Experimental Analysis of Mechanical Properties of Aluminium Hybrid Metal Matrix Composites

A. Basithrahman
PG Scholar
Department of Aeronautical Engineering
Nehru Institute of Engineering and Technology,
Coimbatore, Tamilnadu.

R. Arravind
Assistant professor
Department of Aeronautical Engineering
Nehru Institute of Engineering and Technology,
Coimbatore, Tamilnadu.

***Abstract*—Aluminium hybrid metal matrix composites have been widely used in automobile, aerospace and structural application because of their good tribological and mechanical properties. This work deals with the preparation of composites and evaluation of mechanical properties by introducing micro size reinforcement particle in the aluminium alloy. The reinforcement of Al alloy hybrid metal matrix composite with Al_2O_3, B_4C, and SiC particles are produced by stir casting. After heat treatment process the casting materials are machined as per ASTM standard size. The mechanical properties such as tensile, hardness, impact test were conducted at room temperature. The mechanical properties are increased by increasing the weight percentage of reinforcement particles.**

Keywords: Hybrid metal matrix composite, Aluminium, stir casting method, mechanical properties, Al_2O_3, B_4C, SiC.

I. INTRODUCTION

Aluminium alloys are an important engineering material for mechanical and wear applications. Because it is have low density, improved machinability, high specific strength, superior wear resistance, and low thermal conductivity. Aluminium alloys are mostly used in automobile, aerospace, marine and mineral processing industries. Hard ceramic phase to a relatively soft matrix alloy, commonly aluminium, improves the strength, creep performance, and wear resistance of the alloy [1, 2]. Aluminum alloy 6061-T6 is widely utilized in aircraft, defence, automobiles and marine areas due to its good strength, light weight and better corrosion properties. But, it exhibits inferior tribological properties in extensive usage [3, 4]. Additions of reinforcement such as sic and Al_2O_3 ceramic particles in the aluminium based composite becomes brittle nature [5]. As a result of these the aluminium composite materials are used in mechanical components such as gears, cams, wheels, impellers, brakes, clutches and bushes and bearings [6, 7]. Many techniques were developed for producing particulate reinforced MMCs, such as powder metallurgy [8], in situ [9], and squeeze casting [10]. From all the above three methods, stir casting technique is the simplest and the most economical process for fabricating particulate reinforced MMCs [11]. Pre-aging at various retrogression temperatures improves the tensile properties, electrical resistivity and hardness of the AA7075 aluminium alloy [12]. The hardness of aged AA7075 alloy increases [13]. The hardness of the specimen measured before the wear test by Rockwell hardness test machine at room temperatures. The magnitude of hardness increases by increasing volume fractions of SiC and B_4C reinforcement particles [14]. Aluminium alloy 6061-T6 reinforced with hybrid composites [(SiC + Gr) and (SiC + Al_2O_3)] using friction stir casting techniques. The wear properties of these HMMC are increased. Presence of hard ceramic particles like sic and Al_2O_3 increases micro-hardness value [15]. The wear resistance of the al7075-sic-b4c composites is increased by increasing sic ceramic particles. The coefficient of friction the specimen decreases with increasing volume content of reinforcements [16]. The mechanical properties such as tensile strength, flexural strength and hardness of the aluminium alloys are increased by adding alumina Al_2O_3 and boron carbide B_4C [17]. AA6061- fly ash composites in T6 condition have exhibited better wear behavior compared to the matrix alloy at room temperatures. This is due to the uniform distribution of hard fly ash particles [18].AA6061 alloy reinforced with SiC and B_4C have better tribological properties. Hybrid composite with different volume fraction (5 to 15 wt. %) has marked effect on wear rate. By increasing the volume fraction of reinforcements the wear rate and coefficient of friction decreases [19]. The mechanical and wear properties of AA7075 reinforced with 0-8 wt. % of the Al_2O_3 and 5 wt. % of graphite particles. From this composition the ultimate tensile strength increases with increasing Al_2O_3 particles. The mechanical strength increased by adding Al_2O_3 particle and decreased due to addition of graphite particle [20].

In this work, an attempt has been made to prepare Al6061 alloy composites by adding Al_2O_3, B_4C and SiC reinforcement particles into matrix by using a stir casting methodology. The Al_2O_3 weight percentage is varied (3, 6, 9, and 12 wt. %) and B_4C and SiC are kept at constant(5 wt. %). The objective of the present investigation is to determine the mechanical properties of the HMMC by adding hard ceramic particles into the aluminum alloy.

II. EXPERIMENTAL PROCEDURE

A. *Material composition*

In the present investigation Al_2O_3, B_4C and SiC are used as the reinforcement particles and aluminium alloy 6061 is used as a base material. The composition of AA6061 is shown in table1. AA6061 is chosen because it is containing magnesium and silicon as its major alloying elements. It has good mechanical properties and exhibits good weldability. It is one of the most common alloys of aluminium for general purpose use. Four different weight percentages of Al_2O_3 (3% to 12%) and fixed weight percentage of B_4C and SiC (5%) were used in the experiments.

TABLE I. COMPOSITION OF ALUMINIUM ALLOY 6061

Element	Si	Fe	Cu	Mn	Mg
Weight %	0.514	0.23	0.161	0.071	0.96
Element	Ni	Zn	Ti	Cr	Al
Weight %	0.010	0.015	0.031	0.103	Bal.

B. *Preparation of composites*

Stir casting method is used for the manufacturing of metal matrix composites. This method helps to get uniform distribution of reinforcement in the matrix material by creating the vortex condition in molten metal. The AA6061 is the base material and Al_2O_3, SiC, and B_4C are used as the reinforcement particles. The 1kg of aluminium alloy was taken in to the graphite crucible and it is heated in the high temperature electric furnace. The aluminium alloy is heated in to above its melting temperature (650^o) for one hour. In preheating furnace the reinforcement particles were preheated in the temperature range of 450-550^{o}c for removing moisture in the particles. The mechanical stirrer is used to stir the semisolid molten material. The mild steel mechanical stirrer is used and the stirring speed is maintained at 550rpm to 1100rpm. During the vortex formation stage the preheated reinforcements are added slowly. After adding the reinforcement particles the stirring speed is increased and stirring duration of 5min is maintained. The melt was then solidified in the preheated mould and the casting materials are obtained. The 6061 hybrid composites of different volume fractions of reinforcement materials were produced.

C. *Heat treatment process*

Cast and composite ingots were T6 heat treated in a muffle furnace to an accuracy of $\pm 1^0$C for 8 hours at 529^{0}C, followed by water quenching and then aged at 159^{0}C for 8 hours. After heat treatment process the casting materials are machined to testing for required dimensions.

III. TESTING METHODS

Experiments on mechanical properties including hardness, impact test and tensile test are conducted for the composite specimen. Test procedures are briefly discussed in following sections.

A. *Hardness test*

Brinell hardness testing was performed for measuring the hardness of the specimen. The test specimens were prepared as per ASTM E-18standard size. The 1/16 ball indenter was used for the testing. The 100Kgf load is applied to the specimens. The test was carried out at five different locations and the average values are taken as the hardness of the specimen.

B. *Impact test*

Impact Test to be carried out over Charpy Impact Testing Machine. The test specimens are prepared from the casting materials and machined as per ASTM E-23standard size. Square cross sections of size (10mmX10mmX55mm) with single V-notches are planned for experiment. The size of V-notches is 45^o and 2mm depth. The impact roughness factor was determined when fracture is occurs.

C. *Tensile test*

The tensile specimens were prepared as per ASTM E-08 standard. The dimension of the specimen is 100 mm length and having diameter of 12 mm. The ultimate tensile strength (UTS) of the specimen was estimated using a computerized Universal Testing Machine (TUE-C1000).

IV. RESULTS AND DISCUSSION

A. *Hardness test*

Table 2 shows thehardness reading for composite samples with different reinforcement percentage. It is seen that, with addition of the reinforcement, hardness of the composite increases when compared to Al 6061. Silicon carbide, aluminium oxide and Boron Carbide particles have very high hardness and when it is reinforced in the matrix material, it helps to improve the hardness properties of composite by considerable amount. Hardness of the composite depends on various factors like porosity, non-uniform distribution, and presence of cluster formation.

From the table, the composition of 12% of Al_2O_3 with 5% of SiC and B_4C (4) has more hardness value compared to other three compositions. By increasing the Al_2O_3 content the hardness value also increased.

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Fig. 1. Hardness test specimens

TABLE II. HARDNESS VALUE OF THE SPECIMENS

Serial no.	Specimen no.	AVRAGE HARDNESS VALUE
1	1	93
2	2	95.6
3	3	93.4
4	4	97.6

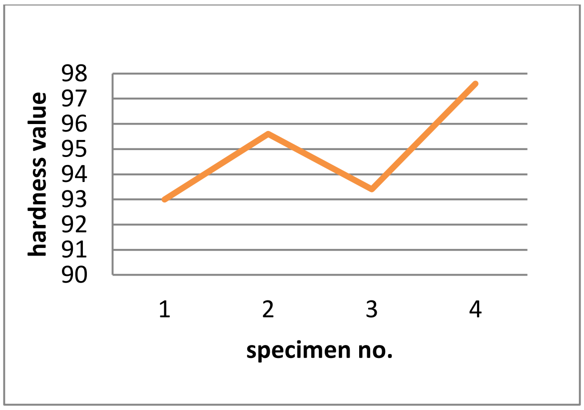

Fig. 2. Hardness value of the specimens

B. *Impact test*

The impact properties are shown in table3. From table3, it is found that the specimen 1 and 2 absorbs more energy than other two specimens since it contain less amount of Al_2O_3 which are evenly distributed in the Aluminium matrix. The 3 and 6 wt. % of Al_2O_3 with 5 wt. % SiC and B_4C hybrid metal matrix composite has more energy absorption when it is fractured.

TABLE III. IMPACT VALUE OF SPECIMENS

Serial no.	Specimen no.	Enengy absorbtion J
1	1	4
2	2	4
3	3	2
4	4	2

Fig. 3. Impact test specimens

C. *Tensile test*

The tensile test was carried out in the computerized Universal Testing machine. The ultimate tensile stress, yield stress and percentage of elongation were determined in the specimens. The tensile properties are shown in the table 4. From table 4, it is found that the second specimen has more ultimate tensile stress, yield stress and % of elongation.

Fig. 4. Tensile test specimens

TABLE IV. TENSILE PROPERTIES OF THE SPECIMENS

Specimen no.	Peak load (KN)	Ultimate tensile stress (Mpa)	Yield stress (Mpa)	% of elongation
1	2.905	58	50	14.500
2	13.04	259	200	17.0
3	10.805	215	165	13.6
4	3.325	66	40	13.0

From the result, the compsoition of 6% of Al_2O_3 and 5% of SiC and B_4C has more tensile properties compared to other compsition.

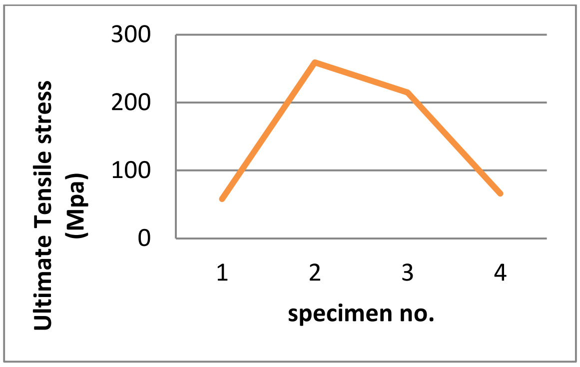

Fig. 5. Ultimate tensile stress value of the specimens.

V. CONCLUSION

The AA6061/Al_2O_3/SiC/B_4C composites have been successfully prepared by the stir casting method for analysis of mechanical properties. The hybrid metal matrix composites are subjected to heat treatment process successfully. The hardness of the specimen increased by increasing alumina weight percentage to the aluminium alloy. The 12% of Al_2O_3 and 5% of SiC, B_4C has more hardness value. The composition 6% Al_2O_3 and 5% of SiC and B_4C in the aluminium alloy has more ultimate tensile stress, yield stress and % of elongation.

The scope of this work can be extended to investigate the mechanical behaviour of AA6061/Al_2O_3/SiC/B_4C by varying weight percentage of SiC and B_4C (10%, 15%) under normal conditions.

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