MONITORING OF A GALVANIZED METAL WATER TANK AT UNIMAS TEMPORARY CAMPUS BY USING ACOUSTIC EMISSION: A CASE STUDY

CHIENG SIONG MING

UNIVERSITY MALAYSIA SARAWAK

2003

MONITORING OF A GALVANIZED METAL WATER TANK AT UNIMAS TEMPORARY CAMPUS BY USING ACOUSTIC EMISSION: A CASE STUDY

BY

CHIENG SIONG MING

SUMMITED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE BARCELOR OF ENGINEERING (HONS.) IN CIVIL ENGINEERING.

CIVIL ENGINEERING PROGRAM

FACULTY OF ENGINEERING

UNIVERSITI MALAYSIA SARAWAK

APPROVAL SHEET

This Final Year Project Report entitled "MONITORING OF A GALVANIZED METAL WATER TANK AT UNIMAS TEMPORARY CAMPUS BY USING ACOUSTIC EMISSION: A CASE STUDY " prepared and submitted by CHIENG SIONG MING in partial fulfillment of the requirement for Bachelor of Engineering (Civil) is here by accepted.

Date: 19-4-2003

DR. LAW PUONG LING

Project Supervisor

Civil Engineering Program

Faculty of Engineering, UNIMAS

Date: 18-4-2003

CHIENG SIONG MING

Author

Civil Engineering Program

Faculty of Engineering, UNIMAS

ABSTRACT

This research project looks into the detection of internal activities such as cracks, corrosion, dislocation of atoms, fatigue, diffusion, etc. of a galvanized metal water tank by using one of the non-destructive methods, namely "Acoustic Emission." In this research project, acoustic emission monitoring work was carried out at different locations of the structure. Internal activities of the structure were subsequently determined based on 1) Counts Vs. Time, 2) Counts Vs. Amplitude, and 3) Energy Vs. Amplitude. For this project, transducer that been used can detect the activity within the radius of 5 m.

The counts vs. time analysis show that internal activities occur fairly uniformly across all the four points under study, and the number of total hits (indicating the level of activities) range from 151 to 1,191. Patterns of counts vs. amplitude plots indicate that the activities are in the range of 40 dB to 60 dB, strongly showing signs of dislocation of atoms within the metal structure. From the energy vs. amplitude plots, energy activities too were detected from those points indicating that energies were being released from those points.

An analysis of the data collected shows that there is no indication of internal activities related to corrosion and cracks in the structure of the water tank. An analysis of the data gathered from the 4 different points concludes that only low amplitude activities were detected in the structure. These low amplitude activities are mainly attributed by the dislocation of atoms that occurs in the range of 40 dB to 60 dB.

ABSTRAK

Kajian projek ini mengkaji tentang pengesanan aktiviti dalaman seperti retakan, karat, perubahan lokasi atom, sebagai contoh tangki air galvani dengan menggunakan kaedah "Acoustic Emissionn (AE)". Dalam kajian ini, pengendalian kerja "AE" dijalankan di beberapa tempat pada struktur tangki air galvani. Aktiviti dalaman dikenalpasti dengan merujuk kepada 1) kiraan lawan masa, 2) kiraan lawan amplitude, dan 3) tenaga lawan amplitude.

Analisis 'kiraan lawan masa' menunjukkan bahawa aktiviti dalaman adalah agak seragam di keempat-empat titik lokasi. Jumlah "hits" (menunjukkan frekuensi aktiviti) adalah di antara 151 hingga 1191. Paten graf 'kiraan lawan amplitude menunjukkan aktiviti berlaku di antara 40 dB hingga 60 dB. Ini jelas menunjukkan perubahan lokasi atom di dalam struktur. Daripada graf 'tenaga lawan amplitude' tenaga yang dikesan menunjukkan tenaga dilepaskan dari titik itu.

Analisis data yang dikumpulkan menyimpulkan bahawa tiada aktiviti dalaman seperti retakan dan pengaratan di dalam struktur tangki air galvani. Analisis data yang dikumpulkan dari keempat-empat titik dapat memberi kesimpulan iaitu hanya aktiviti yang mempunyai amplitude rendah dikesan di dalam struktur. Amplitud yang rendah adalah kerana perubahan lokasi atom yang berlaku di antara 40 dB hingga 60 dB di dalam struktur tangki air galvani ini.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Walking on the thin ice, we jump when we hear it crack. The principle of 'listening' for warning of structural problems goes back into prehistory. Users of the first log bridges jumped when they heard the wood cracking underfoot. Residents near to the site of the Mianus River Bridge failure reported noises in the weeks before the disaster (Carlyle, 1993).

The connection between fissures and the sounds that they make is so strong, that the word 'crack' itself has acquired a double meaning: it refers to both fissure and sound. And 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 the sound of crack growth (Carlyle, 1993).

The sounds of crack growth came under intensive scientific investigation during the 1960's, when it was realized that they could be made the basis of a 'new' non-destructive testing method. Instruments and techniques were developed for measuring 'acoustic emissions' (as they were called) and displaying the results in numerical and graphical forms. The micromechanical material processes that produced acoustic emission (AE) were also investigated (Carlyle, 1993).

The 1970's saw many practical applications of the emerging technology, including the first bridge monitoring studies funded by the Federal Highways Administration. Many of these projects had the nature of feasibility demonstrations, as the AE pioneers tried to show that they could successfully detect and locate the growth of flaws in the presence of interfering background noise, in more and more challenging environments (Carlyle, 1993).

In the 1980's the infrastructure of Acoustic Emission Testing took shape. Written test procedures were developed and standardized for metal and fibreglass pressure vessels and storage tanks, for aerial man lift devices and railroad tank cars, and for weld monitoring. A labor pool of technicians with AE knowledge and experience came into being alongside the scientists and engineers who had developed the methodology. Personnel qualification and certification became attainable and specifiable for AE testing just as for other non-destructive testing (NDT) methods (Carlyle, 1993).

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 solutions to the problem; and it must be readily accessible to those who would use it.

1.2 Objectives and Specific Aims

The objectives of this project are 1) to detect the internal activities such as cracks, corrosion, dislocation of atoms, fatigue, diffusion, etc. of the structure of a galvanized metal water tank by using one of the non-destructive methods, namely "Acoustic Emission," and 2) to determine the suitability of acoustic emission monitoring method to "tanks" structure.

In this research project, acoustic emission monitoring work was carried out at different locations of the structure. Internal activities of the structure were subsequently determined based on 1) Counts Vs. Time, 2) Counts Vs. Amplitude, and 3) Energy Vs. Amplitude.

The specific aims of this research project are as follows:

1. Identification of a metal structure for study – a galvanized metal water tank with dimensions Length=36 feet, Width=24 feet, and Height=12 feet located at Unimas's temporary campus.

2. Four (4) points on the surface of the water tank (3 points on the side wall and 1 point on the floor) were chosen for this study in an attempt to determine or detect any form of internal activities of the structure (**Figure 3**).

3. Data interpretation or analysis for internal activities were based 1) Counts Vs. Time, 2) Counts Vs. Amplitude, and 3) Energy Vs. Amplitude.

4. Parameters Setting of the Acoustic Emission Equipment:

Threshold	=	40 dB (for medium to low sensitivity)
Experiment Time	=	1 hour 30 minutes (5400 seconds)
Filter	=	100-400 kHz
Peak Definition Time (PDT)	=	1 000
Hit Definition Time (HDT)	=	2 000
Hit Lockup Time (HLT)	=	20 000
No. of Channel	=	1

1.3 Structure of the report

This report consists of five chapters namely Introduction, literature review, methodology, results, and conclusion. The introduction is chapter basically about the background of the acoustic emission, and the objectives of the project. The literature review chapter are about the definition of the acoustic emission (AE), sources, comparison of AE with other methods, advantageous of AE and etc. Methodology is mainly about the set up of the experiment. Result chapter is the data that collected from the experiment meanwhile; conclusion chapter is the summary of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Acoustic Emission (AE)

Acoustic emissions are stress waves produces by sudden movement in stressed in materials. The classic sources of acoustic emissions are defect-related deformation processes such as crack growth and plastic deformation. The process of generation and detection is illustrated in the **Figure 1**. Sudden movement at the source produces a stress wave, which radiates out into the structure and excites a sensitive piezoelectric transducer. As the stress in the material is raised, many of these emissions are generated. The signals from one or more sensors are amplified and measured to produce data for display and interpretation (Miller, et al, 1987).

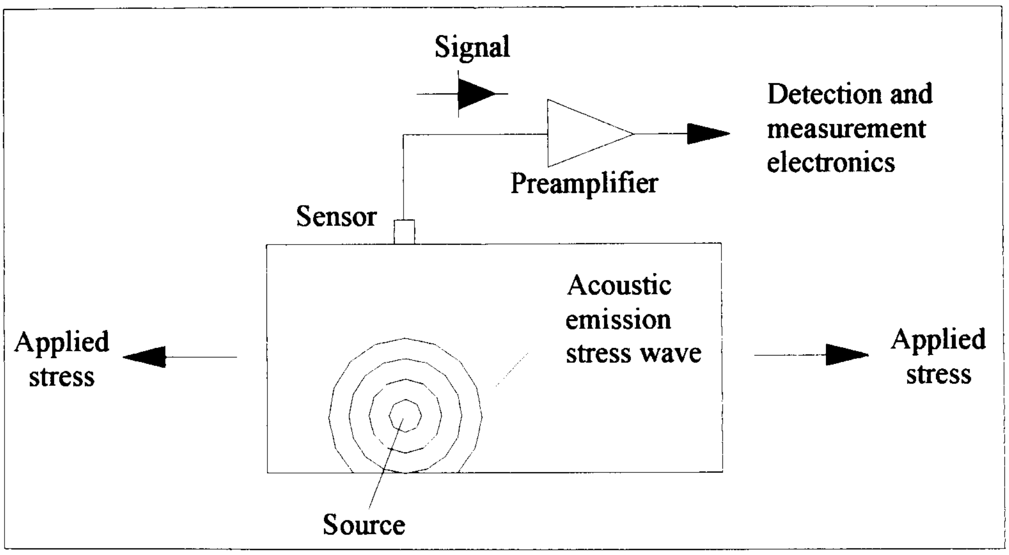

Figure 1: Basic principle of the acoustic emission method

The source of the acoustic emission energy is the elastic stress field in the material. Without stress, there is no emission. AE inspection is used because it gives valuable additional information about the performance of the structure under load. Others than that, AE inspection are selected for reasons of economy or safety, and a special loading procedure is arranged to meet the needs of the AE test.

The most widely used acoustic emission signal measurement parameters are counts, amplitude, rise time, and the measured area under the rectified signal envelope (MARSE) sometimes referred to as energy counts. The relationship of these parameters is shown in **Figure 2** (Efird).

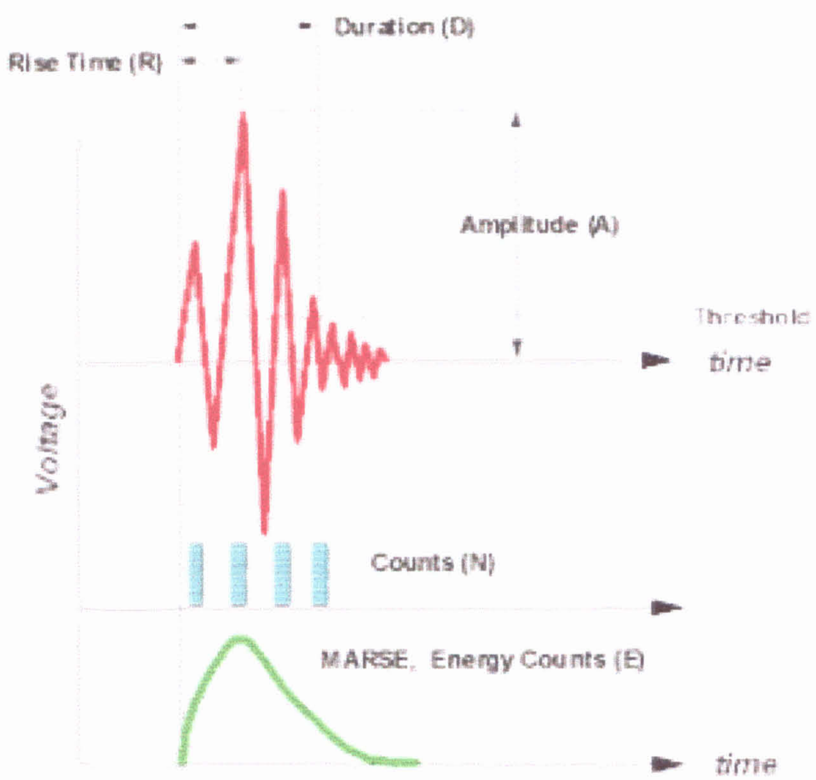

Figure 2: ***Commonly measured parameters of an acoustic emission signal.***

2.2 Acoustic Emission Sources

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

Stress can be imagined as a three-dimensional field having different components in different directions at each point. In response to stress, the material changes slightly in 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 the 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 dislocations. The movement of dislocations is the microscopic mechanism that underlies the gross changes in the shape that we recognize as yielding, buckling, denting etc. Acoustic emission from the movement of dislocations has been extensively studied with special laboratory techniques.

Other kinds of permanent deformation take place when material breaks and new surfaces are created. On a microscopic scale inside a piece of steel, the materials most likely to break are specks of sulphide, oxide, carbide and other non-metallic materials. The smallest of these items are carbide 'precipitates' scattered within the metal grains: microscopic plats of iron carbide, only a few hundred atoms thick, distributed in 'pearlite colonies'. These precipitates play a big part in governing the steel's mechanical properties. On a larger scale there are non-metallic 'inclusions' lying between the metal grains: manganese sulphide 'stringers' formed during the rolling of the steel plate, and slag inclusions introduced during welding. There may also be non-metallic corrosion products intimately connected to the metal surface. All these non-metallic components are less ductile than the metallic matrices in which they are embedded, so they break more easily when the metal is strained. The breaking of these non-metallic components is the main source of the acoustic emission observed when crack-free metals are deformed.

But when the metal is cracked, this is a different kind of acoustic emission source and this one is the most important for non-destructive testing. A crack, jumping forward with the sudden creation of new surface is a major threat to the structure integrity. It is also the best recognized source of high-amplitude acoustic emission. Detection of emission from growing cracks has been the most common single goal in the many applications of AE technology (Harris, et. al., 1974).

When a surface breaking, crack grows and the whole structure opens up a little in response to the applied forces. This is a more far reaching process than, say the breaking of an inclusion which would tend to have only a local effect. Therefore, cracks tend to give larger-amplitude signals that are more readily detectable.

As well as giving large amplitude AE waves as they jump forward, cracks produce small amplitude AE waves from the rubbing of crack surfaces as they open and close and grind in response to changing loads. This emission can be enhanced by corrosion products forming on the crack surfaces, which make cracks even more emissive.

When material deforms in response to the loading, the deformation tends to relieve and smooth out the local stresses. This means that after an acoustic emission event has taken place, the elastic energy stored in the stress field will have been reduced and some of it will be released. The energy released from the stress field is used to create new surfaces, to deform and warm the material and to produce the acoustic emission. In different words, the source of the acoustic emission energy is the energy in the elastic stress field produced by the loading.

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 up to some high upper limit, on the order of 1000 kHz. It turns out that high sensitivity is most easily achieved by using contact sensor in the upper part of this frequency range, between 100 kHz and 500 kHz (Harris, et. al., 1974).

But we can also detect the same emissions, if they are large enough with our ears which respond to much lower frequencies from 50 Hz to 15 Hz. This confirms the idea that the energy of acoustic emissions is spread over a very wide frequency range (Miller, et. al., 1987). And the theory that AE carries frequencies all the way down to zero is evidenced by the largest acoustic emissions of all, earthquakes which shake people and buildings a hundred miles away at frequencies of a few Hz and less. Finally, the zero frequency component itself is identical with the permanent change in stress field, created by the action of the source event (Harris, et. al., 1974).

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.

The association between acoustic emission and crack growth has been intensively studied. Processes involving some form of embrittlement such as hydrogen induced cracking and stress. Corrosion cracking are generally among the better emitters. Ductile processes such as slow fibrous fracture are generally quieter. Weldments are more emissive than parent metal (Harris, et. al., 1974).

It is useful to distinguish different classes of source activity:

- Primary activity from new, permanent changes in the originally fabricated material. This is typically due to local stresses higher than the material has seen before.
- Secondary activity from materials which were not part of the original fabrication, such as corrosion products.

- Secondary activity from repetitive processes such as crack surface rubbing (friction) that do not produce new and permanent changes in the material.

Secondary activity can be either helpful or a nuisance, depending on the way it is treated. Secondary emission is different from 'noise' which is always a nuisance.

'Noise' in AE testing means any unwanted signal. Noise is a major topic in acoustic emission technology. The chief types of acoustic noise sources are friction and impact, which can come from many environmental causes. Frictional sources are stimulated for example wind loads which cause movement at moveable connectors and loose bolts. Impact sources include rain, wind driven dust and flying objects.

An indispensable part of AE test technique is the ability to eliminate all these noise sources and to focus on what is relevant. Noise is addressed in three ways:

i. By selecting an appropriate test strategy and instrumentation setup
ii. By taking practical precautions on site to prevent noise sources as far as possible
iii. By recognizing and removing noise indications from the recorded data

This last process is the domain of data interpretation.

2.3 Relationship to Other Test Methods

Acoustic emission differs from most other non-destructive testing (NDT) methods in two key respects. First, the signal has its origin in the material itself, not in an external source. Second, acoustic emission detects movement, while most other methods detects existing geometrical discontinuities. The consequences of these fundamental differences are summarized in the table below (Miller, et. al., 1987).

Table 1: Characteristics of acoustic emission inspection compared with other methods

Acoustic emission	Other methods
Detects movement of defects	Detect geometric form of defects
Requires stress	Do not require stress
Each loading is unique	Inspection is directly repeatable
More material-sensitive	Less material-sensitive
Less geometry-sensitive	More geometric-sensitive
Less intrusive on plant/process	More intrusive on plant/process
Requires access only at sensors	Require access to whole area of inspection
Tests whole structure at once	Scan local regions in sequence
Main problems: noise related	Main problems: geometry related

Source: Acoustic Emission Testing, Vol. 5, 2nd ed., NDT Handbook, R.K. Miller & P. Mclutire, 1987

A major benefit of AE inspection is that it allows the whole volume of the structure to be inspected non-intrusively in a single loading operation. It is not necessary to scan the structure looking for local defects. It is only necessary to connect a suitable number of fixed sensors, which are typically placed 1 to 6 m apart. This leads to major savings in testing large structures for which other methods require removal of insulation, decontamination for entry to vessel interiors, or scanning of very large areas (Miller, et. al., 1974).

2.4 Range of Applicability

Acoustic emission is a natural phenomenon occurring in the widest range of materials, structures, and processes. The largest scale acoustic emissions are seismic events, while the smallest scale processes that have been observed with AE inspection are the movements of small numbers of dislocations in stressed metals. In between, there is a wide range of laboratory studies and industrial testing.

In the laboratory, AE inspection is a powerful aid to materials testing and the study of deformation and fracture. It gives an immediate indication of the response and behaviour of a material under stress, which intimately connected with strength, damage, and failure. The AE response of the materials depends on its microstructure and deformation mode, materials differ widely in their AE response. Brittleness and heterogeneity are two major factors conducive to high emissivity. Ductile deformation mechanisms such as microvoid coalescence in soft steels are associated with low emissivity (Miller, et. al., 1974).

In production testing, AE inspection is used for checking and controlling welds, brazed joints, thermocompression bonding, and forming operations such as shaft straightening and punch press operations. In general, AE inspection can be considered whenever the process stressed the material and produces permanent deformation (Miller, et. al., 1974).

In structural testing, AE inspection is used on pressure vessels, storage tanks, pipelines and piping, aircraft and space vehicles, electric utility plants, bridges, railroad tank cars, bucket trucks and a range of other equipment. Typical uses include the detection of cracks, corrosion, weld defects, and material embrittlement.

Procedures for AE structural testing have been published by the American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM), and other organizations. Successful structural testing comes about when the capabilities and benefits of AE inspection is correctly identified in the context of all inspection needs and when the correct techniques and instruments are used in developing and performing the test procedure (Miller, et. al., 1974).

Acoustic emission equipment is highly sensitive to any kind of movement in its operating frequency range (typically 20 to 1200 kHz). The equipment can detect not only crack growth and material deformation but also such processes as solidification, friction, impact, flow, and phase transformations. Therefore, AE techniques are also valuable for (Miller, et. al., 1974):

- Detecting and monitoring leaks, cavitation, and flow
- Detecting wear and loss of lubrication in rotating equipment, and tribological studies