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A Study on Effect of Sintering Temperature and Compaction Load on Mechanical Properties of Aluminium-Magnesium Alloy by Powder Metallurgy

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Abstract

The presented study is intended to investigate the mechanical properties of an aluminium-magnesium alloy (Al-Mg) produced by powder metallurgy process and sintered at different temperatures. The investigation involves aluniminum is alloyed with different weight percentages of magnesium powder (0%, 2%, 4%, and 6%), which were compacted under 260 KN and 300 KN pressure using a compaction die in the room temperature. The compacted green samples were then sintered at two different temperatures, 540°C and 580°C. Sintered specimens of Al-Mg alloys are tested for mechanical properties like hardness, density, wear resistance and Microstructure. The investigation shows that there is an increase in hardness by 36% for specimens compacted at 300kN load and sintered at 580°C.

Major Findings: *Overall, the results highlight the potential for tailoring the mechanical properties of Al-Mg alloys through careful control of compaction pressure and sintering temperature. This knowledge could be valuable in optimizing the fabrication process for various industrial applications where enhanced mechanical performance is desired.*

Keywords: *Aluminium-Magnesium Alloy, Compaction Load, Hardness, Microstructure, Powder Metallurgy, Sintering Temperature*

1.0 Introduction

Aluminum has a lower density, Aluminum is a preferred for applications that weight reduction, particularly in the aerospace industry[1]. Aluminum has advantages like a material, including its strength-to-weight ratio, its corrosion resistance, and its ability to be easily form and its ability to machined[2]. Aluminium is used in various other applications including automotive parts, and electrical lines for transmission, because of its highly reactive for oxygen, when exposed to air it forms a protective oxide layer on its surface[3]. Al has some disadvantages, such as its high conductivity, causes problems in electrical applications, and it leads to certain types of damage, such as crack and fatigue[4].

Magnesium[5,6] is alkaline earth metal has a density of 1.7 g/cm³. Magnesium is widely available and can be found in various forms such as magnesite, dolomite, and carnallite[7]. Mg is a reactive metal, and it reacts with oxygen to form a protective layer of magnesium oxide on its surface. This makes magnesium a useful material in construction, as it is resistant to corrosion

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and fire. Magnesium has many applications in industry and manufacturing. It is used as an alloying element in aluminum production to create lightweight and sturdy alloys. In the production of metals like titanium, magnesium is used as a de-oxidizing agent to remove impurities[8,9].

Powder metallurgy[10,11] is a manufacturing process used to produce metal parts and components by compacting metal powders in a die after then sintering them in a furnace[12]. PM is a versatile technology that can produce complex parts with excellent dimensional accuracy, uniformity, and mechanical properties. The four processes of the PM process are generally powdering creation, powder mixing, compacting, and sintering. In the powder production step[13], raw materials are processed into metal powders of a desired size and composition. The powder blending step involves mixing the metal powders with lubricants and other additives to improve their flowability and handling[14]. The final mixture is called has powder blend, is then compacted. During compaction, the powders are subjected to high pressure to form a green compact, which is a shape that is close to the final product[15]. The green compact is then sintered in a furnace at a high temperature, typically in a controlled atmosphere to prevent oxidation. In sintering, the metal powder specimen is fuse together, resulting in a solid metal part with the desired shape, and properties. Its advantages include the ability to produce complex shapes[16], reduce material waste, and improve material properties through alloying and heat treatment. The novelty of this research is to know the importance and effect of sintering temperature and compaction load on properties of Al-Mg alloy. Which has more effect on the properties of prepared alloy by powder metallurgy.

2.0 Methodology

2.1 Mixing

To create a durable alloy material that matches the desired product specifications, it is necessary to combine two or more powdered materials during the mixing process. A mortar and pestle are common tools used for mixing small quantities of powders in a laboratory. It is possible to use mortar and pestle for powder mixing.



Figure 1. AluminiumMicroparticles (150 µm).

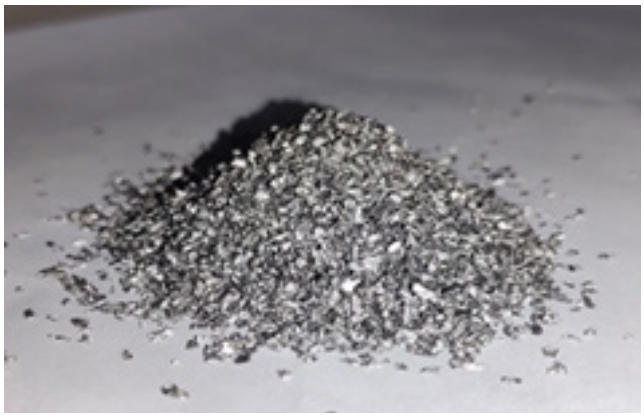


Figure 2. Magnesium Microparticles (86 µm).



Figure 3. Weighing Machine.

2.1.1 Chemical Composition of Powders

Table 1. Composition of Aluminum powder

Constituents	Fe	Cu	Si	Mn	Hydrogen Loss	Mg	Al
Wt.Percentage	0.17%	0.0015%	0.1313%	0.005%	0.48795%	0.25%	Balance

Table 2. Composition of Magnesium powder

Constituents	P	Ca	W	Mn	Cr	Cu	Fe	Ni	Mg
Wt.Percentage	3.1%	1.8%	0.4%	0.3%	0.3%	0.3%	0.2%	0.1%	Balance



Figure 4. Mortar and Pestle are used for mixing powder.

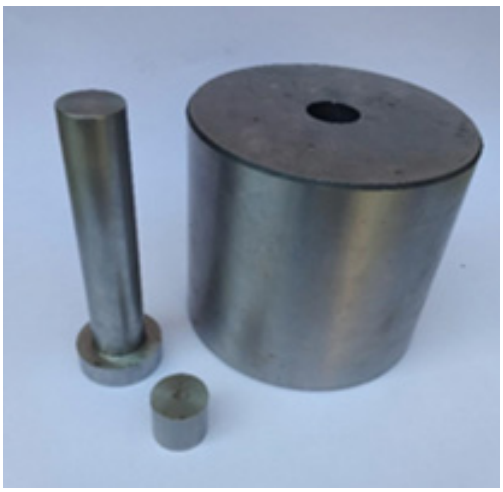


Figure 5. Die set.

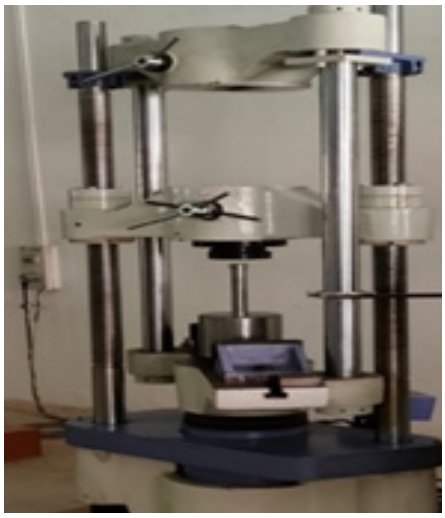


Figure 6. Compaction using UTM.

2.2 Compaction

During the manufacturing of metal parts, compaction is employed as a technique where a die, plunger, and stopper are used to shape a metal powder. To assess the strength of the compacted metal, a compression test can be performed with UTM. To maintain a uniform composition, it is essential to accurately measure and blend the aluminum magnesium alloy powder. The die should be selected based on the desired shape of the final part. The plunger should be selected to fit close inside the die, and the stopper should be selected to fit on bottom of die. The powder should be carefully poured into the die, making sure it is evenly distributed. The plunger



Figure 7. Specimen after compaction.

should be placed on top of the die. The stopper should be placed on bottom of the die. The die, plunger, and stopper should be placed in the universal testing machine, and the compression test should be performed. The machine will apply a controlled two different amount of pressure like 260kN and 300kN to the powder.

2.3 Sintering

Sintering is a process that involves heating green samples into a temperature just below its melting point of base metal. The particles join due to heat and create a solid mass. The specimens were sintered at atmospheric temperatures of 540°C and 580°C and soaking period of one hour. The sintering temperature is an important parameter that determines the final microstructure and properties of the material. Higher temperatures can lead to better densification and higher strength but may also increase the risk of oxidation.



Figure 8. Furnace where specimens are placed.



Figure 9. Specimens inside the furnace.



Figure 10. After Sintering.

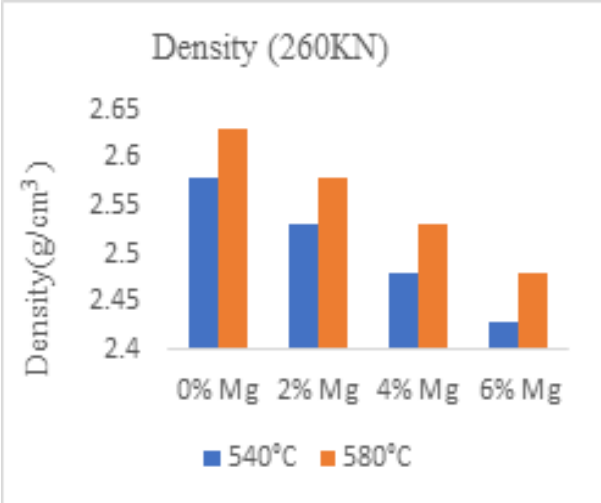
3.0 Results and Discussion

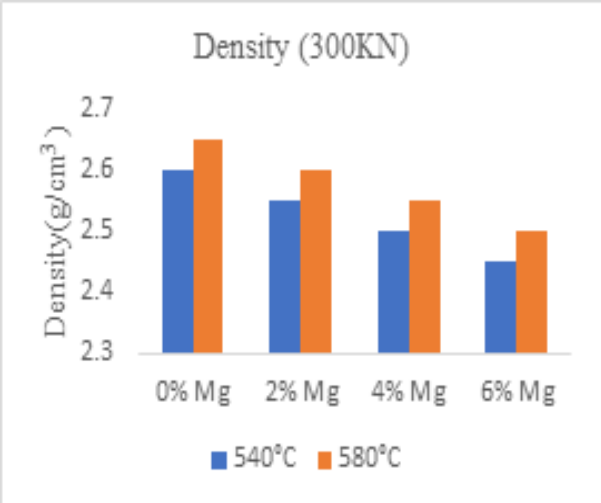
3.1 Density

The density samples are calculated by Archimedes principle. The density of the material can be calculated as the weight of the specimen in air divided by amount of

Table 3. Density of each specimen

Sample	%Al	%Mg	Compacting Pressure (KN)	Sintering Temperature (^{O}C)	Density (g/cm^3)
1	100	0	260	540	2.58
1	100	0	260	580	2.63
1	100	0	300	540	2.60
1	100	0	300	580	2.65
2	98	2	260	540	2.53
2	98	2	260	580	2.58
2	98	2	300	540	2.55
2	98	2	300	580	2.60
3	96	4	260	540	2.48
3	96	4	260	580	2.53
3	96	4	300	540	2.50
3	96	4	300	580	2.55
4	94	6	260	540	2.43
4	94	6	260	580	2.48
4	94	6	300	540	2.45
4	94	6	300	580	2.50





the water displaced by specimen in water. They are then weighed in air using a precision balance.

$$\text{Density}(\rho) = \frac{\text{Mass of the specimen (m)}}{\text{amount of water displaced(v)}} \quad (1)$$

3.2 Rockwell Hardness Test

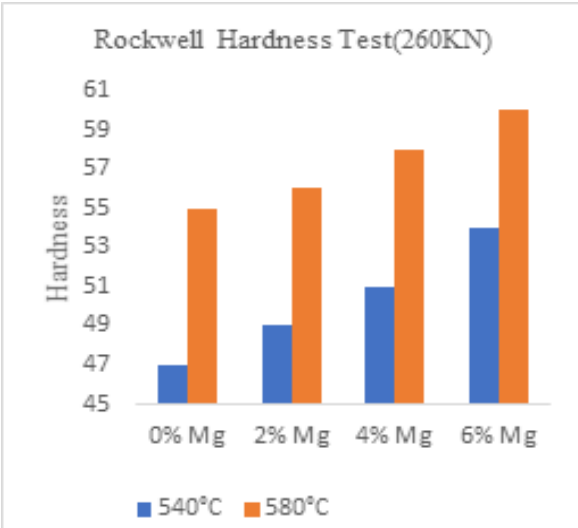
Each sample is subjected to Rockwell hardness testing to evaluate its mechanical properties. Rockwell hardness testing involves applying a load to the surface of the sample and measuring the depth of penetration of an indenter. The Rockwell hardness value is determined by measuring the difference in the depth of penetration of the indenter when the load is applied and when it is released.

3.3 SEM Analysis

The grain size of the starting materials (Aluminum and Magnesium) can also influence the properties of the alloy. Smaller grain size can result in improved mechanical properties due to the presence of smaller grains leading to a greater number of grain boundaries, which can

Table 4. Rockwell Hardness value on each specimen

Sample	Compaction pressure (KN)	Sintering Temperature (°C)	%Al	%Mg	Hardness
1	260	540	100	0	47
1	260	580	100	0	55
1	300	540	100	0	50
1	300	580	100	0	58
2	260	540	98	2	49
2	260	580	98	2	56
2	300	540	98	2	51
2	300	580	98	2	59
3	260	540	96	4	51
3	260	580	96	4	58
3	300	540	96	4	53
3	300	580	96	4	61
4	260	540	94	6	54
4	260	580	94	6	60
4	300	540	94	6	56
4	300	580	94	6	64



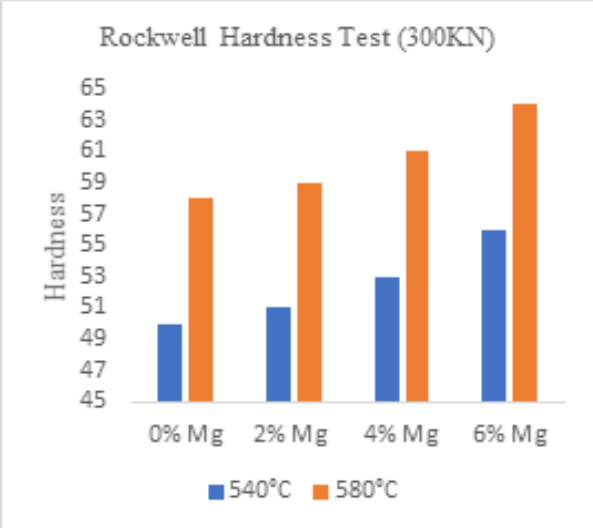




Figure 11. Indentation on specimen.

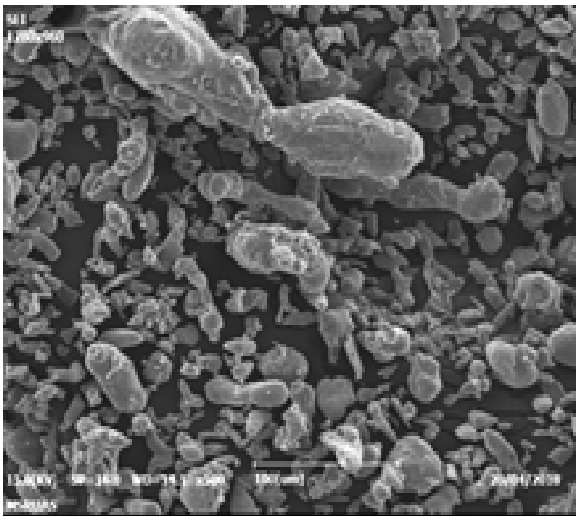


Figure 13. SEM image of Mg powder.

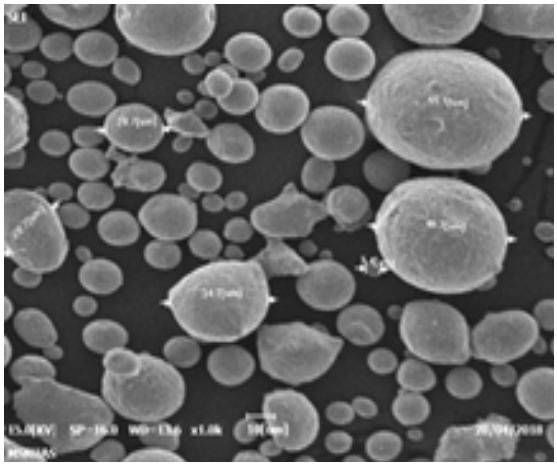


Figure 12. SEM image of Al powder.

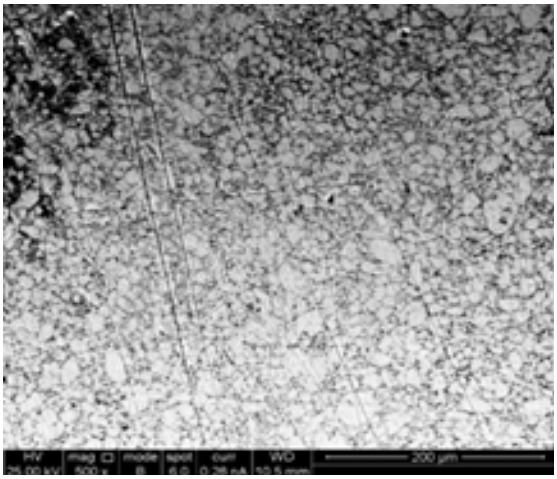


Figure 14. BSE-500X 0%Mg.

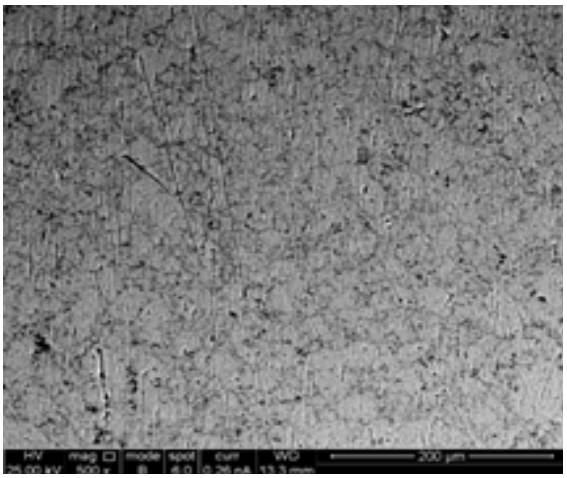


Figure 15. BSE-500X 2%Mg.

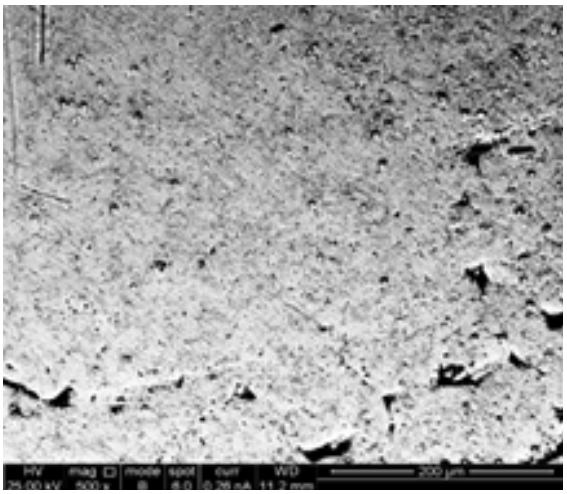


Figure 16. BSE-500X 4%Mg 260kN, 580^{0}C

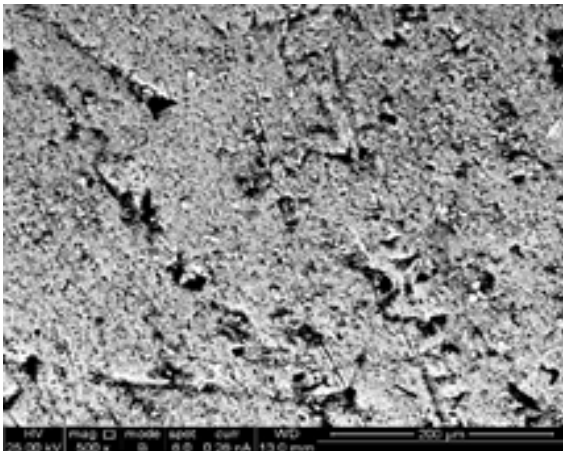


Figure 17. BSE-500X 6%Mg.

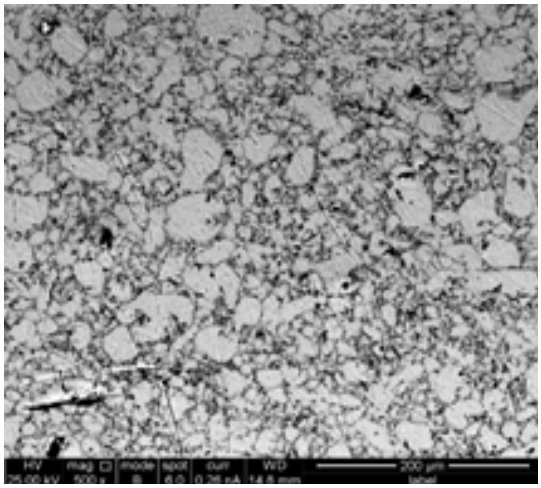


Figure 18. BSE-500X 0%Mg.

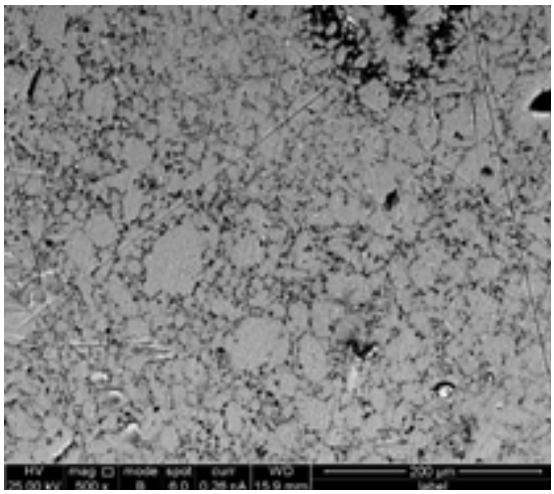


Figure 19. BSE-500X 2%Mg.

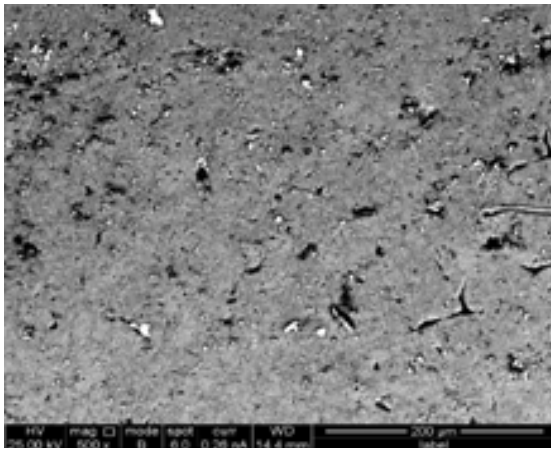


Figure 20. BSE-500X 4%Mg.

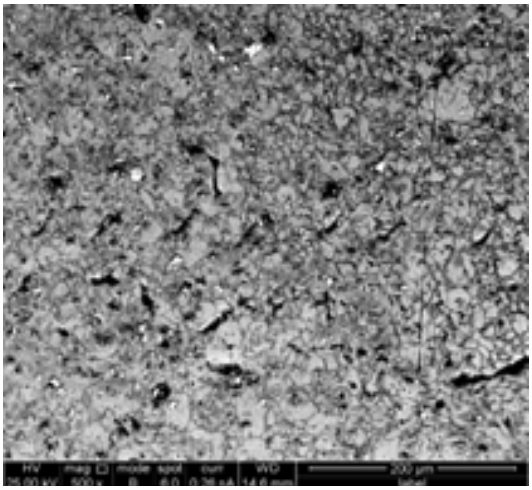


Figure 21. BSE-500X 6%Mg.

300kN, 540° C

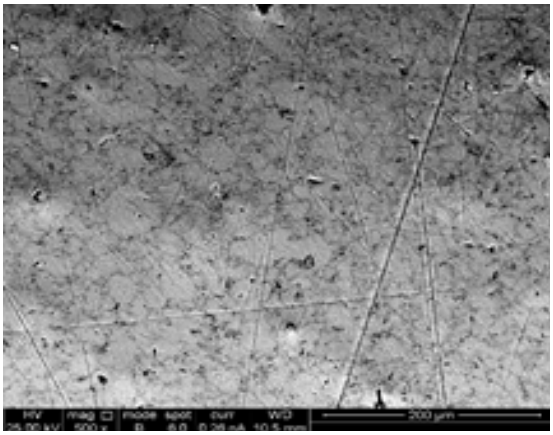


Figure 22. BSE-500X 0%Mg

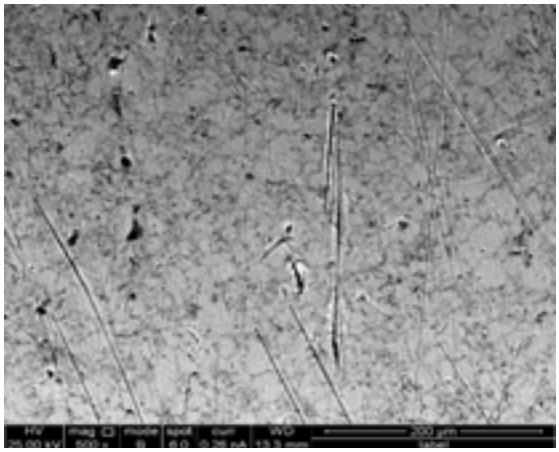


Figure 23. BSE-500X 2%Mg.

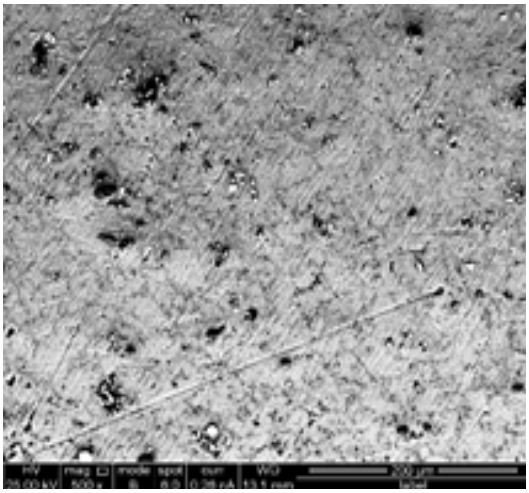


Figure 24. BSE-500X 4%Mg.

300kN, 580° C.

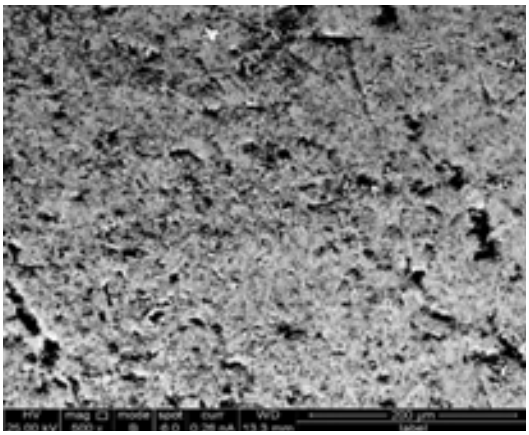


Figure 25. Indentation on specimen.

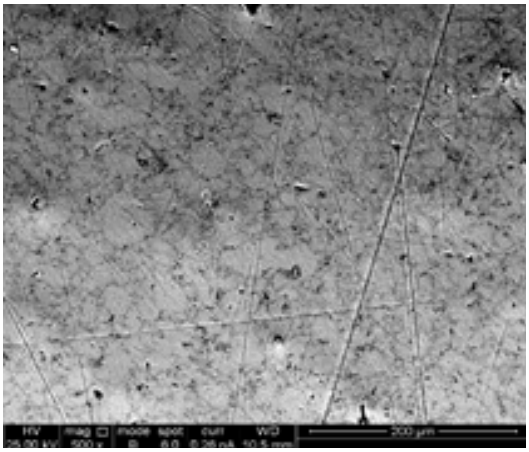


Figure 26. Indentation on specimen.

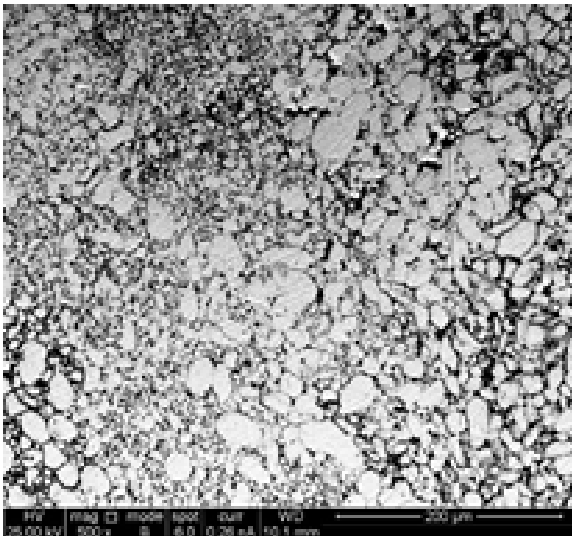


Figure 27. BSE-500X 2%Mg.

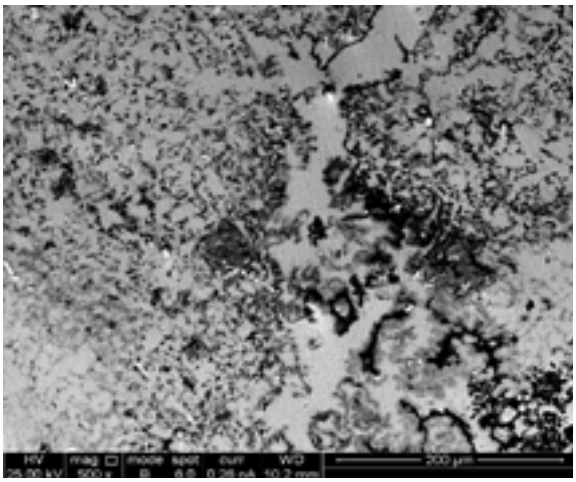


Figure 28. BSE-500X 4%Mg.

improve strength. The five different samples with varying amounts of aluminum and magnesium will also affect the final properties of the alloy. The addition of magnesium can result in improved strength and corrosion resistance but may also decrease ductility. To evaluate the effect of sintering temperature and compacting pressure on the properties of the Aluminum magnesium alloy, SEM analysis can be performed on each sample. The SEM can reveal the microstructure of the samples, providing information on the size and distribution of the grains and any defects or voids in the material. In summary, the sintering temperature, compacting pressure, grain size, and composition of the starting materials can all affect

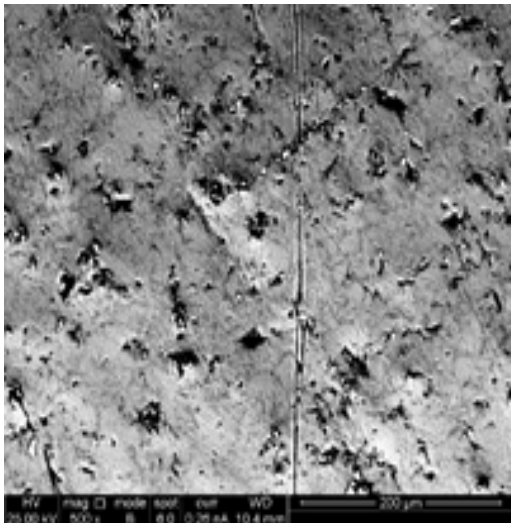


Figure 29. BSE-500X 6%Mg.

the properties of Aluminum magnesium alloys. SEM analysis can provide insights into the microstructure of the samples, which can help in determining the optimal sintering conditions for these alloys.

4.0 Conclusion

In conclusion, this study investigated the mechanical properties of aluminum-magnesium (Al-Mg) alloys fabricated via powder metallurgy and sintering processes. Through systematic experimentation involving different magnesium weight percentages, compaction pressures, and sintering temperatures, several key findings emerged. Firstly, the variation in compaction pressure significantly impacted the hardness of the Al-Mg alloy, with specimens compacted at 300 KN demonstrating a notable increase in hardness by 36%, particularly when sintered at 580°C. Sintering at higher temperatures, such as 580°C, resulted in improved hardness, indicating enhanced material performance under specific thermal conditions. Moreover, the investigation explored additional mechanical properties, including density, wear resistance, and microstructure, providing a comprehensive understanding of the Al-Mg alloy's behavior under different processing conditions.

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