THE EFFECT OF HEAT TREATMENTS ON MECHANICAL PROPERTIES OF ALUMINUM ALLOY AA 2024-T6

Ekhlas Ahmed
Institute of Technology / Mechanical Department
m_r_abboud @yahoo.com

ABSTRACT

This paper is aimed to study the effect of solution heat treatment on mechanical properties of Al alloy AA 2024-T6 (Tensile, hardness, wear resistance), many specimens were prepared according to ASTM and then heated to 500ºC for one hour and water quenched.

Artificial aging carried out at 190ºC for (1, 2, 5) hours and cooled slowly by air to show the effect of aging time on mechanical properties, many examinations (Microstructure, hardness Tensile and wear test) were done for specimens.

From the obtained results it can be see that heat treatment contributed in mechanical properties improvement.

Key words: heat treatments, Al alloy AA 2024 T6, wear resistance, mechanical properties

تأثير المعاملات الحرارية على الخواص الميكانيكية لسبيكة الالمنيوم T6 – 2024

الخلاصة

يهدف البحث الى دراسة تأثير المعاملات الحرارية على الخواص الميكانيكية لسبيك ة الالمنيوم 2024 AA T6 (مقاومة الشد والصلادة ومقاومة بلى)، حيث تم تصنيع عينات وفق المواصفات القياسية , ASTM بعدها اجريت عدة اختبارات قبل وبعد المعاملة المحلولية التي تضمنت تسخين العينات الى حرارة 500ºC ثم التبريد السريع بالماء وبعدها تم اعادة التسخين الى درجة 190ºC لمدة (1, 2, 5) ساعة ومن ثم التبريد البطيء بالهواء لغرض التعتيق الصناعي . النتائج التي تم الحصول عليها اظهرت ان المعاملات الحرارية ساهمت في تحسين الخواص الميكانيكية.

INTRODUCTION

Aluminum and its alloys are being used successfully in a wide range of applications, from Packaging to aerospace industries. Due to their good mechanical properties and low densities, these alloys have an edge over other conventional structural materials. 2024 variant alloys, such as higher purity 2124 and 2324 and 2024 in different tempered situations (T3, T351, T81, T62. etc) with improvements in strength and other specific characteristics, 2024-T6 alloy have also found application in critical aircraft structures **Benachour .M** (2009).

Some aluminum alloys can be solution treated to increase their strength and hardness. The heat treatment process can be classified into two processes; including solution heat treatment and artificial aging. This consists of heating the alloy to a temperature between 460^0C and 530^0C at which the alloying elements are in solution. By heating the solution heat – treated material to a temperature above room temperature and holding it there **zbek L.**(2007).The precipitation accelerates and the strength and hardness is increased which means that great improvements in the mechanical properties of Al alloys can be achieved by suitable solution treatment and aging operations **N.E. Bekheet** (2002).

And since the fracture of many engineering components is promoted under dynamic conditions, there is need to understand the fracture behavior of materials under dynamic loads. For that there is a need to improve the tensile and wear resistance of alloys to overcome this fracture **Swami N. G.** (2012)

wear resistance can classified to many types such as, adhesive wear which occurs when two surfaces are moving relatively one over the other, and this relative movement is in one direction or a successive movement under the effect of the load so that the pressure on the adjacent projections is big enough to make a load plastic deformation and adhesion. **Eyre T.S.** (1979)

Khairia Salman (2011) studied the effect of ageing on mechanical properties of Al-2024-T3.it was found that artificial ageing contributed in improving the tensile and impact proprieties of the alloy.

Muhammad Riaz Khan (2008) study the effect of heat treatment on mechanical properties of aluminum alloys that used in aerospace, he found that the grain size was fined on solution heat treatment and cause increasing in hardness and reducing in electrical conductivity ,for that An aluminum-magnesium based alloy is highly useful alloy because it has reduced density but increased strength.

Nikolaos D. Alexopoulo (2009) studied the effect of different artificial aging conditions of the Al 2024-T3 on the mechanical properties degradation due to corrosion exposure he found that Both, yield and tensile strength reach their maximum values after only 2 h of artificial aging. This point of maximum strength is accompanied by an essential drop on the alloy’s ductility and, hence, the alloy has reached its (PA) condition.

Jiang Na (2005) study the effect of different ageing temperatures on the mechanical properties of Al alloy suggesting that better comprehensive properties can be obtained when the alloy is aged to 160C

The aim of the present work is to investigate the mechanical properties of 2024-T6 Al alloy with different ageing treatments and its role in improving these properties.

EXPERIMENTAL WORK

1- Metal select

Chemical analysis had been done to Aluminum alloy AA 2024T6 by spectrometer and the results are listed in **Table 1**

2-Preperation of specimens: many specimens for mechanical properties wear prepared as shown

- Wear specimen for the adhesive wear tests were prepared with dimensions (10x20mm) according to ASTM specifications
- Tensile specimens test prepared with the dimensions shown in **Fig. 1**

According to ASTM specifications

3 – Categorization

After completing the preparation of specimens, these specimens were categorized and sorted into groups as shown in **Table 2**

4- Heat Treatment

Solution heat treatment at 500ºC and water quenched was applied on specimens groups in **Table 2** except (A) and artificial aging was applied on specimens groups B,C,D,in the same table by preheating the specimens to 190 ºC for (1,2,5,) hr respectively and cooling in the air,

5 – Testing

5-1 Microstructure test

Test of microstructure on specimens groups in **Table 2**, the specimens were prepared as follows:

A- The specimens are treated with emery papers of grades 120,350,500,800.

B- They were polished with cloth and Alumina Al_2O_3 solution.

C- Aqueous treatment with HF which consist of 52% of Hydrofluoric Acid and 48% of water

D- The optical micrograph for alloy AA 2024 T6 is in **Fig. 2**

5-2 hardness test

Hardness test was implemented on all specimens in table (2) by using Vickers hardness method.

The result are shown in table (3) by using the below equation (1)

$$Hv = 1.854 * \frac{p}{d^2} \qquad (1)$$

Were (p): is the applied load in kg_f

(d): was penetration diameter in mm

Specimens were cutting from sheet metal in dimension by length (20*20 *6mm)

And the surface prepared by using emery paper at different degree for obtaining smooth surface

5-3 tensile test

Tensile test was implemented by using Testing machine smart series with preload value (N) 100 and cross head speed (mm/min) or rat. 20. Extension or position measured by XHD _ 100(XHD 100) on all specimens in **Table 2**, the obtained results are shown in **Table 3**.

5-4 Adhesion wear test

Adhesion wear test is done by using pin on disc method

According to the following steps:

1- Weighting the specimen before test by digital sensitive balance, with accuracy 0.0001g of type XB 220 A Precise

2- Specify the variables which want to know its effect on the wear rate like time and fixing other variables (load, sliding speed).

3- Specify the hardness of the steel disc and it was found, HRC=40 RC

4- Fixing the specimen by the holder in vertical position on disc.

5- Fitting the operation time.
6- Checking the cleanness of the disc before the test start.
7- Operate the apparatus with select specified times (10, 20, 30) min. with fixing other variables.
8- Stopping the operation and weighing the specimen.
9- Repeat the process with fixing time (10) and changing other variables (at load 1, 1.5 and 2) kg and at sliding speed of (2.5, 5, 7) cm at time (10) and load (1, 5) kg
The wear rate is calculated from the following equation (2)

$$Wr = \Delta W / 2\pi r\ n\ t \qquad (2)$$

Where

Wr: wear rate is in gm /cm
W:weight of specimen
r: sliding distance (cm)
t: time (min)
n: number of cycle=940 r p.m.

RESULT AND DISCUSSION

After all test s were investigated on specimens in table 2 and the result were obtained by calculating its depending on the rule in equation which referred above and the results shown as follows
1-Mechanical results (Tensile and hardness) which shown in **Table 3** and **Fig. 3**
2-Wear result
Wear results which obtained after calculating it and then put in relationship represent all wear parameter and its rate as shown in **Fig.s (4, 5)**
From **Fig. 2** which presented the microstructure for all specimens in **Table 2** It can be observed that when the aging time increases the precipitation process would have sufficient time to occur. The kinetics of phase precipitations are usually affected by the variations in aging time and heating temperature, this behavior can be attributed to the difference in microstructure of the alloy [4] we see specimen D give large grain size compared with other specimens groups A,B,C for the same reason above
From **Table 3** and **Fig.3** Show the result of tensile and yield strength of all the specimens and also see that specimen (D) give high result compared with the result of specimen (A). This was because of increasing in hardness that occurs for increasing in ageing time and air cooling that will actually promote toughness values. On other hand hardness value for the specimens (B.C, D) has a decrease in its value for the increasing in heating time which effect on the cooling rate then promote the ductility of the specimen **Muna K. Abbass** (2011)
Fig.(4)(5) Show the relationship between wear rate and its parameters (Time, Load, and from the figures we see increasing in wear rate when parameter time, load, increased by different percentage and this because of effect of heat treatment on mechanical properties mainly hardness result in **Table 3**
we see an increasing in hardness are shown in this figure give improvement in wear rate because of increasing in implemented load caused an increasing in the plastic deformation in surface tips peaks between two sliding surfaces, the adhesive process of the two tips surfaces depends on applied load, if the load is low the contact appears in upper bit and this was very thin during sliding process that causes a thin layer from Oxide works as a protective surface film which limits the touching between the two sliding surfaces and prevent the direct metallic connection between the surfaces tips thus the required force to cut and spate the occurred connection between the two surfaces tips less than the force between the metal atoms itself and

that will cause a decrease in wear rate ,on the other hand an increasing in applied load this will break the oxide film because of its brittleness for its shoots out the friction sliding surfaces for both the discs and specimen during the sliding process which causes a strong metal contact between them make the required force to shear its contact tips more than the force between the metal atoms itself.

CONCLUSIONS

1-Aging time for 5 hours was the best result aging time, because increasing the aging time cases increase of precipitated phases.
2-The relationship between wear rat and their parameter was depending on heat treatment.

Table 1 Chemical composition for Aluminum Alloy AA (2024-T6)

Element	Al %	Ti%	Cr%	Zn%	Si%	Fe%	Mn%	Mg%	Cu%
Real value	92.6	0	0.05	0.1	o.4	0.3	0.6	1.5	4.4
tandard value	Rem.	0-0.15	0-0.1	0-0.25	0-0.5	0-0.5	0.3-0.9	1.2-1.8	3.8-4.9

Table 2 categorization of specimens

A	As received
B	Solution heat treatment at500 ºC artificial ageing for 1 hours at 190 ºC
C	Solution heat treatment at 500 ºC artificial ageing for 2 hours at 190 ºC
D	Solution heat treatment at 500 ºC artificial ageing for 5 hours at 190 ºC

Table 3 the results of mechanical properties

Sample	σu N/mm²	Yield stress σy N/mm²	Elongation %	Hardness Hv(kg\mm^2)
A	350	295	4	82
B	326.5	258	4	96
C	288	180	6	88
D	477	370	10	87

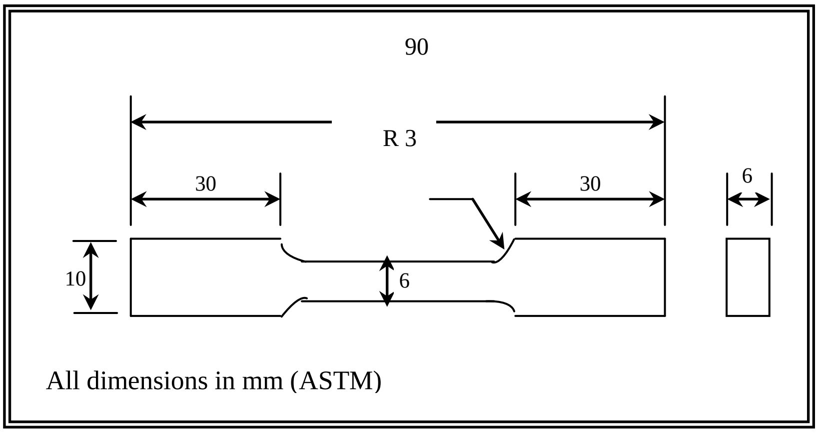

Fig. 1 Tensile test specimen

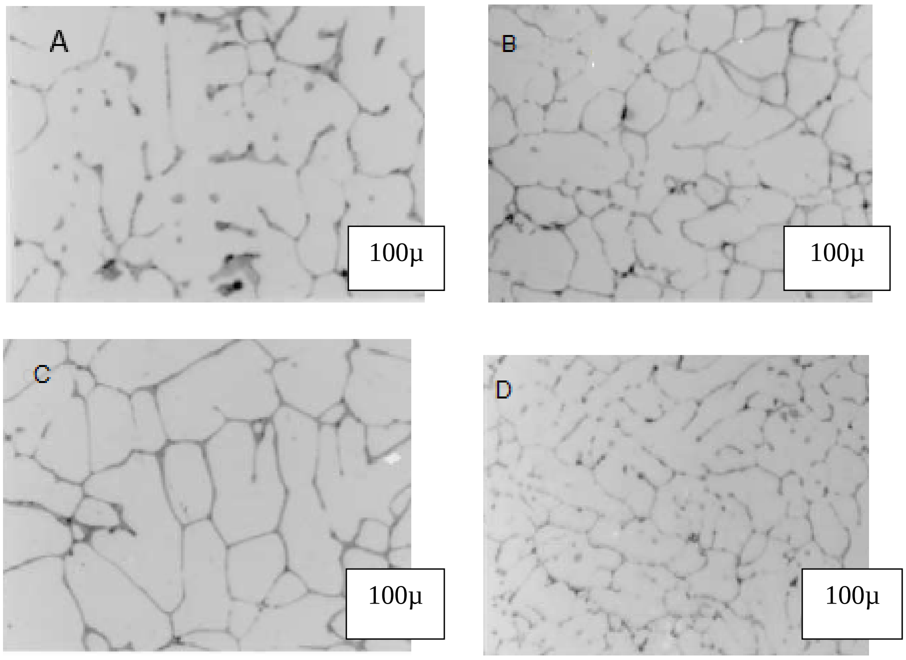

Fig. 2 Microstructures of specimens in Table 2 at 100µ

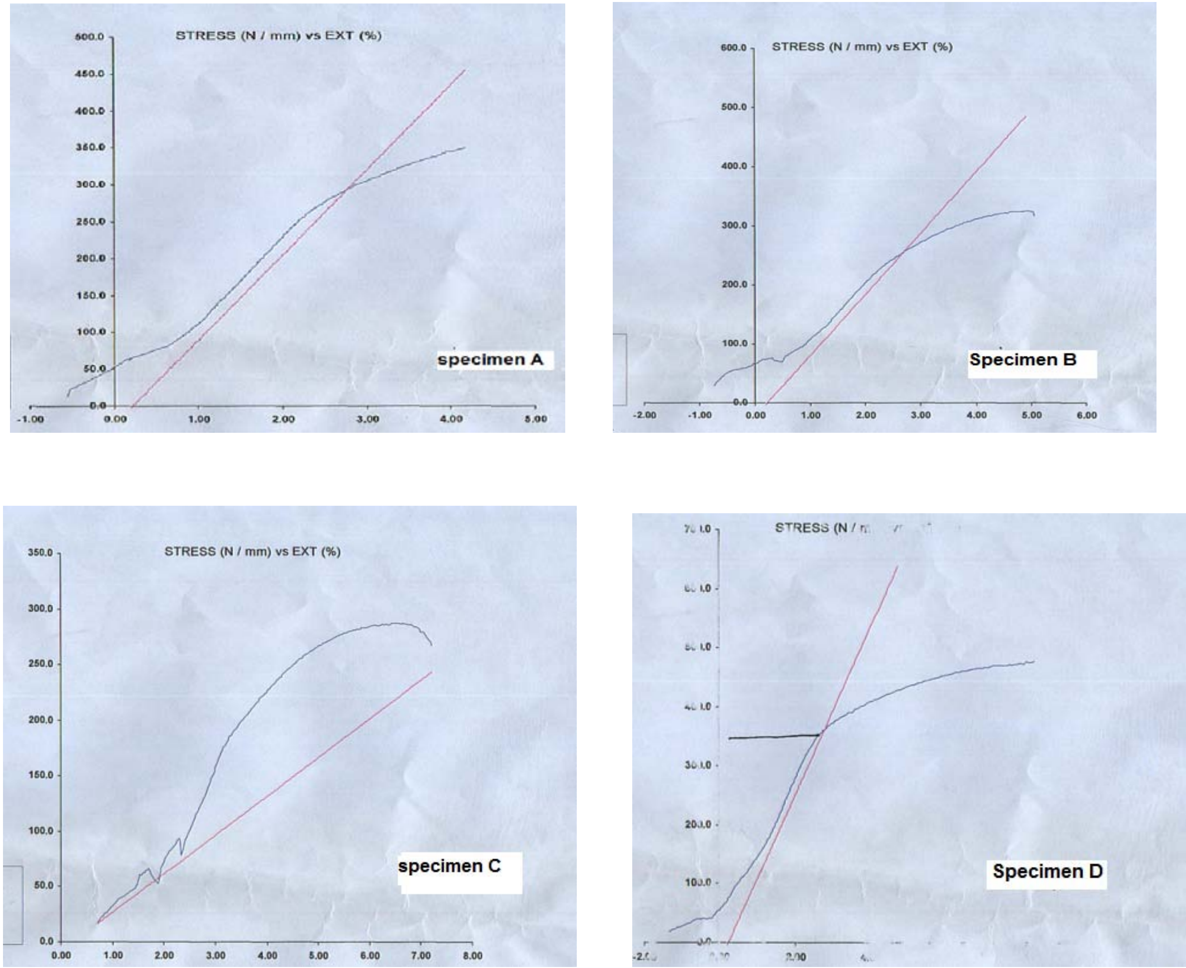

Fig. 3 the relationship between stress (N/mm^2) via elongation %

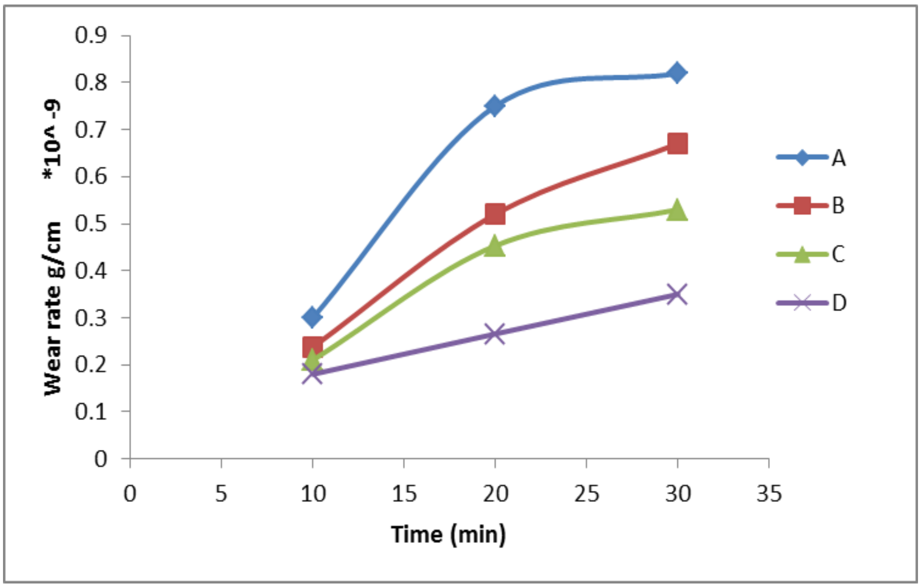

Fig.4 relationship between wear rate and time

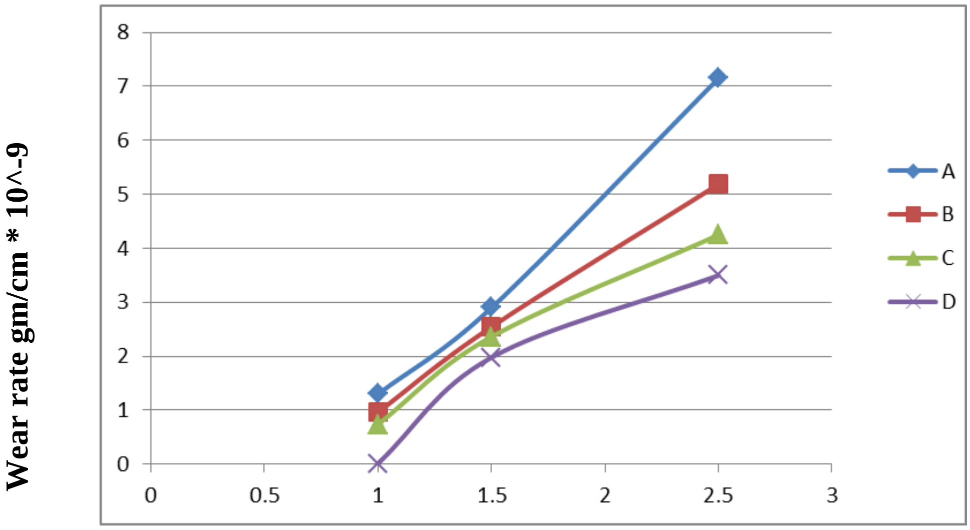

Fig.(5) relationship between wear rat and load

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