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EXPERIMENTAL STUDY OF THE EFFECT OF CRACKS ON ALUMINUM 5083-H111 AND THE DIRECTION OF CRACK GROWTH, NUMERICALLY AND EXPERIMENTALLY.

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Abstract:

In this study we will provide an overview of the surfaces affected by cracking through the fatigue process which is subjected to a number of rotations with a constant amplitude and a load value of 6 kN. By using a type of aluminum 5083-H111, the samples were examined after being exposed to fracture by Scanning Electron Microscopy (SEM) examination, as well as the direction of Crack Growth Direction (CGD) by making holes away from the original crack, which was made at a vertical and horizontal distance of (11,15) mm. The sample contains three holes, and the distance between the center of each circle is (11,15) mm. The number of rotations is measured with the length of the crack, and the Stress Intensity Factor (SIF) is measured at each length in the sample, and the experimental figures are compared with the numerical figures, and there is a clear match and agreement on the accuracy of the results.

Key world: Crack length, scanning electron microscopy, SIF, CGD.

1. Introduction:

Al-Mg alloys' many qualities, such as their excellent formability in soft tempers, high resistance to corrosion, particularly in marine environments, durability at low and high temperatures, good weldability, light weight, and ballistic qualities, make them widely used in a variety of fields. [1].

Alloys made of aluminum and magnesium have a high strength-to-weight ratio, outstanding formability, weldability, and corrosion resistance. Marine structures, tank containers, vessels for pressure testing, cryogenic applications, transmission of power towers, drilling platforms, missile components, and armor plates are among the alloys that use 5083 because of its remarkable performance in severe situations. [2]. Aluminum's mechanical qualities, corrosion resistance, and light weight make it essential to modern technology [3]. 5083 and kindred 5xxx alloys are used in shipbuilding because of their high specific strength, excellent weldability, and remarkable resistance to corrosion in maritime environments. [4-5]. Aluminum alloys are commonly employed in industries like airplane constructions because of their high strength to weight ratio. When compared to other materials and alloys, such as high-strength steel alloys, the majority of aluminum alloys offer superior strength-to-weight

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ratios. [6]. Although internal fatigue cracks were the subject of a recent special edition of the journal Fatigue & Fracture of Engineering Materials and Structures, internal fracture propagation was not directly seen [7]. Therefore, in order to increase the lifespan and safety of aluminum alloys for aerospace applications, fatigue and corrosion fatigue (CF) concerns need to be addressed [8]. The Paris law is a widely used model for fatigue crack propagation, where a power function describes the link between the stress intensity factor ΔK and the cyclic crack development rate da/dN [9]. The aim of this study is to demonstrate the effect of crack growth as well as the microstructure of the surfaces after the cracking process through the advanced electron microscope and the effect of the direction of crack growth after making holes in the samples after applying fatigue loads.

1.1 Experimental procedure

The material used in this study is aluminum alloy 5083-H111 Figure (1- 1) which is used in many industries due to its resistance to corrosion. It is used in marine industries and to resist external conditions, it is used in some internal and external parts of aircraft. Some engineering tests were conducted before the fatigue test to determine the mechanical properties, including tensile and hardness tests, and chemical properties tests. Figure (1-1)Aluminum 5083-H1116 plate.

Table (2-1) shows the mechanical properties and Table (1-2) shows the chemical properties.

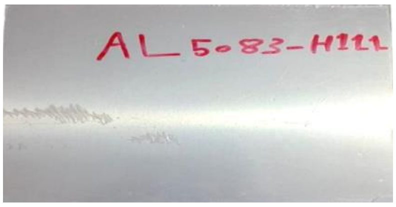

Figure (1- 1)Aluminum 5083-H1116 plate.

Table (2-1) The Mechanical Properties of AL-5083-H111.

Material	Thickness mm	Yield stress σy(MPa)	Ultimate Stress σu(MPa)	Elongation %	Modulus of Elasticity E(GPa)	Poisson's Ratio υ
AL 5083-H111	3	270	311	16	69	0.33

Table (1-2)The Chemical properties of of AL-5083-H111.

Sample	Si%	Mg%	M n%	Fe%	Cr%	Cu%	Zn%	Ti%
AL5083-H111	0.186	4.45	0.445	0.219	0.0840	0.0731	0.0634	0.0571

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1.2 Rockwell B hardness test

To evaluate the mechanical properties, Vickers hardness test was conducted for five different areas of the sample as shown in **Table (2-3)**The average of these values was taken and the hardness of the metal was evaluated.

Table (2-3) Rockwell Hardness test

AL 5083-H111	
17.5	
18.5	
17	
18	
16.5	
Average	**17.5**

1. Manufacturing test samples

Test samples were designed in the laboratory with dimensions of 60*180*3 mm and a crack in one of the edges in the middle. The length of the crack was 5 mm. I designed it in AutoCAD 2022. The samples were cut after drawing and transferred to the cutting machine. A model containing three holes was used. The distances between the center of the circle and the other circle were (11 and 15) mm. Also, its distance from the original crack was in horizontal and vertical directions, as shown in the figure (3-1).

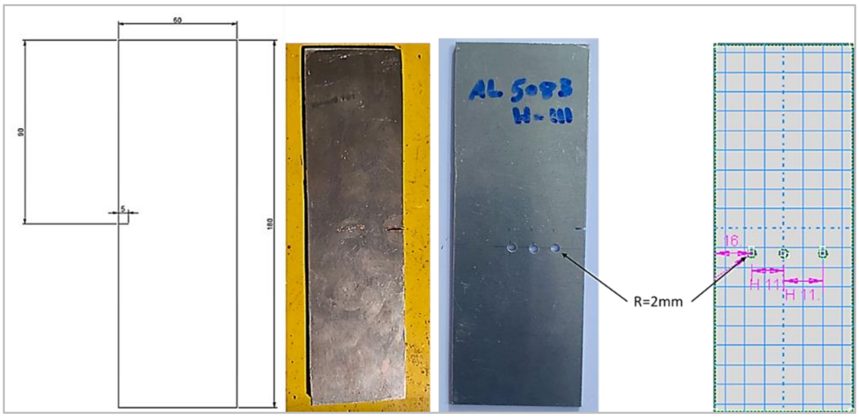

Figure (3-1) Dimensions of the designed test specimens

2. Fatigue test

The samples were tested in a uniaxial fatigue machine at a constant amplitude with a dynamic load of 6 kN and a number of cycles at 24 Hz, as shown in Figure (4-1). This shows the

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fatigue test to which the test samples were subjected. A number of samples were tested, and the changes occurring in each sample were monitored. After that, an average was taken in our research.

Figure (4-1) fatigue test machine

3. Result and discussion

5.1 tensile result

The mechanical properties of the metal were obtained by tensile testing as shown in Figure (5-1), which shows the relationship between stress and strain. The elongation was 16%, the yield point was 270 MPa, the Young's modulus was 69 GPa, and the maximum tensile stress (ultimate strength σu) was 311 MPa. The samples were used according to international standards.

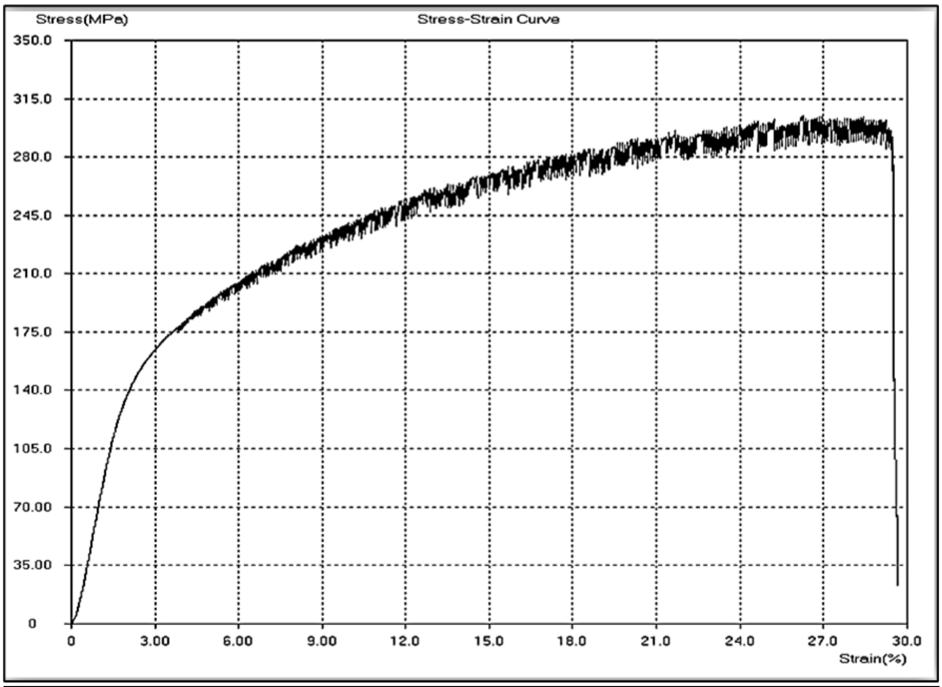

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Figure (5-1) stress strain curve.

5.2 Scanning Electron Microscope (SEM)

Based on the electron microscope data obtained from the test site, cracks tend to develop. There are damage zones ranging from microns to nanometers. The damage zones are shown after the artificial crack area. The fracture surface after the failure of the specimen was enlarged, focusing on a specific area and magnifying it several times. The trend indicates that the cracks tend to produce parallel maximum tensile strength. Figure (5-2) shows the results obtained after the samples were exposed to failure and mechanical fracture during cyclic loads. High-resolution microscopic examination sieves used a number of times of magnification and focused on the damaged areas. It showed areas of dislocations and some voids in the surfaces and the shape of some dimples. This is due to some manufacturing processes and impurities contained in the materials. The other reason is due to cyclic loads. This makes it possible to use a scanning electron microscope (SEM) for longer periods of time to detect nano cracks more precisely. This could somewhat stop fast fracture and improve resistance to crack propagation. As a result, during cycle loading, significant damage evidence and fracture growth routes can be effectively examined with a scanning electron microscope.

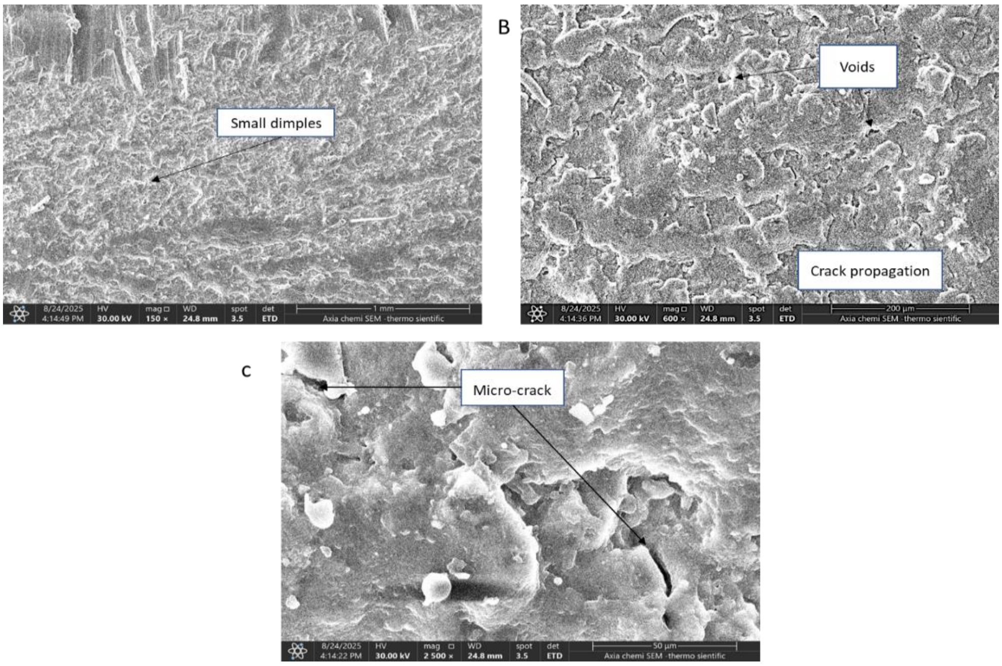

Figure (5-2) SEM levels alloys.

5.3 X-Ray Diffraction (XRD)

Figure (5-3) shows the diffraction of samples after they were subjected to stresses and whether there was a difference in the composition and crystal structure. After matching them with the schematic diagram of this mineral, they were completely identical. These peaks appear at a range of angles. We note the maximum peak at an angle of 38.5 degrees (111°),

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44.6° (200°), 65.2° (220°), and 77.9° (311°), in addition to some peaks from magnesium and silica (Mg2Si).

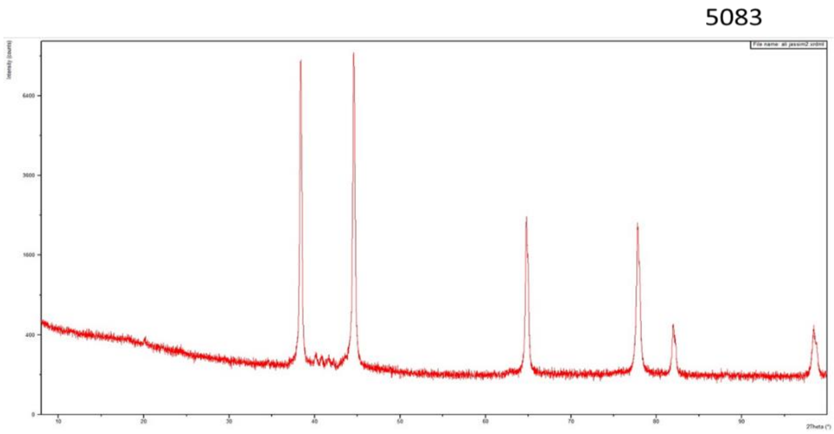

Figure (5-3) XRD of AL-5083-H111.

5.4 Crack Growth Direction

One of the most important problems that vehicles and other structures are exposed to is making holes in the samples with the crack manufactured in the sample. Figure (5-4) shows how the crack grows and the effect of spacing. In the first spacing, the crack was directed towards the third hole and there were clear curves in the direction of the crack and the effect of the distribution of the faces through the holes. As for the second spacing, the effect and direction of the crack was growing towards the middle hole when it was exposed to fatigue loads. This shows the effect of spacing on the holes. This difference in path in the same metal and the same load capacity is due to the effect of spacing, manufacturing processes and some internal structures in the material. This is shown through the direction of the crack and then it changes its path when observing the sample with a microscope camera. There is consistency between the experimental and numerical work. The simulation program Software was used using the extended finite element method(XFEM). Among the methods followed through the enrichment method, some properties were fed to the program and fed according to the practical models and the effect of forces. The extended element method showed its efficiency in this work.

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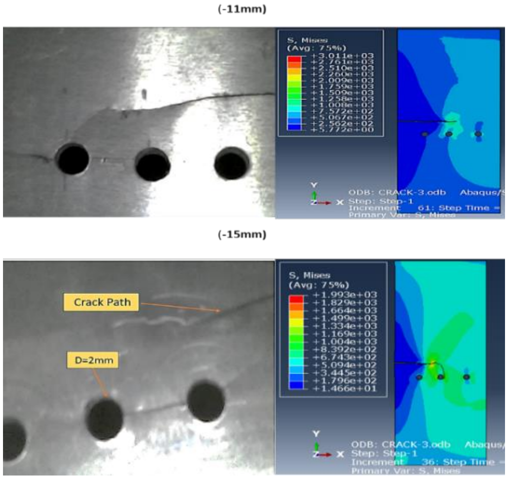

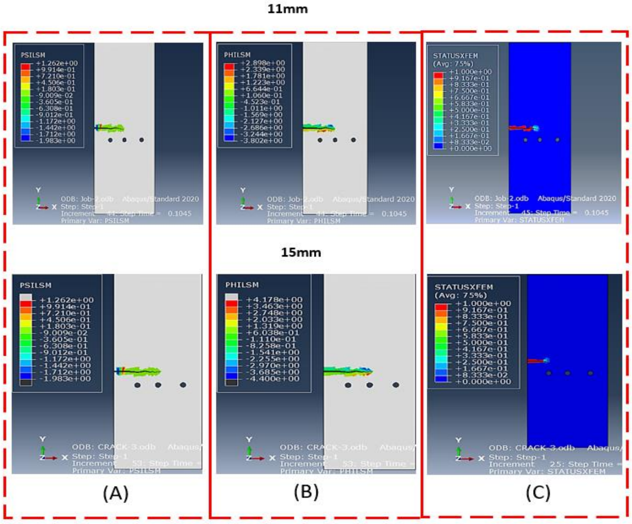

Figure (5-4) Effect crack growth of AL.

5.6 Fatigue crack growth behavior

Fatigue behavior was verified by knowing the number of cycles the models are exposed to with the crack length. Figure (5-5) shows the crack length at any of the cycles that indicates the growth of the crack and knowing the stress intensity factor at any length. Also, identifying the crack spread and using the Paris equation, which by knowing the constants of this material, the change in shape indicates the resistance of the material through the calculated time and slow growth that the testing process takes. In this analysis, the experimental method, numerical methods and the mathematical method were used using the MATLAB program, while the numerical method will use the ABAQUS program for analysis.

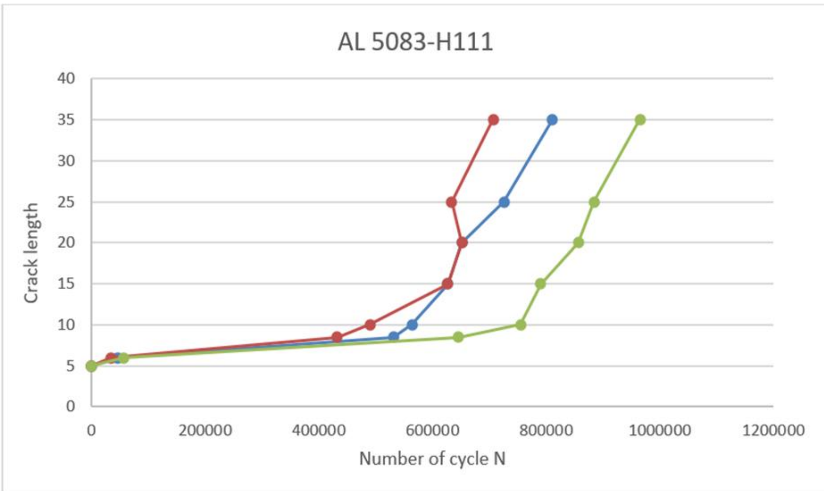

Figure (5-5) Crack length and number of cycle.

Conclusion

In this study, we investigated the effect of crack growth under constant amplitude cyclic loads on crack growth in 5083-S111 aluminum. We concluded that cyclic loads lead to an

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increase in the crack growth rate and that the hole spacing affects the crack direction. These results contribute to a better understanding of the behavior of materials under dynamic loads. Our study provided a new insight into this material, which has recently been used in the shipbuilding industry and some aircraft parts and structures. However, there are some limitations that must be taken into consideration, such as further studies, different loadings, and variable amplitudes. We suggest conducting further explorations on other materials to predict crack behavior.

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