wjert, 2016, Vol. 2, Issue 6, 49 -57 Research Article ISSN 2454-695X

World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 3.419

TRIBOLOGICAL INVESTIGATION ON MICRO TITANIUM AND B_4C REINFORCED AL-Mg ALLOY USED IN AUTOMOTIVE APPLICATIONS.

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Article Received on 24/09/2016 Article Revised on 14/10/2016 Article Accepted on 03/11/2016

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ABSTRACT

Today's interest in Aluminium-Magnesium alloys for automotive applications is based on the combination of high strength properties and low density.[1] For this reason Aluminium-Magnesium alloys are very attractive as structural materials in all applications where weight savings are of great concern. In automotive applications weight reduction will improve the performance of a vehicle by reducing the rolling resistance and energy of acceleration, thus reducing the fuel consumption and moreover a reduction of the greenhouse gas CO2 can be achieved. The use of pure Aluminium-Magnesium is rare due to its volatility at high temperatures and it is extremely corrosive in wet environments. Therefore the use of Aluminium-Magnesium alloys when designing aerospace and automotive parts is critical. Specific alloys are better for certain applications and often also need a coating to provide the longest life of the part[2 -3] Hence in our present study we have developed a new hybrid composite by mixing of Aluminium-Magnesium alloy, Micro Titanium and Boron Carbide powders using a Stir- Casting technique at different weight fractions, i.e. addition of Boron Carbide (1%, 2%, 3%) and Micro Titanium (5%). After production, the machining of the hybrid metal matrix composites is carried out as per ASTM standards. This review paper is aimed to summarize tribological properties and to study the effect of reinforcements on Aluminium-Magnesium alloy. This has resulted in the improvement in the properties of hybrid composites.

KEYWORDS: Aluminium-Magnesium alloys, light weight, strength, stir-casting, Ti, B_4C, Tribological properties.

1. INTRODUCTION

Magnesium and its alloys have low density (1.74 gm /cc), high specific mechanical properties and excellent damping characteristics. Due to these reasons, they exhibit tremendous application potential in automobile and aerospace industries, where weight reduction is critical.[4] However, the inherent poor mechanical characteristics such as low elastic modulus, strength and ductility and poor high temperature stability of magnesium and its alloys restrict its extensive utilization in critical engineering applications. In this regard, magnesium metal matrix composites (Mg-MMCs) reinforced with ceramic elements in the form of fibres/particulates exhibit superior elevated temperature strength alongside improved elastic modulus, hardness and wear resistance.[5-6] However, the incorporation of such ceramic reinforcements in pure Mg and its alloys often results in brittleness. Recently, high strength, high modulus metallic elements like Ti, Ni, and Cu were added to improve the mechanical properties of pure Mg and its alloys. When 5 wt. % Ti which is insoluble in Mg was added to pure Mg, an overall improvement was reported. When soluble metallic elements like Ni and Cu (with limited solubility in Mg) were added to pure Mg, significant strength improvement was reported, but with poor ductility. On the other hand, an overall enhancement in strength and ductility was reported when nano-sized ceramic reinforcements[7] (such as Al2O3, ZrO2 or ZnO) were added to Mg and its alloys. Recent works have shown the positive influence of hybrid reinforcement (prepared by mechanical alloying) on the mechanical response of Mg materials.

In our recent work on the influence of hybrid particulate reinforcement addition (micronsized metallic Ti and B_4C) on the Mg, we identified that the method of hybrid reinforcement addition also played a major role in determining the Tribological response of the Mg-composites (in addition to the properties of the individual reinforcements and the strengthening mechanisms).

In the present work, micron-sized Ti particulates are added with varying weight fractions of B_4C particulates and this hybrid (5wt. % Micro-Ti, 1%, 2%, & 3% wt of B_4C) mixture are used as reinforcements in pure AL-Mg. The results of mechanical properties were increased compared to base matrix.

1I. MATERIALS AND EXPERIMENTAL DETAILS

AL-Mg is one of the alloy in which Magnesium is the major alloying element usually it is in combination with Manganese. Alloy of this type have the highest strength among all. This kind of Alloy possesses highest mechanical strength when heat treated.

AL-Mg based metal matrix composites (AMCs) are of lightweight high performance material systems. Among the several types of aluminium alloy being used, AL-Mg is extensively used in marine and aerospace applications because of their superior corrosion resistance, excellent formability and good welding characteristics.[8-9] AL-Mg is broadly used for the construction of ship buildings/structures, however due to low strength and poor wear resistance the application of this material is limited. The addition of reinforcement to aluminium-magnesium matrix drastically alters mechanical properties. The reinforcement could be in the form of continuous/discontinuous fibers, whiskers or particulates. The hybrid composites have been prepared by incorporating different types of fibers into a single matrix. Due to two or more fibers in the hybrid composite, the advantages of one type of fiber could complement with what are lacking in the other. The properties of hybrid composite primarily depend upon fiber content, length of individual fibers, orientation, extent of inter- mingling of fibers, fiber to matrix bonding and arrangement of the fibers.

AL-Mg alloy is one type wrought Aluminium alloy, containing Magnesium as a major alloying element. The density of AL-Mg is taken as 3.9 g/cm^3 theoretically. The main advantage of introducing reinforcement material to base metal or alloy is to increase the properties there by enhancing the mechanical properties of composites. In the current research work Boron Carbide and Titanium particulates of size 100 microns (µm) were used as reinforcement materials. With the automotive industry constantly striving to reduce fuel consumption as well to lower emissions, there are two broad approaches that could be followed to attain these objectives. Either, the combustion process and other related aspects could be optimized for better fuel efficiency or the mass of the vehicle could be reduced as much as possible within limits. For the reduction in vehicle mass approach (by replacing heavier steel components with lightweight materials such as titanium), a fundamental total life cost model for energy reduction is presented which relates vehicle mass to energy consumption and hence emissions.

Boron carbide (B_4C) particulates are promising candidates as reinforcement for light weight metal matrix composites. B_4C has a lower specific gravity than either Al or SiC (2.52 g/cm ^{3} compared with 2.7 for Al and 3.2 for SiC). It has a similar thermal expansion coefficient, higher specific stiffness and strength as compared to SiC. Increased application of chills in Al alloy B_4C composites and their mechanical properties have been studied. In the present investigation, we have prepared B_4C particulate-reinforced Al-Mg matrix composites using stir casting technique. The purpose of this paper is to fabricate and characterize the Hardness and Wear properties of the resulting composites.[10]

Titanium is the seventh most abundant metal and the fourth most abundant structural metal in earth's crust behind aluminium, iron and magnesium. Titanium and its alloys are considered as alternatives in many engineering applications due to their superior properties such as retained strength at elevated temperatures, high chemical inertness and resistance to oxidation. Titanium has traditionally been utilized as a lightweight, very strong and exceedingly corrosion resistant material in the automotive and aerospace industry.[11]

Properties of Al-Mg

Table 1: Properties of Aluminium-Magnesium.

Density (g/cm3)	Modulus of elasticity (GPa)	Poisson's ratio	Tensile strength (MPa)	Fracture toughness (MPa√m)	Coefficient of thermal expansion (10−6(°C)−1)	Thermal conductivity (W/m-k)
3.9	380	0.22	282 - 551	4.2 - 5.9	7.4	39

Preparation of AL-Mg / B_4C / Ti hybrid Composite.

There are many techniques used to manufacture Metal Matrix Composites (MMCs), but Stir-Casting and Powder Metallurgy are extensively used to manufacture the composites. The powder metallurgy technique is more cost effective than the casting methods, but it cannot be used for the production of complex shapes. Compared with Powder Metallurgy, Stir-Casting[12] which involves stirring of the particles into melt has some advantages: better matrix bonding, easier control of matrix structure, low-cost, simplicity, a nearer net shape can be produced and there is a wide selection of materials that can be used in this method. The fabrication of AL-Mg hybrid composite used in this study was carried out by using Stir Casting method. In this, firstly AL-Mg alloy was placed in a clay graphite crucible. It was then melted in a resistance heated muffle furnace to the desired temperature of 720°c. In the meantime B_4C and Ti powders of 100 mesh size were heated in another crucible to a temperature of 250°C to remove moisture, and the die was pre heated to a temperature of 300°c. Then the Boron Carbide and Micro Titanium powders were mixed in into the molten metal. The crucible was covered with flux and degassing agents to improve the quality of Aluminium composite casting. The mixture was stirred continuously by using mechanical stirrer for about 10-15 minutes at an impeller speed 300 rpm. The melt temperature was maintained at 730°c during addition of the particles. The molten metal was then poured into the preheated die to caste plates.

Fig 1 : stir casting equipment.

III. RESULTS AND DISCUSSION

Hardness Test: Hardness tests were carried out on the Hybrid composite material specimens on a Brinell hardness testing machine. A define force is mechanically applied on the specimen for about 30 seconds.

AMCs are tested using the steel ball indenter of 5mm Diameter (D) under a load 250Kg (P) into the specimen for 30s and the mean diameter (d) of the impression left on the surface after the removal of the load is measured. The Brinell Hardness Number (BHN) is then calculated using the equations (1) and (2).

$$\mathrm{BHN} = \frac{2P}{\pi D(D - \sqrt{(D^2 - d^2)})}$$

Where,

P=Load applied in kg=100kg

D=Diameter of ball indenter

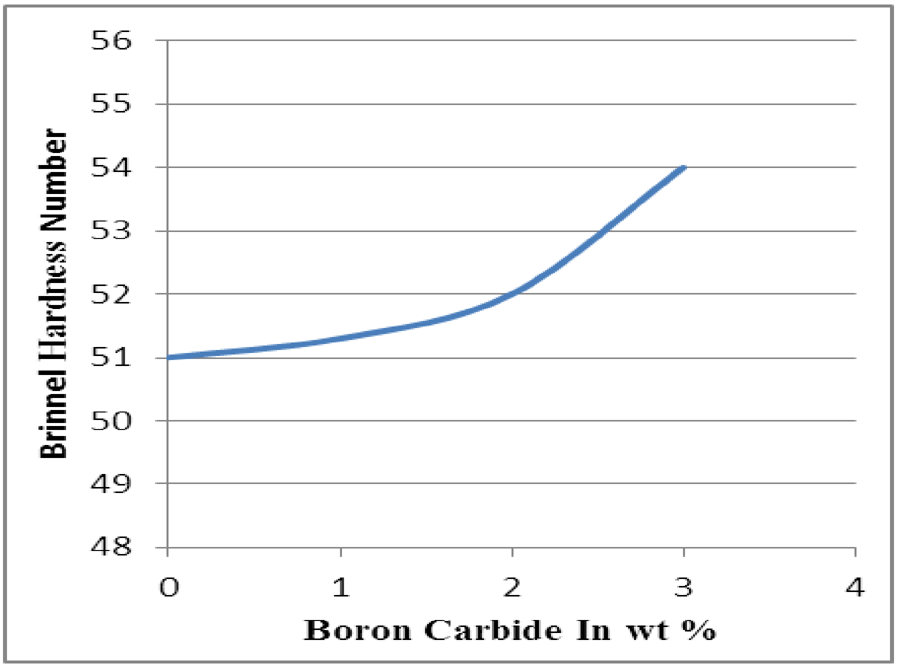
d=Average diameter indentation made on the specimen

Table 1: Hardness number for different composition.

Slno	Al-Mg %	Titanium %	boron carbide %	Brinell hardness number
1	100	0	0	51
2	94	5	1	51.3
3	93	5	2	52
4	92	5	3	54

This **S**hows variation of Hardness of AL-Mg alloy matrix with wt. % of B_4C particulate reinforced composite. It can be seen that by adding wt % of reinforcement particulates Hardness strength of the AL-Mg alloy increased there is an increase in the hardness of Al-Mg with addition of 1, 2 and 3wt % of B_4C particulate.

The graph shows the variation of hardness of Al-Mg alloy with B_4C reinforcement particulate. It can be concluded that the addition of wt. % of B_4C particulate results in increasing the hardness. The



Graph 1: Comparison of % of Boron carbide Vs Hardness number.

hardness of a soft material such as aluminium-magnesium matrix is increased when it is reinforced with a hard particulate i.e., B_4C.B_4C is the third hardest material in the world and hence as the percentage of B_4C added it Increases the hardness Such an increase in micro hardness values can be attributed to the higher constraint offered by the hard reinforcements and other intermetallic phases towards localized matrix deformation during indentation of the base matrix and also increases for the addition of higher percent of B_4C.

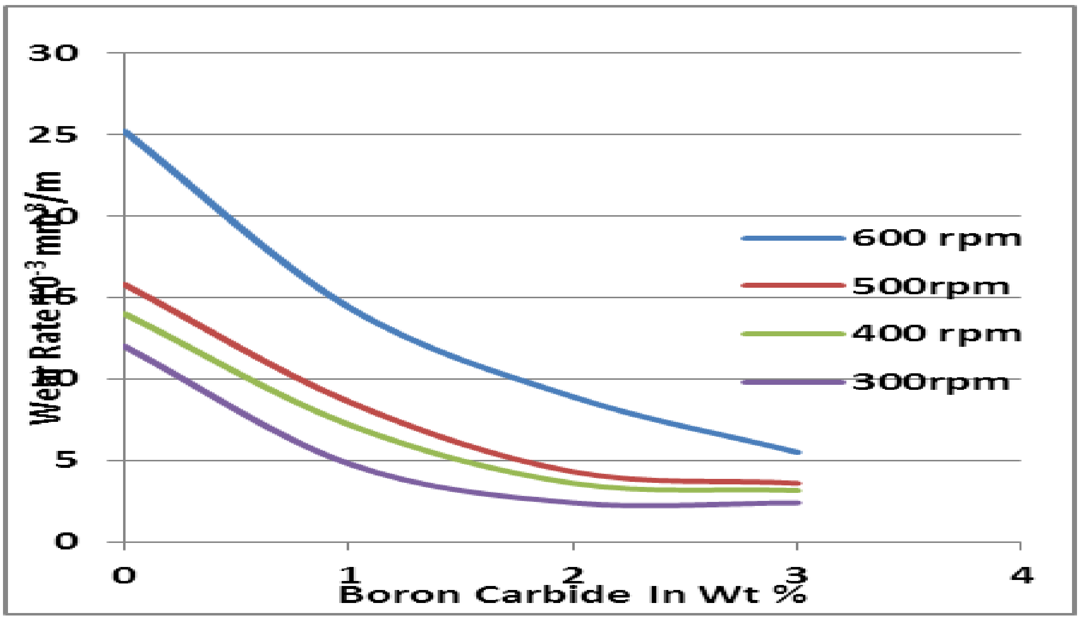
Wear Test- A pin on disc apparatus is used to investigate the dry sliding wear characteristics of the Aluminium-Magnesium Hybrid composites under different speed conditions. The applied speed is varied from 300, 400, 500, and 600 rpm with respective Loads and sliding distance. Wear specimens of 6mm diameter and35mm height were machined from the cast samples and polished metallographically for the wear test. Before each test, the disc surface was polished with grade 220 SiC paper to a Central Line Average (CLA) value of 2µm. A digital weighing balance machine is used for determining the weight of the pins before and after the wear test and the corresponding Volume and Mass wear is calculated.

The wear rate is calculated from the equation

$$Wear\ Rate(W) = \frac{M}{\rho T}$$

Table 2: Comparison of Wear Rate for different composition.

Sl no	Al-Mg+TI (%)	boron carbide (%)	Wear rate for different speeds (*10^{-3} mm^3/m)			
			300 (Rpm)	400 (Rpm)	500 (Rpm)	600 (Rpm)
1	100	0	12	14	15.8	25.2
2	94+5%Ti	1	4.8	7.2	8.6	14.4
3	93+5%TI	2	2.4	3.6	4.3	8.9
4	92+%%Ti	3	2.4	3.15	3.6	5.5



Graph 2: Comparison of % of Boron carbide Vs Wear Rate.

The above graph 2 depicts wear rate of Al-Mg, Ti and B_4C reinforced hybrid composites under different B_4C Composition (1% 2% and 3%) with Ti ratio kept constant at 5% and the highest wear was exhibited at 0% B_4C.

Least wear rate was at 3% of B_4C. From graph it is clear that with increase in B_4C content the wear rate decreases. The addition of reinforcement to Al-Mg matrix enhances the effective bonding between reinforcements and matrix by allowing the larger interfacial area of contact, and there by increasing the wear resistance of the hybrid composite. So, the wear rate has reduced by using the reinforcements in Aluminium-Magnesium hybrid MMC.

At definite proportions the AMCs exhibits better wear resistance compared to base alloy. It is observed from the results that the wear rate of the composites is reduced with the increase in reinforcement content at certain level and also it is seen that as the load increases the wear rate also increases among AMCs.

Such a reduction in Wear values can be attributed to the higher constraint offered by the hard reinforcements and other intermetallic phases towards localized matrix deformation during Wear of the base matrix and also Decreases for the addition of higher percent of B_4C.

IV. CONCLUSION

The important conclusion on the Evaluation of AL-Mg MMC reinforced with Micro Ti and B_4C particulates are as follows.

Stir casting process were used in the preparation of AL-Mg hybrid composites containing varying % of Micro Ti and B_4C particulates as reinforcement. And the test specimens were prepared according to ASTM standards.

The hardness of Al-Mg hybrid composites increased with the addition of B_4C particulates in Al-Mg base alloy. Because B_4C is the third hardest metal after diamond and hence as the % of reinforcement is increased the hardness also increases.

The wear result of Al-Mg hybrid composites increased with the increase in speeds hence wear is maximum for higher speed. The wear rate for a particular speed was reduced as the percentage of the reinforcement was increased. Hence more the reinforcement added better will be the wear rate.

From this Research work it can be concluded that the Micro Titanium and B_4C proves to be a good reinforcement combination with AL-Mg matrix phase. And stir casting techniques were used effectively for uniform dispersion of less denser reinforcements eg: B_4C, Ti.

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