TIME-FREQUENCY DOMAIN ANALYSIS OF ACOUSTIC EMISSION SIGNAL FOR MILLING PROCESS

MOHD SHAFAWI BIN CHE IBRAHIM

Report submitted in partial fulfillment of the requirements
for the award of the degree of Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

This project is to investigate using the time-frequency domain analysis acoustic emission (AE) signal for the milling process. The objective of this project is to study the properties of acoustic emission signal during the machining process at different surface quality using the time frequency localization method. This thesis describes the pattern of graph that being shown from different of machining parameter. Several steps being followed to ensure that the experiment will run. First step to run the experiment is to design of experiments. Before running the experiment, the materials be facing to get parallel surface and several parameters of machining being chosen to get the variations of surface roughness. The materials will clamp at the table of the milling machine and the sensor will be placed on the materials. To remove the gaps between the sensor and the workpiece, the function of grease be used. To check whether the AE system will detect the signal, pencil break test will be done. This action can produce AE signals that like as the experiment will be run. For the cutting tools, the carbide coated cutting tools being used and for the materials using Haynes 188 as the experimental material. To get the variation of surface roughness, parameter that being selected before being used. Different parameters give different AE signal and the surface roughness also varies. When all the data collected, it can be used in manufacturing field. And the result that obtained is for the smooth the range of the Ra is about from 0.270 µm until 0.384 µm. And for the medium surface quality, it from 1.370 µm to 2.058µm. For the rough surface, the Ra is about 6.033 to 7.042 µm. In STFT windows, the graph looks to their pattern of the colour of the graph. From the colour at the graph, colour that more dominant shows the high value of amplitude. STFT windows are most suitable to view of the times, frequency and the amplitude of the signal and that show it the most suitable method to analyze the condition monitoring of machining.

ABSTRAK

Projek ini adalah untuk menyiasat analisis domain frekuensi masa isyarat pancaran akustik bagi proses milling. Objektif projek ini adalah untuk mengkaji sifat isyarat pancaran akustik semasa proses pemesinan pada kualiti permukaan yang berbeza dengan menggunakan kaedah penyetempatan kekerapan masa. Tesis ini menerangkan corak graf yang ditunjukkan dari parameter pemesinan yang berbeza. Beberapa langkah perlu diikuti untuk memastikan bahawa eksperimen akan dilakukan. Langkah pertama untuk menjalankan eksperimen adalah untuk mereka bentuk uji kaji. Sebelum menjalankan percubaan, bahan-bahan akan menghadapi untuk mendapatkan permukaan yang selari dan beberapa parameter pemesinan yang dipilih untuk mendapatkan variasi kekasaran permukaan. Bahan eksperimen akan dikepit di meja mesin milling dan sensor akan diletakkan di atas bahan eksperimen. Untuk membuang jurang antara sensor dan bahan kerja, fungsi gris digunakan. Untuk memeriksa sama ada sistem AE akan mengesan isyarat, ujian patah mata pensil akan dilakukan. Tindakan ini boleh menghasilkan isyarat AE yang seperti eksperimen akan dijalankan. Bagi alat pemotong, alat pemotong karbida bersalut yang digunakan dan menggunakan Haynes 188 sebagai bahan eksperimen. Untuk mendapatkan perubahan parameter kekasaran permukaan, parameter yang dipilih sebelum ini digunakan. Parameter yang berbeza memberi isyarat AE berbeza dan kekasaran permukaan juga berbeza-beza. Apabila semua data yang dikumpul, ia boleh digunakan dalam bidang pembuatan. Dan hasil yang diperolehi adalah untuk julat yang licin daripada Ra adalah lebih kurang daripada 0,270 μm sehingga 0,384 μm. Dan untuk permukaan sederhana, dari 1,370 μm 2.058μm. Untuk permukaan kasar, Ra adalah kira-kira 6,033 hingga 7,042 μm. Dalam STFT tingkap, graf yg dilihat adalah berdasarkan corak warna pada graf yg dipamerkan. Dari warna pada graf, warna yang lebih dominan menunjukkan nilai amplitud yg tinggi. Tingkap STFT dalah yang paling sesuai untuk melihat masa, frekuensi dan juga amplitud isyarat dan merupakan kaedah yang paling sesuai untuk menganalisis pemantaun kaedah pemesinan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AE	Acoustics Emission
dB	Decibels
CNC	Computer Numerical Control
FFT	Fast Fourier transform
NDT	Nondestructive Testing
RPM	Revolution Per Minute
STFT	Short Time Fourier Transform

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In the manufacturing field, Milling machines are the most widely used for manufacturing applications after lathes. In milling, the workpiece is fed into a rotating milling cutter (Trent and Wright, 2000).

Milling is operational that the cutting action is achieved by rotating the tool while the work is clamped to the table. And the feed action is obtained by moving it under the cutter. The cutting action of the many teeth around the milling cutter provides a fast method of machining. The machined surface may be flat, angular, or curved. The surface may also be milled to any combinations of shapes (Juneja and Seth, 2003). The milling is classed into several processes such as peripheral milling, face milling, and end milling. In this project, it only used face milling process method to investigate the problem.

Milling also is the most versatile machining processes and a large number of different shapes can be machined by this process (Rao, 2000). For quantity production, it is adaptable as well as in job shops and tool rooms. The versatility of milling is because of the large variety of accessories and tools available with milling machineries.

Acoustic emission is the class of phenomena whereby transient elastic waves are generated by the rapid release of energy from a localized source or sources within a material or transient elastic waves so generated. Acoustic emission is a method of nondestructive testing and materials characterization that uses mechanical waves moving through materials. When a structure is subjected to an external force, a defect in the structure is activated and enlarged dynamically, and thus generates waves which spread through the materials at a certain speed.

Such waves, known as acoustic emission signals are detected by sensors attached to the surfaces of the structure (Inasaki, 1998). In this project, it to acquired acoustic emission signal that released during the machining process along with surface roughness of the work piece. Those signals were then analyses using time frequency domain analysis such as Short-Time Fourier Transform (STFT) in order to study the characteristics of the AE signal at different surface quality machining.

1.2 PROBLEM STATEMENT

In the milling process, some defect can be viewed after finish process. Surface quality is the most important outcome in the milling process. To make the surface quality being control or make it better in the milling process, the condition of that surface needs to analyze. Before this, analyze of the surface quality being operated after the machining or offline monitoring. In this project, it will analyze during the machining or online monitoring. When does the online monitoring, if something detected by the sensor, the parameter can be changed.

To predict of the surface quality of the milling process, acoustic emission is being used to check on it. In predict it, the frequency domain being to analyze it. But if used frequency domain, it used the average of the frequency. So, the results are not accurate. To make it accurate, time –frequency domain analysis are used in this project.

1.3 PROJECT OBJECTIVES

To study the properties of acoustic emission signal while machining process at the different quality surface using time-frequency localization method.

1.4 HYPOTHESIS

When does some machining like face milling, the material has some crack on the surface of the metal. To predict of that quality of the surface it's being analyzed by using acoustic emission. If the lesser quality of the surface of the metal, more signals can get from acoustic emission.

1.5 PROJECT SCOPES

i. Conduct face milling experiment using CNC machines
ii. Acquired AE signal released during the machining process using AEDAQ
iii. Develop an algorithm to analyses the acquired signals using STFT

CHAPTER 2

LITERITURE REVIEW

2.1 INTRODUCTION

Manufacturing can be defined as the process for the converting the material to another form. In the manufacturing process, it converts the raw material to the other form, by one process to another process. This process can be done by hand or by machine or by combine of this. On the other form, manufacturing also can be simplified as making something new (Schrader and Elshennawy, 2000).

Manufacturing also defines as changing the value of the material or transform the material to the greater value of the material or form. It maybe takes some of the process to make it. The changing process maybe from it shapes or its properties or maybe it's being combined with another part of other material to make it more valuable (Groover, 2007) to produce parts, it needs a variety of manufacturing process of being flown. It can be classified into 5 groups:

i- Casting
ii- Machining
iii- Forming
iv- Powder
v- Joining

Machining are the most commonly used to produce the product. It's being done through the forming and shaping processes. Because none of these processes are capable of producing parts with such specific characteristics this process being done.

From the small part to large part, it can be used by machining. Machining can be simplified as the removing the material from the work-piece by using tools equipment.

In this process, it changes shape, surface finish, or mechanical properties of the material to get the required size, dimensions and shape needed. In this process it removes unwanted material from the region of the raw material. This process uses the application of the special tools and equipment to produce the needed part. Machining section can be divided into several categories:

i- Milling
ii- Turning
iii- Drilling
iv- Grinding
v- Chip formation

2.2 INTRODUCTION MILLING PROCESS

One of the most versatile machining operations is milling process. Milling is the one process that the tolls of the machine that rotates and fed past a rotating cylindrical tool with multiple cutting edges .The milling cutter has multi tooth which means that tools can produce a lot of numbers of chips in one revolution when the operation is started. . In the milling process, the tools that rotate are parallel to the surface that wants to be machined. And the direction of feed is perpendicular to the axis of rotation of the cutting tool (Kalpakjian and Schmid, 2006).

There are 2 types of milling process (Groover, 2007). These are the type of type of milling process:

i- Peripheral Milling
ii- Face Milling

In Figure 2.1 below, it shows the orientation of the type of the milling process. It shows the direction of spindle rotation, the field of tools and etc. From that figure, the difference of those two types can be figured out.

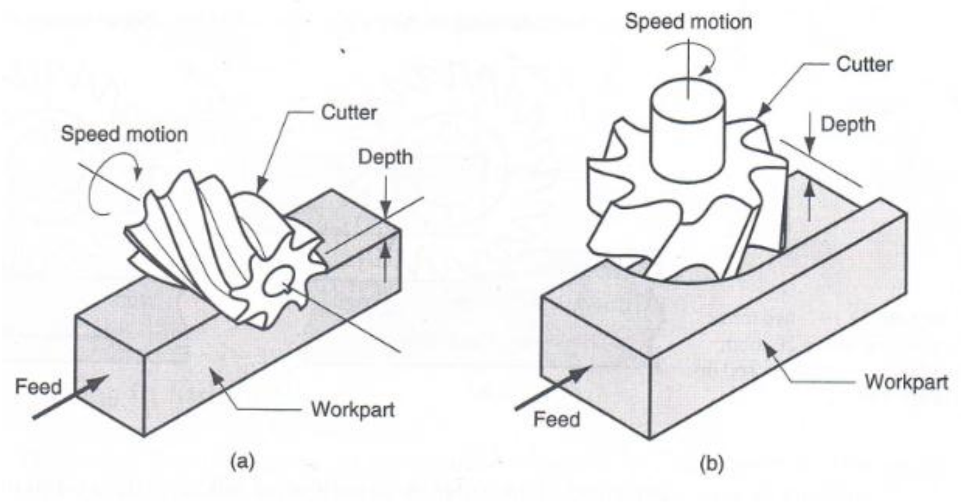

Figure 2.1: Basic types of milling operations :(a) Peripheral Milling (b) Face Milling

Source: Groover, 2007

2.2.1 Peripheral Milling Process

A peripheral milling process also is known as the plain milling. In this peripheral milling process, the material that want to machining are parallel to the axis of the tools of machine. When the cutting edges on the outside periphery of the cutter, so the operation is performed. Peripheral milling can be divided into several types as shown below (Groover, 2007). Figure 2.2 shows the conditions of the tools.

i- Slab milling
The width of the cutter extends beyond the work piece on both sides.

ii- Slotting (slot milling)
The cutter width is less than the workpiece width or the cutter width is to smaller than width of material.

iii- Side milling
The cutter machines only take the sides of the workpiece in one side only.

iv- Straddle milling
It's same like side milling but it takes on the both sides of the workpiece.

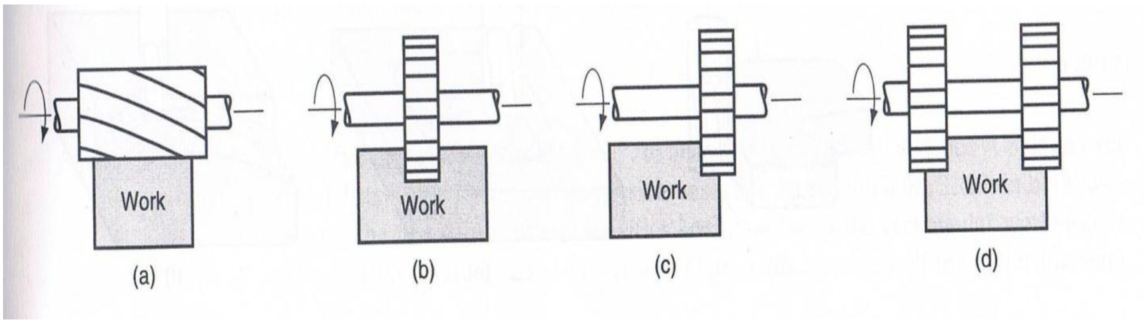

Figure 2.2: Peripheral milling: (a) Slab milling (b) Slotting milling (c) Side milling (d) Straddle milling

Source: Groover, 2007

In peripheral milling, there are two types of metal cutting methods. The directions of rotation of the cutter make these two types differ. The types as shown below:

i. Up Milling (Conventional Milling)

When the teeth cut into the work, the feed direction is opposite to the direction of the cutter motion of the cutter teeth. This feed also known as "against the feed". And the direction being is shown in Figure 2.3. Each cutter tooth starts out the very thin formed chips and increases in thickness during the sweep of the cutter. The cutter starts the cut with zero depth of cut, reaches the maximum value as the tooth leaves the cut.

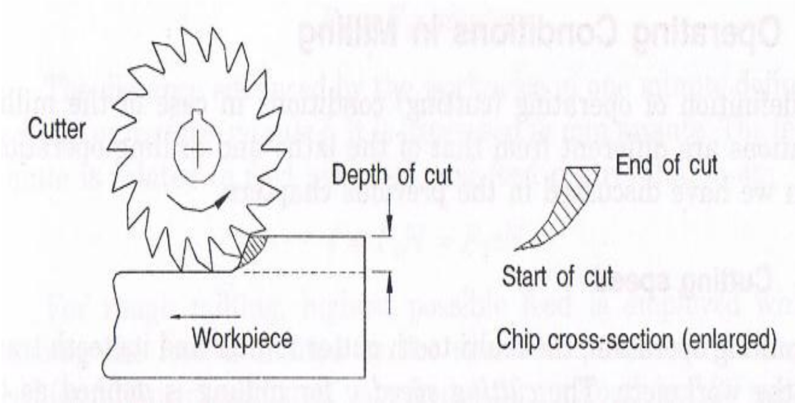

Figure 2.3: Up milling operation and the chip cut by a cutter tooth

Source: Groover, 2007

ii. Down Milling (Climb Milling)

The feed direction is the same to the direction of cutter motion when the teeth cut the work. This feed also been known as "with the feed". During milling, each cutter tooth starts out the thick formed chips and decreases in thickness during the sweep of the cutter. The chips formed are less in the length than in up milling. The maximum thickness of the chip at the start of the cut decrease to zero thickness at the end of the cut. Figure 2.4 shows the down milling and the chip cut by a cutter tooth.

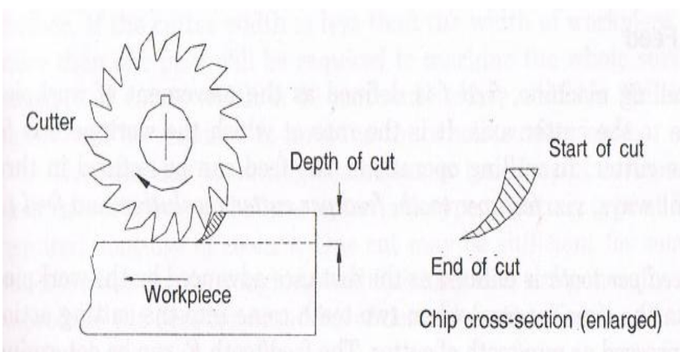

Figure 2.4: Down milling operation and the chip cut by a cutter tooth.

Source: Groover, 2007

2.2.2 Face Milling Process

In face milling, the surface that want to milled is perpendicular to the axis of the cutter. And the machining is being performed when the cutting edges on both the end and outside periphery of the cutter. There are several forms of the face milling. The various forms are (Groover, 2000). The figure that shows all of that forms of face milling are shown in Figure 2.5. The forms of face milling are:

i. Conventional Face Milling

The cutter diameter is bigger than the workpiece width and the cutter being overhang on the both sides of the workpiece.

ii. Partial Face Milling

The cutters of the mile being hang on the one side only of the workpiece.

iii. End Milling

The cutter diameter is less than the width of the workpiece, and it being cut into parts.

iv. Profile Milling

A form of end milling that milled the outside periphery of a flat part.

v. Pocket Milling

This milling form by end milling to mill shallow pockets into flat parts.

vi. Surface Contouring

It used the ball-nose cutter milling. The fed of this milling is fed back and forth across the workpiece along a curvilinear path at close intervals to create a three dimensional surface form.

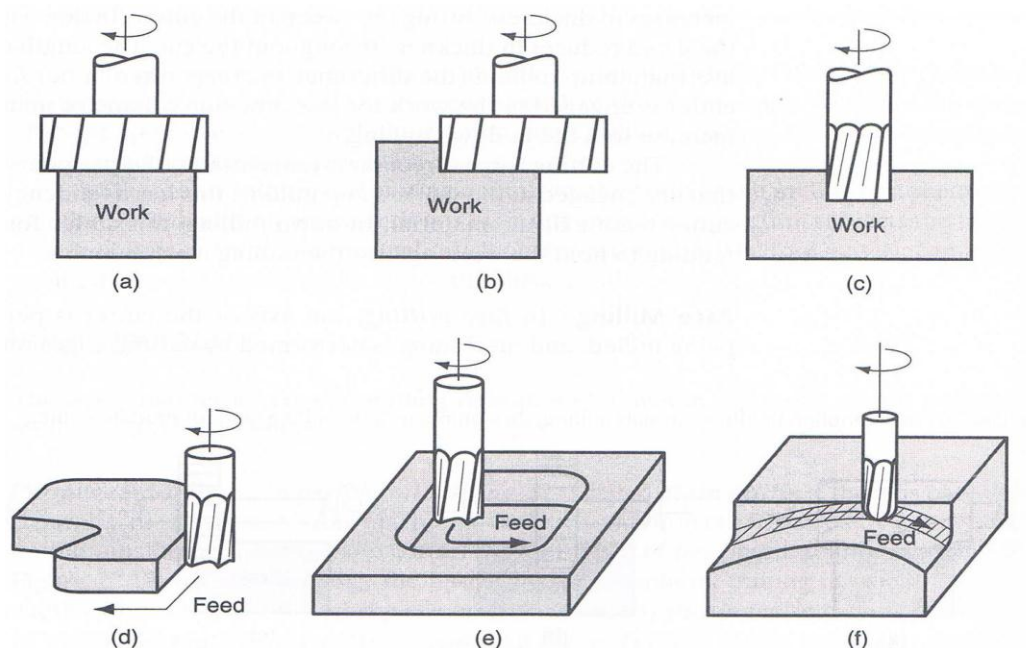

Figure 2.5: Face milling (a) Conventional face milling (b) Partial face milling (c) End milling (d) Profile milling (e) Pocket milling (f) Surface contouring

Source: Groover, 2007

2.3 HAYNES 188

Haynes 188 alloy chromium-cobalt-nickel-tungsten alloy that combines excellent high temperature strength with excellent resistance to oxidizing environments up to 2000^{o}F for prolonged exposure and a very good resistance to hot corrosion sulfate deposits. It is easily designed and developed by conventional techniques and has been used for cast components. Other interesting features include excellent resistance to chloride molten salt and a good resistance to sulfidation gas.

It has seen use for the gas turbine combustor liners and for tubes carrying high pressure cryogenic oxygen through zones of steam-rich, high pressure, high temperature hydrogen in the Space Shuttle Main Engine. Haynes 188 was chosen as a model for this study because often used in aeronautics and space. It is because it has high thermal shock applications. Haynes 188 also being used in military parts.

Table 2.1: Chemical composition of Haynes 188

Element	Weight, percent
Sulphur	<0.002
Boron	0.002
Phosphorous	0.012
Carbon	0.10
Silicon	0.40
Lanthanum	0.034
Manganese	0.75
Iron	1.24
Tungsten	13.95
Chromium	21.84
Nickel	22.43
Cobalt	Balance

Source: Bonacuse and Sreeramesh, 1995

Haynes188 was chosen as a model for this study because often used in aeronautics and space based. And the other criteria that this material being chooses are it's expensive and has hardened steel. The composition of this material as shown in Table 2.1 (Bonacuse and Kalluri, 1995):

2.4 NONDESTRUCTIVE TESTING (NDT)

2.4.1 Introduction Nondestructive Testing

Non-destructive testing (NDT) is defined as comprising those test methods used to examine the object, material or system without damaging the future use. The term is usually used for nonmedical integrity of the investigation.

Strictly speaking, the definition of non-destructive testing does not include noninvasive medical diagnostics. Ultrasound, X-rays and endoscopes are used for both medical testing and industrial testing. Medical nondestructive testing, however, has come to be treated by the separate study of non-destructive testing industry today most doctors do not use the word non-destructive (Wenk and McMaster, 1987).

Non-destructive tests are used to investigate the integrity of the test object. But NDT are not used to evaluate the specific material properties. Non-destructive testing is concerned with the practical with the performance of a test for how long a piece may be used and when it should be checked again. Radar and sonar are classified as nondestructive testing when used to inspect the dam, for example, but not when it is used to draw up the river.

Non-destructive testing is a branch of materials science related to all aspects of consistency, quality and serviceability of materials and structures. Science nondestructive testing incorporates all the technologies for the detection and measurement of tangible property, including discontinuities, in goods between the specimen's research tools and finished products. By definition, non-destructive technique is a way of materials and structures can be examined without any interruption or impairment of serviceability (Graborski *et al*, 2011).

The idea of future use in connection with the sampling quality control practices. Sampling is non-destructive test if the sample is returned to service. If steel alloys tested to confirm the number of bolts, then the non-destructive testing which can then be returned to service. In contrast, damaging process where the test sample removed after the test although spectroscopy is used in many chemical liquid natural non-destructive.

By the indentation hardness test provides an interesting test case for the definition of non-destructive testing. Hardness testing machine looks a bit like pressing the drill. The force applied is controlled as a bit down to make a small dent on the surface of the test piece. Then the diameter or depth measured dents.

Applied a force associated with the size of the dent to provide a measurement of surface hardness. Future use of a test is not affected, except in rare cases occur when a high surface quality is important. However, non-destructive testing is rarely considered because the contour of a modified. Non-destructive alternative to test this force can use non-destructive testing of electromagnetic (Wenk and McMaster, 1987).

Non-destructive testing is not limited to the detection of cracks. Discontinuities include porosity, thinning of the walls of many types of corrosion and disbonds. Non-destructive characterization of materials is a growing field concerned with the nature of the material, including the introduction of materials and microstructural characteristics such as curing resin, cases of force and pressure have a direct influence on the service life of the test object. Non-destructive tests have also been defined with a list or classify the various methods. This approach is practical because it often highlights the methods used by the industry.

2.4.2 Application of NDT

Non-destructive testing in a large variety of used worldwide to detect changes in the structure, changes in the surface finish of minutes, the presence of cracks or other physical discontinuities, to gauge the thickness of the materials and coatings and to determine the characteristics of products other industries. No other main method of visual inspection to determine the quality (McMaster and Wenk, 1951).

Modern nondestructive tests used by the manufacturer:

i. To ensure the integrity of the product, and therefore, reliability

ii. To avoid failures, prevent accidents and save lives

iii. To make a profit for the user

iv. To ensure customer satisfaction and maintain the reputation of the manufacturer

v. To assist in the design of better products

vi. To control the manufacturing process

vii. To reduce manufacturing costs

viii. To maintain a uniform level of quality

ix. To ensure readiness of operation

2.5 ACOUSTIC EMISSION

Acoustic emission can be defined as the generation of transient elastic-wave generation phenomenon caused by the rapid release of strain energy that caused by a structural change in a solid material and this phenomenon also known as stress-wave emission.

In another form, acoustic emission can be defined as the class of the phenomena in which transient elastic waves generated by rapid release of energy from the material to localize the source, or the transient waves generated (Ramachandran, 2006). Figure 2.6 shows the materials cracks under stress.

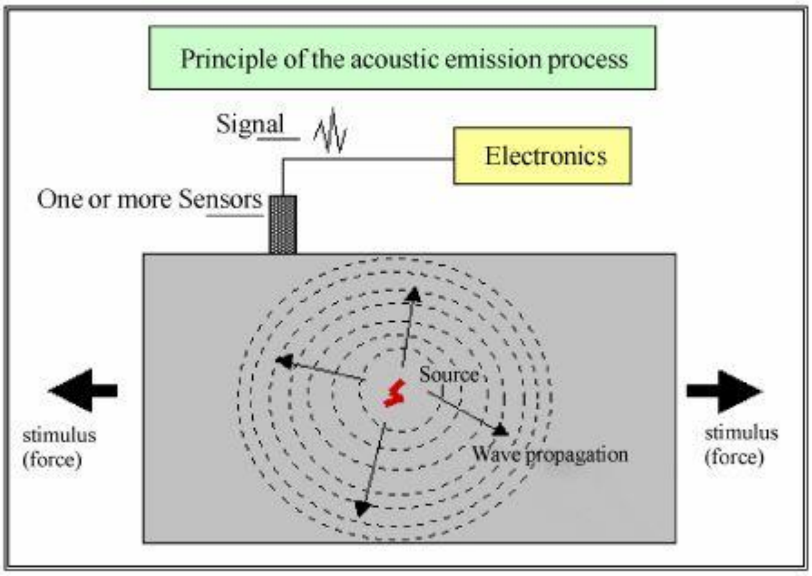

Figure 2.6: Detection of Acoustic Emission events

Source: Srivastava and Prakash, 2009

On the other form, acoustic emission is a term used to describe the pressure waves arising from various sources. An attempt made in this project is to evaluate the possible types of acoustic emissions generated by the motion of dislocations.

Acoustic emission sensors in contact with the material being monitored, to detect the shock wave and converts the mechanical displacement is very low, high frequency mechanical, electronic signals are amplified by a preamplifier and processed by the AE instruments. AE in many applications, the pressure is automatically used by the process itself, and others, the pressure exerted by the external driven forces.

AE is a passive inspection technique that uses the elastic energy generated by moving dislocations, cracks, fiber breaks, disbands and other to detect and analyze the source of the waves depends on the material being monitored. In the composite, matrix cracking, fiber breakage and debonding of the fibers was normal source emission (Fowler, 1979). One of the principle advantages of AE is to monitor a large area in a short time and with a small number sensor. The number of sensor and location will depend on the information requested in the test.

AE is considered as the "global method" since the overall performance of the structure can be monitored without the need for access to all parts of the structure. As a global test, AE complement to other non-destructive examination methods used to make up for local inspection. In addition, the sensor can be left in place during the loading stage of the test.

Acoustic emission tests used to monitor changes in the integrity of the vessel during the hydrostatic test pressure of the test is not harmful. Some investigations involve taking samples of the test is examined for damage. Noncritical part of the pressure vessel can be scraped or shaved to obtain samples for electron microscopy, for example. Although the future use of the ship not affected by the loss of material, the procedure is inherently destructive and shoving him in a sense the true "test object" has been removed from service permanently.

Past over 15 years, AE has become an increasingly useful method and received non-destructive evaluation in the paper industry. AE applications in the paper industry