Effect of Heat Treatments on the Tensile Properties and Impact Toughness of (6063) Aluminum Alloy

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ABSTRACT

The effect of heat treatments on the tensile properties and impact toughness of (6063) aluminum alloy have been studied. This study aims to preparing the aluminum alloy (6063) and study the effect of solid solution temperature, ageing time and the ageing temperature on the tensile properties and impact toughness. Preparing alloy samples were homogenized at 560℃ for 2h, then they were solution heat treated at various temperatures (500, 530,560)ºC for 1 h and then rapidly quenched in water at room temperature. The quenched specimens were then aged at (150,175, and 200)ºC for different time periods. The results showed that the best solution treatment temperature is 530ºC and the best ageing temperature is 175ºC. The highest value of the tensile strength and yield stress are (288.6 and 264.5)Mpa respectively, in samples aged at 175ºC for 6h, while the highest value of impact toughness is 24.6J in samples aged at 175ºC for 2h. The specimens with the lowest impact toughness corresponds to the highest value of the tensile strength and yield stress for all ageing temperature

Keywords: 6063 alloy, solid solution temperature, ageing time, ageing temperature

1. INTRODUCTION

Aluminum and its alloy have a wide range of applications in the industries due to their excellent properties, such as high strength-to-weight ratios, high thermal conductivity, good corrosion properties and excellent workability [1-5]. The 6xxx-group contains magnesium and silicon as major addition elements. These multiphase alloys belong to the group of commercial aluminum alloys, in which relative volume, chemical composition and morphology of structural constituents exert significant influence on their useful properties. In the technical 6xxx aluminum alloys contents of Si and Mg are in the range of 0.5-1.2 wt%, usually with a Si/Mg ratio larger than one. Besides the intentional additions, transition metals such as Fe and Mn are always present. If Si content in Al alloys exceed the amount that is necessary to form Mg2Si phase, the remaining Si is present in other phases, such as Al-Fe-Si and Al-Fe-Si-Mn particles [6]. The required material properties are achieved by thermally treating the material. This thermal treatment consists of three main processes [7,8]:

1. SHT (Solution Heat Treatment): this is where the material is held at an elevated temperature for a sufficient time, so that all the constituents are taken into solid solution, giving one single phase.

2. Quenching: this is when the material is rapidly cooled from the SHT temperature to room temperature, so as to “freeze” this super-saturated state within the material at room

temperature, giving a microstructure condition known as "Super Saturated Solid Solution" (SSSS).
3. Ageing: age-hardening is the final stage in the development of the properties of heat treatable alloys.
Temperature, time and cooling rate are the most important variables to consider during the homogenizing heat treatment [9]. It is well known that in aluminum alloys improvement of the mechanical properties is classically obtained by the precipitation produced by decomposition of the supersaturated solid solution during ageing [10]. During the aging treatment the supersaturation of the solute atoms in aluminum matrix is gradually reduced. The strength is thus increased because a high density of fine coherent or semi-coherent precipitates nucleates and grows. The controlling of the precipitation during artificial aging is critical to obtain optimal mechanical properties of the alloys [11]. A generally accepted precipitation sequence of a solution and quenching treated Al-Mg-Si alloy during artificial ageing can generally be described as follows: supersaturated solid solution (SSSS) $\rightarrow G.P$ zones $\rightarrow$ metastable β'' precipitates $\rightarrow$ metastable β' precipitates $\rightarrow$ stable β phase [11-14]. The objective of this research work was to study the influence of solid solution temperature, ageing time, and ageing temperature on the tensile properties and impact toughness of (6063) alloy.

2. EXPERIMENTAL WORK

The present study was carried out on (6063) aluminum alloy, the chemical composition of the alloy is indicated in Table 1. Alloys were prepared by melting aluminum at 675ºC then remain for 5 minutes after each element addition and then cast in especially design. Steel die which is designed and manufactured with dimension and tolerance with respect to the required ingot. The cast samples were machined to standard tensile and impact test specimens. The machined samples were homogenized at 560℃ held at this temperature for 2h, and cooled in the furnace, then solution heat treated at various temperatures (500, 530,560)ºC in an electric heat treatment furnace, soaked for 1h at these temperatures and then rapidly quenched in water at room temperature. The quenched specimens were then aged at (150,175, and 200)ºC for different time periods before cooling in air. The specimens were then subjected to the tensile and impact testing.

Table (1) Chemical Composition of (6063) aluminum alloys

Element	Si	Mg	Fe	Cu	Al
Wt %	0.71	0.48	0.23	0.08	Bal.

2.1 Tensile Test

Standard test bars shown in Figure 1 were machined according to the ASTM B 557M–2a standard with a gauge length(*g=30mm*), diameter(*d=6mm*), radius of fillet(*r=6mm*) and the length of reduced section(*a=36mm*). The specimens were tested to evaluate the tensile strength and yield stress at room temperature using the tensile equipment type (Instorn 1195, made in Germany).

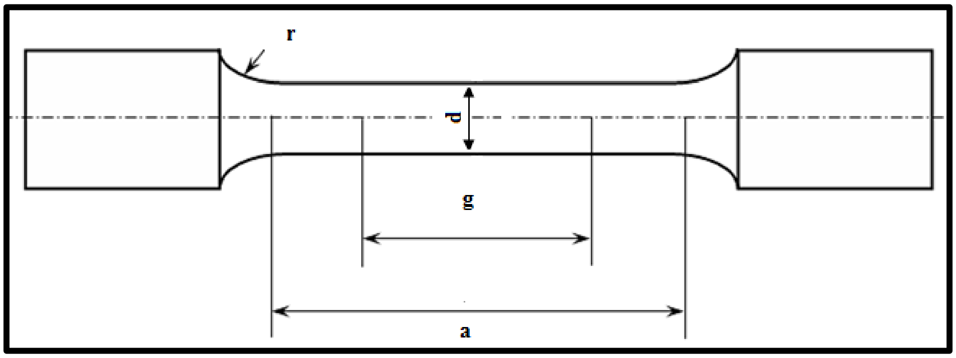

Fig.(1) Tensile Test Specimen

2.2 Impact Strength Test

Impact testing was performed on Charpy testing machine using (55*10*10) mm with 45° V notch, 2mm deep with 0.25 mm root radius as shown in Figure 2. The equipment that used in this test was (FIT-300(N)) type.

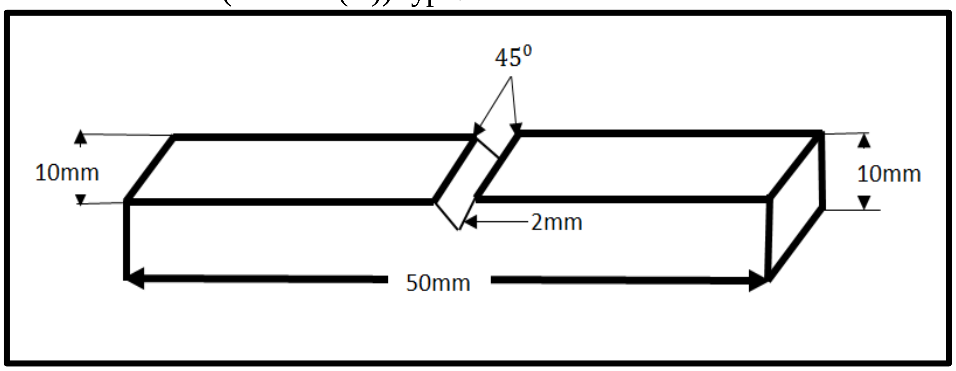

Fig.(2) Impact Test Specimen

3. RESULTS and DISCUSSION

3.1 Tensile Results at Solid Solution Treatment

Figure 3 and Figure 4 shows the variation in tensile strength and yield stress with variation in solid solution temperature .With the increase of solution temperature from 500ºC to 560ºC, tensile strength and yield stress were increasing . This result is similar to the previous studies[15].

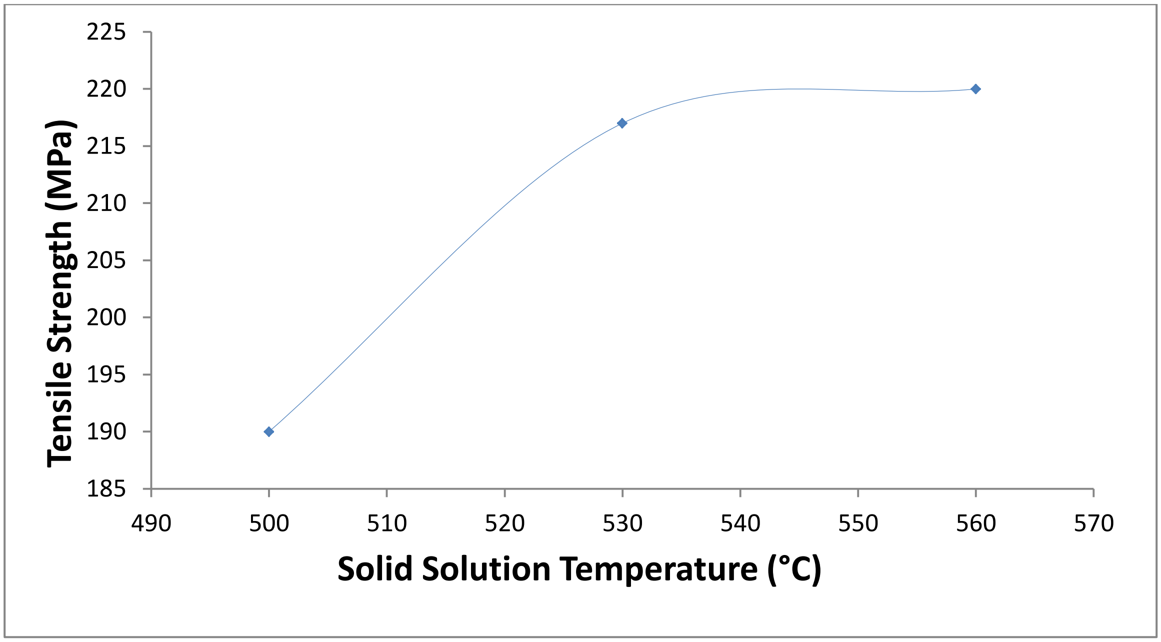

Fig.(3) Effect of Solid Solution Temperature on the Tensile Strength

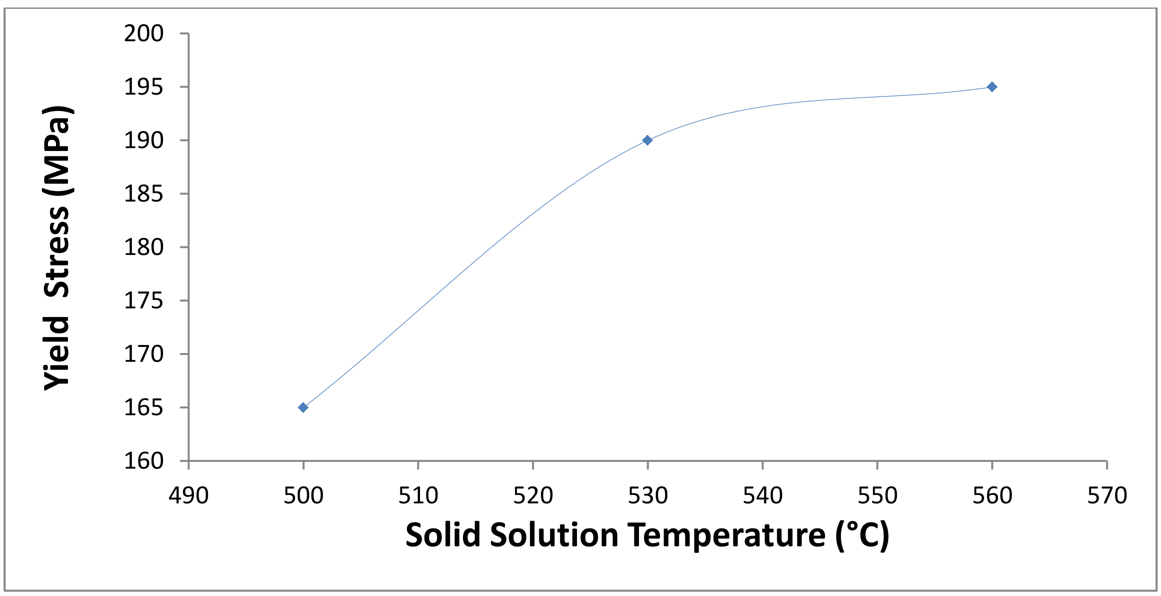

Fig.(4) Effect of Solid Solution Temperature on the Yield Stress

3.2 <u>Impact Toughness Results at Solid Solution Treatment</u>

Figure 5 shows the impact energy strength measurements for specimen alloy which solid solution treated for one hour at three solid solution temperatures (500, 520 and 540)°C. It is notice that the absorbed energy increases from 16.6 to 19.8J , When solution temperature increasing from 500ºC to 530ºC, then decreasing to 18.4J when solution temperature at 560ºC. This result is similar to previous studies [16]. From all properties tests that achieved during this work, it is concluded that a better solid solution temperature was 530°C, since it gives the best value of the tensile properties and impact toughness together.

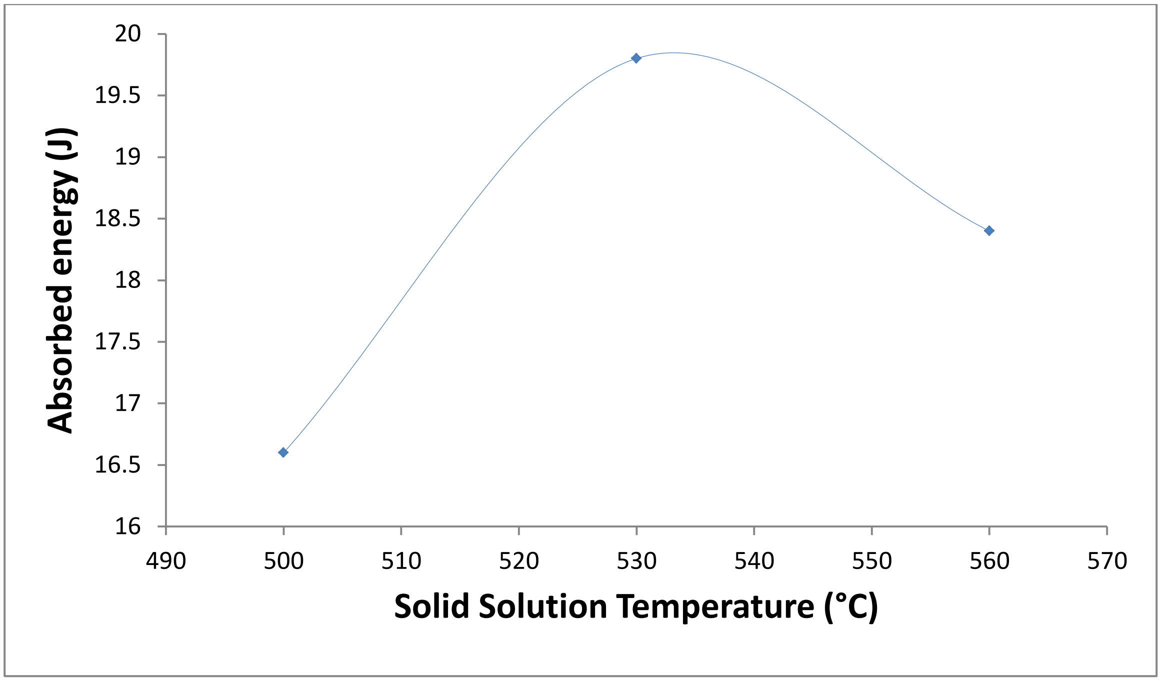

Fig.(5) Effect of Solid Solution Temperature on the Impact Toughness

3.3 <u>Tensile Results at Ageing time</u>

Figure 6 and Figure 7, shows the tensile strength and yield stress as a function of the artificial ageing time, when the ageing time increases from 2 to 6h the tensile stress and yield stress were increasing of the samples aged at 150ºC and 175ºC. Then the tensile strength and yield stress were decreasing when the ageing time increases from 8 to 10h. For samples aged at 200ºC the tensile strength and yield stress were decreasing when the ageing time increases from 2 to 10h. It is notice that the ageing time 6h at temperature 175ºC gives maximum tensile strength (288.6 MP) and yield stress (264.5MP).

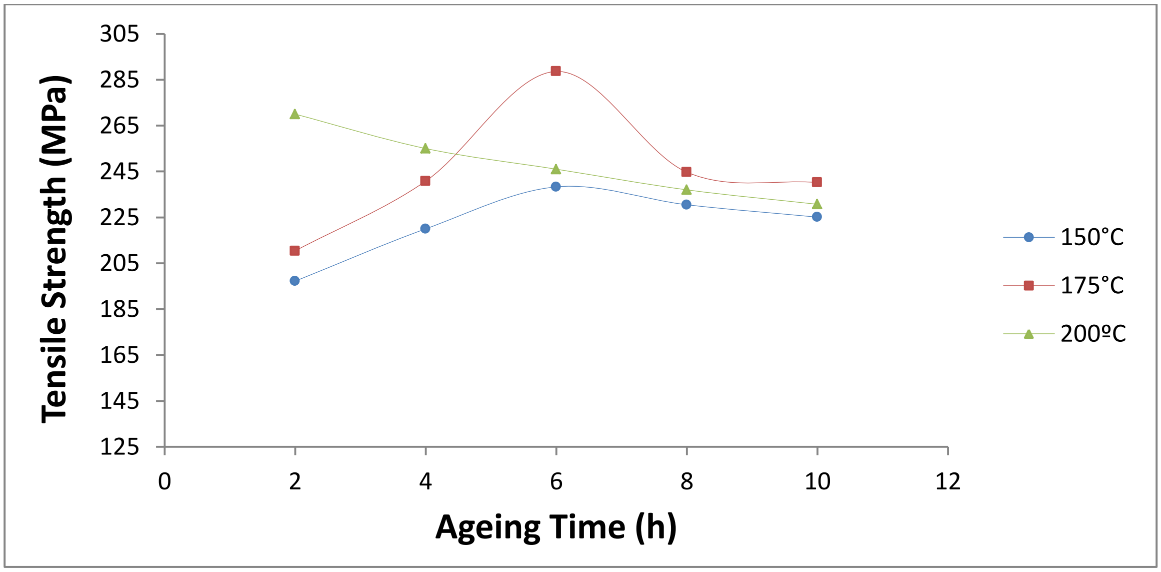

Fig.(6) Effect of Ageing Time on the Tensile Strength

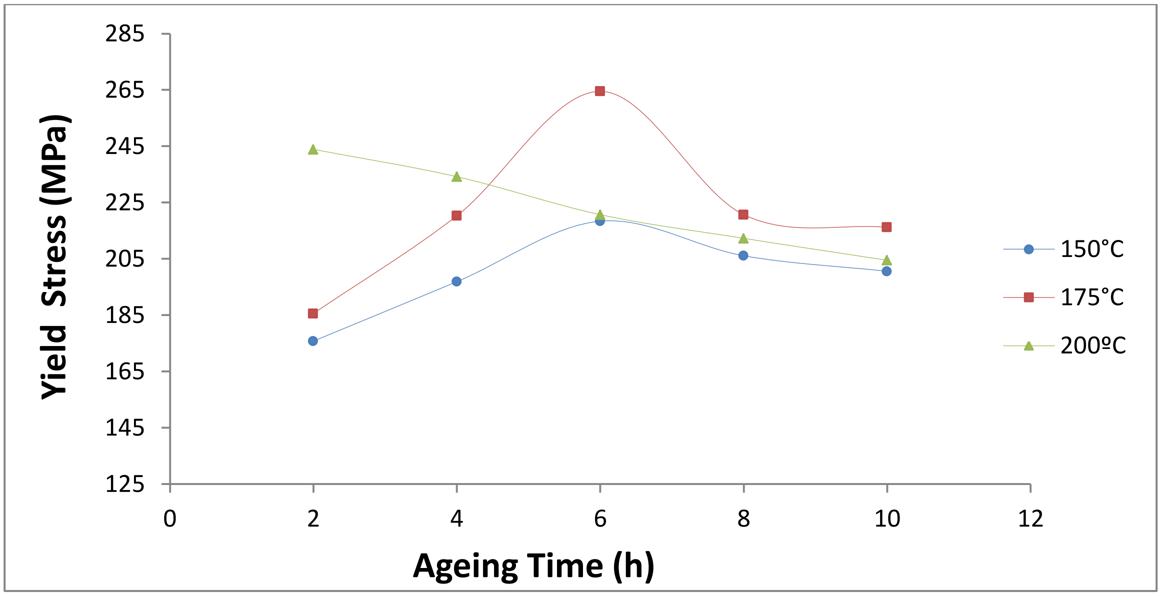

Fig.(7) Effect of Ageing Time on the Yield Stress

3.4 Impact Toughness Results at Ageing time

Figure 8, shows the variation of absorbed energy of the samples with the artificial ageing time at three temperature (150,175,and 200)°C, it is observed from the figure that the absorbed energy of samples when aged at 150°C reaches its maximum 20J within the first four hours then, decreases down to 16.7J at 6h after that the absorbed energy gradually increases with the increasing of ageing time from 8 to 10h. The samples when aged at 175°C the absorbed energy slightly decreases with the increasing of ageing time from 2 to 6h after that the absorbed energy increases with the increasing of ageing time from 8 to 10h. The absorbed energy of the samples when aged at 200°C increases with the increasing of ageing time and its reaches highest peak 21.8 J for 10h. By comparison with the Figures 6 and 7 it can be seen the specimens with the lowest impact toughness corresponds to the highest values of the tensile strength and yield stress.

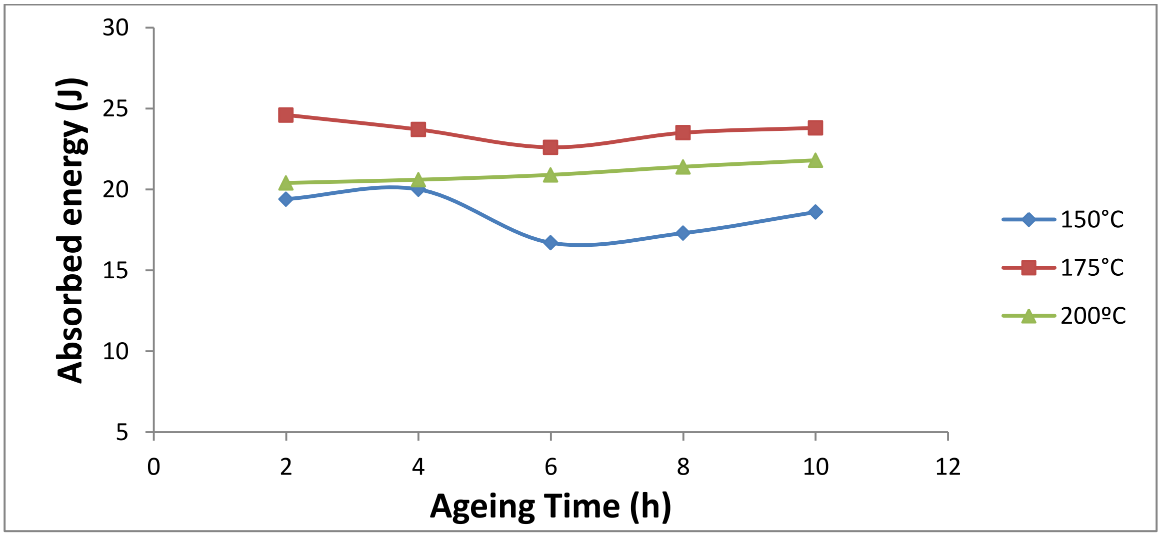

Fig.(8) Effect of Ageing Time on the Impact Toughness

3.5 Tensile Results at Ageing Temperature

Figure 9 and Figure 10, shows the effect of ageing temperature on the tensile strength and yield stress of the specimens soaked for 2,4,6,8,and 10h, it is observed that the tensile strength and yield stress of the samples soaked for 2 and 4h at various ageing temperature increase with increasing of ageing temperature. While the tensile strength and yield stress increase with increasing of ageing temperature from 150ºC to 175ºC then decrease when ageing temperature 200ºC for the specimens soaked for 6,8,and 10h. It could be seen that for samples aged at 175ºC soaked for 6h gives the highest value of the tensile strength and yield stress because of that temperature is sufficient to the refining intermetallic Mg_2Si and its homogenous distribution in precipitation form.

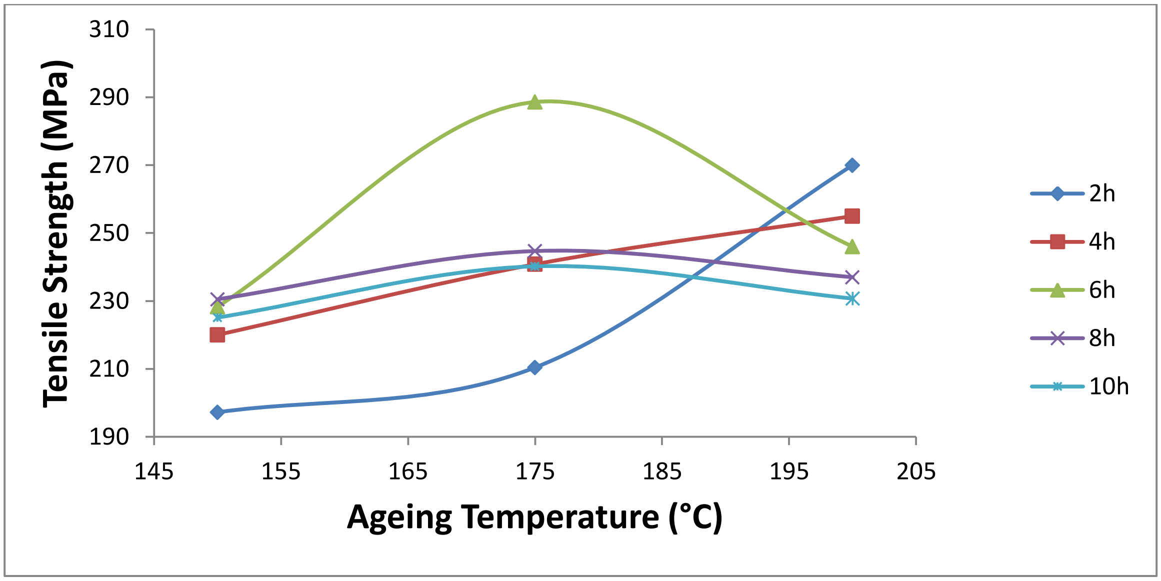

Fig.(9) Effect of Ageing Temperature on the Tensile Strength

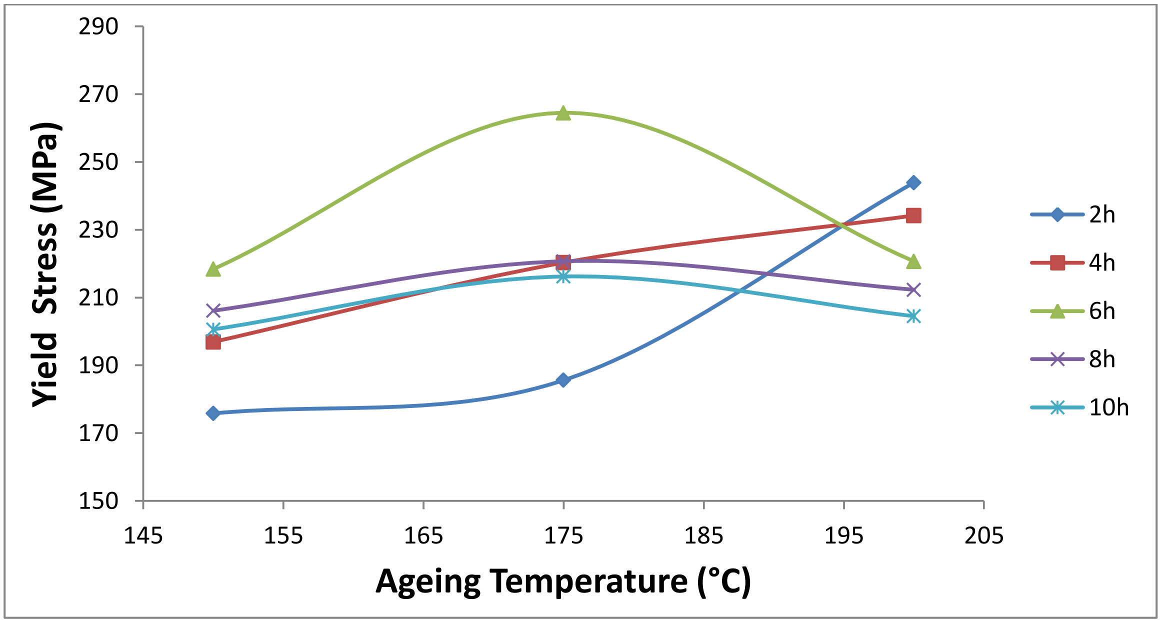

Fig.(10) Effect of Ageing Temperature on the Yield Stress

3.6 Impact Toughness Results at Ageing Temperature

Figure 11, shows the relationship between the absorbed energy and ageing temperature when the specimens aged for different ageing times (2,4,6,8,and 10)h. It can be noted that, absorbed energy of all alloy specimens increases with increasing of ageing temperature from 150ºC to 175ºC for various ageing time then decrease when ageing temperature 200ºC due to the precipitation of intermetallic phases at this temperature. It is observed that the maximum value of impact toughness at 175ºC for various ageing time and the ageing time 6h at 175ºC gives the lowest value of impact toughness, while, this ageing time gives the highest value of the tensile strength and yield stress. The decrease in impact toughness, in contrast to tensile strength and yield stress, can be related to the formation of metastable precipitates.

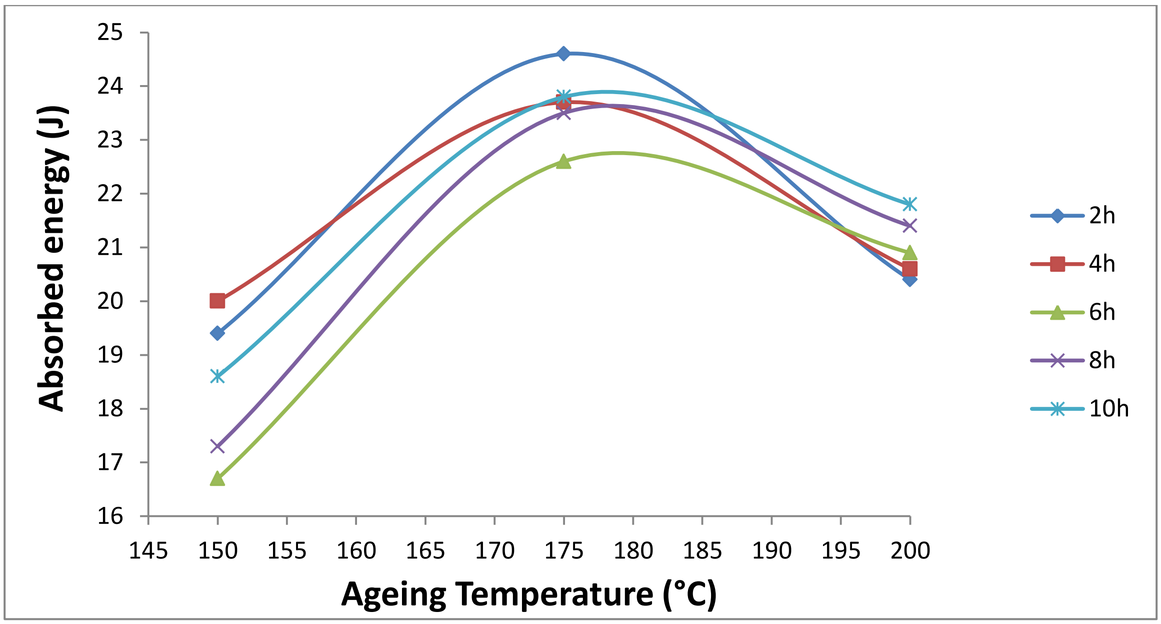

Fig.(11) Effect of Ageing Temperature on the Impact Toughness

4. Conclusions

The effect of heat treatment on the tensile properties and impact toughness of the (6063) aluminum alloy was investigated. The following conclusions were obtained:

1. The best solid solution temperature is 530ºC because it gives the best value of the tensile strength, yield stress, and impact toughness.
2. The best ageing temperature is 175ºC because it gives the highest value of the tensile strength, yield stress, and impact toughness .
3. The highest value of the tensile strength and yield stress in samples aged at 175ºC for 6h, while the highest value of impact toughness in samples aged at 175ºC for 2h.
4. The specimens with the lowest impact toughness corresponds to the highest values of the tensile strength and yield stress for all ageing temperature .

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تأثير المعاملات الحرارية على خصائص الشد ومتانة الصدمة لسبيكة الالمنيوم(6063)

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الخلاصة

تم دراسة تأثير المعاملات الحرارية على خصائص الشد ومتانة الصدمة لسبيكة الالمنيوم 6063 . الدراسة الحالية تهدف الى تحضير سبيكة الالمنيوم (6063) ودراسة تأثير درجة المعاملة المحلولية , زمن التعتيق ودرجة حرارة التعتيق على خصائص الشد ومتانة الصدمة. نماذج السبائك المحضرة تم مجانستها بدرجة حرارة 560°C ولمدة ساعتين ثم المعاملة المحلولية بدرجات حرارة مختلفة (500, 530,560)ºC ولمدة ساعة واحدة ثم تم اخمادها بسرعة في الماء بدرجة حرارة الغرفة . بعد ذلك النماذج المخمدة تم تعتيقها بدرجات حرارة (150,175, and 200)ºC ولفترات زمنية مختلفة. النتائج اظهرت بأن افضل درجة معاملة محلولية هي 530ºC وافضل درجة حرارة تعتيق هي 175ºC. اعلى قيمة لمتانة الشد واجهاد الخضوع هي (288.6 and 264.5)Mpa على التوالي في النماذج المعتقة بدرجة حرارة 175ºC ولمدة 6 ساعة بينما اعلى قيمة لمتانة الصدمة هي 24.6J في النماذج المعتقة بدرجة حرارة 175ºC ولمدة 2 ساعة. النماذج التي لها اقل قيمة لمتانة الصدمة تقابل اعلى قيمة لمتانة الشد واجهاد الخضوع ولجميع درجات حرارة التعتيق.