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Experimental Study on wear behaviour of Al-TiO_2 Metal Matrix Composites Processed through Stir Casting Method

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***Abstract*—In recent trend Aluminium based metal matrix composites are most commonly used in mechanical and automobile component design applications because of their excellent mechanical, Tribological and its physical properties. Also Aluminium metal matrix composites are used for a variety of applications such as military, aerospace, electrical industries and automotive purposes. This paper presents Tribological tests results of pure Aluminium with 0%, 3%, 6%. And 9% TiO_2 reinforcement. The reinforcement was in the shape of particles with size of 44 microns, and the technology for producing of composite was stir casting. Dry sliding wear tests of the specimens were conducted using pin-on-disc test apparatus conforming to ASTM G99 standards with electronic data acquisition system. EN32 hardened steel disc with a hardness of 65HRC and Ra value of 2.5-3.5 µm was used as the counter surface. The wear displacement with respect to sliding distance of different test specimens at different loads were studied and analysed.**

***Keywords*— Aluminium- TiO2, Stir Casting, wear**

I. INTRODUCTION

The development of technology needs advanced engineering materials for various applications. To fulfill such demand metal matrix composite (MMC) is one of the reliable sources**.** Metal matrix composite is the combination of two or more materials, first being a metal necessarily; the second material may be a different metal, such as a ceramic or organic compound. In structural applications, the matrix is usually a lighter metal such as aluminum and magnesium and provides a compliant support for the reinforcement. The reinforcement materials are embedded into a matrix and are used to change Mechanical properties such as wear resistance, fracture strength, Tensile strength Hardness**.** Metal matrix composites manufacturing can be carried in three ways such as solid, liquid and vapor state methods. The Solid-state method consists of powder metallurgy, the liquid state methods are stir casting, Squeeze casting, spray deposition etc. and the vapor deposition technique under vapor state method.

Honnaiah C [1] synthesized aluminium metal matrix composites (AMMCs) with different weight percentages of Al_2O_3 particles by stir casting process. Aluminum- Al_2O_3 composites reinforced with various with size of 25, 45, 75 and 120 microns. Dry sliding wear tests of the specimens were conducted using pin-on-disc test apparatus conforming to ASTM G99 standards with electronic data acquisition system. The experimental result show that the wear resistance of composites increased with decreasing particle size of Al_2O_3 particulates.

Vinaykumar S Shet, [2] synthesized aluminium metal matrix composites (AMMCs) with different weight percentages of TiO_2 particles by stir casting process. The extent of incorporation of TiO_2 particles in the composite will be varied from 2-8 wt% in steps of 2. Microstructure studies, wear properties, hardness of as cast Al 6063 alloy and Al 6063- TiO_2 composites will be evaluated. TiO2 when used as reinforcement have owed to an increase in the micro hardness (VHN), wear resistance and Density of the composite

Manojkumar M et al [3] in his study showed that the A hybrid MMC was developed for the cylinder liner of advanced diesel engines. Composites of Al-6063 aluminium alloy reinforced with, fly ash particulate containing 10% and graphite particulate containing 5, 10 and 15 % were produced by stir casting. The wear and frictional properties of the casted hybrid metal matrix composites were investigated by performing dry sliding wear test using a pin-on-disc wear tester. The investigation was done to find the influence of applied load, sliding speed and sliding distance on wear rate, as well as the coefficient of friction during wearing process. From the investigation, it is evident that wear resistance of Al-6063 is increased while adding the fly ash and graphite reinforcement content.

Ajit.S.Dange [4] in this paper to study of mechanical and wear properties of aluminum alloy and effects of reinforcement material such as short fiber alumina. The composite is fabricated by stir casting method. Adding reinforcing material as 10%, 15%, 20% respectively at same time wear rate reduces and mechanical properties improve. To study wear test and test conduct on pin on disc apparatus as dry sliding condition with ambient temperature for different affecting parameter i.e. Normal Load, sliding velocity, sliding distance. From the investigation, Wear rate is decreased when adding alumina to aluminium alloy.

Rekha Ganeshkar et.al [5] made an attempt to study the influence of operating parameters like applied load, sliding speed and sliding distance on the dry sliding wear of LM6 aluminum alloy reinforced with different percentages of SiC particulates and constant percentage of aluminum oxide fabricated stir casting method. Dry sliding wear tests were carried out with the use of computerized Pin-on-disc wear testing machine by varying parameters such as normal load, sliding distance (SD) and Temperature for the MMC's. The tests are carried out under dry conditions. Wear specimen (pin) of size 12 mm diameter and 25 mm length as per the ASTM standard G99. The results show that wear rate reduction when addition of the SiC particulates with the matrix.

T R Hemanth Kumar et.al [21] studied on Tribological properties of aluminium metal matrix composites, the composites fabricated by stir casting technique. The pure Aluminium was reinforced with TiO_2 particles 4% by wt., 6% by wt., 8% by wt. this study evaluates the influence of wear test parameters like applied load, sliding speed. The test specimens prepared as per the ASTM G99 standard, the dimensions of the pin specimen measured 8 mm in diameter and 30 mm height. The experimental results show that higher sliding speed and titanium dioxide reinforcement will favor for reducing the wear rate of composites.

II. SELECTIONS OF MATERIALS

The matrix material in present study is pure Aluminium, and the reinforcing material selected is Titanium dioxide (TiO_2) of different composition. The Titanium dioxide is varied by 0%, 3%, 6% and 9% weight of Aluminium. Some of the attractive property combinations of Al based matrix composites are: high specific stiffness, strength, thermal conductivity, and low thermal expansion. TiO_2 (rutile) is a soft powder. The reinforced particles size of TiO_2 is 44 microns. The material properties of the Al and titanium dioxide (rutile) are shown in table 2.1.

Table 2.1: Physical properties of aluminium

Properties	Values
Elastic Modulus (GPa)	68-72
Density(g/cc)	2.7
Poisson's ratio	0.33
Hardness Vickers (Hv)	30-100
Tensile strength in MPa	70-360
Melting temperature	582-652°C

Table 2.2: Properties (TiO_2) powder

Properties	Values
Density (g/cm^3)	4.23
Poisson's Ratio	0.28
Melting point °C	1843
Boiling point °C	2972
Tensile Strength MPa	300-350
Vickers Hardness kgf/mm^2	980
Modulus GPa	240

III. STIRCASTING

In conventional stir casting method, reinforced particulate is mixed into the aluminium melt by mechanical stirring. Mechanical stirring is the most important element of this process. After the mechanical mixing, the molten metal is directly transferred to a shaped mould prior to complete solidification. The essential thing is to create the good wetting between particulate reinforcement and aluminium melt. The distribution of the reinforcement in the final solid depends on the wetting condition of the reinforcement with the melt, relative density and rate of solidification etc. Distribution of reinforcement depends on the geometry of the stirrer, melt temperature and the position of the stirrer in the melt.

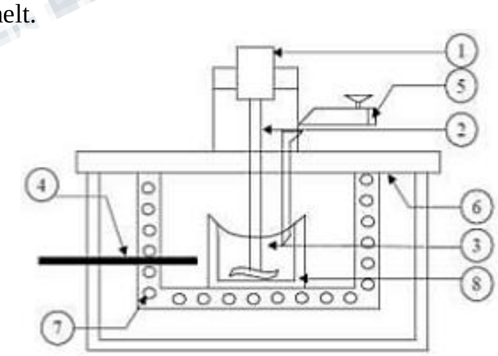

Figure 3.1: schematic diagram of stir casting process

1) Motor
2) Shaft
3) Molten Aluminium
4) Thermocouple
5) Particle Injection Chamber
6) Insulation Hard Chamber
7) Furnace
8) Graphite Crucible

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Figure 3.2: Casted MMCs.

3.1 PREPARATION OF ALUMINUM AND TiO2 COMPOSITE

The stir casting setup was prepared initially. The Aluminum with 0%, 3%, 6% and 9% of TiO2 powder respectively were prepared by stir casting technique where Aluminium is the base material and TiO2 is the reinforcement material.

Step 1: Melting of base metal Aluminium in furnace.

Step 2: One sample metal was prepared without adding TiO2 and another three different compositions of molten metal were prepared by adding 3%, 6%, and 9% TiO2 reinforcement material.

Step 3: Stirring of Al and TiO2 powder.

Step 4: Pouring of molten metal mixture into the mould and solidification.

Figure 3.3: Machined component.

IV. EXPERIMENTAL DETAILS

4.1 Wear Test

Dry sliding wear tests were carried out with the use of computerized Pin-on-disc wear testing machine by varying parameters such as normal load, sliding distance (SD) and speed for the MMC's. The tests are carried out under dry conditions. Wear specimen (pin) of size 12 mm diameter and 25 mm length was cut from the cast samples machined and then polished. A single pan electronic weighing machine having least count of 0.0001gram was used for the measurement of the initial weight and final weight of the specimen. The cylindrical pin of size 25 mm length and 12 mm diameter were tested EN32 hardened steel disc with a hardness of 65HRC and Ra value of 2.5-3.5 µm was used as the counter surface. After running through a certain sliding distance, the specimens were removed and cleaned with acetone. Then measure the final weight to calculate weight loss due to wear. The differences in weight measured before and after test give sliding wear of composite specimen and then the wear rates were calculated for different samples. The dry sliding wear tests were carried out at controlled parameter levels. The set up of Pin on Disc machine shown in figure 4.1. And Table 4.2 shows the technical specifications of wear and friction test rig.

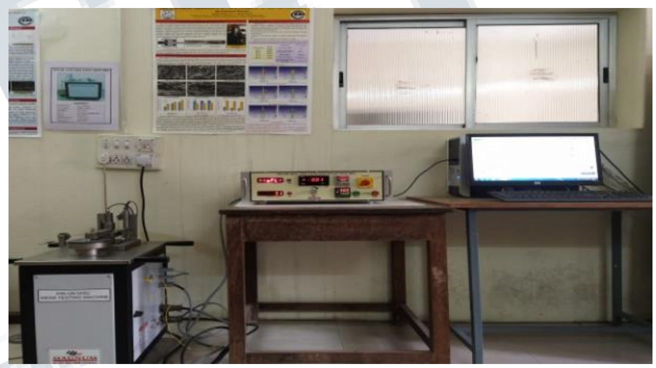

Figure 4.1: photograph of Pin on Disc Apparatus.

Table 4.1: Specification of Pin on Disc Apparatus.

Rotational speed	Up to 2000 rpm
Track diameter	40mm - 118mm
Load range	Up to 200 N
Disc Size	Dia 120 mm × Thickness 8 mm
Pin Size	6 to 12 mm
Wear or Displacement	± 2000 microns
Frictional Force	Up to 200 N

V. RESULTS AND DISCUSSION

5.1 SEM (SCANNING ELECTRON MICROSCOPE) RESULTS

The surface images of fabricated metal matrix composites were examined by using scanning electron microscope (SEM). From the images, it is noticed that the distribution of filler or reinforcing contents in the matrix alloy are uniform. From this we can identified that the homogeneity of the cast composites. The Minor level of porosity also present in the

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composites and bonding between the particles was satisfactory. Figure 5.1 to 5.4 shows SEM images with different weight percentage of titanium dioxide particles.

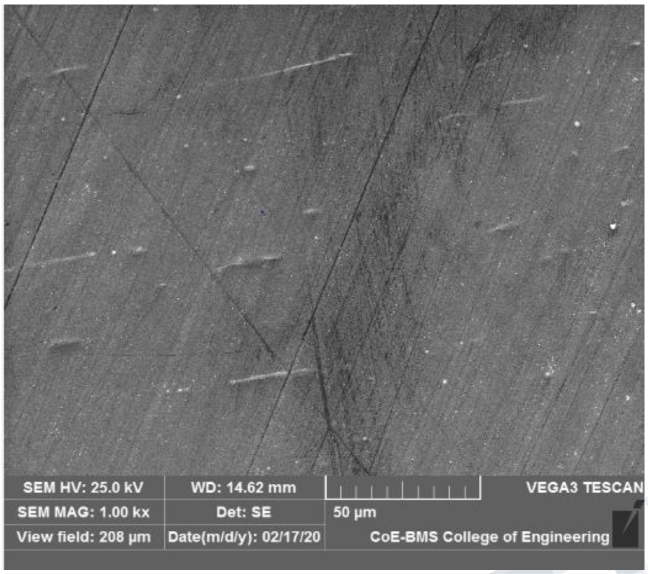

Figure 5.1: The distribution of Al and 0% weight composition of TiO2 composite sample.

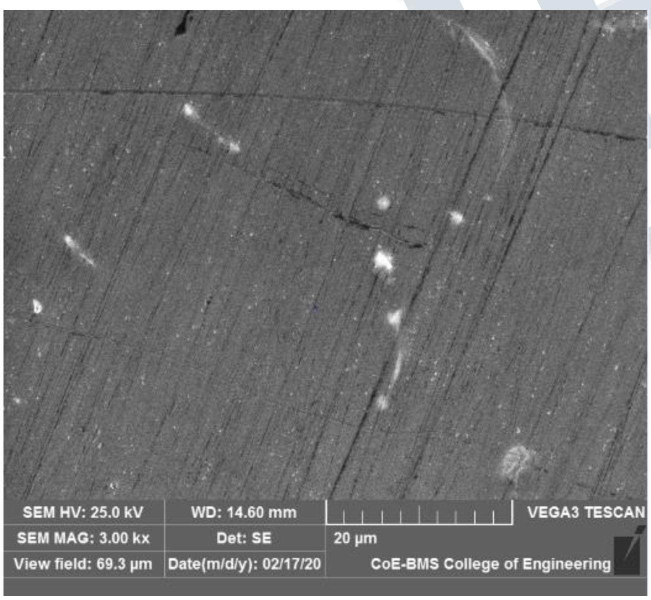

Figure 5.2: The distribution of Al and 3% weight composition of TiO2 composite sample.

The Figure 5.2 shows that the distribution of 3% weight composition of Titanium di-oxide reinforced with the pure aluminium.

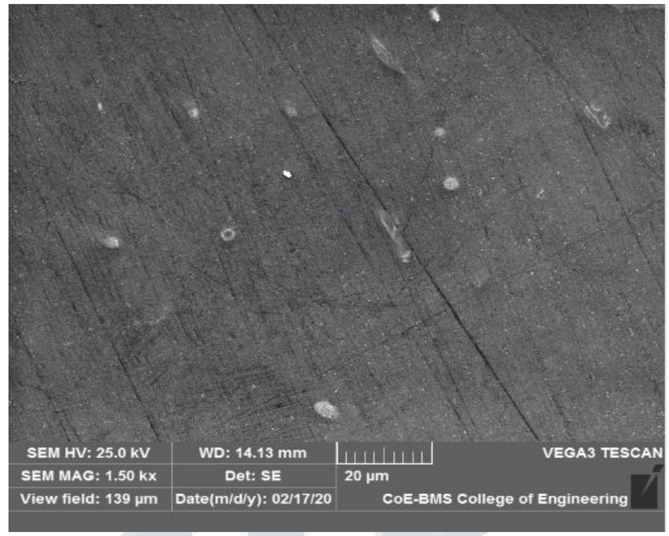

Figure 5.3: The distribution of Al and 6% weight composition of TiO2 composite sample.

The Figure 5.3 shows that the distribution of 6% weight composition of Titanium di-oxide reinforced with the pure aluminium.

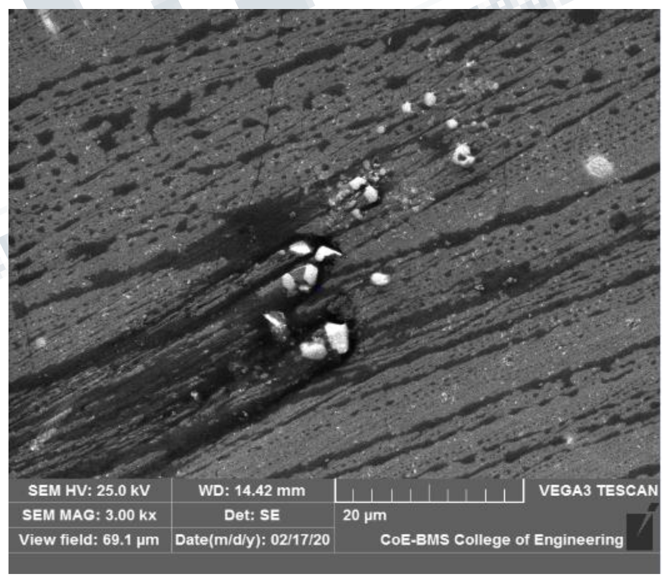

Figure 5.4: The distribution of Al and 9% weight composition of TiO2 composite sample.

The Figure 5.4 shows that the uniform distribution of 9% weight composition of Titanium di-oxide reinforced with the pure aluminium.

5.2 EDAX (ENERGY DISPERSIVE SPECTROSCOPY ANALYSIS) RESULT

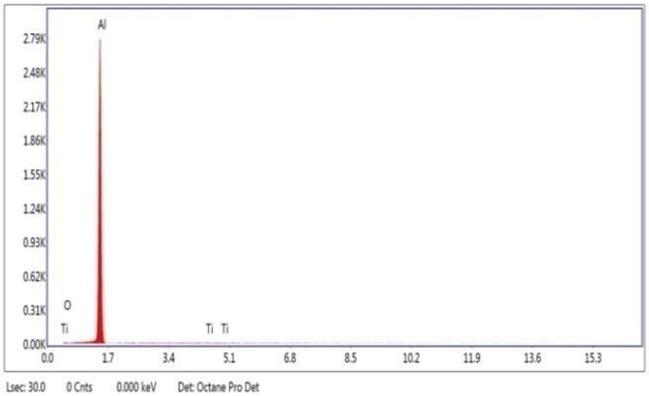

Fig 5.5 Energy dispersive spectroscopy analysis Of the pure Al+TiO_2 composites

The EDAX spectrum shows that the presence of the element i.e., Al and TiO_2. It is clear that the Aluminium peak is higher than the titanium dioxide. Energy dispersive spectroscopy analysis of the aluminium With TiO_2 reinforced composite is shown in figure 5.5 It Is Clear that titanium peaks were observed in The EDS analysis confirms that TiO_2 particles are present in The composites.

5.3 WEAR TEST RESULTS

The wear resistance is increases while increasing adding reinforcement (TiO_2) particles into the matrix. From the table 5.1 it can be observed that the wear resistance of composites is higher than that of their base matrix. The wear loss reduced from 0.0426 Gms to 0.0224 Gms as the percentage of titanium dioxide (TiO_2) percentage increased from 0% (As cast) to 9% for a normal load 10N. The wear loss reduced from 0.0667Gms to 0.0263 Gms as the percentage of titanium dioxide (TiO_2) percentage increased from 0% (As cast) to 9% for a normal load 20N.

Table5.1: wear test results

S.No	Load (N)	Mass loss (gm)	Wear rate mm^3/m	COF	Frictional force (N)
1	10	0.0426	0.00779	0.52	5
2	10	0.0256	0.00489	0.50	10
3	10	0.0252	0.00463	0.35	4
4	10	0.0224	0.00412	0.30	3
5	20	0.0667	0.0122	0.69	14
6	20	0.0589	0.0110	0.59	6
7	20	0.0493	0.00907	0.57	11
8	20	0.0263	0.00484	0.51	10

Figure 5.6: mass loss for different composition of TiO_2.

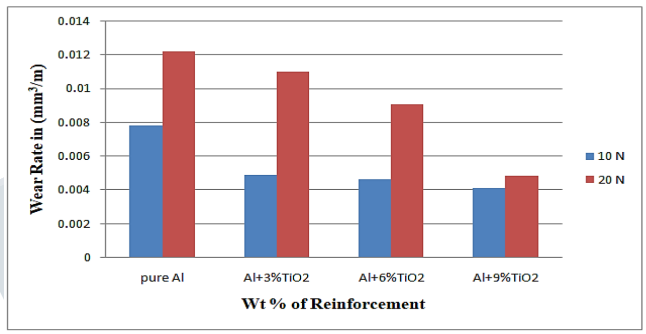

Figure 5.7: wear rate for different composition of TiO_2.

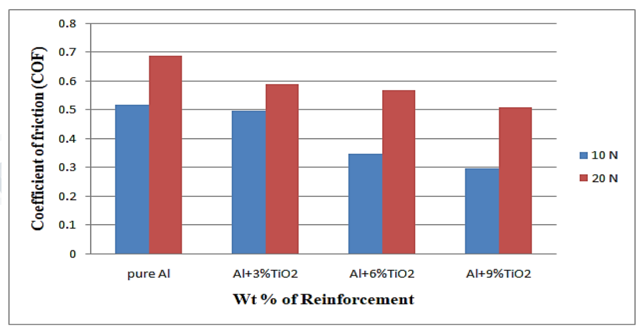

Figure 5.8: coefficient of friction for different composition of TiO_2.

Figure 5.9: frictional force for different composition of TiO_2.

VI. CONCLUSION

The Aluminium-TiO_2 metal matrix composite is prepared by stir casting method by varying the amount of TiO_2 particles. The wear test conducted as per ASTM G99 standard. Composites reinforced with 9% of TiO2 exhibits good wear resistance as compared to other percentage with the increase in composition of 9%. TiO_2 reinforced with aluminium were successfully fabricated. The TiO_2 Particles distribution with Aluminium is confirmed by SEM images.

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