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The Microstructure, Hardness, and Density Investigation of Mg Composites Reinforced with Kaolin

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Abstract

The demand for lightweight, high-performance aerospace and automotive components is growing, prompting interest in utilizing abundant materials like magnesium and its alloys and composites. However, pure magnesium's reactivity and mechanical weaknesses hinder its use in demanding engineering applications. To address this, magnesium is often reinforced with nanoparticles, leading to the development of magnesium matrix composites with improved mechanical properties. This paper systematically investigates the effects of kaolin on microstructure, hardness, and density for magnesium composites through the use of powder metallurgy. Results indicate that increasing kaolin content generally enhances density and hardness. These findings contribute to the understanding of kaolin-reinforced magnesium composites and their potential for improved mechanical properties in various applications.

Keywords: Kaolin, Mg composites, hardness, microstructure and density measurement

1. Introduction

There exists a growing need for lightweight and economical aerospace and automotive components showing superior performance. This increases the rising interest in leveraging naturally abundant materials. Specifically, magnesium and its alloys are contemporary lightweight materials. They find extensive applications across diverse industrial sectors, ranging from aerospace and automotive to biomedical [1]. On the other hand, pure magnesium's high reactivity and weak mechanical properties make it unsuitable for demanding engineering applications. To address this, magnesium is commonly reinforced with nanoparticles [2-6]. Researchers have concentrated their efforts on developing magnesium matrix composites with various reinforcements. These composites are designed to augment the overall performance of the material by integrating reinforcements into the magnesium matrix.

A wide array of reinforcement components, including Al_2O_3 [7], B_4C [8], SiC [9], WC [10], TiC [11], TiB_2 [12], carbon nanotubes (CNT) [13, 14], and graphene nanoplatelets (GNPs) [15], have been extensively employed in the fabrication of magnesium matrix composites. The integration of these reinforcements enhances mechanical properties such as tensile strength, hardness, and wear resistance, thereby broadening the potential applications of magnesium composites. Researchers endeavor to strike a delicate balance between desired properties and the specific requirements of diverse sectors through meticulous selection and optimization of the reinforcement elements [16-19]. Anbuchezhiyan et al. [20] studied TiC reinforced magnesium nanocomposites by varying its weight percentage (3%, 6% and 9%) using powder metallurgy for marine applications. As the percentage of reinforcement rises, the compressive strength and hardness of magnesium nanocomposites increase. This enhancement occurs as a result of integrating stiffer and stronger reinforcements into the matrix alloy. Raja et al. [21]

conducted a study of mechanical and microstructural properties of graphene reinforced magnesium composite. Results showed that the incorporation of graphene nanoplatelets (GNPs) has led to slight alterations in the crystallographic texture and grain size of the magnesium alloy. Additionally, there has been a remarkable increase in tensile strength, hardness, and impact strength, Ponappa et al. [22] focused on Y_2O_3 reinforced Mg composites. Scanning electron micrographs revealed a uniform distribution of Y_2O_3 particles within the magnesium and magnesium alloy matrix. Furthermore, macro and microhardness tests demonstrated a noticeable increase in hardness corresponding to the augmented amount of Y_2O_3 reinforcement.

Kaolin can be used as reinforcing particles. For instance; Zaimi et al. [23] studied Sn-Ag-Cu reinforced with kaolin with different weight percentages. In their study, the addition of 1.0 wt.% kaolin was determined to be the optimal value for enhancing the performance of the Sn-3.0Ag-0.5Cu solder. Furthermore, the incorporation of kaolin decreases the formation area of β-Sn while simultaneously increasing the eutectic area with fine intermetallic particles. Additionally, kaolin additions lead to a reduction in the undercooling value of the Sn-3.0Ag-0.5Cu solder. Ogunrinola et al. [24] conducted another study where they successfully produced aluminum metal matrix composites reinforced with silica and kaolin through the process of stir casting. The composites reinforced with kaolin exhibit higher hardness compared to those reinforced with silica sand. This difference is attributed to the higher molecular weight of kaolin.

In this paper, the microstructure evaluation, hardness, density of kaolin reinforced mg composites were studied employing powder metallurgy routine. To the best our knowledge, this is first time study. However, pure magnesium's reactivity and mechanical weaknesses hinder its use in demanding engineering applications. To address this, magnesium was reinforced with kaolin.

2. Materials and Methods

In the fabrication of kaolin reinforced magnesium composites, magnesium and kaolin were sourced from Nanografi, and ZAG Chemistry. 10 g of samples were weighted. 3, 5, 7 and 10 weight percentages of kaolin were chosen. Then, the powders were combined in a beaker and mixed thoroughly using a magnetic stirrer for thirty minutes. The magnetic stirrer was set to 800 rpm. After achieving a homogeneous distribution, the powder samples were cold pressed in a steel die at 98 MPa to form bulk samples.

3. Results and Discussion

To produce kaolin-reinforced Mg composites, kaolin were utilized at the weight percentages of 3%, 5%, 7% and 10%. Using the Archimedean principle, the densities of these materials were determined. Figure 1 illustrates the measured densities of the composites at varying kaolin weight percentages. As the kaolin content increases, the densities of the composites tend to rise. This outcome is anticipated, given that the density of kaolin (2.6 g/cm^3) exceeds that of magnesium (1.738 g/cm^3). However, it's notable that the composite reinforced with 7% kaolin exhibits a lower density compared to the one reinforced with 3% kaolin. This could be attributed to agglomerations within the structure. This leads to increased internal voids, thereby compromising the composite's density. Consequently, this weakens the overall strength of the density of the composite. Similar observations have been reported in studies involving various types of reinforcement particles [14, 25, 26].

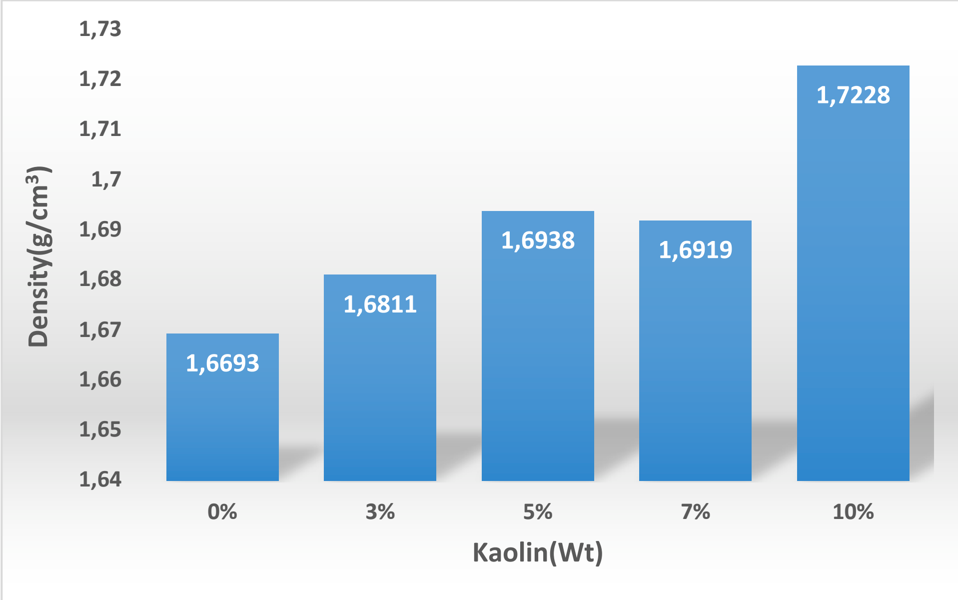

Fig. 1 The density measurements of the given kaolin weight percentages.

The metallographic procedures involving sanding and polishing were applied. Sanding was performed using 1000 and 2000 mesh sanders to refine the material surfaces. Subsequently, the specimens underwent polishing with 6μ diamond suspension, followed by 3μ diamond suspension to attain a polished finish of higher quality. To assess the hardness of the investigated composites, measurements were conducted using an AOB Vickers Microhardness tester with a load of 0.3 kgf and a dwell time of 10 seconds. Each sample underwent ten indentations, and the average hardness values were recorded. Fig. 2 illustrates the Vickers hardness values of the composites. The highest hardness value was observed in the composite with a 10% weight percentage of kaolin. Furthermore, an increase in the kaolin content correlates with an increase in hardness. However, there is a decrease in hardness observed at the 7% weight percentage of kaolin when compared to the other composites. These findings are consistent with density measurements.

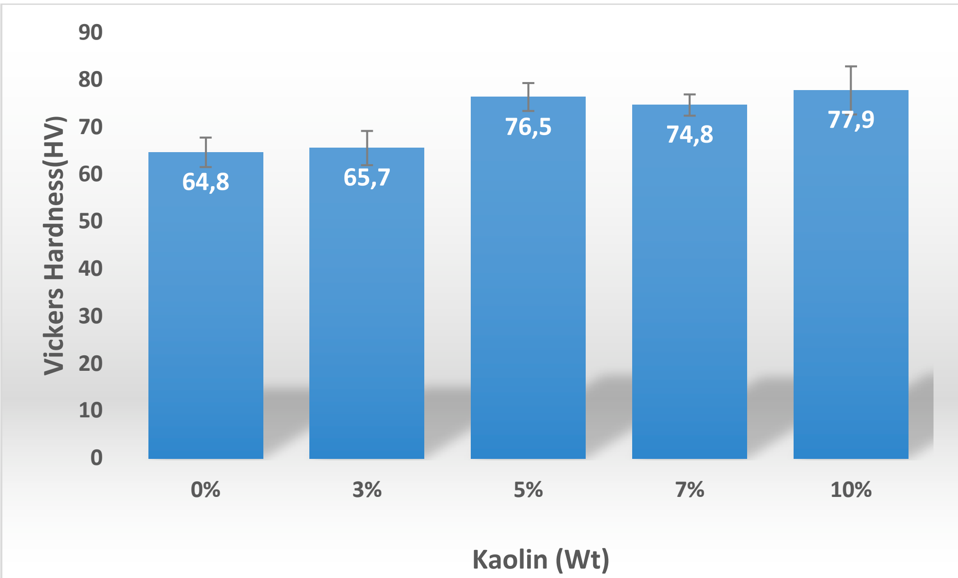

Fig. 2 The vickers hardness measurements of the given weight percentages of kaolin

Fig. 3 displays optical images of the given structures. Within these structures, metallographic spots are visible, indicative of contamination. Upon closer examination, some kaolin particles are observed at the Mg/Mg interfaces or within Mg/MgO, while others are enveloped within the Mg particles. Another notable feature is that the grain size of pure Mg is notably smaller compared to that of other composites. Additionally, MgO oxide particles are present in the structures. These dispersed oxide particles are expected to contribute to the reinforcement of the composites to some extent.

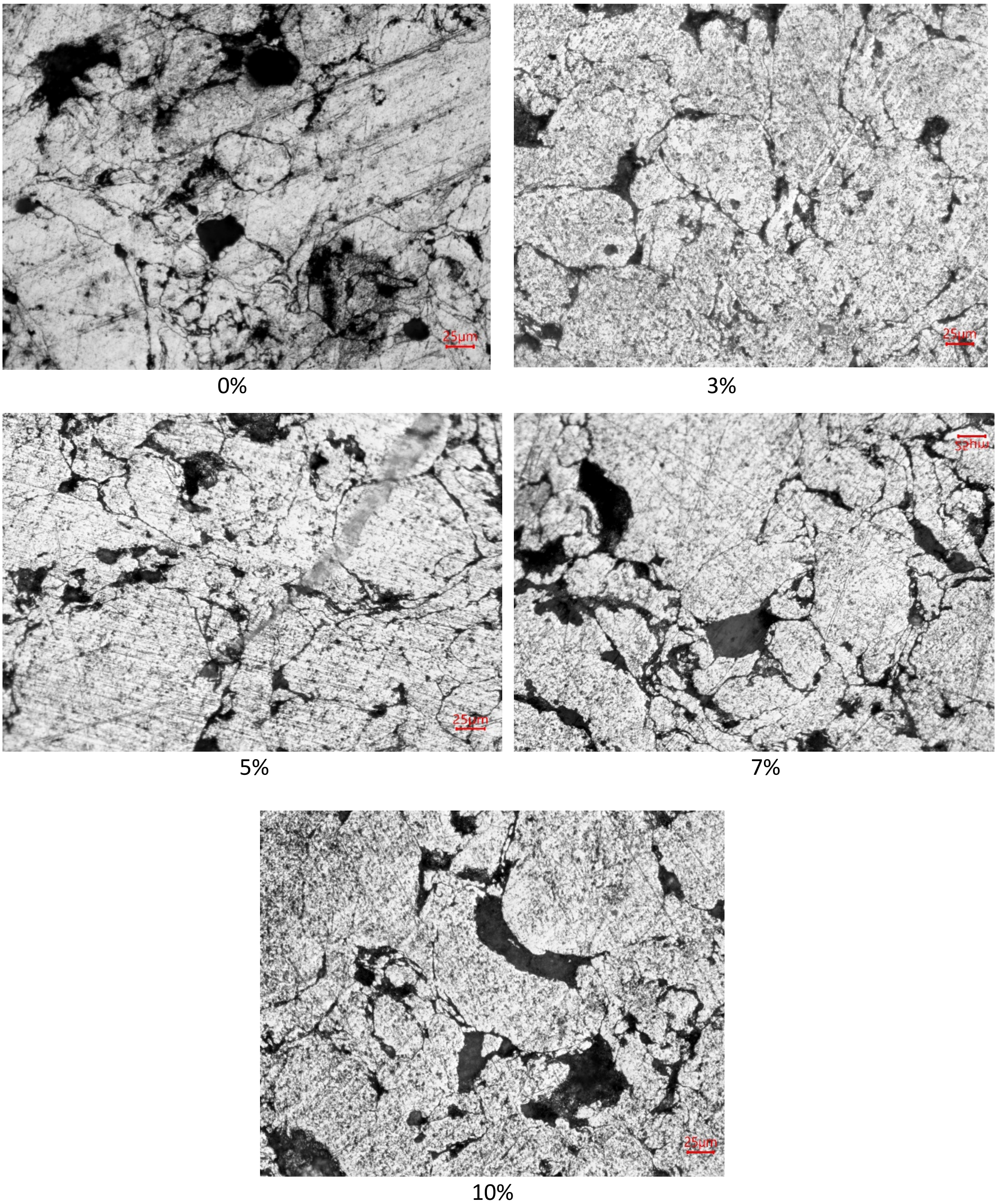

Fig. 3 Optical İmage view of the given composites

4. Conclusion

This study aimed to fabricate magnesium composites reinforced with kaolin through a powder metallurgy process. Magnesium was selected as the matrix material, with kaolin serving as the reinforcing component. The main goal was to analyze how different ratios of kaolin affect the properties of the resulting metal matrix composites.

It's worth noting that the composite reinforced with 7% kaolin demonstrates a lower density in comparison to the counterpart reinforced with 3% kaolin. This phenomenon could be attributed to agglomerations within the structure, resulting in increased internal voids and consequently compromising the composite's density. As a result, this weakening effect extends to the overall strength of the composite.

The composite containing 10% kaolin by weight exhibited the highest hardness value. Additionally, there was a direct correlation between kaolin content and hardness, with an increase in kaolin concentration resulting in higher hardness values. However, a decrease in hardness was noted at the 7% kaolin weight percentage compared to the other composites. These observations align with the findings from density measurement

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