Investigation of Microstructural and Mechanical Properties of AA6061 alloy after heat treatment effects

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Abstract- Aluminum has been used in wide range of applications. AA6061 alloy most widely used in different applications such as aerospace and automotive. Heat treatment process helps to improve the mechanical properties and strength of AA6061 alloy. This study investigates how the microstructure and mechanical properties of AA6061 alloy vary before and after process of heat treatment. The heat treatment process included in this research are quenching process. The cyclic heat-treating process was studied, microstructure evolution was observed, and a comparison study with cold working of AA6061 alloy was conducted. Variable Pressure Scanning Electron Microscope (VPSEM), Optical Microscope and X-ray diffraction (XRD) were used to study the effect of heat treatment on the microstructure of AA6061 alloy. The mechanical properties counting tensile strength and Vickers microhardness were measured. The experimental results showed that the mechanical of these aluminum alloys were obviously affected by heat treatment process.
Keywords: 6061 aluminum alloy; Heat treatment; Microstructure; Heating Time; Microhardness; Tensile Test.

1. Introduction

Aluminum is one of the most important non-ferrous metals [1]. Aluminum and its alloys are widely utilized for various structural parts in aerospace and automobiles, because these materials have a good metallurgical and mechanical properties such as high specific strength and excellent resistance to corrosion [2]. Most products of aluminum are collected from components containing of aluminum alloys that are produced by addition some various elements like Si, Mn, Mg, Cu and Zn to improve the mechanical properties, corrosion resistance and processability. Aluminum alloys are kind of alloys that aluminum is the main metal. These kind of alloys also typically have the modulus of elastic about 70 GPa, which is less than most types of steel and steel alloys. Consequently, for a given load, a unit or component composed of an aluminum alloy will experience a more preponderant deformation in the elastic system than a steel part of identical shape and size. Though there are aluminum alloys with remotely-higher tensile strengths than the commonly used kinds of steel, simply superseding a steel part with an aluminum alloy might lead to quandaries. The typical alloying elements are silicon, magnesium, copper, manganese, zinc and tin. There are two principal relegations, namely wrought alloys and casting alloys, both of which are further subdivided into the heat treatable and non-heat treatable categories. This alloying element will reinforce the aluminum alloys so that the tensile vigor is incremented [3].
AA6061 alloy is a precipitation hardening aluminum alloy, containing silicon and magnesium as its main alloying elements [4]. It has good properties of mechanical and exhibits good ability for welding. This alloy is one of the most widespread alloys of aluminum for general-purpose use. The defining composition of these series (6XXX) is the addition of Silicon and Magnesium to create Mg_2Si. 6061Aluminum alloy also contains many other materials to give it some of its selecting features. Sometimes, the series can have some excess of Magnesium or Silicon. Having an excess of magnesium can lead to better corrosion resistance; however, it can also reduce its strength and formability. Alternatively, having an excess of silicon can increase the strength without hurting the formability or weldability but can lead to the aluminum being more susceptible to corrosion. Titanium can be added to aid in controlling grain size. The addition of zinc and copper aids in aluminum strength will not result in a significant reduction in corrosion resistance [5]. Al 6061 combines these alloying properties to achieve a good strength, machinability, balance of corrosion resistance and price [6]. It is commonly available in pre-tempered grades such as 6061-0 (annealed), 6061-T4 (heat-treated solution, quenched and naturally aged) and 6061-T6 (heat-treated solution, quenched and artificial aged).
AA6061 is a precipitation hardening aluminum alloy, containing Mg and Si as its major alloying elements [7]. This is the lower cost and most multipurpose of the heat-treatable aluminum alloys. It has most of the good aluminum qualities. It offers a range of good properties of mechanical and good resistance of corrosion [8]. It can be produced by most of the usually used techniques. Heat treatment is the combination of operations involving the heating and cooling alloys in the solid state. The aim of heat treatment is to improve the mechanical properties of the alloy, in addition to form more strengthening and soften to these alloys. The

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required results achieved by the heat treatment process by either permanent or temporary modification of the alloy grain structure.

The aim of this investigation was to show the effect of various precipitation hardening and cooling rate on microstructure and mechanical properties of AA6061 alloy. Samples were solution treated at 560°C for various times 2, 4 and 6 hrs. before cooling in furnace in the air quenching. AA6061 alloy was chosen due to wide range of applications and well-known properties. AA6061 alloy is a precipitation-hardening alloy. The major alloying elements are magnesium and silicon, which has good mechanical properties and exhibits good weldability. Aluminum alloys is one of the most common for general-purpose application [9].

2. Materials and methods

AA6061 alloy was used for this research with the chemical composition: 96 wt.% Al, 2.1wt.% Si, 0.95 wt.% Mg, 0.33 wt.% Fe, 0.17 wt.% Cu, 0.07 wt.% Cr and 0.022 wt.%. It was supplied by a local supplier (Heap Sing Huat Metal and Machinery Sdn. Bhd. Malaysia). The AA6061 alloy cylinder bars with a length of 200 mm was cut into the required sizes (20 mm × 16 mm) using a cutting band saw machine (UE−712A). For each set of experimental data, at least three samples were used to average mechanical tests. The surfaces of samples were cleaned using acetone to remove the dirt and grease. The AA6061 alloy samples were subjected to heating process by storing in heat treatment furnace at constant temperature 560 °C for various times 2, 4 and 6 hrs. Afterwards, the air quenching process was used in this experimental for fast cooling rate. After heat-treated process, the effects were studied in terms of microstructure using metallurgical analysis and mechanical properties by Vickers microhardness test and tensile tests. The microstructure characterizations of these metal alloys before and after heat treatment was observed using Optical Microscope (Raxvision Metallurgical) and Variable Pressure Scanning Electron Microscope (JEOL JSM-IT300LV, Japan). The tensile test was done on Instron Tensile tester with a 150N load cell. ASTM B 557 standard test method was used for the preparing the tensile test specimen. Microhardness testing using Future-Tech (FV-700) microhardness tester measurements according to standard ASTM E 384. The measurements were taken for hardness, at least 30 Vickers type indents on the polished cross section metal alloy samples with force of 4.9 N (0.5 Kgf) an the holding time of 10 sec. Following the mechanical tests applied to all the AA6061 alloy specimens, the fractured surfaces were characterized under Variable Pressure Scanning Electron Microscope (VPSEM, Japan) to understand the fracture mechanism of heat treatment of aluminum alloy. The effect of quenching process of AA6061 alloy on the changing of the ductility or toughness of that alloy could be followed using the VP-SEM.

3. Results and discussions

1. Microstructure characteristics at the base AA6061 alloy: The materials used in the present study were commercial AA6061 alloy bar rods, which are typically used for applications of automotive and aerospace [10]. Fig. 1 shows the diffraction pattern for AA6061 alloy. The peaks of this metal alloy indicate the phase used in this study. The relevant parameters corresponding to the diffraction peaks in the diagram have been computed by the X' Pert HighScore Plus software and indicates AA6061 alloy as cubic structure. The XRD peaks relative intensities of AA6061 alloy matched with one reference code (98-010-1523). The microstructural characterization was also performed for the base AA6061 alloy to measure the grain shape and size using image analysis for VPSEM. The image (Fig. 2) shows that the AA6061 alloy contains of average grain size around 13.75 μm. The base AA6061 alloy is seen to have equal grains size and distribution, with the grains tending to be regular. Fig. 3 shows the analysis of EDX for the AA6061 alloy, which identified the existence of Al and O. The presence of O is due to the aluminum being oxidized after surface polishing. This indicates that the Al is an alloy with addition of the different elements, to improve or to achieve the mechanical, fabrication and welding characteristics [11].

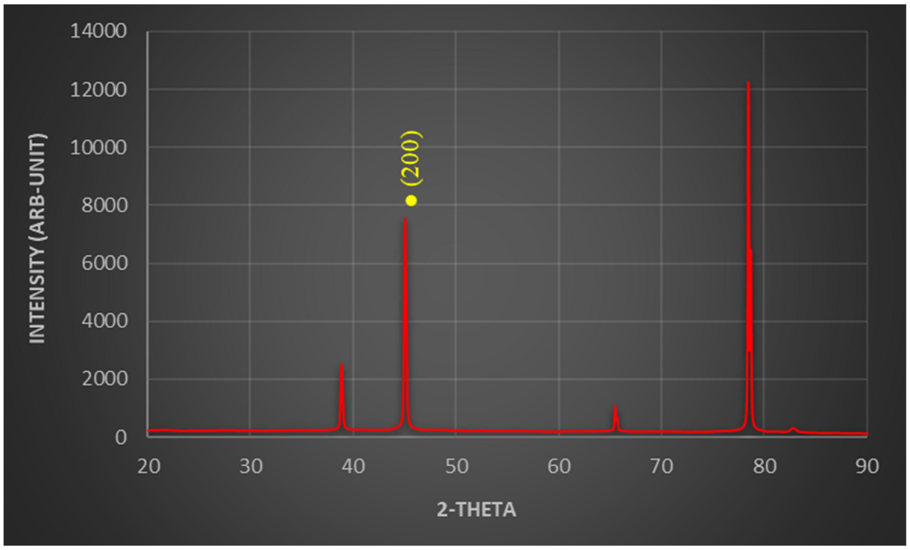
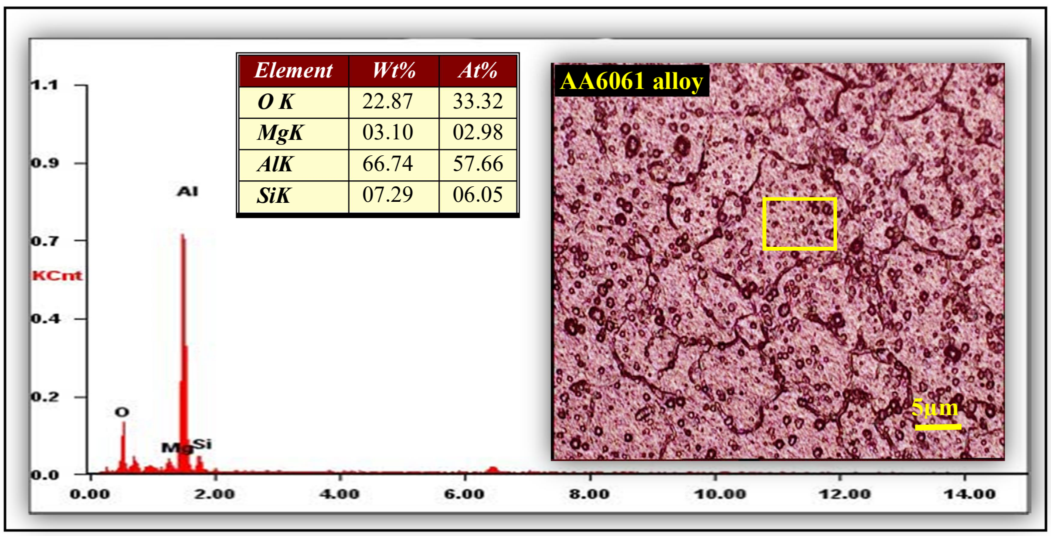


Fig. 1: XRD spectrum of AA6061 alloy



Element	Wt%	At%
O K	22.87	33.32
MgK	03.10	02.98
AlK	66.74	57.66
SiK	07.29	06.05

Fig. 2: The microstructure of AA6061 alloy by optical microscopy

2. Mechanical Properties of AA6061 alloy before and after heat treatment: The Vickers microhardness values obtained as a result of heating process of AA6061 alloy are given in Fig. 4. Depending on the heating time, an increase was observed in Vickers micorhardness values of AA6061 alloy samples. As can be seen in Fig. 4, mean microhardness values were measured according to the at least 30 Vickers type indents on the polished cross section AA6061 alloy samples. According to this study, it can observe that the Vickers microhardness values of AA6061 alloy increased parallel with the heating time at constant temperature. The microhardness increase in AA6061 alloy because of the heating process may be clarified by phases formed within the microstructure, change in grain sizes and precipitation[12, 13].

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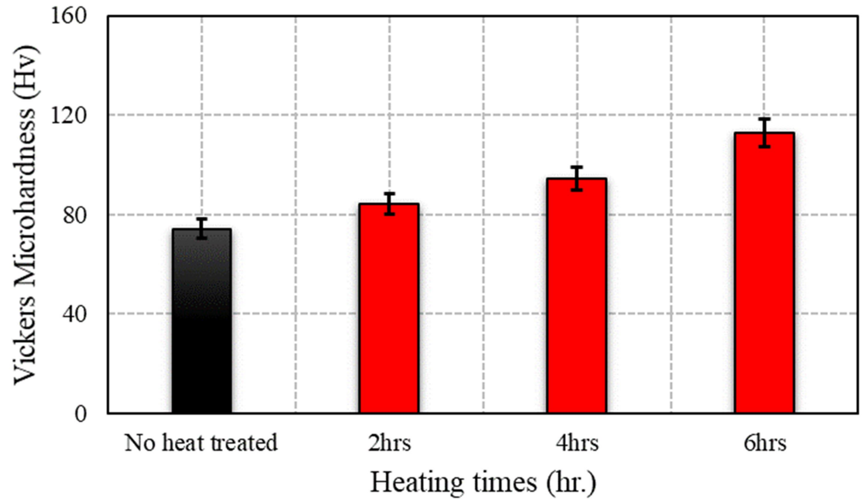

Fig. 4: Vickers Microhardness traverse of AA6061 alloy after aging times

Fig. 5 shows the effect of heating time (2, 4 and 6 hrs.) after solution treating (560 °C) on ultimate tensile strength of AA6061 alloy. It was observed that the strength of the aluminum alloy decreased when the heating time increased [14, 15]. The higher ultimate tensile strength of extrusion sample without heat treatment. But when the heat treatment will be done, the higher ultimate tensile strength of ~143.79 MPa was recorded by quenching samples after 2hrs aging time. Afterwards, the ultimate tensile strength started to reduce after increasing the heating time until 6 hrs. to become around 124.64 MPa.

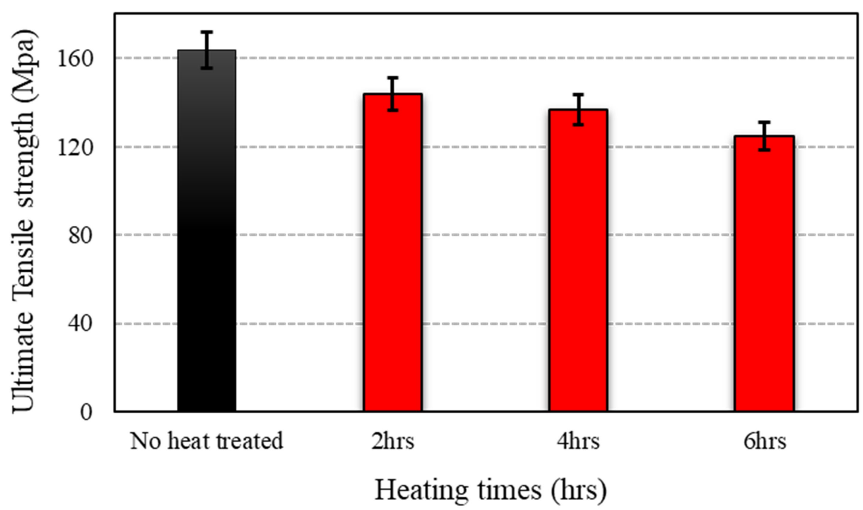

Fig. 5: Ultimate tensile strength of AA6061 alloy quenching after different aging time

3. Fractography after tensile tests: VPSEM was used to describe the fracture surfaces of the tensile tested specimens to understand the failure pattern. VPSEM photographs of AA6061 alloy were taken from chosen areas at the surface of the tensile fractured specimens. Fig. 6. shows VPSEM micrographs of the fractured surface under different heated time conditions. Different dimples sizes were formed with different heating time, whereas smaller dimples were observed for all VPSEM images. However, there is no significant difference in the fractured surface related to the heating time during to the process of heat treatment [16]. All the fracture surfaces have dimples, which are usually assumed to be an advantage of the ductile fracture mode. However, the brittle fracture increased with increasing heated times.

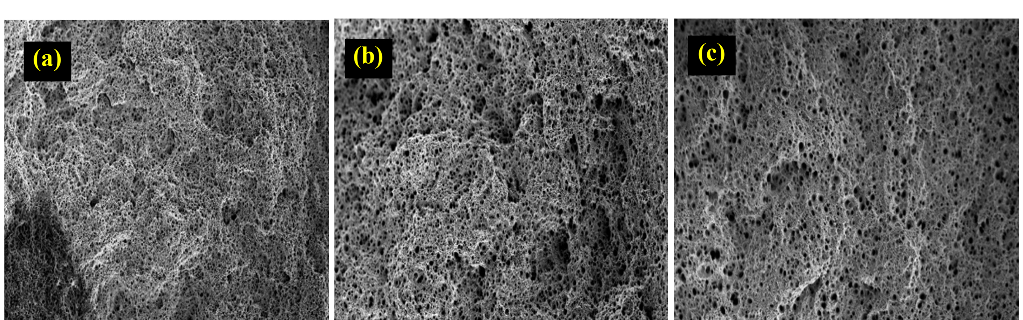

Fig. 6: VPSEM images of the fracture surfaces of the AA6061 alloy at constant temperature 560°C after different heating times (a) 2hrs, (b) 4hrs and (c) 6hrs

4. Conclusions

A commercial AA6061 alloy bars were exposed to heat treatment using constant heating temperature with different heat times quenching in air media to study the mechanical properties of these kind of aluminum alloy. The microhardness increase in AA6061 alloy as a result of heating process may be clarified by phases formed within the microstructure, change in grain sizes and precipitation. The ultimate tensile strength of AA6061 alloy decreased with increasing heating time to 6hrs.

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