PROCEEDINGS OF JOHOR INTERNATIONAL INNOVATION INVENTION COMPETITION AND SYMPOSIUM 2024 (JIIICaS 2024)

"Flourish and Nurturing Sustainable Innovation for a Prosperous Nation"

JOHOR INTERNATIONAL INNOVATION, INVENTION COMPETITION AND SYMPOSIUM

Editorial Board

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Preface

In the name of Allah, the Almighty who gives us the enlightenment, the truth, the knowledge and with regards to Prophet Muhammad (peace be upon him) for guiding us to the straight path. We thank to Allah for giving us guidance and strength to write this e-book.

This e-book compiles the extended abstracts that submitted to Johor International Innovation Invention Competition and Symposium 2024 (JIIICaS2024), where JIIICaS2024 is a virtual platform for all creative minds to share and present their invention and innovation. Each abstract gives a brief background on the innovation or project.

We hope that this e-book will help the readers to get to know the innovation done by the students and get some ideas to develop future innovation products.

Foreword Rector

Assalamualaikum warahmatullahi Wabarakatuh,
Salam Sejahtera, Salam Malaysia MADANI and Salam UiTM Dihatiku.

In the name of Allah, the Most Gracious, the Most Merciful.

It is a great honor to welcome you to the Johor International Innovation, Invention, Competition, and Symposium 2024 (JIIICaS 2024). This event connects various disciplines, focusing on education and engaging educators, students, researchers, and innovators from all walks of life.

Innovation is not just about ideas; it demands perseverance, creativity, and determination to turn those ideas into reality. The remarkable projects showcased today highlight the dedication and spirit of all participants. Initiatives like this not only explore new technologies but also cultivate skills and leadership among our youth. At Universiti Teknologi MARA (UiTM) Johor Branch, we are fully committed to fostering a dynamic culture of innovation, promoting the commercialization of new products, and encouraging meaningful collaborations with industry and society.

As we celebrate this event, I would like to extend my heartfelt gratitude to all sponsors, judges, the College of Computing, Informatics and Mathematics, UiTM Pasir Gudang Campus as the event organizer, as well as to the researchers and participants for their hard work in making this event a success. Let us continue striving for innovation and excellence. May the ideas presented today inspire us and lay the groundwork for future achievements.

Thank you.

Associate Professor Dr. Saunah Zainon
Rector
Universiti Teknologi MARA (UiTM)
Johor Branch

(A-PP037) ACOUSTIC EMISSION MONITORING FOR MEANINGFUL FATIGUE LIFE PREDICTION IN ALUMINIUM ALLOY 6061

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ABSTRACT

This study introduces a novel method for predicting the fatigue life of aluminium alloy 6061 under block spectrum loading using acoustic emission (AE) data signals. Specimens were subjected to cyclic loading patterns, specifically constant amplitude loading and block spectrum loading, under Low-High and High-Low conditions. AE signals were continuously monitored and recorded, capturing events related to crack initiation and propagation. Key features of the AE data, such as amplitude, frequency, duration, counts, and energy, were extracted and analysed. The cumulative AE activity was correlated with the material's fatigue life, revealing distinct trends at various stages of fatigue damage. Statistical methods were applied to the AE data to develop predictive models for estimating the remaining fatigue life of the specimens. The proposed method demonstrated high accuracy in predicting fatigue life, offering a reliable, non-destructive tool for early detection of fatigue damage. This approach has significant implications for improving the safety and reliability of aluminium alloy 6061 components in critical applications, such as aerospace and automotive industries.

Keywords: acoustic emission, constant amplitude loading, block spectrum loading, data distribution

1.0 INTRODUCTION

Aluminium alloy 6061 is widely used in critical industries like aerospace and automotive due to its excellent strength-to-weight ratio, corrosion resistance, and workability[1]. Despite these benefits, it is prone to fatigue under cyclic loading, which can lead to crack formation and propagation, threatening the structural integrity of components. Therefore, accurately predicting the fatigue life of Aluminium 6061 is essential for ensuring the safety and reliability of these components. Traditional methods for predicting fatigue life often rely on empirical models based on extensive, controlled testing[2]. While these approaches are effective, they usually involve destructive testing and do not provide real-time, in-situ assessments of material health. Acoustic Emission (AE) monitoring has emerged as a valuable technique for detecting and characterizing fatigue-related phenomena [3]. AE monitoring captures transient elastic waves from localized sources within the material, such as crack formation. By analysing AE signals, it is possible to assess the material's damage state and predict its remaining fatigue life [4]. This study introduces a novel method for predicting the fatigue life of Aluminium 6061 under block spectrum loading using AE data. This method offers a reliable, non-destructive tool that could significantly improve the safety and performance of Aluminium 6061 components in demanding applications.

2.0 OBJECTIVE

The primary objective of this research is to develop and validate an innovative methodology for predicting the fatigue life of Aluminium 6061 under block spectrum loading conditions by utilizing acoustic emission (AE) data. The study focuses on the continuous monitoring and analysis of AE signals generated during cyclic loading, including both constant amplitude loading and block spectrum loading with Low-High and High-Low sequences.

3.0 METHODOLOGY

3.1 Material and Specimen Preparation

The material selected for this study is Aluminium alloy 6061, chosen for its prevalent use in critical engineering applications. According to Figure 1, the specimens were machined in accordance with the specifications outlined in ASTM E647, which governs the standard test method for determining the fatigue crack growth rates using compact tension (CT) specimens.

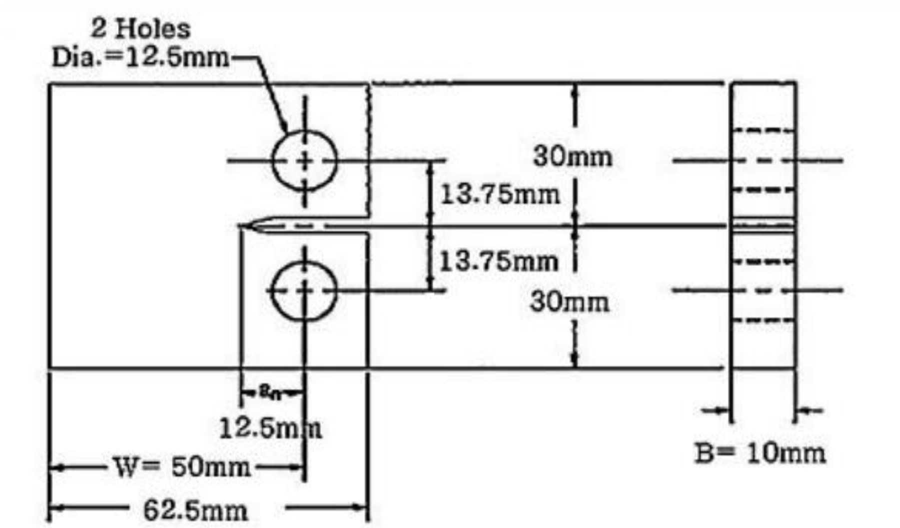


Figure 1: Geometric diagram of specimen based on ASTM E647.

3.2 Experimental Setup

The experimental setup was designed to subject the CT specimens to cyclic loading while simultaneously monitoring the acoustic emission (AE) signals. The specimens were subjected to cyclic loading under controlled conditions using a servo-hydraulic testing machine. The tests were conducted at a frequency of 10 Hz, with a load ratio of 0.1. Two loading scenarios were considered, $\text{Load}_{\text{low}} =$ 4000N and $\text{Load}_{\text{High}}$ = 6000N sequences of Low-High and High-Low conditions which are based on values of UTS (Ultimate Tensile Strength) 0.8 and 0.5 of the material. Each loop comprises 10,000 cycles, with each load phase for 5,000 cycles, and the process will continue until the specimen fails.

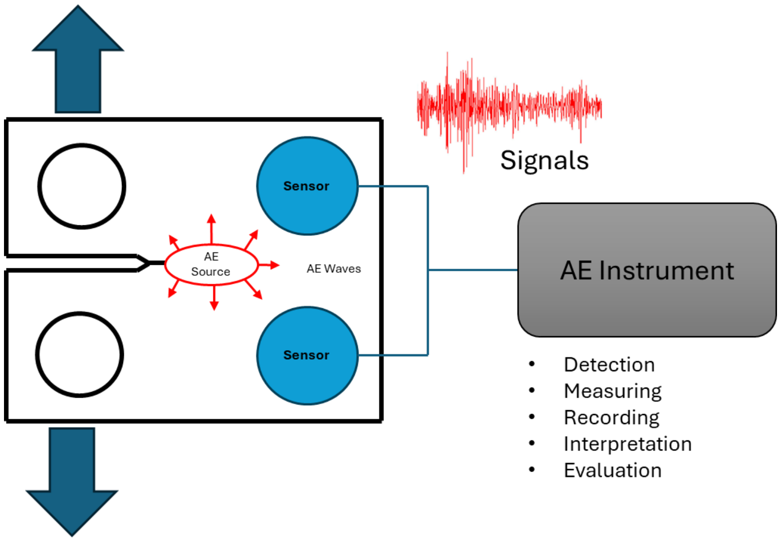
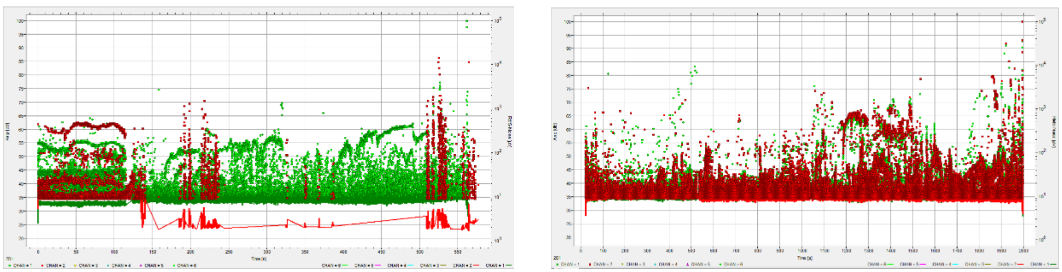


Figure 2: Experimental Setup.

According to Figure 2, two wide-band AE sensors were attached to each specimen using a couplant to ensure optimal acoustic coupling. The sensors were placed at a distance of approximately 20 mm from the notch on either side of the specimen to maximize the detection of AE events originating from the crack tip. The sensors were chosen for their sensitivity to frequencies in the range of 100 kHz to 1 MHz, which is suitable for detecting AE signals generated by crack initiation and propagation in Aluminium 6061.The AE signals were continuously monitored and recorded using a multi-channel AE data acquisition system with a sampling rate of 5 MHz [5]. The system was equipped with preamplifiers to enhance the signal-to-noise ratio. All the sensors were calibrated using pencil lead fracture (PLF) to ensure their connectivity to the specimen's surface [6].

4.0 RESULTS

For each both low-high and high-low loading scenario the specimen failed at ±19,000 cycles. Subjected to the raw AE signal data captured in both Figure 3 (a) and (b) indicates the progression of fatigue damage in the material over time. Initially, the AE activity is moderate, but as time progresses, the signals become more frequent and intense, indicating increasing damage, likely due to crack growth and coalescence.

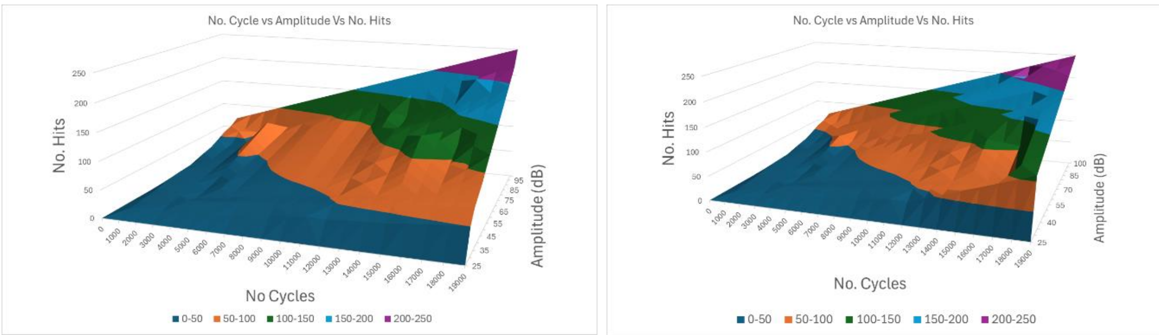


(a) (b)

Figure 3: AE signals Amp(dB) Vs Time(s) of specimen (a) Low-High (b) High-Low.

Low-high and High-low specimens exhibit initial crack formation at approximately 7,000 cycles and 4,000 cycles, respectively. In these cases, amplitude values exceeding 65 dB indicate an aggressive onset of crack initiation. The use of multiple channels allows for a comprehensive understanding of the damage mechanisms at play, which is crucial for predicting the remaining fatigue life of the material. The raw AE data was filtered to remove background noise and irrelevant signals using a high-pass filter with a cutoff frequency of 100 kHz [7]. By filtering out noise from the AE data, it becomes possible to obtain accurate data for plotting the cumulative AE signals against the estimated fatigue life of the material.

Figure 4 (a) and (b) illustrates how the number of cycles, stress intensity, and AE signals interact during a fatigue test. Initially, as the material endures low cycles and stress, AE activity is minimal. As stress increases and more cycles are applied, AE amplitude and hits become more frequent, indicating progressive damage. The data presented in the graph can be used to predict the material's remaining fatigue life by analysing the trends in AE hits as a function of stress and cycles.



(a) (b)

Figure 4: Life estimation vs Stress vs No. Hits (a) Low-High (b) High-Low.

Figure 4 (a) and (b) shows a clear trend where higher stress intensities correspond to higher numbers of AE amplitude and hits, especially as the number of cycles increases. This correlation is consistent with the understanding that as stress intensifies, the material is more likely to undergo microcracks that result in acoustic emissions.

5.0 CONCLUSION

The integration of AE data with traditional fatigue testing enables the early detection of fatigue damage, offering a reliable, non-destructive tool for enhancing the safety and reliability of critical components. Both low-high and high-low loading scenario the specimen failed at ±19,000 cycles although the initial crack formation at approximately 7,000 cycles and 4,000 cycles, respectively. Through continuous monitoring, key features of AE signals can be extracted and analysed to provide real-time insights into the material's health. The insights gained from AE data, when combined with advanced signal processing techniques, offer a reliable means of enhancing the safety and durability of critical components in engineering applications.

6.0 REFERENCES

[1] N.R.J. Hynes, M.V. Prabhu, P.S. Velu, R. Kumar, R. Tharmaraj, M.U. Farooq, An experimental insight of friction stir welding of dissimilar AA 6061 / Mg AZ 31 B joints, 236 (2022) 787–797. https://doi.org/10.1177/09544054211043474.

[2] D. Chernyavsky, D.Y. Kononenko, J.H. Han, H.J. Kim, J. van den Brink, K. Kosiba, Machine learning for additive manufacturing: Predicting materials characteristics and their uncertainty, Mater Des 227 (2023). https://doi.org/10.1016/j.matdes.2023.111699.

[3] Z. Li, X.F. Zou, F.B. Bao, F.S. Gu, A.D. Ball, A Review of Acoustic Emission Monitoring on Additive Manufacturing, PROCEEDINGS OF INCOME-VI AND TEPEN 2021: PERFORMANCE ENGINEERING AND MAINTENANCE ENGINEERING 117 (2023) 867–878. https://doi.org/10.1007/978-3-030-99075-6_70 WE - Conference Proceedings Citation Index - Science (CPCI-S).

[4] D.Y. Kononenkoa, V. Nikonovaa, M. Seleznevb, J. V Brinka, D. Chernyavsky, An in situ crack detection approach in additive manufacturing based on acoustic emission and machine learning, ADDITIVE MANUFACTURING LETTERS 5 (2023). https://doi.org/10.1016/j.addlet.2023.100130.

[5] C. Barile, C. Casavola, G. Pappalettera, V.P. Kannan, Application of different acoustic emission descriptors in damage assessment of fiber reinforced plastics: A comprehensive review, Eng Fract Mech 235 (2020) 107083. https://doi.org/10.1016/j.engfracmech.2020.107083.

[6] V. Pandiyan, R. Wróbel, R. Axel Richter, M. Leparoux, C. Leinenbach, S. Shevchik, Self-Supervised Bayesian representation learning of acoustic emissions from laser powder bed Fusion process for in-situ monitoring, Mater Des 235 (2023). https://doi.org/10.1016/j.matdes.2023.112458.

[7] N. Md Nor, S. Abdullah, M.A.H. Mohamad Halim, A. Arifin, Evaluation of the Behaviour of Steel Bar in the Concrete under Cyclic Loading Using Magnetic Flux Leakage and Acoustic Emission Techniques, Materials 16 (2023). https://doi.org/10.3390/ma16062172.