Characterization and Early Detection of Hydrogen Embrittlement in Offshore Bolts Using Acoustic Emission

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Introduction

- In the offshore industry, high-strength steels are prone to Hydrogen Embrittlement (HE).
- HE causes a permanent loss of ductility leading to corrosion and cracking.
- Acoustic Emission sensors placed on a structure can be used to detect, locate and characterize damage.

Figure 1- Fractured Steel Bolt (Left) and macroscopic view of the fractured surface of the bolt (Right) [3]

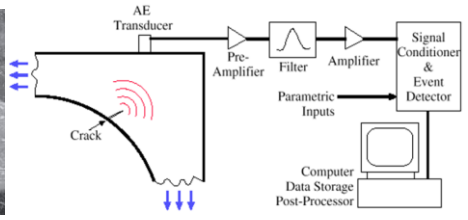


Figure 2- A typical AE System Setup

Electrochemical Hydrogen Charging

- 3.5% Sodium Chloride and 3 g/L Ammonium Thiocyanate charging solution used.
- Specimens charged with current density of 10 mA/cm2
- Charging time of 48 hours.

Figure 3- Experimental set-up of hydrogen charging

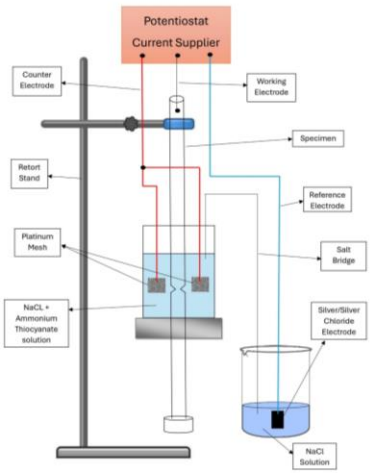


Figure 4- Schematic diagram of the electrochemical Hydrogen Charging

Fatigue Testing

- Axial fatigue testing of property class 10.9 of size M20 bolts of 400 mm length using the setup shown in Figure 3.
- One sample charged for 48 hours was tested and one non charged specimen was tested.

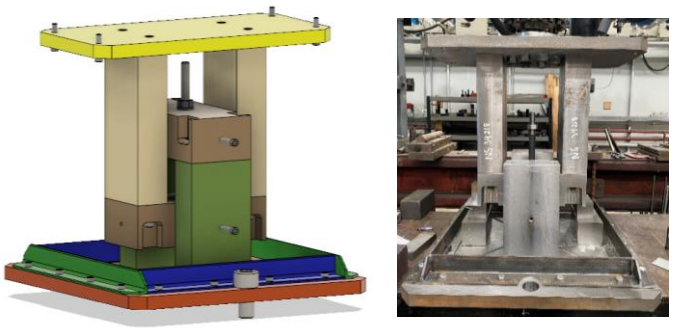


Figure 5- Overview and experimental setup of the rig used in the lab

- 4 nano 30 sensors placed on the rig
- Frequency response between 125 to 750 Hz
- A gel-based couplant was used to mount the sensors

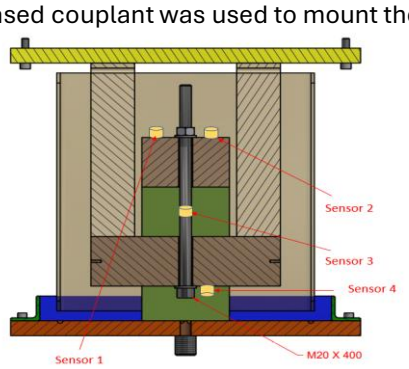


Figure 6- Location of AE sensors on the rig during testing

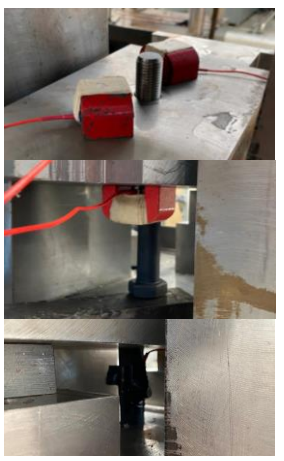


Figure 7- Mounting of the 4 sensors on the rig

- A flat surface also created on the bolt to mount the AE sensor
- A notch of 5 mm produced on the bolt
- Test run at 20 kN load

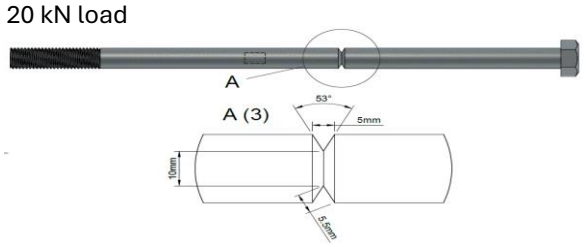
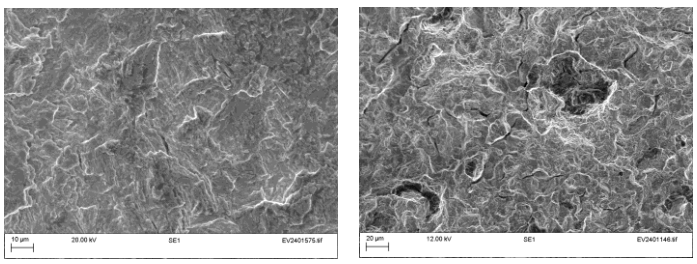


Figure 8- 5 mm V-notch on the bolt

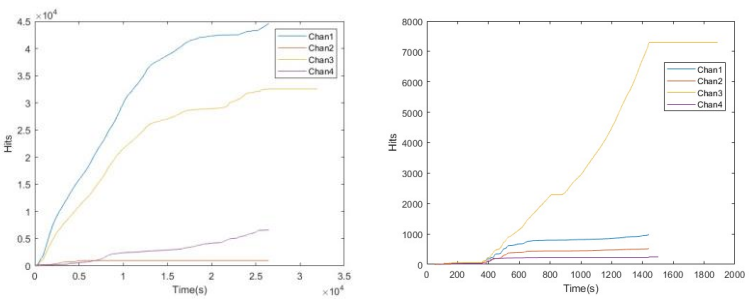
Results

- SEM results of failed bolt surface shows Hydrogen Embrittlement in charged samples.
- Charged specimen failed at 1000 cycles in the notched area and non-charged specimen failed at 26000
- AE data recorded shows sensor 3 with maximum data for charged specimen.



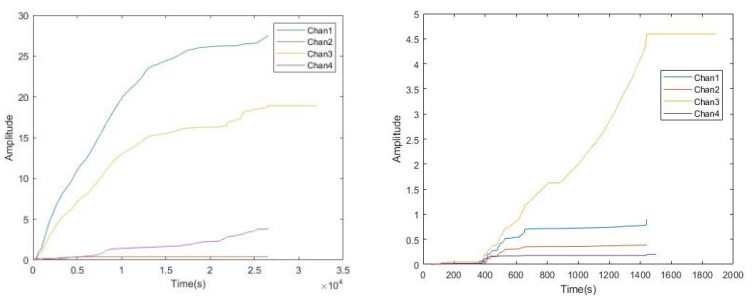
(A) *(B)*

Figure 9- SEM results of failured bolt Surface of (A) non-charged sample (B) charged sample



(A) *(B)*

Figure 10- Cumulative Hits vs Time AE Data of (A) non-charged sample (B) charged sample



(A) *(B)*

Figure 11- Cumulative Amplitude vs Time AE Data of (A) non-charged sample (B) charged sample

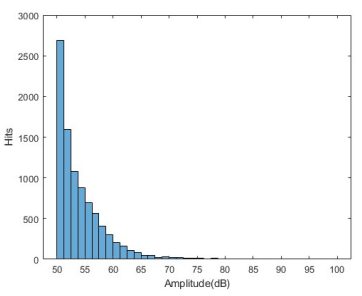


Figure 12- Hits vs Amplitude

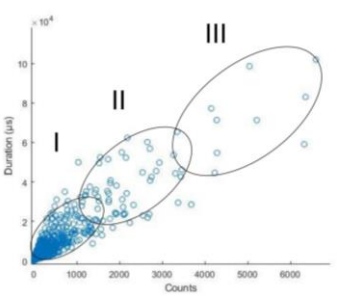


Figure 13- Duration vs Counts

References:

[1] S. Brahimi, "Fundamentals of hydrogen embrittlement in steel fasteners," *IBECA Technology Corp*, 2014.

[2] Y. Chung and L. Fulton, "Environmental hydrogen embrittlement of G41400 and G43400 steel bolting in atmospheric versus immersion services," *Journal of Failure Analysis and Prevention*, vol. 17, no. 2, pp. 330-339, 2017.

[3] R. Unnþórsson, "Hit Detection and Determination in AE Bursts. Acoustic Emission-Research and Applications. Ed. by W. Sikorski," ed: InTech, 2013.

[4] A. Bhattacharya, N. Parida, and P. Gope, "Monitoring hydrogen embrittlement cracking using acoustic emission technique," *Journal of materials science*, vol. 27, no. 6, pp. 1421-1427, 1992.

[5] B. S. I. Staff, *Threaded Fasteners. Axial Load Fatigue Testing. Test Methods and Evaluation of Results*. B S I Standards, 1994.