BEARING FAULT MONITORING SYSTEM USING ACOUSTIC EMISSION

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

Dr Rosdiazli bin Ibrahim
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

MAY 2011

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Noorasyikin binti Arshad

ABSTRACT

Detecting mechanical faults in bearings and machinery has long been recognized as being important for preventing catastrophic failure and effective maintenance planning. The human senses of sound and touch were the first mechanisms used to detect machinery problems. Electronic sensors have since offered the ability to feel and listen to machinery with more precision, at more locations, and over more time than was ever before possible. Interpretation of the electronic signals delivered by sensors has provided the maintenance engineer with the diagnostic information necessary to pinpoint bearing faults, thus enabling a more efficient and predictable maintenance effort. However, skilled and trained personnel have been required to effectively interpret this diagnostic information. As electronic sensors have become more sophisticated, and also have the diagnostic techniques, leading to the ability of earlier detection of failures with less required skill. This project proposes an implementation of bearing fault monitoring system by using acoustic emission (AE). The signal is captured and analyzed by MATLAB software. Generally this project is carried out by detecting ultrasonic waves captured by AE sensor of tested bearing and interprets the data which mean either the bearing is healthy or having defect. The benefit of having early detection of bearing fault will be able to save maintenance cost and also human life.

ACKNOWLEDGEMENTS

With my sincere appreciation, I would like to express my utmost gratitude to my supervisor, Dr Rosdiazli bin Ibrahim for his detailed and constructive comments along with continuous help , support, motivation and guidance from the initial to the final level of the project.

My greatest gratitude and appreciation is extended to Intan Soraya, a master student who is put under the same project especially for the entire efforts and contribution of her ideas in this project, and also for the guidance in MATLAB programming.

Above all, I thank my beloved parents, Salamiah binti Ahmad and Arshad bin Tarmas for always standing beside me and continuously supporting throughout my life.

Last but not least, I express my regards and blessing to all lecturers and colleagues who supported me in any respect during the completion of the project.

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LIST OF ABBREVIATIONS

AE	Acoustic Emission
DAQ	Data Acquisition
FFT	Fast Fourier Transform
SPM	Shock Pulse Method
REB	Rolling Element Bearing

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Bearing fault monitoring system using acoustic emission (AE) focusing on detection of bearing as major contribution of motor to become dysfunctional and can lead to extremely maintenance cost if a company has a improper unplanned maintenance or specific fault analysis.

Rolling element bearing (REB) condition monitoring has received considerable attention for many years because the majority of problems in rotating machines are caused by faulty bearings. The classical failure mode of rolling element bearings is localized defects, in which a sizable piece of the contact surface is dislodged during operation, mostly by fatigue cracking in the bearing metal under cyclic contact stressing [18].

During the bearing operation, bursts of acoustic emissions (AE) result from the passage of the defect through the roller and raceway contacts. Defects at different locations of a bearing (inner race, roller and outer race) will have characteristic frequencies at which bursts are generated. Theoretical estimations of these frequencies are called characteristic defect frequencies [24].

Basically, AE sensor is converting high frequency elastic waves to electrical signals. This is accomplished by directly coupling piezoelectric transducers on the surface of the structure under test and loading the structure [25]. The output of each piezoelectric sensor is amplified through a low-noise preamplifier, filtered to remove any extraneous noise and furthered processed by suitable electronic equipment. The signals thus are transferred to monitor. From monitor, the waveform is analyzed.

1.2 Problem Statement

Induction motors play a very important part in the safe and efficient running of any industrial plant. Early detection of abnormalities in the motor would help to avoid costly breakdowns. The failures of electric motors are catalogued into mechanical, insulation and magnetic faults. The surveys show that bearing failures cause nearly half of all failures and stator winding failures about 15 to 35% while rotor & shaft is less than 10% depending on the application [26].

Many factors can contribute to premature failures of bearings. These include poor lubrication, excessive vibration, contamination, faulty installation, improper loading and cooling conditions. Regardless of the types of failures that occur in bearings, e.g. contact staining, corrosion, surface damage, fracture, raceway distress and thermal instability, they are all closely related to the contact force between the rolling elements and the bearing rings [27]. Thus, a study of detection of bearing fault is very important in other to detect motor breakdown at first stage and increase motor's lifetime.

1.3 Project Objectives

Below are the objectives of this project:

- To improve bearing fault condition monitoring technique by using another type of condition monitoring techniques which utilizes acoustic emission because it is more accurate than other ancient techniques.
- To develop the bench top marking of healthy and unhealthy bearing. In this project data analysis is done by MATLAB software.
- To reduce maintenance cost and save human life from injuries due to dysfunctional motor which mainly caused by bearing fault.

1.4 Scope of Study

The scope of study for this project covers:

- To develop the AE system and run actual motor testing that can detect ultrasonic sound emitted from healthy and unhealthy bearing
- To acquire signal emits from healthy and unhealthy bearing
- To represent signals in time domain and frequency domain
- To produce statistical data analysis

To successfully implement the whole system, milestones that have to be achieved are:

- To fully understand the basic principles of AE
- To master in MATLAB software
- To fully understand analog to digital (A/D) conversion
- To ensure the system is reliable for any type of bearing and condition

CHAPTER 2

LITERATURE REVIEW

2.1 Bearing

A bearing is a device to allow constrained relative motion between two or more parts, typically rotation or linear movement. Bearings may be classified broadly according to the motions they allow and according to their principle of operation as well as by the directions of applied loads they can handle [1]. Rolling element bearings generally consist of two rings, an inner and an outer, between which a set of balls or rollers rotate in raceways [2].

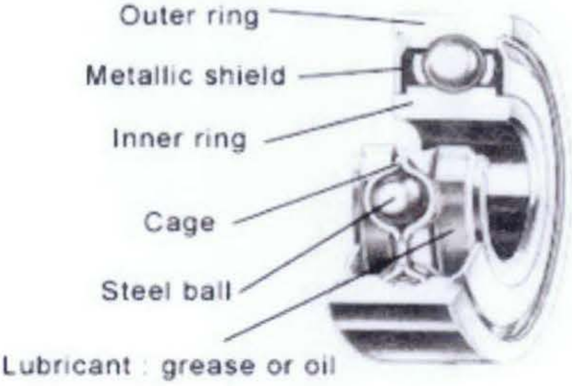


Figure 1: Bearing cutaway

2.1.1 Bearing Life Estimation

Bearing life is defined as the length of time (number of revolutions) until a specific failure occurs. "Life" is the number of hours that a percentage of similar bearings have survived under an essentially identical set of operating conditions and loads. Life can be affected by a number of factors including loads, speed, lubrication, fit, maintenance, temperature, contamination, and other [3].

Because of the diverse variety of contributing factors, it is extremely difficult to predict life precisely. Because handling and contamination damage can dramatically reduce bearing life, bearings should be properly stored, mounted, dismounted, and inspected. Optimized performance and life is also contingent on appropriate lubrication and sufficient protection from foreign matter. Bearings should be stored in a cool, clean, low humidity environment free of dust, shocks and vibrations. Proper fitting, using specialized tools and techniques, will also help maximize bearing life [3].

Nevertheless, the life for ball bearings is approximately inversely proportional to the load raised to the third power and inversely proportional to the speed. These relationships are only valid within certain constraints relating to the bearing size, design, lubrication, temperature, load and speed [5].

$$L10 = \frac{10^6}{60n}\left(\frac{C}{P}\right)^a \qquad (1)$$

a = 3 (Ball Bearings)

$a = \frac{10}{3}$ (Roller Bearings)

n = Speed (rpm)

C = Bearing dynamic load rating

P = Load

Due to factors mentioned above, it is important to always keep maintaining the bearing in good condition so that it will not affect rotating machinery. Early detection of bearing fault in rotating machinery will save cost for maintenance and increase productivity.

2.1.2 Bearing Fault

The most common failure modes of rolling element bearings are contact fatigue, wear, plastic flow, and fracture. These classes are further divided into very specific types of failure that can be traced back to their root cause, which may be improper installation, misalignment, contamination, inadequate lubrication, or over-loading [20].

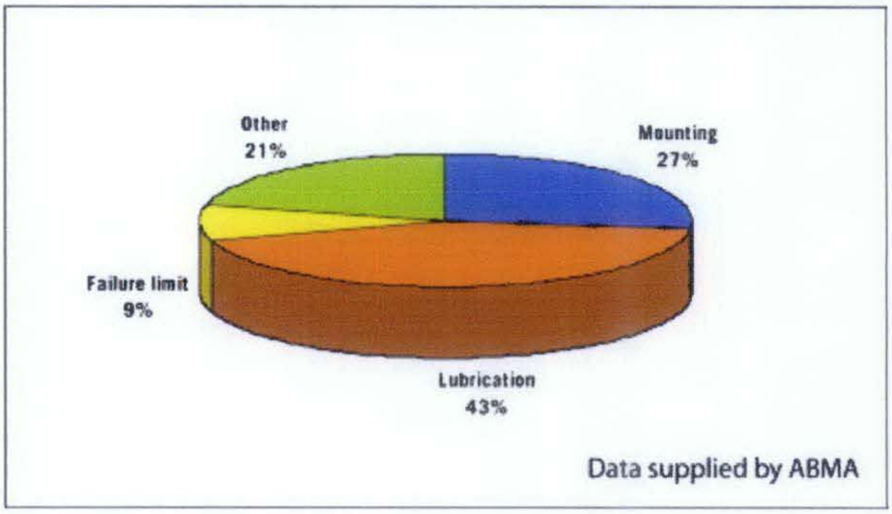


Figure 2: Distribution of Failure

Based on the pie chart above, it is clearly shown that bearing malfunction due to inadequate or excessive lubrication takes the highest percentage among the other failures. Lubricant is important to prevent the direct metallic contact between the various rolling and sliding elements. Bearing failure is affected either inadequate or excessive lubricant apply to the bearing. Greases are the most common lubricants for rolling bearings. About 90 % of all rolling bearings are lubricated with grease [6, 7]. The contaminants of the grease cannot be filtered away like in oil lubricated bearing applications. The contaminants accumulate in the vicinity of the contact zone, making the lubrication situation worse [8]. Inadequate or excessive lubricant affects the bearing to become fretted. Fretting occur due to repeated sliding between the two surfaces. Discoloured (blue/brown) ball tracks and balls are symptoms of lubricant failures [9].

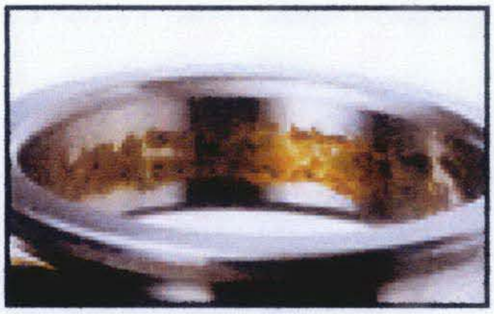


Figure 3: Fretting due to poor lubricant

But, as long as the stresses acting upon bearing are keep within design capabilities it will not lead to premature failure [5].

2.2 Condition Monitoring Technique

Because of the bearing fault is the major contribution for the failure of rotating machine, thus there many researches on condition monitoring of bearing to overcome this matter. It is a nature laws that bearing capability decrease over years. But sometimes even though the bearing suppliers guarantee that their bearing is the best among the best and long-lasting, due to mishandling during the installation of the bearing can lead the bearing to have premature failure. Thus, earlier detection is important to monitor the performance of the bearing.

There are many condition monitoring methods used for detection and diagnosis of rolling element bearing defects: vibration measurements, stator current, shock pulse method (SPM) and acoustic emission (AE) [10].

2.2.1 Vibration

Each bearing has a characteristic rotational frequency. With a defect on a particular bearing element, an increase in vibration energy at this element's rotational defect frequency may occur. A local defect produces successive impulses at every contact of defect and the rolling element, and the housing structure is forced to vibrate at its natural modes. The vibration pattern of a damaged bearing includes the low-frequency components related to the impacts and the high-frequency components in which the structural information of the bearing structure or the machine is stored [12].

2.2.2 Stator Current

Vibration monitoring methods are utilized to detect the presence of incipient failure. However, it has been suggested that stator current monitoring can provide the same indications without requiring access to the motor [13]. This technique utilizes results of spectral analysis of the stator current (precisely, the supply current) of an induction motor to spot an existing or incipient failure of the motor or the drive system [14].

2.2.3 Shock Pulse Method (SPM)

Another method that has been widely used as a quantitative method for bearing condition monitoring is SPM. SPM Method detects development of a mechanical shock wave caused by the impact between two masses. At the instantaneous moment of impact, molecular contact occurs and a compression (shock) wave develops in each mass. The SPM Method is based on the events occurring in the mass during the extremely short time period after the first particles of the colliding bodies come in contact [15].

2.2.4 Acoustic emission (AE)

Acoustic emissions (AEs) are defined as transient elastic waves generated from a rapid release of strain energy caused by a deformation or damage within or on the surface of a material [11]. 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 [16]. Defects known to produce acoustic emissions are:

- Growth of delaminations
- Cracking
- fracture of fibres
- fracture of matrix,
- fibre-matrix debonding
- fibre pull-out
- relaxation of fibres after failure
- large flaws (eg interlaminar defects),
- fracture of brittle interfacial layers.

The emitted stress waves can be detected by coupling piezo-electric sensors to the surface of the structure under the study. By analyzing the quantity and the properties of the acoustic emission signals, information can be obtained about the process is that are active in the material under loading [22].

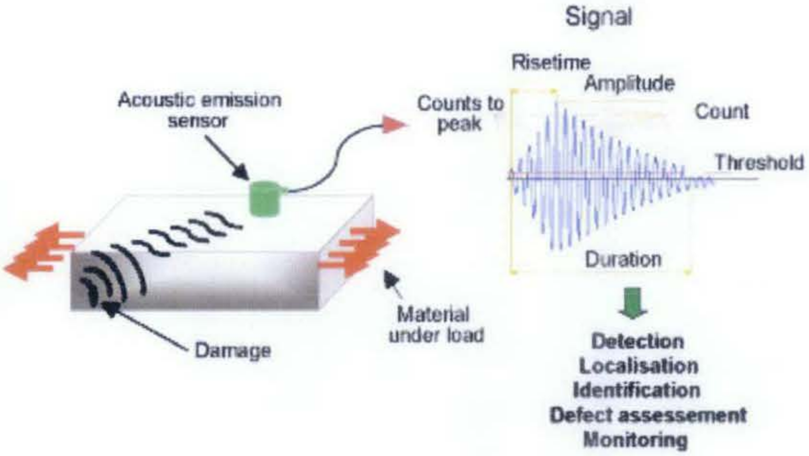


Figure 4: Diagram shows AE detects fracture on material

Yoshioka [21] have shown that AE technique can detect defects before they appear in the vibration acceleration range and can also identify possible sources of AE generation during a fatigue life test of thrust ball bearing. Other advantages of using acoustic emission testing are [23]:

- Real time monitoring in service structures;
- Cost reduction;
- Time reduction;
- High sensitivity;
- Defect localisation;
- Global structures monitoring;
- Control of non accessible zones;
- No intentional injection of an acoustic signal into the component under test are needed;
- Can be used with other destructive and non destructive techniques.

2.2.4.1 AE Data Analysis

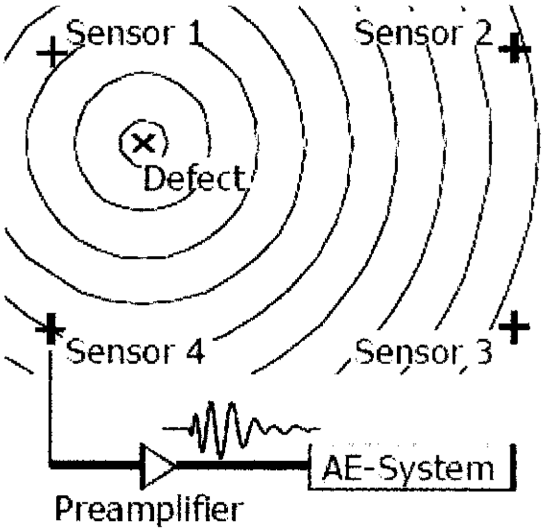


Figure 5: Propagation of Sound

AE occurs when a crack grows or when crack borders rub against each other, e.g. when a crack closes after relaxation of the test object. Usually, the test object must be stressed mechanically exceeding the operating level in order to have local defects grow and emit acoustic emission. Therefore AE analysis is the appropriate technique especially n those cases, where test object are anyway stressed more than under normal condition. The AE analysis "listen" to the defects right at the moment of their occurrence, thus, in real time. Because of this real-time monitoring, the AE testing method can be used as warning system to avoid a failure of the system with possibly disastrous consequences for environment and testing object [22].

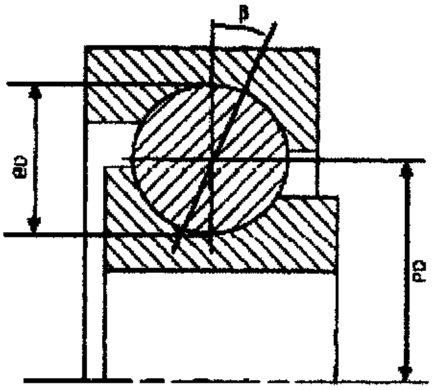


Figure 6: cross sectional view of a ball bearing in which the inner race, outer race and ball are shown

Characteristic defect frequencies [18] are actually the roller-passing frequencies for a defect on different locations of a bearing. Assuming pure rolling contact and negligible elastic deformation of bearing components, roller-passing frequencies can be calculated by knowing the geometry and speed of a bearing using the equations below. Fig.6 is a cross sectional view of a ball bearing in which the inner race, a ball and the outer race are shown. The ball-passing frequency can be calculated using Equations. (2) - (4)

The outer race defect frequency is given by:

$$f_{OD} = \frac{n}{2} f_{rm} \left(1 - \frac{BD}{PD} cos\emptyset\right) \tag{2}$$

Then, the inner race defect frequency is given by:

$$f_{ID} = \frac{n}{2} f_{rm} \left(1 + \frac{BD}{PD} cos\emptyset\right) \tag{3}$$

And, ball defective frequency is given by:

$$f_{BD} = \frac{PD}{2BD} f_{rm} \left(1 - \left(\frac{BD}{PD}\right)^2 cos^2\emptyset\right) \tag{4}$$

Where,

f_{OD}	characteristic defect frequency for defect on outer race
f_{ID}	characteristic defect frequency for defect on inner race
f_{BD}	characteristic defect frequency for ball
BD	ball diameter
PD	bearing pitch diameter
f_{rm}	bearing rotating speed
B	contact angle between race and ball
n	number of balls

CHAPTER 3

METHODOLGY

3.1 Procedure Identification

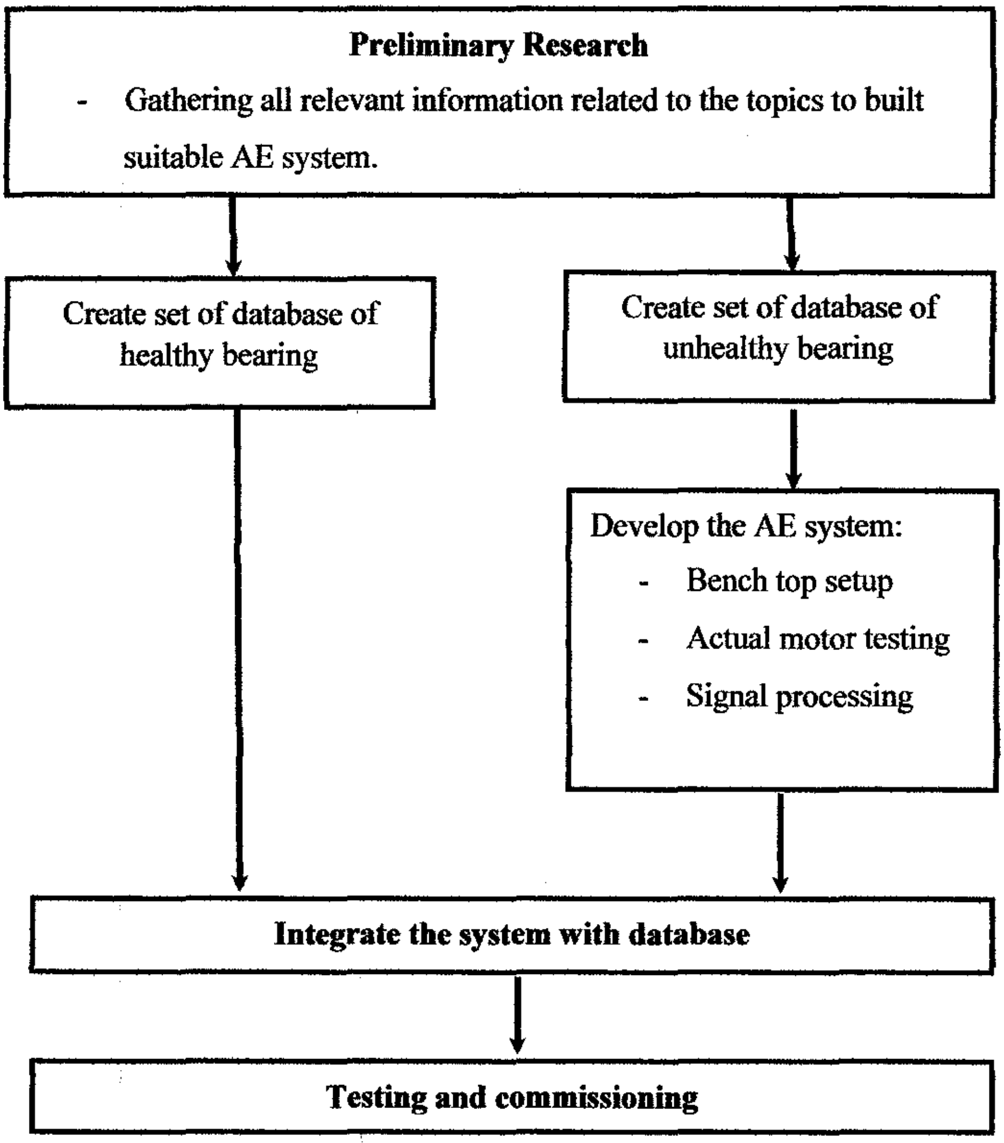


Figure 7: Flow chart research methodology

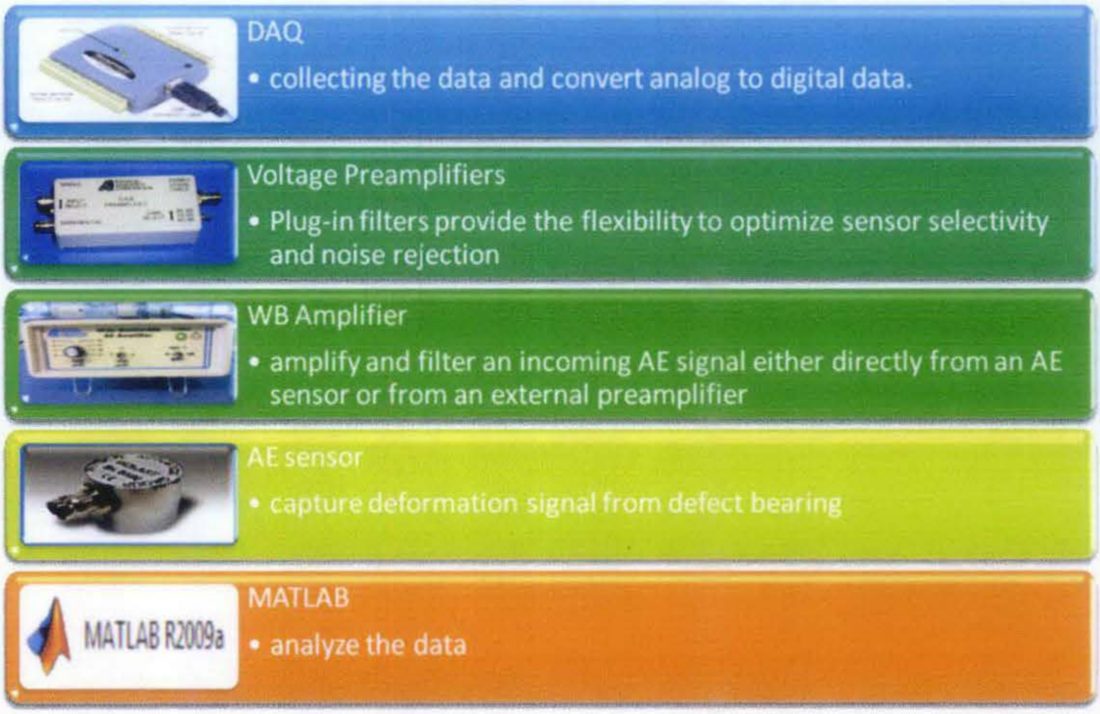
3.2 Tools

The major software for this project is MATLAB 2009 which includes Data Acquisition Toolbox and Measurement Computing for AE sensor. For AE sensor, this project utilizes WDI Sensor with Integral Preamplifier from Physical Acoustic Corporation (PAC) together with Voltage Preamplifier and AE5A Wide Bandwidth Acoustic Emission Amplifiers System from same company, PAC. Data Acquisition card used for this project is Measurement Computing 1208FS.

3.3 Overall System Overview

The objective of this project is to develop an AE system which capable to detect bearing fault. The main idea of this project is the faulty bearing, if detected, is compared to a set of healthy bearing database. It is very useful for the technician to do corrective maintenance and lead to the cost saving for a company since premature failure of the bearing is detected then the company has no worry to replace new machine which might be cost thousand or million ringgit Malaysia.

Below is the AE system which consisting of:



DAQ
- collecting the data and convert analog to digital data.

Voltage Preamplifiers
- Plug-in filters provide the flexibility to optimize sensor selectivity and noise rejection

WB Amplifier
- amplify and filter an incoming AE signal either directly from an AE sensor or from an external preamplifier

AE sensor
- capture deformation signal from defect bearing

MATLAB
- analyze the data

Figure 8: AE systems and its function

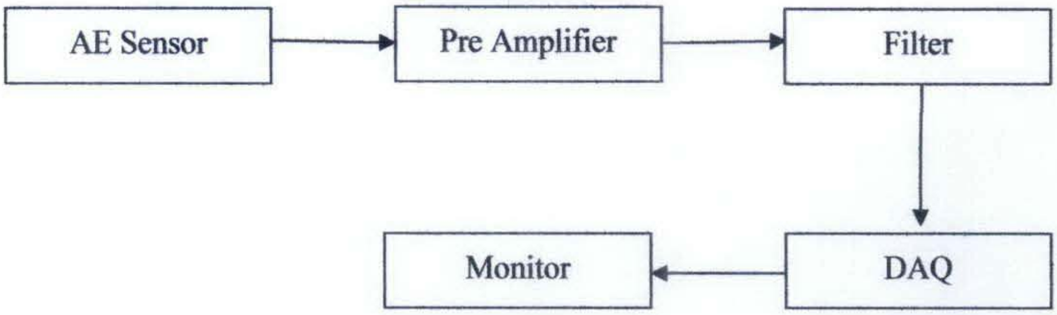


Figure 9: Block diagram of AE system

The system setup is shown below:

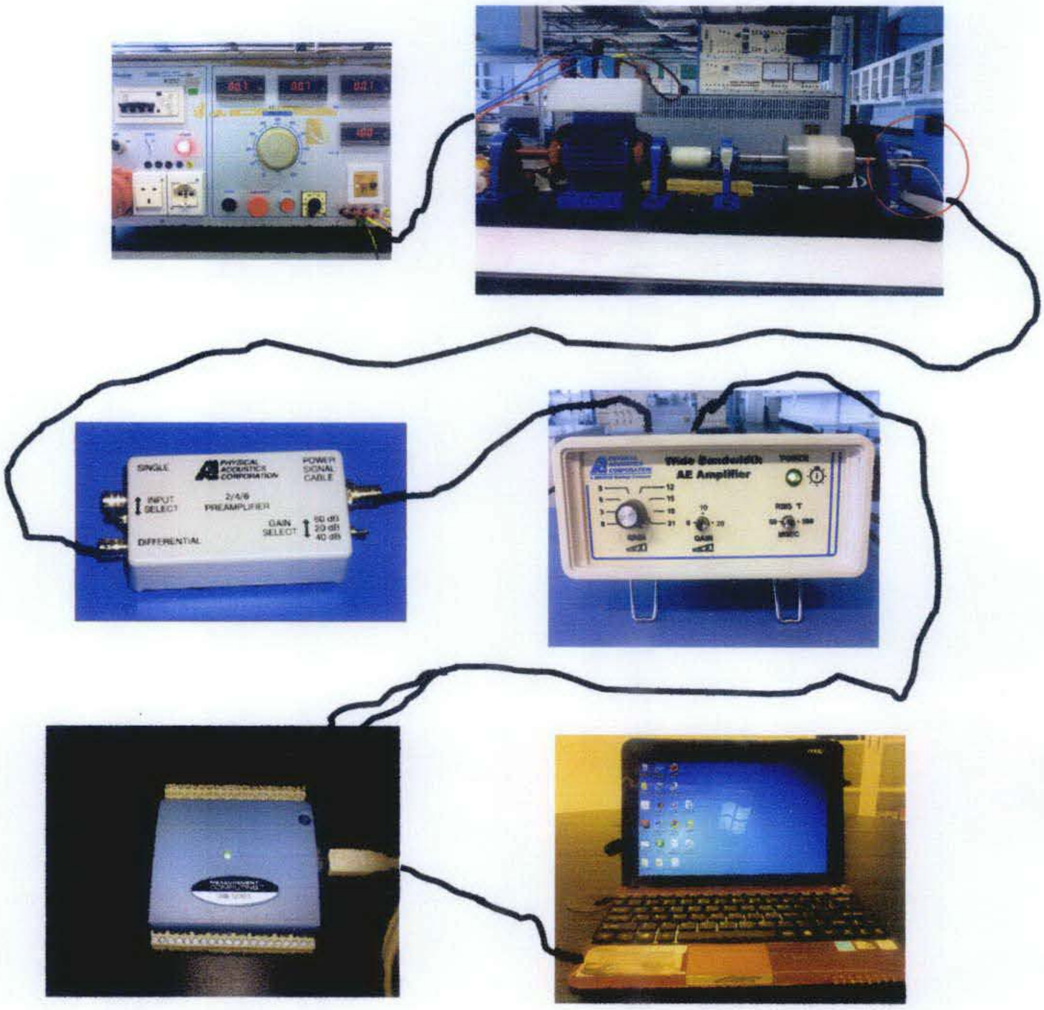


Figure 10: component of the bearing test rig (in the circle is the sensor)

To run the actual motor testing, several setups are made to the system. The setups as below:

- Motor run at 2500 rpm
- Load used is 2kg
- Preamplifier is set to differential at 60dB gain
- WB amplifiers is set to 41dB gain
- The data taken for 10000 samples
- To ensure data consistency, the bearing is tested for five time.

In the MATLAB Simulink, the simulation to acquired signal is constructed as follows:

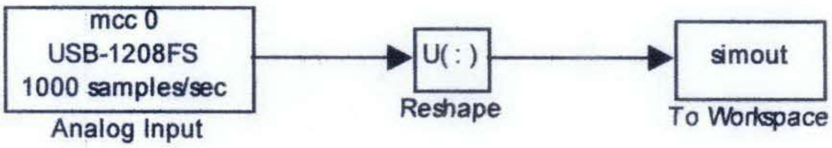


Figure 11: Simulink block diagram

CHAPTER 4

RESULT AND DISCUSSION

4.1 Bearing Sample

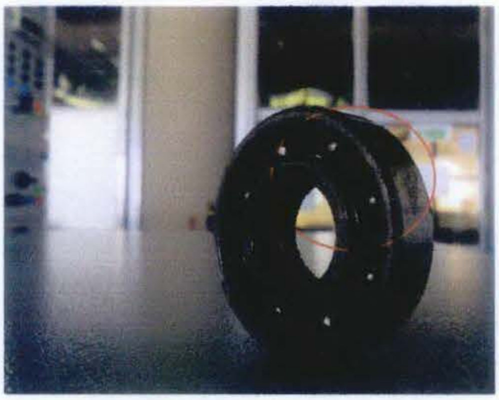
Bearing sample is split into 2 categories which are healthy (HB) and unhealthy bearing. For the unhealthy bearing, there are defect for poorly lubricated (LD), inner defect (ID) and outer defect (OD).

(a)

(b)

(c)

(d)



(e)

Figure 12: photo of healthy bearing sample (a) and (b); poorly lubricated (c); outer defect (d) and inner defect (e)

4.2 Time Domain Analysis

In the time domain analysis, three statistical data are extracted from the signal captured are voltage peak to peak (Vpp), Kurtosis value and standard deviation. Analysis of voltage peak to peak gives the energy of the acoustic emission emitted from bearing tested. The higher the peak will indicate the bearing is not in good condition. But there is a limit to determine the bearing is having fault. In addition, to strengthen the evidence that a bearing either having a fault or not, Kurtosis value is also extracted from the signal captured. Kurtosis is a measurement for peakediness indicator for roughness distributions and is frequently used as a machine condition indicator. While the standard deviation is used to calculate data distribution.

Below is the result of healthy sample (a):

Test 1

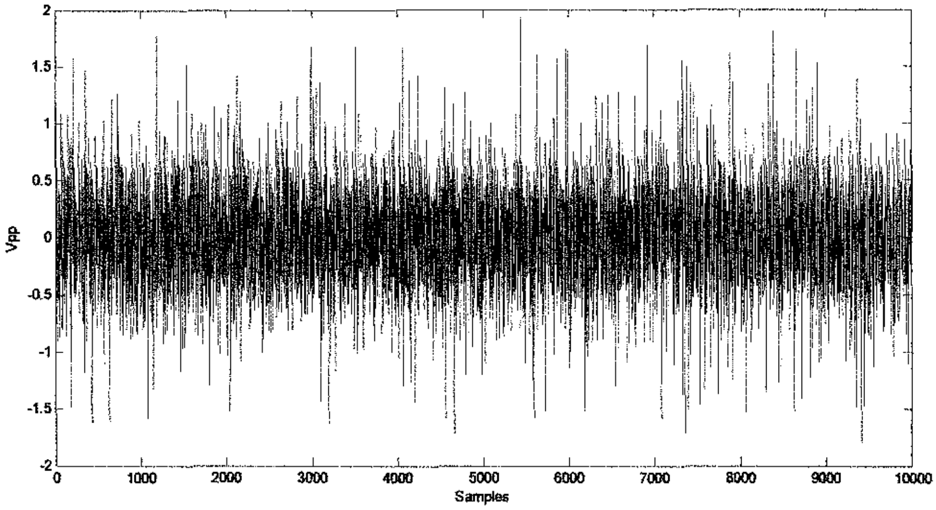


Figure 13: Time Domain Analysis for sample (a) test 1

Vpp	1.9247
Kurtosis	2.6440
Standard Deviation	0.3743

Test 2

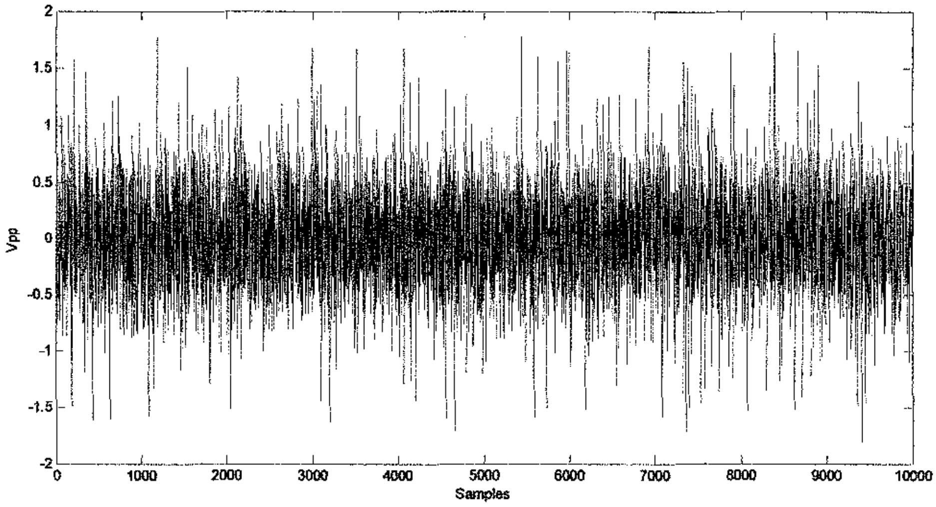


Figure 14: Time Domain Analysis for sample (a) test 2

Vpp	1.8046
Kurtosis	2.599
Standard Deviation	0.3738

Test 3

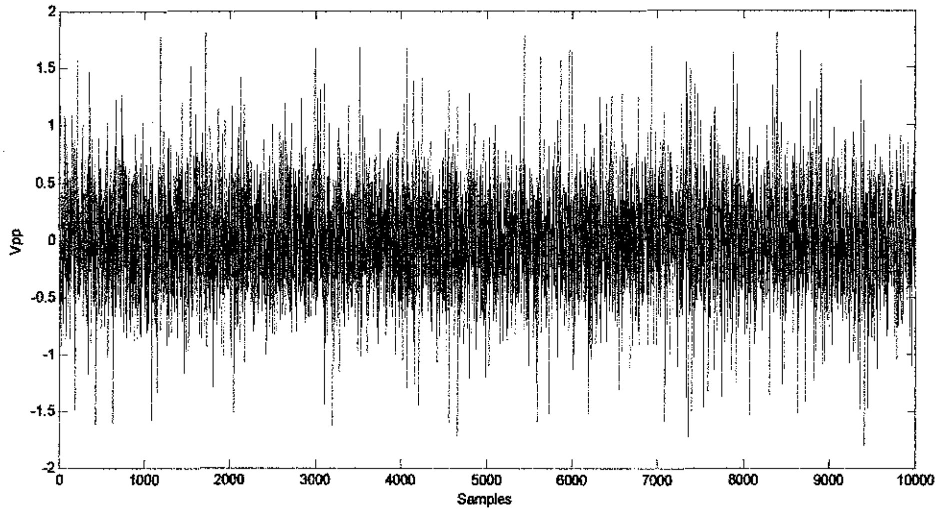


Figure 15: Time Domain Analysis for sample (a) test 3

Vpp	1.8095
Kurtosis	2.639
Standard Deviation	0.3741

Test 4

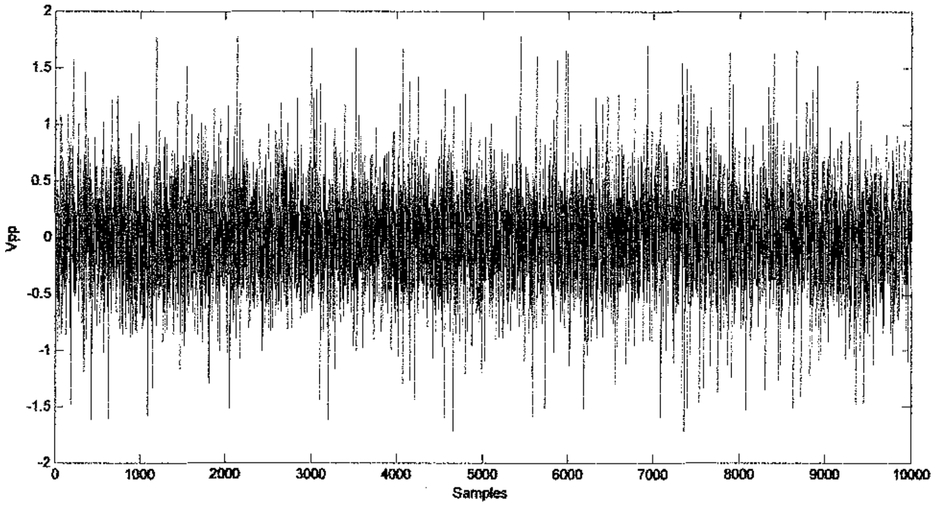


Figure 16: Time Domain Analysis for sample (a) test 4

Vpp	1.7802
Kurtosis	2.5516
Standard Deviation	0.3734

Test 5

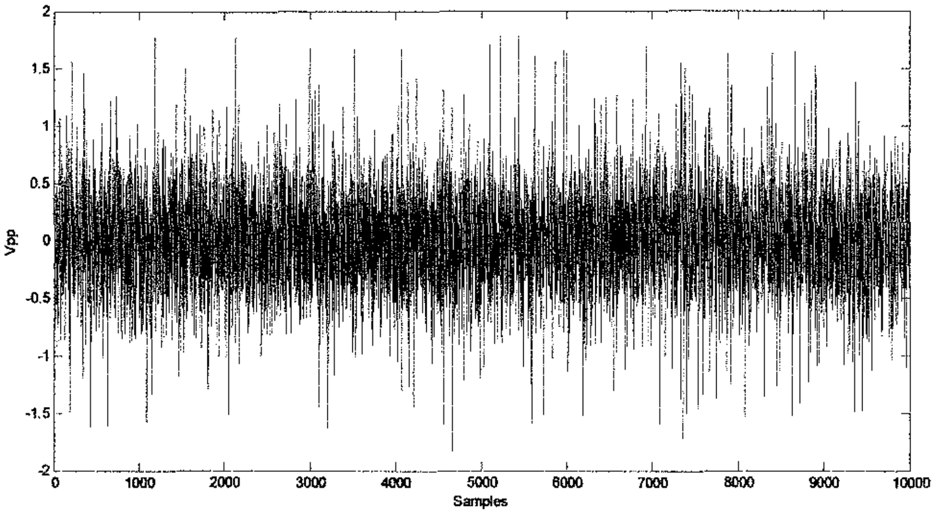


Figure 17: Time Domain Analysis for sample (a) test 5

Vpp	1.7939
Kurtosis	2.6457
Standard Deviation	0.3744

Result for healthy bearing sample (b)

Test 1

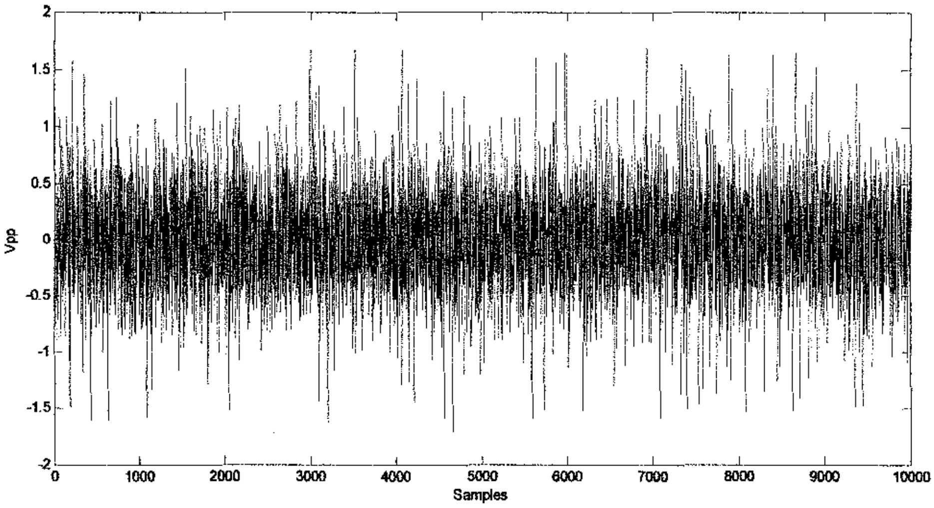


Figure 18: Time Domain Analysis for sample (b) test 1

Vpp	1.6874
Kurtosis	2.4318
Standard Deviation	0.3725

Test 2

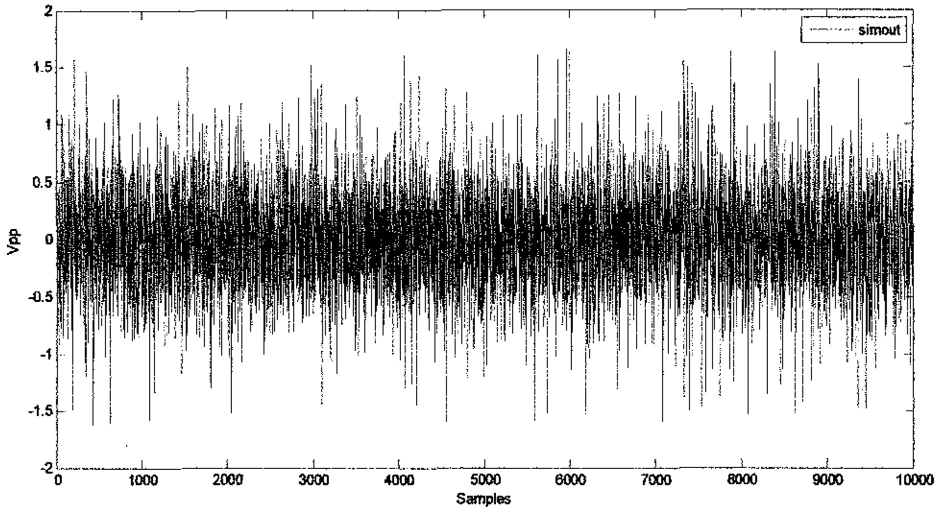


Figure 19: Time Domain Analysis for sample (b) test 2

Vpp	1.6484
Kurtosis	2.2666
Standard Deviation	0.371

Test 3

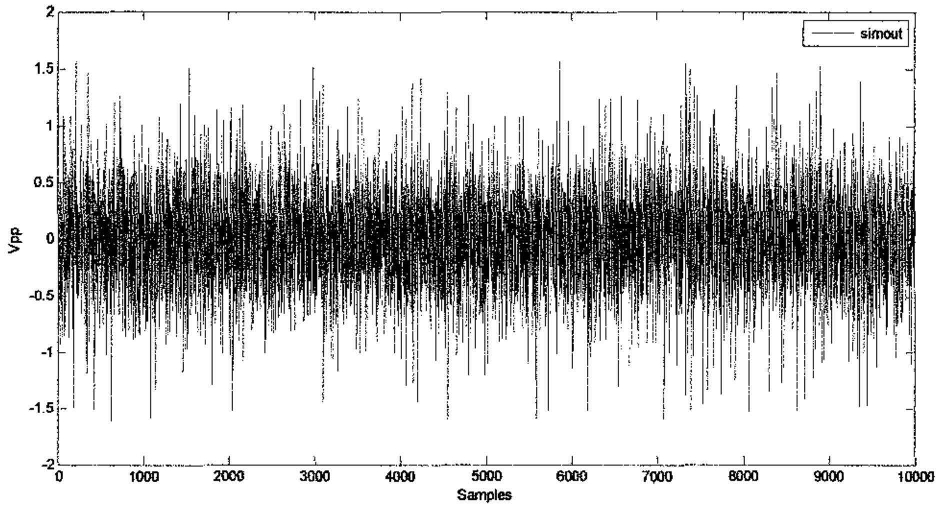


Figure 20: Time Domain Analysis for sample (b) test 3

Vpp	1.5702
Kurtosis	2.1301
Standard Deviation	0.3693

Test 4

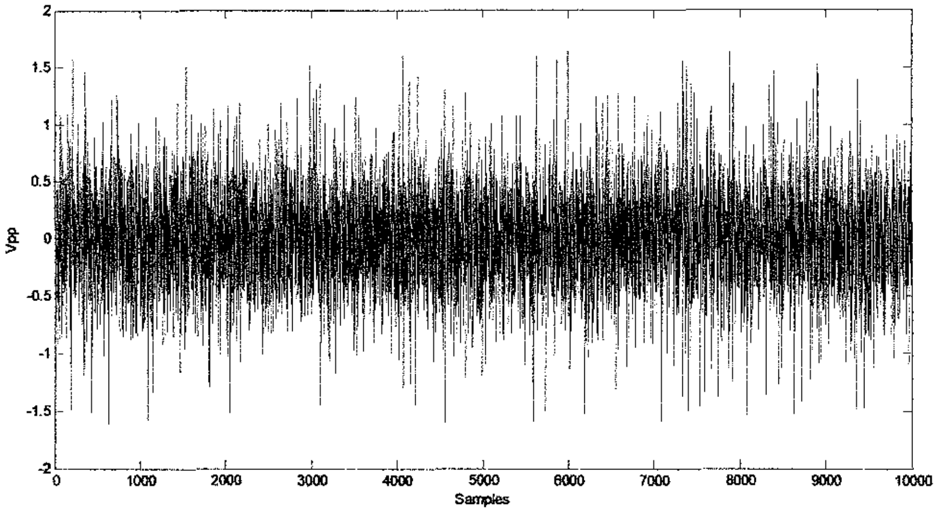


Figure 21: Time Domain Analysis for sample (b) test 4

Vpp	1.6337
Kurtosis	2.166
Standard Deviation	0.3705

Test 5

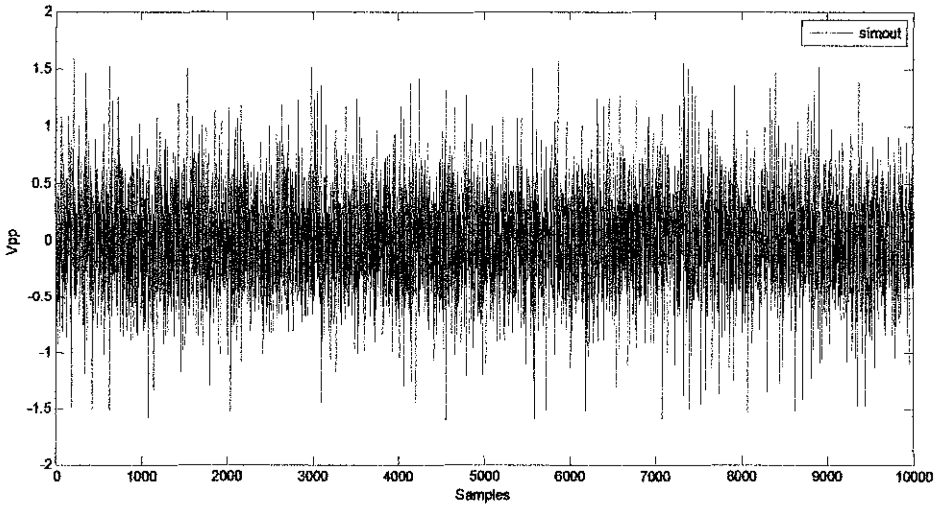


Figure 22: Time Domain Analysis for sample (b) test 5

Vpp	1.5900
Kurtosis	2.1546
Standard Deviation	0.3700

Below is the result for unhealthy bearing:

Poorly lubricated bearing sample (c)

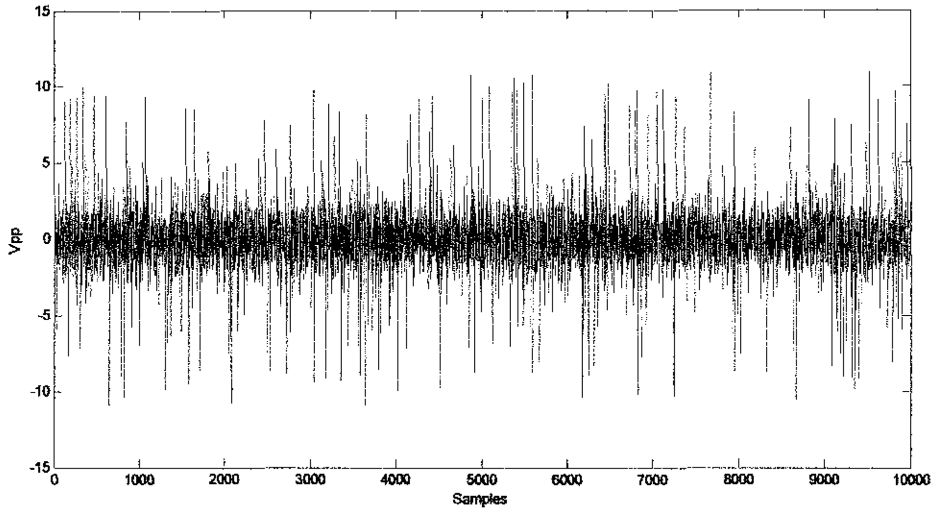


Figure 23: Time Domain Analysis for sample (c)

Vpp	10.9060
Kurtosis	13.3590
Standard Deviation	1.584

Outer defect

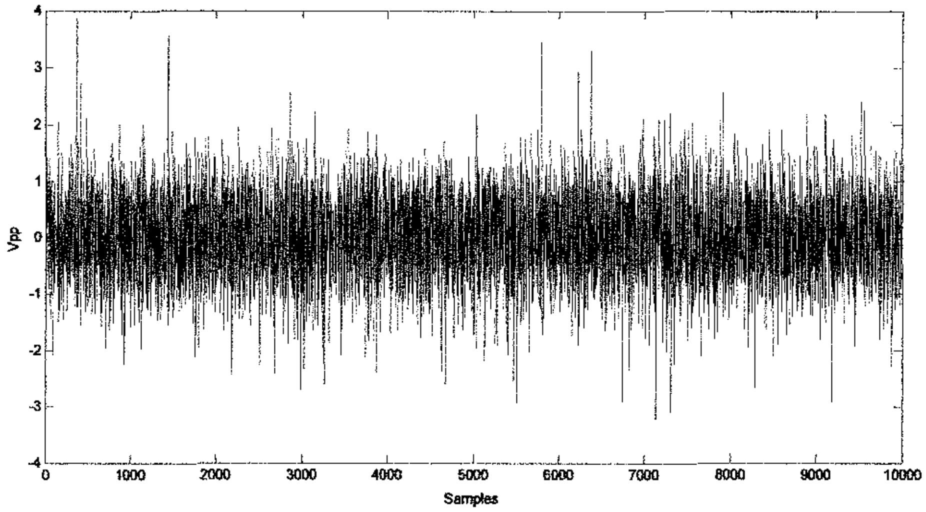


Figure 24: Time Domain Analysis for sample (d)

Vpp	3.8535
Kurtosis	3.8076
Standard Deviation	0.6639

Inner defect

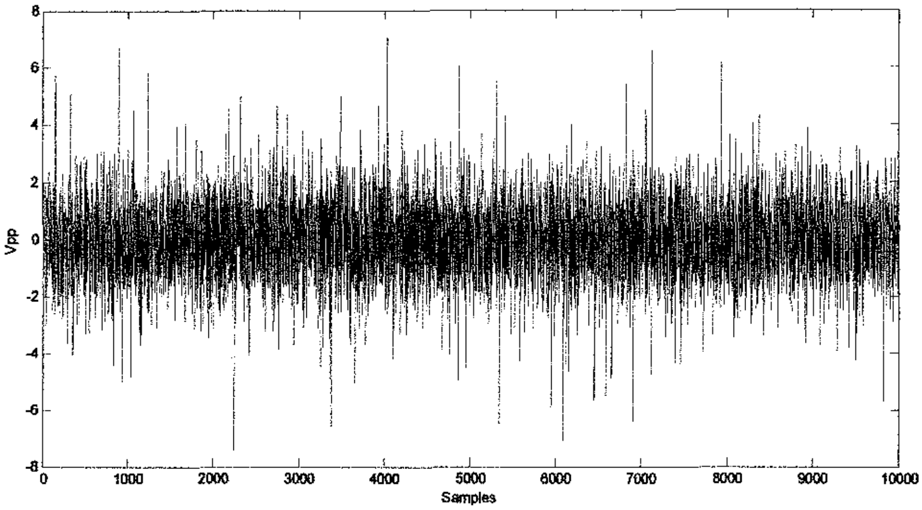


Figure 25: Time Domain Analysis for sample (e)

Vpp	7.0476
Kurtosis	4.7212
Standard Deviation	1.194

From the above data, clearly shown that for healthy bearing the Vpp is should not more than 2.2Vpp and for Kurtosis Value is not more than 3. While the standard deviation is not more than 0.5

4.3 Frequency Domain Analysis

For frequency analysis, the magnitude of normalized frequency is counted for indicating the condition of the bearing. Besides that, fast fourier transform (FFT) is used to determine frequency boundary for the same reason.

Below is the result of bearing sample (a)

Test 1

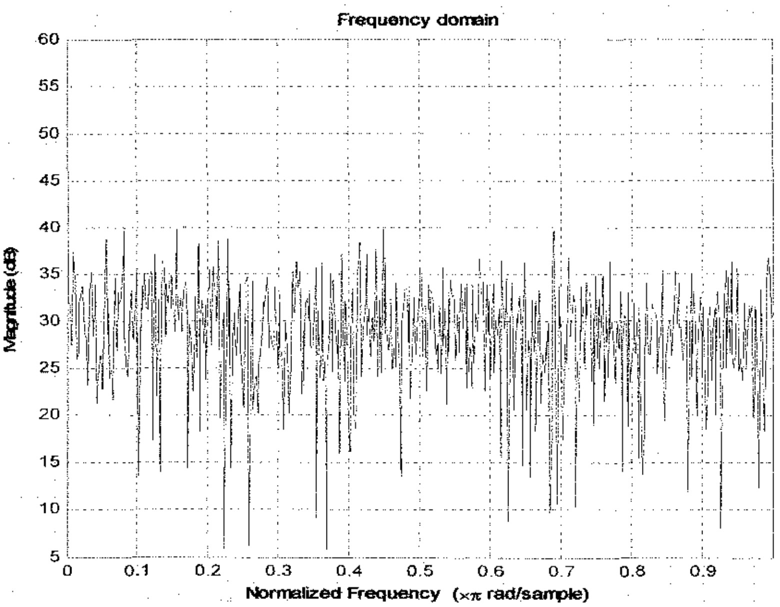


Figure 26: Magnitude of Normalized Frequency for sample (a) Test 1

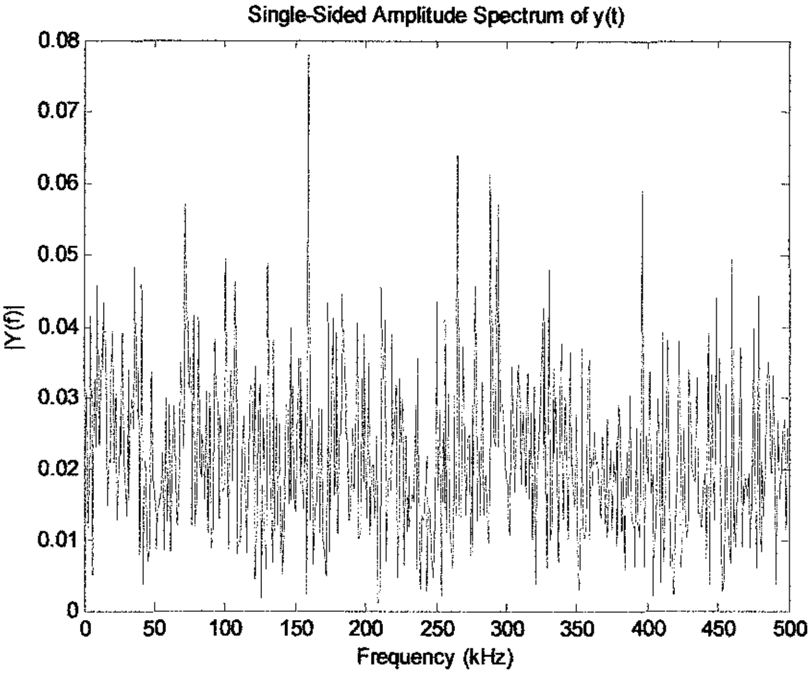


Figure 27: Frequency Boundary for sample (a) Test 1

Test 2

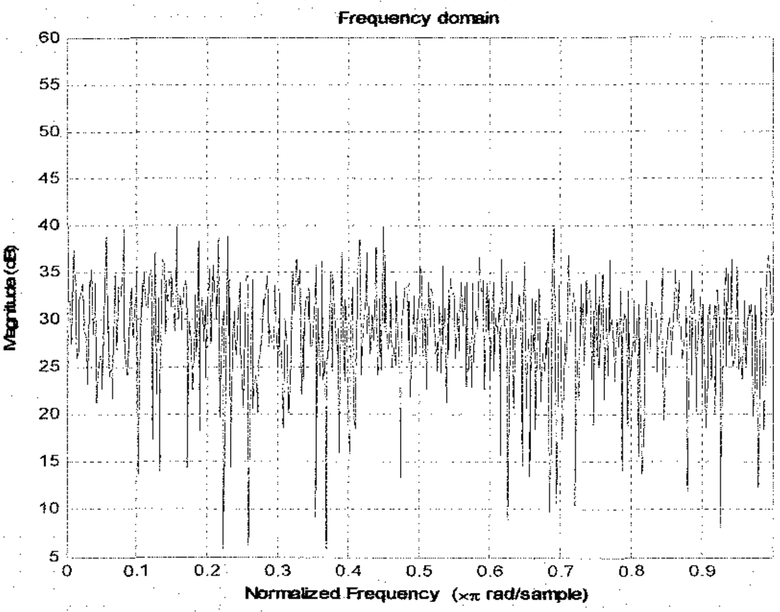


Figure 28 : Magnitude of Normalized Frequency for sample (a) Test 2

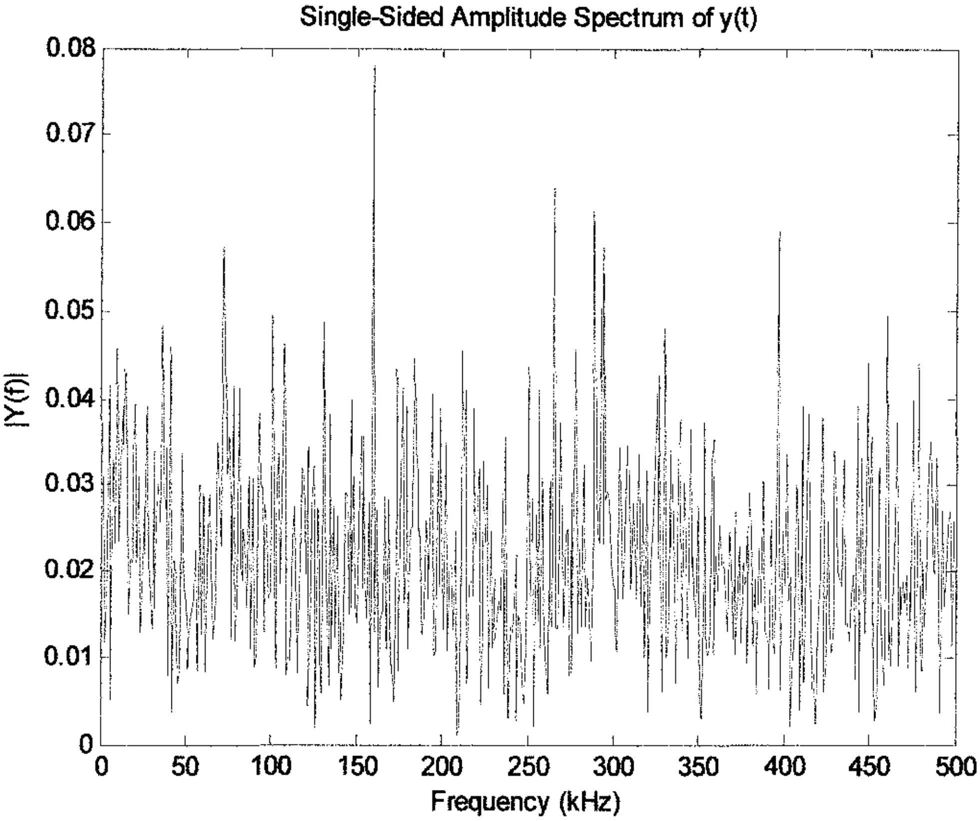


Figure 29 : Frequency Boundary for sample (a) Test 2

Test 3

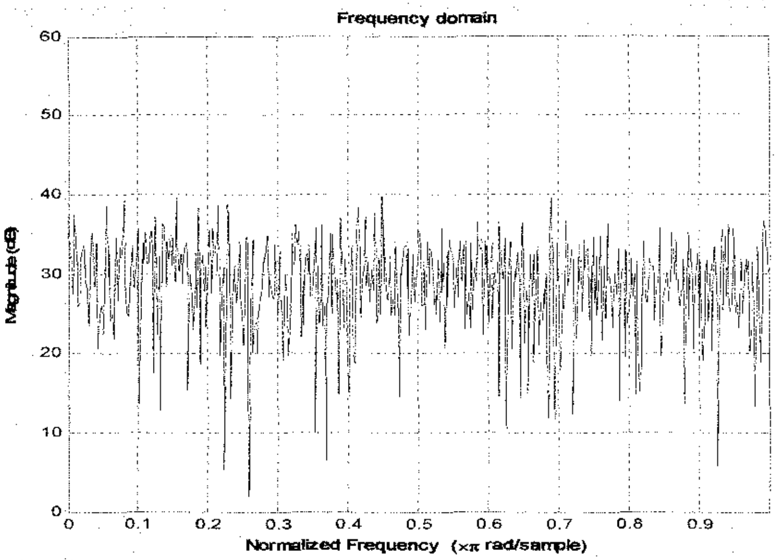


Figure 30 : Magnitude of Normalized Frequency for sample (a) Test 3

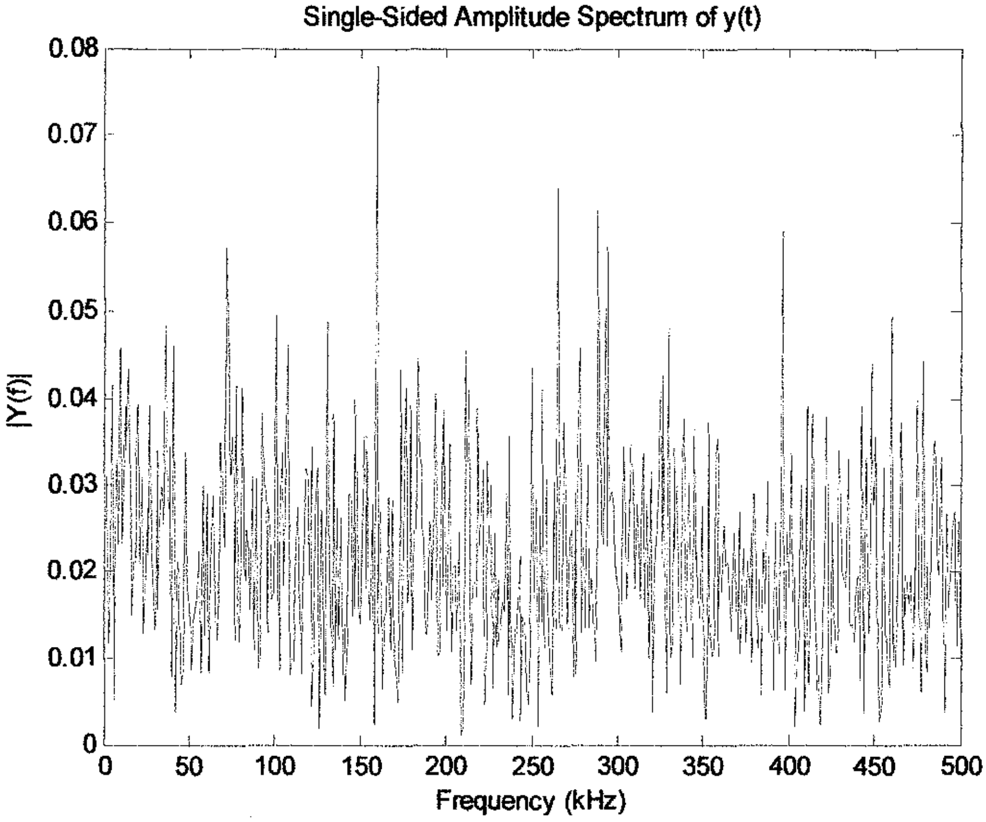


Figure 31 : Frequency Boundary for sample (a) Test 3

Test 4

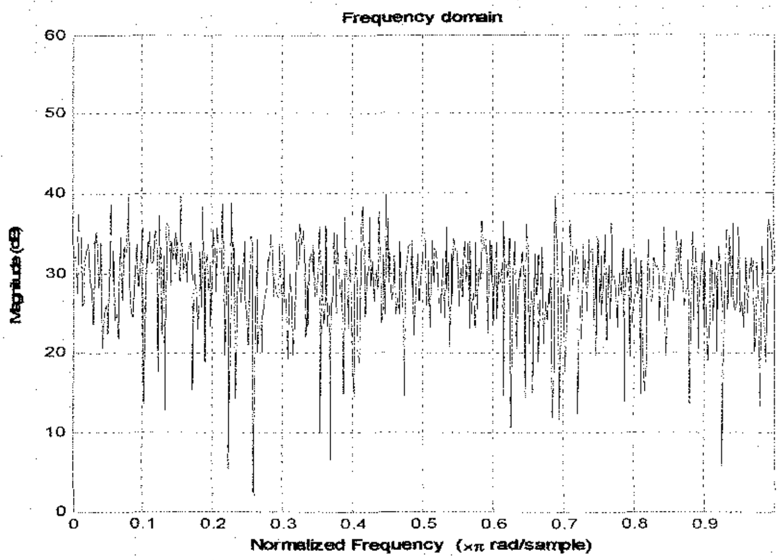


Figure 32 : Magnitude of Normalized Frequency for sample (a) Test 4

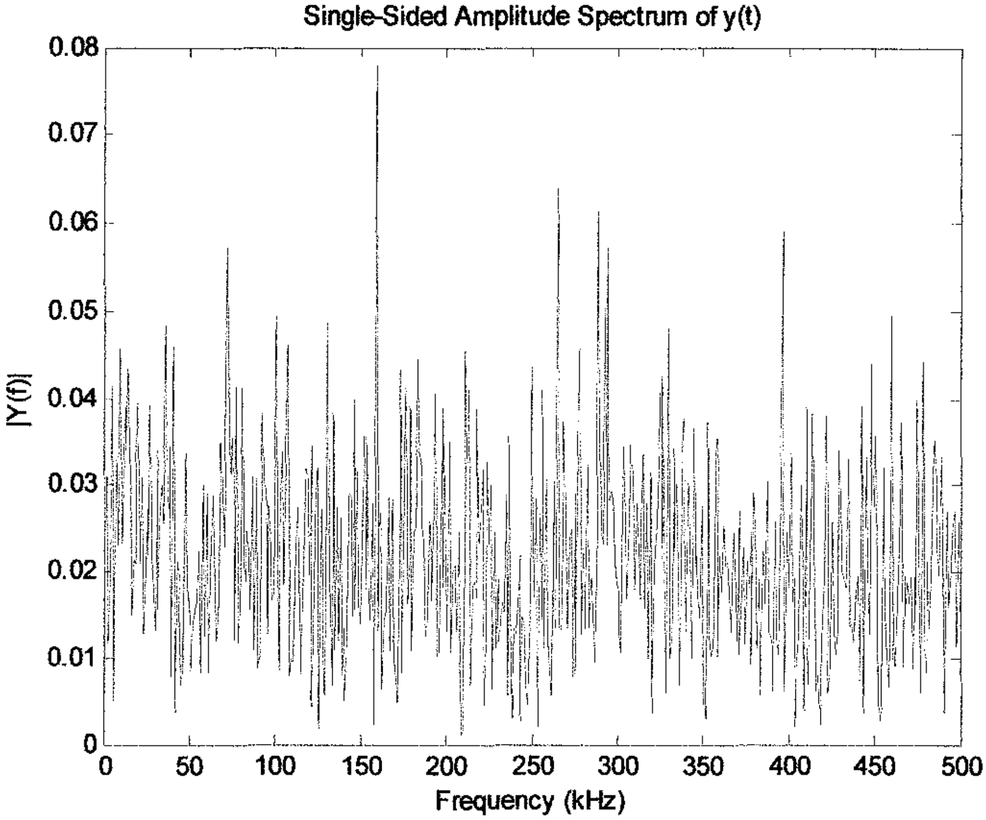


Figure 33 : Frequency Boundary for sample (a) Test 4

Test 5

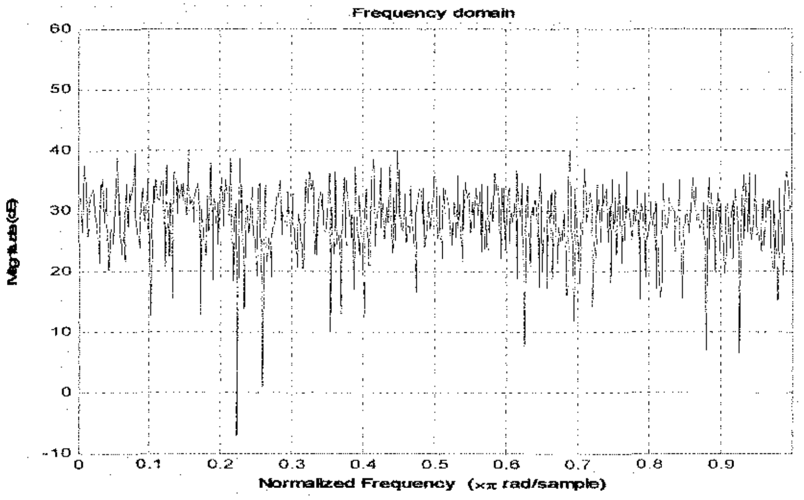


Figure 34 : Magnitude of Normalized Frequency for sample (a) Test 5

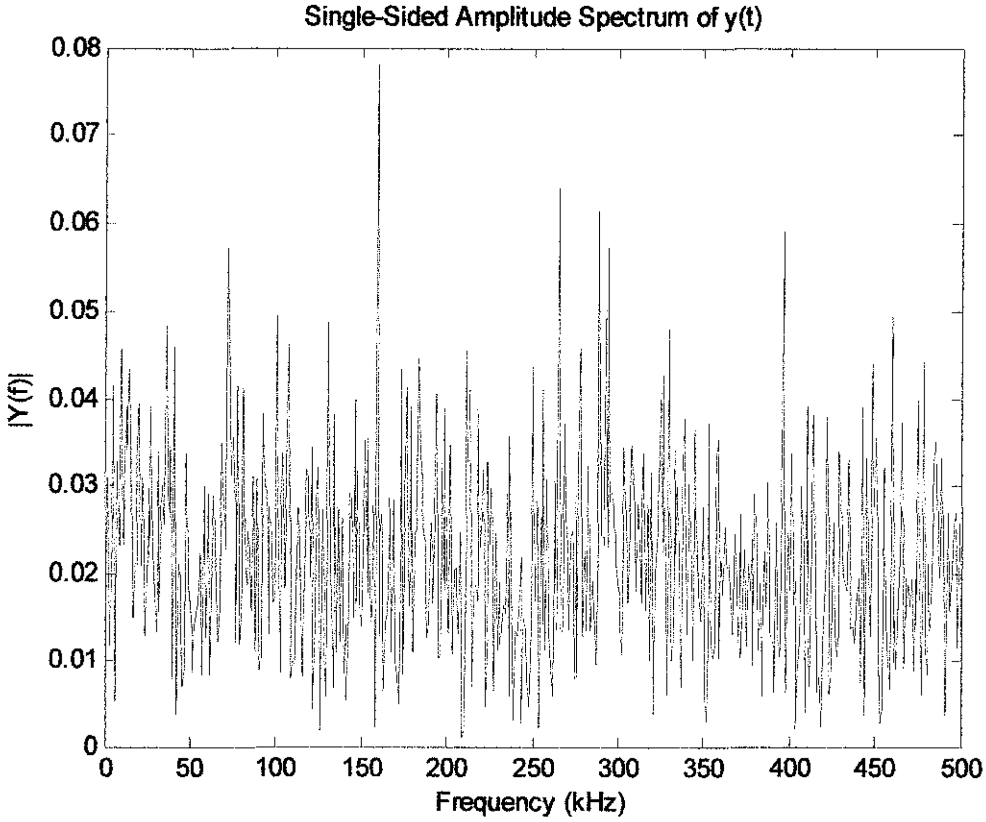


Figure 35 : Frequency Boundary for sample (a) Test 5

Below is the result of bearing sample (b)

Test 1

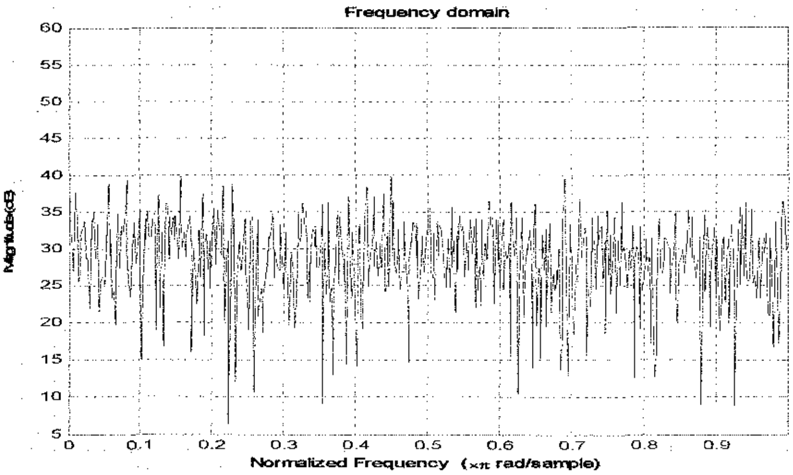


Figure 36: Magnitude of Normalized Frequency for sample (b) Test 1

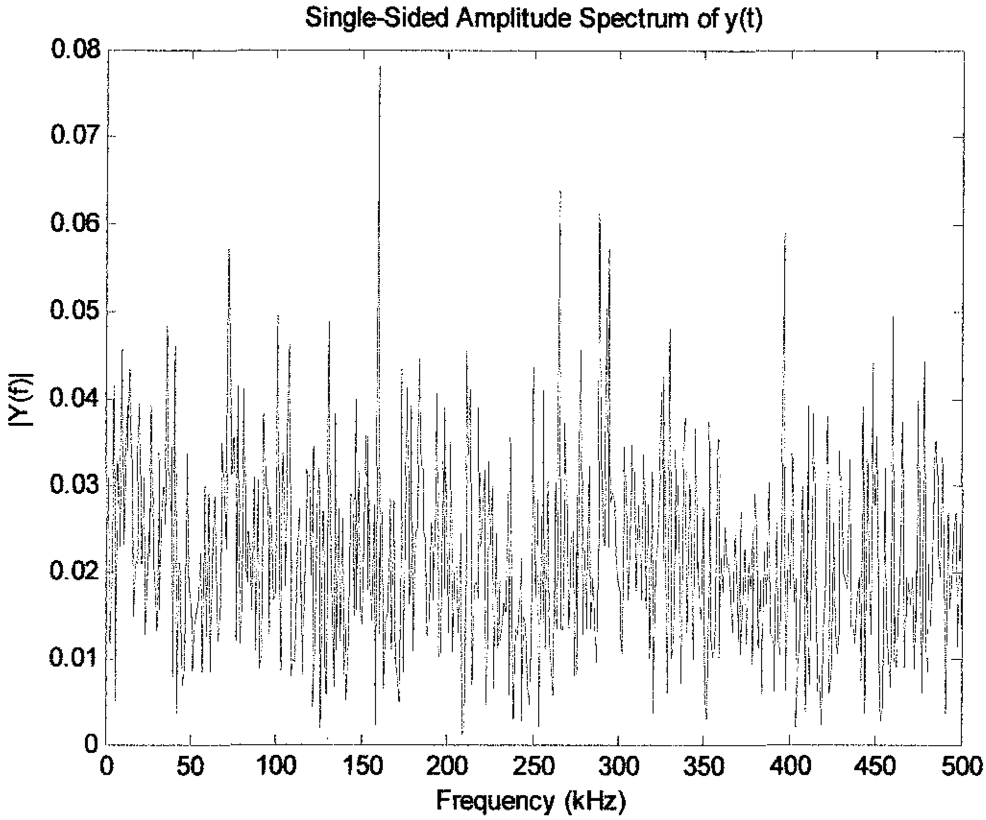


Figure 37: Frequency Boundary for sample (b) Test 1

Test 2

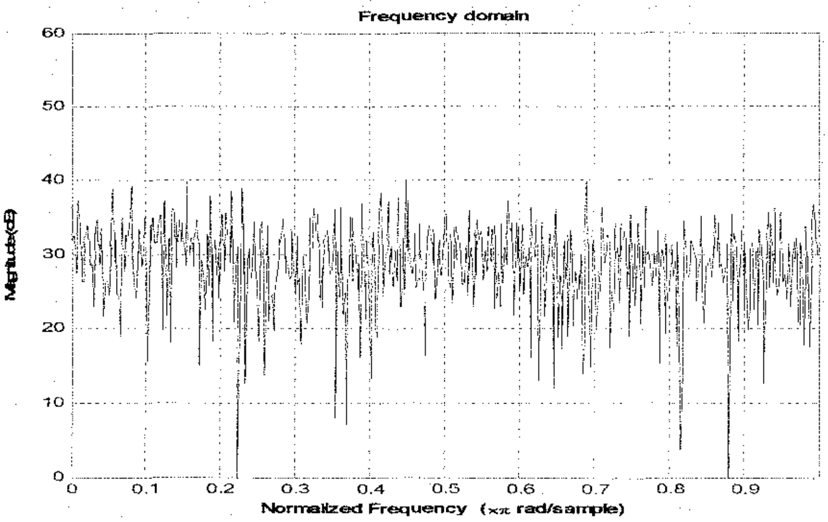


Figure 38 : Magnitude of Normalized Frequency for sample (b) Test 2

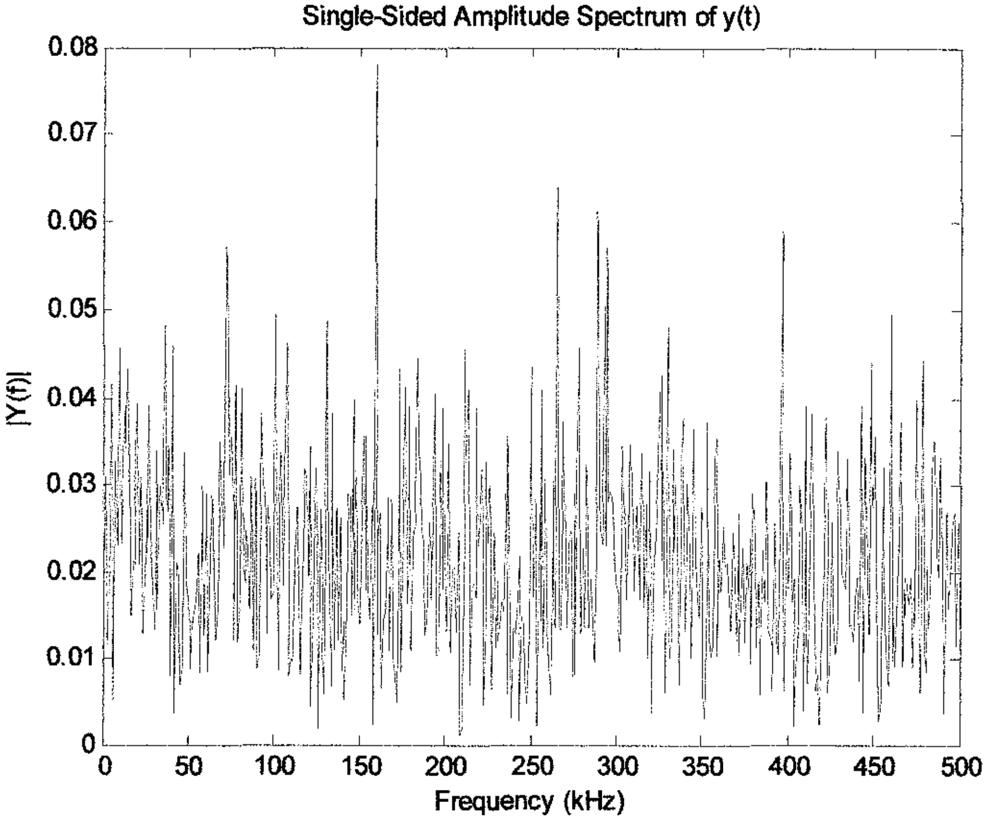


Figure 39 : Frequency Boundary for sample (b) Test 2

Test 3

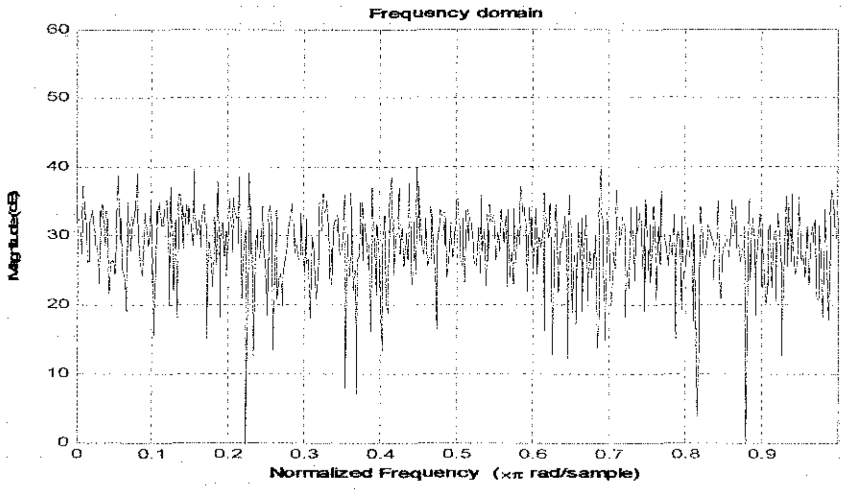


Figure 40 : Magnitude of Normalized Frequency for sample (b) Test 3

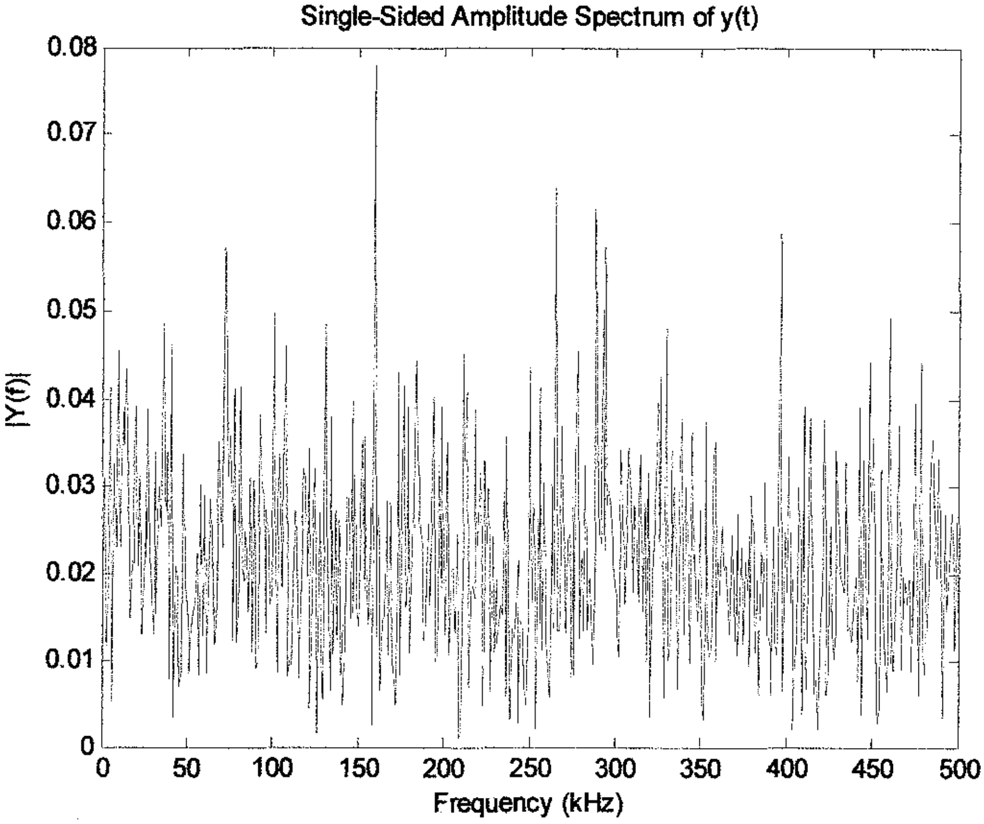


Figure 41 : Frequency Boundary for sample (b) Test 3

Test 4

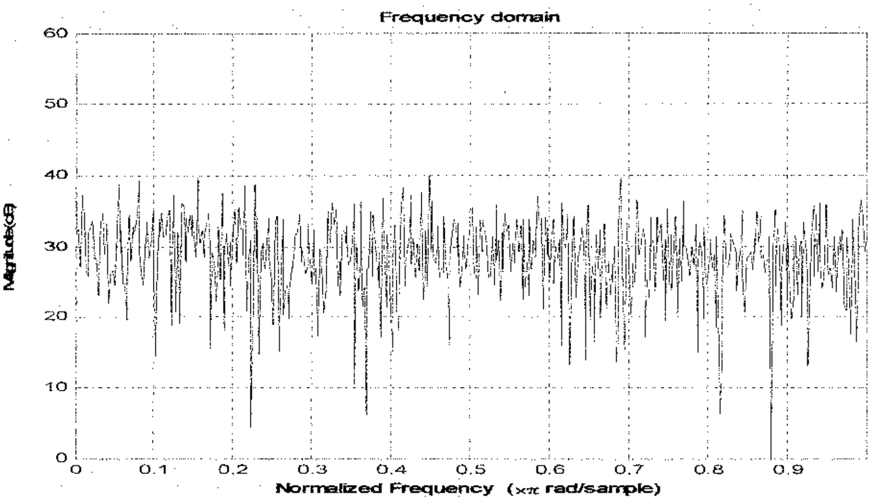


Figure 42 : Magnitude of Normalized Frequency for sample (b) Test 4

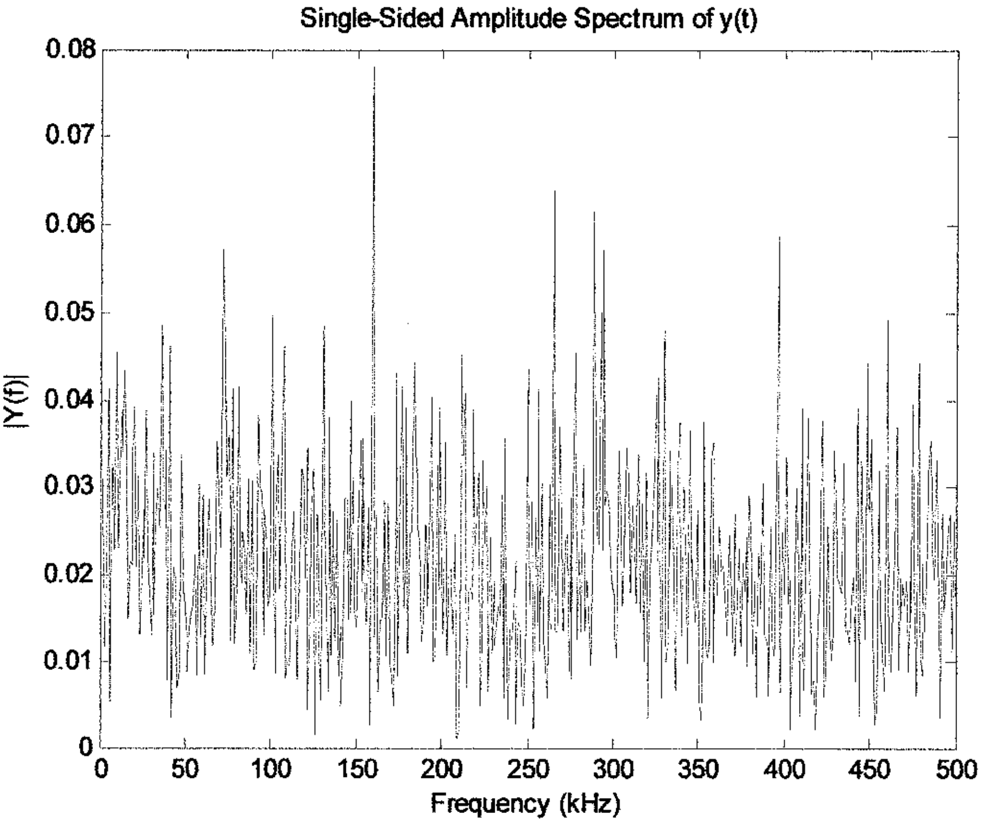


Figure 43 : Frequency Boundary for sample (b) Test 4

Test 5

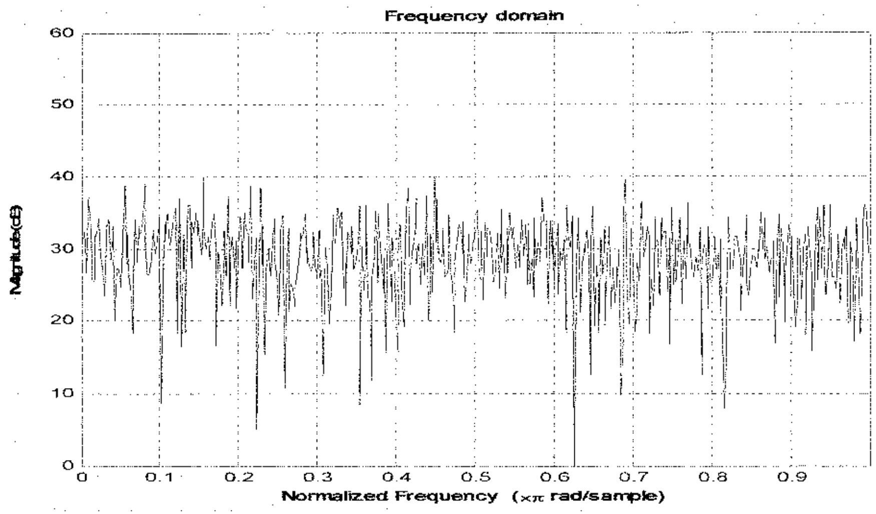


Figure 44: Magnitude of Normalized Frequency for sample (b) Test 5

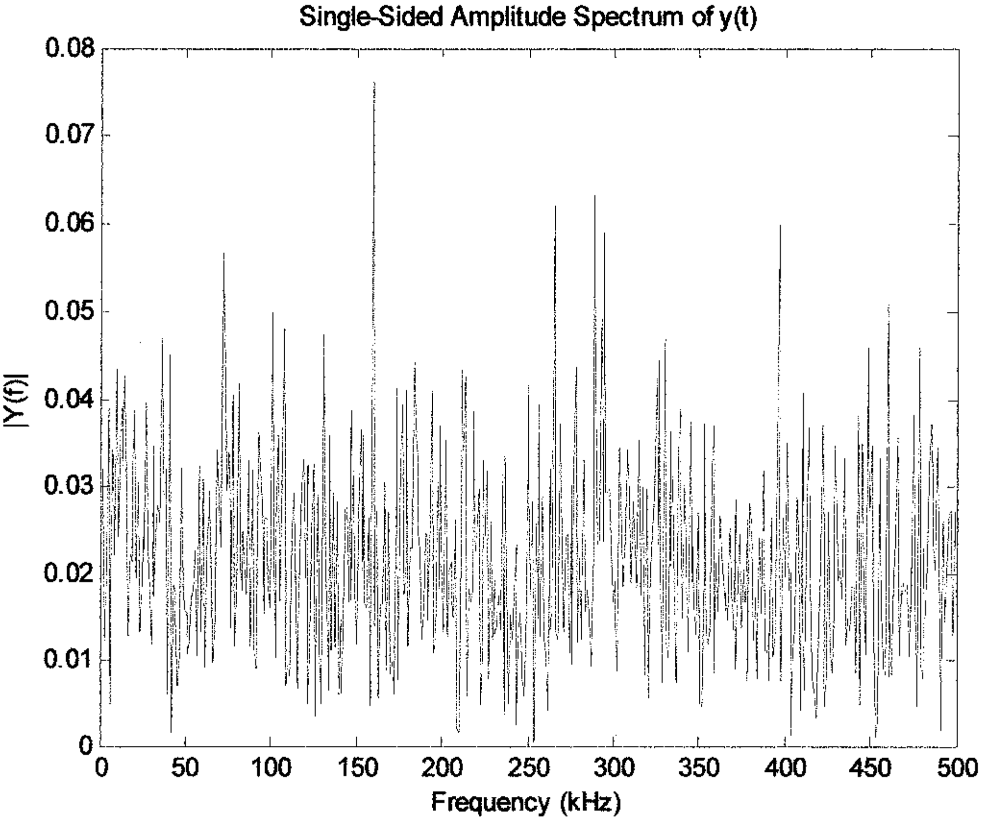


Figure 45 : Frequency Boundary for sample (b) Test 5

Below is the result for unhealthy bearing:

Poorly lubricated

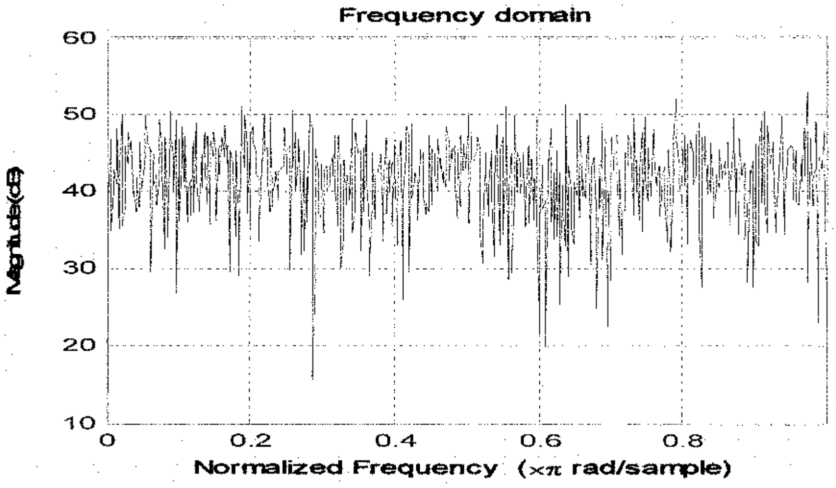


Figure 46 : Magnitude of Normalized Frequency for sample (c)

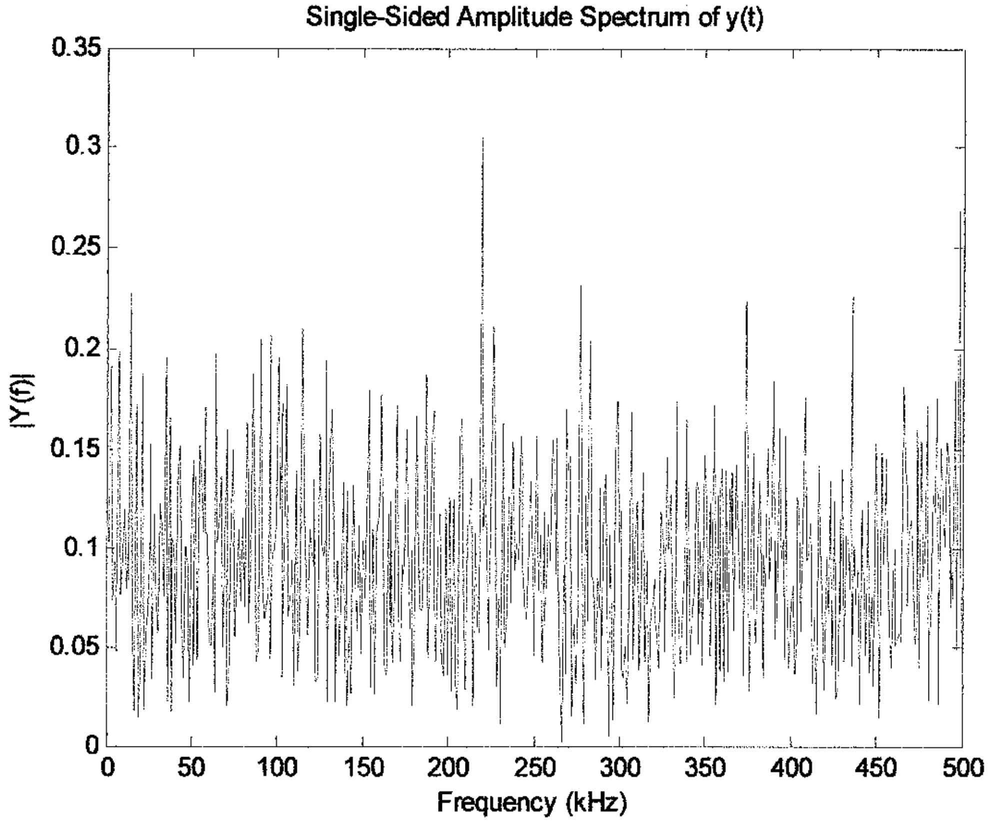


Figure 47 : Frequency Boundary for sample (c)

Outer defect

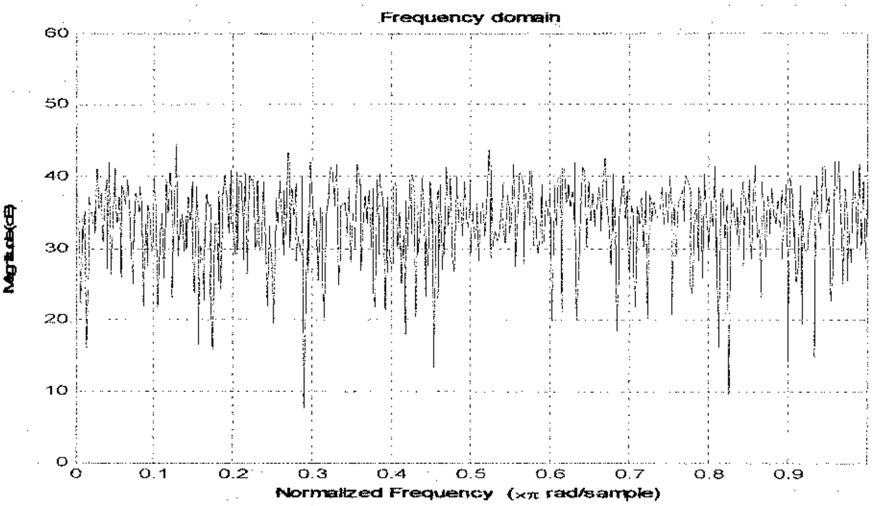


Figure 48 : Magnitude of Normalized Frequency for sample (d)

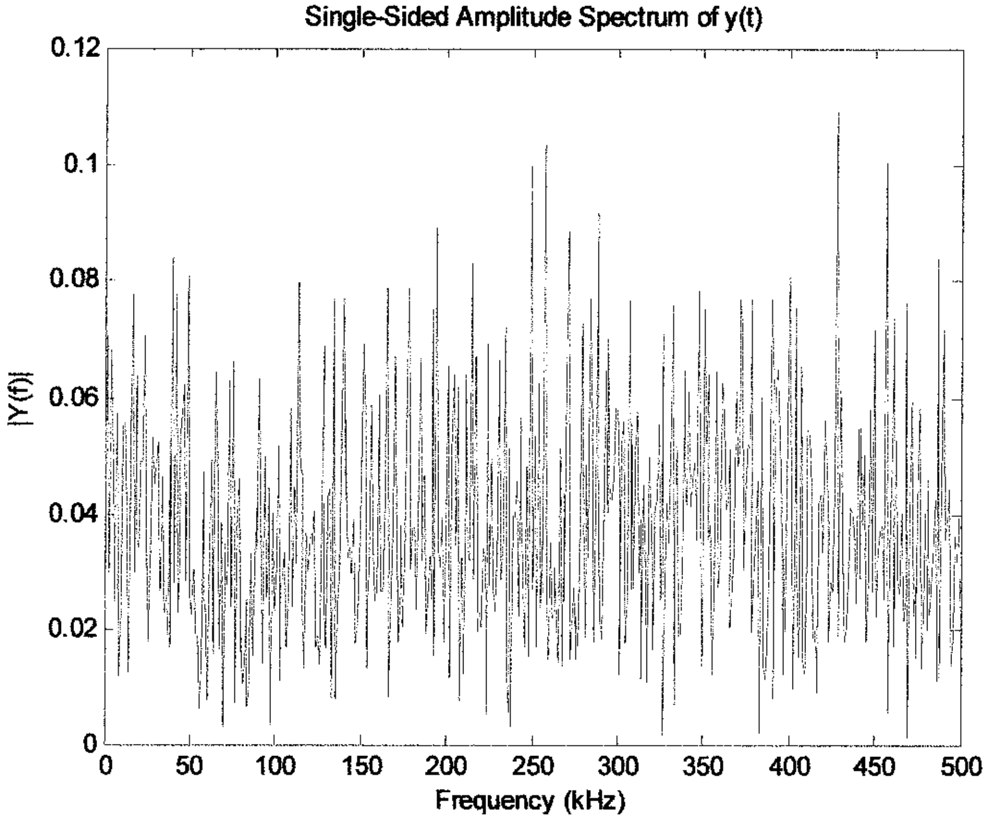


Figure 49 : Frequency Boundary for sample (d)

Inner defect

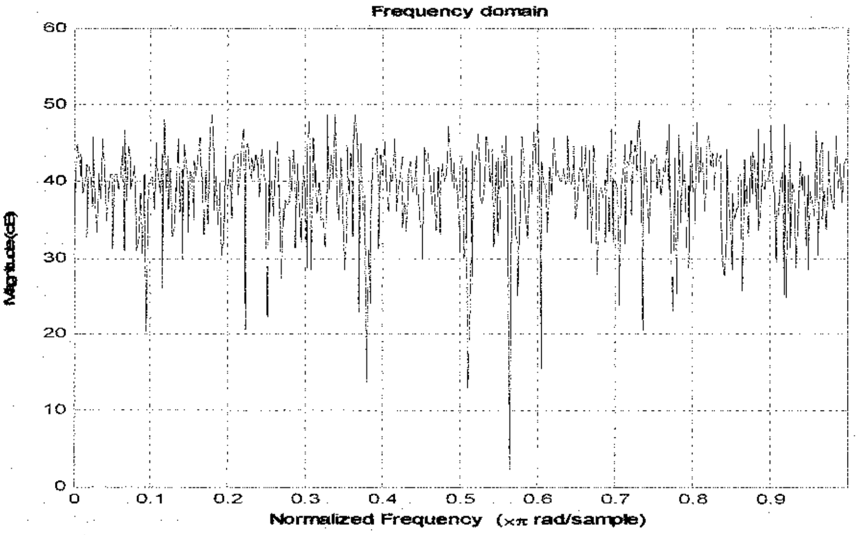


Figure 50 : Magnitude of Normalized Frequency for sample (e)

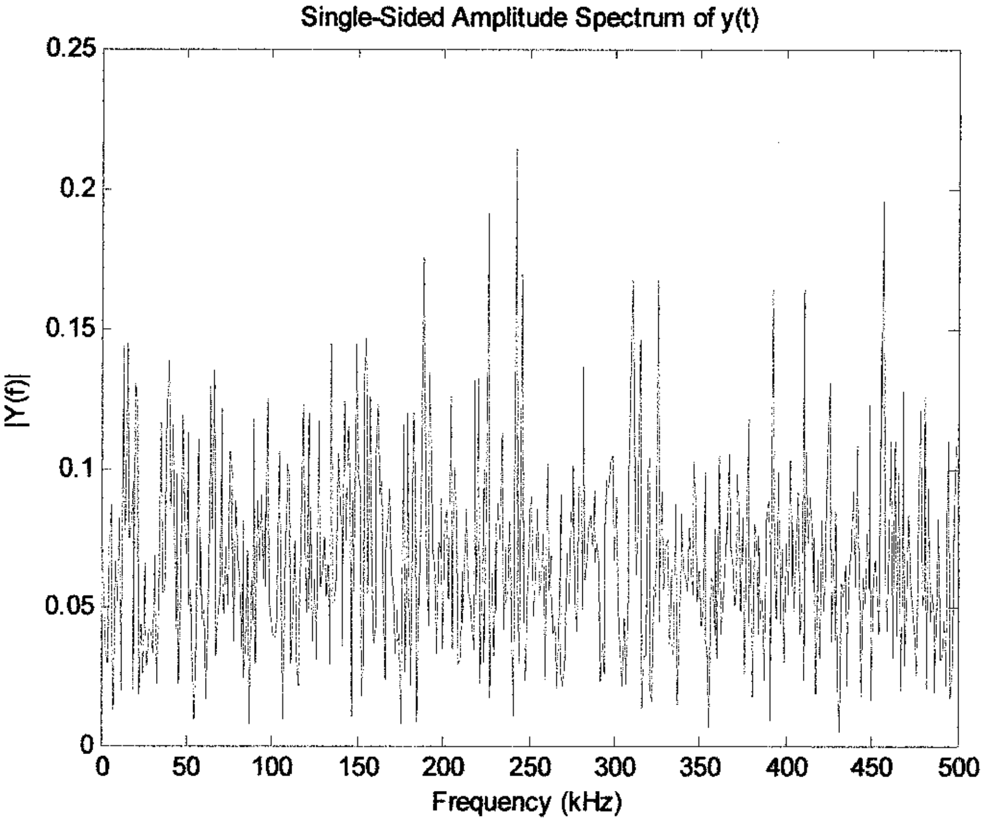


Figure 51 : Frequency Boundary for sample (e)

In frequency domain analysis, the normalized magnitude of healthy bearing is should more than 40 dB and for frequency boundary for a bearing to be considered as healthy bearing is should not more than 150 kHz. Which mean the first peak to rise is not more than 150 kHz. From the above data, the frequency for poorly lubricated bearing is between 200 kHz and 250 kHz. These prove the evident that the bearing is faulty.

As summary, the time domain as follows:

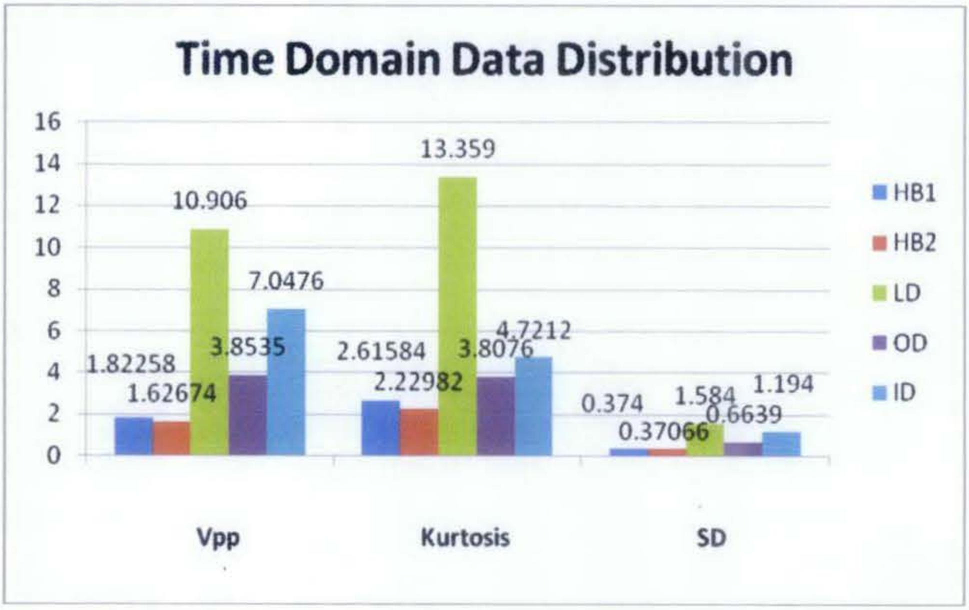


Figure 52: Time Doamin Data Distribution

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Acoustic emission is the preferable method to detect premature fault at incipient stage since this technique can detect wide band signal. This technique has achieved its objective where it can save time and cost to repair the rotating machine by replacing faulted bearing. Acoustic emission technique is reliable to use although the surrounding is full with noisy machine.

5.2 Recommendation

For optimal implementation of this project, there is some room for improvement to be made. To reduce the implemented AE system cost, the preamplifier and filter can be designed in MATLAB since the software has its own toolbox for amplifier and filter. This also can simplify the AE system. And for further studies, the frequency domain would be the best signal analysis to be focused on.

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APPENDICES

APPENDIX A

GANTT CHART FOT FYP 1

No	Detail/Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**		**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Selection of Project Topic	■	■						**Mid-semester break**							
2	Preliminary Research Work		■	■	■											
3	Submission of Preliminary Report				●											
4	Seminar 1 (optional)					■	■	■								
5	Project Work					■	■	■								
6	Submission of Progress Report									●						
7	Seminar 2 (compulsory)										■	■	■	■		
8	Project Work (continues)									■	■	■	■	■		
9	Submission of Interim Report Final Draft														●	
10	Oral Presentation															●

APPENDIX B

GANTT CHART FOT FYP 2

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work (continues)	■	■	■	■	■	■	■	Mid-semester break	■	■	■	■	■		
2	Submission of Progress Report									●						
3	Pre EDX												●			
4	Submission of Draft Report														●	
5	Submission of Final Report (Soft Copy)															●
6	Submission of Technical Paper															●
7	Viva														■	■
8	Submission of Final Report															●

APPENDIX C

FFT MATLAB CODING

```
Fs = 1000;              % Sampling frequency
T = 1/Fs;              % Sample time
L = 1000;               % Length of signal
t = (0:L-1)*T;


NFFT = 2^nextpow2(L); % Next power of 2 from length of y
Y = fft(simout,NFFT)/L;
f = Fs/2*linspace(0,1,NFFT/2+1);

% Plot single-sided amplitude spectrum.
plot(f,2*abs(Y(1:NFFT/2+1)))
title('Single-Sided Amplitude Spectrum of y(t)')
xlabel('Frequency (Hz)')
ylabel('|Y(f)|')
```