Experimental Investigation of Wear Behaviour of AA6061 Hybrid Metal Matrix Composites

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***Abstract*— In the present investigation the hybrid composite was prepared by stir casting method. The AA6061 is used as matrix material and Al_2O_3, B_4C and SiC are used as reinforcement particle for preparation of hybrid metal matrix composites. The weight percentage of Al_2O_3 is varied B_4C and SiC kept at constant weight percentage. Wear test was done on a Pin on Disc apparatus at varying load of 9.81 N, 19.62 N, 29.43 N and 39.24 N under dry sliding conditions. The variation of coefficient of friction (COF) during the wear process was recorded by using a computer. The Microstructural study was done by using Scanning Electron Microscope (SEM), which revealed the uniform distribution of Al_2O_3 and B_4C and SiC in matrix alloy. The wear results revealed that the volumetric wear loss was increased with increase in normal load. The results also indicated that the volumetric wear loss of the Al6061- 3wt.%Al_2O_3- 5wt.%B_4C- 5wt.%SiC composites were less compared to other compositions.**

Keywords: Aluminium, Metal matrix composites, stir casting method, Wear behaviour, SEM, Wear rate, Al_2O_3, B_4C, SiC.

I. INTRODUCTION

Aluminum and its alloys are attractive engineering materials for many applications in chemical, aeronautical, automotive, food and aerospace industries, because of their low density in combination with good mechanical properties and good Tribological properties [1]. Metal matrix composites (MMCs) are types of material which have great potential because of the unique property combinations that can be achieved [2-3]. Many researches have reported that, compared to unreinforced alloys the reinforced composites have superior wear resistance [4-5]. Many techniques were developed for producing particulate reinforced MMCs, such as powder metallurgy [6], in situ [7], and squeeze casting [8]. From all the above three methods, stir casting technique is the simplest and the most economical process for fabricating particulate reinforced MMCs [9]. The aluminium alloy reinforced with Al_2O_3 particle content are examined for wear behaviour. The addition of Al_2O_3 content with aluminium alloy reduces the wear rate of the composites [10]. The metal matrix composites containing SiC and Al_2O_3 particle exhibit improved wear resistance [11]. The mechanical and sliding wear resistance properties are increased as a result of heat treatment and forming composites by adding 15 wt.% of SiC [12]. Aluminium alloy reinforced with 5% SiC and 5% B_4C hybrid composites is investigated by dry sliding wear test. The hybrid composites retain the wear resistance properties up to 60N loads and sliding speed ranges 1-4 m/s [13]. The mechanical properties such as hardness, tensile are increased and electrical resistivity of the composites increased by various pre-aging retrogression temperatures of the AA7075. The wear properties are improved by increasing hardness of the composites [14]. The hardness of the matrix alloy has a strong influence on the dry sliding wear behaviour of AA6061-Al_2O_3 composites [15]. The wear properties are analyzed in the aluminium alloy reinforced with silicon carbide and boron carbide. The addition of SiC and B_4C in aluminium alloy improving wear resistance of the composites [16]. The effect of temperature and applied load on the wear behaviour of AA6061-SiC composites is analyzed. The wear rate decreases with increasing applied load [17]. AA7075 and 6061 were reinforced with 5 wt. % of graphite and 10 wt. % of Boron carbide are investigated through the liquid casting technique. % of elongation and high hardness values are obtained in AA7075 hybrid composites. The wear resistance property is improved in AA7075/B_4C/graphite composites compared AA6061 hybrid composites [18]. The wear behaviour of aluminum hybrid metal matrix composites is examined by increasing load and sliding distance. With increasing load the wear loss is increases as the sliding speed increases the wear loss is reduced. The applied load and sliding speed increases the coefficient of friction increases [19].

In this work, an attempt has been made to prepare Hybrid Metal Matrix Composites by adding Al_2O_3, B_4C and SiC reinforcement particles into AA6061 matrix alloy using a stir casting method. The Al_2O_3 weight percentage is varied and B_4C and SiC are kept at constant. The objective of the present investigation is to determine the wear properties of the HMMC by adding hard ceramic particles into the aluminium alloy.

II. EXPERIMENTAL PROCEDURE

A. Material composition

In this 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 has good Mechanical and Wear properties. It is one of the most common alloys of aluminium for general purpose use. Four different volume percentages of Al_2O_3 (3% to 12%) and fixed volume percent of B_4C and SiC (5%) were used in the experiments.

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TABLE I. COMPOSITION OF AA6061

Element	AA	Mg	Cu	Si	Fe
Weight%	97.85	0.960	0.161	0.514	0.230
Element	Cr	Ti	Mn	Zn	Ni
Weight%	0.103	0.031	0.071	0.015	0.010

B. Preparation of composites

The hybrid metal matrix composites was prepared by using stir casting method. This method helps to get uniform distribution of reinforcement in the matrix material by creating the vortex condition in the molten metal. Aluminium alloy 6061 is used as a matrix material and Al_2O_3, B_4C and SiC ceramic particles are used as reinforcement particles. The 1 Kg of aluminium alloy 6061 is taken in to the graphite crucible and it is heated in the range of 780ºC to 850ºC in high temperature electric furnace for one hour. The reinforcement particle such as Al_2O_3, B_4C and SiC particles are preheated in the temperature range of 450ºC-550ºC in the preheating electric furnace. The mechanical mild steel stirrer was used for stirring process. During vortex formation stage the pre-heated reinforcement particles are introduced into the melt at constant feed rate of 1.2-1.4 g/sec. The stirring speed is maintained at 550-1000 rpm for 5 minutes durations. The melt was then solidified in the preheated cast iron mould in atmospheric air. The 6061 hybrid metal matrix composites, containing different weight percentage of reinforcement particle were produced. Cast and composite ingots were T6 heat treated in a muffle furnace to an accuracy of +1ºC for 8 hours at 529ºC, followed by water quenching and then aged at 159ºC for 8 hours. After heat treatment process the casting materials are machined to testing for required dimensions.

III. TESTING METHOD

A. Wear analysis

The wear behaviour of the hybrid metal matrix composites was investigated using pin-on-disk apparatus according to ASTM G-99 standards. The wear pin samples made from hybrid metal matrix composites were approximately 10 mm diameter and 20 mm height. The specimens are then polished using different size emery paper for smooth surface. The EN31 steel was used as a counter disk for wear test. Before and after each test, the weight of the specimen has been measured and weight loss is calculated. The weight has been measured in digital balance having least count 0.1 mg. after each test the disk was cleaned. For experiments the four different levels of load (1kg-4kg) and constant sliding speed and constant time duration is considered. The sliding distance for entire test is kept at constant at 20m, the sliding speed is 300 rpm and duration is 10min.The coefficient of friction of the specimen recorded during wear test. Figure shows the wear test specimens of different compositions.

Fig. 1. Wear test specimens

IV. RESULT AND DISCUSSION

A. Microstructural studies

Figure shows the SEM microphotographs of hybrid metal matrix composites. The aluminium alloy 6061 reinforced with Al_2O_3, B_4C and SiC particles are analyzed using Scanning Electron Microscopy. The four different compositions of the composites were analyzed with different magnitude (500, 1000, and 2000). For SEM analysis the specimens are machined from the cast composites and then it is polished using different grit size paper. From the figure it is shown that the uniform distribution of Al_2O_3, B_4C and SiC particles into the matrix alloy and very low agglomeration and segregation of particles, and porosity. It is expected to possess better mechanical properties due to uniform distribution of reinforcement.

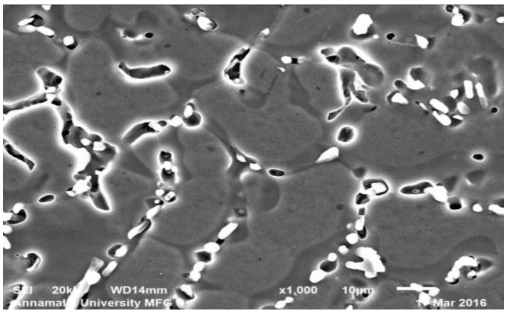

Fig.2. SEM microphotograph of AA6061 with 3 wt. % of Al_2O_3 and 5% of B_4C and SiC of 500X magnification.

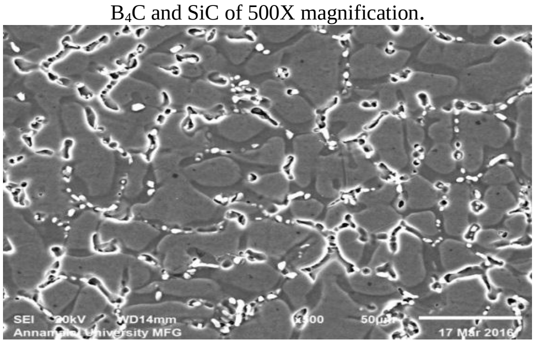

Fig. 3. SEM microphotograph of AA6061 with 3 wt. % of Al_2O_3 and 5% of B_4C and SiC of 1000X magnification

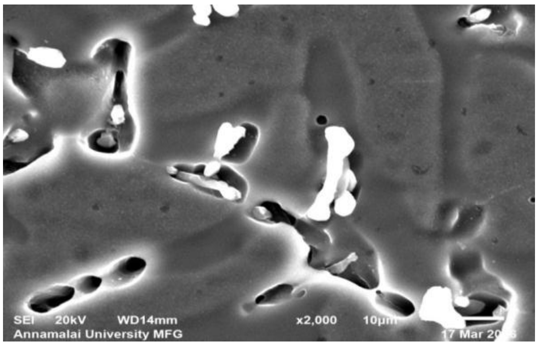

Fig. 4. SEM microphotograph of AA6061 with 3 wt. % of Al_2O_3 and 5% of B_4C and SiC of 2000X magnification

B. *Wear result*

The variation of wear rate with different composition of hybrid composite is shown in the table 2. It is shown that at low applied load and constant sliding speed the pin surface predominantly reveals fine and shallow grooves in the sliding direction. The wear rate increases with increasing applied load due to increasing contacting pressure in the pin, leads to increases in wear rate in prepared hybrid composites. The presences of hard ceramic reinforcement particles in the aluminum alloy increases hardness and wear resistance of the composites. It may also be seen that the heat treatment decreases the wear rate of the composites. From the table it is shown that the 3 wt. % of Al_2O_3 and 5% of B_4C and SiC has the less wear rate compared to other compositions.

TABLE II. WEAR RATE VALUES

Load (N)	Wear rate (mm^3/m)			
	1	2	3	4
9.81	0.00555	0.01296	0.00925	0.00555
19.62	0.02222	0.02037	0.02407	0.02407
29.43	0.03703	0.02037	0.02407	0.02777
39.24	0.02592	0.04074	0.03703	0.03703

The figure shows the variation of wear rate of the AA6061-Al_2O_3-B_4C-SiC hybrid composites of different composition.

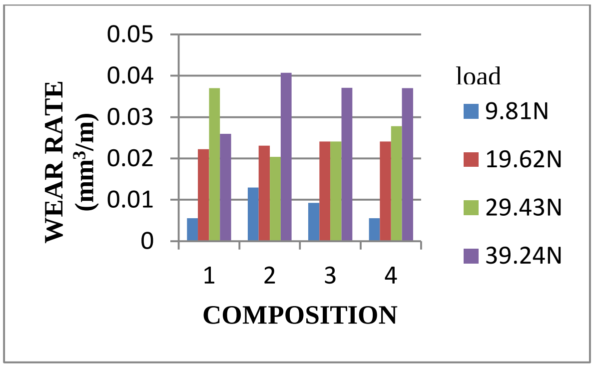

Fig.5. variation of wear rate with different compositions

C. *Coefficient of friction*

The value of coefficient of friction of AA6061-Al_2O_3-B_4C-SiC hybrid composites of different composition is shown in table 3. The coefficient of friction increases with increasing applied load. From the table it is shown that the 6 wt. % of Al_2O_3-5% of B_4C-5% of SiC hybrid composites have less coefficient of friction values compared to other composition for all applying load condition.

TABLE III. COEFFICIENT OF FRICTION VALUES

Load (N)	Coefficient of friction			
	1	2	3	4
9.81	0.165	0.191	0.148	0.248
19.62	0.275	0.044	0.182	0.383
29.43	0.335	0.227	0.224	0.366
39.43	0.392	0.318	0.297	0.337

The figure shows the variation of wear rate of the AA6061-Al_2O_3-B_4C-SiC hybrid composites of different composition.

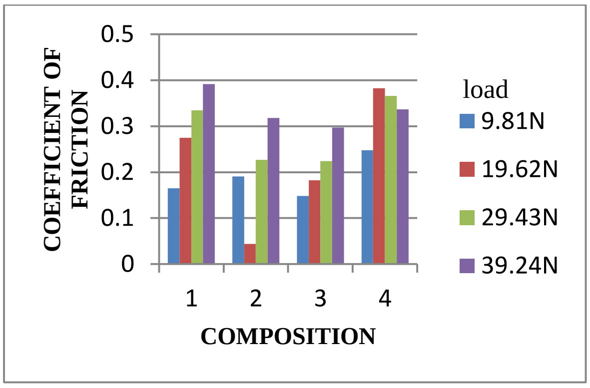

Fig.6. coefficient of friction value with different composition at all applying load condition.

V. CONCLUSION

The final conclusion of the investigation is using stir casting method AA6061-Al_2O_3-B_4C-SiC hybrid metal matrix composites were prepared successfully. The prepared hybrid composites are heat treated into T6 conditions successfully. Microstructural studies of hybrid composites studied using Scanning Electron Microscopy. This clearly shows that the uniform distribution of reinforcement particles throughout the matrix. The wear rate of the AA 6061- 3wt. % Al_2O_3- 5wt. % B_4C- 5wt. % SiC hybrid composites is less compared to other compositions. By increasing the applying load the wear rate of the specimens are increased. The coefficient of friction values are less in AA6061- 6wt. % Al_2O_3- 5wt. % B_4C- 5wt. % SiC hybrid composite compared to other compositions.

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