CHARACTERIZATION AND EARLY DETECTION OF HYDROGEN EMBRITTLEMENT IN OFFSHORE BOLTS USING ACOUSTIC EMISSION

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INTRODUCTION

When hydrogen gets absorbed into the surface of steel, it can lead to corrosion and cracking which is why it has been widely investigated as it can lead to catastrophic results if not catered to.

Large bolts and other connectors such as studs and fasteners, typically used in the offshore Energy and the oil and gas industries, have been reported to fail prematurely due to hydrogen induced cracking.

By placing sensors on a structure, AE emitted from damage can be detected and located and thus, the damage can be detected, located and characterised. By monitoring for AE over time, an assessment of a structures condition can be made and an estimate on the useful remaining life can be made.[1]

BACKGROUND

AE method has been used in several research on hydrogen-induced cracking in steel throughout the last decade. Dedhia and Wood [2] tracked cumulative counts, events, and amplitude distribution for AISI 4340 steel and found a correlation between breakage and average counts per event. Because the cumulative AE event count is proportional to the number of intergranular microcracks during stable crack propagation, Nozne and Kishi [3] concluded that the main source of hydrogen embrittlement in 4340 steel is microscopic intergranular fracture. Hieple and Carpenter [4] discovered a link between AE activity and the embrittlement process in carbon steel when they investigated the influence of hydrogen charging on the embrittlement process. However, none of these investigations focus on the hydrogen embrittlement process with a focus on "incubation" under constant load conditions. The primary goal of this study will be to track the incubation time for nucleating microcracks in terms of various directly observable AE parameters

OBJECTIVES

Conduct a thorough literature review on the mechanism of hydrogen embrittlement in steel structures and relate to AE.

Develop a methodology for using acoustic emission to monitor bolts for hydrogen embrittlement under representative in-service conditions

Design an experimental test program that will aim to establish the parameters and conditions for successfully detecting AE from hydrogen embrittlement.

Develop the data handling and processing methodologies in order to achieve successful detection and use the results to detect exact point of location of hydrogen embrittlement.

With the help of obtained results a predictive model will be built which will determine the current condition of a bolt and its remaining useful life.

INITIAL TEST PLAN

- The initial testing setup is shown in Figure 1 below which will be axial fatigue testing to be conducted on the chosen bolt grade and size following ISO 3800 standard. [6]
- The aim of this axial fatigue testing would be to test the effect of preload on the fatigue life of bolts by producing a series of S-N curves for different levels of preload.
- The key feature will be to test several bolt grades to see which one will be most suitable for final testing
- bolt grades like AISI 4340 and property class 10.9 are the two options based on ISO 898 – 1 standard.[7]

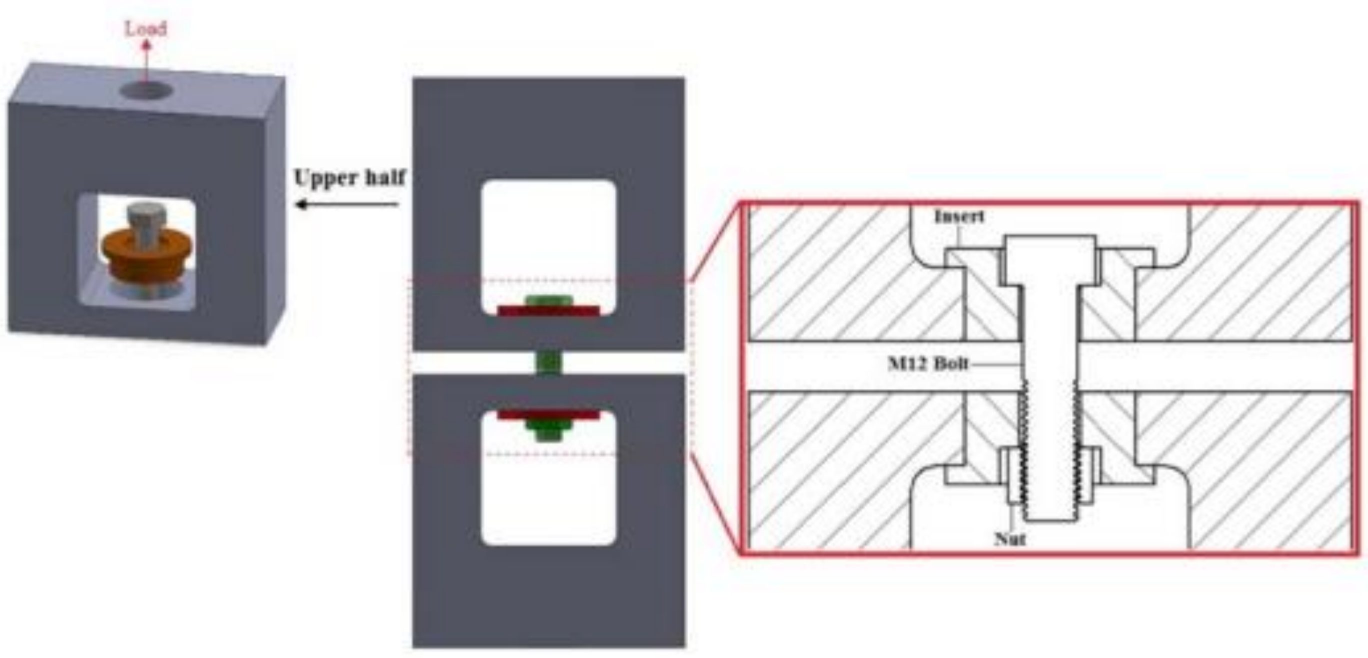

Figure 1 - A general view of the designed fixture [5]

- Along with axial fatigue testing, sensors will be located at appropriate parts of equipment to capture the AE signals which will then be co-related to the SN curves obtained.
- Figure 2 shows a typical AE signal and some of the important features in an AE signal
- Figure 3 shows a basic testing setup which is followed when using AE sensors to detect signals

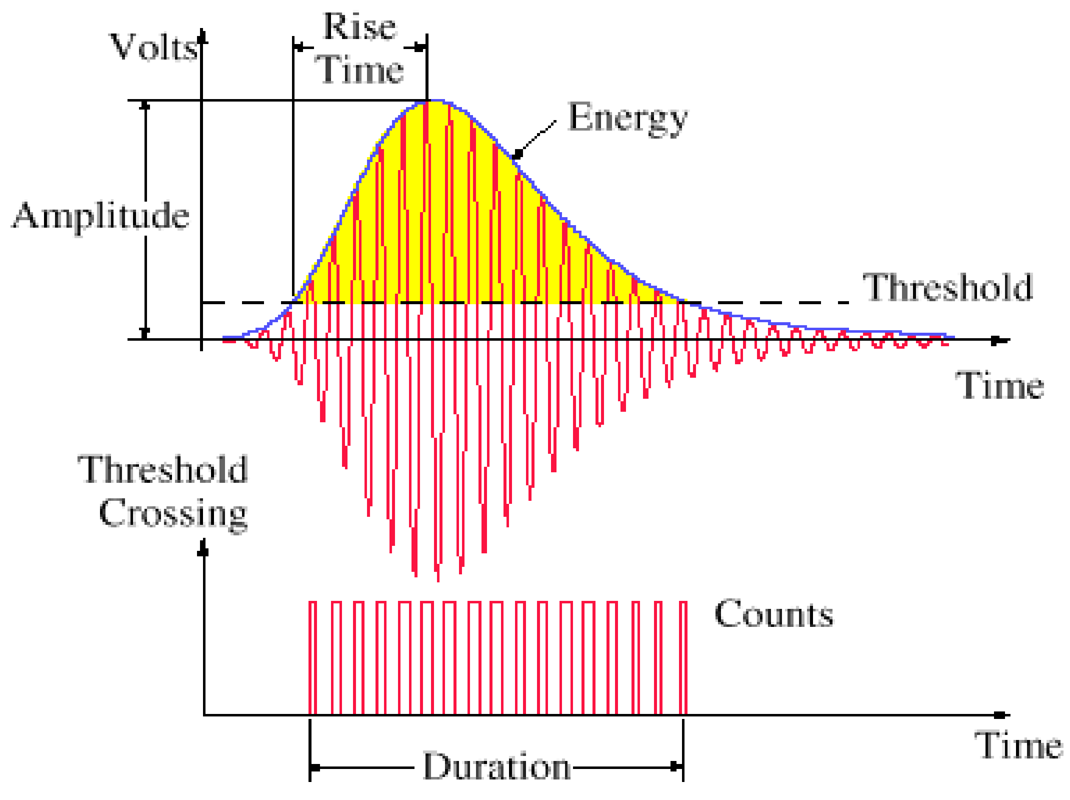

Figure 2 - The definitions for acoustic-emission events

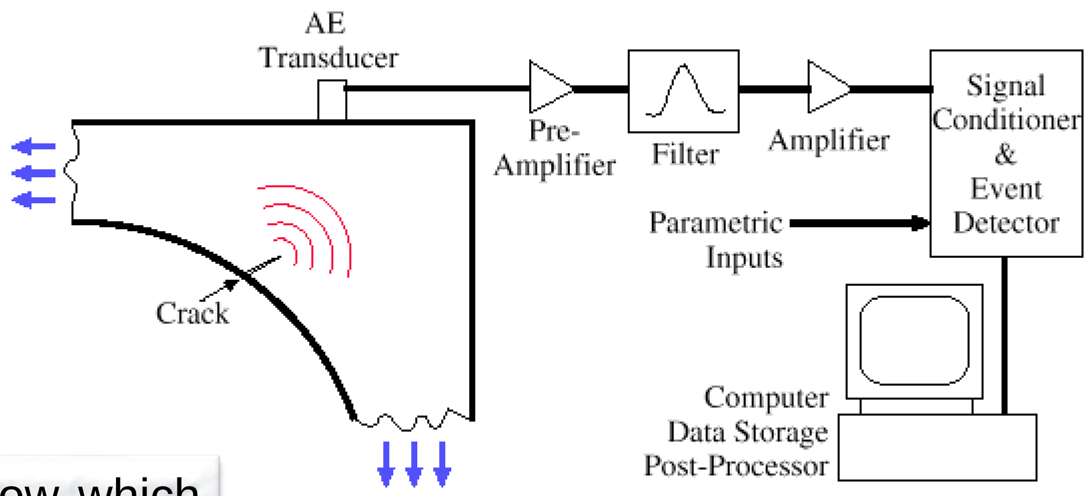

Figure 3 - A typical AE system setup

FUTURE WORK

When comparing AE results in various materials, one finds that there are more publications regarding composites, rocks, and ceramics than metals. The reason for this trend is that the AE signals are stronger and vary more significantly in composites, rocks, and ceramics than in metals. On the other hand, because of the homogeneity and simplicity of metals, the wave propagation in metals should not be as complex as in composites and rocks, since there are less reflections, diffractions, and scattering in metals. Therefore, metals represent a good subject for studying source-function and waveform analyses.

References

[1] Bhattacharya, A.K., Parida, N. and Gope, P.C., 1992. Monitoring hydrogen embrittlement cracking using acoustic emission technique. *Journal of materials science*, *27*(6), pp.1421-1427.
[2] Dedhia, D.D. and Wood, W.E., 1981. Application of acoustic emission analysis to hydrogen-assisted cracking. *Materials science and engineering*, *49*(3), pp.263-273.
[3] Nozue, A. and Kishi, T., 1982. An acoustic emission study of the intergranular cracking of AISI 4340 steel. *Journal of Acoustic Emission*, *1*(1), pp.1-6.
[4] Thompson, D.O. and Thompson, R.B., 1980. Proceedings of the DARPA/AFML Review of Progress in Quantitative Nondestructive Evaluation, 8-13 July, La Jolla, California.
[5] Shahani, A.R. and Shakeri, I., 2015. Experimental evaluation of the effect of preload on the fatigue life of bolts. *International Journal of Steel Structures*, *15*(3), pp.693-701.
[6] ISO 3800 (1993). Threaded fasteners, axial load fatigue testing, test method and evaluation of results.
[7] ISO 898-1 (1999). Mechanical properties of fastners made of carbon steel and alloy steel. Part 1: Bolts, screws and studs, International Organization for Standardization, 1999
[8] Huang, M., Jiang, L., Liaw, P.K., Brooks, C.R., Seeley, R. and Klarstrom, D.L., 1998. Using acoustic emission in fatigue and fracture materials research. *Jom*, *50*(11), pp.1-14.