APPLICATION OF ACOUSTIC EMISSION (AE) TECHNIQUE IN VARIOUS MATERIALS (METAL, WOODS AND BRICKS)

by

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Dedicated to my father (Musa Asit),

my mother (Helen Beni Untor), my brother (Thomas Musa),

my sisters (Doris Musa and Sabrina Musa) and all my friends

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ABSTRACT

Acoustic Emission (AE) technique is a new term to my and to some of us. Why acoustic emission (AE) technique is important in civil engineering work? Acoustic emission technique is important because we can detected and know the problems of the materials. From that, we can make decision what kind of solution to solve the problem.

What is acoustic emission technique? Acoustic emission is the energy release rapidly by the material when load are apply to the materials. In generally, acoustic emission can be define as a stethoscope to the materials. With this acoustic emission technique, every micro activity within the material can be detected.

This final year project is more to detect the acoustic emission on three types of materials. The three types of materials are metals, woods and bricks. The result from this three types of materials, we can make the comparison acoustic characteristic.

During the test, we should consider some precaution step. This is important to prevent the result being disturbing by the unnecessary source. This unnecessary sources are called noise. While the test start, make sure the noise around the area not to loud which can influence the results.

ABSTRAK

Istilah teknik "Acoustic Emission" (AE) adalah istilah yang baru kepada saya dan juga sesetengah daripada kita. Kenapa "acoustic emission" (AE) begitu penting dalam kerja-kerja kejuruteraan awam? "Acoustic emission" (AE) penting kerana ia dapat mengesan dan mengetahui masalah bahan tersebut. Daripada itu, kita akan memilih jalan penyelesaian terhadap masalah tersebut.

Apakah teknik "Acoustic Emission" (AE)? Teknik "Acoustic emission" (AE) adalah tenaga yang dikeluarkan oleh bahan secara drastik apabila beban dikenakan terhadap bahan tersebut. Secara umumnya, teknik "acoustic emission" bolehlah didifinasikan sebagai stetoskop kepada sesuatu bahan. Dengan teknik ini, setiap aktiviti mikro akan dapat dikesan.

Projek tahun akhir ini adalah cenderung untuk mengesan pengeluaran akustik di dalam tiga bahan yang di uji. Tiga bahan tersebut ialah besi, kayu dan batu-bata. Keputusan ujian terhadap bahan-bahan ini akan dibuat perbandingan sifat-sifat akustiknya.

Semasa ujian, kita hendaklah mengambil langkah berjaga-jaga. Ini adalah penting untuk mencegah keputusan daripada diganggu oleh sumber-sumber yang tidak di ingini. Sumber yang tidak di ingini adalah dikenali sebagai "noise" (kebisingan). Apabila ujian bermula, pastikan tahap kebisingan tidak melampau sehingga mempengaruhi keputusan ujian.

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Chapter 1

Introduction

1.1 Introduction

1.1.1 General information of Acoustic Emission Technique

Before further information about Acoustic Emission, we should know the definition of Acoustic Emission Technique. Acoustic Emission Technique is a rapid energy released when load acting to the material that we test. Acoustic Emission is also one of the Non-destructive testing method (NDT).

There are different type of Acoustic Emission(AE) system such as standard, powerful, integral PC computer and up to 56 AE channels. Several different chassis are available, including sizes for 8, 16, 24 and 56 channels.

The DiSP-56, large capacity 56-channel chassis includes hardware for both AE feature extraction and complete hit waveform. The DiSP-24 is a portable AE system, equipped with a handle for carrying and integral keyboard built within the hinged front protective cover. Built-in AE features include a digitally controlled audio monitor, 8 parametric and AE Hit indicator LED's.

The DiSP-16L AE system is geared for laboratory use, holding up to 4 PCI-DSP4 cards for up to 16 AE channels of operation. The DiSP-16L has added features for reliable day to day operation, including extra cooling, ventilation and powerful PC computer motherboard.

1.1.2 Typical AE application

Acoustic Emission(AE) can be apply for many thing such as :

- Tube trailers and High Pressure Gas Cylinders.
- Advanced Materials.
- Stress Corrosion Cracking.
- Petrochemical Pipelines.
- Nuclear Components.
- Composites.
- Above Ground Storage Tanks.
- Weld Monitoring.
- Others application.

1.2 The objectives of this study are:

1.2.1 Comparison of different graphs and result for different material.

There are three types of material will be use in the test. Every of the material will have a different graphs and different results. Nevertheless, the comparison of result from same material but different method of testing. For example, testing of steel without load apply and testing steel with load apply.

1.2.2 General information of acoustic emission (AE) technique.

Acoustic emission (AE) is refer to the generation of transient elastic waves during the rapid release of energy from a material due to occurrence of micro structural changes. The source of this emission in material is closely associated with the dislocation movement accompanying plastic deformation and extension crack in structure under stress. The acoustic emission technique is based on the detection and conversion of high frequency elastic waves to electrical signal. Beside that, with acoustic emission equipment it is able to "listen" to the sounds of cracks growing, fibres breaking, martensitic transformations and other modes of active damage in the stressed material.

1.2.3 General information about material (metals, woods and bricks)

There three types of materials will be test. The material are metal, wood and brick. All information about the material will be explain briefly. This is important to know the characteristic of the material and to know the characteristic wave inside the materials.

Chapter 2

Acoustic Emission (AE) Principle

2.1 Introduction

Acoustic emission (AE) is a naturally occurring phenomenon within materials under load (force, temperature) and the term of AE is used to define the transient elastic waves that result from a sudden strain energy release within a material due to the occurrence of microstructure changes. If enough energy released, audible sounds are produced.

The acoustic emission technique allow us to extend our hearing to detect sound of higher frequencies and lower intensities. With AE equipment you can "listen" to the sounds of crack growth, fibred breaking, martensities transformations and other modes of active damage in the stressed material.

The weak acoustic signal is captured by an AE sensor and preamplified. After the preamplifier the signal can be filtered or go directly to the AD-converter which digitizes the signal. This AD-converter can be inside the PC as a plug-in card or outside the PC as a separate system.

2.2 The history of Acoustic Emission (AE) Technique

The principal of "listening" for warning of structural problems goes back into prehistory. The connection between fissures and the sounds that they make is so strong, that the word "crack" itself has acquired a double meaning, it refer to both fissure and sound. The phrase "crack the whip" shows that the sound we are talking about is short and sharp not a rumble or a vibration but a discrete shock. This is called the sound of crack growth.

Intensive scientific investigation about the sound of crack growth during 1960's, when it was realized that they could be made the basic of a "new" nondestructive testing method (NDT). Instruments and techniques were developing for measuring "acoustic emission" and displaying the result in numerical and graphical forms.

1970's, many practical application of the emerging technology, including the first bridge monitoring studies funded by the Federal Highways Administration. These projects had the nature of feasibility demonstration as the AE pironeers tried to show that they could successfully detect and locate the growth of flaws in the presence of interfering background noise in challenging environment.

1980's, the infrastructure of Acoustic Emission testing took shape. Written test procedures were developed and standardized for metal, fiberglass pressure vessels, storage tank, aerial man lift devices and railroad tank cars and for weld monitoring.

For a technology to be widely used, it is not enough for it to be technically feasible. Beyond feasibility, it must compete cost-effectively with the other possible solution to the problem and it must be readily accessible to those who would use it.

2.3 Introduction of Acoustic Emission (AE) Technique

The Acoustic Emission Technique is relatively new Non-Destructive Testing technique. When the structure is not loaded the acoustic emission can not detect any discontinuity-the acoustic emission does not exist. Consequently, it does not detect geometrical inaccuracy. Acoustic emission sensor collect the burst type of signal(hits). There are two basic ways of hit descriptions. Hit description by parameter is easier and does not need so many recorded values. Time recording of hit amplitude contains more information about acoustic emission phenomenon, but the number of recorder values is higher then by the parameter's description.

Scientists of all world endeavour to find some method (mathematical) for easier identification and classification of physical phenomena from the hits. Transformation from time to frequency domain was the first attempt at finding this way. However it has long been known that the description in frequency domain is very useful for stationary signal but for non-stationary one it is not much suitable. Time-frequency analysis appears as powerful tool to determination non-stationary signals. This specifies frequency components in particular time moment. Wigner spectrum (the tool from the group of time-frequency analyses) for description of acoustic emission hits.

2.4 Wigner Spectrum

The Wigner spectrum ***W(t,f)*** is defined by integral equation,

$$W(t,f) = \int x(t + \tau/2)x^*(t - \tau/2) \exp(i\, 2\pi\tau f)\, d\tau$$

Where,

x(t) is the time representation of hit amplitudes

f is the frequency parameter

τ is the variable delay

This transformation is the kind of combination correlation function $C(\tau)$,

$$C(\tau) = \int x(t + \tau/2)x^*(t - \tau/2)\, dt$$

and Fourier transformation $F(f)$,

$$F(f) = \int x(t) \exp(i\, 2\pi f t)\, dt$$

Thus this spectrum is the Fourier Transform of the auto-correlation function of signal with respect to the variable delay. Wigner spectrum has much better resolution than the short Time Fourier Transform or Wavelet Transform. But there are two general problems aliasing and cross-term. That spectrum has only real part (it has not imaginary one).

Discrete Wigner Spectrum is defined follow,

$$W(n,F) \approx 2 \sum_{m} x(n + m)\, x^*(n - m) \exp(i4nmF)$$

It is symmetric along frequency axis.

2.5 Acoustic Emission and Applications.

Acoustic Emission (AE) testing is powerful method for examining the behavior of materials deforming under stress. Acoustic Emission may be defined as transient elastic wave generated by the rapid release energy within a material. With Acoustic Emission equipment, we can "listen" to the sounds of crack growing, fibers breaking and other damage in the stressed material. Small-scales damage is detectable long before failure, so AE can be use as a non-destructive technique to find defects during structural proof test and plant operation. AE also offers unique capabilities for materials research and development in the laboratory. Finally, AE equipment is adaptable to many form of production quality control (QC) testing, including weld monitoring and leak detection.

Some typical applications of the Acoustic Emission principle in testing material are as follow:

a) Behavior of materials: metals, ceramics, composites, rocks, concrete.

- Crack propagation.
- Yielding.
- Fatigue.
- Corrosion, stress corrosion.
- Creep.
- Fiber fracture, delamination.

b) Nondestructive testing during manufacturing processes.

- Material processing.
- Phase transformation in metals and alloys (martensitic transformation).

- Detection of defects such as pores, quenching cracks, inclusions.
- Fabrication.
- Deforming processes such as rolling, forging and extruding.
- Welding and brazing – detects detection (inclusions, cracks, lack of penetration).
- TIG, MIG, spot, electron beam.
- Weld monitoring for process control.

c) Monitoring structure.

- Continuous monitoring (metallic, structure, mines).
- Periodic testing (pressure vessel, pipelines, bridges, cable).
- Loose Part Detection.
- Leak Detection.

d) Special application.

- Petrochemical and chemical: storage tanks, reactor vessel, offshore platform, drill pipe, pipelines, valves, hydro-treaters.
- Electric utilities: nuclear reactor vessels, piping, steam generators, ceramic insulators, transformers, aerial devices.
- Aircraft and aerospace: fatigue cracks, corrosion, composite structure.
- Electronics: loose particles in electronic components, bonding, substrate cracking.

2.6 Principles of AE technology

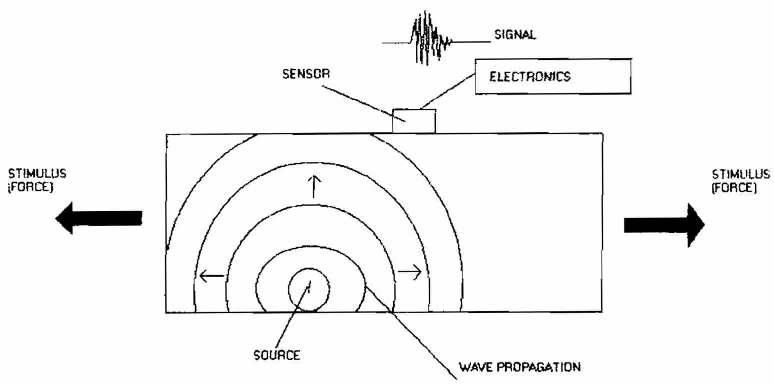

Fig 2.1 Principles of AE technology.

The AE process is begin with forces acting on a body, the resulting stress is the stimulus that causes deformation and with it, acoustic emission. The stress acts on the material and produces local plastic deformation, breakdown of the material at specific places. The material breakdown produces acoustic emission: an elastic wave that travels outward from the source, echoing through the body until it arrives at a remote sensor. The sensor produces an electrical signal, which is passed to electronic equipment for further processing.

a) Acoustic Emission Sources.

AE process begins with stress. Stress is like an internal force field in the bridge that transmits and balances the externally imposed force. Depending on its directional properties, stress may be described as tensile or compressive, bending, shear or torsional. Stress is measured in pound per square inch or psi. To calculate stress, the force is divided by the area that carries it.

Stress can be imaged as a three-dimensional field having different component in different direction at each point on the bridge. In response to stress, the material of the bridge change slightly shape. This change in shape is called "strain". The material deforms elastically and if the stress is high enough, plastically as well. "Plastic" in this context means "permanent". Plastic deformation involves a permanent change in relative positions of the atoms in the material.

On the small scale, plastic deformation involves the sliding of atomic planes over one another, through the agency of atomic-scale irregularities known as dislocation. The movement of dislocation is the microscopic mechanism that we recognize as yielding, buckling, denting and other. On a larger scale, there is nonmetallic "inclusion" lying between the metal grains: manganese sulphide "stringers" formed during the rolling of the steel plate and slag inclusions introduced during welding.

But when metal cracked, this is a different kind acoustic emission source and this one is the most important for nondestructive testing. A crack, jumping forward with the sudden creation of new surface. Detection of emission from growing cracks has been the commonest single goal in the many application of AE technology. When surface-breaking crack grows, the whole structure opens up a little in response to the applied forces. This is a more far-reaching process, the breaking of an inclusion, which would tend to have only a local effect. Therefore, cracks tend to give larger-amplitude signal that more readily detectable. Large-amplitude AE waves as they jump forward, cracks produce small-amplitude AE waves from material deformation at the crack tip. Emission can also produced from the rubbing of crack surfaces as they open and close and grind in response to changing traffic loads. Corrosion products forming on the crack surfaces, which make cracks even more emissive, can enhance this emission.

Acoustic emission is produced, at the source, as a short pulse of elastic and kinetic energy that travels through the material as an elastic wave. The theory of frequency spectra tells us that being a short impulse, it carries energy at all frequencies from zero to high upper limit (1000kHz). High sensitivity is most easily achieved by using contact sensor in the upper part of this frequency range, between 100kHz and 500kHz.

The amount of acoustic emission energy released, and the amplitude of the resulting wave, depend on the size and the speed of the source event. A big crack jump produces a larger signal than a small crack jump: the theory is that emission amplitude is proportional to the area of new surface created. A sudden, discrete crack jump will give much more signal than a slow, creeping advance of the crack tip over the same distance: the theory is that emission amplitude is proportional to the crack velocity.

"Noise" in AE testing means any unwanted signal. Noise is a major topic in acoustic emission technology. The chief types of acoustic noise source are friction and impart, which can come from many environmental causes. Frictional source are stimulated by traffic and wind loads, which cause movement at movable connector and loose bolts. Impart sources include rain, wind-driven dust and flying object.