Evaluation of Properties of Aluminum-Alumina-Boron Carbide MMC

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***Abstract* - Aluminium metal matrix composites are significantly important in the various demanding fields of medicine and engineering like aerospace, defense, automobiles, dental and consumer goods. The industrial need of good materials with light weight, excellent properties and low cost demanded the scientists to research on composite materials. Among the MMCs, aluminium matrix composites (AMMCs) sought over other conventional materials because of their high strength to weight ratio, high wear resistance and low economic. These AMMCs offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. The Addition of various reinforcements such as Al_2O_3, B_4C to aluminum matrix will enhance the mechanical and tribological properties. This paper is focus on the different combinations of Al_2O_3, B_4C with Al 6061 and usage of reinforced materials as a reinforcing agent in different Aluminium matrix alloys in the processing of aluminium metal matrix composites along with its properties.**

Keywords — Aluminium, Alumina-Boran Carbide, MMC.

I. INTRODUCTION

Now-a-days, aluminium Metal Matrix Composites are under serious consideration for a large number of structural applications such as those in the aeronautical/aero-space, defense and sports industries because of their superior properties. The excellent mechanical properties and the comparatively less cost make them as an attractive option. A large number of fabrication techniques are currently used to manufacture the aluminum MMC materials according to the type of reinforcement used like stir casting. It has been observed a rapid increasing utilization of aluminum alloys, particularly in the automobile industries, due to low weight, density, coefficient of thermal expansion, high strength, and wear resistance [1]. The various reinforcements used are Silicon Carbide, Aluminium Oxide, Titanium carbide, Boron Carbide [2] SiC reinforcement increases the tensile strength [3], hardness, density and wear resistance of Al and its alloys.Al_2O_3 reinforcement has good compressive strength and wear resistance [4]. B_4C is one of hardest known elements because of its high elastic modulus and fracture toughness. The stir casting process as shown in fig.1, the particulate reinforcements are distributed by mechanical stirring in the molten matrix. Alumina particles are introduced into aluminium melt by stirring molten aluminium alloys containing the ceramic powders [3].

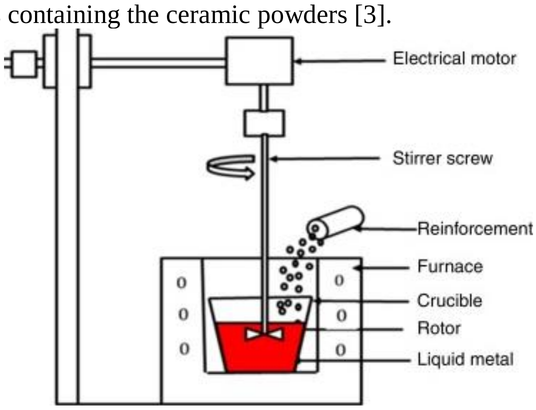

Fig 1: Stir casting process [3]

II. FABRICATION OF ALUMINUM MMC AND EXPERIMENTAL DESIGN

Al 6061 is an aluminium alloy, 6061 is a precipitation-hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded. It is one of the most common alloys of aluminum for general-purpose use.

Aluminum oxide (Al_2O_3) is a chemical compound of aluminum and oxygen. It is commonly called alumina [5]. Al_2O_3 0is an electrical insulator but has a relatively high thermal conductivity like ceramic material. Its hardness makes it suitable for use as an abrasive and as a cutting tool.

Table 1: Properties of 6061 Aluminium alloy

Property	Value
Density (ρ)	2.70 g/cm^3
Young's modulus (E)	68.9 GPa (9,990 ksi)
Tensile strength (σ_t)	124–290 MPa
Poisson's ratio (ν)	0.33
Melting temperature (T_m)	585 °C (1,085 °F)
Thermal conductivity (k)	151-202 W/m*K

Boron carbide (B_4C)

Boron carbide is one of the mainly hopeful ceramic materials due to its attractive properties, including high strength, low density, exceptionally high hardness (the third hardest material after diamond and boron nitride), good chemical stability and neutron combination capability [6] .Boron carbide has stability to ionizing radiation. Its hardiness is almost equal to diamond.

Table 2: properties of boron carbide and its properties

Property	Value
Density (g. cm^{-3})	2.52
Melting Point (^0C)	2445
Young's Modulus (GPa)	450 - 470
Electrical Conductivity (at 25 ^0C) (S)	140
Thermal Conductivity (at 25 °C) (W/m. K)	30 - 42

Al 6061 based composites were prepared using stir casting process shown in Fig.2. A coke feed melting furnace with graphite crucible was used for melting, Al6061 alloy was melted in crucible by heating in a melting furnace [7].

Fig 2: Stir casting setup.

Composite is prepared by stir casting technique. Stir-casting technique is currently the simplest and most commercial method of production of MMCs [8]. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this technique aluminium alloy 6061 [9] ingot pieces will be heated in the furnace to its molten state. When the temperature is maintained between 700-750C^0, a vortex will be created using a mechanical stirrer. Reinforcement particles will be preheated in the furnace. The temperature of the furnace is maintained between 700-750C^0 [10]. Preheated particles are added to the melt when the stirring is in progress. Stirring is continued for about 15 min after addition of particles for uniform distribution in the melt. Castings are prepared by pouring the melt into preheated moulds of cylindrical shapes

Table 3: Percentage values of samples to be casted for 250gm of work piece

Sample No. (%)	Sample1	Sample2	Sample3	Sample4
Al 6061	100	96	94	92
Al_2O_3	0	2	4	6
B_4C	0	2	2	2

III. RESULTS AND DISCUSSION

A. Tensile Test

A Figure 3 showing the effect of percentage increase in aluminium oxide and boron carbide on the tensile strength of the composites [ASTM B557M]. It was observed that as the aluminium oxide content increased from 0 to 6%, the tensile strength was found to be higher value i.e.144.272 N/mm_2, by the addition of 6% of aluminium oxide and 2% boron carbide. The enhancement of tensile strength with incorporation of particulate fillers can be explained as follows. With the presence of hard particulates, the load on the matrix gets transferred to the reinforcement elements thereby increasing the load bearing capability of composites.

With increase in volume fraction of the filler materials, more loads get transferred to reinforcement which leads to increase in tensile strength.

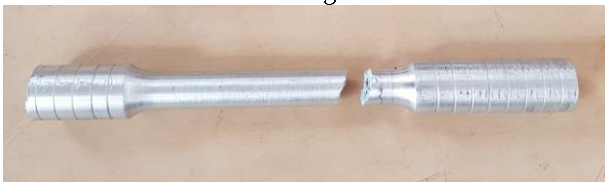

Fig 3: Tensile tested sample

Moreover, with the presence of ceramics like boron carbide, there is a restriction to the plastic flow as a result of dispersion of these hard particles in the matrix, thereby providing enhanced tensile strength in the composite.

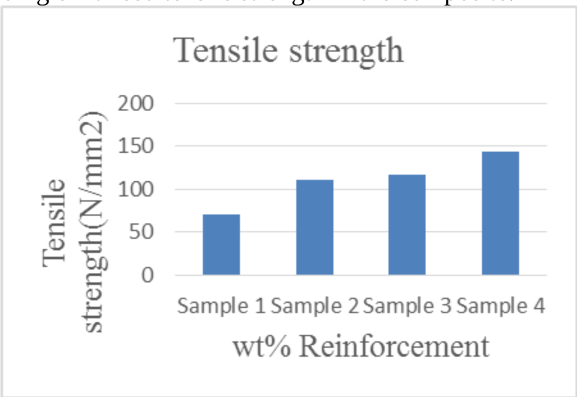

Fig 4: Tensile strength v/s wt% Reinforcement graph

B. Hardness

Rockwell Hardness which is described as a measure of a materials resistance to surface indentation may be thought as a function of the stress required to produce some specific types of surface deformation. Fig.4 is a graph showing the effect of percentage increase of aluminium oxide and a constant percentage of boron carbide on the hardness of the composites. It is evident that as the percentage of aluminium oxide is increased from 2% to 6% by weight, the hardness value increases with the addition of aluminium oxide and boron carbide in Al6061. The maximum hardness value is found at 6% aluminium oxide and 2% boron carbide. The increased hardness is attributed to the presence of aluminum oxide and boron carbide particles which acts as barriers to the movement of dislocation within the matrix.

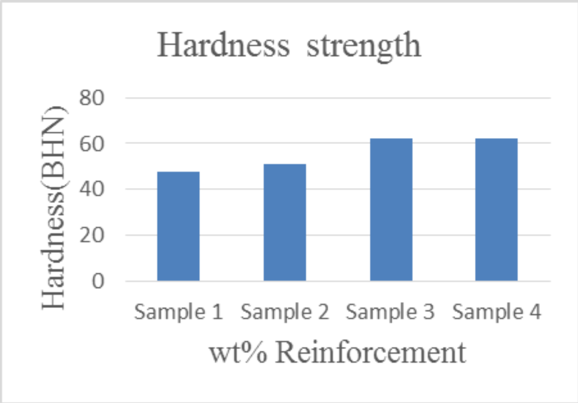

Fig 5: % Reinforcement v/s hardness graph

Fig5 is a graph showing the effect of percentage increase in aluminium oxide and boron carbide on the tensile strength of the composites. It was observed that as the aluminium oxide content increased from 0 to 6%, the weight loss was found to be lowest value i.e. 0.02625gmsby the addition of 6% of aluminium oxide and 2% boron carbide. The enhancement of wear strength with incorporation of particulate fillers can be explained as follows. With the presence of hard particulates, the load on the matrix gets transferred to the reinforcement elements thereby increasing the wear resistance of composites.

C. Wear Test

It observed that as the aluminium oxide content increased from 0 to 6%, the weight loss was found to be lowest value i.e. 0.02625gmsby the addition of 6% of aluminium oxide and 2% boron carbide. The enhancement of wear strength with incorporation of particulate fillers can be explained as follows. With the presence of hard particulates, the load on the matrix gets transferred to the reinforcement elements thereby increasing the wear resistance of composites.

IV. CONCLUSION

The effect of incorporation of aluminum oxide and boron carbide particles on mechanical properties of Al 6061 has been investigated. Based on the results the conclusions drawn are that aluminum based metal matrix composites have been successfully fabricated by stir casting technique with fairly uniform distribution of aluminium oxide and boron carbide particulates, addition of aluminum oxide and boron carbide particles increases the hardness of the matrix alloy, significant improvement in the tensile properties, wear properties and hardness of the material with the incorporation of aluminum oxide and boron carbide particles. The test results ensure that as the B_4C percentage is increased the mechanical properties of this composition is also increasing positively. The Al6061 alloy reinforced with 6% aluminum oxide and 2% boron carbide shows a significant improvement in the hardness, tensile strength compared to other weight percent composition.

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