Effect of Quenching Media on Mechanical Properties of 7075 Aluminium Alloy

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Abstract: ***In this study, the effects of quenching media on some selected mechanical properties of Aluminium alloy were studied. Heat treatment is the process of modifying the required properties of metal and metal alloys. Aluminium alloy 7075 is one of the most extensively used of the 7XXX series aluminium alloys. The Al7075 alloy has been subjected to solutionizing heat treatment at a temperature of 475°C for 2 hours followed by quenching in water and oil. Tensile strength, impact strength and hardness were carried out on the untreated and heat treated specimens. The specimen with the highest tensile strength, impact strength and hardness was found in samples quenched in oil.***

Keywords: Aluminium alloy, 7075 Aluminium alloy, heat treatment, quenching media, mechanical properties

1. Introduction

Aluminium is the world's most abundant metal and is the third most common element, comprising 8% of the earth's crust [1]. It is second largest used metal and largest nonferrous industry in world. Top six aluminium producing countries and percentages in the world shown in figure-1. Aluminium was produced in above 40 countries in 2017, with two thirds coming from just three countries (China, Russia, and Canada) and three quarters from five countries (China, Russia, Canada, India, and United Arab Emirates) [2]. Pure aluminium is well known for its low density and high corrosion resistance. However, pure aluminium cannot be used for structural applications due to low strength. Alloy development involves the addition of different alloying elements to improve material properties. Aluminium alloys usually contain 90-96% aluminium and about two major alloying elements to obtain a combination of properties. Zinc, magnesium, manganese, copper and silicon are used as major alloying elements.

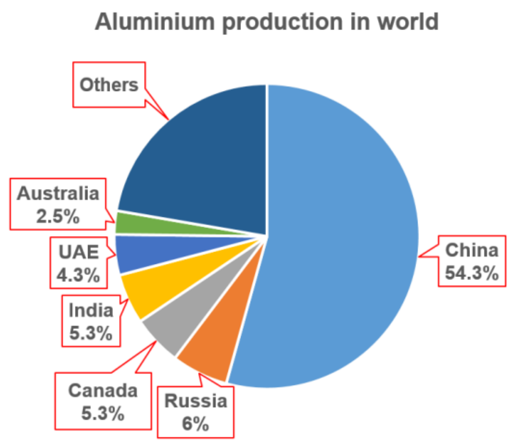

Figure 1: Top six aluminium producing countries and percentages

Aluminium alloys are widely used in aircraft, automotive, bicycle components, construction, fuse parts, high pressure hydraulic units, marine, mechanical components, meter gears and shafts, military industries, mold tool manufacturing, piping systems, regulating valve parts, sports equipment's etc. The main advantages of aluminium alloys are easily recyclable, lightweight, ductility, malleability, good strength-weight ratio, excellent thermal and electrical conductivity, non-toxic, easy to work, non-magnetic, non-sparking, good corrosion resistance etc.

Aluminium alloys are divided into casting alloys and wrought alloys, both of them are further subdivided into the categories heat-treatable and non – heat treatable alloys. Heat treatable and non-heat treatable wrought aluminium alloys shown in table-1.

Table 1: Heat treatable and non-heat treatable wrought aluminium alloys

Classification	Alloys
Heat treatable	2xxx, 6xxx, 7xxxx and 8xxx series alloys
Non heat treatable	1xxx, 3xxx, 4xxxx and 5xxx series alloys

1.1 Wrought Alloy Designation System

Wrought alloys designation system shown in table-2. Wrought alloy designation system is given a four-digit number. The first digit (Xxxx) indicates the principal alloying element, which has been added to the aluminium alloy and is often used to describe the aluminium alloy series, i.e., 1000 series, 2000 series, up to 8000 series. The second single digit (xXxx), if different from 0, indicates a modification of the specific alloy, and the third and fourth digits (xxXX) are arbitrary numbers given to identify a specific alloy in the series. Example: In alloy 7150, the number 7 indicates that it is of the zinc alloy series, the 1 indicates that it is the 1st modification to the original alloy 7050, and the 50 identifies it in the 7xxx series. The only exception to this alloy numbering system is with the 1xxx series aluminium alloys (pure aluminums) in which case, the last 2 digits provide the minimum aluminium percentage above 99%, i.e., Alloy 1350 (99.50% minimum aluminium).

Table-2: Wrought alloys designation system

Alloy Series	Principal Alloying Element
1xxx	99.000% Minimum Aluminium
2xxx	Copper
3xxx	Manganese
4xxx	Silicon
5xxx	Magnesium
6xxx	Magnesium and Silicon
7xxx	Zinc
8xxx	Other Elements

7000 series aluminium alloys are high strength, heat treatable alloys containing zinc and magnesium as the main alloying elements. This series of alloys can be divided into Al-Zn-Mg and Al-Zn-Mg-Cu alloys. Al-Zn-Mg alloys are relatively weldable and are medium strength alloys. Al-Zn-Mg-Cu alloys have the highest strength. The 7000 series of aluminium alloys show higher strength when compared to other classes of aluminium alloys.

The first 7075 was developed in secret by a Japanese company, Sumitomo Metal, in 1935, but introduced by Alcoa in 1943. Al 7075 is an aluminium alloy, with zinc as the primary alloying element. It has excellent mechanical properties, and exhibits good ductility, high strength, toughness and good resistance to fatigue. 7075 aluminium alloy's composition roughly includes 5.6–6.1% zinc, 2.1–2.9% magnesium, 1.2–2% copper, and no more than 0.5% of silicon, titanium, chromium, iron, manganese, and other metals. The chemical compositions of 7075 aluminium alloy are given in Table-3.

Table 3: Chemical composition of 7075-Al alloy (amount of the components as % weight)

Zn	Mg	Cu	Cr	Mn	Si	Fe	Ti	Al
5.1-6.1	2.1-2.9	1.2-2	0.18-0.28	Max 0.3	Max 0.4	Max 0.5	Max 0.2	Balance

2. Literature Review

O. K. Abubakre et al [3], made investigation of the quenching properties of selected media on 6061 aluminium alloy. They subjected specimens to heat treatment at different temperature (400^0C, 450^0C & 530^0C) for 2 hours followed by quenching in different media like water, shea-nut oil and palm oil. The tensile strength, hardness and impact strength were evaluated. The results showed that the specimen heat-treated to 530^0C and quenched in water has the highest tensile strength and hardness. Also impact strength values exhibiting significant improvement as compared to control sample.

Prashanth K et al [4] investigated the effect of heat treatment on hardness and toughness of Al6061, Al6082 and Al7075. All the Al-alloy specimens, except those in the as-received condition, were solution heat treated at 435°C for 3 hours followed by quenching in water at room temperature. The hardness and impact test were conducted. It was concluded that the hardness value decreases for heat treated aluminium alloy and the toughness increases for heat treated aluminium alloys.

Shuaibu O. Yakubu et al, [5] investigated the influence of the quenching medium effect on the mechanical properties of 6061 aluminium manganese alloy. The Al 6061 alloy was subjected to solution heat treatment at different temperature for 2 hours followed by quenching in water, sheanut oil and local gin. Treated and untreated samples were subjected to various tests to determine their tensile strength, hardness and impact strength. The results showed that the specimens heat-treated at 530°C and quenched in water have the highest tensile strength. The specimens heated at 530°C and quenched in local gin gave the highest hardness. The toughness property of the alloy, as indicated by Charpy impact test values, was better at 530°C for specimen quenched in sheanut oil.

Dr. B. N. Sarada et al, [6] investigated the effect of quenching media on the mechanical properties of Al 6061-TiO2 metal matrix composite. The specimens have been subjected to solutionizing heat treatment in a muffle furnace at a temperature of 530^0C for 1.5 hours followed by quenching in different media i.e. air, water, aqueous polymer solution and ice. Hardness and tensile tests were conducted on the as cast and heat treated Al 6061-TiO2 composites. It was observed that the quenching has significant effect on hardness and tensile strength, exhibiting significant improvement as compared to as cast composites.

C. A. Obi et al, [7] studied the effect of soaking time and quenching media on the structure and mechanical properties of aluminium bronze. Standard specimens were prepared from the as-cast and heat treated samples for tensile, hardness and impact strength tests according to standard. The samples were solutionized at temperature of 900^0C for 30, 60 and 180mins and quenched in water, brine and SAE 40 respectively. The tensile, hardness and impact strength test were conducted. It was observed that the optimum ultimate tensile strength and hardness values of 710MPa and 513MPa respectively were recorded for the specimen solutionized at 900^0C for 30 minutes and quenched in water and brine respectively. But the impact strength of all the heat treated specimens was less than that of the as-cast specimen.

P. Dinesh et al [8] investigated the effects on mechanical properties such as tensile strength, shear strength, hardness of distilled water quenched aluminium friction stir spot welded joints and unquenched friction stir spot welded joints. It was concluded that the tensile strength and shear strength for the quenched welded Aluminium 2024 alloy was higher than the non- quenched welded Aluminium 2024 Alloy. But hardness of material of quenched welded Aluminium 2024 Alloy was lower than the non- quenched welded Aluminium 2024 Alloy.

J. Ridhwan et al [9] studied the effect of heat treatment on microstructure and mechanical properties of 6061 aluminum alloy. The samples were prior solution treated in the furnace for two hours at 400^0C before undergoing the cooling process. Normalized, annealed and quenched samples was cooled at room, furnace and water quenched respectively after solution treating. It was observed that the fast coolingrate on quenched sample produced finer grain and higher strength while slow cooling rates on annealed sample produced coarser grain and lower tensile strength.

3. Methodology

3.1 Heat treatment of specimens

Heat treatment is a process that involves a combination of time-controlled heating and cooling operations of metal without changing the product shape that will produce desires mechanical properties. The general types of heat treatments applied to aluminium and its alloys are solution heat treating, normalizing, annealing, quenching, and precipitation hardening. Certain heat treatment processes were used to enhance the properties of the material. Quenching is a type of metal heat treatment process. Quenching involves the rapid cooling of a metal to adjust the mechanical properties of its original state. To perform the quenching process, a metal is heated to a temperature greater than that of normal conditions, typically somewhere above its recrystallisation temperature but below its melting temperature. Then the metal has been held at the desired temperature, it is quenched in a medium until it returns to room temperature. In this study, heat treatment usually includes two main stages namely.

3.1.1 Solution Heat Treatment: Heating alloys into solid solution at 475°C for two hours, then the specimens quenched by different ways of cooling.

3.1.2 Quenching: Quenching is an important part of the heat treatment process. The process involves cooling the material after heat treatment in various mediums and various speeds. Water and oil are common quenching mediums for aluminum alloy are used in this studied.

3.2 Mechanical test

3.2.1 Tensile testing

The samples for tensile testing were cut according to ASTM E8 standards. The tests were carried out at room temperature using Universal Testing Machine.

3.2.2 Impact testing

Impact test samples were made according to the ASTM E23 standards. The tests were carried out using charpy impact test method. All the tests were performed at room temperature.

3.2.3 Hardness testing

Hardness of the specimens was measured using Brinell hardness testing machine. These tests were conducted in accordance with the ASTM E10 standard.

4. Results and Discussions

Table -4 shows the mechanical properties of the as–received and heat treated aluminium alloy samples with the two quenchants. Figures 2-4 are plots of variations of mechanical properties when different quenchants are used.

Table 4: Shows the mechanical properties of as-received and quenched aluminium samples.

S. No	Sample types	Tensile strength (MPa)	Impact strength (Joule)	Brinell hardness (BHN)
1	As-received	227	16	61
2	Water quenched	509	57	152
3	Oil quenched	531	73	159

4.1 Tensile Strength

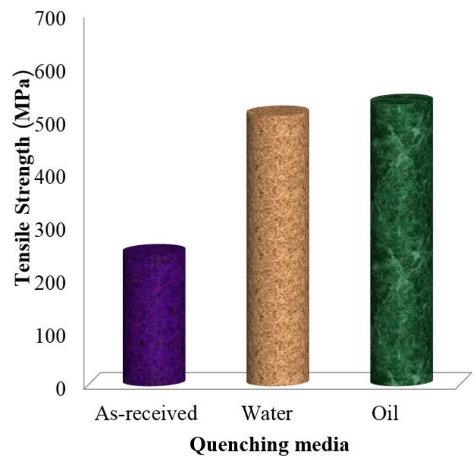

Figure 2: Effect of quenching media on the tensile strength of aluminum alloy

Figure-2 shows the effect of quenching media on the tensile strength of aluminium alloy. It is observed that the highest tensile strength value is obtained in oil quenched aluminium alloy (531 MPa) which is more than twice the value (227 MPa) for the as received aluminium alloy. This show that the sample quenched in engine oil can withstand more loads.

4.2 Impact Strength

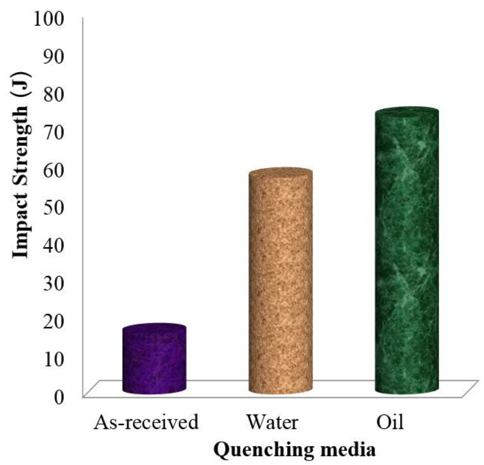

Figure 3: Effect of quenching media on the impact strength of aluminium alloy

Figure-3 shows the effect of quenching media on the impact strength of aluminium alloy. The impact energy test reveal that the oil quenched sample absorbed the highest amount of energy (73J) before fracture while as-received sample absorbs the least energy (16J). This further show that the oils can be used to improve the toughness of aluminium alloy, since it has higher impact energy values than water which is the common quenching medium.

4.3 Hardness

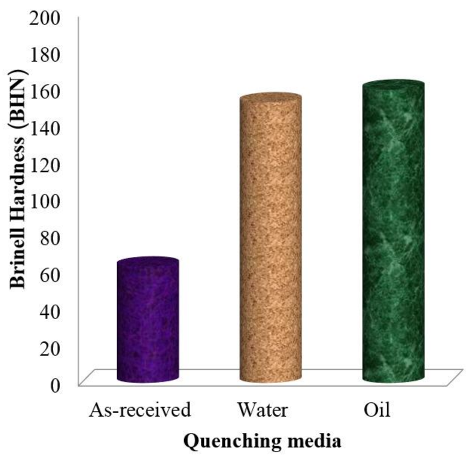

Figure 4: Effect of quenching media on the hardness of aluminium alloy

Figure-4 shows the effect of quenching media on the hardness of aluminium alloy. It is observed that the maximum hardness value of 159 BHN is obtained in oil quenching.

5. Conclusions

In this research work, Investigation the effect of quenching media on some selected mechanical properties of Aluminium alloy has been studied. The study has shown that using of water and oil as quenching media improves the mechanical properties when compared to the as-received aluminium alloys. Aluminium 7075 alloy with quenching in oil has height values of tensile strength, impact strength and hardness.

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