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Comparison of Mechanical and Tribological Behaviour of Magnesium in Composition with Various Metal

R. Praveen Kumar, P. Periyasamy, S. Rangarajan, T. Sathish

Abstract*: *The metal matrix composition has wide attention industries due to it mechanical behaviour. These are various metals are considered in make composition. In this paper, we consider five metal in composition with magnesium to compare mechanical and tribological behaviour. The metals considered in the proposed study are Aluminum, silicon carbide, hybrid silicon carbide and aluminium oxide, TiC particle and hard tungsten carbide. Then there performance are analysed based on the strength, tensile strength, flexural strength, and micro-hardness. The performance analysis proves that the magnesium composition with hard tungsten carbide has better performance than the other metal. Ultimately the proposed study proves the betterment of the hard tungsten carbide reinforced magnesium for the metal matrix composition.

Index Terms*: *Metal Matrix Composition, Silicon Carbide Reinforce, Aluminium Oxide, Tic Particle, Hard Tungsten Carbide.

I. INTRODUCTION

Now days the metal matrix composites are mostly used in the industries for the purpose of enhancing strength and other mechanical properties [1]. In the initial stage the aluminium based metal matrix were tried for the most of automotive and aerospace components [2]. Later the ceramic reinforced aluminium were used for the components such as piston rings, brake rotors and cylinder liners in most of the automobiles. Those MMC provided acceptable strength and also provided valid mechanical and tribological properties. But these composites are heavy, so it made some issues in some other performance. Thus the researchers have engaged in research to find the better alternative for the aluminium metal [3]. Finally the researchers found that the magnesium was the most suitable alternative for aluminium for the preparation of MMC [4]. The magnesium is one the lightest metals and it also has density compare to the aluminium. The density of magnesium is only 30% of the density of aluminium [5]. Thus the magnesium was considered for most of the combination for MMC. The magnesium metal also has better strength, machinability, castability and damping capacity. Hence in shorter period the aluminium is replaced by the magnesium for the manufacturing of most of the automobile and aerospace components [6]. The magnesium is used for the production of industrial equipment and other components, for example, heat exchanger, ship container, pipelines, support structure for solar, geothermal energy component, and structural materials for construction building. The reinforced magnesium matrix composites have provided better tribological, chemical and mechanical properties. These matrix composites also provided better wear resistance, and mechanical strength [7]. In some research, it was found that the properties of reinforced magnesium matrix composites were varied based on the size, type, shape, spatial dispersion and weight fraction of the ceramic particles used for the reinforcement [8]. Hence the researchers have involved in the research to determine as suitable ceramic material for the reinforcement of magnesium [9]. The most used ceramic materials in the research were, SiC, TiC, B_4C, TiO_2, Si_3N_4, BN, Al_2O_3, WC, ZrB_2 and SiO_2 etc [10]. In this paper we have analysed the mechanical properties of some materials for the reinforcement of magnesium for metal matrix composite.

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* Correspondence Author
R. Praveen Kumar*, Department of Mechanical Engineering, St. Peter's Institute of Higher Education and Research, Avadi, Chennai, Tamil Nadu, India.
P. Periyasamy, Department of Mechanical Engineering, St.Peter's Institute of Higher Education and Research, Avadi, Chennai, Tamil Nadu, India.
S. Rangarajan, Department of Mechanical Engineering, St.Peter's Institute of Higher Education and Research, Avadi, Chennai, Tamil Nadu, India.
T. Sathish, Department of Mechanical Engineering, SMR East coast college of Engineering and Technology, Thanjavur, Tamil Nadu, India.

II. PROPERTIES OF CERAMIC MATERIALS

In the proposed paper, five types of ceramic materials are used for the reinforcement of magnesium for metal matrix composite. Among them four single material and a hybrid material is used, such as Aluminium oxide, silicon carbide, hybrid silicon carbide and aluminium oxide, TiC particle and hard tungsten carbide.

A. Properties of Aluminium Oxide

Aluminium Oxide is the chemical compound of aluminium and oxygen, it is also called as alumina. The natural occurrence of crystal form of alumina is corundum. Its properties are given in table 1.

Table 1: Properties of Aluminium Oxide

Chemical formula	Al_2O_3
Thermal Conductivity	30 $Wm^{-1}K^{-1}$
Molar Mass	101.960 $g{\cdot}mol^{-1}$
Density	3.987g/cm^3
Melting Point	2,072 °C

B. Properties of silicon carbide

Silicon carbide is a semiconductor material with the combination silicon and carbon. It is also called as carborundum. It is a rare material found naturally, moissanite is the only Silicon carbide material found naturally. The properties of silicon carbide is given in table 2.

Table 2: Properties of Silicon Carbide

Chemical formula	SiC
Molar Mass	40.096 $g{\cdot}mol^{-1}$
Density	3.16g/cm^3
Melting Point	2,830 °C

C. Properties of Titanium carbide

The titanium carbide are hard and refractory ceramic material. Khamrabaevite is a rare material and it is the only naturally available titanium carbide. The properties of titanium carbide is given in table 3.

Table 3: Properties of Titanium carbide

Chemical formula	TiC
Molar Mass	59.89 $g{\cdot}mol^{-1}$
Density	4.93 g/cm^3
Melting Point	3,160 °C

D. Properties of tungsten carbide

The tungsten carbide is also a hard material, it the composition of equal part of both tungsten and carbon. The stiffness of tungsten carbide is twice as compared to the steel. The properties of tungsten carbide is given in table 4.

Table 4: Properties of Tungsten carbide

Chemical formula	WC
Molar Mass	195.85 $g{\cdot}mol^{-1}$
Density	15.63 g/cm^3
Melting Point	2,785–2,830 °C

E. Properties of Magnesium

Magnesium is a light weight metal, and it is a chemical component. The properties of magnesium is given in table 5.

Table 5: Properties of Magnesium

Chemical formula	Mg
Thermal Conductivity	156 W/(m·K)
Density	1.738 g/cm^3
Melting Point	650 °C

III. Experimental Procedure

In the proposed study the AZ31B magnesium alloy is consider as matrix material for the MMC. Then the reinforce materials such as Al2O3, SiC, Al2O3+SiC, TiC, and WC are considered in the volume of 40 to 60 microns. The properties of these material are given in the table 1 to table 5. The matrix and reinforce material is mixed in the proportion of 100%:0%, 95%:5%, 90%:10%, and 85%:15%. The experimental procedure is as follows;

1. Initially the magnesium is molten, then the reinforce materials are powdered.
2. Then both the materials are mixed and the molten mixture in maintained at the temperature of 6500C.
3. Then for four minutes the mixture melt is stirred constantly at 400rpm.
4. Then the separate mixture is poured to the separate preheated mould.
5. Then the prepared composite is undergone various tests

IV. Testing

The prepared composite material is tested to analysis the mechanical and tribological behaviour. Hence composite is subjected to various testes such as microstructure characterization, flexural test, tensile and micro hardness test. The micro hardness test is conducted using Vicker's hardness tester at an average weight of 0.5kgf. The specified weight was applied for eight seconds at three locations. The computerised universal tensile machine was used for the tensile and flexural test. The tensile strength was analysed at the strain rate of 1mm and 2.5mm per minute. The dimension of tensile element of the computerised universal tensile machine is given in fig 1.

Fig 1. Tensile element dimension

The pin on disc apparatus is used to analysis the wear properties of the composite. The wear test was taken at 1500m sliding distance and 1m/s sliding velocity. The normal force for the wear test is varied as 10N, 20N and 30N.

V. Performance Comparison

The major intension of this paper is to compare the performance of various reinforce material for the composition of Mg matrix. The performance is analysed based on the micro hardness, tensile strength, yield strength. The performance of various material at different proportion of mix is given in table 6.

Table 6: micro hardness comparison of various reinforce material

Reinforce Material	Proportion (Mg:Reinforce)			
	100%:0%	95%:5%	90%:10%	85%:15%
Al_2O_3	56	53	59	63
SiC	56	58	62	66
Al_2O_3+SiC	56	62	67	71
TiC	56	62	66	70
WC	56	63	70	75

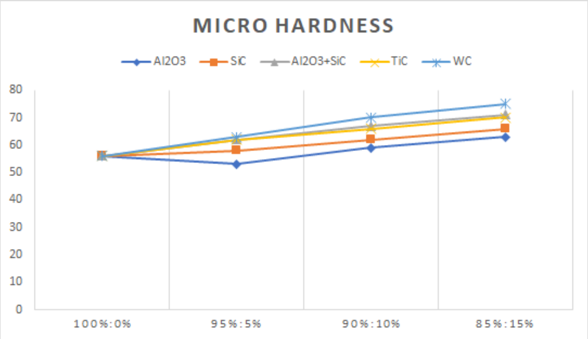
Table 7: tensile strength comparison of various reinforce material

Reinforce Material	Proportion (Mg:Reinforce)			
	100%:0%	95%:5%	90%:10%	85%:15%
Al_2O_3	100	105	121	130
SiC	100	108	125	132
Al_2O_3+SiC	100	115	137	148
TiC	100	116	138	147
WC	100	120	140	150

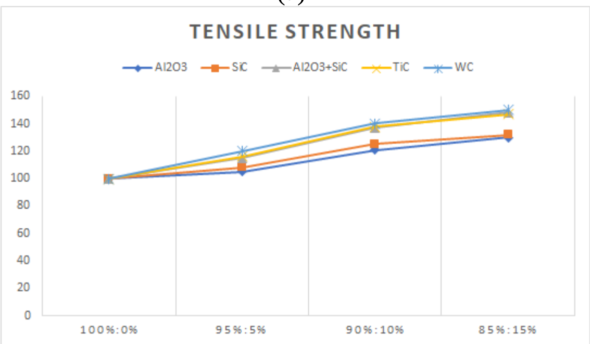
Table 8: yield strength comparison of various reinforce material

Reinforce Material	Proportion (Mg:Reinforce)			
	100%:0%	95%:5%	90%:10%	85%:15%
Al_2O_3	80	77	96	111
SiC	80	78	98	115
Al_2O_3+SiC	80	89	107	126
TiC	80	90	108	129
WC	80	90	110	130

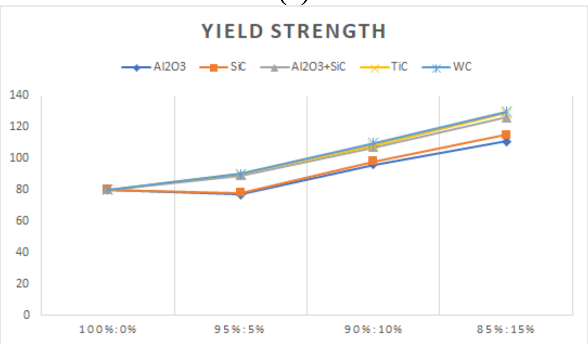
The table 6, table 7 and table 8 gives the comparison of hardness, tensile and yield strength of various composites respectively. The comparison table shows the variation of performance in terms of strength based on the property of reinforce material. The graphical illustration of these comparison is given in fig 2.



(a)



(b)



(c)

Fig 2. Comparison of various Mg matrix composites; (a) hardness, (b) tensile strength, (c) yield strength

The comparison chats given in the fig 2 proves that the performance of WC reinforced Mg matrix composite provided better performance that the other composite. Thus for this study we can conclude that the Tungsten carbide become best material for the reinforce of Mg matrix.

VI. CONCLUSION

The proposed study aimed to analysis the performance of the various reinforce material for the magnesium matrix composite. In this analysis five different materials are considered for the performance evaluation, such as Al2O3, SiC, A12O3+SiC, TiC, and WC. The performance of these materials are analysed based on an experiment, in which reinforce Mg composite is prepared in molten condition. The composition is made at for different proportion such as 0%, 5%, 10% and 15% of reinforce material and rest is magnesium. After preparation of composite, their properties are analysed based on hardness, tensile and yield strength. The performance analysis clearly showed that the performance of WC reinforced Mg matrix composite is better than all other composite. Thus from this study, we suggest that the WC with Mg become the most suitable materials for the MMC of low weight metal.

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