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Production of Magnesium Matrix Composite and the Corresponding Mechanical Properties: A Review

KO. Babaremu[1], M. Udoh[1], O. O. Joseph[1], O.S.I. Fayomi[1, 2] and M.E. John[1]

[1]Mechanical Engineering Department, Covenant University, Ota, Ogun State, Nigeria.
[2]Department of Mechanical Engineering Science, University of Johannesburg, South Africa.
Corresponding author: kunle.babaremu@covenantuniversity.edu.ng

Abstract-
In this article we question the influence of the production method on the microstructure and mechanical properties of magnesium particulate reinforced composite. Magnesium matrix composite could be produced using either of the four methods discussed in this article such as ultrasonic vibration, powder metallurgy, stir casting and Shear compaction processing. The microstructural properties of the resulting composite benefited greatly from further processing when producing the composite through liquid metallurgy rout like stir casting method. The choice of ceramic reinforcement like Silicon carbide significantly improved the mechanical properties such as hardness, tensile strength but had negative effect on the ductility of the developed composite.

Key words: Production, SiC, metal matrix composite, magnesium, Particulate reinforcement

1. Introduction
Conventional materials such as aluminium alloys, steel and plastics do not outperform magnesium metal and its alloys in areas of specific strength, stiffness and thermal conductivity, which are higher in magnesium compared to them [1], [2]. This properties make it suitable for magnesium to be applied in automobile, aerospace and electronical industries. Magnesium and its alloys find difficulty in broader application because of its poor resistance to wear, ductility at room temperature and formability [3], [4].

Developing a magnesium matrix composite is a possible solution in solving the issues affecting monolithic magnesium being widely adopted in other industries [5]–[7]. The reinforcement material in a composite provides properties the base material does not possess [8]–[10]. Ceramic particulate reinforcement such as SiC is the more common form of reinforcement used in reinforcing composite (widely used in aluminium to improve mechanical properties). Unlike aluminium, magnesium is very reactive which could be an advantage in some cases and could be a disadvantage in others.

An instance, the reactive nature of magnesium makes it a suitable implant composite material in humans and animals. In this scenario magnesium reacts in the biological environment to aid tissue development and healing of specific areas of the body [11]–[13] . Contrast that to the difficult of casting magnesium without using a protective inert layer, if a protective gas layer is not used magnesium would oxidise or burn in the atmosphere to form magnesium oxide.

SiC particulate reinforcement is a suitable ceramic reinforcement for magnesium because it does not react readily with the highly reactive magnesium matrix [14], [15]. Additionally, the reinforcement ceramic improves the mechanical and thermal stability of the resulting composite. In this article we question the influence of the production method on the microstructure and mechanical properties of magnesium particulate reinforced composite.

2. Production method

Manufacturing method available for the production of magnesium matrix composite can be classified into three distinct production method [12], [16], [17]. The first processing method is done in the solid phase of the material and includes powder metallurgy and diffusion bonding. The liquid phase processing method is the second processing method for composites and includes stir casting [18] and liquid matrix infiltration method. Finally the last mode of producing metal matrix composite is the semi-solid method which includes spraying and rheo casting. The production method of metal matrix composite has a significant influence on the microstructure of the resulting composite and interfacial bonds that occur between the matrix and reinforcing material.
When reducing magnesium matrix composite with SiC particulates, different production methods as shown in Table 1 have been researched upon. Because magnesium oxidises at elevated temperatures, authors have found it difficult producing magnesium using the traditional stir casting method although it is a cheaper production rout in producing composites.

Table 1: Different processing method used in producing Magnesium matrix composite [19], [20]

Method	Phase of Production	Cost	Damage on reinforcement
Powder Metallurgy	Solid Phase	Expensive	Fracture
Stir Casting	Liquid Phase	Moderate	Little damage
Ultrasonic Vibration	Semi Solid	Moderately expensive	-
twin roll casting		Moderately expensive	-
Shear compaction processing		Moderately expensive	-

2.1 Stir Casting

Wang et al. produced magnesium particulate reinforced composite using the stir casting method [21]. The composite which was reinforced with 10µm of silicon carbide at differing volume fraction was stir cast under a protective atmosphere of CO_2 and SF_6. The casted composite was extruded on a 2000KN press. This was because of micro-voids which are present on the as cast composite samples. The micro structure of samples where studied at differing extrusion temperatures from 250°C to 350°C at an interval of 50°C and the authors discovered that extruding the samples improved the distribution of SiC in the composite matrix. Also, the authors discovered that the gain size of the samples increased as extrusion temperature increased.

Unlike Wang et al., Deng et al. decided to forge the composite produced from the stir cast processing method [22] [23]. The samples developed where forged at varying temperatures and constant speed. Upon microstructural analysis, it was discovered that samples forged at lower temperatures has a high level of dislocation. Also, increase in forging temperature had a similar effect on the dynamic recrystallization of the samples. Lastly, there was a reduction in grain size of particles located close to the reinforcement compared to particles situated furrier away.

Deng et al. in their 2010 study discovered the forging temperature had a positive effect on the mechanical properties of the composite. They discovered that the optimum temperature for forging the SiC reinforced composite was at 420 °C after which the tensile strength of the material is reduced drastically [23]. Where as Deng et al. discovered in another study the increasing the percentage of SiC reinforcement in magnesium matrix composite cased a decrease in mechanical properties they attributed this to an increase in particulate agglomeration during the stir casting processing technique [22]. Finally, Wang et al. discovered that increased extrusion temperature had a negative impact on the mechanical properties of the resulting composite which was evident in the smaller grain size.

2.2 Ultrasonic Vibration

Nie et al., successfully fabricated Magnesium alloy AZ91 composite reinforced with SiC particuate using ultrasonic vibration [24]. The study was on the morphology of the resulting composite and it was discovered that the phase $Mg_{17}Al_{12}$ transformed from coarse plates to lamellar precipitates. The author recorded that there was a visible decrease in grain size of the resulting composite compared to the matrix alloy. Shen et al., developed a composite of bimodial sized particulate reinforcement to a AZ31B magnesium matrix. Which after development was further extruded they discovered that the mechanical properties of the composite was greatly improved [25]. Figure 1 depicts a schematic diagnam of ultasonic vibration setup.

The effect of the research conducted by Shen et al. on the mechanical properties of the resulting composite reveealed that the bimodial sized SiC particulate had better yield and ultimate tensile strenght when compared to the source material [25]. This was ecoed by Nie et al. who made simmilar discoveried.

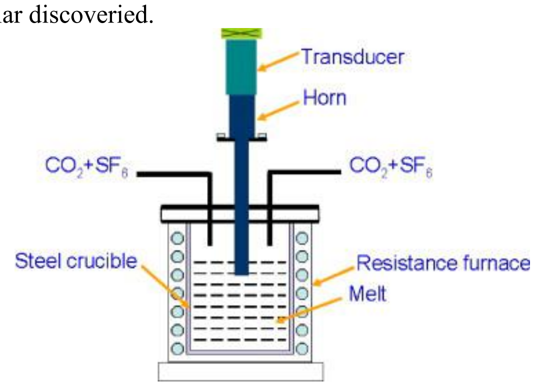

Figure 1: schematic diagram of Ultrasonic Vibration

2.3 Powder Metallurgy

Li et al. [27] developed a SiC particulate reinforced composite with magnesium AT81 alloy as reinforcement through the powder metallurgy rout. The powders of particulate and matrix where first blended together then green compacted at room temperature then sintered at temperatures where oxidation would not take place. The authors observed that the particulate

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reinforcement was well distributed within the matrix of the composite and exhibited well bonded interface between matrix and reinforcement material.

Li et al. [27] attributed the improvement in mechanical strength to the refinement of the composite grain size and well bonded interface between matrix and reinforcement. Consequently, Labib et al. [26] studied the wear behaviour of a similar composite at varying temperatures and discovered that the wear properties of the composite reduced significantly compared to the base matrix alloy.

2.4 Shear compaction processing

Narvan et al.[28] developed an novel method of producing magnesium based composite using machined chips and SiC particulate of particle size within the nano-scale. A pictorial representation of the set-up is depicted in figure 2. Where the magnesium machined chips are first compacted in the shear processing setup then the SiC particulate is added. Furthermore, the materials are compacted together by a spindle rotating at a constant speed. The effect of this processing rout was evident during the microstructural analysis, it was discovered that the SiC was well distributed in the material matrix. With significant improvement in grain refinement and excellent interfacial bonding was discovered in the microstructure.

Studying the mechanical properties of the specimen, Narvan et al. discovered that the composite produced from this process has a higher hardness than the parent material. Narvan et al. also attributed the speed of rotation of when producing the composite to the improvement in wear properties of the resulting composite compared to the matrix metal.

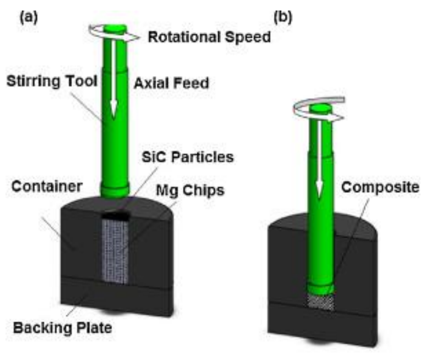

Figure 2 set-up of Shear compaction processing

3. Conclusion

Magnesium matrix composite could be produced using either of the four methods discussed. The microstructural properties of the resulting composite benefited greatly from further processing when producing the composite through liquid metallurgy rout like stir casting method. The choice of ceramic reinforcement like Silicon carbide improved mechanical properties such as hardness, tensile strength but had negative effect on the ductility of the composite.

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