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Heat Treatment Effect on Microstructure and Mechanical Properties of Magnesium Alloy

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ABSTRACT - In the present research study, the effect of heat treatment on mechanical properties, and microstructure characteristics of magnesium alloy with 99.94 % magnesium was studied. The heat treatment of samples was conducted at 150 ⁰C, 300 ⁰C, and 450 ⁰C for 2 hours. The samples were characterized by microstructure characterization using optical microscope (OEM) by observing the evolution of the microstructure of the heat-treated magnesium alloy. The hardness test was done on the surface of each sample using the load of 50 N to show the effect of heat treatment on the cross-section surface of magnesium alloy. From the results, the average grain sizes of the materials are different due to the different heat treatment and cooling rate of the materials.it is found that the hardness of the surface of the samples is higher at the edges of the samples than in the middle.The changes in average hardness of magnesium with the increase in temperature is due to an increase in grain size

Keywords – Microstructure, Magnesium, heat treatment, micro-hardness measurements

I. INTRODUCTION

Magnesium and its alloys have been attracting attention from the researchers because of being the lightweight material. And because of this, Magnesium alloys are used in weight reduction in structures and together in the automobile industry [1]. It is found that when Magnesium alloy is compared to other metal such as steel and aluminum, it is 75% lighter than steel and 35% lighter than aluminum [2]. Because of this weight ratio, magnesium alloy is used to replace steel and aluminum in structures to reduce weight [3]. The application of magnesium alloy has been limited by its low corrosion resistance and poor mechanical properties such as low elastic modulus, low strength, limited room temperature ductility and toughness, rapid loss of strength with temperature, and poor creep resistance [4].

The improvement of magnesium properties has been in research for decades now, researchers are trying to improve the properties of magnesium alloy since magnesium is an intelligent metal which has light weight, but unfortunately is also very soft in its pure form and has low melting point. Adding alloying elements is one way of improving the properties of magnesium alloy. Heat treatment is also the other method to alter the properties of magnesium alloy, researchers have been heat treating magnesium alloy to improve its properties. It was found that mechanical properties, microstructure characteristics, and corrosion resistance can be improved by heat treating alloyed magnesium [6-7].

Geng et al. [8-10] studied the microstructure, mechanical properties and corrosion behavior of magnesium alloy, in the study, the effects of Gd addition on microstructure, mechanical properties, and corrosion behavior of degradable Mg-17Al-7Cu-3Zn-xGd (x = 0, 1, 2, 3. weight fraction) alloys were investigated. There was a significant improvement in compression strength and degradable rate of the magnesium alloy when the weight fraction (X) of Gd was increased.

The main aim of this research is to investigate the effect of heat treatment on the mechanical properties, andmicrostructure characteristics, of the magnesium alloy (almost pour 99.94% magnesium alloy) and to determine the effects of heat treatment on magnesium alloy on the hardness of magnesium alloy over the entire surface area of the sample of heat treated magnesium alloy.

II. II. EXPERIMENTAL TECHNIQUES

99.94 % magnesium alloy was used for this research work. The samples were heat treated at different temperatures and holding time using an electric furnace. The heat treatment of samples was conducted at 150 ⁰C, 300 ⁰C, and 450 ⁰C for 2 hours. The samples were quenched immediately when they were removed from the furnace. The samples were characterized by microstructure characterization using optical microscope (OEM)

Microstructural observations and quantitative evaluations of the samples were examined before and after heat treatment using Digital optical microscopy (OM). For the OM, the processed discs were mounted in cold resin and all the samples were ground, polished and etched, following the guidelines in the Struers application note of metallurgical preparation of titanium [11]. The etchant was prepared with 100 ml of water

(H2O), 5 ml of Nitric acid (HNO3) and 3 ml of Hydrofluoric acid (HF). Thus, each sample was slightly deep into the Kroll's reagent for 15 seconds prior to microstructural surveillance on the Olympus BX51M microscope. The hardness test was done on the surface of each sample using the load of 50 N to show the effect of heat treatment on the cross-section surface of magnesium alloy.The microhardness test was carried out on the unetched samples using the TIME Group Inc TH722 Vickersfor dwell time of 15 seconds using a force of 500 gf according to the E384 -11e1 ASTM standard [12].

III. III. RESULTS AND DISCUSSION

Microstructure

Figure 1 show the microstructure of the parent material used for the experiment. The average grain size of the parent material was measured to be 144,34μm. For the heat-treatedmaterials, Figure 2 shows the microstructure of material heat treated at 150 deg for 2 hrsand figure 3 and figure 4 shows the microstructure of material heat treated at 300 deg for 2 hrs and at 400 degree for 2 hours respectively. Table 1 shows the average grain size of magnesium alloy heat treated at a different temperature and holding time of 2 hours.

From the results, it was found that at heat treating temperature of 150℃ for the holding time of 2hr the grain size was 111.64μm, at heat treating temperature of 300℃ for holding time of 2hr, the grain size was 140.27μm, and lastly at heat treating temperature of 450 ℃ for holding time of 2hr the grain size was 169.24 μm, The results for the average grain size agrees with the theory covered in the literature review, the grain size of magnesium must increase under the heat treatment process as the material (Magnesium alloy) is a nonferrous metal.

Fig.1.the microstructure of parent material

Temp (°C)	150 °C	300 °C	450 °C
Time (hr)	Av Size (μm)	Av Size (μm)	Av Size (μm)
2	111,6419146	140,2751124	169,247713

Table 1: Average grain size

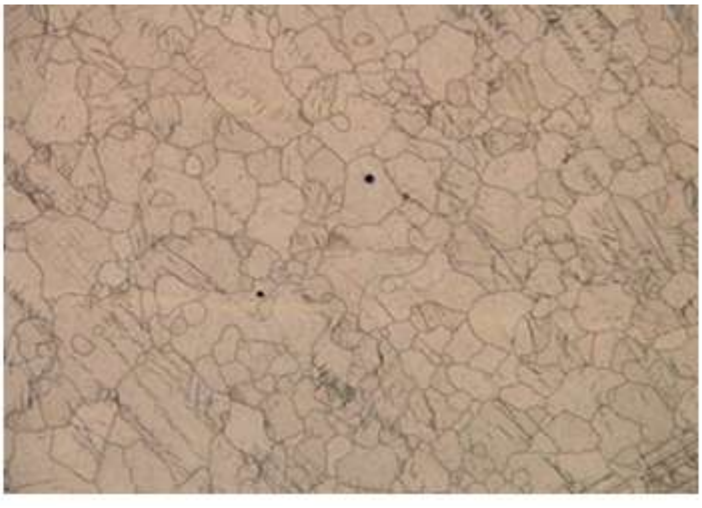

Fig. 2.The microstructure of material heat treated at 150 deg for 2 hrs

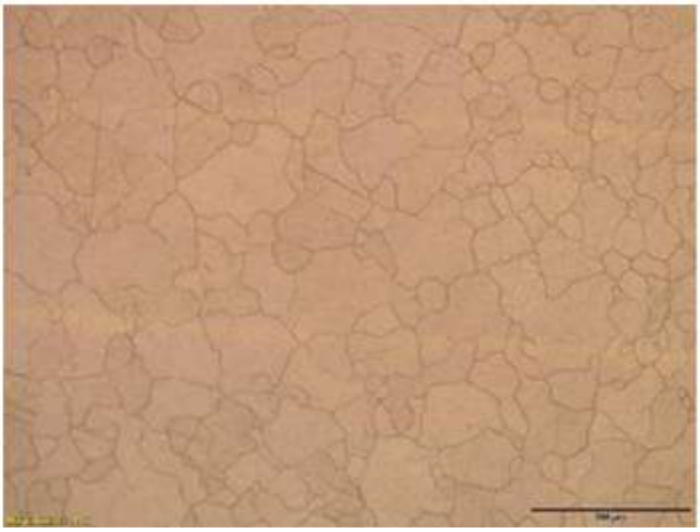

Fig. 3. The microstructure of material heat treated at 300 deg for 2 hrs

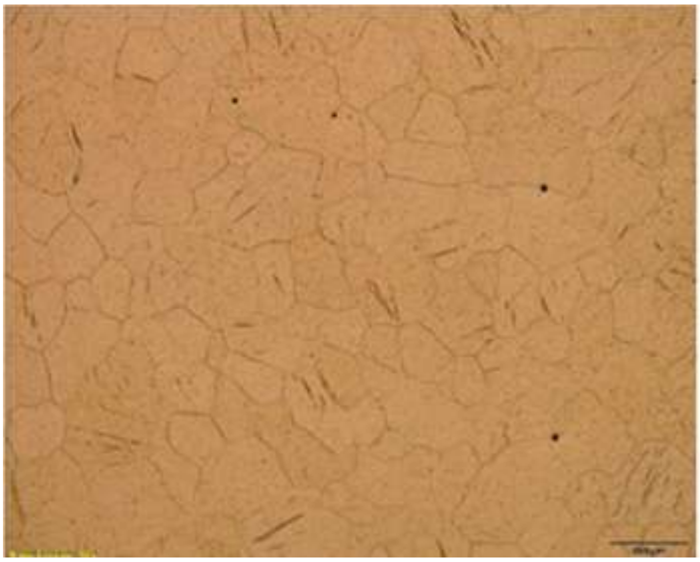

Fig. 4. The microstructure of material heat treated at 450 deg for 2 hrs

Micro Hardness

Figure 5 shows the result of micro-hardness test for the parent magnesium alloy used for the experiment. All the micro hardness results are presented in a form of a contoured plot using Sigma Plot. To analysis the micro-hardness test effect of heat treatment on the cross-section surface of magnesium alloy. The results of heat treated materials at temperature of 150-degree, 300 degrees and 450 degrees are showing in figure 6, 7 and 8 respectively. The measuredaverage hardness value of parent (not heat treated) material was 27.65 HV. It is found that the average hardness at 150℃ heat treating temperature and 2hr holding time was 28.44 HV, From the results, it is found that the hardness of the surface of the samples is higher at the edges of the samples than in the middle, this is due to the rate of cooling of the samples when are quenched during the heat-treating process (the outer surface material cool faster than the inner material).At heat treatment temperature of 300 ℃ the average hardness at 2hr holding time was 25.8 HV, and lastly, the average hardness at 450℃ heat treating temperature for 2hr holding time was 22.37. The changes in average hardness of magnesium with the increase in temperature is due to an increase in grain size of the material when is heat-treated under the specified conditions.

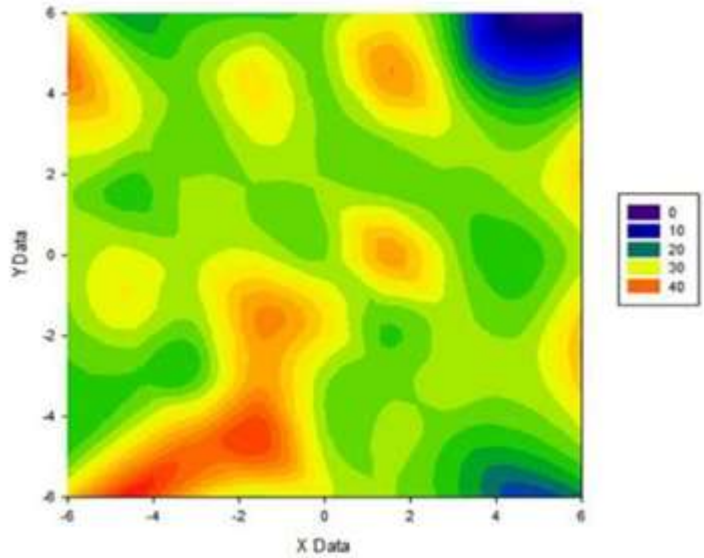

Fig. 5. Micro-hardness test result for parent material

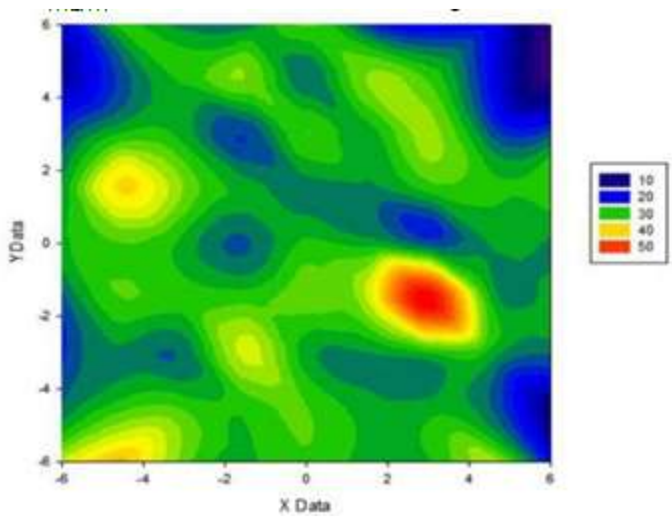

Fig. 6. Micro-hardness test result for material heat treated at 150 deg for 2 hrs.

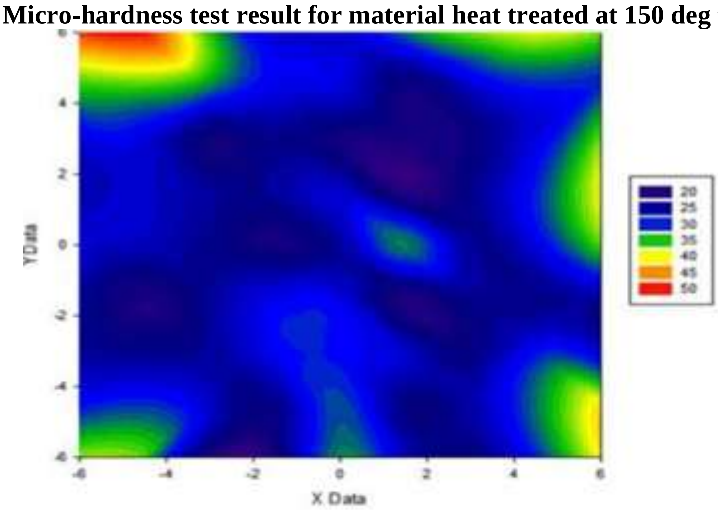

Fig. 7. Micro-hardness test result for material heat treated at 300 deg for 2 hrs.

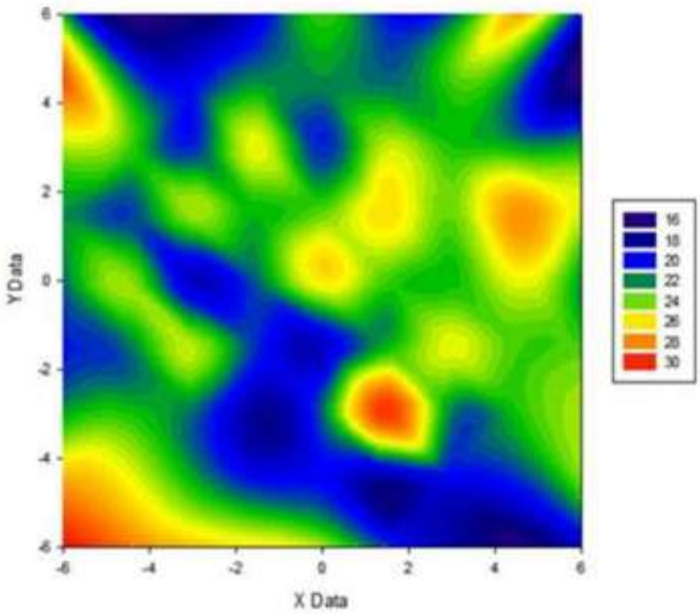

Fig. 8. Micro-hardness test result for material heat treated at 150 deg for 2 hrs.

IV. CONCLUSIONS

- The average grain sizes of the materials are different due to the different heat treatment and cooling rate of the materials.
- The grain size contributes to the effect of mechanical properties of the heat treated magenseium alloy under specified conditions .
- it is found that the hardness of the surface of the samples is higher at the edges of the samples than in the middle, this is due to the rate of cooling of the samples when are quenched during the heat-treating process.
- The changes in average hardness of magnesium with the increase in temperature is due to an increase in grain size of the material when is heat-treated under the specified conditions

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