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"Estimation of Wear Rate When TiC Particle is Reinforced With Al-2219 Metal Matrix Composites Fabricated by Stir Casting Technique."

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Abstract –***Aluminium is a preferred alloying element for various particle reinforced composites. It develops strength, wear resistance and hardness and widens freezing range and improves the castability. Growing demand for lightweight materials in automotive and aerospace applications, aluminium based composites and its alloys are increasing attention of the scientific community and the industry. The incorporation of ceramic reinforcements into the Al alloy enhances its load carrying capacity, thereby increasing the load range and wear resistance of the developed composites. Many researchers have conducted extensive research on this topic, opening new perspectives for the application of Al-MMCs in which wear resistance is a concern. The study of the wear behavior of friction materials by***

Al-MMCs has been given particular attention, as these materials can be used in disc brakes in automotive applications. The profit of MMCs from industrial point of view with apprehending improvements in mechanical properties, wear life, corrosion behaviour, fatigue life, environment profits like noise resistance and monetary benefits like easy machinability. The accumulation of reinforcement particulate such as tungsten carbide, silicon carbide, titanium carbide, aluminium oxide, boron carbide and graphite will enhances wear resistance, corrosion resistance and mechanical properties of the base metal.The choice of processing could be made depending on the potential for economic savings from replacement of conventional material by composite for different applications. Casting is one of the most inexpensive methods of producing MMCs and lends itself to the production of large ingots, which can be further worked by extrusion, hot rolling or forging.

In the current work an attempt has been made to know the effect of TiC particles reinforced with Al 2219 Aluminium alloy with Wt. % of 0, 3, 6 and 9 and is produced by means of bottom pour stir casting technique and Microstructure, hardness and tribological behaviour have been assessedaccording to ASTM Standards for the developed Metal Matrix Composites.

Keywords –Wear Resistance, Al2219 Alloy, TiC Particles, Hardness, Stir Casting.

1. INTRODUCTION

Metal matrix composites improves mechanical properties, wear properties, corrosion and damping properties when compared with base materials. At the same time there is a reduction in density of the metal matrix composite. Metal matrix composites (MMC) are progressively becoming eye-catching materials for advanced aerospace, automobile industries due to the light weight, economic cost, easy fabrication and machinability, and ever increasing engineering demands for modern technology. In MMC, Aluminum Metal Matrix Composites (AMMCs) have acknowledged specific consideration over the last three eras because of high specific strength, stiffness and their excellent wear resistance. However, their application is limited since of its low wear resistance. Currently Particle-reinforced aluminum matrix composites is well-thought-out to have higher mechanical and tribological properties than conventional alloys. As such, these composites are widely finds applications in the automotive and aerospace industries. The focus is on developing aluminium MMC at a reasonable price, with numerous hard and soft reinforcements, such as SiC, Al2O3, TiO2, TiC, B4C, Zircon, Tungsten Carbide, Graphite and mica.

MMCs characterise a new generation of engineering materials in which a strong ceramic reinforcement is amalgamated into a metal matrix to enhance the properties which includes specific strength, specific stiffness, wear resistance, corrosion resistance and elastic modulus. Thus, they have significant scientific, technological and commercial importance. During the last decade, because of their improved properties, MMCs are being used extensively for high performance applications such as in aircraft engines and in the automotive industries. Titanium Carbide reinforced aluminium alloy matrix composites are extensively used in the automotive and aircraft industries as engine pistons and cylinder heads, where the tribological properties of these materials are considered important. Therefore, the development of aluminium matrix composites is receiving considerable emphasis in meeting these requirements of various industries. Incorporation of hard second phase particles in the alloy matrices to produce MMCs has also been reported to be more beneficial and economical due to its high specific strength and corrosion resistance properties.

Normally the liquid-phase fabrication method is more efficient than the solid-phase fabrication method because solid-phase processing requires a longer time. The matrix metal is used in various forms in different fabrication methods. Generally, powder is used in pneumatic impaction and the powder metallurgy technique, and a liquid matrix is used in liquid-metal infiltration, plasma spray, spray casting, squeeze casting, pressure casting, gravity casting, stir casting, investment casting, etc. A molecular form of the matrix is used in electroforming; vapor deposition and metal foils are used in diffusion bonding, rolling, extrusion, etc. There are certain main manufacturing processes which are used presently in laboratories as well as in industries are diffusion bonding, the powder metallurgy route, liquid-metal infiltration, squeeze casting, spray co-deposition, stir casting and compo casting.

Stir-casting techniques are currently the simplest and most commercial method of production of MMCs. 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 process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal. Non-homogenous Microstructure can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Non-homogeneity in reinforcement distribution in the cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solid-liquid interface during solidification. This process has major advantage that the production costs of MMCs are very low.

2. LITERATURE SURVEY

Suresh et al. [1] anticipated the mechanical and wear behavior of Al-TiB2 composites synthesized by using high energy stir casting method. The results showed that as the TiB2 Particles increases the Mechanical and Wear properties were also enhanced compared to base material Al 6061. Microstructure study shows the uniform distribution of TiB2 Particles, XRD and EDS results confirm the presence of TiB2 in Al6061 alloy matrix.

S.A. Sajjadi et al [2] in his work disclosed the three-step mixing procedure to improve the wettability and distribution of the reinforcing particles in the matrix. The technique includes heat treating micron and nanoparticles, injecting heat-treated particles into the melted aluminum alloy with inert argon, besides agitating the melt at different speeds with the stirrer. Compared with conventional methods, these techniques recovers the wettability and distribution of the particles in molten aluminum by using thermally treated particles, thereby improving the particle injection and agitation system.

Anand Kumar et al [3] studied the properties of the Al-Cu alloy (2014 aluminum alloy series) as a matrix and reinforced with TiC by means of an in situ route. The percentage growth in yield and tensile strength was recorded to be around 15% and 24%, and the Vickers hardness was improved by almost 35% relative to base metal Al -2014. The higher the hardness value, the more TiC particles contribute to the hardness of the matrix. The fracture surface of the tensile specimen of the composite indicates the occurrence of a dimpled surface, thus signifying a fracture of the ductile type. In the fabrication of composite materials, intermetallic particles such as Al3Ti, Al2Cu and Al3C4 in metal matrix composites are recognized in different shapes and sizes.

Baradeswaran et al. [4] investigated the mechanical and wear properties of Al7075 alloy reinforced with Al2O3 and graphite particulates. The investigation reveals the effect of graphite and alumina particulates on ultimate tensile strength and wear behavior of Al7075 alloy composites. The hardness, tensile strength and compression strength of the Al7075-Al2O3-graphite hybrid composites are found to be increased by increased weight percentage of ceramic particulates. The wear properties of the prepared composites exhibited the superior wear properties compared to Al7075 base matrix alloy.

Suresh et al. [5] predicted the mechanical and wear behavior of Al-TiB2 composites. Al6061 alloy was reinforced with TiB2 particulates by using high energy stir casting method. Characterization of prepared samples was done by using scanning electron microscopy, XRD and energy dispersive spectroscopy. Mechanical properties such as hardness, tensile strength and wear properties were evaluated. XRD and EDS results confirm the presence of TiB2 in Al6061 alloy matrix. Wear resistance of Al6061 alloy was increased by the addition of TiB2 particulates.

Umanath et al. [6] studied the dry sliding wear behavior of Al6061-SiC-Al2O3 hybrid metal matrix composites. The test specimens are prepared and tested as per ASTM standard. The experiments were conducted by using computerized pin-on-disc wear testing machine. The results indicated that the wear resistance of the 15% hybrid composite is better than that of the 5% composites.

G. Baskaran et al [7] studied the wear behaviour of composites synthesized by powder metallurgy with aluminium matrix and TiC and TiO2 as reinforcements. The outcomes shows that the wear rate of composite material obtained by wear test performed at sliding distance of 500m and at load level of 5, 10, 15 and 20N with sliding speeds of 3.14 m/s. For all these combinations the rate of wear is 0.22, 0.24, and 0.27mm respectively, and for sliding distance of 1000m with same level of other input parameter the rate of wear obtained by wear test is 0.23, 0.25, and 0.28 mm respectively, for 1500m sliding distance with same level of other input parameters the rate of wear is 0.24, 0.27, and 0.28mm respectively. From the result it is noted that the sliding distance is the greatest inducing parameter in wear rate of prepared aluminium composite material.

S Raghu et al. [8] studied the wear behaviour of LM0-TiO2 Nano Metal Matrix Composites synthesised by using bottom pouring stir casting furnace. Study shows that as the wt% of Nano TiO2 Particles increases in the composites the wear resistance also increases. it has been observed that as the sliding distance increases the cumulative Volume loss also increases for both varying the speed and by varying the load. The result displayed that as the Speed and Load increases the wear rate also increases. From the results it is concluded that as the nano TiO2 reinforcement increases the wear rate decreases because of the existence of TiO2 nanoparticles which might protect the matrix phases from the counter face caused due to an applied load. The presence of TiO2 nanoparticles on the surface will causes part of the shear strains built up in the subsurface to get relieved.

3. EXPERIMENTAL SET UPS & METHODS

Processing of Al2219-TiC Particulate Composites by Using Bottom Pouring Stir Casting Furnace:

A stir casting furnace cum bottom pouring set-up has been used in this research work for solidification processing of all the different Al2219-TiC composites with a maximum melting capacity of 1 kg. The schematic diagram of the experimental set-up is as shown in Fig. 1.

Fig. 1: Schematic diagram showing experimental set-up for stir casting used for solidification processing of cast composites and unreinforced base alloys.

Approximately 1000g of Al2219 aluminium was melted to a preferred processing temperature in a clay-graphite crucible inside the muffle furnace. Before any addition, the surface of the melt was cleaned by skimming. The weighed amounts of elemental TiC particles were preheated to about 400°C and the rate of addition of particles was controlled at an approximate rate of 0.2-0.3 g/s. A four pitched blade stirrer (45° pitch angle) was used to disperse the TiC particles in the melt. The speed of the stirrer was kept constant at 500 rpm. The temperature of the melt was measured by using a digital temperature indicator connected to a chromel-alumel thermocouple placed at a depth of 15-20 mm inside the melt. During stirring, the temperature of the slurry was maintained within ±10°C of the processing temperature. A magnesium lump of 3 wt% was enclosed in aluminium foil and charged into the melt-particle slurry before the addition of TiC particles. When thepreferred time of the stirring elapsed, the stirrer was stopped and taken out from the crucible. Then, the graphite plug at the bottom of the furnace was removed and the slurry of melt-particle was poured into a pre-heated permanent type mold of split type, having a size of 40x40x 150 mm kept below the plug. The cast composite ingot was immediately cooled by immersion in to water bath.

Titanium Carbide as a Reinforcement Material:

The reinforcement particulate used is titanium carbide powder for the metal matrix composite the particle size of reinforcement material is 50 microns. It is a ceramic particle type having hardness similar to that of the tungsten carbide reinforcement particle. The colour of the particulate is black in colour. In most of the industries for machining of the steel parts at the higher speeds it is used as cermets. With addition of about 30% of the titanium carbide to tungsten carbide material there will be tremendous improvements for the machining tool in terms of wear corrosiveness. It is used as an abrasion-resistant surface coating on metal parts for the tool bits and also for watch mechanism.

Al2219 Alloy as a Matrix Material:

The major alloying elements of the Al2219 are copper. The Al2219 has very good fracture toughness, high corrosion resistance, self-healing capacity, high elevated temperatures.Al2219 applications in many industrial, automotive, Service industry and aerospace research work. The common application are transport applications, marine, rock climbing equipment, bicycle components, in line skating-frames and mobile equipment, and other high stressed parts.

Scanning Electron Microscopy:

Metallography is the study of the microstructure of materials. Analysis of the microstructure of the material determines whether the material has been properly processed and the mechanical properties depend on how the TiC particles are distributed in the composite and therefore constitute a crucial step in determining the reliability of the product and determining the reason for failure of material. Field emission scanning electron microscopy (FE-SEM), Carl Zeiss, German model: Neon 40.

Hardness Testing:

The Brinell hardness test method as used to determine BHN, as defined in ASTM E10, the hardness of prepared nano composites are assessed using ball indenter of diameter 10mm at an applied load of 500kg. The Brinell hardness of the cast composites and cast unreinforced alloys were studied on the samples. The load was applied with a ball indenter for about 180 seconds on a sample and then the diameter of indentation was measured with the help of travelling microscope. For each indentation, an average of two diameters measured perpendicular to each other was used to find the corresponding hardness. On each sample, at least three indentations for hardness measurement were made at different locations and the average of these readings is reported as the hardness value of the material. The formula used to calculate BHN is given by: $BHN = 2P/(D - \sqrt{D^2 - d^2})$.

Where,

P= Load Applied in Kg.

D= Steel Ball Indenter diameter in mm.

d= Impression made by steel ball indenter in mm.

Wear Test

Dry sliding wear tests were carried out as per ASTM–G99, by sliding a cylindrical pin with a flat polished end against a counterface of hardened steel disc under ambient condition using a pin-on-disc machine, Model: TT-10, DUCOM Bangalore, India. The test pin has a diameter of 8 mm and length of 25 mm as shown schematically in Fig. 2. The counterface disc is made of EN-32 steel hardened to 62-65 HRC. Different loads of 9.81 N, 19.62 N and 29.43 N were applied on the pin normal to the sliding contact during wear test of developed composite. The track diameter was kept constant at 120 mm and the rotating speed of the disc was varied from 600 to 800 rpm in steps of 100 rpm. The wear tests were carried out for a total sliding distance of about 2000 m. Prior to wear testing, all the test pin surfaces were polished with 4/0 grade emery paper, so that the surface roughness of the test pin is approximately Ra = 0.4 µm. Both the counterface disc and the test pin were cleaned well by acetone followed by drying under ambient condition. In order to check the reproducibility, the wear tests were replicated thrice. The specimen is fixed in the pin holder and is held against the counter face of a rotating disc with wear track diameter 120mm. The disc can rotate at different speeds, thereby effecting different rates of wear. The pin was loaded against the disc through dead weights of 9.81 N, 19.62 N and 29.43 N, the wear rates were measured. The amount of material lost after rotating the disc for a pre-determined amount of time is given by the indictor on the machine.

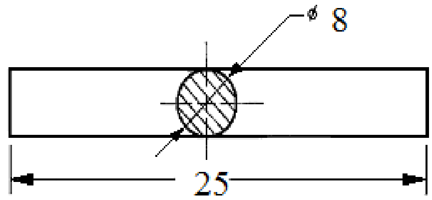
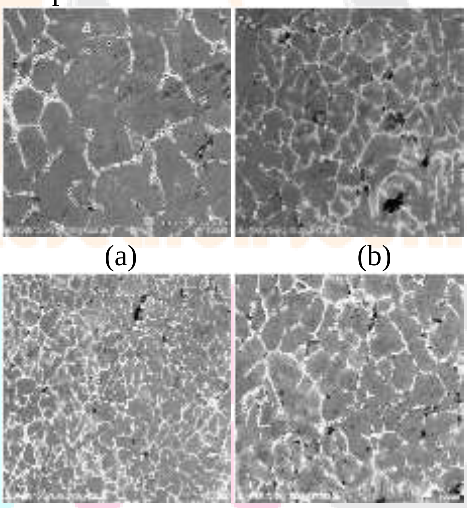


Fig.2: Specimens used in Wear Test.

4. RESULTS & DISCUSSIONS

Microstructure Analysis:

Figure 3 (a) - (d) shows the Scanning Electron Microscope micrographs of as cast Al2219 alloy and its composites. The microstructure clearly shows the uniform distribution of the TiC particles in the developed composites. The porosity was less in the developed composites because of good wettability between the matrix and reinforcement particles which are observed from the SEM images. The dark black areas in the SEM picture indicate to some extent the presence of porosity in the composite. The typical microstructure consists of primary aluminum matrix (dark gray) and TiC particles (black color). The SEM image shows that for the 9 wt. % composite has more clustering and agglomeration than the 3 and 6 Wt. % composites.



(a) (b)

(c) (d)

Fig.3: Showing the SEM microphotographs of (a) as cast Al2219 alloy (b) Al2219-3 wt. % TiC (c) Al2219-6 wt. % TiC (d) Al2219-9 wt. % TiC

Hardness:

The hardness increases gradually as the TiC particles increases in the composites. In fact, the hardness of a composite depends on the hardness of the reinforcement and matrix. The increase in hardness is principally owed to the fact that the coefficient of thermal expansion (CTE) of the ceramic particles is lesser than the coefficient of thermal expansion of the aluminum alloy and because of sudden quenching with water. Therefore, a large quantity of dislocations is produced at the particle-matrix interface during solidification, which further increases the matrix hardness. The greater the amount of particle-matrix interface, the more is the hardening owing to dislocations. The brittle nature of TiC particles increases the hardness in the composites. The hardness value of Al2219 with 3 wt. % TiC is nearly 14% increased as compared with the unreinforced alloy Al-2219, respectively for Al2219 with 6% TiC and Al-2219 with 9% TiC the increase in hardness is 34.2% and 46.4% with Al-2219 alloy.

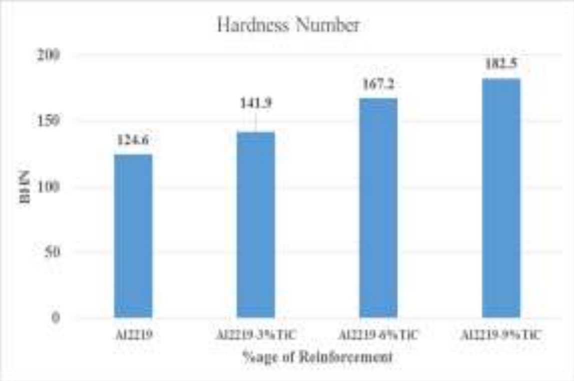


Fig.4: Variation in Hardness of Al2219 with wt. % of TiC particulates Composites.

Wear Properties:

From the results we can see that as the TiC particles increases the wear rate decreases. But as the load increases the wear rate also increases irrespectively of the wt. % of the TiC particle reinforcement. From the wear result we can see that, while the load applied on the pin is increased, the tangible contact area will also increase towards the nominal area which in-turn enhances the frictional force between the pin and steel disc, because of the high frictional force the wear rate also increases.

Table 1 (a) Effect of Load on the Wear Rate for 600 rpm Speed.

Composite Composition	Load in N	Speed in RPM	Sliding Distance in m	Wear Rate in 10^{-8} mm^3/m
Al2219	9.81	600	2000	4.23
	19.62			6.09
	29.43			7.35
3%TiC	9.81			3.78
	19.62			5.84
	29.43			7.01
6%TiC	9.81			3.33
	19.62			5.48
	29.43			6.89
9%TiC	9.81			2.98
	19.62			5.19
	29.43			6.44

Table 1 (b) Effect of Load on the Wear Rate for 700 rpm Speed.

Composite Composition	Load in N	Speed in RPM	Sliding Distance in m	Wear Rate in 10^{-8} mm^3/m
Al2219	9.81	700	2000	4.59
	19.62			6.33
	29.43			7.68
3%TiC	9.81			3.95
	19.62			6.01
	29.43			7.25
6%TiC	9.81			3.54
	19.62			5.65
	29.43			7.04
9%TiC	9.81			3.15
	19.62			5.55
	29.43			6.68

Table 1 (c) Effect of Load on the Wear Rate for 800 rpm Speed.

Composite Composition	Load in N	Speed in RPM	Sliding Distance in m	Wear Rate in 10^{-8} mm^3/m
Al2219	9.81	800	2000	4.85
	19.62			6.67
	29.43			8.01
3%TiC	9.81			4.11
	19.62			6.38
	29.43			7.63
6%TiC	9.81			3.82
	19.62			5.85
	29.43			7.23
9%TiC	9.81			3.51
	19.62			5.88
	29.43			7.01

From the result we can analyze that the wear rate will increase with the rise in the sliding speed and load. This is predominantly owing to growth in heat generation among the composite specimen and steel disc, which in-turn leads to more softening of the matrix owing to the overheating.

It is observed that for a given normal load, the wear rate will also surges linearly with increasing sliding distance as observed in both unreinforced and TiC reinforced particulate composites, representing that Archard's adhesive wear phenomena for the synthesized composites is being followed.

Also it could be seen that wear rate of composites decreased with the addition of TiC particulates into the Al2219 base matrix alloy. The increase in the wear resistance can be attributed to the strengthening of the matrix due to the reinforcement, which results from an increase in the dislocation density as the percentage of reinforcement increases.

5. CONCLUSIONS

i. The microstructure analysis displays that TiC particulate have been uniformly distributed in the composites but care has to be taken for increasing TiC wt. %age to minimize agglomeration and clustering.

ii. The Brinell hardness increases with increase in TiC particles in the composites.

iii. The wear rate decreases gradually as the TiC particle content increases in the composites.

iv. As the Load & Sliding Distance Increases the wear rate also increases.

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