Development Of Biomaterial Orthopedic Devices On Sintering Temperature Changes On Crystal Structure, Porosity And Density In Mg0.92Zn0.05C0.03 Alloy

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Abstract Magnesium-based alloys are one of the alloys that are widely used in the health and industrial sectors. The aim of the following research is to understand the effect of calcination holding time of Mg0.92Zn0.05C0.03 on the crystal structure, prososity and density of the Mg0.92Zn0.05C0.03 alloy. Therefore, research was carried out on the effect of calcination holding time on crystal structure, porosity and density in the manufacture of Mg0.92Zn0.05C0.03 alloy using the granular metallurgy method at a fixed temperature of 360˚C and variations in calcination holding time of 10, 20, 30 minutes. From the results of XRD analysis, it was found that the diffraction peaks were Mg phase, MgZn phase (intermetallic) and Zn phase. From the calculation of the crystallite size, it shows that the higher the calcination temperature, the smaller the crystallite size becomes. However, the dislocation density, microlattice strain, and yield strength will increase inversely with the crystallite size.

1 Introduction

Magnesium (Mg) and its alloys are recognized as significant biomaterials for various biomedical applications [1]. This is because Mg alloys exhibit highly biodegradable and bioabsorbable properties. However, the yield strength of Mg alloy of 170 MPa is less favorable in terms of mechanical properties compared to other non-biodegradable materials [2]. Although the use of Mg alloys as potential materials for human body implants is preferred, they have poor mechanical performance especially in orthopedic applications [3]. Adding reinforcing particles to Mg alloy parts is one of the best ways to make Mg alloys stronger [4]. Reinforcing particles are used to make the composite stronger and less likely to rust [5]. Today, carbon particles are a versatile element and are commonly used as particle reinforcements for metal alloys due to their ability to improve the mechanical properties of any material [6-10]. In general, the use of nanoparticles such as carbon nanofibers (CNF) as reinforcing particles is one possible solution in increasing the strength of the matrix [11-13].

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This research has limitations, namely the type of material used is Mg0.92Zn0.05C0.03., Testing of crystal size, dislocation density, physical strain, hardness and density of the material, Mg content 90 gr, Zn 6 gr, Co 4 gr [14-15]. The goal of this study is to look into how changes in the sintering temperature affect the crystal size and dislocation density of the Mg0.92Zn0.05C0.03 alloy biomaterials. The goal is to look into how different sintering temperatures affect the hardness and density of Mg0.92Zn0.05C0.03 alloy biomaterials.

2 Research Methods

The flow diagram for the effect of sintering temperature on the mechanical properties, microstructure, and decay rate of Mg-Zn alloys for orthopedic devices applications using the powder metallurgy method includes **Fig 1**. The powder sample processing started from weighing the sample, mixing the powder, molding or compaction, and sintering in temperature variants of 380°C, 400°C, 420°C. Then the next step was testing the synthesis of the Mg0.92Zn0.05C0.03 alloy biomaterial. This research employs an experimental methodology, specifically utilizing a one-shot case study design. Experiments with this design entail executing a singular treatment on the workpiece, directly observing it, and systematically recording the outcomes. The data from the treatment of changes in sintering temperature are then tested and put into a table. Now we can look at the data we've gathered. Based on our analysis, we can see how the changes in sintering temperature affect the density, crystal structure, and porosity of the Mg0.92Zn0.05C0.03 alloy. Once all treatments have been carried out, the next step is characterization. The characterizations performed include porosity, density, XRD (X-Ray Diffractometer) analysis, and SEM (Scanning Electron Microscope) analysis.

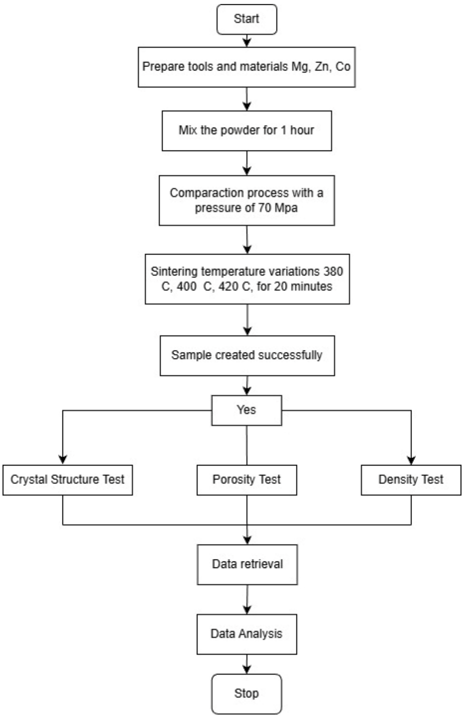

Fig. 1. Flow Diagram

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3 Analysis

3.1 Test results with XRD on Mg0.92Zn0.05C0.03 alloy samples

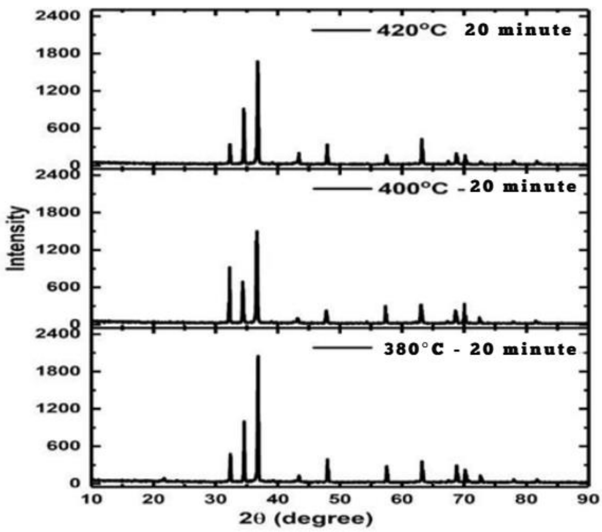

Fig. 2. X-ray Deiradiogram of Mg0.92Zn0.05C0.03 alloy with temperature variations of 380°C 400°C 420°C

The crystal structure test on the Mg0.92Zn0.05C0.03 alloy shows that there are two distinct phases: the MgZn phase and the alpha magnesium phase. This is because Zn has a high solubility level and the addition of Zn up to 6.2%. Thus, the Mg0.92Zn0.05C0.03 alloy is During the cooling process, an α-magnesium phase is formed with dissolved MgZn and Zn phases. However, because the Mg content is still high, a stronger Mg α phase is formed. As we talked about, the highest amount of Zn that can dissolve in Mg is 6.2% at 341°C. This can break down into MgZn and alpha magnesium intermetallic phases when it cools down. Fig. 2, shows that the Mg0.92Zn0.05C0.03 alloy has a number of X-ray difragmentation peaks. At 2Θ 21, 36, 39 degrees are the defragmentation peaks of Mg elements, at 2Θ 43 degrees are the defragmentation peaks of Zn elements and at 2Θ, 63 and 68 degrees are the defragmentation peaks of MgZn/intermetallic elements.

3.2 Effect of temperature on crystallite size in Mg0.92Zn0.05C0.03 alloy material

The crystallite size (D=Å) is shown in graph 3.2. The crystallite size of the calcination sample with a holding time of 20 minutes remains constant and the temperature is 380°C (magnesium/Mg element at 2θ = 360 = 9.615 Å, zinc/Zn element at 2θ = 430 = 7.568 Å, magnesium-zinc/MgZn element at 2θ = 680 = 8.925 Å; holding time 20 minutes and temperature 400°C (magnesium/Mg element at 2θ = 360 = 8.275 Å, zinc/Zn element at 2θ = 430 = 6.283Å, magnesium-zinc/MgZn element at 2θ = 680 = 6.165Å, and holding time 20 minutes and temperature 420°C (magnesium/Mg element at 2θ = 360 = 15.936Å, zinc/Zn element at 2θ = 430 = 7.156Å, magnesium-zinc/MgZn element at 2θ = 680 = 10.073Å

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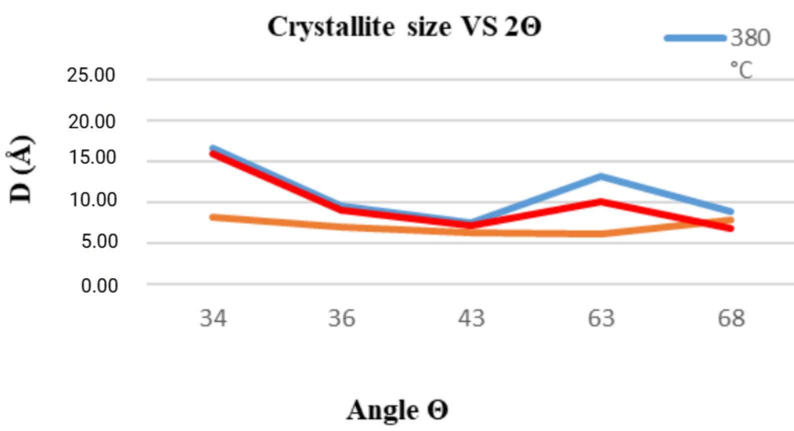

Fig. 3. Graph of Relationship Temperature and Crystallite Size of Mg0.92Zn0.05C0.03 alloy

From **Fig. 3**., it shows that the largest crystallite size is at a temperature of 380°, the increase in crystallite size may be due to grain growth during calcination and recrystallization stages.

3.3 Effect of calcination temperature on dislocation density in Mg0.92Zn0.05C0.03 alloy

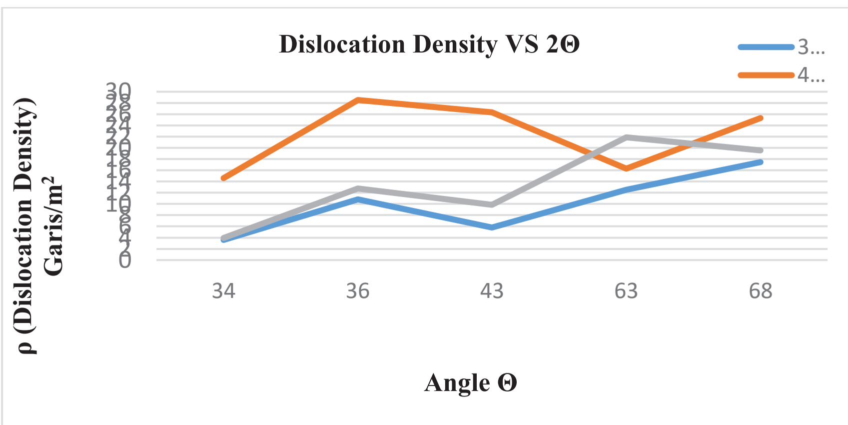

Fig. 4. Graph of the Relationship between Temperature and Dislocation Density of Mg0.92Zn0.05C0.03 Alloy

The dislocation density (ρ = m/m^3) is shown in **Fig. 4**. Dislocation density of calcined samples with holding time of 20 minutes and temperature of 380°C (magnesium/Mg element at 2θ = 360 = ρ = 0.010816 m/m^3, zinc/Zn element at 2θ = 430 = ρ = 0.017459 m/m^3, magnesium-zinc/MgZn element at 2θ = 680 = ρ = 0.012554 m/m^3; holding time of 20 minutes and constant temperature of 400°C (magnesium/Mg element at 2θ = 360 = ρ = 0.020852 m/m^3, zinc/Zn element at 2θ = 430 = ρ = 0.02533 m/m^3, magnesium-zinc/MgZn element at 2θ = 680 = ρ = 0.016294 m/m^3, and holding time 20 minutes and temperature 420°C (magnesium/Mg element at 2θ = 360 = ρ = 0.012738m/m^3, zinc/Zn element at 2θ = 430 = ρ = 0.019528 m/m3, magnesium-zinc/MgZn element at 2θ = 680 = ρ = 0.021870 m/m^3. From **Fig.** 4., it shows that the largest dislocation density at a temperature of 400°C, the increase in crystallite size may be due to grain growth during calcination and recrystallization stages

3.4 Effect of calcination time on lattice strain in Mg0.92Zn0.05C0.03 alloy

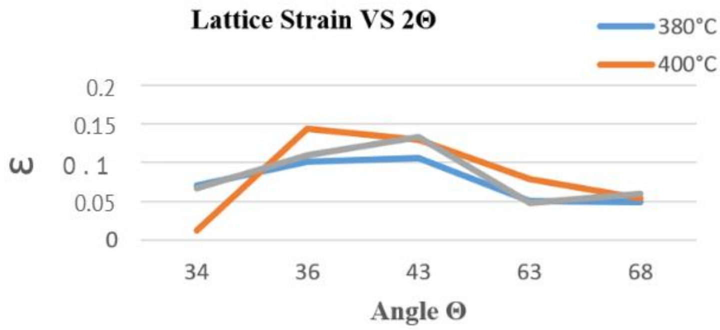

Fig. 5. Graph of Relationship Temperature and Porosity of Mg0.92Zn0.05C0.03 alloy

Micro strain (ε) (ε = %) is shown in **Fig.** 5. Dislocation density of calcined samples with a holding time of 20 minutes and a temperature of 380°C (magnesium/Mg elements at 2θ = 360 = ε = 10.1%, zinc/Zn elements at 2θ = 430 = ε = 10.6%, magnesium-zinc/MgZn elements at 2θ = 680 = ε = 4.84%; holding time of 20 minutes and a temperature of 400°C magnesium/Mg elements at 2θ = 360 = ε = 14.3%, zinc/Zn elements at 2θ = 430 = ε = 12.9%, magnesium-zinc/MgZn elements at 2θ = 680 = ε = 5.3%, and holding time of 20 minutes and a temperature of 420°C (magnesium/Mg elements at 2θ = 360 = ε = 10.9%, zinc/Zn element at 2θ = 430 = ε = 13.3%, magnesium-zinc/MgZn element at 2θ = 680 = ε = 6%. From **Fig.** 5., it shows that the highest dislocation density at a temperature of 400°C, the increase in crystallite size may be caused by the plastic formation stage of zirconium and zircalloy experienced through the twin and slip dislocation stages.

3.5 Effect of calcination temperature on the yield strength of Mg0.92Zn0.05C0.03 alloy.

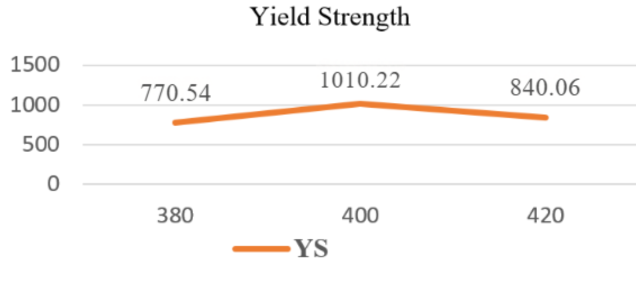

Fig. 6. Graph of Relationship Temperature and Yield Strength of Mg0.92Zn0.05C0.03 alloy

The yield strength (Ys = MPa) can be observed in graph 4. The yield strength of the sample with a fixed holding time of 20 minutes and a temperature of 380°C is 770.54 MPa, a temperature of 400°C minutes is 1010.22 MPa, and a temperature of 420°C is 840.06 MPa. These data suggest that at a temperature of 420°C, the reduction in yield strength may result from grain growth occurring during the calcination and recrystallization phases. As discussed in the section on crystallite size, most of the plastic deformation in MgZnC alloys happens in the twin dislocation and slip stages. The stress applied to the material does not cause particle elongation, but rather rotation in the crystal lattice. These changes in the crystal lattice make microcrystals. As the temperature rises, the dislocation density and yield strength both go down. This is because ZN 419.58 has a melting point.

4 Conclusions

Based on the calcination process with increasing temperature variations starting from 380°C, 400°C, 420°C will cause the porosity to slowly decrease 380°C = 70.06%, 400°C = 65.60%, 420°C = 57.32%. The calcination temperature process from 380°C to 400°C causes grain growth and recrystallization which is visible from the increase in micro strain from 7.5% to 8.3%, the increase in yield strength from 770.54 Mpa to 1010.22 Mpa, the decrease in crystallite size from 11.9Å to 7.10Å and the decrease in porosity from 70.06% to 65.60%.

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