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EFFECT OF BRINE QUENCHANTS AND PRECIPITATION HARDENING ON THE MECHANICAL PROPERTIES OF ALUMINIUM ALLOY (AA6061)

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ABSTRACT

This article demonstrates the influence of varying quenchants and precipitation hardening on the mechanical characteristics of Aluminium alloy 6061. Three samples were chosen for the impact test. Solution treatment was performed at 540°C for 2 hours and then cooled at three different brine concentrations (3%, 7%, and 10%). As a result, brine (3%) had the best result with the lowest rate of shock absorption (18.31 J); therefore, for this study, brine (3%) was selected as the quenching medium. All specimens for the tensile, impact, and hardness tests were solution-treated at 540 °C for two hours, subsequently cooled in Brin 3% to ambient temperature, and artificially aged at 180 °C. for 1,2, and 4 hours, at 195°C for 1,2, and 4 hours, and at 210°C for 1,2, and 4 hours. Due to the formation of finely dispersed grains, notable increases in strength and hardness were seen alongside a decrease in ductility. The overall best result achieved was by precipitation hardening at 210°C for 2 hours, which increased the ultimate tensile strength to 340.3 MPa compared to the as- received and annealed samples values which were 260 MPa and 152.02 MPa respectively. In addition, Hardness value increased from annealed condition (18.23 HRB) to (44.14 HRB).

KEYWORDS

Aluminium alloy 6061; Heat treatment; Precipitation hardening; Quenching; Brine.

1. INTRODUCTION

Aluminium has lagged behind iron and steel in the metals industry for more than 50 years. Due to a special combination of qualities that make Aluminium one of the most adaptable engineering and building materials, the demand for it is increasing quickly (Das and Yin, 2007; Rashid et al., 2023).

Aluminium is a lightweight metal with a specific gravity of 2.7g/cm^3, making it just 30% lighter than copper and 33% iron. It is the lightest common metal, except magnesium. Its alloys can be stronger than structural steel in some cases. It also possesses excellent thermal and electrical conductivities and high heat and light reflectance. Under any service conditions, it is highly corrosion-resistant and non-toxic (Akande et al., 2022; Tan and Radzai, 2009).

In addition to being cast and made into nearly any type of product, Aluminium may have a wide range of surface treatments applied to it. With all these excellent capabilities, it is not unexpected that Aluminium has grown to be a material of utmost importance in engineering (Ramesha et al., 2005).

Aluminium alloy has many applications in the automotive, aerospace, and military fields due to its high strength to low weight ratio. This property of Aluminium alloy provide the advantage of energy savings through weight reduction of the automotive, aerospace, and military component designs (Akbar et al., 2020; Rashid et al., 2023). There is always high demand on higher strength of the material which leads the researchers to think about improving the mechanical characteristics of the materials. Heat treatment is one of the suitable techniques to enhance the mechanical characteristics of Aluminium alloy, Solution heat treatment and ageing are critical processes for attaining the appropriate mechanical characteristics of the material. (Akbar et al., 2020).

A typical Al-Mg-Si series wrought alloy with exceptional heat resistance, low density, high strength, and good formability is Aluminium alloy 6061. Aluminium has many grades and is classified as Pure Aluminium (1xxx series), Al-Cu Alloy (2xxx series), Al-Mn Alloy (3xxx series), Al-Si Alloy (4xxx series), Al-Mg Alloy (5xxx series), Al-Mg-Si Alloy (6xxx series), and Al-Zn-Mg Alloy (7xxx series) are a few of the classes of Aluminium alloys (Davis, 2001; Moy et al., 2012; Westermann et al., 2016; Staszczyk et al., 2019; Sun et al., 2021).

One alternate technique for increasing the material's strength without further alloying is heat treatment of Aluminium alloy. The precipitation-hardening method is typically used to heat-treat the 2xxx, 6xxx, and 7xxx series. therefore (6xxx series) is selected for this study.

This study aims to illustrate the influence of ageing parameters and solution treatment, specifically ageing temperature and time, on the mechanical characteristics of Aluminium alloy

6061, while highlighting the significant role of artificial ageing in improving mechanical characteristics, specifically ultimate tensile strength and hardness of Aluminium alloy 6061. Despite prior research on this specific material, certain temperature and time parameters remain unexplored, which could potentially enhance its strength (Naronikar et al., 2018).

2. EXPERMENTAL WORK

2.1. Materials

This research was performed on Aluminium alloy 6061., Table 1 below displays the Chemical Composition of the material tested by IRALX company in Iraq.

Table 1. displays the Chemical Composition of Aluminium alloy 6061

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Other	Al
composition %	0.49	0.15	0.22	0.02	0.88	0.07	0.04		REM

Both the Aluminium alloy 6061 plate and Aluminium alloy 6061 round bars were used to prepare the required samples used in this study as:

1- A 10 mm-thickness Aluminium alloy 6061 plate. Charpy V-notch test specimens were manufactured in accordance with ASTM standards, having dimensions of 10 mm in width, 10 mm in thickness, and 55 mm in length.

2- A 20 mm diameter aluminum alloy 6061 round bar used for the manufacturing of tensile test specimens, which were produced on a CNC lathe in accordance with the ASTM E8 standard. As shown in the Fig. 1.

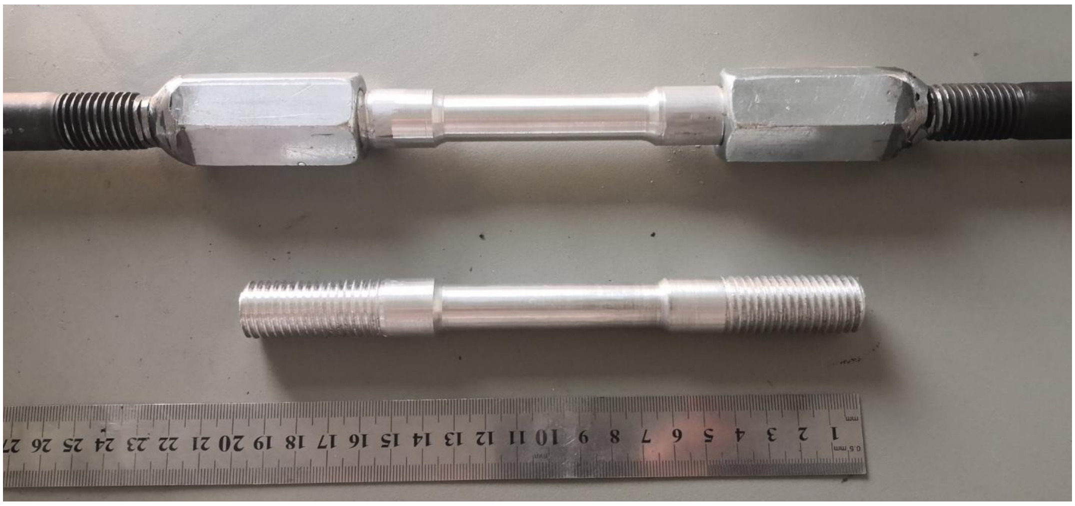

Fig. 1. Specimen of the tensile test made on CNC Turning machine in Sulaimani Technical Institute.

A tension test was conducted on the received material Al alloy 6061 specimen, so as to know the tensile strength values which can be used for later comparison in the study,

Table 2 shows the experimental values for ultimate tensile strength, and yield strength values.

Table 2. Tension test value for as-received material specimen

As-received material	Experimental Value
Ultimate tensile strength	260 MPa
Yield strength	240 MPa

2.2. Heat treatment

To select optimum quenching media, three impact test specimens were heated in an electric furnace for 2 hours, then the samples were quenched at different brine concentrations (3%, 7%, and 10%). A Charpy Impact test was performed on the samples, revealing that those quenched in 3% brine had the lowest shock absorption rates.

Therefore brine 3% was selected as the optimum quenching medium for this study.

Fig. 2 illustrates the impact test results of the three specimens.

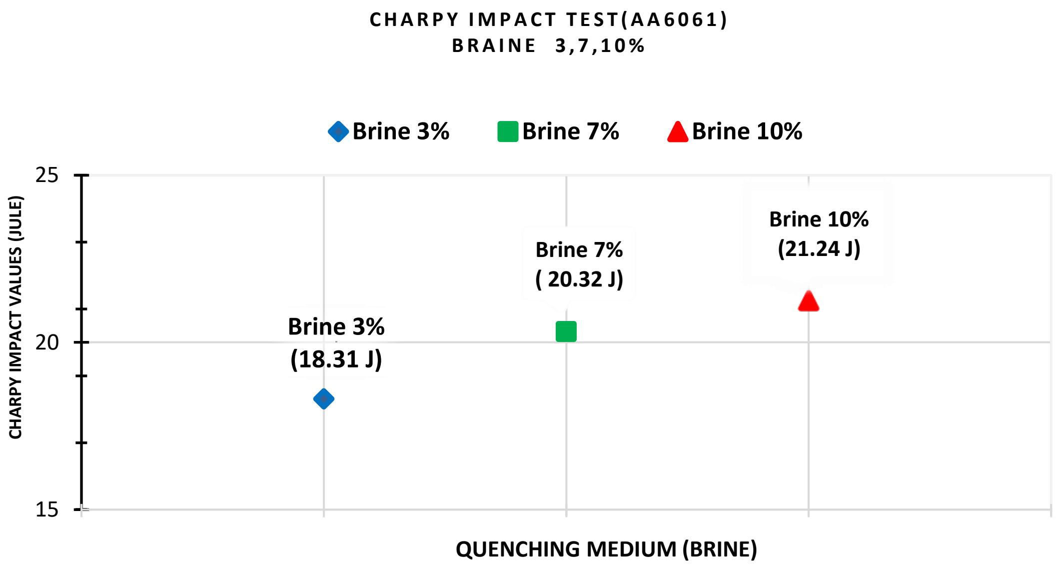

Fig. 2. Result of Charpy impact tests in various quenching media, solution heat treated at 540°C for 2 hours.

Following the selection of the optimal quenching medium (Brine 3%), all specimens for the tensile and impact tests were subjected to heating in the furnace at 540 °C for a duration of 2 hours, this temperature is selected based on the previous studies done for Solution treatment of Aluminium alloy (Abubakre et al., 2009; Akbar et al., 2020; Liu et al., 2020). Subsequently quenched in 3% brine to ambient temperature, followed by artificial ageing at 180°C for 1, 2, and 4 hours, at 195°C for 1, 2, and 4 hours, and finally at 210°C for 1, 2, and 4 hours. Concurrently, two samples from the tensile and impact tests underwent annealing, being subjected to a furnace temperature of 540°C for a duration of 24 hours to restore the specimens to their original state.

Fig. 3 illustrates a schematic representation of the heat treatment procedure.

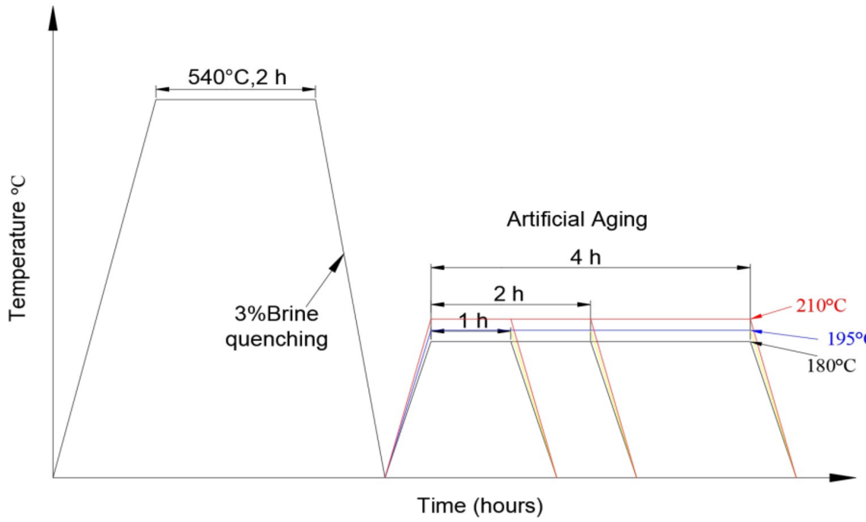

Fig. 3. Schematic of Solution Treatment and Ageing parameters on Aluminium alloy 6061.

3. RESULTS AND DISCUSSION

The outcomes of all tests conducted on the specimens for this investigation are shown as a quick reference in Table 3**.** The results of tensile, hardness, and impact tests are discussed separately in the subsequent sections.

Table 3. Hardness, ultimate tensile strength, and impact values.

Sample No.	Brine (3%), Ageing Temperature and Time	Hardness (HRB)	Charpy Impact Value (J)	Tensile Strength (N/mm^2)
1	180 °C / 1hour	25.39	29.59	308.56
2	180 °C / 2hour	29.66	27.24	338.72
3	180 °C / 4hour	22.43	30.88	269.15
4	195 °C / 1hour	34.85	24.16	302.4
5	195 °C / 2hour	39.48	22.12	314.34
6	195 °C / 4hour	37.23	23.24	309.8
7	210 °C / 1hour	35.24	20.17	322.1
8	210 °C / 2hour	44.14	18.25	340.3
9	210 °C / 4hour	36.52	19.42	337.01
10	Annealing 540 °C / 24 hour	18.23	40.25	152.02

3.1. Results of Tensile Tests

A "Universal Testing Machines 1000KN, in Sulaimani Steel Co. in Iraq" was used to perform the tensile tests. The samples were previously subjected to heat treatment and ageing as outlined in the preceding section of this investigation. The stress and strain curve of all samples with different heat treatment parameters are shown in Figs 4 to 6.

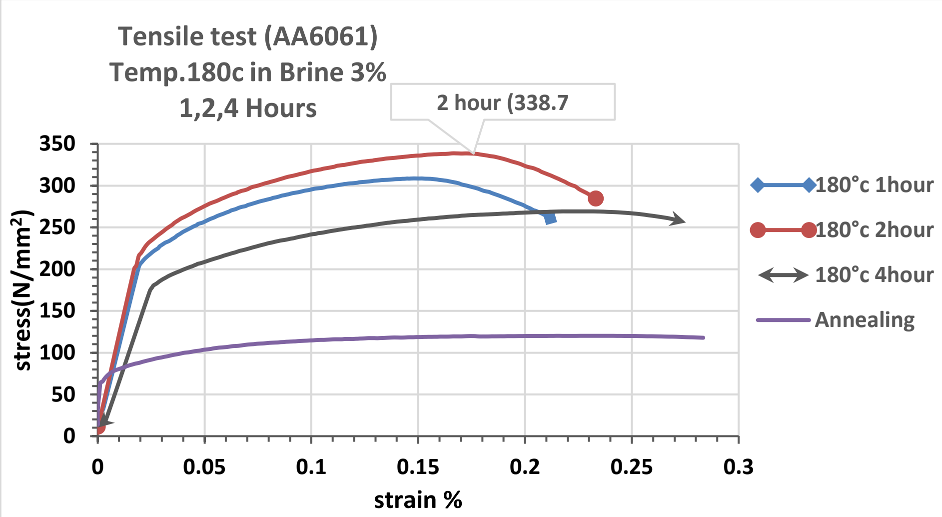

Fig. 4. Tensile strengths vs. Strain curves for Aluminium alloy 6061, solution heat treated in (Brine3%) and aged at 180 °C (1,2,4) hrs.

Fig. 4, illustrates that the maximum ultimate tensile strength attained (338.7 N/mm²) occurs at 180°C for 2 hours. here the achieved value (338.7 N/mm^2) is more than twice the value of annealed condition (152.02 N/mm^2) which can be considered as a valuable improvement in the mechanical characteristics of the alloy.

In Fig. 5, it is clear that the best ultimate tensile strength obtained (314.3 N/mm^2) at 195 °C is at 2 hrs. Here the achieved value (314.3 N/mm^2) is also more than twice the value of annealed condition (152.02 N/mm^2). Compared to 180°C 2 hrs. the improvement is lower, although, both the ageing times are same, the only difference is the ageing temperature by 10°C. Therefore, it is always important to be aware that small changes in temperature or time in heat treatment process may affect the mechanical properties and produce high difference strength values.

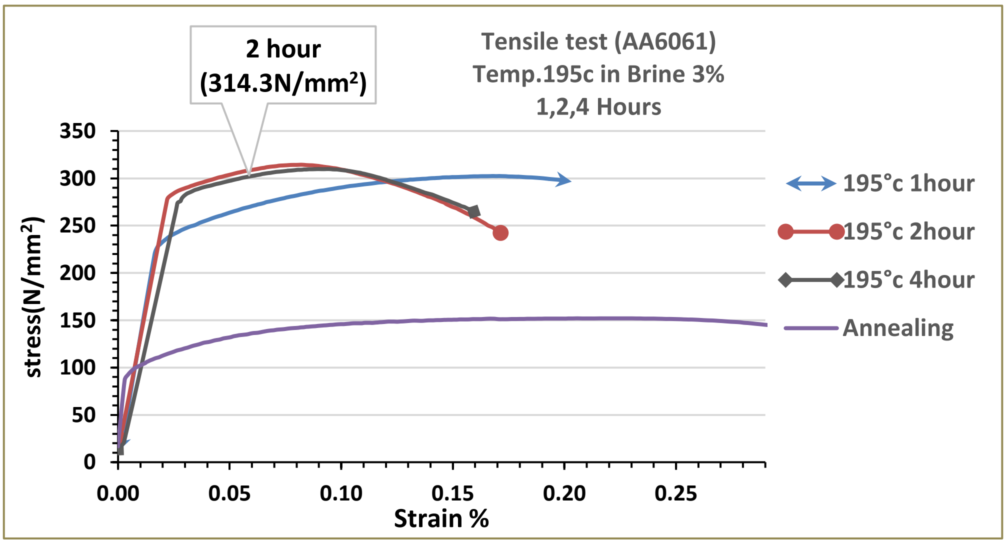

Fig. 5. Tensile strengths vs. Strain curves for Aluminium alloy 6061, solution heat treated in (Brine3%) and aged at 195 °C (1,2,4) hrs.

Fig. 6, illustrates that the maximum ultimate tensile strength attained (340.3 N/mm²) occurs at 210 °C for 2 hours, being the highest value among all solution treatment temperatures and ageing times.

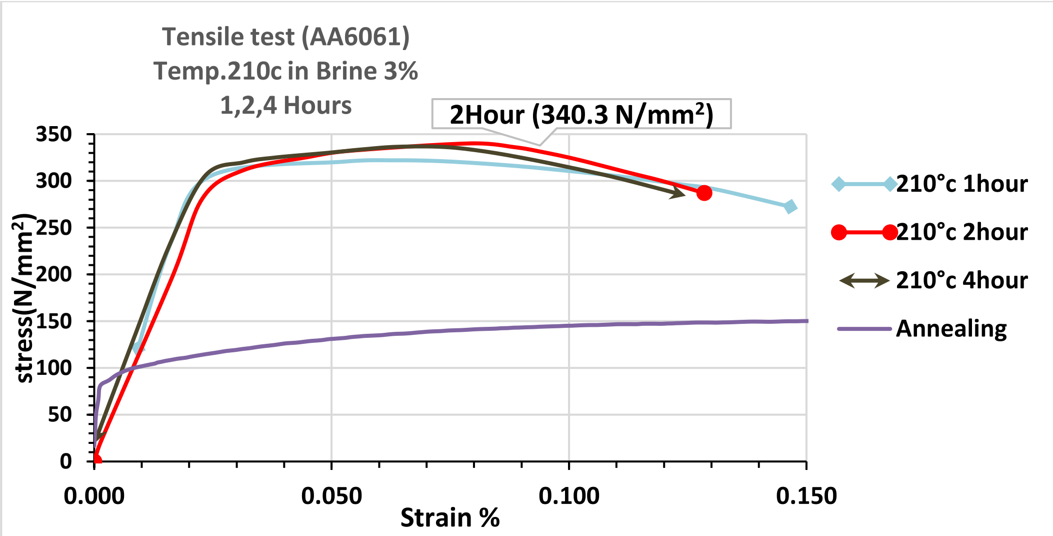

Fig. 6. Tensile strengths vs. Strain curves for Aluminium alloy 6061, solution heat treated in (Brine3%) and aged at 210 °C (1,2,4) hrs.

Furthermore, Fig. 6 illustrates that the maximum ultimate tensile strength attained (340.3 N/mm²) occurs at 210 °C for 2 hours. In contrast to the annealed sample (152.02 N/mm²), there exists a significant disparity between the two values; the ultimate tensile strength of the solution heat-treated specimen in 3% brine and aged at 210 °C for 2 hr. is more than twice that of the annealed sample. It is noteworthy to mention that the enhancement in the mechanical properties is due to production of mini particles of Mg-Si due to the heat treatment which leads to make barriers of dislocation movements as a result increasing tensile strength and hardness values (Akbar et al., 2020).

3.2. Results of Hardness Tests

Utilizing "Brinell Testing Machines in the Mass Iron and Steel Industry Company, Iraq." Hardness tests were conducted on the Charpy V-notch specimens. Subsequent to the completion of the solution treatment and artificial ageing processes. Each number presented is the mean of three hardness test readings conducted at different locations on each sample.

Fig. 7 illustrates the hardness in relation to the temperature and time of artificial ageing for the samples.

The highest hardness number of the Aluminium alloy 6061achieved is (44.14 HRB) belongs to the specimen aged at 210°C for a period of 2 hrs. Compared to the annealed condition value (18.23 HRB), The achieved value is more than twice of the annealed condition of the sample.

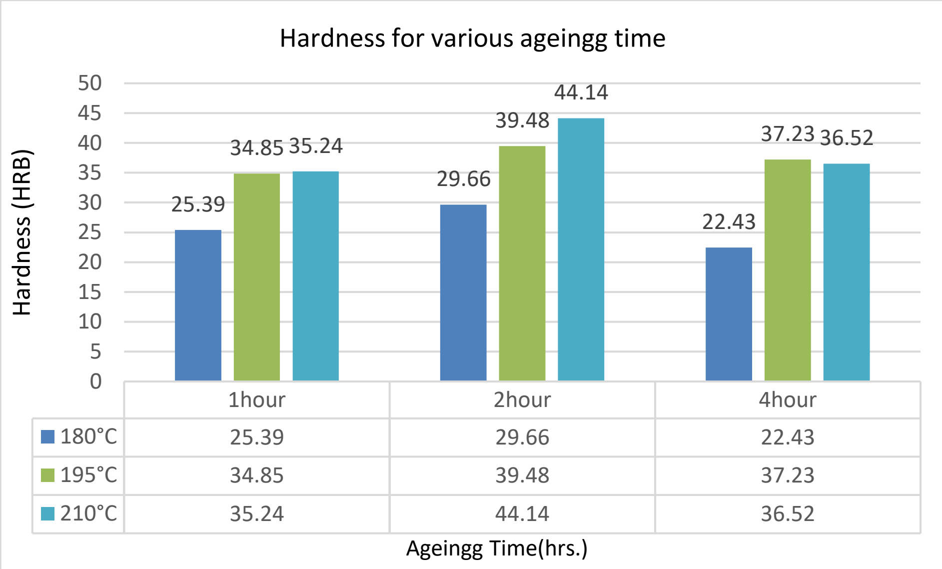

Fig. 7. Hardness value of various ageing time and temperature for Aluminium alloy 6061.

3.3. Results of Impact Tests

Utilizing the "Charpy Impact Testing Machine at Sulaimani Polytechnic University, Department of Mechanical and Manufacturing Engineering, Iraq". The Impact Test was conducted on the Charpy V-notch specimens. Fig. 8 illustrates the outcomes of the Impact Test performed on Aluminium alloy 6061 specimens, which were solution treated in 3% brine and artificially aged at temperatures of 180°C, 195°C, and 210°C for durations of 1, 2, and 4 hours. Fig. 8 demonstrates that the minimum impact energy value, obtained is18.25 J, corresponds to the sample aged at 210°C for 2 hours, and this is totally logical compared to the hardness value of the sample aged at 210°C for a period of 2 hrs. which is the highest value (44.14 HRB) as shown in Fig. 7.

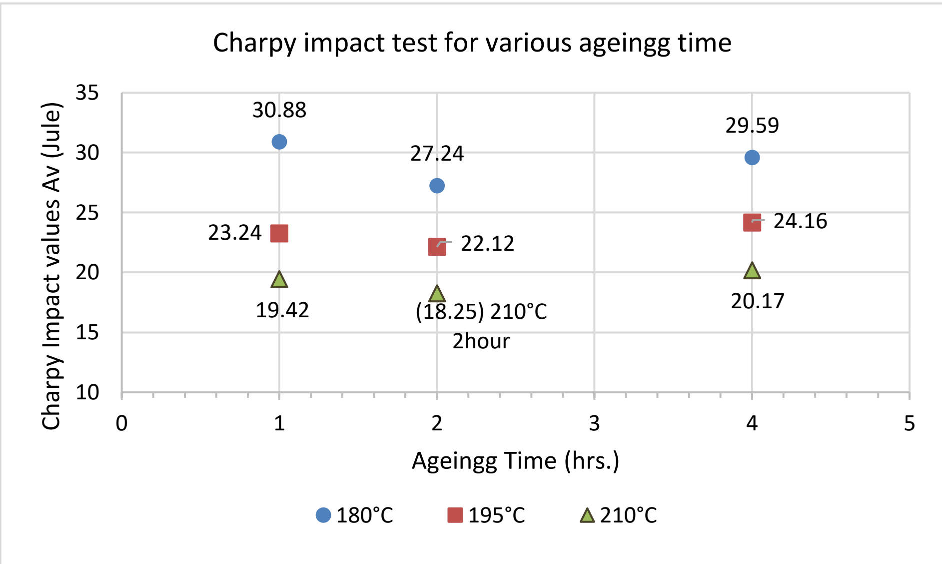

Fig. 8. Charpy impact test results for different aging durations and temperatures for Aluminium alloy 6061.

4. CONCLUSIONS

This study investigates the impact of Solution treatment and ageing on the mechanical characteristics of Aluminium alloy 6061. Solution treatment and artificial ageing were performed on aluminum alloy 6061 specimens. The impact of Solution Treatment and Ageing on mechanical characteristics was examined. The key points were summarized as follows:

1. The quenching medium significantly influenced the results, with 3% brine yielding the lowest impact value of 18.31 J, in contrast to 7% brine as 20.32 J and 10% brine as 21.24 J.
2. The findings of the tensile, hardness, and impact tests indicate that the optimal ageing duration and temperature are 210 °C for 2 hours.
3. The results achieved is considerably high and are more than twice of the annealed condition values for both the ultimate tensile strength and hardness value which can be considered as a considerable achievement in mechanical properties of the alloy.

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