Mechanical Characteristics of Mg/TiC Matrix Composites for Bio-Medical Application

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Abstract – **Magnesium matrix composites are widely used in biomedical application for it slight weight with improved strength, stiffness and bio-compatibility as a predetermined for biomedical application. The near to net shape of composites were fabricated through Powder Metallurgy (PM) routine to attain a high strength and fine distribution of particles. The improvement of mechanical strength in Mg matrix were attained by adding hard ceramic particles as Titanium carbide (TiC) with varying level of wright percentage (Wt. %). In this work, the physical and mechanical properties such as density, hardness and compression tests were carried out as per ASTM standards. The results revealed that Theoretical Density (TD) of composites increase with increase wt. % of TiC level and practical density shows lesser value than TD. The hardness of 8 Wt. % TiC shows 31.13 % increased hardness as compare to pure magnesium. The presence of TiC particles resist dislocation motion and improve the hardness of Mg matrix composite. Compression strength of composite increased with increasing Wt. % of reinforcement, due to effective compacting, sintering and TiC particles act as a load bearing elements hence composite material have higher compressive strength than pure magnesium. The results shows that the increasing mechanical properties were achieved by addition of TiC particles in magnesium matrix and it's concluded as most suitable for Bio-Medical application.**

Keywords — **Metal Matrix, Magnesium, Titanium Diboride, Powder metallurgy, Hardness, Compression strength.**

I. Introduction

The increasing demand on Magnesium based alloy and composites in biomedical application as replacement of hip joints, dental implants, bone fixation, stents in cardiovascular. The Mg alloys have excellent physical and mechanical properties. In further improving the bio-corrosion compatibility and improve the mechanical properties to react in dynamic loading condition through addition of hard particulate ceramics. The addition of various ceramic particles such as SiC, TiC, TiN, TiB_2 etc., among the ceramic particles TiC ceramic particles paid a great attention due to high hardness with extreme wear resistance and can easily incorporated with magnesium alloy. The effective fabrication of Mg composite is play major criteria for improving mechanical and microstructure behaviour to attain a net-shape structure. Hence fabrication of Mg composites is processed through powder metallurgy technique. Falcon et al. adopted pressure less infiltration process to develop Aluminium Nitride reinforced Magnesium matrix composite for light weight structural application. AZ91E alloy were used as matrix for weight reduction and the results notified that AlN particle enhanced hardness and elastic modulus. The Better tribological behaviour were observed by wear analysis at dry lubrication. Fida et al. developed Nickel reinforced Magnesium matrix composite through powder metallurgy. The Ni dispersion into Magnesium matrix improves hardness with an improved tensile strength. Rashad et al. utilized powder metallurgy to disperse Graphene Nano Platelet of varying wt. % into Mg matrix to improve its strength. The observed mechanical characteristics notifies that an increment in tensile strength and young's modulus while compared to pure Magnesium. Xiang et al. developed GNPs reinforced Mg matrix composite disintegrated melt deposition and Magnesium were selected as base matrix material and GNPs was mixed as reinforcement. The selected method were helped in to obtain uniform dispersion of GNPs. Yoo et al. developed CNT reinforced Magnesium matrix through roll bonding method. Study observation over its mechanical behaviour and microstructural shows for the development in strength and uniformed dispersion of CNT particles. The Mg reinforced matrix composite were prepared through several methods including stir casting, squeeze casting and powder metallurgy. Powder metallurgy (PM) technique is most likely used to develop Magnesium matrix composites. Due to uniform distribution of reinforcement in the metal matrix was achieved by using powder metallurgy technique. It's done with or without chemical reactions between the matrix and reinforcements without melt.

Magnesium matrix composites have widespread industrial applications due to their low density. Magnesium is light and an ideal for the various transportation industries. It is a need to develop its ductility and strength by developing, the traditional alloys and various composite materials thereby implementing the newer materials to replace the recent technical up gradations. The certain addition of reinforcements to magnesium matrix composites defines for improvement in mechanical characteristics, good thermal properties and other vital properties.

II. Materials and Methods

In present work, pure Mg as matrix material and reinforcement as titanium carbide, Mg/TiC composite were developed by powder metallurgy technique. The physical and mechanical characteristic such as density, hardness and compression strength of developed composite specimens has been investigated. The mixed Mg/TiC powder as shown Fig. 1 and fabricated samples are shown in Fig. 2. The properties of magnesium and titanium carbide were displayed in Table 1 and Table 2.

TABLE 1. PROPERTIES OF MAGNESIUM

Material	Magnesium
Phase	Solid
Melting point	650 °C (1202 °F)
Boiling point	1363 K (1091 °C, 1994 °F)
Density	1.738 g/cm3

TABLE 2. PROPERTIES OF TITANIUM CARBIDE

Material	Titanium Carbide
Phase	Solid
Melting point	3160 °C (5,850 °F)
Boiling point	4820 °C (8710 °F)
Density	5.1 g/cm3

Figure. 1. Mg-TiC Matrix material

Figure. 2. Mg-TiC Matrix Composite

A. Blending

Magnesium metal powder were mixed with Titanium carbide as per the required quantity using a ball mill in a ratio of ball-to-powder weight ratio of 4:1.The rotation speed of the steel vials was set at 200 rpm. After milling, the powders were naturally air dried.

B. Compacting

Compaction was done by using punch and die which is machined to fine tolerances on high pressure. The mixed powder was poured into the die and also compacted by Universal Testing Machine under 5 MPa pressure in the high H-13 steel mould. The value of applied load increases, the density of the compacted powder also increases on compacting.

C. Sintering

The compacts was sintered in a muffle furnace of 450 °C for 30 minutes at the heating rate of time in an argon atmosphere. Normally metals were sintered at 90% of the melting temperature of base metals. Here furnace were used to sintering operation. During sintering, the bonding relation between the metal powder particles takes place continuously and results in growth of grain boundaries. The Magnesium matrix composites was prepared for various level of compositions. The percentage of reinforcements are shown in Table 3.

TABLE 3. MATRIX AND REINFORCEMENT OF MAGNESIUM MATRIX COMPOSITE

Specimen code	Magnesium(Mg)	TiC
1	100%	0 wt.%
2	98%	2 wt.%
3	96%	4 wt.%
4	94%	6 wt.%
5	92%	8 wt.%

III. RESULTS AND DISCUSSIONS

A. Density measurement

TABLE 4. OBSERVED THEORETICAL DENSITY AND PRACTICAL DENSITY

Sample (wt. %)	Theoretical Density g/cm^3	Practical Density g/cm^3
100% Mg	1.691	1.623
2%Tic + 98% Mg	1.710	1.689
4%Tic + 96% Mg	1.915	1.857
6%Tic + 94% Mg	2.025	2.013
8%Tic + 92% Mg	2.127	2.101

Based on the Archimedean principle, the value of density measurements were made by comparing the weight of the samples in air and immersed in distilled water. Theoretical density was calculated as per formulation of rule of mixture. The theoretical and actual values of density were displayed below shows that the density of before specimens fabricated and also after sintering for different level composition of Mg metal matrix composites. The conclusion is that the increase in Wt.% of reinforcement, the density of

Mg composites also increases due to the higher density of Titanium carbide compared to magnesium matrix. The addition of TiC were increased the overall density of the reinforced matrix composites.

B. *Hardness*

The value of hardness were observed on different level of reinforcements by Vicker's hardness tester as shown in below Table. 5. A load of 200gm mass was applied on the specimen through the diamond indictor with dwell time of 40 seconds. The indictor indentation was carried out in three different locations and average value is reported. From the measured results, the increasing percentage of titanium carbide were increased the hardness values. The increasing percentage of titanium diboride increases the hardness from 38.50 HV to 69.63 HV. This increasing hardness was attained due to the increasing percentage of high strength ceramic as titanium carbide. The observed results shown evidently, the maximum value of hardness were increased by the addition of 8% Wt. of TiC.

TABLE 5. HARDNESS VALUES FOR VARIOUS LEVEL OF COMPOSITES

Composition	**Mean hardness in HV**
100% Mg	38.50
2%Tic + 98% Mg	47.80
4%Tic + 96% Mg	57.60
6%Tic + 94% Mg	62.96
8%Tic + 92% Mg	69.63

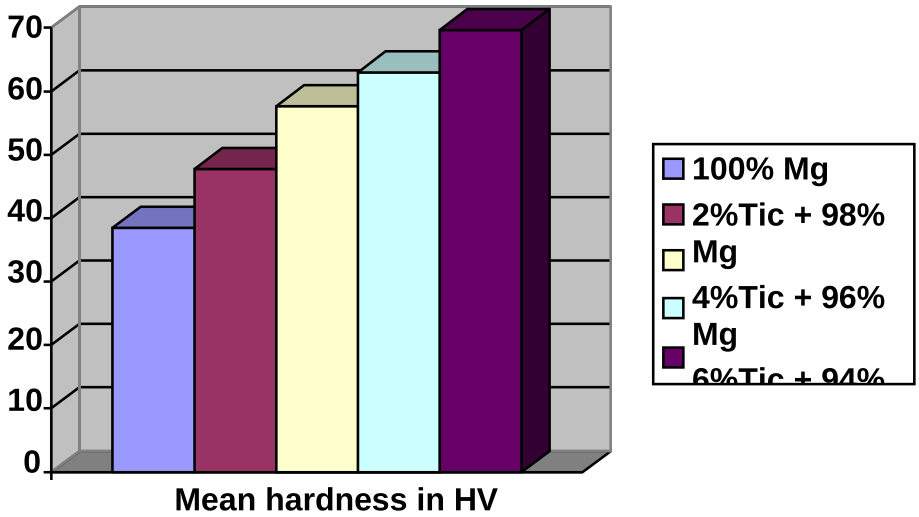

Figure 3. Variation of Hardness of Mg matrix reinforcements

C. *Compression strength*

The compression test of Mg matrix composites were carried out using universal testing machine where the compression plate compress the work samples, the load increases gradually and compression test is computed using data logger. The compression load were stopped before the initial crack formation. The Mg/8 Wt. % TiC composite shows a higher compression strength than alloy and another composites. The hard ceramic particles act as a load bearing elements it share the applied stress directly by the stress transfer to matrix material and improvement is through dislocation strengthening in the matrix are major factors for improving the strength of composite.

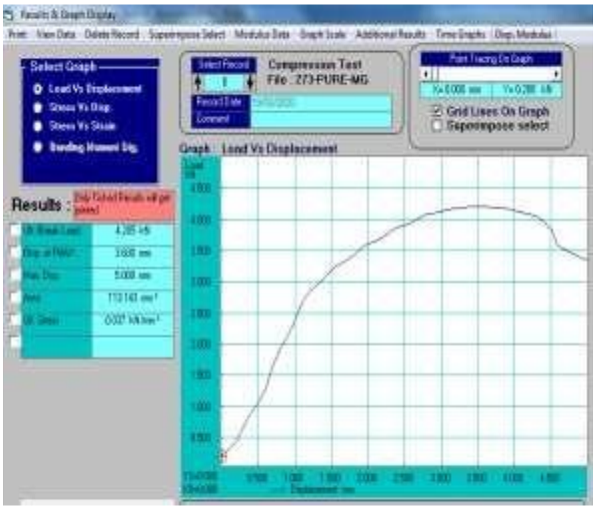

Figure 4. Compression strength of Pure Mg matrix

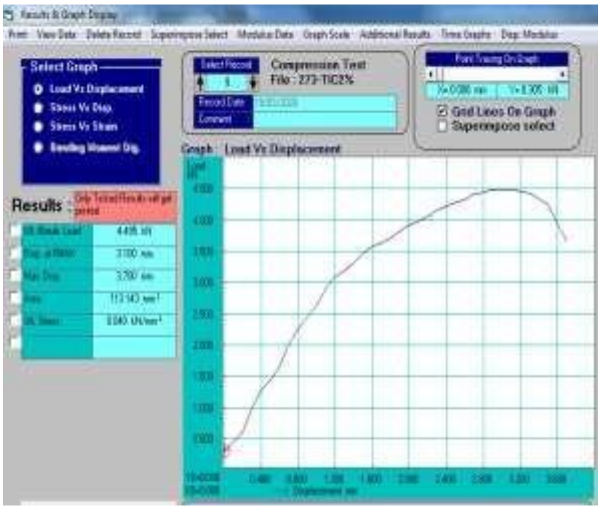

Figure 5. Compression strength of Mg with 2% TiC matrix

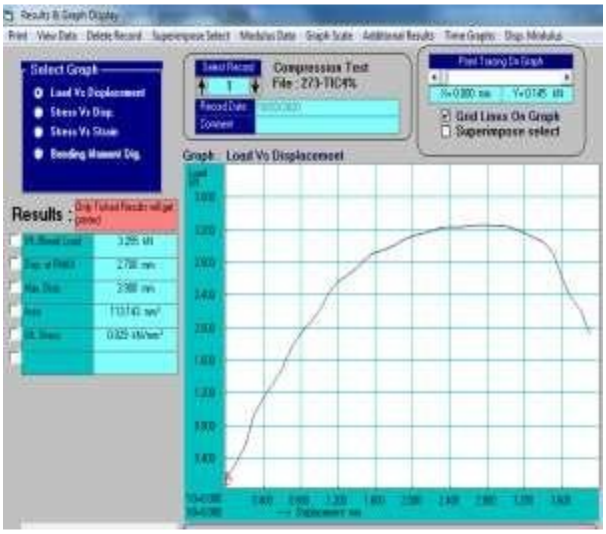

Figure 6. Compression strength of Mg with 4 % TiC matrix

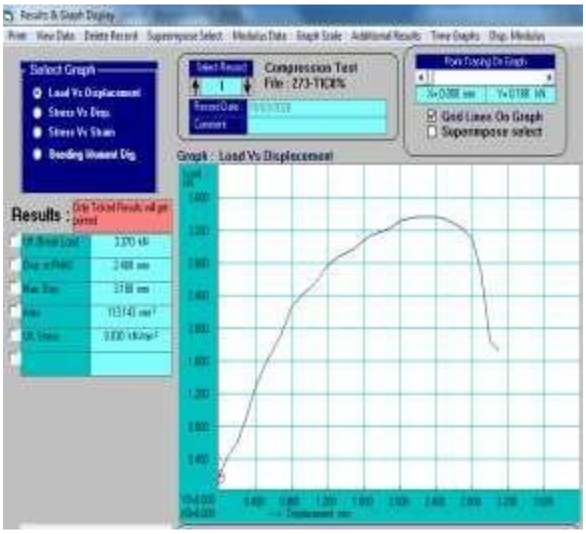

Figure 7. Compression strength of Mg with 6% TiC matrix

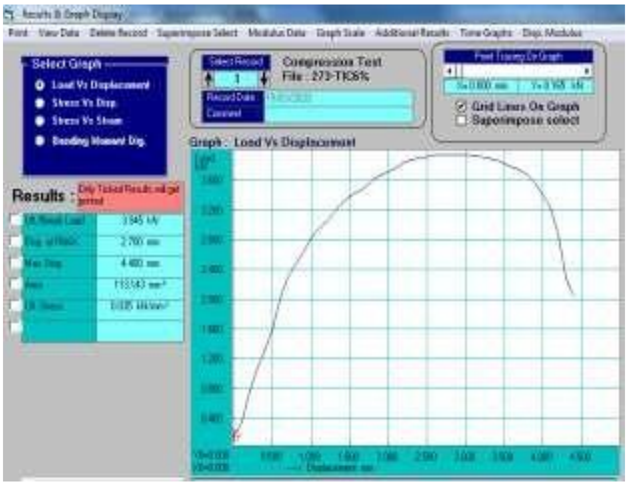

Figure 8. Compression strength of Mg with 8% TiC matrix

IV. CONCLUSIONS

In this article, Mg-TiC composites were successfully fabricated using powder metallurgy and evaluation of physical and mechanical behaviour are done. The experiment study was successfully observed on test ready composite specimen for the compaction of magnesium as matrix and titanium carbide as reinforcement by using the process of powder metallurgy. The following conclusion have been drawn.

1. Density of the composite was higher than the magnesium due to higher density of TiC particles.
2. An improved hardness of Mg-TiB2 composites due to high load bearing capacity was offered by reinforcement particle as 38.50 HV to 69.63 HV. The presence of titanium carbide particles offers higher resistance against to deformation which is leads to develop and increase in the hardness of fabricated Mg matrix composites.
3. The Mg/ 8 wt. % TiC composite shows a higher compression strength than alloy and another composites. The improvement in composite due to dislocation strengthening in the matrix.

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