Study The effect of Microwave Furnace Heat Energy Effects On Mechanical Properties And Estimated Fatigue Life of AA2024-T3 and AA7075-T6

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Abstract
The research aims to make a comparison between two highly used aluminum alloy though studding the effects left by the microwave furnace wavelengths by (middle dry and amid aqueous solutions) on the mechanical properties and estimated fatigue life of highly resistant widely use aluminum alloy AA 7075-T6 and AA 2024-T3. Since the microwave effect differ from other heating methods through its effects (Heat Transfer) r heating methods effects on the surface of the alloy, which might change some of its properties as well as resistance to fatigue, also to see how this effect changes from alloy to another through this study. The results show some great effects on both mechanical properties and estimated fatigue life for both alloys but with different levels. This new technique is differing from other traditional heat treating ones that is simple, cheap and fast accurate method than the other techniques.
There is a common misconception about the use of minerals in microwave ovens and the concept is unscientific and based on false grounds and simplest proof of that is that most of these ovens are built from the inside metal fully, how dangerous this is consistent? This research aims to focus on and remove those problematic and misconceptions.

Keywords: Microwave furnace, Mechanical Properties, Fatigue Life.

1. Introduction
Aluminum alloys has a low density with normal strength and relatively a very good resistance for corrosive. Both strength and hardness of the alloys were extremely needed to be improved in any engineering applications. So, to apply this, a heat treatment process is needed in order to improve the mechanical properties of such alloys. In many modern researches a microwave furnace energy has been used in a wide range of applications like medical therapy industrial modern application and food keeping processing etc. In this work, a microwave furnace energy has been used, as one of the most modern application and one of the greatest material processing techniques to improve mechanical properties of metals. At this work, a newer technique including microwave furnace post heat treatment of specimen core to surface were employed. A period microwave furnace was used efficiently to process AA2024-T3 and AA7075-T6. In microwave furnace processing, microwave furnace energy heats the alloy at a different heat levels, which will might leads to a uniformly bulk heating, conversely in the conventional heating systems, the alloy heated from the surface to inner core which produces thermal stress and/or longer time required for homogenization. A heat-treating process by microwave furnace can be used for a wide application of surface treatments such as carburizing, carbonating, chromizing, and bronzing. The fracture strength, toughness and hardness arrived from microwave furnace energy of treated specimen components were reported to be higher than others conventionally heat treated application ones. The research concentrated on the mechanical properties and estimated fatigue life effected by the microwave furnace energy heat treatment of the alloys used. In this work two sheets of AA2024-T3 and AA-7075-T6 was heat treated using microwave furnace energy at 4GHz and 1500W and the estimated fatigue life as long as its effect on mechanical properties is discussed and compared in this work in details.

2. Tests and Material Selection
In this work, the material used was aluminum alloys AA2024-T3 and AA7075-T6 of sheet metal with 3 mm thickness in order to made a standard tensile test specimen of standard dimension is as shown as in Figure (1). Where the gauge length (60 mm), shoulder length (75 mm), (R = 40 mm) for plane sheet spacemen and overall length (165 mm). The tests were taken at the COSQC-Baghdad (Central Organization for Standardization and Quality Control) according to the ISQ (Iraqis Specification Quality) 1473/1989, the tests were included general properties such as hardness, strength, toughness …etc. the results are as shown as in Table-1.

The chemical composition tests were done at the COSQC-Baghdad according to the ISQ (Iraqis Specification Quality) 1473/1989 by the device (Spectrometer, ARC. MET 8000, 2009) shown in Figure (2). These tests result and standard are shown in Table-2.

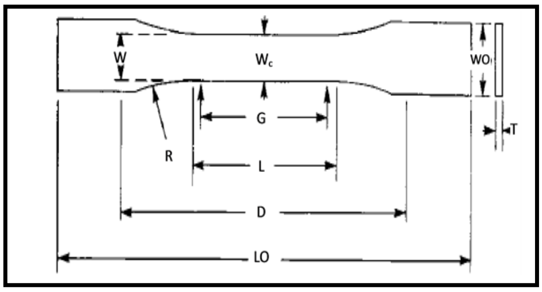

Figure 1: Standard Tensile Test Specimen with (T=3, LO=165, W=WC=12.5, WO=20, D=75, L=65, G=60 and R = 75, (Note that all dimensions in mm) for plane specimen [ASTM D-638-I]

Figure 2: AMETEK Material analysis division instrument

3. Tensile Test [ASTM E9M]

The most important component of tensile testing test is specimen, because it could determine the actual physical and mechanical properties of the material which had been tested. The selected specimen for such tests must conform to exact physical dimensions and it must be free of heat distortion or induced cold working. Specimen must be personnel and accurately calibrated as long as the tensile machines and this is very important before applying the test, because these test results were based on the accuracy and quality of the test specimen that been used. A preparation steps including a precision milling machine, highly skilled machinist and considerably highly skills hand finishing can achieve the required configurations of the test specimen needed Figure (3).

Figure 3: Tensile Test Machine Type Tinius Olsen

To achieve accurate results, a test specimen must be prepared accurately and properly. The following rules are suggested for general guidance:

a. Using Standard dimensions and sizes such as ASTM standards and like.
b. Surface finishing is very important in preparing tensile test specimens because it might be affecting on the results.

Other preparation concludes:

1. Grinding the specimen faces and sides with grinding papers (Silicon Carbide) starting from 120, 320, 500, 1000 and 2000 type.
2. Polishing the specimen by polishing instrument (Alumina Powder) of a grain size 0.5 µm.
3. Washing the specimen by water, oil soap and alcohol to remove grinding and polishing remained particles.
4. Finally, smoothly clean the specimen by soft silky fabric until you should almost see yourself on it. Figure (4) shows the specimen before and after polishing.

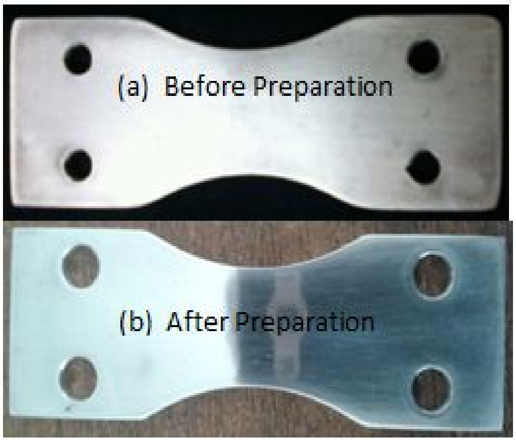

Figure 4: Standard Fatigue Test Specimen Preparation Steps

4. Fatigue Test [Avery Standard Test]

In this research, a fully reversed reciprocating plane bending fatigue testing machine (Bend Test) type Avery Model 7305 with stress ratio R = -1 was used, see Figure (5). To perform the tests, the following steps should be followed:

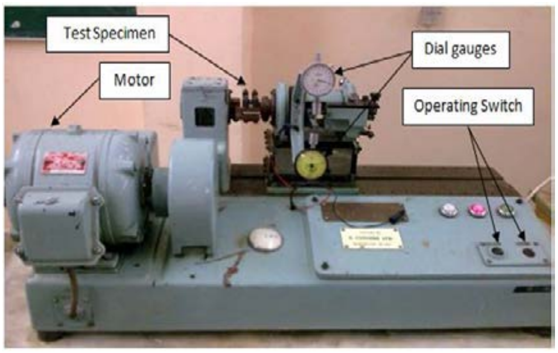

Figure 5: Plane Bending Fatigue Testing Machine Type Avery Model 7305

Step 1: Preparing the Machine:

As said, the machine should be calibrated to stress ratio R = -1 and for that two dial gages were used as shown in Figure (5).

Step 2: Machine Calibration:

Static Calibration: In machines, it is importance to know exactly the speed of the machine, as an error in its speed corresponds might be to a doubled error in the applied load where the load is produced by centrifugal forces or by reciprocating masses. Therefore, the motor speed must be checked and calibrated with the standard, specified in the instruction manual of the machine. These are: 1 HP constant and maximum rating, 1400 rpm, 2 Amperes at start and 380/440 volts, 3 phases ,50 Hz.

Dynamic Calibration: During the operation of the testing machine, a source of error sometimes appears, these errors come from the arrived vibration of rotating parts of the machine, which might lead to errors in the estimated results of the test. In the present work, a rubber isolator was used between the machine and the table to eliminate the inertia effects.

5. Other Mechanical Properties Tests

Other tests included hardening test [ASTM E110 - 14] and surface roughness test [Mitutoyo Standard Test].

The first test was done by (Rockwell Hardness Testing Machine) Figure (6), while the second test was done by (Mitutoyo Surface Roughness Testing Machine) Figure (7), all test was made by the COSQC-Baghdad (Central Organization for Standardization and Quality Control) according to the ISQ (Iraqis Specification Quality) 1475~1476/1989.

Figure 6: Rockwell Hardness Testing Machine

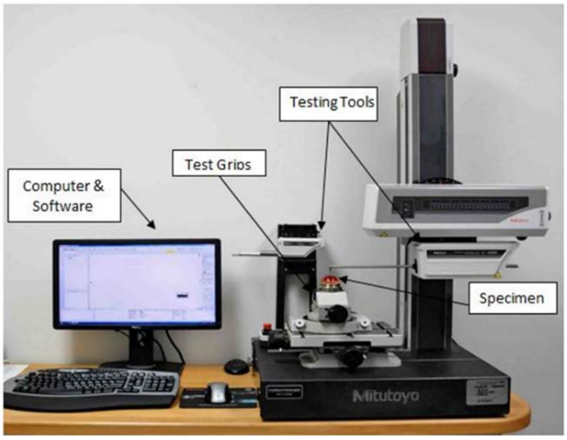

Figure 7: Surface Roughness Testing Machine Type Mitutoyo

6. Experimental Work

According to above a 20th tensile and fatigue specimens model [ASTM D-638-I] and [Avery Standard Fatigue Specimen] should been made and divided into four groups of 5 specimens each, the 1st group were tested dryly for one hour in the microwaves furnace, Figures (10,11 and 12), while the 2nd one were tested for only half hour, a wet test using waterbed for one hour were used to made the 3rd group, and finally the same waterbed test for half hour were made the last group, a comparison between these tests were made as in **Table-3.**

Figure 10: The Microwave Furnace used in this work Type Daewoo

Figure 11: Tensile Test Specimens each three for specific test from right to left (Water 30min, Water 60min, Dry 30min and Dry 60min)

Figure 12: Fatigue Test Specimens each three for specific test from left to right (Water 30min, Water 60min, Dry 30min and Dry 60min)

7. Result and Discussion

For the mechanical properties, the results that been calculated after the four tests processes is as shown as in, **Table-1**.

1. For Hardness, for AA2024-T3, it has been noticed that the major value was for test group of dry 60 min in microwave furnace with increment of about 13% from standard without treatment specimen, while the miner value was for test group of wet tests with 30 min in microwaves furnace of only about 6%. While for AA7075-T6, it has been noticed that the major value was for test group of dry 60 min in microwave furnace with increment of about 15% from standard without treatment specimen, while the miner value was for test group of wet tests with 30 min in microwaves furnace of only about 4%.
2. For both the ultimate and yield tensile strength, for AA2024-T3, there were little enhancement for test group of dry 30 min in microwave furnace of about 20% from its standard values, while for other test groups, there were less of 15% for test group of wet 30 min in microwave furnace and less noticed enhancement for other two group tests of 13% and 5% respectively all according to its standard values, Figures (13). And for AA7075-T6, there were little enhancement for test group of dry 60 min in microwave furnace of about 20% from its standard values, while for other test groups, there were less of 23% for test group of dry 30 min in microwave furnace and less noticed enhancement for other two group tests of 28% and 26% respectively all according to its standard values, Figures (14).

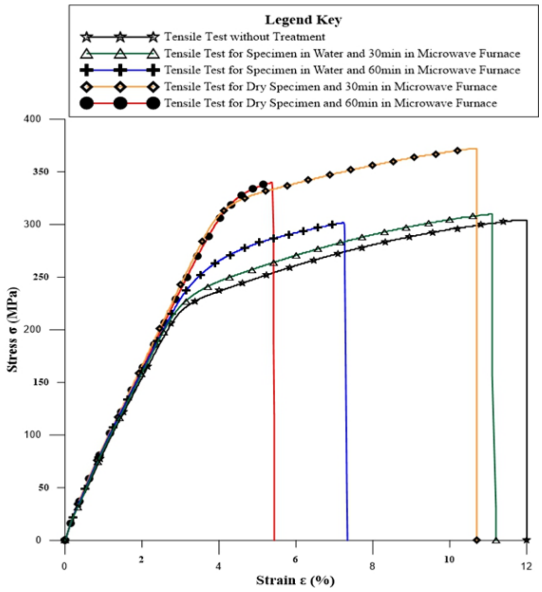

Figure 13: Stress – Strain diagram for tensile test of all tests specimens of AA2024-T3

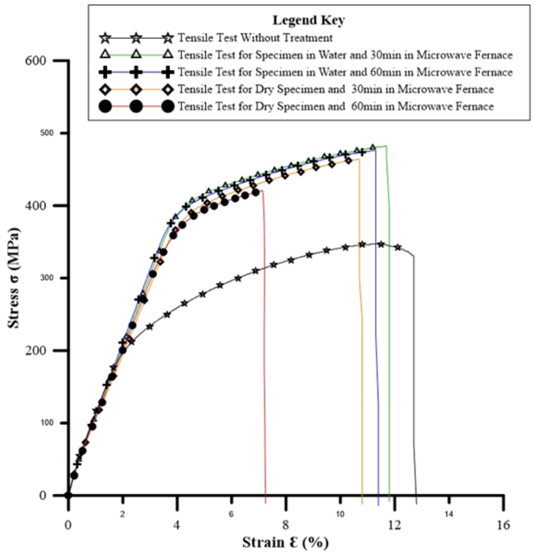

Figure 14: Stress – Strain diagram for tensile test of all tests specimens of AA7075-T6

3. For Elongation at break, for AA2024-T3, the calculated results indicated that the alloys brittleness is increased due to the excessive heat from the Microwaves furnace with respect to duration time, which is maybe or might made some changes in phases of the alloys surfaces leads the gran size of both alloys to decrease. The extension of these alloys is decreased generally from references due to the same reasons above but the major increment was for the test group of dry 60 min in microwave furnace of about 55% and about 40% for test group of dry 30 min in microwave furnace than reference, while there was less increment of about 10.5% for test group of wet 60 min in microwave furnace and only 6.5% for the last group all than its references. Where AA7075-T6, the

calculated results indicated that the alloys brittleness is increased due to the excessive heat from the Microwaves furnace with respect to duration time, which is maybe or might made some changes in phases of the alloys surfaces leads the gran size of both alloys to decrease. The extension of these alloys is decreased generally from references due to the same reasons above but the major increment was for the test group of dry 60 min in microwave furnace of about 18% and about 10% for test group of dry 30 min in microwave furnace than reference, while there was little increment of about 7% for test group of wet 60 min in microwave furnace and only 4% for the last group all than its references.

4. It is also noticed that, for the fatigue strength for AA2024-T3, test group of dry 60 min in microwave furnace was increased its value of about 30% higher than references, while for test group of dry 30 min in microwave furnace there was increment of about 19%. Other test shows very little effect almost not noticed for that parameter. While for AA7075-T6, the test group of dry 60 min in microwave furnace was increased its value of about 29.5% higher than references, while for test group of dry 30 min in microwave furnace there was increment of about 18.2%. Other test shows very little effect almost not noticed for that parameter.
5. For surface roughness of AA2024-T3 & AA7075-T6, the majority effects were at 60min dry test while the 30min wet test shows minimum effect as shown in **Table-3**.
6. There was not a great noticed change in the modulus of elasticity and Poisson's ratio for all tests groups for both alloys.
7. For fatigue life, a high cyclic fatigue tests were used. For AA2024-T3, the major enhancement was also for test group of dry with 60 min in microwave furnace of about 35% increment from its original life and the general equation form of life using *(Basquin equation*, $\sigma_a = \sigma_f N_f^{-b}$) is: $\sigma_a = 142\ N_f^{-0.0766}$. While for test group of dry and 30 min in microwave furnace the increment was about 5% only with equation life, $\sigma_a = 123\ N_f^{-0.0992}$. Other tests groups were less effected on this criterion. Figure (15). Where for AA7075-T6, the major decrement was also for test group of dry with 60 min in microwave furnace of about 25% from its original life and the general equation form of life using *(Basquin equation*, $\sigma_a = \sigma_f N_f^{-b}$) is: $\sigma_a = 156\ N_f^{-0.0655}$. While for test group of dry and 30 min in microwave furnace the decrement was about 7% only with equation life, $\sigma_a = 138\ N_f^{-0.0931}$. Other tests groups were less effected on this criterion. Figure (16).

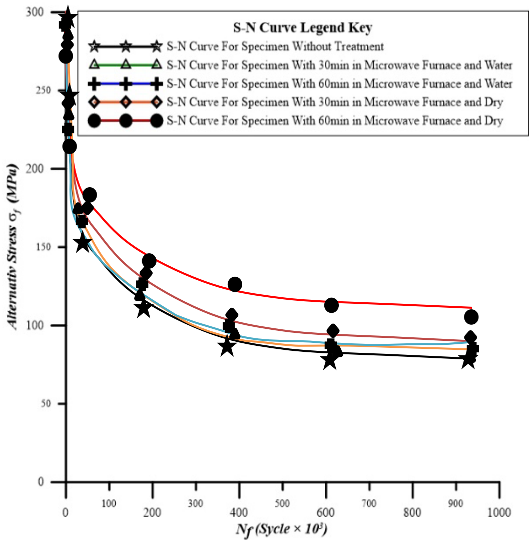

Figure 15: S – N Curves for all the Fatigue tests specimens of AA2024-T3

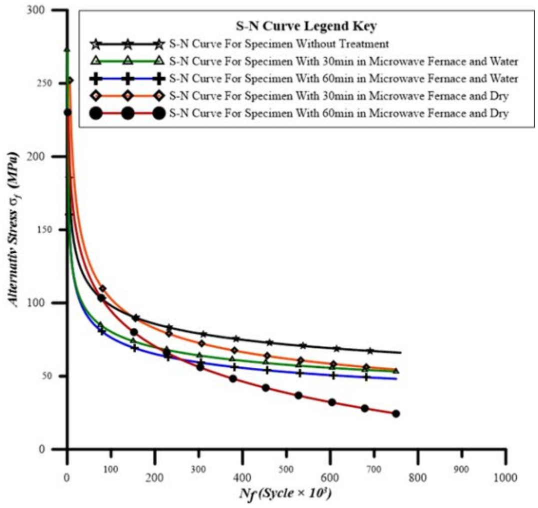

Figure 16: S – N Curves for all the Fatigue tests specimens of AA7075-T6

8. Conclusion

1. Its well-known that the yielding dependent upon nature of the material or alloy, also known that if the yielding increased this leads the materials to became more brittle which decreases the extension percentage at the tensile test and verse versa. Inscrutably in this work it has been found that a certain microwaves furnace duration time could made major effects on one or more of the mechanical properties including fatigue life, ultimate stresses and yielding stress for the alloys used.
2. Also, found in this work that increasing the yielding with decrement in extension percentage too. The result it was found that for AA2024-T3, the increment in yielding was of about 31% for test group of dry

60min in microwave furnace and about 26% for test group of dry 30 min while for group of wet specimen and 60 min in microwave furnace was 15.5% and a decrement in yielding of about 2.5% for the last group. While for AA7075-T6 a decrement of about 18% for test group of dry 60min in microwave furnace and an increment of about 9% for test group of dry 30 min while the decrement for group of 60 min in microwave furnace and with water was 6% and only about 4% for the last group.

3. From this work, it can be found that using a microwaves furnace might be useful if knowing its effects on the mechanical properties because that will shorten both the time and cost of changing these properties into certain levels by only using suitable method and/or duration time and amount of heat.
4. There is no figure out or earlier study in these experiments, the set of groups tests were made by the researchers, so for farther investigation its extremely recommended using different duration times and or another environment to investigate its effects on the mechanical properties of the alloys.
5. The great benefits of availability of microwaves furnace in industrial application was found that these microwaves furnace changes it's mechanical properties in deferent 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 amount 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 which gives this processes privilege as the other applications doesn't optimize the material beater, so for those how need quick not expensive easily handled safe and with acceptable change of mechanical properties, the microwaves furnace is the best choice for them.

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References

Table 1: Mechanical Properties of AA 2024-T3 and AA 7075-T6 as taken from the COSQC for the four groups

Group-1 Dry 60min in Microwave Furnace				
Mechanical Properties	AA2024-T3		AA7075-T6	
	Test	Standard	Test	Standard
Hardness, Rockwell B	93	80	98	85
Ultimate Tensile Strength value	345 MPa	300 MPa	418 MPa	320 MPa
Tensile Yield Strength value	325 MPa	225 MPa	395 MPa	206 MPa
Modulus of Elasticity value	75.5 GPa	72 GPa	76.5 GPa	74 GPa

Poisson's Ratio	0.333	0.35	0.363	0.35
Fatigue Strength value	123 MPa	85 MPa	128 MPa	90 MPa
Group-2 Group-1 Dry 30min in Microwave Furnace				
Mechanical Properties	AA2024-T3		AA7075-T6	
	Test	Standard	Test	Standard
Hardness, Rockwell B	91	80	96	85
Ultimate Tensile Strength value	375 MPa	300 MPa	475 MPa	320 MPa
Tensile Yield Strength value	305 MPa	225 MPa	401 MPa	206 MPa
Modulus of Elasticity value	74 GPa	72 GPa	75 GPa	74 GPa
Poisson's Ratio	0.338	0.35	0.348	0.35
Fatigue Strength value	105 MPa	85 MPa	110 MPa	90 MPa
Group-3 Group-1 Wet 60min in Microwave Furnace				
Mechanical Properties	AA2024-T3		AA7075-T6	
	Test	Standard	Test	Standard
Hardness, Rockwell B	87	80	92	85
Ultimate Tensile Strength value	305 MPa	300 MPa	480 MPa	320 MPa
Tensile Yield Strength value	265 MPa	225 MPa	405 MPa	206 MPa
Modulus of Elasticity value	73 GPa	72 GPa	74 GPa	74 GPa
Poisson's Ratio	0.343	0.35	0.333	0.35
Fatigue Strength value	91 MPa	85 MPa	95 MPa	90 MPa
Group-4 Group-1 Wet 30min in Microwave Furnace				
Mechanical Properties	AA2024-T3		AA7075-T6	
	Test	Standard	Test	Standard
Hardness, Rockwell B	86	80	91	85
Ultimate Tensile Strength value	315 MPa	300 MPa	495 MPa	320 MPa
Tensile Yield Strength value	220 MPa	225 MPa	410 MPa	206 MPa
Modulus of Elasticity value	72.5 GPa	72 GPa	73 GPa	74 GPa
Poisson's Ratio	0.347	0.35	0.337	0.35
Fatigue Strength value	88 MPa	85 MPa	92 MPa	90 MPa

Table 2: Aluminum alloys chemical composition comparison with standard [ASTM E1251-11, Standard Test Method for Analysis of Aluminum and Aluminum Alloys by Spark Atomic Emission Spectrometry].

Aluminum Alloy 2024-T3 Chemical Composition					
Component	% Si	% Fe	% Cu	% Mn	% Mg
Standard	≤ 0.5	≤ 0.5	3.8-4.9	0.3-0.9	1.2-1.8
Actual	0.25	0.09	4.53	0.81	1.51
Component	% Cr	% Zn	% Ti	% other	% Al
Standard	≤ 0.1	≤ 0.25	≤ 0.15	≤ 0.2	Reminder
Actual	0.014	0.13	0.014	0.065	Reminder
AL Alloy 7075-T6					
Component	% Si	% Fe	% Cu	% Mn	% Mg
Standard	≤ 0.4	≤ 0.5	1.2-2.0	≤ 0.3	2.1-2.9
Actual	0.26	0.24	1.81	0.11	2.15
Component	% Cr	% Zn	% Ti	% other	% Al
Standard	0.18-0.28	-6.1 5.1	≤ 0.2	≤ 0.15	Reminder
Actual	0.183	5.52	0.028	0.089	Reminder

Table 3: Aluminum alloys Surface roughness results as measured by Mitutoyo surface roughness testing machine

Aluminum Alloy 2024-T3 Surface Roughness				
Condition	Dry 60	Dry 30	Wet 60	Wet 30
Ra (μm) Read No.1	0.788	0.634	0.556	0.451
Ra (μm) Read No.2	0.784	0.637	0.550	0.452
Ra (μm) Read No.3	0.787	0.633	0.549	0.455
Ra (μm) Read No.4	0.785	0.630	0.547	0.454
Ra (μm) Average	0.786	0.634	0.552	0.453
Alloys Type	AL 7075-T6			
Condition	Dry 60	Dry 30	Wet 60	Wet 30
Ra (μm) Read No.1	0.795	0.652	0.567	0.481
Ra (μm) Read No.2	0.792	0.648	0.562	0.478
Ra (μm) Read No.3	0.796	0.645	0.569	0.479
Ra (μm) Read No.4	0.797	0.655	0.565	0.480
Ra (μm) Average	0.794	0.650	0.566	0.479

دراسة تأثير الطاقة الحرارية لأفران المايكروويف على الخواص الميكانيكية وعمر الكلال لسبيكتي الألومنيوم 7075-T6 و 2024-T3

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الخلاصة

يهدف البحث إلى عمل مقارنة بين سبيكتي الأمونيوم واسعتي الاستخدام وذلك من خلال دراسة التأثيرات التي تخلفها طاقة افران المايكروويف وبأوساط مختلفة (وسط جاف ووسط مائي) على الخواص الميكانيكية وعمر الكلال المحسوب لسبيكتي الألومنيوم واسعتي الاستخدام شديدتي المقاومة من نوع 2024 و 7075. حيث ان طاقة افران الميكروويف تختلف عن باقي طرق التسخين الأخرى بكون طريقة انتقال الحرارة بها توثر على الجسم من الداخل إلى الخارج في حين ان باقي طرق تسخين المواد يتم انتقال الحرارة فيها من الخارج إلى الداخل وتؤثر على سطح السبيكة حتى لبها. مما قد يغير بصورة مختلفة من بعض خواصها وكذلك من مقاومتها للكلال وبالتالي فيمكن معرفة مدى ذلك التأثير من خلال هذه الدراسة. أظهرت النتاج المستحصلة من البحث تغيرات معتبرة سواء بالخواص الميكانيكية او عمر الكلال ولكلا السبيكتين المستخدمتين ولكن على مستويات متباينة من سبيكة لأخري .

هنالك مفهوم شائع خاطئ حول محاذير استخدام المعادن بأفران المايكروويف وهذا المفهوم هو غير علمي ومبني على أسس خاطئة وابسط برهان على ذلك هو أن اغلب تلك الأفران مبنية من الداخل بالمعدن بالكامل فلو كان استخدام المعادن خطراً فكيف يتوافق ذلك؟ وهذا ما يهدف البحث التركيز عليه وإزالة تلك الإشكالية والمفاهيم الخاطئة.