

STUDY ON MICROSTRUCTURE AND MECHANICAL PROPERTIES OF QUENCHING AZ31B IN NANO-FLUID



BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS



Faculty of Mechanical and Manufacturing Engineering Technology



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Bachelor of Manufacturing Engineering Technology with Honours

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Faculty of Mechanical and Manufacturing Engineering Technology

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DECLARATION

I declare that this Choose an item. entitled "Study on microstructure and mechanical of quenching AZ31B in nano-fluid" is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



APPROVAL

I hereby declare that I have checked this thesis, and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology with Honours.

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DEDICATION

This study is wholeheartedly dedicated to my parent, who have been my source of inspiration and gave me strength and continually provide their moral, spiritual emotional and financial support when I want to give up in doing this study .

To my brother, sister, relative, friends, classmate and housemate who share their words of advice and encouragement to finish this study.

-

Finally, I dedicated this study to my supervisor Ts .Dr. Yusliza Binti Yusuf who guide me and give some strength to me on doing this study.

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1.1

ABSTRACT

AZ31B Magnesium Alloy was widely employed in a variety of applications, including automotive, contemporary aircraft fuselages, mobile phone, and laptop casings. This is due to its high strength and flexibility at room temperature, as well as its corrosion resistance and weldability. However, studies indicate that the composition of AZ31B is insufficient to sustain energy absorption, leading this material to fracture. This is owing to the Hexagonal Close-Packed (HCP) structure's low mechanical strength and ductility. Thus, this investigation will explore the impact of Graphene Oxide (GO) as nano fluid quenching medium on the mechanical properties of AZ31B. The AZ31B undergo a 3-hour heat treatment process at the specified temperatures of 250 °C and 350 °C, then immersed for 30 minutes in five different fluid media: air, distilled water, distilled water mixed with 0.1 wt %, 0.3 wt %, and 0.5 wt % of Graphene Oxide to examine the effect of nano fluid media on AZ31B strength. The microstructure analysis was conducted using the Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDX) to observe the surface properties of Magnesium Alloy AZ31B and the presence of GO in varying amounts in the quenching medium. The surface roughness analysis was also carried out to determine the roughness,(Ra)value of AZ31B Magnesium Alloy's after the heat treatment and quenching process done. Besides, the tensile test utilising dog-bone shaped sample was performed to estimate the ultimate tensile strength (UTS), yield strength, and young modulus of AZ31B following the heat treatment and quenching method for mechanical characteristics analysis. From the analysis, result showed that specimen with temperature treatment of 350 °C has a smooth surface and low (Ra) value in between 1.869 till 1.964 µm. Besides, the specimen also showed high (UTS), Yield Strength and Young Modulus value in compared to the control sample and specimens that undergo 250°C as heat treatment temperature. Furthermore, result from the analysis also proved that specimen with various wt % of GO in quenching media affect the microstructure and mechanical properties of AZ31B Magnesium alloy to have a smooth surface and high mechanical properties such as UTS of (250.305 MPa), Yield Strength value of (130.086 MPa) and Young Modulus of (5608.85 MPa) due to the presence of high concentration element Carbon (C) and Oxygen (O). Therefore, this study concluded that specimen with temperature of heat treatment of 350 °C followed by sink in Distilled Water + 0.3 wt % GO medium showed is the best parameter to achieve smooth surface and good mechanical properties for AZ31B alloy.

ABSTRAK

AZ31B Magnesium Alloy digunakan secara meluas dalam pelbagai aplikasi, termasuk automotif, fiuslaj pesawat kontemporari, telefon mudah alih dan sarung komputer riba. Ini disebabkan oleh kekuatan dan fleksibiliti yang tinggi pada suhu bilik, serta rintangan kakisan dan kebolehkimpalannya. Walau bagaimanapun, kajian menunjukkan bahawa komposisi AZ31B tidak mencukupi untuk mengekalkan penyerapan tenaga, menyebabkan bahan ini patah. Ini disebabkan oleh kekuatan mekanikal dan kemuluran struktur Hexagonal Close-Packed (HCP) yang rendah. Oleh itu, penyiasatan ini akan meneroka kesan Graphene Oxide (GO) sebagai medium pelindapkejutan cecair nano ke atas sifat mekanikal AZ31B. AZ31B menjalani proses rawatan haba selama 3 jam pada suhu yang ditetapkan 250 °C dan 350 °C, kemudian direndam selama 30 minit dalam lima media bendalir berbeza: udara, air suling, air suling dicampur dengan 0.1 wt %, 0.3 wt %, dan 0.5 wt % Graphene Oxide untuk mengkaji kesan media cecair nano pada kekuatan AZ31B. Analisis struktur mikro juga dijalankan menggunakan Scanning Electron Microscope (SEM) dan Energy Dispersive X-Ray Spectroscopy (EDX) untuk memerhatikan sifat permukaan Magnesium Alloy AZ31B dan kehadiran GO dalam jumlah yang berbeza-beza dalam medium quenching. Analisis kekasaran permukaan adalah juga dijalankan untuk menentukan nilai kekasaran, (Ra) AZ31B Magnesium Aloi selepas proses rawatan haba dan pelindapkejutan dilakukan. Selain itu, ujian tegangan menggunakan sampel berbentuk tulang anjing telah dilakukan untuk menganggar kekuatan tegangan muktamad (UTS), kekuatan hasil, dan modulus muda AZ31B mengikut kaedah rawatan haba dan pelindapkejutan untuk analisis ciri mekanikal. Daripada analisis, keputusan menunjukkan bahawa spesimen dengan rawatan suhu 350 °C mempunyai permukaan licin dan nilai (Ra) rendah di antara 1.869 hingga 1.964 µm. Selain itu, spesimen juga menunjukkan nilai (UTS), Kekuatan Hasil dan Modulus Muda yang tinggi berbanding sampel kawalan dan spesimen yang mengalami 250 ℃ sebagai suhu rawatan haba. Tambahan pula, hasil daripada analisis juga membuktikan bahawa spesimen dengan pelbagai % berat GO dalam media pelindapkejutan mempengaruhi struktur mikro dan sifat mekanikal aloi Magnesium AZ31B untuk mempunyai permukaan licin dan sifat mekanikal yang tinggi seperti UTS sebanyak (250.305 MPa), nilai Kekuatan Hasil. daripada (130.086 MPa) dan Modulus Muda sebanyak (5608.85 MPa) kerana kehadiran unsur kepekatan tinggi Karbon (C) dan Oksigen (O). Oleh itu, kajian ini merumuskan bahawa spesimen dengan suhu rawatan haba 350 °C diikuti dengan sink in Air Suling + 0.3 wt % GO medium menunjukkan adalah parameter terbaik untuk mencapai permukaan licin dan sifat mekanikal yang baik untuk aloi AZ31B

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LIST OF SYMBOLS AND ABBREVIATIONS

Al	-	Aluminium
Zn	-	Zinc
Mn	-	Manganese
Si	-	Silicon
Cu	-	Copper
HCP	-	Hexagonal Close-Packed
Mg	-	Magnesium
MgO	-	Magnesium Oxide
ASTM	- WA	American Society for Testing and Material
RHA	A.	Rolled Homogeneous Amour
GO	<u> -</u>	Graphene Oxide
EDX / EDS	-	Energy Dispersive X-Ray Spectroscopy
Be	1000	Beryllium
Ca	- 11	Calcium
Sr	ملاك	اونيوم سيخ تنڪنڪ Strontium
Ra	-	Radium
RE	JNIVE	Rhenium EKNIKAL MALAYSIA MELAKA
Y	-	Yttrium
Zr	-	Zirconium
С	-	Carbon
0	-	Oxygen
CRSS	-	Critical Resolved Shear Stress
Th	-	Thorium
RE	-	Rare Earth
AZ	-	Aluminium-Zinc
FCC	-	Face Centered Cubic
BCC	-	Body Centered Cubic
SCC	-	Stress Corrosion Cracking
PAH	-	Polycyclic Aromatic Hydrocarbons

rGO	- reduced Graphene Oxide
Dwg	- Drawing
SEM	- Scanning Electron Microscope
mm	- millimeter
TEM	- Transmission Electron Microscopy
SCFEA	- Side Cutting Edge Angle
Ra	- Roughness Average
Rq	- Root Mean Square
UTS	- Ultimate Tensile Strength
E	- Young Modulus
σ	- Stress
ε	Strain Uten اونيونر،سيتي تيڪنيڪل مليسيا ملاك
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CHAPTER 1

INTRODUCTION

1.1 Background

Magnesium Alloy is a combination of Magnesium mix with other metal (alloy) like Aluminum (Al), Zinc (Zn), Manganese (Mn), Silicon (Si), Copper (Cu), Rare Earth Metal and Zirconium to improve the Physical Properties. Magnesium Alloys are the current trend that will be used in US military industry because this alloy is the lightest metallic material that has high potential for weight reduction of Automotive vehicle. The density of magnesium with the value of 1.7g/cm3 is approximately 35% lower than aluminum (2.7g/cm3) and 77% lower than steel (7.9g/cm3) (Mubasyir et al., 2021).

Magnesium Alloy is very suitable in manufacturing Automotive and Aerospace applications. It has an enormous potential for application in the electronics, automobile, and aerospace industries due to their low density and high specific strength. However, this material also has disadvantages too. It has low ductility at room temperature which is related to their Hexagonal Close-Packed (HCP) structure. This scenario has been occurred because there are some gaps/voids that occur between the atoms when all the large atoms are closely pack together in a small area.

Most common Magnesium (Mg) alloy are AZ31B. The word "AZ" stands for Aluminium Zinc Manganese which are the two major alloying elements of the metal. The numbers 3 and 1 indicate the percentage of aluminium and zinc (3 wt.% and 1 wt.% respectively) that had been rounded-off to the whole number while the "B" in AZ31B is the second composition which has registered at the American Society for Testing and Materials (ASTM) (Abdullah et al., 2016). Magnesium Alloy AZ31B normally used in automotive, aerospace, industrial electronic, biochemical, and commercial application because it has high energy absorption capability, high electrical and thermal conductivity, excellent weldability and good castability (particularly for high pressure die casting) (L. Wang et al., 2013).

Magnesium Alloy AZ31B could replace Rolled homogeneous amour (RHA) for armoured vehicle due to its impact behaviour. However, the composition of AZ31B is insufficient to support energy absorption(Salvado et al., 2017). Therefore, to overcome this problem, a quenching method was introduced where the Magnesium Alloy AZ31B with certain temperature will be directly immersed into the medium that consist of nano particle like Graphene Oxide (GO). The nano particle will be able to fill in the void that appear between the large atom to produce van der Waals bonds and prevent structure to be collapse . This will be able to obtain a high energy absorption and AZ31B will not be fracture easily (Abdullah et al., 2016; Mubasyir et al., 2021)

Therefore, this study will be focusing on improving energy absorption through a series of heat treatment and quenching in medium presence of nanoparticle. The characterization will be conducted to determine the suitable combination of composition factors like temperature, and the quenching medium that consist of nanoparticles through Magnesium Alloy AZ31B. Some experiment will be involved to analyse the microstructure and the mechanical properties on Magnesium Alloy AZ31B by using Tensile Test and EDS analysis.

1.2 Problem Statement

Magnesium Alloys such as AZ31B have an immense potential for application in the electronics, automobile, and aerospace industries due to their low density and high specific strength. For example, Magnesium Alloy AZ31B could replace Rolled homogeneous amour (RHA) due to its impact behaviour. However, the composition of AZ31B is insufficient to support energy absorption that will cause this material to be fracture (Salvado et al., 2017). This is because, Magnesium Alloy, AZ31B has low mechanical strength and poor ductility that is related to their Hexagonal Close-Packed (HCP) structure. This scenario has been occurred because there are some gaps that occur between the atoms when all the large atoms are closely attached with each other in a small area.

To solve this problem, a technique such as quenching was introduced. Quenching defines as the soaking of the metal at a hot temperature that above the recrystallization phase, followed by a rapid cooling process to adjust the mechanical properties of its original state to change it become more stronger or weaker than before. Normally, Air, Water, Oil, Liquid Polymer and Brine (combination of water and salt) as quenchant was used (Kresnodrianto et al, 2018).But, conventional quenching has their own Bolling point. For example, water is the common quenchants that been used in forging because its cheap, easy to be manage and has minimal safe handling or disposal consideration. However, when facing hot tool steel or other steel alloys, the absorbed gases within the water tend to bubble out. These bubbles result in softening of the steel with subsequent cracking or warping. Oil has a higher boiling range (230°C and 480°C) that suitable for high-speed steels and oil-hardened steels. But it has a slower rate of cooling compared to either water or brine, but faster than air, making it an intermediate quench (Thomas, 2019).

Therefore, Graphene Oxide is suitable to be use as the quenching medium because it has high tensile strength (13 MPa) and it easily to be mix with distilled water due to the plenty of oxygen-containing groups in GO (Yuan et al, 2018).

When the hot melting of Magnesium Alloy AZ31B will be directly immersed into the medium that consist of nano particle like Graphene Oxide (GO), the nano particle will be able to fill in the void that appear between the large atom to produce van der Waals bonds and this will be able to obtain a high energy absorption. However, quench process parameter like temperature & nano element composition is crucial to determine. Thus, in this study, a systematic study consisting of the evaluating of quenching that consist of nano particle on various temperature and wt.% of graphene oxide (GO) to have better understanding on the influence of temperature and wt.% to the surface and the mechanical properties of Magnesium Alloy AZ31B.

1.3 Objective

The purpose of this research is to study the microstructure and mechanical Properties of Magnesium Alloy AZ31B after quenching in the medium that contain nano particle. Therefore, the objectives are as follows:

- To evaluate the effect of various temperature of heat treatment and various wt % of Graphene Oxide (GO) medium towards the microstructure and mechanical properties of Magnesium Alloy AZ31B.
- To analyze the microstructure and mechanical properties of Magnesium Alloy AZ31B.

1.4 Scope

The material that will used is Magnesium Alloy AZ31B.It will be cut into Dog-Bone Shaped by referring to ASTM Standard E8-04.Sample for SEM &EDX analysis with dimension of 10mm x 10mm had been prepared during cutting process. Heat treatment process will be conducted on Magnesium Alloy AZ31B with temperature of 250 °C and 350 °C.Specimen 1,3,5,7 and 9 will be heat with temperature of 250 °C while specimen 2,4,6,8 and 10 will be heat with temperature of 350 °C for 3 hours. The quenching medium that used is combination of distilled water with Graphene Oxide (GO) at various wt % and medium like air and distilled water as control parameter. Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS or EDX) analysis will be conducted to see the microstructure of Magnesium Alloy AZ31B and the present of Graphene Oxide at the surface of that material to determine whether each specimen consist of Graphene Oxide or not. To know the presence of Graphene Oxide, color mapping was added during Eds analysis. This will easily identify which area contain a lot of Go and which area that had been oxidized. Surface Roughness analysis was conducted to know the surface roughness value of AZ31B Magnesium Alloy after heat treatment and quenching process at 250 °C and 350 °C. Tensile Test will be conducted to test the energy absorption of Magnesium Alloy AZ31B to measure how much it can be deformed before it fractures.

CHAPTER 2

LITERATURE REVIEW

2.1 Magnesium and Its Alloy

Magnesium, Mg is a chemical element, with atomic number of twelve in periodic table. It is a gleaming gray solid with many physical and chemical features that like other five alkaline earth metal which are Beryllium (Be), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra). Magnesium can be mixed with other element such as Aluminium, Zinc, Manganese, Silicon, Copper, Rare Earth Metal and Zirconium to produce Magnesium Alloy. The Magnesium Alloy has poor ductility and formability but good fatigue and stress corrosion. Therefore, it was used in manufacturing automotive and aerospace application. It also used for sheet forming process. Figure 2.1 shows the application of Magnesium Alloy in automotive industry (Viswanadhapalli & Raja, 2019).

Magnesium Alloy can be classified into cast alloy and wrought alloy. Cast alloy is the alloy that melted in furnace and poured into mould (die casting) and allow it cool into the specific shape (Traverso, 2020). It can be divided into two group which are Mg-Al alloys that the amount of Aluminium (Al) does not exceed 10% with an addition of Zn and manganese Mn and Magnesium Alloys that free from Al, but mostly contain zinc (Zn), rhenium (RE) and yttrium(Y) with an addition of zirconium (Zr) (Jarka, 2022). Most common cast alloys are AZ63, AZ81, ZK61, HZ32 etc. The proof stress and the tensile stress of magnesium cast alloys was 75–200 MPa and 135–285 MPa.

Wrought alloy is the alloy that worked in the solid form such as forging, extrusion, and rolling operations, to achieve the desired shape with the help of specific tools (Traverso, 2020). The proof stress and the tensile stress of magnesium wrought alloys is typically 160-

240 MPa and 180-440MPa. The mechanical properties of magnesium wrought alloys is better than cast alloys because it has high tensile stress and good elongation than magnesium cast alloy (Viswanadhapalli & Raja, 2019). Magnesium wrought alloy can be classified into three basic group. The first group is alloys that contain aluminium, zinc, and manganese. The second group consists of alloys with elements such as Zn, Re, Y, Zr, and Th, while the third group consists of magnesium wrought alloys with ultra-light Li. Figure 2.2 shows the classification of magnesium wrought alloy (Dziubinska & Gontarz, 2015).



Figure 2.1 Application of Magnesium Alloy in automotive industry. (Source:<https://www.researchgate.net/publication/337109418_Application_of_Magnesium_Alloys_in_Automotive_Industry-A_Review)



Figure 2.2 Classification of magnesium wrought alloy

Magnesium Alloy has a low density of 1.7g/cm³ and low young's modulus value which are 42 GPa compared to other common alloys such as aluminium or steel alloys. It has good mechanical properties and excellent to corrosion resistance. The physical and mechanical properties of various Magnesium Alloy are showed in Table 2.1 (Fernández Martín et al., 2020). and Table 2.2 showed the composition of Magnesium Alloy with the name of each alloy and the proportion of each element that mix with magnesium.

In Table 2.1 Magnesium Alloy AZ91B has good physical and mechanical properties follow by Magnesium Alloy AM60B and lastly Magnesium Alloy AZ31B. In Table 2.2 Magnesium Alloy AZ31B has high concentration of magnesium (97%) follow by Magnesium Alloy AM60B (93.5%) and Magnesium Alloy AJ612A has the lowest concentration of magnesium which is 89.8-91.8%.

Alloy	AZ31B	AM60B	AZ61A	AZ91D
Properties				
Density (kg/m ³ x10 ³)	1.78	1.79	1.77	1.81
Liquid temperature (°C)	630	615	610	595
Solid temperature (°C)	575	540	495	470
Specific heat (J/kg°C)	1050	1050	1050	1050
Thermal conductivity	96	62	80	72
(W/m°C)				
Latent heat (kJ/kg)	373	373	373	373

Table 2.1 Physical and Mechanical properties of Magnesium Alloy

Table 2.2 Composition of Magnesium Alloy

	-							
Alloy	Proportion (%)							
-								
	Magnesiu	Aluminiu	Zinc (Zn)	Mangan	Silicon	Coppe	Iron	Nickel
	m (Mg)	m (Al)	يكل	ese (Mn)	(Si)	r (Cu)	(Fe)	(Ni)
AZ31B	97 NIV	2.50-3.50	0.60-1.40	0.20	0.10	0.050	0.005	0.005
AZ61A	92.83	6.18	0.99	0.13	0.05	0.006	0.011	0.0015
AZ91D	90.25	8.10	0.72	0.17	0.02	0.002	0.011	0.0006
AM60B	93.5	6.00	0.10	0.35	-	-	-	-
AJ612A	89.8-91.8	5.6-6.6	0.2	0.26-0.5	0.08	-	-	-

Magnesium Alloy is the lightest metallic substance with the greatest weight-saving potential. Unfortunately, it has low ductility and poor formability at room temperature because of its low symmetry of Hexagonal Closed Packed Structure (HCP). These alloys have lattice parameters of $\langle a \rangle = 3.18$ and $\langle c \rangle = 5.19$, resulting in a $\langle c \rangle / \langle a \rangle$ ratio of 1.62354 at 25 °C, which is slightly less than the ideal $\langle c \rangle / \langle a \rangle$ ratio with the value of 1.633 (Alaneme & Okotete, 2017). Plastic slip will be occurred on atomic planes and directions with significantly different activation barriers. Critical resolved shear stress (CRSS) for Non-Basal Slip to activate the available slip systems in the (a) direction are several times smaller than the Basal Slip to activate the 12 slip systems in the $\langle c + a \rangle$ direction. This is also cause by the deformation being governed by $\{0001\}$ $\langle 1120 \rangle$ basal $\langle a \rangle$ dislocation slip and $\{1012\}$ (1011) tensile twinning. Basal <a> slip does not allow for strain accommodation along the crystal c-axis but allows for a rotation of the crystal c-axes parallel to the loading direction, leading to the component of basal texture. As a result, magnesium fails at low strains (see Figure 2.3) (Sandlöbes et al., 2017). Therefore, magnesium needs to be alloying with other material like Aluminum (Al), Zinc (Zn), yttrium (Y) and rare earth (RE). It also can be conduct through the Heat treatment process and quench in the nano fluid to improve the ductility at the room temperature significantly.



Figure 2.3 Dutile and Brittle for Pure Magnesium and Magnesium Alloy (Source: < https://www.nature.com/articles/s41598-017-10384-0#Fig1)

2.2 Properties of Magnesium Alloy AZ31B and its application

Most common mangnesium wrought alloy are Magnesium Alloy AZ31B that belong to the AZ Series with high concentration of Aluminium and Zinc. The word "AZ" stands for Aluminum Zinc Manganese which are the two major alloying elements of the metal. The numbers 3 and 1 indicate the percentage of aluminum and zinc (3 wt.% and 1 wt.% respectively) that had been rounded-off to the whole number while the "B" in AZ31B is the second composition which has registered at American Society for Testing and Materials (ASTM) (Abdullah et al., 2015). AZ31B has the composition of 97 % of Magnesium, 2.50 to 3.50 % of Aluminium, 0.60 to 1.40 % of Zinc, Minimum 0.23 % of Manganese, 0.10 % of Silicon, 0.05 % of Copper, 0.031 % of Calcium, Maximum 0.005 % of Iron and Maximum 0.005 % of Nickel by the weight of the element (wt %) (Subramani et al., 2019).

Because of its high boiling point and good machinability, Magnesium Alloy AZ31B was normally use in machining process like metal forming, welding, annealing and extrusion. It has a good room-temperature strength and ductility, as well as corrosion resistance and weldability.AZ31B was widely used in the range of applications, including

automotive, modern aircraft fuselages, cell phone and laptop cases, speaker cones, and concrete tools. At feverish temperatures, Magnesium Alloy AZ31B can be super formed to produce a wide range of intricate automotive components. It also available in plate, tooling plate, sheet, rod, and bar to produce the complex part or component that benefit from the dimensional stability such as jigs, fixtures, optical benches, vibration test equipment and inspection gauges. The physical, mechanical, and thermal properties of Magnesium Alloy AZ31B was showed in Table 2.3 and 2.4 (Pu et al., 2011).

Although Mg AZ31B has the potential to replace Rolled homogeneous amour (RHA) due to its impact behavior (Mubasyir et al., 2021).However, the composition of AZ31B is insufficient to support energy absorption (Salvado et al., 2017). Thus, to overcome this problem Magnesium Alloy AZ31B will undergo heat treatment process and directly immersed into the medium (quenching) that consist of nano particle like Graphene Oxide (GO). The nano particle will be able to fill in the void that appear between the large atom to produce van der Waals bonds and prevent structure to be collapse. This will be able to obtain a high energy absorption and AZ31B will not be fracture easily (Abdullah, Abdullah, Omar, et al., 2015; Mubasyir et al., 2021).

PROPERTIES	IMPERIAL	METRIC
Density	0.0639 lb/in ³	1.77 g/cm ³
Tensile Strength	37700 psi	260 MPa
Yield Strength	29000 psi	200 MPa
Compressive Yield Strength	18900 psi	130 MPa
Ultimate Bearing Strength	18900 psi	495 MPa
Shear Strength	27600 psi	190 MPa
Shear Modulus	2470 ksi	17 GPa
Elastic Modulus	6948 ksi	44.8 GPa
Poisson's Ratio	0.35	0.35
Young Modulus	45,000	45,000

Table 2.3 Physical and Mechanical properties of AZ31B

Table 2.4 Chemical Properties of AZ31B

PROPERTIES	IMPERIAL	METRIC
Heat Of Fusion	340 J/g	146 TU/lb
CTE, Linear	14.4 µin/in-°F at 32 – 212 °F	26.0 μm/m-°C at 0 – 100 °C
UNIVERSITI	15.0 μin/in-°F at 68 – 392 °F	27.0 μm/m-°C at 20 – 200 °C
Specific Heat Capacity	0.239 BTU/lb-°F	1.00 J/g-°C
Thermal Conductivity	666 BTU-in/hr-ft²-°F	96.0 W/m-K
Thermal expansion co- efficient (0-100°C/32- 212°F)	14.4 μin/in°F	26 μm/m°C
Melting Point	1120 – 1170 °F	605 – 630 °C
Solidus	1120 °F	605 °C
Liquidus	1170° F	630 °C

2.3 Heat Treatment

Heat treatment is the process of heating the metal in solid-form and cool it in a controlled way to obtain the desired mechanical properties without changing the composition of the metal. It is used to modify the structure of the metal to become more stronger, more malleable, resistant to abrasion and increase its ductility to make it become more valuable in machining. The purpose of heat treatment is to improve magnetic and electrical properties, increase resistance to wear, heat, and corrosion (Saif M, 2020). The heat treatment was used on ferrous metals like cast iron, AHSS, stainless steel, and other alloy steels, and some non-ferrous metals like aluminium, magnesium, titanium, copper, and brass.

Heat treatment can be divided into three stages which are heating, soaking, and cooling. Heating is the stages where the metal will be heat slowly to maintain a uniform temperature (in the range of 2400 °F / 1316 °C) at the inner and the outer surface of the metal. During heating stage, the forecasting will be conducted to estimate the time taken that needed to heat the metal uniformly. If the metal has been heated unevenly, one piece of the metal may expand more quickly than another, resulting in a deformed or broken section. There are some factors that need to be consider when choosing the heating rate. One of them are, the thermal conductivity of the metal where the metal with high heat conductivity heats up faster than those with poor conductivity. Next is the condition of the metal. Tools and parts that have been hardened, or stressed, previously should be heated slower than tools and parts that have not. Finally, is the size and cross-section of the metal. Larger pieces or parts with uneven cross sections must be heated more slowly than small parts for the inner temperature to be near to the surface temperature. Otherwise, there will be a risk of breaking or extreme warping (Natalie Spira, 2020).

Soaking Stage was happening when the outer layer of the metal reaches the furnace's predetermined temperature, the temperature is not consistent across the thickness. The

purpose of the soaking is to keep the metal at the proper temperature until the desired internal structure is formed. "Immersion period" refer to time of metal that kept at the proper temperature. Chemical analysis of metal was needed to determine the length and the soaking time of the metal with a smooth cross section surface. For uneven section, the maximum section has been used to determine the soaking time of the metal after the heating stages. The final stage of the heat treatment is cooling stage. It is used to cool the metal back to the room temperature after the heating process. There are some ways to cool the metal either air quenching (in a furnace) or using water, brine, oils, and polymer solution as quenchant. Not all metals should be quenched because quenching can cause cracking or warping in some metals. In general, brine or water can quickly cool the metal, whereas oil cool the metal slowly than the water. Water can be used to harden carbon steels, oil can be used to harden alloy steels, and water can be used to quench nonferrous metals(Natalie Spira, 2020).Figure 2.4 (a) show the Heat Treatment and 2.4(b) show the graph of temperature versus time for Heating, Holding and Cooling.



(a)

(b)

Figure 2.4 (a) Heat Treatment (b) Graph Temperature versus Time for Heating, Holding and Cooling

(Source: < https://www.ftmmachinery.com/blog/11-heat-treatments-of-metal.html)

Heat Treatment can be classified into five technique which are Annealing, Normalizing, Hardening, Tempering and Nitriding. Annealing is one of the most important processes because it softens the steel (softening process) to improve its machinability, removes the internal stresses developed during the previous process to obtain desired ductility, malleability, and toughness. Next, is Normalizing. To achieve uniformity in the material microstructure, this process involves homogenization or grain refinement. To produce a homogeneous austenitic phase, the material is heated above the upper critical line of the iron carbide phase diagram. After that, a cooling phase in slightly agitated air is used to form ferrite. Normalizing was commonly applied to ingots prior to working and hardening of steel casings. Normalizing reduces hardness while increasing ductility and it's typically ALAYSI, used after other processes have unintentionally increased hardness while decreasing ductility (Saif M, 2020). Heat Treatment was normally used in Automobile, Aerospace, Computers, Metalworking, Machinery and Construction because it helps to get desired mechanical and chemical properties, to reduce stresses and increase the lifetime of the parts to ensure the اويبوبر سيتي تيڪنيڪل .part can be used for a long time

2.3.1 Heat Treatment of Magnesium Alloy AZ31B

Magnesium Alloy AZ31B can be used as a material in aerospace, automobile, and electronics, due to the advantages of light weight, high specific strength, and stiffness. It also can be super formed at elevated temperatures to create a wide range of complicated vehicle components. However, it may have some undesirable properties like Poor wear resistance and low mechanical strength which limited their use in a variety of industrial applications (Xu et al., 2018). The strength of the composition of AZ31B was insufficient to support the impact of structure deformation . This was happened because of its polycrystalline face centered cubic (FCC) structure where the metal of FCC have a better

packing efficiency and more closely packed slip planes than BCC (body centered cubic) metals, making them less ductile because the energy required to move atoms along denser planes is less than that required to move atoms along less dense planes (Salvado et al., 2017). Pre-Treatment such as heat treatment was needed to increase the energy absorption of AZ31B to increase the wear resistance and mechanical properties to make it more ductile than before.

A lot of research that was done by other people to study the effect of Heat Treatment process on Magnesium Alloy AZ31B.An experiments were conduct by G. Wang et al., 2017 to study the microstructure and mechanical properties of friction stir-welded AZ31B Magnesium Alloy by post-weld heat treatment. Two metals with dimension of 75 x 300mm were joined to become a plate with dimension of 150x300mm.A post-weld heat treatment was carried out with different rotational speeds of 1100, 1200 and 1300 rev min⁻¹ at welding speed of 300 mm min⁻¹ with a variety of PWHT, 150, 200, 250, 300, 350, 400 and 450°C for1 h in a vacuum and cooled in air. Tensile tests were carried out to the welding direction to determine the tensile properties of the welded joints and the specimens for the tensile tests were prepared according to the GB/T 228-2002 standard.G. Wang et al., 2017 found that the average yield tensile, tensile strength, and elongation of friction stir-welded joints were 92.5 MPa,199.1 MPa, and 7.3 percent, respectively, at rotational speeds of 1200 rev min⁻¹ and welding speeds of 300 mm min⁻¹. The study also found that the post-weld heat treatment at 300°C for 1 hours to be more beneficial than other heat treatments in terms of improving mechanical properties with the maximum yield and tensile strength of 139.9 and 238.4 MPa respectively.

On the other hand, LI Hongzhan, 2019 had conduct another experiment to study the microstructure and mechanical properties of Magnesium Alloy AZ31B at different temperatures for different time by using annealing technique. The metal with the dimension

 $300 \text{mm} \times 200 \text{mm} \times 30 \text{mm}$ was heated at three different temperatures -200°C, 250°C and 300° C for 15,30 and 45 minutes. OLYMPUS-PMG3 metallographic microscope has been used to see the microstructure of the Magnesium Alloy AZ31B and evaluated the mechanical properties of three different specimen with INSTRON-5982 universal material testing machine. The study found that, the heat treatment process can affect the microstructures of AZ31B where the average grain size is about 3-5 µm at 250 °C for 30 minutes. When temperature reach 300°C, the tensile strength and Yield Strength decreased, and the value of elongation increased. Heat treatment will affect the microstructure and mechanical properties of Magnesium Alloy AZ31B.

Heat Treatment process will influence the properties of Magnesium Alloy AZ31B.It reduce brittleness and improve mechanical properties of a material by changing the structure of crystals and eliminating imperfections in microstructures (DING et al., 2018).It improved hardness value to prevent the metal being fractured when external force was applied on it. Heat Treatment is a powerful method to maximize the strength and ductility of Magnesium Alloy AZ31B because of unbalanced microstructures and casting defects in the interface and/or basal metals by strengthen the interfacial bonding strength and the overall properties of bimetal composites. However, it is difficult to be control when metal reached high melting point at 650° to 1050°F or 340° to 565°C, the microstructure and mechanical properties will be modified to become too soft or too hard (Xu et al., 2018).Heat treatment on Magnesium Alloy AZ31B at room temperature or at slightly elevated temperatures may retain internal working stresses. Under some conditions, this could result in stress-corrosion cracking (Figure 2.5 (a) and (b)).

A quenching medium with nanoparticle was needed, to increase the energy absorption of Magnesium Alloy AZ31B and prevent stress-corrosion cracking. This may also increase its ductility to ensure Magnesium Alloy AZ31B can be used as a material in transportation and various kinds of modern applications like laptop, handphone, smart watches, air pods etc.



Figure 2.5 (a) Photograph of Stress Corrosion Cracking (SCC) of Magnesium Alloy AZ31B.

(b) Microstructure of the AZ31B with Stress Corrosion Cracking (SCC)

(Source: < https://www.researchgate.net/Figure/Stress-corrosion-cracking-test-results-of-

AZ31B-Mg-alloy-a-A-photograph-of-Stress_fig17_272150019)

2.4 Quenching Of Magnesium Alloy AZ31B

Quenching defined as the soaking of the metal at a hot temperature that above the **UNIVERSITITEKNIKAL MALAYSIA MELAKA** recrystallization phase, followed by a rapid cooling process to adjust the mechanical properties of its original state to change it become more stronger or weaker than before. In quenching, an austenized steel is tranform to martensite (a non-equilibrium constituent) by immersed in a liquid, called quench medium or quenchants.Each medium have their own cooling characteristics. Improper quench medium can cause the material to become brittle, suffer geometric distortion, and develop undesirable residual stress, that will effect the mechanical property and become fracture (Kresnodrianto et al., 2018).

The effectiveness of a quenchant is largely determined by its properties.Some factor that influenced its properties which are temperature of quenchant,vaprozation of latent heat,
specific heat of the quenchant, thermal conductivity of the quenchant, viscosity of the quenchant and the agitation level of the quenching bath.

The temperature of the quenching medium is very important because it wil influence the properties of the metal. The shorter the time required to achieve thermal equilibrium between the coolant and the work-piece when temperature of the coolant are high. As a result, cooling rates are slowed, and higher temperatures are generally used where distortion or cracking problems are severe. Water is used at temperatures ranging from 20 to 40°C. As the temperature rises above 60°C, the cooling power of the water decreases rapidly. Mineral oils as a quenchants are typically used in the temperature range of 50–80°C. Hot quenching oils are used at temperatures ranging from 100 to 150°C, whereas marquenching oils are used at the temperature that above 150°C.

The latent heat of vaporization of a liquid is defined as the amount of heat that required to convert one unit mass of liquid into vapor without any changes in temperature. Quenchants with a low latent heat of vaporization are easily to be converted into vapour. This will speed up the initial stage of cooling. Furthermore, significant fuming will occur upon quenching, and there may be a pollution issue. Also, the quenchant will be consumed in large quantities. Quenchants with a high latent heat of vaporization, will shorten the first stage's duration. However, the majority of the heat generated by the workpiece will be confined to the quenchant, raising the temperature of the quench bath significantly.

Factor that control the charactiristic of the quenching process are the viscosity of the quenchant. The higher the viscosity, the slower the cooling rate because heat transfer from the work-piece to the quenchant and within the mass of quenchant will be poorer. When a faster cooling rate is required, a quenchant with a lower viscosity is used. Low viscosity in a quenchant also limits the duration of the first stage of cooling (T.V. Rajan, 2011).

2.4.1 Conventional Quenching

Water, oil, liquid polymer and brine are the example of conventional quenching that will be used after heat treament process.Water is popular to be used as a quenching medium becasue it does not required any payment and easy to be handle.It has high cooling rate which suitable to cool down some carbon steels, alloy steels and non-ferrous alloys like alluninium alloy,copper alloy and nickel alloy.This is because water can break the down the layer of scale that forms on the surface during heat trament process, thus eliminating an additional process of surface cleaning (T.V. Rajan, 2011).

In automotive and maufacturing indsutry,water as a cooling medium was used to harden plain carbon steels and few grade of low alloy steels. This also known as shallow-hardening steels. For Deep Hardening, quenching in water can be cooled more quickly than critical cooling in oils without cracking.Water is the medium that used in heat treament process however when facing with hot tool steel or other steel alloys with temperature that exceeded 65 °F or 18.33 °C. The gases tend to form bubbles on the surface of the metal. These bubbles tend to collect in holes or recesses and softening the steal that caused cracking or warping (Thomas, 2019). Quenching medium such as Oil could solve this problem because it has high boiling point and good thermal conductivity.

Oil is a conventional quenching agent that suitable for high-speed steel and oilhardened steel. Oil is frequently to be used because it transfers heat very quickly without causing any significant distortions. However, it has low cooling rate than water or brine but faster than air, making it as intermediate quench. Examples of oil quenching is Mineral Oil. It has good cooling capacity for most alloy steels, but they are more expensive and nonbiodegradable. Furthermore, mineral oils oxidize at elevated temperatures, resulting in the accumulation of toxic polycyclic aromatic hydrocarbons (PAH) as can see in Figure 2.6. Inhaling oil mists from these processes (Quenching in mineral oil after heat treatment process) has potential been linked to health problem. The accumulation of such degradation products after repeated use has a significant impact on the quenching performance of the oils (Thomas, 2019).



Polycyclic Aromatic Hydrocarbons

Figure 2.6 Polycyclic aromatic Hydrocarbons (PAH)

(Source: < https://microbewiki.kenyon.edu/index.php/File:Pah.png)

Brine is a mixture of rock salt that dissolve in water to reduce the absorption of atmospheric gases and prevent bubbling. This improves the surface wetting and cooling rate, promoting uniform rapid cooling. High carbon steels or low alloy steels, on the other hand, may have uneven cross-sections, which can cause stress or cracking.it also not suitable for non-ferrous metals like Aluminium, Silver, Lead, Copper etc. because this material has potential for being corrode by Brine due to the concentration of rock salt that being dissolved in distilled water. A quenching medium that consists of nano particles was recommended to increase the ductility of Magnesium Alloy AZ31B.

2.4.2 Quenching In Nano-Fluid

The common nanomaterial that will be used is Graphene Oxide (GO) as can see in Figure 2.7 (a). It was discovered by Benjamin Brody in 1859 in the form of tiny crystal with molecular weight of 33 kg/mol (Geim, 2012). The structure of Graphene Oxide consists of a single atom layer with some functional groups such as carboxyl acid, hydroxyl, and epoxy which could make it amphiphilic. GO is a single-layered material that made up of carbon, hydrogen, and oxygen molecules by the oxidation of graphite crystals, which are inexpensive and abundant. Due to the considerable number of oxygen-containing groups in graphene oxide, it has excellent dispersion ability in water or suitable organic solvents (Yuan et al., 2018).

Graphene Oxide is the precursor of graphene with higher yields and lower cost. It can be reduced to formed reduced graphene oxide (rGO) by removing a substantial portion of oxygen groups of its hexagonal lattice structure to make graphene-like sheets. GO can be synthesized in different ways such as the Modified Hummer's method and Staudenmaier method. Figure 2.7 (b) show the preparation of Graphene Oxide (GO). It also can improve the corrosion resistance and the biocompatibility of Magnesium Alloy because the atom will fill the gap that occurred between two big atoms (Gao et al., 2019). In biotechnology and medicine, an oxidized derivative of graphene oxide is now employed for cancer therapy, drug delivery, and cellular imaging. GO also has a variety of physicochemical features, such as nanoscale size, large surface area, and electrical chargeability. However, the toxic effect of GO on living cells and organs is a limiting factor that limits its use in the medical field (Rhazouani et al., 2021). Therefore, it was suitable to be used as a quenching medium to be immersed by AZ31B after heat treatment process to increase the energy absorption because the nano particle will be able to fill in the void that appear between the large atom to produce van der Waals bonds.







(b)

Figure 2.7 (a) Structure of Graphene Oxide (b) Preparation of Graphene Oxide (Source: (a) https://www.biolinscientific.com/blog/what-is-graphene-oxide,
(b) https://www.researchgate.net/Figure/Depiction-of-different-routes-for-the-GO-preparation_fig1_279313049)

Most of the previous study indicates that the temperature and wt % of Graphene Oxide (GO) are the crucial parameter which can affected the microstructure and mechanical properties of Magnesium Alloy AZ31B when quenching in the medium that consist of nanoparticle after heat treatment process. A lot of experiment that had been conducted to study the temperature and wt % of nanofluid that will affect the properties of the material. A study that was conducted by (Mubasyir et al., 2021),the heat treatment process was conducted at the temperature of 260 and 350 °C. The metal will be soak at three different medium which is distilled water, distilled water with carbon nanotube and distilled with nano silica for 30 and 60 minutes .A tensile test was carried out on Magnesium Alloy AZ31B. Result show that temperature with 350 °C and in the medium that have carbon nano tube for 60 minutes give a high value of tensile test of 78.54 J.

According to the study by Srivastava et al.in 2021,the metal was heated at a temperature of 800 to 850 °C and quenched in the medium at various wt.% of graphene oxide which are 0.4%, 0.8% and 1.2% respectively. The result shows that tensile strength of Magnesium Alloy AZ31B was increased to 333.68Mpa when quench in the medium with 1.2 wt.% of graphene oxide. The percentage of elongation was also decreased from 11.296 % to 9.216 % as shown in Figure 2.8 (a) and (b).

In addition,Kresnodrianto et al., 2018 had carried out an experiment which the heat treament of AZ31B at 344°C (650°F) for an hour and quench in water and nanofluid (Graphene Oxide) with three different concentration of 0.1%, 0.3% and 0.5%.As a result the harndenss and tensile value of 729.89 MPa after quenching in 0.1% of nanofluid was higher than cooling by water which was 594 MPa.It is also provied that quenching in nanofluid that consist of Graphene Oxide will increased the corrosion resistance of Magnesium Alloy AZ31B.



Figure 2.8 (a) Ultimate Tensile Strength versus wt% of Graphene Oxide (GO)(b) Elongation at peak versus wt% of Graphene Oxide(GO) (Kresnodrianto et al., 2018)

2.5 Summary Of Literature Review

Magnesium Alloy such as AZ31B have been used un automotive, modern aircraft fuselages, cell phone and laptop cases, speaker cones, and concrete tools becuase it has has a good room-temperature strength and ductility, as well as corrosion resistance and weldability.However it has a low energy absorption that will effect the properties of the material when condcuted some testing on it.Therefore the metal will be undergo heat treament and quench in the medium that consist of nano-particle.The temperature and wt % of graphene oxide are the most important pramaneter that will affect the microstructure and mechanical properties of AZ31B.Many experiment was been conducted to studied this prameter however,there are lack of experiement that carry out the heat treament and quench in distilled water that mix with Graphene Oxide.Thus an experiement will be conducted to study microstructure and mechanical properties of quenching AZ31B in the medium that consist of Graphene Oxide with the parmeter that was been set which are temperature and wt% of Graphene Oxide (GO).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter will explained the procedure of experiment for heat treatment and quenching process for Magnesium Alloy AZ31B.First, Dog-Bone Shaped will be drew at Solidwork software by referring to ASTM standard E8-04. The material was cut into the Dog-Bone Shaped using Laser Cutting Machine. Sample for SEM & Eds Analysis with dimension of 10mm x 10mm was been cut using Laser Cutting Machine. Heat treatment process will be carried out at 250 °C and 350 °C for 3 hours. Then, Magnesium Alloy AZ31B will be guenched in 5 different medium which are Air, Distilled Water, Distilled Water+0.1 wt % Graphene Oxide, Distilled Water+0.3 wt % Graphene Oxide and Distilled Water+0.5 wt % Graphene Oxide for 30 minutes. Some analysis will be conducted which are Microstructure analysis and Tensile Test analysis. The microstructure and chemical composition of Magnesium Alloy AZ31B were observed in SEM analysis and EDX analysis. To know the presence of Graphene Oxide, color mapping was added during the analysis to the specimen that used Graphene Oxide as quenching medium. Surface Roughness analysis was conducted to know the surface roughness value of AZ31B Magnesium Alloy after heat treatment and quenching process at 250 and 350 °C. Finally, Tensile test was carried out to study the Ultimate Tensile Strength, Yield Strength, and Young Modulus of AZ31B after the quenching process.Figure 3.1 show the process flow of overall experiment of Magnesium Alloy AZ31B.



Figure 3.1 Process Flow of overall experiment of Magnesium Alloy AZ31B

3.2 Sample Preparation

Raw material Magnesium Alloy AZ31B will be bought at Lazada with dimension of 200 mm (length) x 200 (width) x 2mm (Thickness). The design of the Dog- Bone Shaped will be draw at the Soliwork Software according to the ASTM Standard E8-04 and convert into Dwg file. A Laser Cutting Machine of AMADA F0 MII 3015 NT will be used to cut the material according to the file that save at the solidwork software at the Advanced Forming Technology Laboratory.10 pcs Cube with dimension 10mm x 10mm will be cut to ensure Microstructure analysis can be carried out at Material Science Laboratory. Figure 3.2 (a) show the raw material of Magnesium Alloy AZ31B.(b) show the Dog-Bone Shaped of ASTM Standard E8-04 (Kumar et al., 2019) while Figure 3.2 (c) show the Cutting Process using AMADA F0 MII 3015 NT Laser Cutting Machine.



(a)



(b) 40



Figure 3.2 (a) Magnesium Alloy AZ31B (b) Dog-Bone Shaped of ASTM Standard E8-04 (Kumar et al., 2019) (c) Cutting Process using AMADA F0 MII 3015 NT Laser Cutting

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(Source:<https://www.lazada.com.my/products/i2789761627-

s13344399180.html?urlFlag=true&mp=1)

3.3 Heat Treatment and Quenching

The heating treatment procedure of Magnesium Alloy AZ31B was carried out in this study using a Nabertherm Heat Treatment Furnace, as illustrated in Figure 3.3 (a). The furnace will be cleaned manually to eliminate dust and impurities, since this may impair the accuracy of the result when the analysis is carried out. The furnace will then be heated for 5 minutes prior to check that the temperature is correct, as the real temperature of the furnace

is rarely the same as the temperature displayed on the screen. It is necessary to guarantee that the whole surface of the specimen is evenly heated throughout the heat treatment procedure. Magnesium Alloy,AZ31B with Dog-Bone Shaped was placed inside the furnance as shown in Figure 3.3 (b). All the sample will be carried out the heat treatment process with the temperature of 250 and 350 °C for 3 hours. To conduct the heat treatment process, a preheating of the furnace on 5 minutes. Magnesium Alloy,AZ31B will be heated at 250 °C and 350 °C for 3 hours. Then it will undergo cooling phase by immersed into the quenching medium for 30 minutes (Akir et al., 1998). Figure 3.4 show the heating profile of AZ31B.

After the material reach the required temperature, it will undergo quenching with the medium that had been set. All the specimen will be classified into 10 specimen according to the parameter that need to be determined which are temperature and wt % of Graphene Oxide (GO). The characterization specimen of AZ31B involved summarized in Table 3.1.The quenching medium that will be used are Air, 50 ml of Distilled water and 50 ml of Distilled +0.1wt %.0.3 wt % or 0.5 wt % Graphene Oxide(GO).

To produce the Graphene Oxide Solution, use an ultrasonic probe to dissolve the Graphene Powder in distilled water until the necessary amount is reached (Anis, 2016; Rahim, 2018).Using a probe type ultrasonic processor QSonica 700 Sonicator , the nanofluids will be put in an ice path during sonication at 20 KHZ for 15 minutes to produce equal dispersion of Graphene Oxide (GO) in distilled water. Using Equation 3.1,mix the amount of nano powder with distilled water to make nano fluid quenching media.

Volume of the solvent (ml) =
$$\frac{\text{Weight of nano particle (g)}}{100\%}$$
 X Volume of the solution(ml) (3.1)

The medium will then be ready to be used to soak Magnesium Alloy AZ31B. Specimens 1 and 2 will utilize Air as quenchants ,3 and 4 will soak in distilled water and specimen 5 through 10 will soak in distilled water mix with various wt percentage of Graphene Oxide, as shown in Table 3.1 and Figure 3.5.To separate the metal with various heating temperatures, marker pen will be utilized. For 30 minutes, all the specimens will soak. Once the process is finished, sample will be dried and put into the Zip lock Bag that fill with Silica Gel to ensure there is not any air that trapped inside the Zip lock Bag.Figure 3.5 show the specimen that quench in Air, Distilled Water, Distilled Water + 0.1 wt % ,0.3 wt % ,0.5 wt % Go and Sealed Specimen using Zip Lock Bag.



(a)

(b)

Figure 3.3 (a) Nabertherm Heat Treatment Furnace (b) Specimen put into the Furnace



Figure 3.4 Heating Profile of AZ31B (Akir et al., 1998)



Figure 3.5 Specimen that quench in Air, Distilled Water, Distilled Water + 0.1 wt % ,0.3 wt % ,0.5 wt % Go and Sealed Specimen using Zip Lock Bag

Specimen Identification	Temperature (°C)	Soaking Time	Quenching Medium
1	250		Air
2	350		Air
3	250		Distilled Water
4	350		Distilled Water
5 5	250		Distilled Water + 0.1 wt %
TEKA	KA		Graphene Oxide
6	350	30 Minutes	Distilled Water + 0.1 wt %
5 N) alumito	بتر. تىكنىغ	Graphene Oxide
7 UNI	250 /ERSITI TEKNIK	ي . AL MALAYSI	Distilled Water + 0.3 wt %
			Graphene Oxide
8	350		Distilled Water + 0.3 wt %
			Graphene Oxide
9	250		Distilled Water + 0.5 wt %
			Graphene Oxide
10	350		Distilled Water + 0.5 wt %
			Graphene Oxide

Table 3.1 Characterization of Specimen

3.4 Sample Analysis

3.4.1 Microstructure Analysis

JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM) is an equipment that use for analysing the microstructure of Magnesium Alloy AZ31B after quenching process. It can handle the specimen with diameter of 0 to 250mm at the analytical working distance of 8.5 mm owing through the combination of large movement stage, inclined detectors, and conical objective lens. High resolution of image which is up to 3072 x 2304 pixel was produced by scanning an extremely small, focused beam of electrons (adjustable down to 1.5 nm in diameter) across the surface of a specimen in an array of picture points (pixels) usually 1024 x768 pixels (Ellen Hodges, 2008).

To analyse the microstructure of AZ31B, a small piece of 10mm x 10mm cube will be placed at the mount. Click the vacuum, select vent and placed the mount under the Vacuum Chamber. Electron Guns creates high electron beam that focused on the sample surface by a set of lenses in the electron column. The electron and the radiation of the sample will be gathered by a detector most usually the Everhart—Thornley detector and the gathered signal is enhanced and showed on the computer. The image of the surface of Magnesium Alloy AZ31B will be produced in 2D intensity map (Ezzahmouly et al., 2019). JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM) has the potential to carry out the analysis because high energy electron carried the kinetic energy and scatted the energy as a signal that produced by interaction between electrons and specimen. So, the electron can reveal the microstructure, chemical composition, and external morphology of the specimen and this will be able to do the comparison after obtained the result from the analysis. Energy Dispersive X-Ray Spectroscopy (EDS or EDX) is a chemical microanalysis technique used in conjunction with scanning electron microscopy. This analysis was used to determine the presence of Graphene Oxide whether it has a lot or only a little bit due to the parameter that had set which are the wt % of Graphen Oxide in quenching medium. Colour mapping was added during the analysis to the specimen that used Graphene Oxide as quenching medium.

EDS is made up of three basic components: an emitter source, a collector, and an analyser. These components are commonly seen on electron microscopes such as a SEM or TEM. The combination of these three elements allows the study of the number of X-rays radiated and their energy compared to the energy of the initial X-rays that were emitted. Figure 3.6 (a) show the JEOL JSM-6010PLUS/LV Scanning Electron Microscope and (b) show effects produced by electron-beam interaction with a specimen and Figure 3.7 (a) are put specimen at the mount (b)was SEM Analysis and (c) was EDX Analysis



Figure 3.6 (a) JEOL JSM-6010PLUS/LV Scanning Electron Microscope (b) Effects produced by electron-beam interaction with a specimen (Ezzahmouly et al., 2019)



Figure 3.7 (a) Put specimen at the mount (b) SEM Analysis (c) EDX Analysis

3.4.2 Surface Roughness Analysis

Surface roughness, also known as roughness, is an element of surface finish that consists of Waviness, Lay and Roughness. It is commonly used to indicate the level of surface roughness of a material, either it has good or bad surface finish after the machining process. Many factors influence surface roughness quality, including machining variables (cutting speed, feed per tooth, and depth of cut), tool macro- and micro-geometries (nose radius, rake angle, side cutting edge angle (SCEA), and cutting-edge type (chamfered, honed, or a combination of chamfered and honed) (Choudhury & Chinchanikar, 2017). High cutting speed or feed per tooth will make the surface become rougher. This will increase the surface roughness value. A proper machining variable during the machining process will determine the surface roughness value either higher or lower. The surface roughness can be evaluated using Roughness average (Ra) as parameter in engineering practice. Ra is the arithmetic average of the absolute values of the profile heights over the evaluation length, while Rq is the root mean square arithmetic average of the absolute values of the profile heights over the evaluation length. Figure 3.8 show the graph of Roughness Average (Ra) and RMS Roughness (Rq) in surface roughness analysis.



Figure 3.8 Roughness Average (Ra) and RMS Roughness (Rq) in surface roughness analysis

(Source: https://upmold.com/surface-finish-ra-rz/)

In this study, surface roughness analysis is carried out by using Mitutoyo SJ-410 Portable Surface Roughness Tester as shown in Figure 3.9 with ISO-1997 Standard. The measurement is done in 1 direction 5 times as shown in Figure 3.10 for each specimen to ensure the measurement is accurate.

To conduct the analysis, the specimen will be placed at the table and fix with clay. Then, move down the Stylus to touch the specimen until it shows green colour on the screen with anti-clockwise direction. Click the Start button and print the result for each specimen once the measurement is finished. Figure 3.11 show Surface Roughness Analysis for AZ31B Magnesium Alloy



Figure 3.9 Mitutoyo SJ-410 Portable Surface Roughness Tester



Figure 3.10 Surface Roughness Measurement in 1 direction



Figure 3.11 Surface Roughness Analysis for AZ31B Magnesium Alloy 3.4.3 Tensile Test Analysis TEKNIKAL MALAYSIA MELAKA

Tensile testing is a disruptive test that provides information about the tensile strength, Yield Strength, and ductility of the metallic material. It measures the maximum force that required to destruct to break a composite or plastic specimen and the extent to which the specimen stretches or elongates (Saba et al., 2018). It also used to see the transformation of metal with a normal size until form a necking then fracture as shown in Figure 3.12

Tensile testing also offers tensile strength (at yield and at break), tensile modulus, tensile strain, elongation, and percentage elongation at yield, elongation, and elongation at break. It also performed on resin-impregnated bundles of fibers ("tows"), through thickness specimens (cut from thick sections of laminates), and area of sandwich core materials (Saba et al., 2018). In this study, tensile strength is tested using Shimadzu Autograph AG-X plus as shown in Figure 3.13 (a).

To start the analysis, power supply and PC need to be turn on. Magnesium Alloy such as AZ31B with dog-bone shaped was clamped at Tensile Test Jig as shown in Figure 3.13 (b). Next, is to create a test method or select the existing test method for same test parameters/same test pieces. It also needs to insert the force to pull the material and the dimension of the dog-bone shaped. After all the parameters have been set, start the tensile test, and save the result once finished. Finally, remove the specimen and turn off the power supply and PC. Figure 3.14 show specimen after Tensile Test Analysis



Figure 3.12 The shape of a ductile specimen changes during tensile testing (Source:< <u>https://www.admet.com/effect-specimen-geometry-tensile-testing-results/</u>)



Figure 3.13 (a) Shimadzu Autograph AG-X plus (b) Clamp Dog-Bone Shape at Tensile



Figure 3.14 Specimen after Tensile Test Analysis

3.5 Summary Of Methodology

Magnesium Alloy such as AZ31B will be formed into the Dog-Bone.10 pcs Cube with dimension of 10mm x 10mm cube will be prepared using laser cutting machine. A Heat Treatment process will be conducted with different temperature and quenching in 5 different medium which are Air, Distilled water, and Distilled water with different wt % of graphene Oxide. Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS or EDX) analysis was conducted to observe the microstructure and determine the presence of Graphene Oxide either it has a lot or only a little bit using color mapping to the Speciemen that quench in the medium that consist of Graphene Oxide (GO). Surface Roughness Analysis was conducted to know the surface roughness value of AZ31B Magnesium Alloy after heat treatment and quenching process at 250 and 350 °C. Finally, tensile test will be carried out the know the max strength that the metal can reach until fracture.It was conducted to study Ultimate Tensile Strength (UTS),Yield Stength and Young Modulus of AZ312B with various heating temperatures and various wt % of Graphene Oxide (GO) that will effect the mechanical properties or no effect after Heat Treatment and Quenching Process.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results of heat treatment and quenching process of Magnesium Alloy AZ31B with different heating temperatures of 250 and 350°C for 3 hours and weight percentage of Graphene Oxide (GO) that added in distilled water will be discussed and analyzed. Microstructure analysis, Surface Roughness analysis and Tensile Test analysis were preformed after Heat Treatment and Quenching Process of AZ31B.

4.2 Microstructure Analysis

4.2.1 SEM Analysis



10 Pcs of specimen with dimension of 10mm x10mm of AZ31B Magnesium Alloy was observed by using JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM). Table 4.1 shows the result of the microstructure of AZ31B with different heating temperature and different wt % of Graphene Oxide.



Table 4.1 Microstructure of Magnesium Alloy AZ31B



According to the result in Table 4.1 shows that specimen that heated with temperature of 250 °C and 350 °C followed by quenching process in 5 difference mediums did not have a smooth surface finish. This is because raw material like Magnesium Alloy AZ31B was produced at the factory by referring to some standard like ASTM B107, ASTM B91 and ASTM B90 to determine the concentration of each element that need to be insert and mix together to produce AZ31B Magnesium Alloy Plate. Therefore, a rough surface will be observed when conducted Microstructure analysis.

By referring Table 4.1, Specimen 3 has a good surface followed by specimen 8 with temperature of 350 °C and soak in Distilled Water + 0.3 wt % Graphene Oxide (GO) for 30 minutes. Specimen 1 has a poor surface when observed using JEOL JSM-6010PLUS/LV

Scanning Electron Microscope (SEM). This is because there are some Pin holes and scratches on it. It also has some irregular wrinkles that will affect the weight percentage of each element either a lot or little bit. There are some specimens that show a big crack on the surface when undergoes SEM analysis. For example, in Figure 4.1 show the area where redox reaction happens. Redox is the chemical reaction of losing electrons (oxidation) and gaining electrons (reduction). In this situation, Magnesium will react with Oxygen to become Magnesium Oxide (MgO) because magnesium atom loses electrons to become the cation (which is being oxidized), while the oxygen molecule gains electrons to form oxygen anions (Helmenstine et al., 2020). For example, the reaction of Magnesium and Oxygen can be expressed in equation 4.1

$$2 \text{ Mg} + \text{O2} \rightarrow 2 \text{ [Mg2+] [O2-]}$$
 (4.1)

As a result, it will generate a big crack on the surface of Magnesium AlloyAZ31B when quenching in the medium that consist of 0.1 wt % Graphene Oxide (GO) after taken out from the furnace with temperature of 350 °C. Specimen that soaks in medium that contain of Graphene Oxide (GO) have a good surface than soak in Air or Distilled Water. Lastly. Specimen 9 contains a lot of white spots on the surface of AZ31B Magnesium Alloy that mean Oxidation occurs between specimen and trapped air after Heat Treatment and Quenching Process.

In general, specimen that heated with 350 °C has a smooth surface than 250 °C when conducted the Scanning Electron Microscope (SEM) analysis.



Figure 4.1 Area where redox reaction happens for specimen 6

4.2.2 EDX Analysis

After conducting the SEM analysis, Energy Dispersive X-Ray Spectroscopy (EDS or EDX) analysis will be carried out with the image that had been captured using JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM). Chemical composition of Magnesium Alloy AZ31B are Magnesium (Mg), Aluminium (Al), Carbon (C), Zinc (Zn) etc. While chemical composition for Graphene Oxide is C140H24O20. To evaluate the presence of Graphen Oxide (GO) on the surface of a specimen after quenching process, colour mapping was applied on specimen 5 to specimen 10. Magnesium will symbolize Sapphire Blue Colour, Carbon with Red colour, Oxygen with Green colour, and Aluminium will be marked with Electric Blue colour. Result of EDX analysis will be displayed in Table 4.2 while Material Composition wt % will show in Figure 4.2.



Table 4.2 EDX result for specimen 1 until specimen 10





Figure 4.2 Material Composition wt % for specimen 1 until specimen 10

By referring to the result of EDX analysis and Material Composition in Table 4.2 and Figure 4.2. noticed that all the specimens contain 4 main element which are Magnesium (Mg), Aluminium (Al), Carbon(C) and Oxygen(O). All specimen has an average percentage of Magnesium in between 65.00 wt % -77.00 wt %. This is because Magnesium is the main element that mix with other element to improve its mechanical properties; therefore, all specimens contain high concentration of Magnesium (Mg). Some specimens have a higher weight percentage of magnesium, and some specimens have lower weight percentage of magnesium. For example, specimen 7 has a high percentage of magnesium (79.25 wt %) followed by specimen 8 (77.06 wt %) while specimen 2 has low weight percentage of magnesium (64.42wt %).

Next is Aluminium (AI). As can see in Figure 4.2 show that Aluminium contains low material composition compared to other element with average of 1.56 wt %. Specimen 7 contain highest weight percentage than the average number of Aluminiun which are 2.31 wt % but specimen 8 contain only 0.01 wt %. This happened because aluminium is a soft, pliable material. If the proportion of aluminium is greater than other chemical element, the plate will be too soft and even it will break when doing some testing or being manufactured to become a part or component. To make it more stable, it will mix with magnesium to enhance its strength and other properties with proper ratio like 96% Magnesium (Mg), 2.5-3.5 % Aluminiun (AI) and 0.7-1.3 % Zinc (Zn) or Manganese (Mn) (Subramani et al., 2019). Therefore, the weight percentage of aluminium is low compared to other Chemical element for all specimen after conducted EDX Analysis.

Next, proceed to the element of Graphene Oxide (GO) which are Carbon (C) Hydrogen (H) and Oxygen (O). Specimen like 1,3,5,7 and 9 that heated at temperature of 250 °C has higher weight percentage value than the specimen like 2,4,6,8, and 10 that heated at temperature of 350 °C. This is because Carbon has large Atomic and Covalent radius which are 1.70 and 0.75. When the temperature increase, it is hard to break the Hexagonal Closed Packed Structure (HCP) of Magnesium. Thus, the percentage of Carbon will be low at heating temperature 350 °C compared to 250°C. It is difficult to determine the weight percentage of Hydrogen (H) because it is a lightest element with atomic number 1 and easily to form as gases when mix with other elements. It required the machine to capture and analyse the weight percentage of gases. Therefore, there is no weight percentage value of Hydrogen for all specimens.

Finally, oxygen that contained at the surface of the Specimen after Heat Treatment and Quenching process. When observed the result that obtain from EDX analysis and refer to the bar chart of Material Composition wt % in Figure 4.2 noticed that specimen 2 has a higher of oxygen value which is 24.11 wt % while the specimen that heated with 250 °C and quench in the medium that consist of 0.3 wt % of Graphene Oxide (GO) only have 11.36 wt % of oxygen. The result shows that the increasing the heat treatment temperature of the furnace, the higher the weight percentage wt % of Oxygen. This can be said like that because oxygen has small atomic radius than magnesium. High temperatures will break the atomic bond of magnesium and the oxygen will fuse with magnesium to stabilize the system and this result occur when carried out the EDX Analysis using JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM).

In conclusion, the result that obtain from EDX Analysis show that the all the specimen contains the four main chemical element which are Magnesium (Mg), Aluminium (Al), Carbon (C) and Oxygen (O). It also shows that magnesium contains highest weight percentage value follow by carbon and lastly aluminium that contain less weight percentage w t % value in specimen 1 until specimen. When temperature increased, the percentage value of oxygen will be increased, and the percentage value of the carbon will be increased. °C.It can be said that specimen that used GO as quenching medium has high wt % of Carbon

and Oxide compared to the specimen that quench in Air or Distilled Water (DW) after Heat Treatment process. Finally, the number of the material composition of Magnesium Alloy AZ31B after Heat Treatment and Quenching Process proved the presence of Graphene Oxide (GO) on the surface of the specimen when observed using JEOL JSM-6010PLUS/LV Scanning Electron Microscope (SEM) (Mubasyir et al., 2021).

4.3 Surface Roughness Analysis

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Surface Roughness testing was conducted using Mitutoyo SJ-410 Portable Surface Roughness Tester. The testing was carried out in 1 direction for 5 times and the result was shown in Table 4.3 and Figure 4.3

Quenching Medium	Specimen Identification	Roughness Average value (Ra) (µm)
A :	1 (250°C)	2.36
بسبا ملاقه	2 (350°C)	2.123 ويس
Distilled Water	3 (250°C)	2.512
Distined water	4 (350°C)	1.869
Distilled Water + 0.1 wt	5 (250°C)	2.11
% GO	6 (350°C)	2.022
Distilled Water + 0.3 wt	7 (250°C)	1.967
% GO	8 (350°C)	1.984
Distilled Water + 0.5 wt	9 (250°C)	2.594
% GO	10 (350°C)	2.026

Table 4.3 Surface Roughness Result of Magnesium Alloy AZ31B



Surface roughness average at 250 $^{\circ}\mathrm{C}$ and 350 $^{\circ}\mathrm{C}$

Figure 4.3 Roughness Average at 250 °C and 350 °C

Based on the outcome in Figure 4.3 show that specimen that heated at 250 °C follow by quenching in Distilled Water \pm 0.5 wt % Go has high surface roughness value which are 2.594 µm while specimen that heated at 350 °C and quench in Distilled Water has low surface roughness value which are 1.869 µm. That mean specimen 9 have rough surface meanwhile specimen 4 have smooth surface. The result also shows that specimen that carried out heat treatment with temperature of 350 °C has low surface roughness value than the specimen that heated with temperature of 250 °C in the furnace for 3 hours. Error bar show that there was not too much difference between the max and min value because the value is divided equally with the average value after obtaining the result from surface roughness analysis for Magnesium Alloy AZ31B. The specimen that quenches in medium that contain Graphene Oxide (GO) has a low surface roughness than the specimen that use Air and Distilled water as quenching medium. This is because the material layer is very thick which about 1.1 ± 0.2 nm and easily hydrated when exposed to water vapour or submerged in liquid water. It can dissolve in water and equally stick on the surface of
Magnesium Alloy AZ31B after the quenching process. A low roughness average value (Ra) will be obtained after conducted surface roughness testing for specimen that quench in the medium that consist of Distilled Water + 0.1wt % ,0.3wt % or 0.5wt % of Graphene Oxide for 30 minutes. These specimens will have a good surface finish compared to other specimen that use air or distilled Water as quenching medium for 30 minutes.

4.4 Tensile Test Analysis

Tensile testing was carried out to study the Ultimate Tensile Strength (UTS), Yield Strength, and Young Modulus of AZ31B after the quenching process.Result of each study are presented with Table and Figure

4.4.1 Ultimate Tensile Strength

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Ultimate Tensile Strength, or Tensile Strength (TS) is the maximum force of a material can endure while being dragged or stretched before it breaks. In brittle materials, failure occurs shortly after the yield point is reached. Table 4.4 show the result of Ultimate Tensile Strength for Magnesium Alloy AZ31B at difference heating temperatures and difference quenching medium that used after heat treatment process while Figure 4.4 summarize the result that obtain from Ultimate Tensile Test with Dog-Bone Shaped that been manufacture according to ASTM Standard E8-04 (Kumar et al., 2019).

Quenching Medium	Specimen	Ultimate Tensile Strength (MPa) Specimen reading	Ultimate Tensile Strength (MPa) Average value
	Control Sample	242.382	242.382
Air	250 °C	Reading 1: 254.905 Reading 2: 252.076	253.491
	350 °C	Reading 1: 244.055 Reading 2: 237.831	240.943
Distilled Water	250 °C	Reading 1: 236.893 Reading 2: 246.573	241.733

Table 4.4 Result of Ultimate Tensile Strength for Magnesium Alloy AZ31B

	350 °C	Reading 1: 253.648	254.366
		Reading 2: 255.138	
		Reading 3: 254.311	
Distilled Water	250 °C	Reading 1: 242.929	243.996
+ 0.1 wt % GO		Reading 2: 240.938	
		Reading 3: 248.122	
	350 °C	Reading 1: 245.301	245.197
		Reading 2: 235.575	
		Reading 3: 254.715	
Distilled Water	250 °C	Reading 1: 246.926	251.598
+ 0.3 wt % GO		Reading 2: 253.717	
		Reading 3: 254.152	
	350 °C	Reading 1: 254.212	250.305
		Reading 2: 253.922	
		Reading 3: 242.780	
Distilled Water	250 °C	Reading 1: 249.779	242.663
+ 0.5 wt % GO		Reading 2: 240.489	
		Reading 3: 237.721	
	350 °С	Reading 1: 252.156	249.287
	MALATSIA	Reading 2: 248.530	
S		Reading 3: 247.175	



Figure 4.4 Ultimate Tensile Strength of AZ31B at 250°C and 350°C

After conducted heat treatment and quenching process, all the specimen has increased in Ultimate Tensile Strength (UTS) value compared to control sample except for the specimen that heated at 250°C and 350°C followed by quenching in air or distilled water for 30 minutes with the value of 240.943 (MPa) and 241.733 (MPa) respectively. Among all the specimen, specimen that heated at 350 °C and soak at distilled water has highest ultimate tensile test value which is 254.336 MPa while specimen that soak at room temperature and heated at 350 °C give the lowest ultimate tensile strength value which are 240.943 MPa. This is because the specimen breaks at the tail of Dog Bone Shape when it been pull with the force that had set at the testing machine. It will influence the result of each specimen to know it will obtain a high ultimate tensile strength value or low ultimate tensile strength value.

Specimen that quenches in the medium that consists of Graphene Oxide (GO) have increased its ultimate tensile strength compared to control sample. For example, specimen that heated at 250°C followed by quenching in 0.5 wt % of Graphene Oxide (GO) has slightly increased its Ultimate Tensile Strength from 242.382 MPa to 242.663 MPa but specimen that heated at with same temperature followed by quenching in 0.3 wt % of Graphene Oxide has rapidly increased its Ultimate Tensile Strength (UTS) value to 251.598 MPa. As can be observed at the result in Figure 4.4 shows that the increasing the wt % of Graphene Oxide will increased the Ultimate Tensile Strength value. For instance, specimen that quenching in the Distilled Water + 0.3 wt % GO for 250°C and 350 °C has increased its UTS value to 251.598 MPa and 250.305 MPa compared to specimen that quench in the medium that consist of 0.1wt % of GO for 250°C and 350°C. Finally, specimen that carried out heat treatment process with temperature of 350 °C has Ultimate Tensile Strength (UTS) value than specimen that carried out heat treatment process with 250°C.

In a nutshell, study that conducted by (Mubasyir et al., 2021; Srivastava et al., 2021) and (Kresnodrianto et al., 2018) proved that specimen that heated at 350 °C followed by quenching in the medium consisted of 0.3 wt% of Graphene Oxide gave highest Ultimate Tensile Strength (UTS) value compared to control sample without any Heat Treatment and Quenching Process.

4.4.2 Yield Strength

Yield Strength or yield stress is the maximum stress that can be applied along its axis before it reaches the plastic deformation stages. Usually, it directly proportional to Strain in Stress-Strain Curve. Yield Strength will decide whether an object is stubborn or malleable. Table 4.5 show the result of Yield Strength for Magnesium Alloy AZ31B at difference heating temperatures and difference quenching medium that used after heat treatment process while Figure 4.5 summarize the Yield Strength of specimen with Dog-Bone Shaped that been manufacture according to ASTM Standard E8-04 (Kumar et al., 2019).

Quenching	Specimen	Yield Strength (MPa)	Yield Strength			
Medium	10	Specimen reading	(MPa)			
3	E.		Average value			
N.	Control Sample	142.169	142.169			
Air 🕒	250 °C	Reading 1: 127.562	127.305			
E		Reading 2: 127.042				
20	350 °C	Reading 1: 151.398	153.351			
	Alkn .	Reading 2: 155.304				
Distilled Water	250 °C	Reading 1: 140.999	136.660			
رك	Lo hundo, LE	Reading 2: 132.320	aug			
	- 350 °C	Reading 1: 141.676	135.347			
		Reading 2: 138.585	A 1 Z A			
UNI	VERSITI TEKN	Reading 3: 125.780	AKA			
Distilled Water	250 °C	Reading 1: 152.536	140.804			
+ 0.1 wt % GO		Reading 2: 142.076				
		Reading 3: 127.800				
	350 °C	Reading 1: 135.563	133.205			
		Reading 2: 138.031				
		Reading 3: 126.020				
Distilled Water	250 °C	Reading 1: 148.866	133.872			
+ 0.3 wt % GO		Reading 2: 127.431				
		Reading 3: 125.299				
	350 °С	Reading 1: 138.031	130.086			
		Reading 2: 126.118				
		Reading 3: 126.108				
Distilled Water	250 °C	Reading 1: 147.094	137.762			
+ 0.5 wt % GO		Reading 2: 125.192				
		Reading 3: 140.999				
	350 °C	Reading 1: 133.558	137.931			
		Reading 2: 131.204				
		Reading 3: 149.032				

Table 4.5 Result of Ultimate Tensile Strength for Magnesium Alloy AZ31B



Yield Strength at 250°C and 350°C

Figure 4.5 Yield Strength of AZ31B at 250°C and 350°C

By refer to the result in Table and Figure in 4.5 showed that specimen with temperature of 350 °C followed by quenching in air has highest Yield Strength value than other specimen while specimen with same quenching medium but different heat treatment temperature has low Yield Strength value compared to another specimen. The Yield Strength for the testing specimen and the control sample is almost same. Magnesium Alloy AZ31B is formed by bunch atom and connect them to become a Hexagonal Closed Packed Structure (HCP). At the beginning of tensile test, the atom has the ability to withstand it. When the specimen is pulling longer and longer, the connection between atom started to break. At the same time, plastic deformation occurred until fracture to all specimens. So, that the reason why each specimen has almost the same of the Yield Strength value with control sample after conducted Tensile Test Analysis using Shimadzu Autograph AG-X plus as testing machine.

4.4.3 Young Modulus

Young Modulus or the modulus of elasticity in tension or compression (i.e., negative tension) is a mechanical property that quantifies the tensile or compressive stiffness of a solid material when a longitudinal force is applied. It quantifies the relationship between tensile/compressive stress σ (force per unit area) and axial strain \mathcal{E} (proportional deformation) in the linear elastic region of a material and is determined using formula that displayed in Equation 4.2

$$E = \frac{\sigma}{\varepsilon}$$
 where E is Young Modulus, σ is Stress and ε is Strain (4.2)

Table 4.6 show the result of Young Modulus for Magnesium Alloy AZ31B at various heating temperatures and various quenching medium that used after heat treatment process while Figure 4.6 summarize the result that obtain from Young Modulus with Dog-Bone Shaped that been manufacture according to ASTM Standard E8-04 (Kumar et al., 2019)

	w warm,	and and a	90 91
Quenching	Specimen	Young Modulus (MPa)	Young Modulus
Medium	VERSITI TEKN	Specimen reading	AKA (MPa)
			Average value
	Control Sample	5488.78	5488.78
Air	250 °C	Reading 1: 3922.03	3787.62
		Reading 2: 3653.03	
	350 °C	Reading 1: 11563.00	9882.56
		Reading 2: 8202.13	
Distilled Water	250 °C	6174.56	
		Reading 2: 6035.96	
	350 °C	Reading 1: 6798.59	5184.84
		Reading 2: 4157.21	
		Reading 3: 4598.72	
Distilled Water	250 °C	Reading 1: 5984.18	5604.82
+ 0.1 wt % GO		Reading 2: 5759.19	
		Reading 3: 5071.08	
	350 °C	Reading 1: 5616.99	5221.70
		Reading 2: 4466.38	
		Reading 3: 5581.73	
	250 °C	Reading 1: 6835.98	4830.62

6	Table 4.6	6 Young	Modulus	for Mag	nesium /	Alloy	AZ31B	
100	IN AL.		the second se	the second se				a. 1.

Distilled Water		Reading 2: 2968.72	
+ 0.3 wt % GO		Reading 3: 4687.17	
	350 °C	Reading 1: 6445.25	5608.85
		Reading 2: 5618.98	
		Reading 3: 4762.33	
Distilled Water	250 °C	Reading 1: 5641.43	5110.50
+ 0.5 wt % GO		Reading 2: 4297.41	
		Reading 3: 5392.65	
	350 °C	Reading 1: 5325-47	5551.67
		Reading 2: 5722.70	
		Reading 3: 5606.85	



Young Modulus at 250°C and 350 °C

In general, all the specimen has increased its young modulus value compared to control sample except for specimen that heated at 250 °C and use air and Distilled water + 0.3 wt % GO with the value of 3787.62 MPa and 4830.62 MPa. Among all the specimen that been tested, specimen that carried out heat treatment process with temperature of 350°C followed by quenching in Air has highest young modulus value which are 9882.56 MPa and specimen that heated at 250°C and quench in air has low young modulus value which are 3787.62 MPa. This scenario happened because specimen break at the tail of dog-bone shaped and one testing specimen that do not break it smoothly at the end of the break point. So, it will

obtain high reading value which are 11563.00MPa and 8202.13MPa respectively. This will definitely affect the young modulus value after conducted Tensile Test Analysis. Figure 4.7 (a) showed the area where the specimen breaks after conducted tensile test analysis and (b) show the surface of the breaking point of the specimen after conducted the analysis. Specimen that uses Distilled Water, Distilled Water + 0.1 wt% GO, Distilled Water + 0.3 wt% GO and Distilled Water + 0.5 wt% GO does not have significantly changes of Young Modulus value with control sample. The Datum divided the maximum and minimum value equally with the average Young Modulus value. That's mean the specimen do not bias to maximum or minimum value that will affect the young modulus value that will determined the specimen will be break out easily or not when carried out Tensile Test Analysis. Finally, specimen that quenching in the medium that consist of Graphene Oxide (GO) gave high Young Modulus Value compared to specimen that use Air and Distilled Water as quenching medium.



(a)

(b)

Figure 4.7 (a) Area of specimen break (b) Surface of breaking point of the specimen

4.5 Summary of Result and Discussion

Based on the result that obtained in SEM analysis, EDX analysis, Surface Roughness analysis and Tensile Test analysis that study for Ultimate Tensile Strength, Yield Strength and Young Modulus, the increased of temperature of heat treatment will affect the microstructure of AZ31B Mangesium Alloy to have a smooth surface compared to the specimen that heated at low temperature in heat treatment process. The increased in heating temperature will affect the microstructure and mechanical properties of the specimen to have a low Roughness Average Value (Ra), high Ultimate Tensile Strength (UTS) and highYoung Modulus Value.

Specimen that used Distiled Water + 0.1wt % ,0.3wt % and 0.5 wt % of Graphene Oxide increased the mechanical properties of AZ31B compared to the speciemen that used Air or Distlled Water as quenching medium for 30 minutues. The number of the material composition is EDX analysis proved the presence of GO on the surface of the specimen.

Although the quenching process does not coat the specimen with a layer of substance but rather treating the outer surface to harden as temperature increased or fall dramatically as can see the result from Ultimate Tensile Strength (UTS),Yield Strength and Young Modulus (MPa).Therefore, this study proved that various of heating temperature and various of wt% of Graphene Oxide (GO) medium will affected the microstructure and mechanical properties of Magnesium Alloy AZ31B (Mubasyir et al., 2021).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this study, the surface characteristics which include microstructure and surface roughness of AZ31B Mangesium Alloy with various of heating temperature and various of different wt% of Graphene Oxide (GO) medium were analyzed.Speciemen was carried out heat treament process with temperature of 250°C and 350 °C for 3 hours followed by quenching process with different quenching medium for 30 minutes. Result that obtained from analysis proved that increased in heating temperature will affect the microstructure of AZ31B Mangesium Alloy to have a smooth surface compared to the specimen that heated at low temperature. To determined whether the result that obtained from SEM analysis was true, Surface Roughness Analysis was carried out.Result that derived from both SEM and Surface Rougness Analysis showed that specimen that heated with heat treatment temperature of 350 °C has low Roughness Average value (Ra) (µm).Therefore it have a smooth surface than other specimen that heated with heat treatment temperature of 250 °C.

Specimen that have high temperature will affect the mechanical properties of Magnesium Alloy AZ31B.This can be see from Tensile Test Analysis that been conducted to study the Ultimate Tensile Strength (UTS) ,Yield Strength and Young Modulus of the specimen with Dog-Bone Shaped .Based on the observation and result, specimen that heated with 350 °C has high Ultimate Tensile Stength (UTS) value which are 254.366 MPa compared with control sample and specimen that heated at 250 °C.It have high Yield Strength and Young Modulus with the value of 153.351 MPa and 9882.56 Mpa.This had proved that increasing of Heat Treament temperatures will affect the microstructure and

incereased its mechanical properties after obtained the result from SEM,Surface Roughness and Tensile Test Analysis.

Various wt % of Graphene Oxide (GO) medium will influence the microstructure and affect the Mechanical properties of AZ31B Magnesium Alloy. This is because Graphene Oxide contain high concentrations of Carbon (C) and Oxygen (O) element that will coat the specimen with a layer of subtances and that will affect the microstructure and mechanical properties of a testing specimen. For instance, specimen that sink in the medium that consist of 0.3 wt% of Graphene Oxide (GO) has a smooth surface and low Roughness Average Value(Ra) which are 1.984 µm. It contain high UTS, Yield Strength and Young Modulus which are 250.305 MPa, 130.086 MPa and 5608.85 MPa. Based on this study proved that different weight percentage (wt%) of Graphene Oxide (GO) will definitely alter the microstructure and mechanical properties of AZ31B.

In a nutshell, it can be summarize that, increased of Heat Treament temperatures and the wt % of GO will made the specimen become smooth and increased its mechancial properties.Specimen that heated with 350 °C follwed by quenching in Distilled Water + 0.3 wt % GO is the best parameter that meet the requirements that been set which was the effect of various temperature of heat treatment and various wt % of Graphene Oxide (GO) medium towards the microstructure and mechanical properties of Magnesium Alloy AZ31B. As a result, the objective that stated in this study were achieved successfully.

5.2 **Recommendations**

In further studies, the surface and mechanical properties can be improved by adding some different wt % of Graphene Oxide towards quenching medium to determine whether the increased of weight percentage (wt%) of GO will influence the microstructure and mechanical properties of AZ31B. The ratio of Distilled Water and Graphene Oxide powder can be adjusted to measure high concentration of Distilled Water or Graphene Oxide powder will have a low surface roughness value or not and this value will affect the mechanical properties of Magnesium Alloy AZ31B or not affect when sink in the medium that have high concentration of Distilled Water and low wt % GO. Furthermore, the parameter such as duration of Heat Treatment and Quenching process can be studied on the effect of improving or reducing the properties of AZ31B Magnesium Alloy after obtaining the result from SEM analysis, EDX or EDS analysis, Surface Roughness analysis and Tensile Test analysis. The method of preparation of the specimen should be considered in order to obtain the most accurate result. For example, specimen can be grinding and polishing before proceeding to Heat Treatment process to revealing a good and clear microstructure of the specimen. Finally, Hardness Testing can be added in this study to determine the specimen that had coated with a layer of Graphene Oxide will affect or not affect the Surface Roughness and Mechanical properties of AZ31B after conducted Heat Treatment and Quenching Process.

5.3 **Project Potential**

In this study, the microstructure, and mechanical properties of Magnesium Alloy AZ31B has been carried out with various temperature of heat treatment and various wt % of Graphene Oxide (GO). It showed that high temperature of heat treatment process followed by quenching in the medium that consist of Graphene Oxide (GO) will increase its mechanical properties to make it become more useful in many sectors like Mechanical, Manufacturing ,Automotive, and Oil and Gas. By applied this method of study it can be used in the industries such as Military, Machining, Marine and Medicine due to is lightweight, good surface and high mechanical properties that will be able to be improved itself in industry area when the times is come.



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APPENDICES

Project Planning PSM 1

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Appendix A Gantt Chart of PSM1

Project Planning PSM 2

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Appendix B Gantt Chart of PSM 2