DEFECT DETECTION IN PIPELINE USING ACOUSTIC EMISSION

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"To my beloved mother, father, my sister and my wife"

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ABSTRACT

Monitoring defects in a pipeline are very important in particularly for buried pipeline. The ability to identify location, type and size of the defects are always necessary to save time and cost. Thus, this research project embarks on identifying defect location and estimating the size of the defect by using Acoustic Emission (AE) technology. Data were acquired from a two inch diameter pipe with 1mm thickness using low cost piezoelectric sensors. Location of the defect was estimated based on the difference on the time arrival coming from the two sensors. Results show that location of the defect can be estimated within certain degree of accuracy. In addition, different sizes of the defect have also been studied using artificially induced defect as well as the actual defect. Defects have been introduced both in the axial and radial direction on the test pipe. AE data from the pencil break has been collected for each defect size and processed using few AE parameters such as R.M.S., energy, amplitude and time-frequency domain. All of these data were then normalized to the reference value and the correlation between defect sizes and normalized AE parameters were developed. The results show that there are good correlations between normalized AE parameter and defect sizes particularly when the defect size was increased in axial direction. In short, it is shown that AE technology is capable in locating defect in pipeline as well as giving estimation on the size of the defect.

ABSTRAK

Pemantauan kerosakan ke atas talian paip adalah amat penting terutamanya untuk talian paip yang tertanam. Kemampuan untuk mengenal pasti lokasi, jenis dan saiz kerosakan sentiasa perlu untuk menjimatkan masa dan kos. Oleh itu, projek penyelidikan ini dijalankan bagi mengenalpasti lokasi kerosakan dan menganggarkan saiz kerosakan itu dengan menggunakan teknologi Pancaran Akustik (AE). Data diperolehi daripada paip berdiameter dua inci berketebalan 1 mm menggunakan sensor piezoelektrik kos rendah. Lokasi kerosakan tersebut dianggarkan berdasarkan perbezaan pada masa ketibaan yang diberikan daripada kedua-dua sensor. Keputusan menunjukkan bahawa lokasi kerosakan tersebut boleh dianggarkan pada tahap ketepatan tertentu. Di samping itu, saiz kerosakan yang berbeza itu juga telah dikaji dengan menggunakan aruhan kerosakan buatan serta kerosakan yang sebenar. Kerosakan telah dikenakan ke atas kedua-dua arah paksi dan jejari pada paip ujian. Data AE daripada patahan pensel telah dikumpulkan untuk setiap saiz kerosakan dan diproses menggunakan beberapa parameter AE seperti R.M.S, tenaga, amplitud dan domain masa-frekuensi. Semua data ini kemudiannya dinormalkan kepada nilai rujukan dan korelasi antara saiz kerosakan dan parameter AE ternormal telah dibangunkan. Hasil kajian menunjukkan bahawa terdapat korelasi yang baik antara parameter AE ternormal dan saiz kerosakan terutamanya apabila saiz kerosakan itu telah meningkat dalam arah paksi. Secara ringkasnya, ia menunjukkan bahawa teknologi AE mampu mengenalpasti lokasi kerosakan ke atas talian paip serta memberikan anggaran mengenai saiz kerosakan itu

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LIST OF ABBREVIATIONS

AE	acoustic emission
SHM	Structural Health Monitoring
NDT	Non Destructive Testing
PB	piezoelectric buzzer
PLB	pencil lead break
TOA	time of arrival
RMS	Root Mean Square
dB	decibel (unit of acoustic emission signal magnitude)
FFT	Fast Fourier transforms
SNR	signal noise ratio
WT	wavelet transform
STFT	short Fourier transform

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Technology of pipeline has been developed in order to increase the potential and ability of this type of transportation. Nowadays, pipelines have become a regular practice to transfer the material from the raw source to the end user. Due to this economic, transportation, pipelines become a major role in the petroleum industry because this method is safe, reliable and can promise constant flow of crude oil, natural gas and petroleum products.

Leak can occur from small holes caused by corrosion up to catastrophic pipeline failure due to man-made damage or natural causes such as earthquakes. Because of this matter, the development of pipe leak monitoring has been introduced and research will keep running to improve the system from time to time. If the surface exposed, the location of the leak can be determined by visual technique. But if the pipe is coated or buried, the location of the leak or crack is difficult to be determined by visual technique. Therefore, there are several non-destructive testing (NDT) techniques which can be

applied to this application to detect the earliest leaking condition. One of these techniques called acoustic emission.

Acoustic Emission (AE) is a phenomenon of all materials where stress waves are released due to micro-structural changes in the material. These micro-structural changes could be propagating cracks or corrosion, but can also be caused by friction between two parts of a structure. The term Acoustic Emission describes the stress waves as well as the NDT technique which uses these stress waves. The waves travel through the structure and result in small displacements on the surface, which can be detected by suitable sensors [1]. AE is a passive NDT technique which means the instrument has just a receiving unit which is capable of picking up the emission caused by the propagation of the flaw itself. An active inspection method, in contrast, needs a transmitting and receiving unit and measures the changes of a signal sent through the structure.

The discovery of the generation of these stress waves by Joseph Kaiser in 1950 marks the beginning of Acoustic Emission as an NDT technique. Joseph Kaiser studied this phenomenon occurring during tensile tests of metal specimens. Earlier, a similar phenomenon was already widely studied prior or during earthquakes and this seismology has much in common with AE. Since the first discovery AE has developed into a widely used NDT technique.

Acoustic Emission has already been measurable from cracks down to a few hundred square micrometers and is therefore able to detect flaws long before structural integrity is affected and before most other NDT techniques, such as Ultrasonic, X-ray or Thermography, can sense those cracks [2]. In the strict sense the flaw propagation is measured, since only the active damage emits stress waves.

Acoustic Emission (AE) is a passive inspection technique which, unlike Ultrasonic, does not actively send any signal through the structure, but detects stress waves from the damage itself when it propagates. A few sensors can monitor a relatively large area and can detect different types of damage usually long before other NDT techniques are able to find them. Also, AE testing can be performed when the structure is in service. This makes AE an ideal tool for SHM applications.

Accurate damage location is important for Acoustic Emission SHM (and NDT) systems since this technique is able to detect signals from propagating damages in relatively far distances from the sensor. Exact source location is not only important to reduce time for further inspection and repairs but, also to identify multiple damage to understand fatigue damage propagation or to find indications about damage origin. Although it is already reported that the actual AE signal can give an indication about the actual damage type, exact source location might also aid to fulfill this SHM task.

1.2 Problem Statement

Pipes are used widely in our domestic and industry. It is one of the most important parts of human life because piping system is a mechanism of delivering or transporting a fluid (liquid or gas), mixture of fluids and others from one location to another. Pipes need to be monitored periodically in order to determine damage to the pipe and its associated equipment, maximize the efficiency and safety of the pipeline, minimize potential accidents, and safeguard company and public interests [1].

1.3 Objective of the Study

The main objective of this study is to localize defect in the pipeline using acoustic emission and estimate the geometry of defect from acoustic emission signals.

1.4 Scope of the Study:

- To use acoustic emission technology to monitor the pipeline.
- To undertake experimental test in the lab scale rig.
- To Analyze AE signals using MATLAB software.

REFERENCES

1. Wevers, M. 1997. Listening to the Sound Of Materials: *Acoustic Emission for the Analysis of Material Behaviour*. NDT & E International, 30(2), 99-106.
2. Finlayson, R. D., Friesel, M., Carlos, M., Cole, P., and Lenain, J. C. 2001. Health Monitoring of Aerospace Structures with Acoustic Emission and Acousto Ultrasonics. *Insight-Wigston Then Northampton-*, 43 (3), 155-158.
3. Shull, P. J. 2002. *Nondestructive Evaluation: Theory, Techniques, and Applications*. CRC Press.
4. Grosse, C. U. 2008. *Acoustic Emission Testing* (pp. 3-18). Heidelberg: Springer.
5. Physical Acoustics Corporation. *PCI-2 Based AE System Users Manual Princeton Junction*, NJ: Physical Acoustics Corporation; 2007.
6. Grosse, C. U., and Linzer, L. M. 2008. Signal-based AE Analysis. In *Acoustic Emission Testing* (pp. 53-99). Springer Berlin Heidelberg.
7. Vallen, H. 2002. AE Testing Fundamentals, Equipment, Applications. *Journal of Nondestructive Testing (Germany)*, 7(9), 1-30.
8. Rose, J. L. 2004. *Ultrasonic Waves in Solid Media*. Cambridge university press.
9. Finlayson, R. D., Luzio, M. A., Miller, R. K., and Pollock, A. A. 2003. *Continuous Health Monitoring of Graphite Epoxy Motorcases (GEM)*. In NDE for Health Monitoring and Diagnostics (pp. 272-283). International Society for Optics and Photonics.
10. Maji, A. K., Satpathi, D., and Kratochvil, T. 1997. *Acoustic Emission Source Location Using Lamb Wave Modes*. Journal of Engineering Mechanics, 123(2), 154-161.
11. Holford, K. M., and Lark, R. J. 2005. *Acoustic Emission Testing Bridges*.

12. Grosse, C. U. 2008. Chapter 3 Sensor and Instrument. *Acoustic Emission Testing*. Verlag: Springer
13. Yoon, D. J., Weiss, W. J., and Shah, S. P. 2000. Assessing Damage in Corroded Reinforced Concrete Using Acoustic Emission. *Journal of Engineering Mechanics*, 126(3), 273-283.
14. Qi, G. 2000. *Wavelet-based AE Characterization of Composite Materials*. NDT and E International, 33(3), 133-144.
15. Grosse, C. U., Finck, F., Kurz, J. H., and Reinhardt, H. W. 2004. Improvements of AE Technique Using Wavelet Algorithms, Coherence Functions and Automatic Data Analysis. *Construction and Building Materials,* 18(3), 203-213
16. Grosse, C. U., Reinhardt, H. W., Motz, M., & Kroplin, B. 2002. Signal Conditioning in Acoustic Emission Analysis Using Wavelets. *NDT. net*, 7(9), 1-9.
17. Ativitavas, N., Pothisiri,T., and T. Fowler, T. 2006. *Identification of Fibre-Reinforced Plastic Failure Mechanisms* from Acoustic Emission Data Using Neural Networks, 193-226.
18. Salinas, V., Vargas, Y., Ruzzante, J., and Gaete, L. 2010. Localization Algorithm for Acoustic Emission. *Physics Procedia*, 3(1), 863-871
19. Ziola, S. M., and Gorman, M. R. 1991. Source Location in Thin Plates Using Cross-Correlation. *The Journal of the Acoustical Society of America*, 90(5), 2551-2556.
20. Scholey, J. J., Wilcox, P. D., Wisnom, M. R., & Friswell, M. I. 2009. A Practical Technique for Quantifying the Performance of Acoustic Emission Systems on Plate-Like Structures. *Ultrasonics*, 49(6), 538-548
21. Chang, P. C., Flatau, A., and Liu, S. C. 2003. Review Paper: Health Monitoring of Civil Infrastructure. *Structural Health Monitoring*, 2(3), 257-267.
22. Holford, K. M., Davies, A. W., Pullin, R., and Carter, D. C. 2001. Damage Location in Steel Bridges by Acoustic Emission. *Journal of Intelligent Material Systems and Structures*, 12(8), 567-576
23. Lozev, M. G. 1997. *Acoustic Emission Monitoring of Steel Bridge Members* (No. FHWA/VTRC 97-R13).

24. Nivesrangsan, P., Steel, J. A., & Reuben, R. L. 2007. Source Location of Acoustic Emission in Diesel Engines. *Mechanical Systems and Signal Processing*, 21(2), 1103-1114.
25. Tobias, A. 1976. Acoustic-Emission Source Location in Two Dimensions by an Array of Three Sensors. *Non-Destructive Testing*, 9(1), 9-12.
26. Shigeishi, M., Colombo, S., Broughton, K. J., Rutledge, H., Batchelor, A. J., & Forde, M. C. 2001. Acoustic Emission to Assess and Monitor the Integrity of bridges. *Construction and Building Materials*, *15*(1), 35-49.
27. Wevers, M., & Lambrighs, K. 2009. Applications of Acoustic Emission for SHM: A review. *Encyclopedia of Structural Health Monitoring*.