Evaluation of Mechanical Properties of Magnesium Reinforced with Titanium Oxide Composites

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Abstract

The experimental investigations of magnesium based matrix material reinforced with the TiO_2 particles with various weight ratios of 2.5, 5, 7.5 and 10% are presented in this research paper. The purpose of this work is to intricate the manufacturing processes of pure magnesium with the addition of Titanium oxide through the powder metallurgy route. The powder blending was done with the energetic ball and jar mill. The compaction pressure of 650Mpa is given to improve the process of cold compaction and strength. The Sintering temperature of 550 °C and holding time of 40 min was used to sinter the compacts to get better results. The microstructural analysis by scanning electron microscopy (SEM) for the starting powders and fabricated samples are carried out and results revealed that homogeneous composition is present. The mechanical properties are evaluated and the results proved that improvement in 13.8%, 17.8% and 29% for the density, hardness values and ultimate tensile strength.

Keywords: *Magnesium, Titanium oxide, SEM analysis, Mechanical properties, Powder metallurgy.*

1. INTRODUCTION

Composite materials could be in the form of natural or synthetic which combines two or more chemically dissimilar materials in order to achieve improved properties over the individual materials. The reinforcing materials are strong with various Properties and in the form of particles, platelets, whiskers, short fibers, and continuously aligned fibers are combined together to get desired properties. The advanced composites are used in aerospace, sporting goods, military and commercial aircraft, etc. Magnesium based composites used in space and satellite structures, Antenna structures, Helicopter transmission structures with the reinforcing particles of Graphite, boron, alumina respectively. Magnesium is useful in manufacturing of electronic devices such as cameras, laptops, mobile phones and integrated circuits [1-3]. The elastic and mechanical properties of metal matrix composites are strongly prejudiced by micro structural parameters of the reinforcement such as shape, size, orientation, distribution and volume fraction [4-5]. Among the several methods, the powder metallurgy process followed by hot extrusion and casting methods is playing vital roles because of producing near net shape[6-8]. The use of powder metallurgy techniques which is more flexible than casting, forging or extrusion and achieved improvement in bonding strength, thermo -physical properties [9-10]. By using powder metallurgy route the various particles reinforced with magnesium matrix composites are prepared and results showed that certain improvements in mechanical properties like yield strength, Ultimate tensile strength and elastic modulus [11]. It is reported that non uniform microstructure was obtained when the reinforcement particle size was smaller than the matrix particle size.[12-13]. The minimal porosity and fairly well distribution of particles were found that improvements in mechanical properties [14-15],and wear resistance [16]. The magnesium metal matrix composites with TiB_2 are fabricated with powder metallurgy technique and increase in hardness from 41% to 181%. The titanium alloys are used in the manufacturing of missiles , aircraft naval ships and spacecraft, with around two thirds of all titanium metal produced is used in aircraft engines and frames

[17].The usage of composite materials gains prominence when it is reinforced with hard ceramic particles which can be used to control the tribological properties. This can be obtained with various composition of the reinforcing particle in the matrix. The hardness of the composites increase with the addition of Ti particles and when the content is 15% its highest value is obtained. [18-19].

2. EXPERIMENTS

2.1 Materials and preparation.

Magnesium is the lightest metal among the metals available for structural applications. It is a silvery-white alkaline earth metal and one third lighter than Aluminium. It also burns in pure nitrogen and pure carbon dioxide. The fire produced by magnesium is not extinguished by water, since water reacts with hot magnesium and releases hydrogen which can cause the fire to burn more ferociously. The properties of the materials are listed in Table 1 and 2.Titanium is present in most igneous rocks and their sediments and it is always found bonded with another element that does not occur in natural pure form.

Table 1 Properties of matrix material.

Material	Magnesium
Phase	Solid
Melting point	650 °C [923 K]
Boiling Point	1091 °C[1363 K]
Density	1.738 g/cm^3
Heat of fusion	8.48 kJ/mol
Heat of vaporization	128 kJ/mol

Table 2 Properties of reinforced material.

Material	Titanium
Phase	Solid
Melting point	1668 °C [1941 K]
Boiling Point	3287 °C [3560 K]
Density	4.506 g/cm^3
Heat of fusion	14.15 kJ/mol
Heat of vaporization	425 kJ/mol

Pure titanium is a transition metal with a lustrous silver-white color and is resistant to corrosion including sea water and chlorine. Powder Metallurgy methodology is used to fabricate the samples in which materials or components are made from metal powders. This process has an influence to get near expected shape and avoid or greatly reduce the need to use metal removal processes, thereby considerably reducing yield losses in manufacture and often ensuing in lower costs.

2.2 Synthesis

Even though various techniques are available for the fabrication of metal composites, Powder metallurgy makes materials properties relatively easy to control by mixing materials with different properties in various proportions. The processes involve collection of matrix and reinforcement particles in powder form and then they are blended by using vibratory ball mill in order to get fine grain sizes. Then the mixture is placed in the dies setup and compacted by cold compaction process. The samples are entered into the sintering process to improve the bonding between the matrix and particulates. The extruded billets are then machined to the desired sizes for the conduction of tests like density, hardness and tensile tests. In the present work both matrix and TiO_2 of equal size particle size of 100 microns are chosen. Fig 1 represents the appearance of matrix material in powder form. The high energy ball mill like planetary ball mill is used to fabricate the nanosized composites to improve the hardness and density of the samples [4,12].The powders are milled to the requirement size of 10 microns separately. The weighed powder for the five proportions are mixed (0%,2.5%,5%,7.5% and 10% of mass) in a high energy ball mill from VBCC Ltd Chennai. Since the particle size of matrix and the reinforcements are 10 microns which is adequate for compaction ball milling was focused only on mixing of 60 min with a speed of 45 rpm for all the reinforcement composition. Fig. 2 shows the arrangement of ball and jar mill used for blending the composites. Powder compaction is the process of compacting metal powder(s) in a die through the application of high pressures or load. The compaction of the powders has been carried out in a standard die – setup to prepare the specimens. The arrangement of die set up is as shown in Fig 3.Then the compactions were carried out in a hydraulic press attached with the universal testing machine with compacting pressure of 650 Mpa is given to carry out the uni-axial pressing of specimens. Zinc stearate is acted as lubricant to improve the powder processing properties of formulations. The purpose of adding

Fig 1 Magnesium powder

Sample	proportion
1	Pure magnesium
2	Mg+ 2.5 % TiO_2
3	Mg+ 5 % TiO_2
4	Mg+ 7.5 % TiO_2
5	Mg+ 10 % TiO_2

Table 3 Percentage of particles in specimens

Fig. 2 Ball and Jar mill.

Fig 3 Die setup .

Fig.4. Samples.

lubricant is to decrease the friction at the interface between billet surface and the die wall during ejection so that the wear on punches and dies are get reduced. Sintering was carried out for prepared billet samples upto 550^{o} C with the holding time of 20 min in Muffle sintering furnace at a variation in rate of heating up to 10^{o}C per minute. After the sintering process the specimens were allowed to cool up to 250^{o}C inside the furnace to avoid atmospheric contamination and sudden cooling and finally to room temperature. some prepared samples are shown in Fig. 4.

2.3Testing

The density of prepared specimens was estimated with Archimedean principle, by determining the specimen mass and volume before and after the immersing the specimen in air and in distilled water. The hardness tests of the fabricated composite materials were made on Rockwell hardness tester . The samples were machined up to the required size to conduct the experiments. The macrohardness of polished cross-sections was determined on the Rockwell 15 T superficial scale using a 1/16 in. diameter steel ball indentor with a 15 kg major load, in accordance with the ASTM E18-92 standard. Three indentations were made on each of the transverse section of samples. The hardness values are estimated for both pure alloy and fabricated composite materials reinforced with the TiO_2 phase particles. Finally the average hardness of each samples were calculated and plotted as a curve. Static tensile tests of the fabricated composite materials were made on the ZWICK 100 type testing machine at room temperature. The cylindrical tensile specimens of 5 mm diameter and 18 mm gauge length according to ASTM E8M-96 standard. The samples were machined from the extruded bars .The Yield stresses (YS), ultimate tensile strength (UTS) and Young module (E) were determined employing at least two specimens for each material.

3. MICROSTRUCTURE.

The Microstructure examination of cross-sections from the prepared specimens revealed that there were equi-axed grains with uniformly distribution of Ti O_2 within the magnesium matrix.The sizes of the pure magnesium powder and of the reinforcing TiO_2 powder particles were determined based on observations of SEM . The particles of magnesium and TiO_2 powders images are presented in Figures 5

a) and b).It was found out that particles of powders used for fabrication of composite materials were

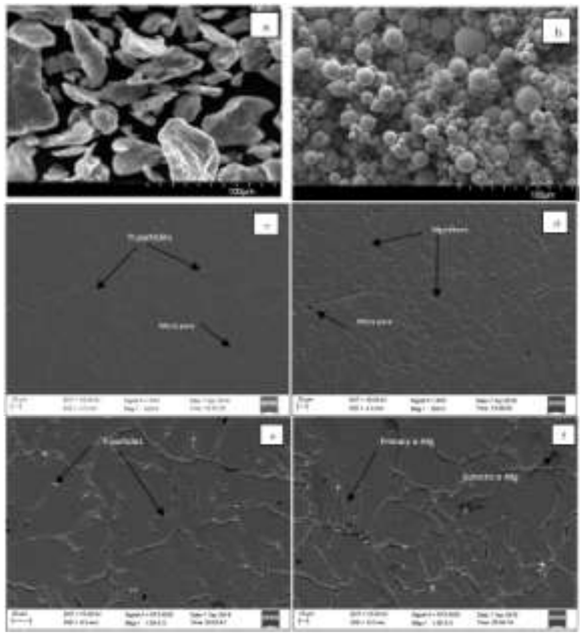

Figure 5 SEM. images a) magnesium powder particles b.) TiO_2 powder particles c.) Mg + 2.5% TiO_2 sample d.) Mg + 5% TiO_2 sample e.) Mg + 7.5% TiO_2 sample f.) Mg + 10% TiO_2 sample.

regular in shape and their size did not exceed 100 µm for the magnesium powder and 25 µm for the TiO_2 powder. The Metallographic examinations of the composite materials after the fabrication of samples revealed the uniform distribution of the TiO_2 reinforcing particles in the aluminum matrix. The distribution TiO_2 particles with weight percentage of 2.5,5,7.5 and 10% reinforced with magnesium matrix are presented in the Figures 5 c-f. The structure obtained from the observation ensures the perfect bonding between the matrix and particles of composites. In the magnification of 1000 x shows that very little micro pores are present on the surface.

4. RESULTS AND DISCUSSIONS.

The density measurements and their comparison with theoretical values are shown in Figure 6. The differences between the real and theoretical densities indicate the presence of porosity.Hardness tests of the fabricated composite materials revealed its diversification depending on the weight ratios of the reinforcing particles in the Magnesium matrix. Mean hardness values of the pure magnesium

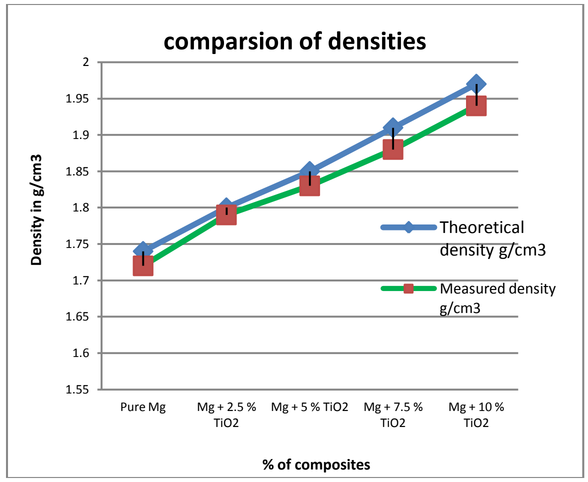

Figure 6. Graphical representation of density values.

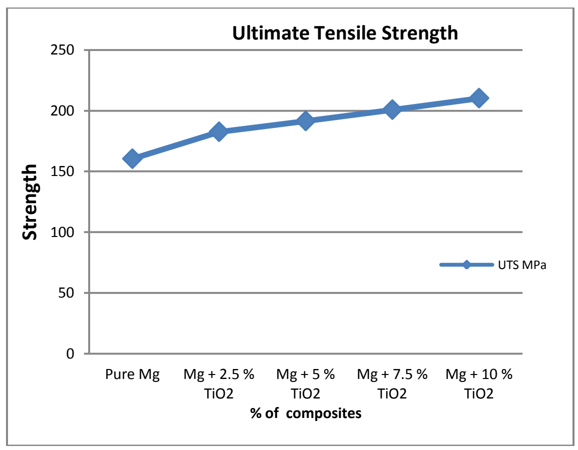

Figure 7. Graphical representation of UTS values.

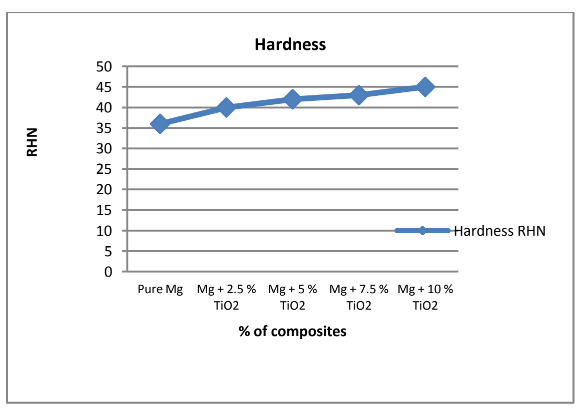

Figure 8 . Graphical representation of Hardness values.

and of the fabricated composite materials reinforced with the TiO_2 ceramic particles with the weight ratios of 2.5, 5, 7.5 and 10 are shown in Figure 8. The values of investigated composite materials are characterized by an higher hardness compared to the non-reinforced material. The Hardness of composite materials increases with increasing content of the reinforcing material in the metal matrix

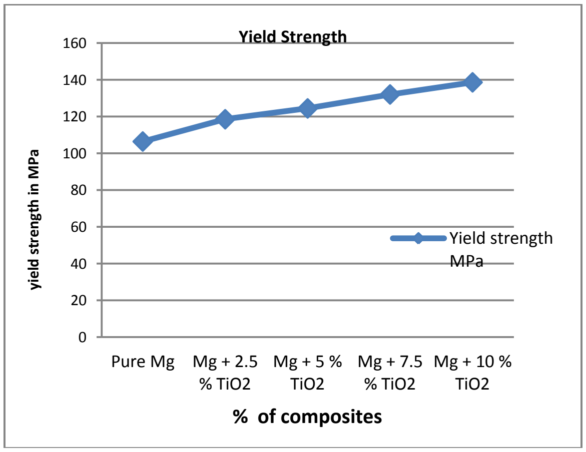

Figure 9. Graphical representation of yield strength values.

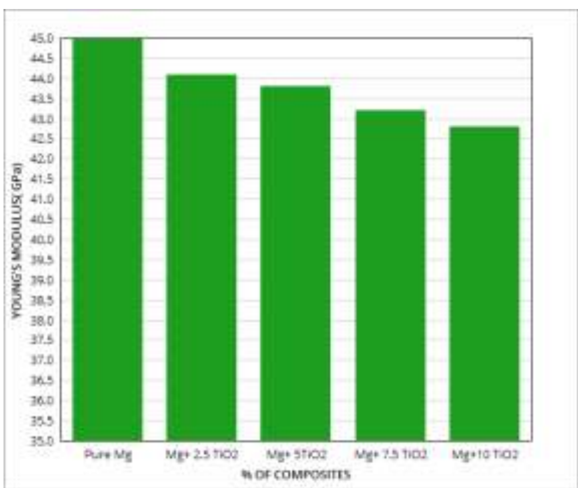

Figure 10. Graphical representation of young's modulus values.

The measured values of mechanical parameters are represented in the *Figures 7,9 and 10* respectively. From the results it is found that there will be significant improvements in mechanical properties of the composites due to reinforcement of titanium oxide particles . The mechanical properties are evaluated and the results proved that improvement in 13.8% ,17.8% and 29% for the density, hardness values and universal tensile strength. There was little bit reduction elastic modulus.

5. CONCLSIONS.

From the experimental investigations of the composites, it is concluded that as follows..

- The Powder metallurgy method is suitable for producing magnesium based composites with an economic manner.
- Due to the presence of TiO_2, the morphology of the Mg phase is changed to discontinuous and fine. There are no imperfections in the interfacial bonding between the matrix and particles.
- The uniform distribution of particles into the matrix is ensured by the investigations' of SEM.
- The values of density for the prepared composite materials are near to the theoretical one but existing differences indicate presence of porosity..
- The improvement of mechanical properties of composites is due to perfect interfacing between matrix and particles.
- The Hardness, Yield strength and Ultimate Tensile Strength of composites were increased to significant level due to addition of reinforcement particles.
- The addition of the TiO_2 particles of the reinforcing material to the magnesium matrix increased the expected hardness of the composite materials and got the value of 17.8% more than the unreinforced material.

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