# CRACK DETECTION OF CERAMIC TILE USING ACOUSTIC EMISSION

**SARKAWI BIN BUANG**

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(TANDATANGAN PENYELIA)

Alamat tetap: 220 Kampung Lintang, Jalan Haji Hashim Jaafar, Petra Jaya, 93050 Kuching, Sarawak.

Prof. Madya Dr. Sinin Bin Hamdan

Nama Penyelia

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This thesis entitled **Crack Detection Of Ceramic Tile Using Acoustic Emission (AE)** was prepared and presented by Sarkawi Bin Buang as a partial fulfillment of the requirement for the degree of Bachelor of Engineering with Honours (Mechanical Engineering and Manufacturing System) was hereby read and approved by:

______________________________ __________________

Prof. Madya Dr. Sinin Bin Hamdan, Date
Supervisor,
Faculty of Engineering,
Universiti Malaysia Sarawak.

Dedicated especially to beloved family, late brother and love one

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# ABSTRACT

The crack behaviour of brittle engineering material such as ceramic tiles is deeply related to micro cracking propagation and brittle fracture that occur in microstructure. In the present study, the Acoustic Emission method is applied to obtain certain information required from the crack activities in the stress condition of ceramic tile. Some of the crack parameter such as acoustic emission (dB), amplitude (mV) and signal energy (ergs) can be measured by the analysis of acoustic emission signal that generated. Moreover, the number of micro crack event can be identified by the ring down counting technique. The arithmetic average calculation from 25 samples of ceramic tiles with varies of load speed have been conducted to achieve more accurate results. Throughout the project, the correlation between the acoustic emission and crack behaviour was obtained by considering the microstructure features that existed in the ceramic tiles.

# ABSTRAK

Sifat keretakan dalam bahan-bahan kejuruteraan yang rapuh seperti jubin seramik sering dikaitkan secara mendalam dengan perkembangan retakan dan retakan rapuh yang berlaku di dalam struktur mikro. Dalam kajian yang dijalankan ini, kaedah 'Penyebaran Akustik'yang lebih dikenali sebagai Acoustic Emission telah diaplikasikan untuk mendapatkan beberapa maklumat yang diperlukan daripada kejadian retakan dalam jubin seramik yang berada dalam keadaan yang tegang. Beberapa parameter retakan seperti bunyi sebaran akustik (dB), amplitud (mV) dan tenaga yang terkandung dalam isyarat sebaran akustik boleh diukur dengan menganalisis isyarat sebaran akustik yang telah dihasilkan. Sebagai tambahan, bilangan kejadian retakan mikro boleh dikenalpasti dengan menggunakan teknik pengiraan 'ring-down'. Pengiraan dengan mengambil nilai purata daripada 25 keping sampel jubin seramik melalui kelajuan beban yang berlainan telah dijalankan untuk mendapatkan keputusan yang lebih tepat. Melalui projek ini, hubungan antara sebaran akustik dengan sifat retakan dapat dikenalpasti dengan mempertimbangkan ciri-ciri struktur mikro yang wujud dalam jubin seramik.

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# NOMENCLATURE

| | |
|---|---|
| *AE* | The phenomenon whereby transient elastic waves are generated by rapid release of energy from localized sources within a material. |
| *AE amplitude* | Peak amplitude of AE signal during signal duration. |
| *AE signal* | Electrical signal gained by detection of one or more acoustic emission events. |
| *AE burst* | Individual emission event generated in brittle material |
| *AE continuous* | Repeated emission that commonly observed in material. |
| *Atomic vibration* | Movement of an atom within a substance. |
| *Covalent bond* | Bonding by sharing electrons. |
| *Ionic bond* | Electrostatic force between oppositely charged ions. |
| *Brittle fracture* | A break that occurs by rapid crack propagation. |
| *Microstructure* | Structural features that can be observed with a microscope. |
| *Piezoelectric* | Material that produces an electrical response to a mechanical force. |

| | |
|---|---|
| *Source Location* | The sources of transient elastic waves that generate acoustic emission. |
| *Threshold, voltage* | Voltage level on an electronic comparator such that signals with amplitudes larger than this level will be recognized. |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The principle of 'listening' the warning of structural failures must take into prehistory. The disaster on the Mianus Rivers Bridge is a good example for human being to take into account about the sound warning of structural failure. Residents near to the bridge reported some noises the week before the disaster. [11]

For many years, acoustic emission technology had been developed as one major procedure in Non-Destructive Test (NDT). Application of acoustic emission technology were expanded widely into process monitoring internal condition of materials structure, monitoring system on automated manufacturing and hence introduces a significant tool condition monitoring (TCM) Its quite unique compares to other a NDT method because it can detect the changes of condition in certain materials which may be fractures, crack formation, crack propagation or failure mechanisms which mention by Knud G Boving.[4]

The failure that occurs to the products in the manufacturing field such as cracking will give a bad assumption to the process personnel that involved. In cracking recognition procedure, acoustic emission technology could provide sufficient data that includes location of the cracking sources and cracking propagation speed. This will be able to avoid worst manufacturing system.

## 1.2 Principles of Acoustic Emission.

Acoustic emission can be refers as the generation of transient elastic waves during the rapid release of energy from localized sources within a material by the micro damage propagation. [2].This elastic wave will carry the mechanical energy that will convert to the electrical signal by the acoustics emission sensor. The sources of these emissions are closely associated with the dislocation movement of microstructure of the materials and initiation and extension of crack in the structure that is under stress.

The acoustic emission (AE) method is considered as a "passive" non-destructive technique, because it is only able to identify defects developing during the test. In the other words, the elastic waves were generated by the materials itself. That means, it does not need any external sources applied to the materials that is involve. A simple example of acoustic emission is the cracking of cube ice and the sound of a stick that is being broken. Acoustic emission technology is also related closely to the seismology when scientists transfer measurement and analysis techniques from earthquake engineering to acoustic emission applications in the 1980's. [5]

Acoustic wave which can be presented in solid or liquid form is a connection between the sources of the elastic wave and the acoustic emission signals that is sense by the sensor. The amount of acoustic wave attenuation depends on the properties of the materials. The greater attenuation can be achieved in the porous materials compare to metallic materials.

As mention in Composite Materials Engineering and Science, [1] attenuation of acoustic wave depends on three factors, which are:

(a) Energy absorption by the material.

(b) Wave distribution due to the frequency dependence of velocity.

(c) Geometrical beam spreading.

## 1.3 Signal Techniques Analysis.

Elastic strain energy that is released from the crack propagation in a material will generate stress wave. This wave is also known as the origin of term 'acoustic emission'. The sensitive transducers are piezoelectric crystals discover and amplify the small surface displacements that is produced by the propagation of stress wave mention previously. Then, the transducer will convert the surface displacement into electrical signal.

The output of each piezoelectric sensor (during structure loading) is amplified through a low-noise preamplifier, filtered to remove any extraneous noise and furthered processed by suitable electronic equipment such as computer which acts as the data storage.

Indications of acoustic emission manners can be obtained by calculating the number of amplified pulses that exceed the threshold value by applying the ring-down counting or event counting.[1]

## 1.4 Objectives.

The objectives of the project are:

(a) Using acoustic emission instrumentations and software to detect and measured cracking on the ceramic tile.

(b) Explore and learn acoustic emission method that can show a relationship between cracking propagation and the acoustic emission signals that produced as well as crack prediction by using acoustic emission.

## 1.5 Structure of the report.

This report consists five chapters namely introduction, literature review, methodology, result and discussion and conclusion and recommendation. The background of the study was mention generally in the introduction. The correlation discussion of Acoustic Emission technology and the material used in this project was stated in literature. The methodology chapter is mainly about the method in conducting the experiment. The collection of data that gained from the study was interpolated in Chapter 4. The summary of the project stated in the Chapter 5.

# CHAPTER 2

# LITERATURE REVIEW

### 2.1 Mechanical failure.

In engineering world, failure must be defined broadly. It can be any condition that causes an industrial plant, manufactured product, process material or service to degrade or become unsuitable or unable to perform its intended function or purpose safely, reliably and cost effectively. Sometimes, the failure cannot be seen on the spot. It will take time to propagate especially mechanical failure such as fatigue, cracks and brittle fracture. It is important for us to detect the failure as soon as possible before it becomes worse and causes damage on the manufacture products. On the other hand, we can learn how to avoid it in the future.

### 2.1.1 Cracks

Crack is one of the mechanical failures that always occur in the engineering materials. The crack propagation always takes into account the time it starts to grow, the length of the propagation and the direction it grow. The crack starts growing when its stress intensity factor (sif) reaches the fracture toughness of the material. It can be written as:

$K_{IC} = K_I$ ..........................................................................(1)

Where, $K_{IC}$ = fracture toughness

$K_I$ = stress intensity factor

The other way to look at when a crack can grow is the energy factor. When a crack is formed, new surfaces also formed at along the edges where the material has split apart, amount of energy required to create these new surfaces. If G is the energy necessary for the crack to grow and R is the material's resistance to crack growth, the condition for a crack to grow is:

$G = R$ ……………………………………………… (2)

The energy necessary to grow the crack may also have changes. In order for the crack to continue growth, the change in energy must equal to the change in resistance. However, if the change in energy less than the change in resistance, then the crack will not grow any more unless more force is applied. If the change in energy is greater than the change in resistance, there will be unstable crack growth. As a result, the crack will propagate until the structure fails.

The direction of crack propagation cannot be estimated accurately. Its direction depends on the structure of the material and the load applied. For the single load, the crack always grows in perpendicular direction to the force loaded. However, if the material is being forced in more than one direction, the crack may have different direction to propagate. It either grows in perpendicular to the greatest forced or in the direction of maximum energy released. [10]

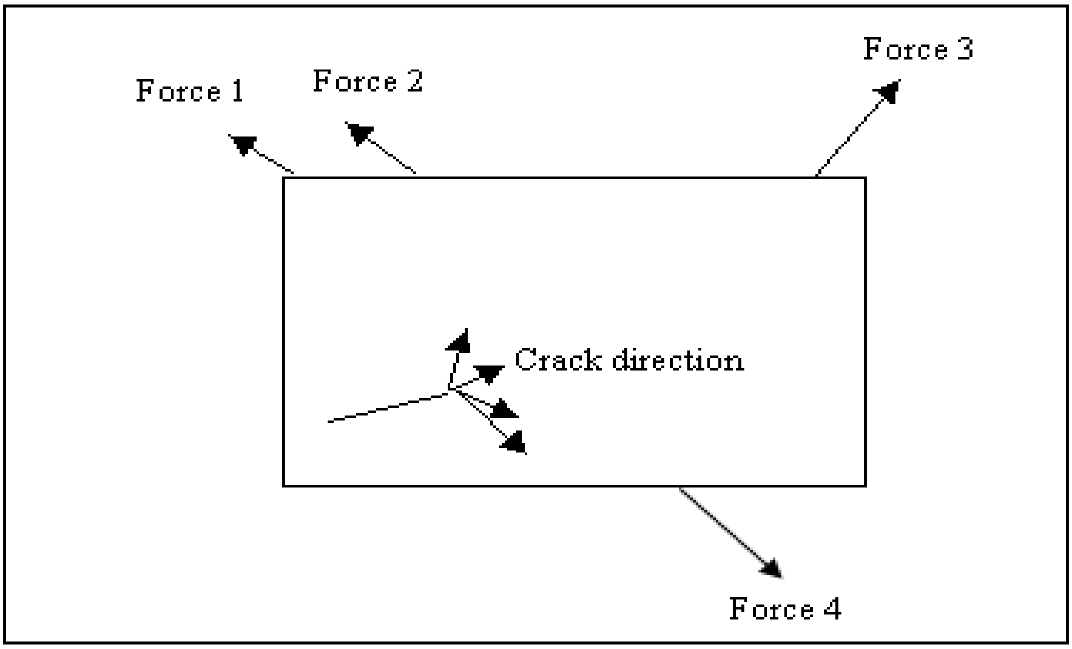


Figure 2.1 The crack direction in multiple forces loaded. [10]

**2.2 Acoustic Emission**

This inspection method utilizes stress wave produced in stressed materials by micro structural events, including cracks and other materials movements such as deformation. [2]. Acoustic Emission inspections are typically conducted during controlled loading or stimulating of the structure or component being evaluated. The loading can be some controlled operating configuration process such as proof test or fatigue test.

### 2.2.1 Generating Mechanisms

Acoustic Emission (AE) is a term that is normally used to describe transient elastic waves which propagate in the materials when the strain energy is released within that material [3]. It is a phenomenon whereby an elastic wave, in the range of ultrasound that usually between 20 KHz and 1 MHz is generated by the rapid release of energy from the source within the materials.

According to A.G. Beattie [2], the acoustic wave was generated from the materials itself in certain condition. In other words, it is not controllable or static imbalance condition in that material arises. As mention by Adrian A. Pollock [5], acoustic emissions are stress waves produced by sudden movement in stressed materials. The movement was caused by the changes in the internal structure.

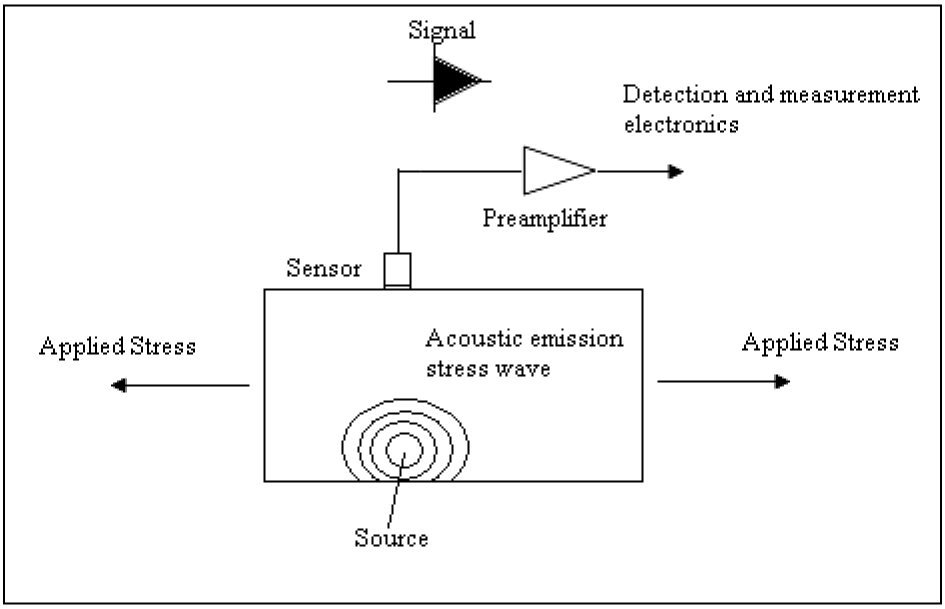


Figure 2.2 Basic principle of the acoustic emission method. [1]