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Effect of Different Holding Times on The Facture Behavior for Low Cycle Fatigue of Aluminum Alloy aa6063 at 350 ° c Temperature

Hussain Jasim M. Alalkawi[1], Mazin Mahmood Yahya [1*], Abdulwahab.M.Al-Mushehdany [1]
[1] Aeronautical Techniques Engineering Department, Bilad Alrafidain University College, Iraq
Dr.algawi@bauc14.edu.iq, . dr.a.w.Mohammed@bauc14.edu.iq,

Abstract

low Cycle Fatigue behavior of aluminum alloy AA6063 heat treated at 350 ° c with different holding times was studied . Constant S – N Curve is designed with the main fatigue parameters . The results are verified with that obtained numerically . Using different holding times with low cycle fatigue properties AA6063 have been observed . Holding times of 2 , 4 , 6 and 8 hours at 350 ° C temperature was used . The yield stress and the ultimate tensile strength were decreased with the increasing the holding time . The strength Coefficient K and the strain hardening index n results were increased as the holding time temperature increased . Also the exponent b of fatigue strength and the exponent C of fatigue ductility were increased as the holding time increased . Cyclic elastic Strain do not change much with increasing the time at Same temperature 350 ° C and the situation is also the Same for fatigue strain coefficient , for the cyclic plastic strain - Optic Micrograph images were taken using variable magnification before and after fatigue test . Moreover the failure mechanisms with microstructural features are studied using scanning electron microcopy (SEM)

Keywords: (LCF), AA6063 , Elevated Holding time Temperature; Cyclic Strain Life Curve, SEM Mechanisms

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1. Introduction

The material must be quenched rapidly from the Solution - treating temperature after removal from formal . During the quenching cycle , the water should be at room temperature , and should be cooled so that the temperature remains below 38 °C (100°F) . The material was quenched through total immersion in water . High volume jets with high velocity cold water was used for some materials . To improve the mechanical properties during precipitation heat treatments cold working is necessary after solution treatment . cold reduction by 1 to 5 % , enhance the strength of the material subsequent to solution heat treatment [1] .

Nano - sized Al_2O_3 , particles (35 nm) was used to reinforced AA7075 alloy by Stir casting route . The mechanical and fatigue properties of Nano cast Composites and matrix was done at room temperature (RT) . High and low cycle fatigue were used for both Composites and base metal . Using the Nano Al_2O_3 enhanced the mechanical and fatigue properties compared to the matrix . The evaluation of microstructure showed uniform distribution of Al_2O_3 Nano particles in the matrix with some porosity . The improvement of the mechanical and fatigue properties was due to the grain refinement and to the Al_2O_3 particles distribution

[2] .

Metal matrix Composite (MMC) of AA6063 with 2 % and 8 % by volume (SiC) particles size 37 nm (400 mesh) was used at room temperature . Low cycle fatigue (LCF) resistance for these metals were carried out under fully reversed strains Control testing . Volume fraction of 2 and 8 % with strain ratio of (R = -1) was used . When the Sic particles Content increases the strain Control fatigue properties will reduces while the transition fatigue life increases. To confirmed low cycle fatigue failure nature , SEM was used to study the microstructure features and failure mechanisms [3] . Fatigue behavior of AA2024-T6 and AA7020-T6 under low Cycle was studied by Zyad Nawaf [4] . Their results showed that precipitation of Zn element in its parent metal in AA7020 T6 is more than cu element in AA2024-T6 using the same heat treatment . The experimental transition fatigue life was 780 and 201 cycles for AA7020 - T6 and AA2024 - T6 respectively . Strength properties and ductility results are more affected using the chemical Composition and strength of the alloy when both alloys are given the Same

* Corresponding author: dr.mazin@bauc14.edu.iq

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heat treatment . Salemo et. al. [5] used classical Criteria to estimate the life time of AA7175-T1 aluminum alloy under the LCF Condition .

Mrawka - Nowataik , et.al [6] studied the solution temperature effect on the ageing kinetics and mechanism of aluminum alloys AA6005 and AA 6082. Also they determined the affects . of extrusion process on the mechanical properties and microstructure of both alloys . Salazar Guapuriche et.al. [7] were tested AA7010 with variable temperature and ageing conditions for tensile stress , proof stress , hardness and electrical conductivity . The aim for these tests to find a good correlation between strength , hardness and electrical Conductivity. Marioara C. D. et.al. [8] designed and carrel out thermal-mechanical tests on the AA6082 to find the effects of solution heat treatment (SHT) time with the mechanical properties . The experimental results showed that increasing the ductility with decreasing in the value of maximum flow stress can be achieved when increases the value of SHT time .

Ortiz D. et al. [9] presented the study on AA6061, AA 2024 and AA7075 under heat treatment to different temperatures These alloys were subjected to a wide range of plastic, strain to find their limit of strain. Also, they evaluated the grain size, hardness, Conductivity and tensile properties .

The effect of aging temperature, aging time and seawater. Corrosion on the property of fatigue resistance of AA6063 aluminum alloy was studied by Siddiqui R. A. et. al. [10]. The maximum value of fatigue resistance of AA6063 alloy was observed at aging time between 7 hours and 9 hours with heating temperatures 160 °C and 200 °C . Also at these temperatures and at Constant load , they found the number of cycles to fail this alloy were decreased when increasing the holding time in seawater. They Conclude that a brittle fracture start to occur when increasing the -aging time and temperature . The fatigue failure was observed clearly at low and high aging temperatures .

The microstructure and mechanical properties of AA6063 alloy as cast and homogeneous states after extrusion was studied by Al – Maraweh G. [11]. The distribution and the volume fraction of the second phase of Mg2 Si was found after various heat treatment . The mechanical properties after extrusion of this alloy was analyzed under the effect of homogenizing. Han , S.W. et. al. [12] examined the effect of Cyclic load on the stress - strain curve at fixed plastic strain for age harder able Al : 7 % Si o.4 % Mg (A356) cast alloys and AA6063 .

Siddiqui R. A. et. al. [13] were given various heat treatments of AA6063 aluminum alloy at various aging temperatures . The precipitation affect on the yield stress , tensile stress , ductility hardness and the required number of cycles to start failure the alloy at constant value of stress was investigated . Different temperature and time was improved the strength and hardness of the alloy , while the ductility was decreased . The SEM used to study the fatigue fracture surface of the under aged alloy . Gupta A. k. et.al. [14] use the differential Scanning Calorimetry (DSC) . and transmission electron microscopy (TEM) to study the hardening potential and precipitation of variable metastable precursors in Al : 0.4 mg : 1.3 % si : 0.25 % Fe (wt.%) alloy . Karamis M.B. et. al. [15] made a good investigation on the cooling rate effect on the low grade Cold deformation properties of AA6063 alloy during homogenization treatment. Increasing the coding rate will increase . the critical strain and will decrease the grain size . Srivatsan T.S. [16] Discuss the cyclic stress - strain curve for fatigue response of aluminum alloy AA7055. Using the strain amplitude control , the alloy exhabit evidence of softening than failure . The cyclic softening was increased with the increasing of temperature. The mode of fracture was identical on the macroscopic scale . Using the microscope scale , the cyclic fracture revealed features of locally ductile with brittle mechanisms. Borrego L.p.et. al. [17] presented a good study for low cycle fatigue tests carried out with two AlMgSi aluminum alloy, namely AA6082 - T6 and AA6060 – T6 . These test's used a strain control and the strain ratio was Re -1 . The behavior observed was discussed and belong to the chemical imposition of the alloys (Mg2si particles and Mn Content) and to the fracture mechanisms . AA6060 - T6 alloy shows ideal massing behavior bout AA6082 – T6 alloy presents large deviations from ideal model . The cyclic deformation behavior of AlMgSi alloys were affected by the dispersed phase.

2. METHODOLOGY

The tensile tests was carried out using cylindrical Hounsfield tensile specimen . Torsion test was also performed Figure (1) illustrate the shape of cantilever specimen used in fatigue test having a 106 mm gage length and 8 mm diameter. Fatigue testing Apparatus (WP140), Germany is shown in figure (2)..

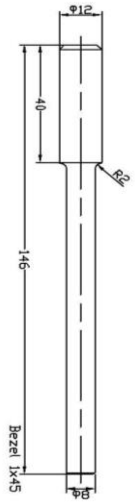

FIG. 1 CANTILEVER FATIGUE TEST SPECIMEN (DIMENIONS IN MM)

FIG. 2 CANTILEVER FATIGUE MACHINE

In this research ANSYS program was used. This program has a finite element analysis which is variable from simple linear, static analysis and complex, nonlinear, transit dynamic analysis . Typical ANSYS program consist of three steps: Making the model. Using the load and obtaining the solution and checking the results .

low cycle fatigue analysis of rotating Cantilever specimen was modeled as static problems using the centrifugal forces arising due to rotation and used the time varying bonding force at the end .Figure (3) shows the boundary conditions Present analysis used PLANE 182 element which is available as two dimensional four modeling solid structures . This element was used in 2 - D modeling of solid structures . The element used was plane (plane stress, plane strain or generalized plane strain) and an axisymmetric element . It was identified by four nodes and each node has two degrees of freedom: translations in the nodal x and y directions.

The element has a wide range of plasticity and hyper elasticity with a good stress stiffness. Also during the plastic range it has large deflection, and large strain capabilities. Moreover it has mixed simulating deformations nearly incompressible elasto plastic with fully incompressible hyper elastic materials.

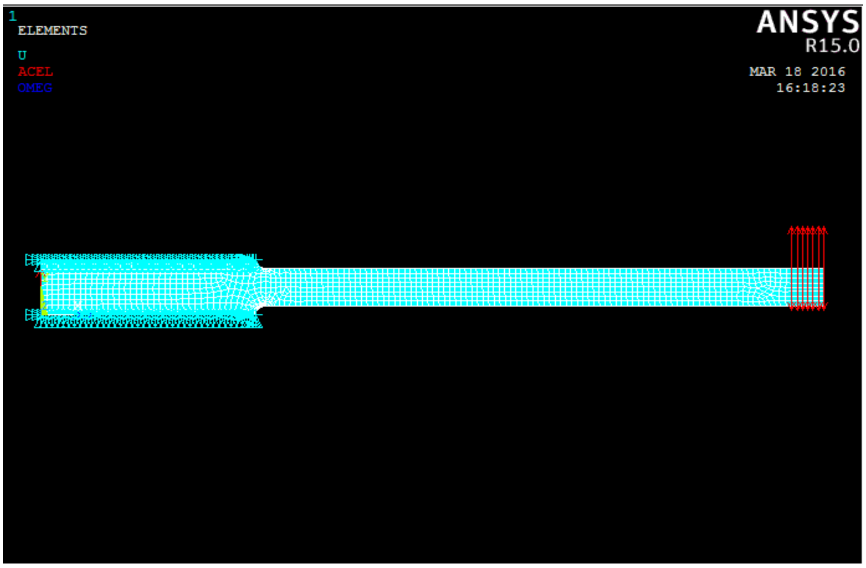

Fig. (3): Cantilever beam with boundary conditions (Meshed model)

Scanning electron micrograph was used for AA6063 alloy under the same temperature and different holding time s.

4 RESULTS

The tensile tests was done at room temperature and 350 with various (holding time) ranging 2, 4, 6 and 8hour using water solution treatment. Table 1 shows values of n, K, , , , , , E for AA6063 and samples of AA6063 at same heat treatment temperature of 350C at different holding time Viz. 2, 4, 6 and 8hour..

Table (1): The monotonic properties of AA6063 at same heat treatment temperature 350 with different holding time

Conditions	n	σ_f	K	σ_{true} Fracture	σ_y (MPa)	σ_{Max} (MPa)	$\varepsilon_{Frac.}$	E (GPa)
As Received	0.25	859.5	776.2	237.49	169.67	214.80	0.2745	68
350°C_2hours	0.28	398.4	338.8	345.91	60.06	117.30	0.2940	60
350°C_4hours	0.27	337.53	288.4	341.15	59.48	106.16	0.3010	58
350°C_6hours	0.342	424.22	343.55	363.5	41.70	106.13	0.2885	57
350°C_8hours	0.49	1196.0	864.9	379.82	34.70	99.10	0.2960	55

Strain hardening index (n) was found using the slopes, and the strength coefficient (K) was found by intercept the y-axis at ,using the equation σ=K . This shows the strain hardening index (n) and strength coefficient (k) was variable with the holding time .

Cyclic data was collected from fatigue test of cantilever beam for AA6063 sample. This sample was heat treated at 350 for different holding time of 2 hours. Figure 4 shows relation of strain life for the sample used. This figure shows the total strain curve which includes the elastic strain-plastic lines. Also the plot shows the transition fatigue life (NT) and elastic region with plastic region. In the same way it gives the low cycle fatigue data for different cases of holding time i.e. 4, 6 and 8 hours. The strain-life relations for these three cases was plotted in Figures (5, 6 and 7). Figure 8 illustrate curves of total strain-life for AA6063 heat treated at 350 and holding time of 2, 4, 6 and 8hours for low cycle fatigue test. The result shows the sample heat treated at 350 with holding time of 6hours have the maximum transition fatigue life. Table 1 illustrated different fatigue parameters , /E , b, c, n′, K′ and NT different holding time cases.

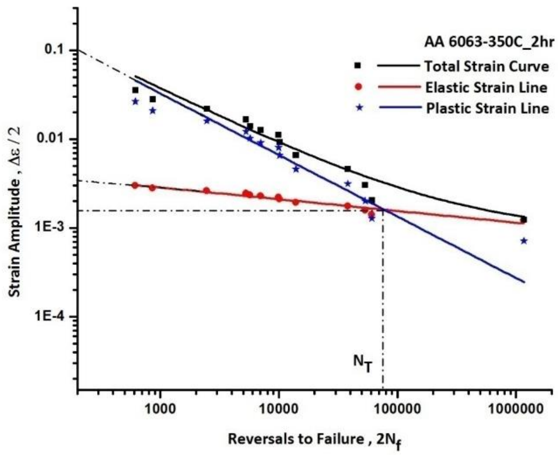

Fig. 3 Strain life of AA6063 alloy at 350 and holding time of 2hours

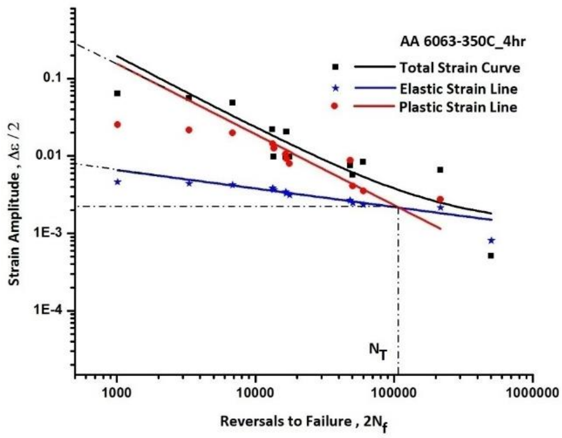

Fig. 5 Strain life of AA6063 alloy at 350 and holding time of 4 hours

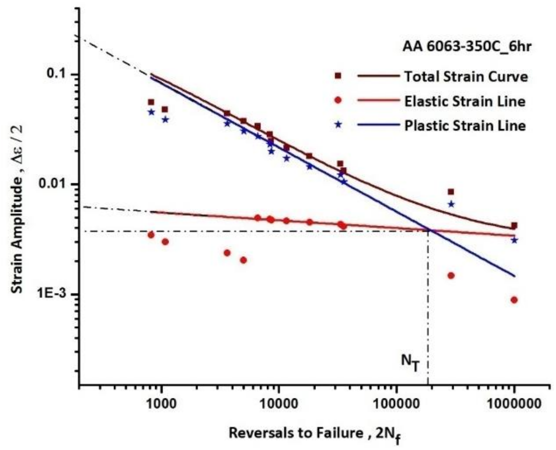

Fig. 6 Strain life of AA6063 alloy at 350°C and holding time of 6hours

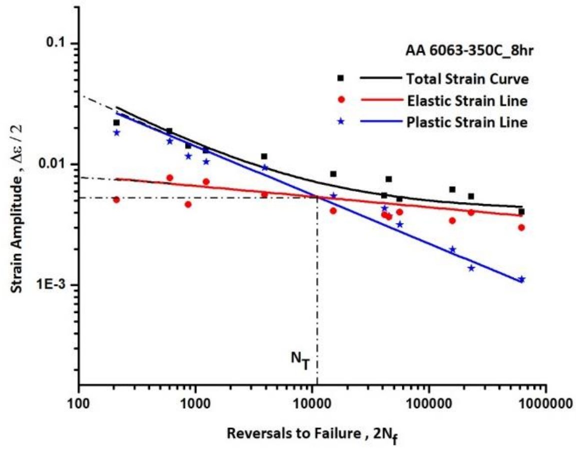

Fig. 7 Strain life of AA6063 alloy at 350°C and holding time of 8 hours

Table 1 Low cycle fatigue properties of aluminum alloy AA6063 at different holding time and same heat treatment temperature 350°C

6063 Alloy	*Cyclic plastic strain (Fatigue Ductility coefficient) ε_f'*	*Cyclic elastic strain σ_f'/E*	*Fatigue Strength Coefficient σ_f' (MPa)*	*Fatigue strength exponent b*	*Fatigue ductility exponent c*	*Cyclic strain hardening exponent n´*	*Cyclic strength coefficient K´ (MPa)*	*Transition fatigue life N_T (cycles)*
6063-T6	0.69	0.00862	586.16	-0.105	-0.72	0.14583	618.75	2170
6063-350 °C _2hour	0.0965	0.00359	215.4	-0.13	-0.6	0.216	356.93	70914
6063-350 °C _4hour	0.3812	0.00921	534.18	-0.07	-0.41	0.1707	629.77	59652
6063-350 °C _6hour	0.231	0.006013	342.72	-0.067	-0.65	0.10307	398.59	158321
6063-350 °C _8hour	0.0427	0.00724	398.2	-0.070	-0.45	0.1555	650.23	7364

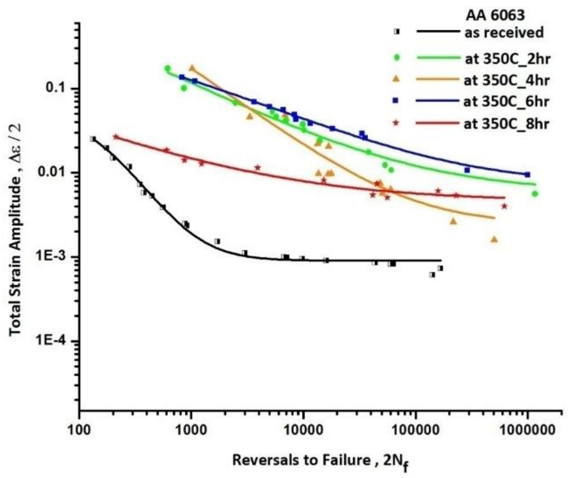

Fig. 4 Strain – Reversals to Failure Curve for AA6063 at different holding time and temperature 350

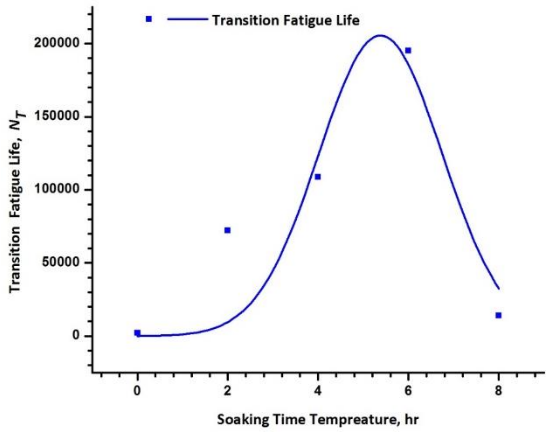

Fig. 9 Transition fatigue life at different holding time and temperature 350

Variation of transition life with soaking is shown in Fig. 9. It can be observed from the figure that NT is maximum at 6 hour holding time while it is increasing till 6 hour and their after it decreases.

Table 2 and Table 3shows the numerical value of elastic strain is not good enough while that of plastic strain is satisfactory. The values of elastic and plastic strain obtained by Morrows method was good..

Table 2 Comparison between experimental, numerical and theoretical results of elastic strain for AA6063 at different holding times and same heat treatment temperature 350

Condition	*Force (N)*	*Cycles*	*Elastic Strain*		
			Exp.	FEM	% Diff.
6063-350°C_2hour	85	613	0.00389	0.0037236	4.27
6063-350°C_4hour	65	1012	0.00236	0.0022598	4.24
6063-350°C_6hour	60	819	0.00323	0.0028914	10.49
6063-350°C_8hour	60	211	0.00231	0.0025226	9.2

Table 3 Comparison between experimental, numerical and theoretical results of plastic strain for AA6063 at different holding times and same heat treatment temperature 350

Condition	*Force (N)*	*Cycles*	*Plastic Strain*		
			Exp.	FEM	% Diff.
6063-350°C_2hour	85	613	0.09838	0.10153	3.2
6063-350°C_4hour	65	1012	0.06411	0.056009	12.6
6063-350°C_6hour	60	819	0.05366	0.054729	1.99
6063-350°C_8hour	60	211	0.01979	0.021745	9.8

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Figure 10 shows the microstructure features of optical Micrograph pictures at variable magnification before and after fatigue test.. It is observed that Silicon (Si) and Magnesium (Mg) particles are observed in Fig. 10 (a,c) at magnification of 50x . The micrograph pictures shows no visible crack before test.

However after test cracks are generated at the grain boundaries as observed from Fig. 10 (b) at 50x magnification and Fig. 10 (d) at 100x magnification. Slip-Band dislocation are also observed in these figures

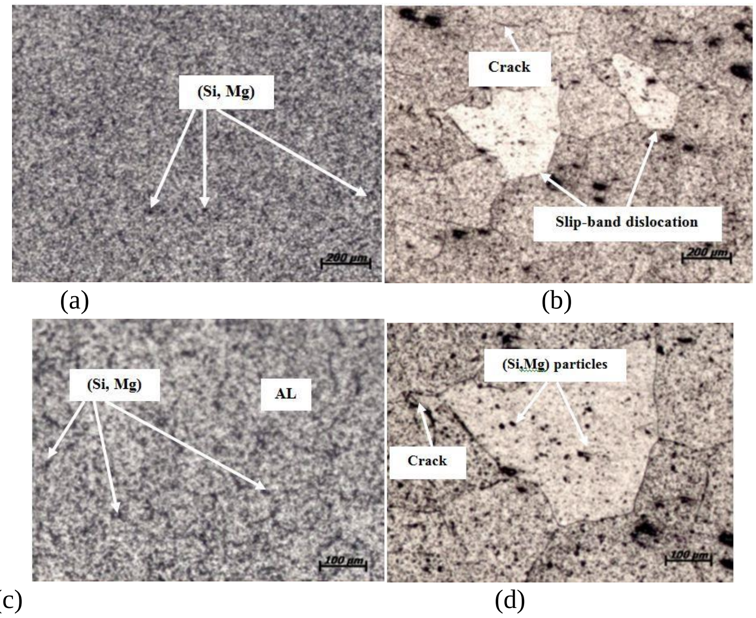
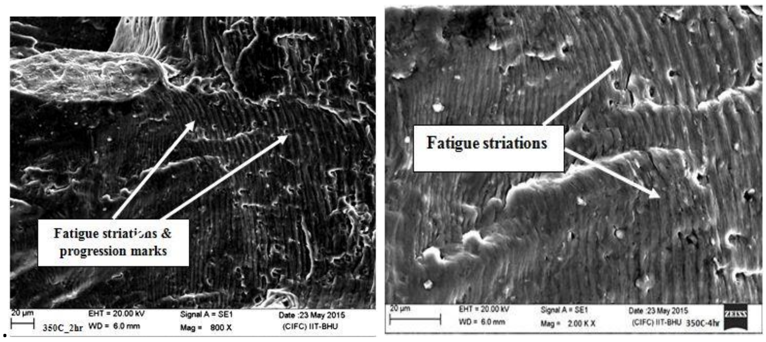


Fig. 10 Optical micrograph pictures of AA6063samples
(a) 50x magnification before the test (b) 50x magnification after the test
(c) 100x magnification before the test (d) 100x magnification after the test

It may be seen from these SEM pictures that dimple morphology was predominant at room temperature as and other long holding time of heat treatment.

Figure 11 shows SEM pictures for AA6063 samples heat treated at different temperatures and at different holding time . These pictures clearly show the progressive direction of fatigue crack which resemble to river on physical map.

Ductile fracture is prefixed by macroscopic plastic strain because of plastic deformation in the slip planes. The slip occurs due to high resistance to fracture of cleavage planes also at grain boundaries. ductile fracture is similar to fibrous fracture due to its shear fracture of the mechanism of crack propagation



(a) (b)

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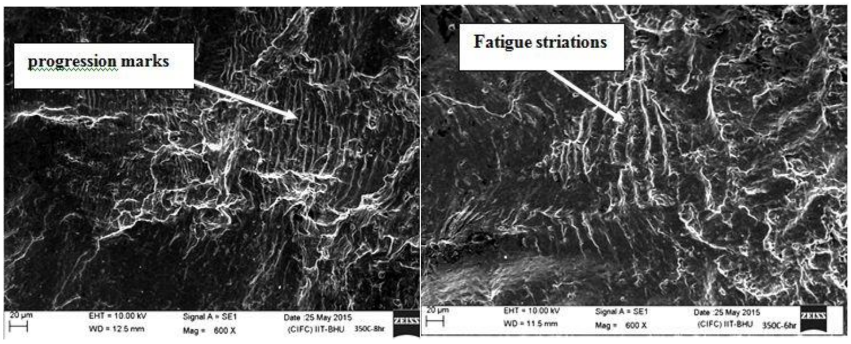

(c) (d)

FIG. 11 SEM FACTOGRAPH (SEGMENT) FRACTURE SURFACE OF THE FATIGUE TESTED AA 6063 AT DIFFERENT HEAT TREATMENT CONDITIONS:

(a) 350ºC_2hour, (b) 350ºC_4hour , (c) 350ºC_6hour, (d) 350ºC_8hour

Progression Marks (beach marks) can be seen at high magnification, these marks explain the progress crack across the test piece. This crack present only when there are variations in stress as the crack increase across the piece . Figure 11 shows the regular fatigue striations because of regular load, one striation per cycle, also it called ductile striations with , regular, large size and spacing.

CONCLUSIONS

1. Yield strength continuously decreased with the increasing holding time for the heat treatments, Similarly, tensile strength founded to continuously decreased.
2. The strain hardening index n and coefficient strength K were increased as the holding time temperature increased, drastically Strength coefficient K decreased at 350^{o}C-6hour, similarly with fatigue strength exponent b and fatigue ductility exponent c they increased when the holding time temperature increase only some dropping at 350^{o}C-6hour.
3. Cyclic elastic strain ( ) not much change with the increasing the time at same temperature 350C, and it is same for fatigue strain coefficient , for the cyclic plastic strain .
4. The different values of fatigue life was defined as the total numbers of cycle to cause failure, Nf at different strain amplitude components.
5. The cyclic strain hardening index n' and strength coefficient K' decreasing with increasing the holding time .
6. Transition fatigue life NT oscillated with the holding time , but the high cycles life reported at higher soaking.

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