EVALUATION of WEAR PROPERTY for ALUMINIUM BASED HYBRID MMC's REINFORCED WITH NANO AL_2O_3 & ZrO_2 CERAMIC PARTICLES

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Abstract

Metal matrix composites are being increasingly identified in now a days as wear resistant material. This paper deals with the wear and hardness properties of the composite material Al-6061 alloy reinforced with Al_2O_3 and ZrO_2 particulate and supported by stir casting method. The wear down rate and frictional properties of the composite were investigated with the help of pin and disk type of wear testing machine. The investigation was carried out with constant length of sliding distance and sliding velocity over different load ranges for aluminium metal matrix composite. The testing result indicated that the wear resistance increases when there is increase in the load. Additionally an effort was made by keeping Al_2O_3 as constant as 5% along with increase in 1, 1.5 and 2% of ZrO_2. It was observed that, the strengthened aluminium metal matrix in addition of ZrO2 and Al_2O_3 decreases the range of wear rate. By using SEM the worn out surfaces were examined and it was observed that the micro cracks, mild and severe wear occurred in the composite worn surfaces and wear structure of the composite.

Keywords: Metal matrix composites, Al_2O_3 , ZrO_2, SEM, wear structure

I. INTRODUCTION

Metal matrix composites (MMC's) are increasingly becoming attractive materials for advanced aerospace applications because their properties can be tailored through the addition of selected reinforcements. In particular, particulate reinforced MMC's have recently found special interest because of their specific strength and specific stiffness at room or elevated temperatures. It is well known that the elastic properties of metal matrix composites are strongly influenced by micro structural parameters of the reinforcement such as shape, size, orientation, distribution and volume fraction. Aluminium-based Metal Matrix Composites (MMCs) have received increasing attention in recent decades as engineering materials. The introduction of a ceramic material into a metal matrix produces a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained with monolithic alloys. There is an increasing need for knowledge about the processing techniques and mechanical behavior of particulate MMCs in view of their rising production volumes and their wider commercial applications. Interest in particulate reinforced MMCs is mainly due to easy availability of particles and economic processing technique adopted for producing the particulate-reinforced MMCs.

The commercial application of Al_2O_3 short fiber reinforced aluminium in piston inserts in automotive engines. This saw a major boost in their use. Particulate reinforced MMC's exhibit the same strengthening mechanism similar to those of precipitating strengthened and dispersion strengthened alloys.

In recent years, considerable work has been done on Zro2 reinforced metal matrix composites which exhibit low friction, low wear rate and excellent ant seizing properties. The Zro2 in these composites presumably imparts improved tribological properties to the composites through the formation of a Zro2-rich film on the tribo-surface which provides solid lubrication.

II MATERIALS AND METHODOLOGY

2.1 Materials

In this present work method of casting, preparation specimens and studying their mechanical properties. Al6061 alloy reinforced with Aluminium oxide and Zro2 to prepare hybrid MMC's

2.1.1 Aluminium (Al6061)

Al6061 is commonly used metal matrix in preparation of composite materials. Among the various useful aluminium alloys, aluminium alloy 6061 is typically characterized by properties such as fluidity, castability, corrosion resistance and high strength-weight ratio. This alloy has been commonly used as a base metal for MMCs reinforced with a variety of fibers, particles and whiskers. The chemical composition and mechanical properties of Al6061 alloy represented in tables 1 and 2.

TABLE I Chemical Composition of Al606

Elements	Mg	Cu	Cr	Mn	Zn	Ti	Fe	Si	Al
Actual values	1.0	0.36	0.20	0.10	0.10	0.10	0.5	0.2	97.44

2.1.2 Aluminium oxide (Al_2O_3)

Aluminium oxide, commonly referred to as alumina, possesses strong ionic interatomic bonding giving rise to its desirable material characteristics. It can exist in several crystalline phases which all revert to the most stable hexagonal alpha phase at elevated temperatures. Its high hardness, excellent dielectric properties, refractoriness and good thermal properties make it the material of choice for a wide range of applications. Aluminium oxide varying percentage. Here its size is 50 micrometer.

2.1.4 Zirconium dioxide (ZrO2):

Zirconium dioxide sometimes known as zirconia, these are in white crystalline oxide of zirconium. Its most naturally occurring form, with a monoclinic crystalline structure, is the mineral baddeleyite. A dopant stabilized cubic structured zirconia, cubic zirconia, is synthesized in various colors for use as a gemstone and a diamond simulant.

TABLE 2 Chemical Composition of Al6061, Aluminium oxide and

Material	Density (gm/cc)	Melting Point (ºc)	Modulus of Elasticity (Gpa)	Poisons Ratio	Brinell Hardness	Ultimate tensile strength (Mpa)
Al 6061	2.7	580	70-80	0.33	30-33	110-182
Al_2O_3	3.72	1700	300	0.21		
ZrO2	5.68	2,715				

(a) Al6061 (b) Zro2 (c) Al2o3

Fig.1 (a,b,c) Shows work materials of Al6061, Al_2O_3(30nm) and Zirconium dioxide (40nm)

Table 3 Sample preparation composition

Composite Samples	Composition
Sample A	Al6061
Sample B	Al6061+5% Al2o3
Sample C	Al6061+5% Al2o3+1%Zro2
Sample D	Al6061+5% Al2o3+1.5%Zro2
Sample E	Al6061+5% Al2o3+2%Zro2

2.2 Steps Involved in Preparation of MMC Casting

2.2.1 Melting Process

Cleaned furnace and aluminium ingots are placed inside the crucible and 1.5kg of Al6061 ingots is placed in a furnace and temperature is set about 900ºc. Once the metal reaches into the liquid state, the slag formed in the furnace is removed slowly and the Zro2 and aluminium oxide added particulate of reinforcements are added into the heated furnace and the molten metal is stirred continuously at a constant speed.

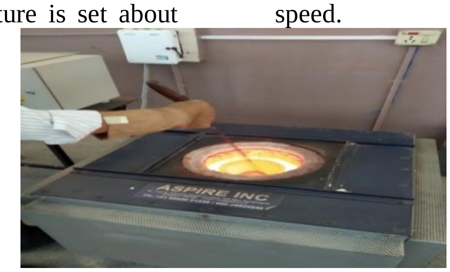
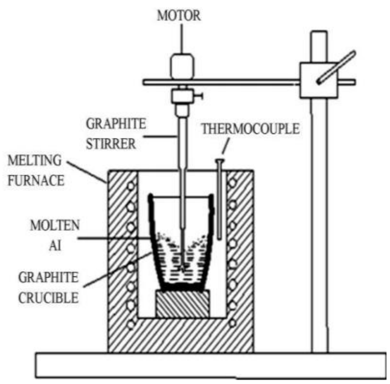


Fig.2 Electric furnace

2.2.2 Pouring

After complete mixing of Zro2 and aluminium oxide particulate with AL6061 which is inside the crucible the molten mixture is taken outside the furnace and poured into the die and for stir casting. Stir casting with the speed about varying 850rpm to 1500 rpm for different casting as shown in fig.4.



(a)

(b)

Fig.3 (a, b) schematic diagram of stir Casting and pouring molten metal into metal mould

2.2.3 Solidification and Machining Process

The molten metal mixture is poured into the die after some few minutes it gets solidified, and slowly remove the cast product slowly by removing the end of the cap of the molding machine as shown in the below fig.4

Fig.4 Solidified specimens after removed from the die

The Machining processes of Mould Components were cut and machined with the help of EDM wire cutting machine as per the ASTM standard specification.

III. Experimental Details and Results and Discussions

3.1 Experimental Details

The Mechanical Properties are considered on Al6061 reinforce with aluminium oxide and Zro2 subjected based on tests of the specimens.

3.1.1 Micro Structure:

Micro structural studies are carried out to examine distribution of reinforcement particles in matrix phase, grain size separated by thin black grain boundaries. Examination were prepared with the help of metallurgical microscope with magnification of 200X. Here by applying etching on the specimens of the surface and wash with the water and allow it 15 mini to dry and test the specimens.

3.1.2 Hardness Test

Brinell hardness test conducted as per the E10-12 ASTM, here the indenter diameter is 5mm and load applying over specimen is 1 kilogram. The hardness specimen dimensions is as shown in fig.8,

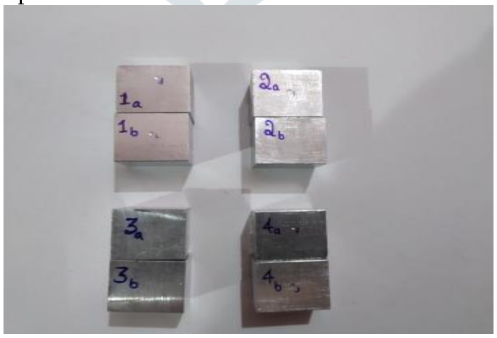


Fig.5 Hardness Test Specimens

3.1.3 Wear Test

The wear test is carried to find wear rate of the composite by using pin and disc method. The wear specimens are prepared as per the G95 ASTM standards as shown in below fig.9 specimens are having dimensions 10 mm diameter and 50mm length.

Fig.6 Wear test machine setup and specimen

3.1.4 Heat Treatment process:

Age hardening heat treatment is done for aluminium composites, heat treatment is carried out at constant temperature of 250 °c for 7 hours and quenched by water and place specimens at room temperature for 5 day for stress distribution and crystalline growth in the composites.

3.2 Results and Discussions

3.2.1 Hardness Test

Hardness test is done using the Brinell hardness tester equipment in the room temperature. Testing has been carried out before and after heat treatment for 4 compositions. The table and graph shows hardness number of different composites varies with without teat treatment and with teat treatment process. Increase in percentage of aluminium oxide with constant Zro2 increases the hardness before and after the heat treatment also there is gradual increases in the hardness after the heat treatment

TABLE 4 Brinell hardness Test Results

Sl. No.	Material	Hardness Number (BHN)
1	Sample A	46
2	Sample B	54
3	Sample C	62
4	Sample D	71
5	Sample E	79

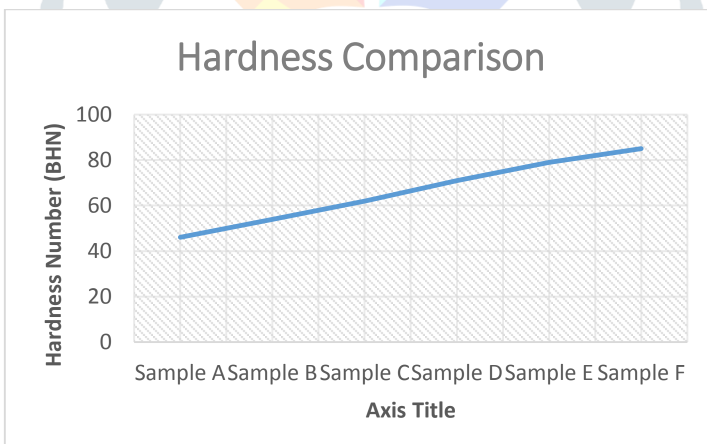


Fig.7 Graphical representation of hardness comparison

3.2.3 Wear Test (varying speed)

The wear test results for varying weight in which the speed of the rotating disc 500rpm and time 5mins is taken as constant for all trials. The weight of the scale selected 1, 2, 3kg respectively and tabulated in the table 5. from table and figure there is a gradual increase in wear rate as the weight increases. Also there is decrease in wear rate as increasing composition of aluminium oxide with the Zro2 before and after the heat treatment.

Table 5 wear test values of composites

Sl.No	Material	Load (kg)	Speed (RPM)	Time (min)	Wear (μm)
1	Sample A	200	500	5	110
		200	600	5	161
		200	700	5	221
2	Sample B	200	500	5	83
		200	600	5	105
		200	700	5	154

3	Sample C	200	500	5	55
		200	600	5	93
		200	700	5	161
4	Sample D	200	500	5	42
		200	600	5	74
		200	700	5	122
5	Sample E	200	500	5	30
		200	600	5	64
		200	700	5	91

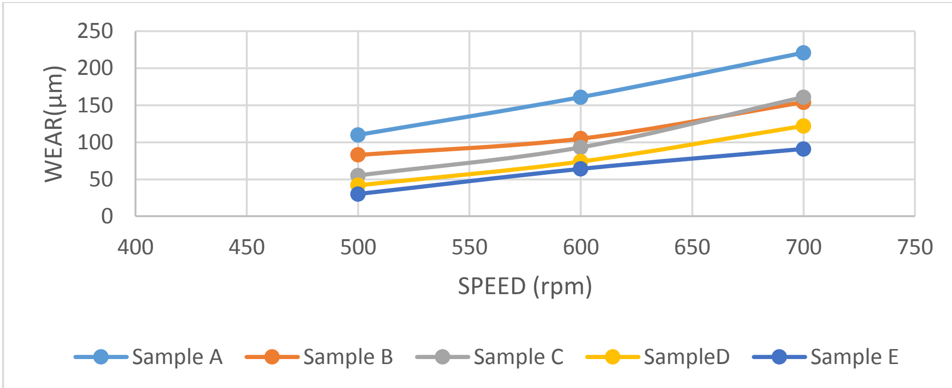


Fig.7 Graphical representation of Wear vs speed comparison

IV. Conclusion

Aluminium oxide and Zro2 reinforcement of Al6061 metal matrix composite is successfully fabricated by stir casting techniques.

From the experimentation work the hardness increased gradually with increase in percentage of reinforcement before and after the heat treatment. Wear resistance of the composite samples will be increased further increasing the percentage of reinforcement. Metallurgical micrographs revealed that reinforced particles are well distributed in aluminium matrix. Hence minimizes defects of casting like blow holes and porosity and will give better result than simple composite material.

The Age hardening heat treatment process have Further changed the physical and chemical properties of the materials like increasing the wear resistance and hardness properties after heat treatment compared to before heat treatment and also structure of the composites.

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