 5 and 6 Bars. It can be considered that the frequency bands are oppositely reversible to the increase of pressure values, i.e. NL1: the frequency band of 72kHz – 84kHz is a response band of 4 bars, NL2: the 72kHz – 80kHz is a response band of 5bars, and NL3 : the 59kHz – 70kHz is a response band of 5 bars. All frequency bands have the magnitude of around -60 dB. In addition, the noises are apparent at low frequency in the range of 0-20kHz while the noise floor is -85dB. For air-leakage conditions, four cases were observed at three different pressure conditions as previously mentioned. Figure4.5 shows the frequency responses of measured time-domain AE signals at the pressure value of 4 Bars. It can be seen that the frequency bands are shifted from the typical value of 72kHz – 80kHz depicted in Figure4.5 (a). The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz – 70kHz, and wide-band noise spectrum, respectively.

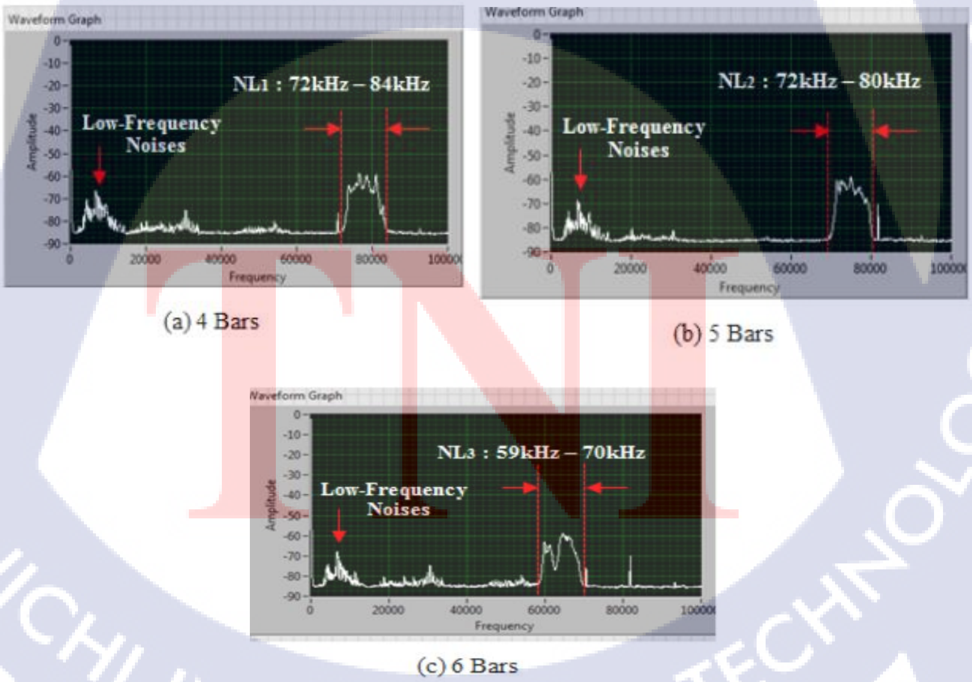


Figure 4.4 The frequency responses of measured time-domain AE signals with no-leak conditions at different pressure values of 4, 5, and 6 Bars

For air-leakage conditions, four cases were observed at three different pressure conditions as previously mentioned. Figure 4.5 shows the frequency responses of measured time-domain AE signals at the pressure value of 4 Bars. It can be seen that the frequency bands are shifted from the typical value of 72kHz – 80kHz depicted in Figure4.5 (a). The frequency response of AE signals at leak points LP1, LP 2, LP3, and LP4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz –70kHz, and wide-band noise spectrum, respectively. Figure 4.6 shows the frequency responses of measured time-domain AE signals at the pressure value of 5 Bars. Apparently, the signal also shifted from the typical value of 72kHz – 80kHz depicted in Figure 4.5 The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 52kHz – 58kHz, 70kHz – 88kHz, 64kHz – 80kHz, and wide-band noise spectrum, respectively. Figure 4.8 lastly shows the frequency responses of measured time-domain AE signals at the maximum pressure values of 6 Bars. The results are in a similar manner of the cases of 4 and 5 Bars. The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz – 70kHz, and wide-band noise spectrum, respectively. Based on the experimental results from Figure4-7, it can be considered that the frequency bands are shifted from the typical value, demonstrating that the proposed method can be used to detect the air leakage in the air pressured pipeline.

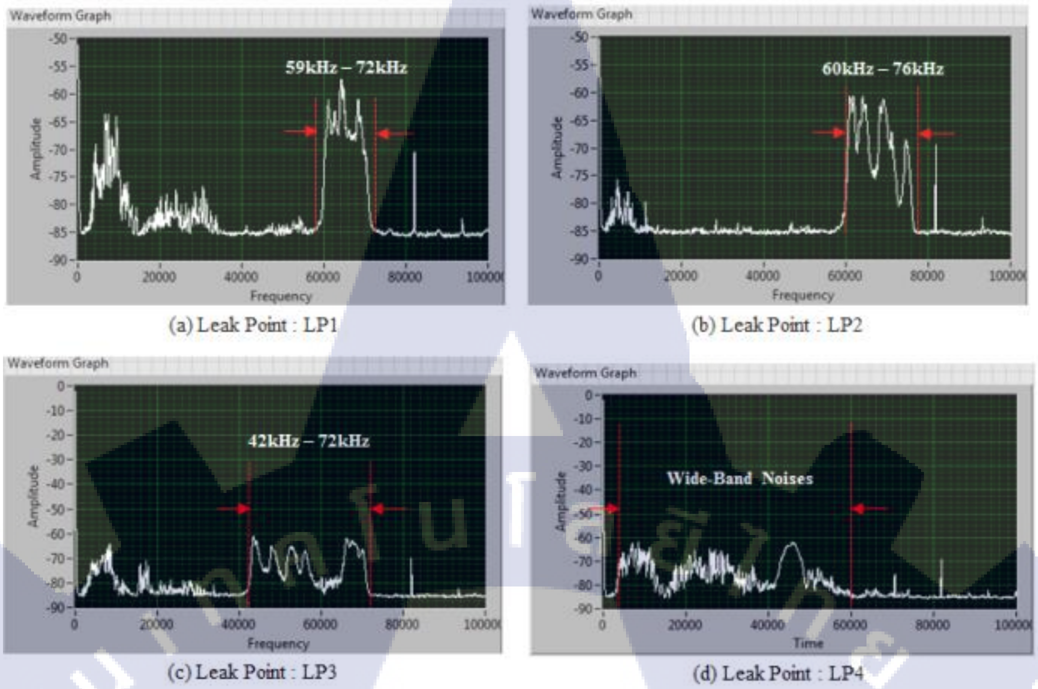


Figure 4.5 The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 4 Bars.

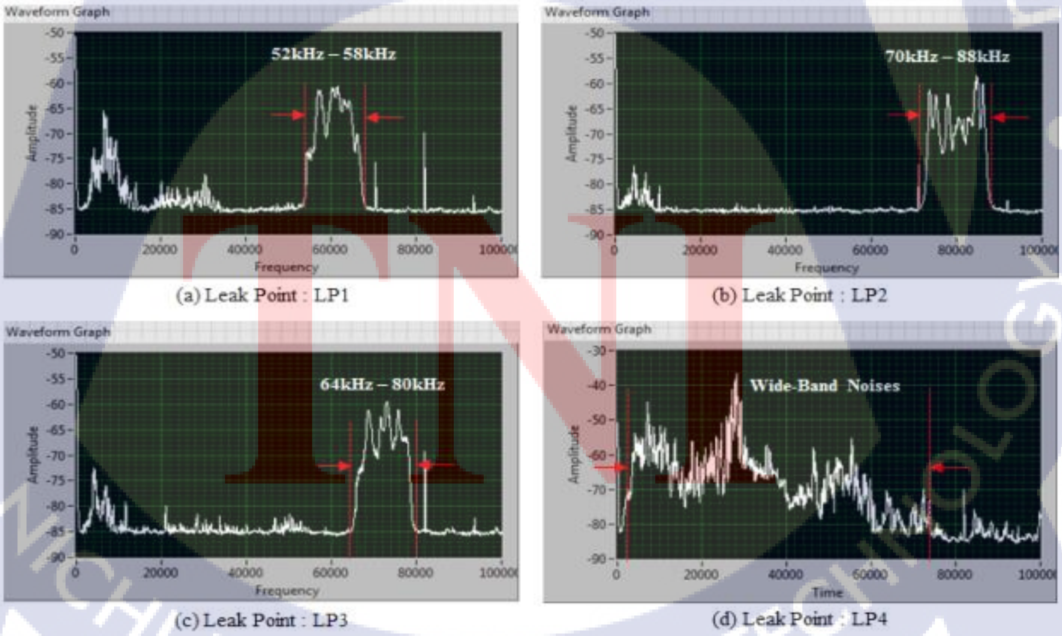


Figure 4.6 The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 5 Bars

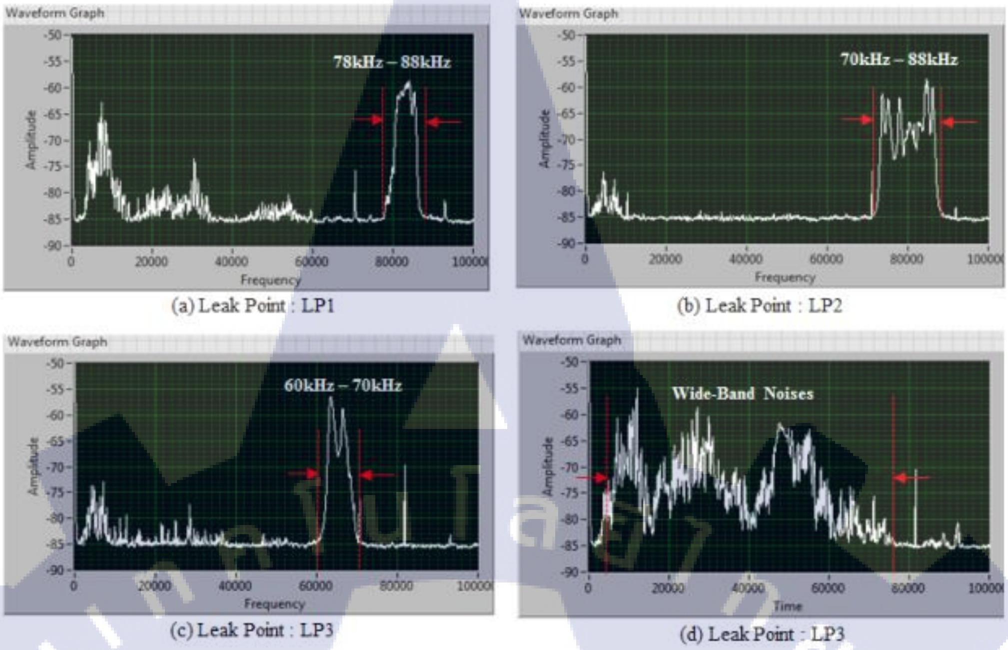


Figure 4.7 The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 6 Bars

Figure 4.6 shows the frequency responses of measured time-domain AE signals at the pressure value of 5 Bars. Apparently, the signal also shifted from the typical value of 72kHz – 80kHz depicted in Figure 4.5. The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 52kHz – 58kHz, 70kHz – 88kHz, 64kHz – 80kHz, and wide-band noise spectrum, respectively. Figure 4.8 lastly shows the frequency responses of measured time-domain AE signals at the maximum pressure values of 6 Bars. The results are in a similar manner of the cases of 4 and 5 Bars. The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz – 70kHz, and wide-band noise spectrum, respectively. Based on the experimental results from Figure 4.5-4.7, it can be considered that the frequency bands are shifted from the typical value, demonstrating that the proposed method can be used to detect the air leakage in the air pressured pipeline.

4.5 Conclusions

A compressed air piping system has long been employed as commercial industrial facilities, and considered as a utility essential to production. The non-destructive inspection using acoustic emission sensors have been suggested as effective inspection techniques in fluid transfer piping system. However, most previously proposed techniques employed complicated measurement algorithms or required many AE sensors, resulting costly implementation. Moreover, the results require specific software with a skilled expertise to read the signal features. This paper has therefore presented a cost-effective AE sensing system for industrial application where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. Experiments were realized through a steel pipeline with a diameter of 0.5 inches to model the industrial compressed air pipelines, completely including a 90o-Degree Elbow (ELL), a T-Shape Elbow (TEE), and blank-end. The AE signal was amplified with 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. Air pressure with four cases, i.e. 3 to 6 Bars, were investigated. The results revealed that the frequency response of AE signals between no-leak and leak conditions could be inspected accurately through the shift in frequency bands. This Thesis has presented an alternative potential for a cost effective AE characterization methods in industrial applications.

Chapter 5
Conclusion

5.1 Introduction

This chapter presents the conclusion of the A Low-Cost Air Leakage Monitoring Technique for Industrial Compressed Air Piping Systems using Acoustic Emission Sensor

5.2 Conclusion

A compressed air piping system has long been employed as commercial industrial facilities, and considered as a utility essential to production. The non-destructive inspection using acoustic emission sensors have been suggested as effective inspection techniques in fluid transfer piping system. However, most previously proposed techniques employed complicated measurement algorithms or required many AE sensors, resulting costly implementation. Moreover, the results require specific software with a skilled expertise to read the signal features. This paper has therefore presented a cost-effective AE sensing system for industrial application where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. Experiments were realized through a steel pipeline with a diameter of 0.5 inches to model the industrial compressed air pipelines, completely including a 90o-Degree Elbow (ELL), a T-Shape Elbow (TEE), and blank-end. The AE signal was amplified with 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. Air pressure with four cases, i.e. 4 to 6 Bars, were investigated. The results revealed that the frequency response of AE signals between no-leak and leak conditions could be inspected accurately through the shift in frequency bands.

References

References

[1] P. Davis and J. Brockhurst, “Subsea pipe infrastructure monitoring: A framework for technology review and selection,” *International Journal of Ocean Engineering*, vol. 104, no.104-540, pp. 540-548, August 2015.

[2] D. Ozevin and J. Harding, “Novel leak localization in pressurized pipeline networks using acoustic emission and geometricconnectivity,” *International Journal of Pressure Vessels and Piping*, vol.92, no.92-063, pp. 63-69, April 2012.

[3] S.L. Yin el al., “Comparison of magnetic flux leakage (MFL) and acoustic emission (AE) techniques in corrosion inspection for pressure pipelines”, *In the Proceeding of Chinese Control Conference*, CCC, Hefei, China, July 27, 2012, pp. 5375 – 5378.

[4] S. Li et al, “Leak detection and location for gas pipelines using acoustic emission sensors,” *In the proceeding of International Ultrasonic Symposium*, Dresden, Germany, October 10, 2012, pp. 957 – 960.

[5] D. Feng et al, “Leakage-detection system in a liquid pipeline,” *In the proceeding of 8th JFPS International Symposium on Fluid Power*, JSPFJP, Okinawa, Japan, October 8, 2011, pp.712-717.

[6] L. Sun et al., “Active defects detection and localization using acoustic emission method,” *In the Proceeding of Intelligent Control and Automation*, WCICA, Jinan, China, July 9, 2010, pp. 5348 – 5351.

[7] R. Wu et al, ”Wavelets application on Acoustic Emission signal detection in pipeline,” *In the Proceeding of Canadian Conference on Electrical and Computer Engineering*, CCECE 2008, Niagara Falls, North America, USA., May 7, 2008, pp. 001211 – 001214.

[8] A.J. Brunner and M. Barbezat, “Acoustic emission leak testing of pipes for pressurized gas using active fiber composite elements as sensors,” *Journal of Acoustic Emission*, vol.25, no.25- 042, pp.42-50, December 2007.

[9] T. Kaewkongkal and J. Lim, “Statistical estimated parameter for pipeline condition monitoring using acoustic emission,” *In the Proceeding of Instrumentation and Measurement Technology Conference*, IMTC 2007, Warsaw, Poland, May 3, 2007, pp. 1 – 3.

[10] M.A. Jeed and C.R.L. Murthy, “A model with nonzero rise time for AE signals,” *Journal of Sadhana*, vol.25, no.5, pp.465-474, October 2001.

Appendix

KARPAGAM
COLLEGE OF ENGINEERING
Rediscover | Refine | Redefine

(Autonomous)
Coimbatore –641032, Tamilnadu, India

[illegible]

ACCEPTANCE/INVITATION LETTER

IEEE 3rd INTERNATIONAL CONFERENCE ON ELECTRONICS AND COMMUNICATION SYSTEMS (ICECS-2016)

25-26, FEBRUARY 2016

Paper Title : **A Low-Cost Air Leakage Monitoring Technique for Industrial Compressed Air Piping Systems using Acoustic Emission Sensor**
Paper Id : 328
Authors : **Mr. Kittipob Aurreethum, Dr.Wimol San-Um**
Organisation : **Intelligent Electronics Systems Research Laboratory, Thai-Nichi Institute of Technology**

Dear authors,

We are pleased to confirm that your paper **"A Low-Cost Air Leakage Monitoring Technique for Industrial Compressed Air Piping Systems using Acoustic Emission Sensor "** has been accepted for publication in our conference. We would like to kindly invite you to present the research paper at the conference site in Coimbatore.

Thank you for submitting your work to our conference.
For conference registration and camera ready paper submission, please access the website http://www.icecs.in

I am looking forward to meeting you at ICECS-2016!

Best regards,
Dr. P Karthigaikumar.ICECS- Convener

KARPAGAM
COLLEGE OF ENGINEERING
Rediscover | Refine | Redefine
Coimbatore,Tamilnadu,India - 641 032

Accredited by NAAC with 'A' Grade

CERTIFICATE

This is to certify that

Dr / Mr / Ms ....Kittipob Aunseethum..............................

of........Thai - Nichi Institute of Technology (TNI)

has ~~participated~~ / presented a paper entitled

A Low-cost air Leakage Monitoring Technique for Industrial compressed Air piping systems using Acoustic Emission sensor ....in

IEEE sponsored 3rd International Conference on Electronics and Communication Systems on 25th and 26th February, 2016 organised by the Department of Electronics and Telecommunication Engineering, Karpagam College of Engineering, Coimbatore, Tamilnadu, India.

Dr.P.Karthigaikumar
CONVENOR

Dr.A.Nirmal Kumar
CHAIRMAN

IEEE ELECTRON DEVICES SOCIETY
ED Coimbatore Chapter

TNSCST

Institution of Electronics & Telecommunication Engineers

A Low-Cost Air Leakage Monitoring Technique for Industrial Compressed Air Piping Systems using Acoustic Emission Sensor

Kittipob Aurreethum and Wimol San-Um
Intelligent Electronic System (IES) Research Laboratory, Faculty of Engineering
Thai-Nichi Institute of Technology (TNI), 1771/1, Pattanakarn Rd, Suan Luang, Bangkok, 10250, Thailand
Tel: (+66) 0 2763 2600, Fax: (+66) 0 2763 2900, E-mails: au.kittipob_st@tni.ac.th, wimol@tni.ac.th

Abstract—*this paper presents Non-Destructive Inspection (NDI) of industrial compressed air piping system using Acoustic Emission (AE) sensing technique. The purpose of this paper is to implement a cost-effective AE sensing system for industrial application where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. The experiment utilizes a steel pipeline with a diameter of 0.5 inches to model the industrial compressed air pipelines, completely including a 90°-Degree Elbow (ELL), a T-Shape Elbow (TEE), and blank-end. The air compressor with an electric regulator provides air pressure with four cases, i.e. 3 to 6 Bars. The AE sensor is attached to various points on the steel pipeline using grease. The AE signal is amplified with 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. The signal characterization was performed through a magnitude in frequency response diagram. The results reveal that the AE signal with no-leak and leak conditions can be inspected accurately. The flaw signatures at different source of leakage can also be observed. This paper presents an alternative potential for a cost-effective AE characterization methods in industrial applications.*

Keywords—Non-Destructive Inspection; Compressed Air Piping System; Acoustic Emission Sensor.

I. INTRODUCTION

A compressed air piping system has been utilized in a variety of commercial industrial facilities and considered as a utility essential to production. Applications are hand tools, air hammers, paving breakers, rock drills, positive displacement, pumps, paint chippers, air-actuated valves, and healthcare. The main purpose of using the compressed air piping system is to deliver compressed air to usage points with enough volume, appropriate quality, and pressure to properly power the components [1]. The compressed air piping system should be designed properly in order to achieve expected production efficiencies otherwise equipment failure and high energy costs may be occurred. In particular, time-dependent aging and instantaneous threats may result in pipeline damage that propagates through structural thickness and causes air leakage. Therefore, an early detection of leakage in pipeline networks is essential to prevent any catastrophic failures. The leak in pressurized pipelines generally causes turbulent flow at its location, which generates solid particles or gas bubbles. The impact energy causes propagating elastic waves that can be detected by the sensors mounted on the pipeline [2].

Acoustic Emission (AE) is the generation of transient elastic waves that occurs when materials undergo deformation fracture leakage. In order to inspect such an AE phenomenon, pipeline leakage can be effectively detected by using an AE sensor [3]. Typically, the AE sensor is a piezoelectric transducer composed of special ceramic elements such as Lead Airconate Titivate (PZT). Mechanical strain of a piezoelectric element generates an electrical signal, which is an indispensable component used to collect information in AE inspection process. The AE sensing technique can be considered as one of Non-Destructive Inspection (NDI) methods that show its ability in monitoring air leakage of a steel pipeline.

The NDI method using the AE sensor is different from other NDI techniques in two approaches [4]. The first difference pertains to the origin of the signal in a manner that instead of supplying energy to the object under inspection, the AE sensing technique is attend for the energy released by the object. The second difference is that the AE sensing technique deals with dynamic processes in materials, which is particularly important as only active features are investigated.

There has been various NDI using AE sensing techniques proposed for detecting and monitoring pipeline leakage. P. Davis and J. Brockhurst [5] presented leak detection in liquid filled buried pipeline using AE sensing technique that detects the turbulent flow at the leak orifice. In addition, the position of the leak is provided through the use of digital AE systems and specialized software. T. Kaewkongkal and J. Lim [6] studied the application of AE for pipeline condition monitoring using pre-processed AE parameter and Gaussian distribution to establish characteristic features relating to each pipeline condition. For AE analysis methods, R. Wu and *et.al.* [7] proposed wavelet transform in AE signal detection under strong noises, which is accurate and computationally implemental for embedded systems. Comparison between Short-Time Fourier Transform (STFT) and wavelet transforms were also made. Besides, L. Sun and *et.al.* [8] compares two non-destructive inspection methods for pressure pipes between Magnetic Flux Leakage (MFL) and AE techniques. Recently, D. Feng and *et.al.* [9] also suggested a leak-detection system suitable for liquid pipeline through the use of two sensors, i.e. AE and pressure sensors. S. L. Ying and *et.al.* [10] presented an adaptive leak detection and location scheme for gas pipelines by using AE sensors. Additionally, S. Li and *et.al.* [11] proposed comparison method using spectral for leak signal with different detection distance, revealing different features of leak signal at different pressure and leakage aperture.

This paper presents the NDI of industrial compressed air piping system using AE sensing technique. The major objective is to implement a cost-effective AE sensing system for industrial applications where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. Focusing on AE signal features in frequency domain as a tool, characteristics of a leakage detection system will be experimentally clarified through normal and faulty conditions.

II. MATHERMATICAL MODELS OF AE SIGNALS

The AE sensing techniques typically counts on a propagating transient wave generated by sudden stress-strain change in a material. According to the standard ASTME 1316 [12], the two categories of AE signals are (1) a burst AE signal considered as a qualitative measure of a discrete signal related to an individual emission event, and (2) a continuous AE signal considered as a qualitative measure of the sustained signal level. The burst AE signal defined as $v_{burst}(t)$ for single frequency f_0 is idealized in order to include the arrival time factor into the formulation as follows

$$V_{burst}(t) = V_0 \sin(2\pi f_0 t)\{(1 - e^{-(t-t_{arrival})/t_{rise}}) \in 0...1\} x e^{-(t-t_{arrival})/t_{decay}} H[t - t_{arrival}] \quad (1)$$

where the term $\{(1\text{-}[exp\ (t\text{-}t_{arrival})/t_{rise}])\varepsilon 0\ldots 1\}$ indicates the rise time function normalized to be in the range of 0-1, t_{rise} is rise time, the term $exp\ (t\text{-}t_{arrival})/t_{decay}$ indicates the decay time with t_{decay}, the term $H[t\text{-}t_{arrival}]$ is Heaviside function indicating the waveform arrival to the sensor at $t_{arrival}$. The continuous AE signal $v_{continuous}\ (t)$ for single frequency f_0 is idealized in as follows;

$$V_{continuous}(t) = \sin(2\pi f_0 t)\sum_{i=1}^{\infty} V_i\{(1 - e^{-(t-t_{arrival}(i))/t_{rise}}) \in 0...1\} x e^{-(t-t_{arrival}(i))/t_{decay}(i)} H[t - t_{arrival}(i)] \quad (2)$$

As compared to the burst AE signal, the continuous AE signal no definite rise time is apparent, and can be considered as the summation of multiple wave arrivals using Heaviside functions.

III. RESEARCH METODOLOGY

The research methodology in this study is a measure of AE signal in time-domain prior to a conversion to the subsequent frequency-domain using FFT analysis. Fig. 1 shows a steel pipeline with a diameter of 0.5 inches that model the industrial compressed air pipelines. The steel pipeline completely includes a 90°-Degree Elbow (ELL), a T-Shape Elbow (TEE), and Blank-end. The air compressor with an electric regulator provides air pressure with three generally used cases, i.e. 4, 5, and 6 Bars. The AE sensor is attached to only one point at the air in-let on the steel pipeline using grease. The detected AE signals are amplified with a gain of 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. Note that the gain of 20 dB since signal swing is less than the

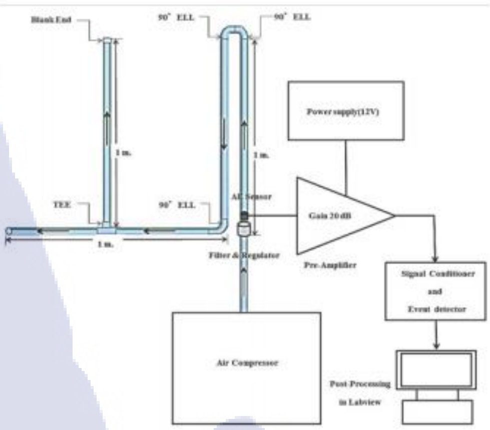
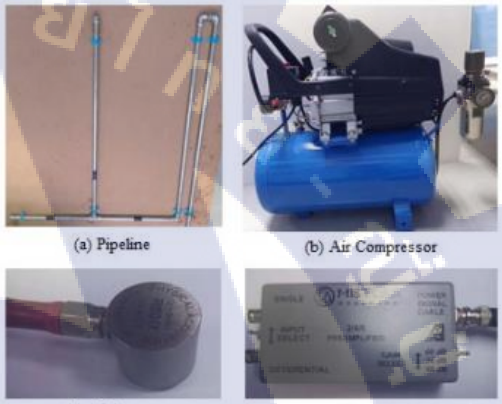


Fig. 1. A steel pipeline with a diameter of 0.5 inches that model the industrial compressed air pipelines.



(a) Pipeline (b) Air Compressor

(c) AE Sensor (b) Pre-Amplifier

Fig. 2. Experiment Equipments, (a) Pipeline, (b) Air compressor, (c) AE sensor, and (d) Pre-Amplifier.

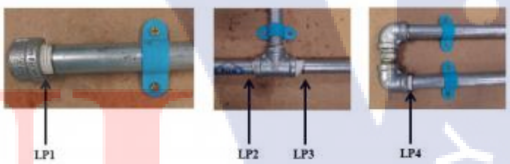
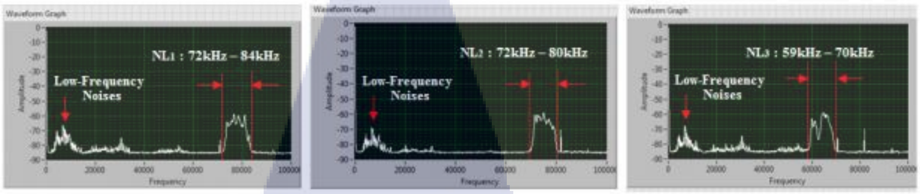
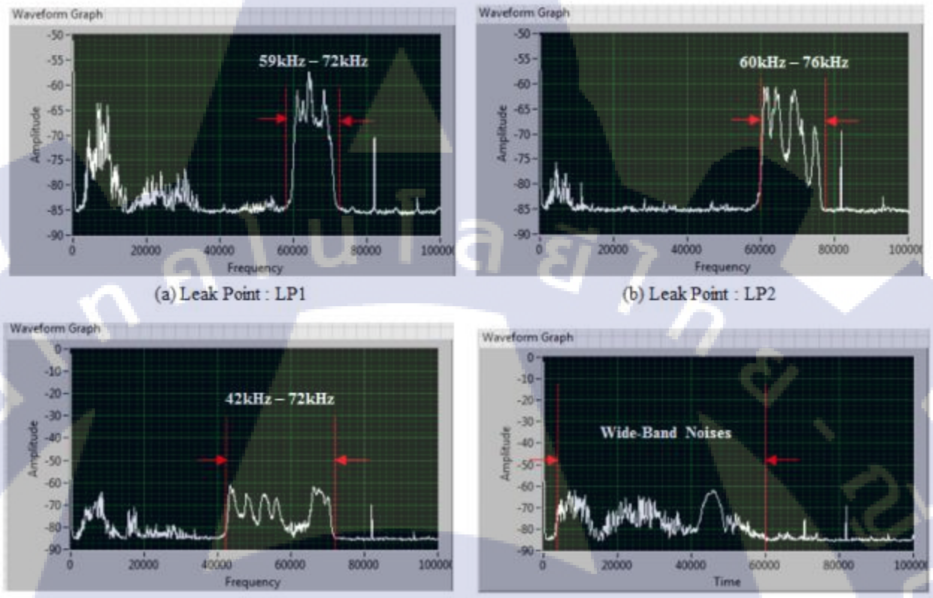


Fig. 3. Four Leak Points (LP_1-LP_4) focusing on the joints of the air compressed steel pipeline.



(a) 4 Bars (b) 5 Bars (c) 6 Bars

Fig. 4. The frequency responses of measured time-domain AE signals with no-leak conditions at different pressure values of 4, 5, and 6 Bars.



(a) Leak Point : LP1 (b) Leak Point : LP2 (c) Leak Point : LP3 (d) Leak Point : LP4

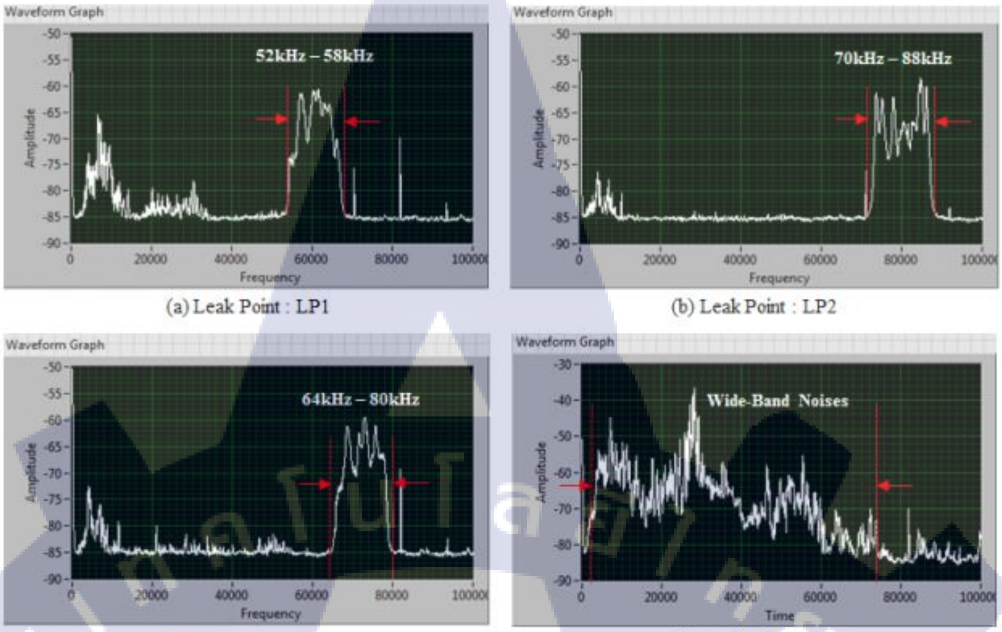
Fig. 5. The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 4 Bars.

power supply of 5 V. Fig. 2 shows the experiment equipment, involving the designed pipeline, the air compressor with a regulator, the AE sensor model R80α, and the preamplifier with three variable gains of values 20dB, 40dB, and 60dB. The inspection procedures are performed at four particular points (LP_1-LP_4), focusing on the joints that vulnerable to air leakage. Fig. 3 illustrates the four leak points in the experiments. The results will be obtained through the comparisons of no-leak and leak conditions.

IV. Experimental Results and Analysis

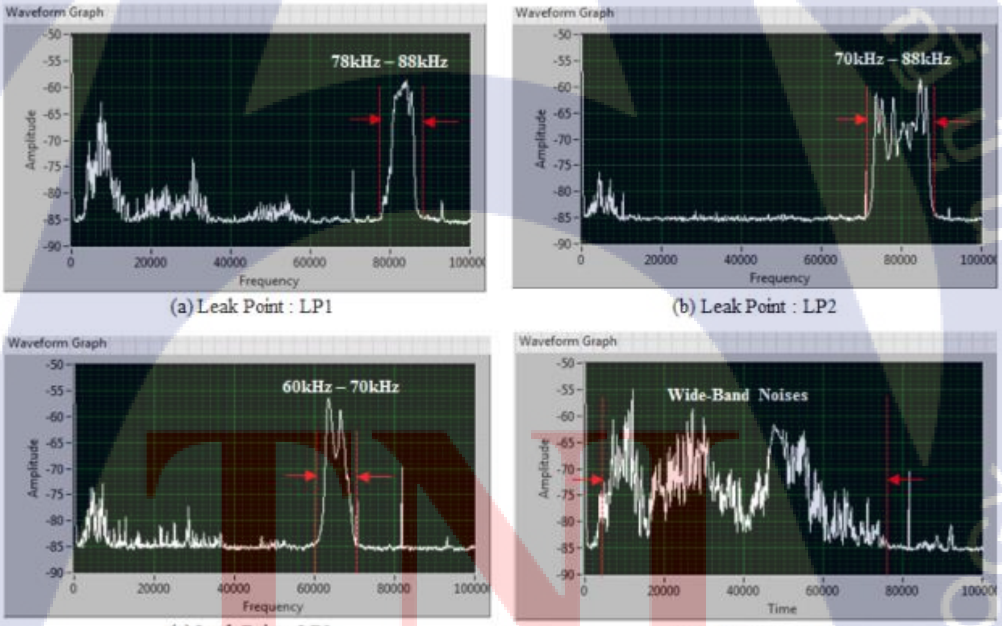
According to the experiment methodology, the results have been achieved through Labview program. For no-leak conditions, Fig. 4 shows the frequency responses of measured time-domain AE signals at different pressure values of 4, 5, and 6 Bars. It can be considered that the frequency bands are oppositely reversible to the increase of pressure values, i.e. NL_1: the frequency band of 72kHz – 84kHz is a response band of 4 bars, NL_2: the 72kHz – 80kHz is a response band of 5 bars, and NL_3 : the 59kHz – 70kHz is a response band of 5 bars. All frequency bands have the magnitude of around -60 dB. In addition, the noises are apparent at low frequency in the range of 0-20kHz while the noise floor is -85dB.

For air-leakage conditions, four cases were observed at three different pressure conditions as previously mentioned. Fig.5 shows the frequency responses of measured time-domain AE signals at the pressure value of 4 Bars. It can be seen that the frequency bands are shifted from the typical value of 72kHz – 80kHz depicted in Fig.5 (a). The frequency response of AE signals at leak points LP_1, LP_2, LP_3, and LP_4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz – 70kHz, and wide-band noise spectrum, respectively.



(a) Leak Point : LP1
(b) Leak Point : LP2
(c) Leak Point : LP3
(d) Leak Point : LP4

Fig. 6. The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 5 Bars.



(a) Leak Point : LP1
(b) Leak Point : LP2
(c) Leak Point : LP3
(d) Leak Point : LP3

Fig. 7. The frequency responses of measured time-domain AE signals with four leakages at the pressure value of 5 Bars.

Fig.6 shows the frequency responses of measured time-domain AE signals at the pressure value of 5 Bars. Apparently, the signal also shifted from the typical value of 72kHz – 80kHz depicted in Fig.5 (6). The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 52kHz – 58kHz, 70kHz – 88kHz, 64kHz – 80kHz, and wide-band noise spectrum, respectively. Fig.8 lastly shows the frequency responses of measured time-domain AE signals at the maximum pressure values of 6 Bars. The results are in a similar manner of the cases of 4 and 5 Bars. The frequency response of AE signals at leak points LP1, LP2, LP3, and LP4 are 78kHz – 88kHz, 70kHz – 88kHz, 60kHz – 70kHz, and wide-band noise spectrum, respectively. Based on the experimental results from Figs.5-7, it can be considered that the frequency bands are shifted from the typical value, demonstrating that the proposed method can be used to detect the air leakage in the air pressured pipeline.

CONCLUSIONS

A compressed air piping system has long been employed as commercial industrial facilities, and considered as a utility essential to production. The non-destructive inspection using acoustic emission sensors have been suggested as effective inspection techniques in fluid transfer piping system. However, most previously proposed techniques employed complicated measurement algorithms or required many AE sensors, resulting costly implementation. Moreover, the results require specific software with a skilled expertise to read the signal features. This paper has therefore presented a cost-effective AE sensing system for industrial application where a single AE sensor is realized for signal characterizations through Fast-Fourier Transform (FFT) algorithm. Experiments were realized through a steel pipeline with a diameter of 0.5 inches to model the industrial compressed air pipelines, completely including a 90o-Degree Elbow (ELL), a T-Shape Elbow (TEE), and blank-end. The AE signal was amplified with 20 dB prior to an analysis in Labview through National Instrument (NI) DAQ board. Air pressure with four cases, i.e. 3 to 6 Bars, were investigated. The results revealed that the frequency response of AE signals between no-leak and leak conditions could be inspected accurately through the shift in frequency bands. This paper has presented an alternative potential for a cost-effective AE characterization methods in industrial applications.

ACKNOWLEDGEMENTS

The authors are grateful to Research and Academic Service Division of Thai-Nichi Institute of Technology for a full financial supports.

REFERENCES

[1] Ecompressedair available at :http://www.ecompressedair.com/library-pages/piping-systems.aspx

[2] D. Ozevin and J. Harding, "Novel leak localization in pressurized pipeline networks using acoustic emission and geometric connectivity" International Journal of Pressure Vessels and piping,Vol.92, pp.63-69, 2012.

[3] A. J. Brunner and M. Barbezat, "Acoustic Emission Leak Testing of Pipes for pressurized Gas using Active Fiber Composite Elements as Sensors", Journal of Acoustic Emission, Vol.25, pp. 42- 50, 2007.

[4] Majeed and Murthy, "A model with nonzero rise time for AE signals", Journal of Sadhana, Vol. 25, No.5, pp.465-474, 2001.

[5] P. Davis and J. Brockhurst, "Subsea pipe infrastructure monitoring: A frame work for technology review and selection", International Journal of Ocean Engineering, No. 104, pp. 540-548, 2015.

[6] T. Kaewkongkal and J. Lim, "Statistical estimated parameter for pipeline condition monitoring using acoustic emission", In the proceeding of Instrumentation and Measurement Technology Conference , pp. 1 – 3, 2007.

[7] Ran Wu, Zaiyi Liao and Lian Zhao, WAVELETS APPLICATION ON ACOUSTIC EMISSION SIGNAL DETECTION IN PIPELINE, In the Proceeding of Canadian Conference on Electrical and Computer Engineering, pp. 001211 – 001214, 2008.

[8] L. Sun , Y. C. Li , L. Wang , and J. Wu, "Active Defects Detection and Localization Using Acoustic Emission Method", pp. 5348 – 5351, 2010.

[9] D. Feng, Y. Zheng, T. Nakarada, and Y. Sakurai, "Leakage-Detection System in a Liquid Pipeline", In the proceeding of 8th JFPS International Symposium on Fluid Power, pp.712-717, 2011.

[10] S. L. Ying, L. Y. Bo, S. L. Bo, and L. Ge, "Comparison of Magnetic Flux Leakage (MFL) and Acoustic Emission(AE) Techniques in corrosion Inspection for Pressure Pipelines", In the Proceeding of Chinese Control Conference, pp. 5375 – 5378, 2012.

[11] S. Li, Y. Wen, P. Li, J. Yang, and L. Yang, "Leak Detection and Location for Gas Pipelines Using Acoustic Emission Sensors", In the proceeding of International Ultrasonic Symposium, pp. 957 – 960, 2012.

[12] ASTM E 1316-Standard terminology for nondestructive examinations.