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# Microwaves Furnace Heat Effect on Aluminum Alloy 7075-T73

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***Abstract*- This paper focusing upon the effects of microwave wavelengths processing when treating AA7075-T73 in microwaves furnace within 1 liter from salt solution, acid and oil at duration time of (30 and 60) min. Where microwave furnace energy lead to many effect on the surface of aluminum alloy, changing the mechanical properties like hardness, ultimate stress, resistance to fatigue life and surface roughness. The results revealed that the microwave furnace heat energy were variations in the mechanical properties with the variation in mediums and duration times without treatment of samples. The ultimate stress, yielding stress and fatigue strength decreased for all states compared with standard values. With reference to fatigue life, the results showed that the major increment in fatigue life occurred for test states of oil in microwave furnace with time of 30 to 60 min respectively, which were (83% and 75%), respectively. Moreover, the increment in hardness range was reached for test state of acid 60 min which was about 7.5 % and only 3% for salt solution medium in 60 min.**

***Keywords—Microwave Furnace, Heat Treatment Mechanical properties, Fatigue life, Aluminum Alloy*.**

## I. INTRODACTION

Microwaves usually considers as a portion of electromagnetic waves in a ranging of frequencies that holds between 300MHz and 300GHz [1,2]. However, 2.45GHz and 915MHz are usually the most microwave frequencies that commonly-been used for the research fields and the application of industrial activities [3]. Microwave technology developed very quickly especially during the second world war because of the excessive demand for better industrial technology applications [4]. When occurrence upon different materials, microwave radiation interacts in different ways, dependent on the electrical and magnetic properties of the material and the penetrative power of microwaves. In microwave energy heating, heat can be formed or generated from the core of the material itself because of the absorption of microwave energy by the material directly and/or it does not depend on the heat transfer from or among the specimen surfaces. The depth of penetration occurs by microwaves usually varies greatly through different materials and is dependent upon many elements such as the magnetic and dielectric properties, microwave frequency, size, power, temperature, densification and conductivity of the different materials [5]. In microwave furnace heat energy, the energy is transported and/or curried directly to the material through molecular itself by interaction with the electromagnetic field between them. Where, the heating is occurring due to the transferring of electromagnetic energy heat into and by thermal energy and the mechanism is represented by energy conversion rather than heat transfer. The Microwave heat energy interaction is also curry through either polarization or by the fundamentals of conduction processing only [6]. Microwave heat energy material processing technology has gained very much interesting due to the relatively low manufacturing and/or costs, the fast sintering process, higher energy efficiency, short soaking time, due to both energy and time saving, also, high yields and improved product uniformity [7,8]. In microwave heat energy furnace processing, microwave furnace energy will heats the alloy surface through the refluxing waves at some determinant varies heat levels, which will in some cases leads to a uniformly bulk heating, that will conversely in the fundamental of conventional heating systems, the alloy will be heated from inner core to the surface also by the wavs absorbs by the material which produces thermal stress and/or longer time consumed or required for the homogenization prosses [9].

## II. EXPERMANTAL TECHNIQUES

### A. *The Materials*

7XXX series of the aluminum alloys family have been used very widely in aeronautical industries, space technology and application as some very suitable structural materials due to their attractive comprehensive properties, such as high strength, toughness, high stiffness, low density, long life, suitable ductility, and resistance to fatigue wear [10], Also it is attracting very much attention because of their favorable properties of strength-to-weight ratio and corrosion wear resistance that compared to other conventional available stainless steels [11,12].

### B. *Specimen Preparation*

AA7075-T73 plat with thickness (3mm) formed to a standard test specimen (tensile, fatigue life) by CNC machine. The sample profile was obtained using a milling machine with a special fixture to achieve specimen geometry in accordance with the standard [ASTM E8M] [13].

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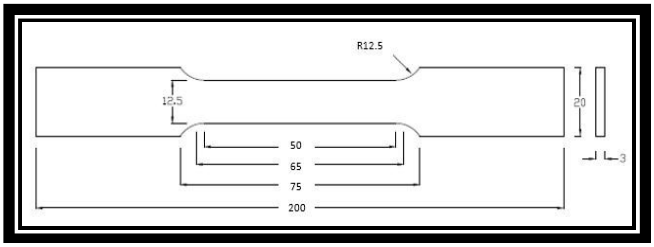



Fig. 1. Standard Tensile Test Sample, dimensions in mm for the selected specimen [ASTM E8M]

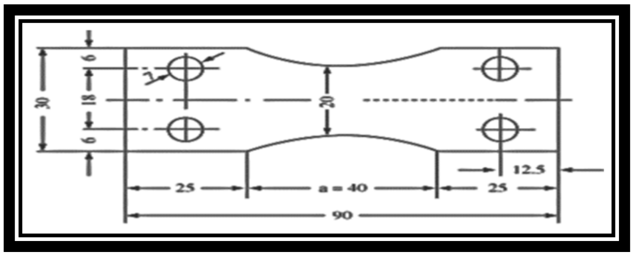



Fig. 2. Standard Fatigue Test Sample with thickness of 3mm all dimensions in mm for plane sample [Avery Manual]

### C. Process Parameters

The study investigation was carried out on AA 7075 composition. The chemical composition of the alloy was conducted by the device (Spectrometer, ARC. MET 8000, 2009). The effects of the test are shown in Table (I) together with the standard materials for comparison resolves. material used is plat of AA7075-T73.Thermal treatment in this study, the samples are subjected in a microwave furnace type (Lifetec Mikrowelle 2450 MHZ, 900W) in 1 liter from salt solution (50% salt percentage), acidic mediums (organic vinegar, acidity 4-6 %). and oil (sunflower oil) treated in microwave furnace at (30 and 60 min), The reason to selecting such interval time is from formal research [7]. The mean idea is to estimate the effects of thermal energy arrived by the heat weaves of microwaves furnace. Then the samples were left to be cooled slowly inside the microwave furnace.

TABLE I. CHEMICAL COMPOSITION OF THE AA ALLOYS [ASTM]

| Component | % Si | % Fe | % Cu | % Mn | % Mg |
|---|---|---|---|---|---|
| [ASTM] | ≤0.4 | ≤0.5 | 1.2-2.0 | ≤ 0.3 | 2.1-2.9 |
| Used | 0.28 | 0.26 | 1.51 | 0.21 | 2.24 |
| Component | % Cr | % Zn | % Ti | % other | % Al |
| [ASTM] | 0.18-0.28 | 5.1-6.1 | ≤0.2 | ≤0.15 | Rem. |
| Used | 0.265 | 5.18 | 0.03 | 0.098 | Rem. |

### D. Mechanical Properties Testes

1. Tensile Test according to the ASTM B557M – 15: Specimen is the most important component of any tensile testing test, because it will determine the actual estimated physical and/or mechanical properties of the selective material that had been tested. Samples were tested from any each heat-treated application condition and/or as simply cast samples. using a computerized (50KN Tinius Olsen) electromechanical testing machines.
2. Test of Estimated Fatigue life by Avery test: A fully reversed reciprocating plane bending fatigue testing machine of the type AVERY DENISON-7305, was used in this research, to carry out the fatigue testing. The tests were undertaken in stress controlled with a stress ratio R= -1 and the cycling rate is 1400 rpm (f=23.6 Hz). The machine is provided with a cycle counter. This cycle counter records the number of cycles in multiples of thousands.
3. Hardness Tests according to the ASTM E110 – 14: The heat-treated specimen by microwaves heat energy samples were subjected to the (Rockwell Hardness Testing Machine) after the specimen samples were prepared, polished and mounted on the machine, then, applied a dwell time of 15sec.
4. Surface Roughness Tests: The state of any machined surface could be indicated by surface roughness. Roughness is an important part in calculating how an actual thing will interact with its surrounding. The test was done by (Surface roughness testing machine type Pocket surf IV).

## III. RESULTES AND DISCUSSION

First, the temperature was estimated experimentally for each medium as shown in the Table (II) below. Secondly, related to the mechanical properties, the results are illustrated after all tests processes Table (III).

TABLE II. TEMPERATURES OF MEDIUMS

| State | Temperature (°C) | |
|---|---|---|
| | *30 min* | *60 min* |
| Salt Solution | 78 | 92 |
| Acid | 70 | 75 |
| Oil | 193 | 218 |

For the mechanical properties results, these results were estimated after four test processes are: -

1. The ultimate tensile stress, which reduced in all groups compared with standard values. Where maximum reduction of 44.5% was for test group of oil 60min in a microwave furnace. There was increment of 25.6% for the test group of oil 30min. For salt solution medium 60min in a microwave furnace only 17% reduction was seen.
2. Also, it was found that a decrement in extension percentage due to the decreasing occurs in the yielding. The reason for this phenomenon is that heat created by microwave furnace only hardened the surface of the alloy, while the core of the alloy stays the same. Also, when the surface cooled, the grain cells became smaller compared with the internal grain cells which was still at its original size as it was cooled in a slower rate. So, when a sample was tested for tensile test and checked the results found a

decrement of about 65% for oil 60 min group, while the decrement for group of oil 30 min in a microwave furnace was 40%, with salt solution medium was 31% only.

3. For Extension (i.e. elongation at the break point), the results show raising in the brittleness of the specimen alloy usually this may be due to the excessive heat energy arrived from the microwaves furnace with respect to time duration differences, Hence, this might have made little changes in phases of the alloy specimen surface that causing the grain size of alloy specimen to be shrinking. The extension of the alloy specimen is generally reduced from specimen without treatments that be considered as reference due to the same above reasons, but the major decrement was occurring for the specimen test group of salt solution medium with 60min in a microwave furnace heat energy of about 41.6%, while for the test group of oil with duration time of 60min group was about 25.5%. A little decrement of about 22% of the test group of acid 60 min in a microwave furnace heat energy, and only about 15% for the test group of oil with duration time of 30 min than that of its references.

4. For the modulus of elasticity, there was no observed variation for all test groups and duration times.

5. For the results of fatigue strength, there was observed changes. Where the test group of oil with duration time of 60min in microwave furnace heat energy with decreased of about 44.5% lower than references. While 25.6% for test group of oil with duration time of 30min group, 17% for salt solution test group with duration of 60min group. But in acid testing group for both (30 and 60) min mediums tests, very little effects showed, that could be assumed as not effected.

6. For the surface roughness tests, it noticed that when time increasing, temperature increase, and the surface roughness increase see Figure (5). The majority effects were at duration time of (60 and 30) min with testing group of acidic mediums (133% and 66%) respectively, because of corrosion occurred on the surface of the sample led to initiation pits which increase surface roughness with increase duration time, for salt solution with duration time of 60min test, increasing in salt precipitation was occurred led to raise the surface roughness to 47.8%, while the salt solution testing group with duration time of 30min shows 26.7%. For oil medium test group, noticed a decreasing in surface roughness of about 16% for duration time of 30min group and 1.7% for duration time of 60min test group. That occurred because of the oil effect on the samples surface, where it causes insolated the surface on environment condition and prevent oxidation and corrosion, so the surface become more smooth compare with other mediums.

7. For the estimation fatigue life tests, through applying a high cyclic fatigue tests at amplitude stress of 100 MPa, the major increment in fatigue life occurred for test groups of oil with duration time of 30min and 60 min respectively in a microwave furnace heat energy of about (83% and 75%), that compared with its original life, where the test group of oil medium causing insolated the surface from the environment condition, so it was filled the porosities and prevent surface oxidation. This state led to remain the surface smooth without pits or surface cracks, a general form of life equation by using ***Basquin Formula*** [14], $\sigma_a = \sigma_f N_f^{-b}$ Table (IV). The salt contains in salt solution medium and acidic percentage in acidic medium led to corrosion in the surface and occurrence of pits on it. These pits are the places for the initiation of cracks, so the higher surface roughness causing increment in crake propagation, therefore decreasing the fatigue life. Where for a test group of acid 60 min the decrement was about 75 %,62.5% for acid 30 min group, for salt solution at (60 and 30) min groups test the decrement in fatigue life were 41.7% and 25% respectively.

8. For hardness, depending on the thermal properties of the medium containing the samples, the heat loss rate differs from one medium to the other, which affects the hardness of the surface of the heat treatment. In the oil medium, the smallest magnitude of hardness was obtained because the heat loss rate inside the microwave is very slow compared to the other mediums and the decrement percentage in hardness for oil test group with duration time of 30min and 60min respectively in microwave furnace heat energy was about 9.5% and 11.7% respectively. While in the acid and salt solution mediums founded that the heat loss rate is faster, with minor differences in hardness values. The higher increment value was about 7.3% for a test group of acid with duration time of 60min in a microwave furnace heat energy and only 3% for test group with salt solution medium with duration time of 60min from standard without treatment samples

1. The variation in duration time according to heat amount and/or for different medium conditions. The change magnitude in mechanical properties as far as estimated fatigue life, even if it could be considered as not high for some test groups but it was significantly noticed especially if we consider this application as safe and less expensive when compared to other applications.

TABLE III. MECHANICAL PROPERTIES OF ALUMINUM ALLOY 7075-T73 FOR ALL GROUPS

| State / Property | Stan. | Salt Solution | | Acid | | Oil | |
|---|---|---|---|---|---|---|---|
| | | ***30min*** | ***60 min*** | ***30 min*** | ***60min*** | ***30 min*** | ***60 min*** |
| σUlt (MPa) | 496 | 485 | 411 | 485 | 482 | 369 | 275 |
| σy (MPa) | 385 | 380 | 265 | 380 | 365 | 230 | 135 |
| Extension % | 18 | 16.5 | 10.5 | 16 | 14 | 15.3 | 13.4 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fatigue Strength Sf (MPa) | 223 | 218 | 185 | 218 | 217 | 166 | 124 |
| Modulus of Elasticity E | 76.3 | 75.3 | 75 | 75.7 | 76 | 75.4 | 77 |
| Hard. HR Rockwell | 89.5 | 87 | 92 | 86 | 96 | 79 | 81 |
| Surf. Rough. | 0.6 | 0.76 | 0.88 | 0.99 | 1.4 | 0.5 | 0.56 |

TABLE IV. REPRESENT OF BASQUIN EQUATION (AMPLITUDE STRESS) ΣA MPA

| State | | $\sigma_a = \sigma_f . N_f^{-b}$ |
|---|---|---|
| **Standard** | | $\sigma_a = \sigma_f . N_f^{-0.079}$ |
| **Salt Solution** | *30 min* | $\sigma_a = \sigma_f . N_f^{-0.0912}$ |
| | *60 min* | $\sigma_a = \sigma_f . N_f^{-0.096}$ |
| **Acid** | *30min* | $\sigma_a = \sigma_f . N_f^{-0.1157}$ |
| | *60min* | $\sigma_a = \sigma_f . N_f^{-0.105}$ |
| **Oil** | *30 min* | $\sigma_a = \sigma_f . N_f^{-0.0614}$ |
| | *60 min* | $\sigma_a = \sigma_f . N_f^{-0.067}$ |

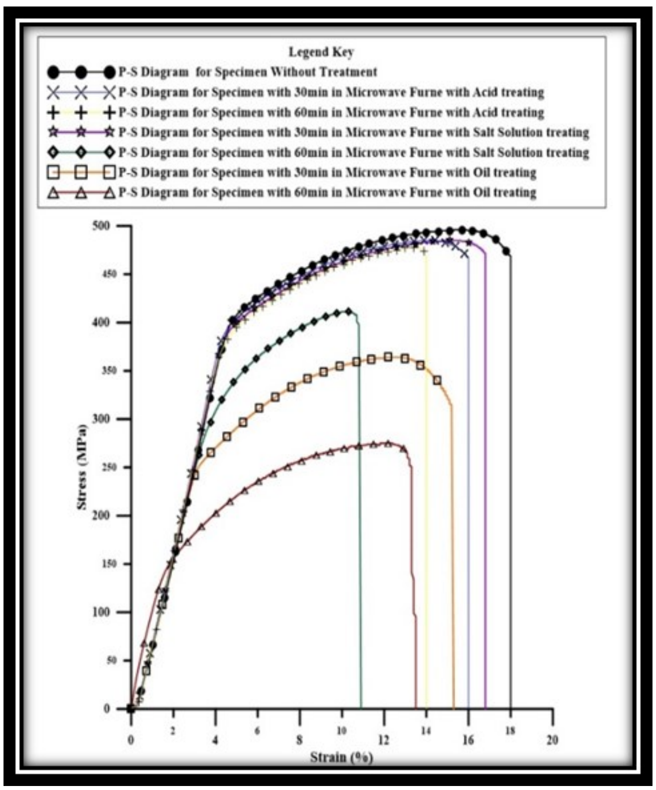



Fig. 3. Stress – Strain chart for tensile test of all tests samples.

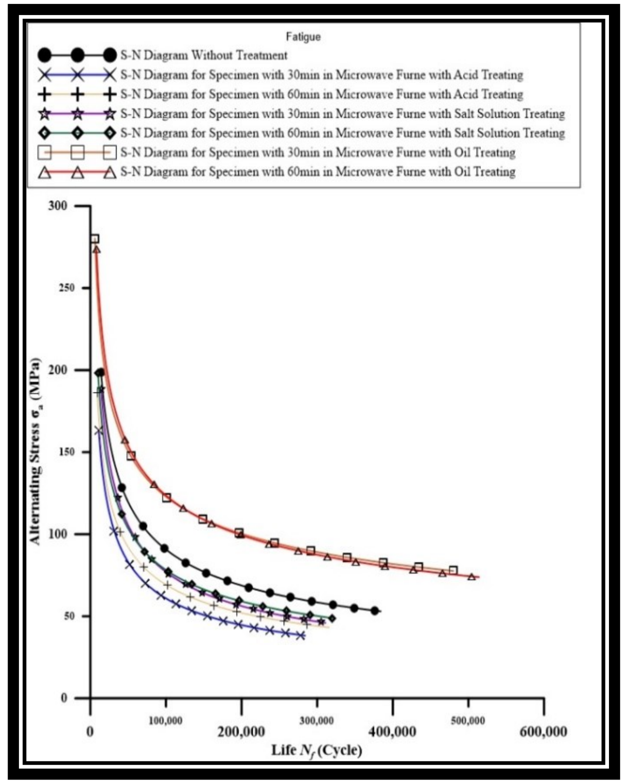
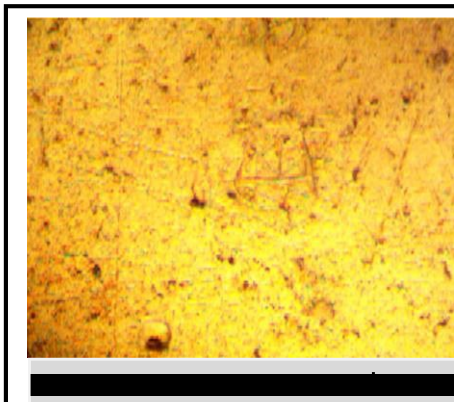
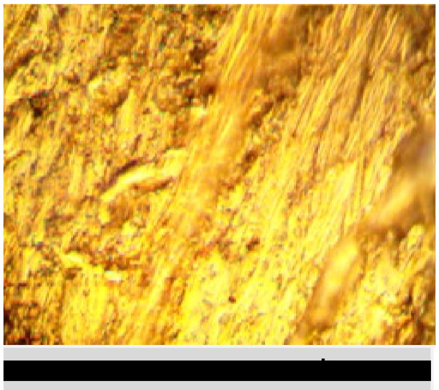



Fig. 4. S – N Curves for all the Fatigue tests sample

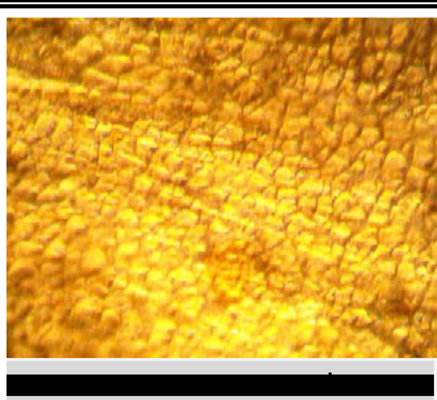


a) Standard

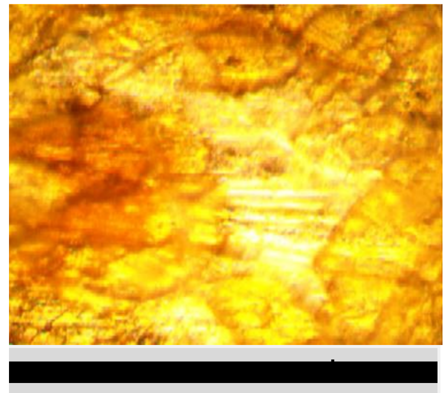


b) Salt solution30 min

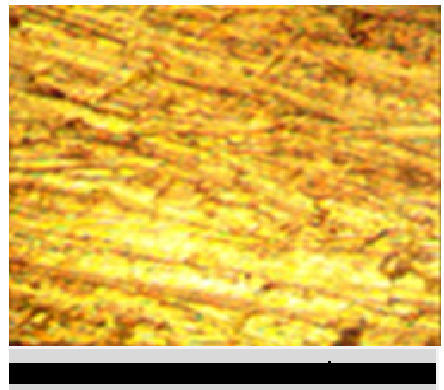
c) Salt solution 60 min



d) Acid 30 min



e) Acid 60 min



f) Oil 30 min

g) Oil 60 min

Fig. 5. Topography of AA 7075-T73 in mediums

## IV. Conclusions

From this research, the following conclusions are drawn:

1. The major conclusion in this research was that, for appropriate microwaves furnace heat energy and with set of duration time, an acceptable effect on some of the

mechanical properties including calculated fatigue life, and/or ultimate stress and yielding stress for the specimen alloys that had been used.

2. Using microwave furnace heat energy application technique reduces both time and cost consumed when compared with other traditional surface heat treatments.

3. In general, the salt contains in salt solution medium and acidic percentage in acidic medium led to corrosion in the surface and occurrence of pits on it. These pits are the places for the initiation of cracks, so the higher hardness of the surface and high surface roughness led to increasing in crake propagation, therefore decreasing the fatigue life.

4. In general, the oils working to insulate the surface from the environment condition so prevent surface oxidation and close porosities. This state led to remain the surface smooth without pits or surface cracks therefore the fatigue life was longer than salt solution and acidic mediums.

5. Since, microwaves furnace heat energy application in industrial field. It was clearly noticed that these microwaves furnace changes the materials mechanical properties in different levels than that for classical heat treatment methods. This change depends upon the parameters applied from changing the time duration to heat amount and different conditions. The magnitude of mechanical properties that changed even if it was not huge in some properties but clearly noticed especially if we know that this application is safe and cheap with respect to other applications.

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