Dry Sliding Wear Behaviour of 2014 Aluminium Alloy Reinforced with Sic Composite

Prashant Mittal
Department of mechanical engineering
M.Tech Student, MANIT Bhopal

Dr. Gajendra Dixit
Department of mechanical engineering
Professor MANIT Bhopal

Abstract-**The objective of this paper is to evaluate the sliding wear rate and microstructural observations of Sic particulate reinforced Al matrix composites as a function of volume of SiC. The gradient in wear behaviour as a function of infiltration length was evaluated using a pin-on-ring device varying load and sliding speed. Towards this purpose, aluminium with 10 & 20 vol.% of Sic and Al, in the form of pins, have been wear tested against a hardened steel disc(EN31 steel disc hardened to 60HRc, grounded to 1.6Ra surface roughness) at different test loads (20N,30N,50N & 70N) and with different sliding velocities (1m/s,3m/s,5m/s & 7m/s). The results indicate that while the wear rate of Al-SIC decreases with increasing fraction of SiC, the corresponding effect on coefficient of friction is only marginal. An addition of even 10% Sic to Al, is shown to prevent the transition from mild to severe wear in the load range used in the present experiments.**

Experiments have been conducted under laboratory condition to assess the wear characteristics of the aluminium SiC composite using a pin-on disc wear test apparatus at different loads, speeds and constant sliding distances and track diameter under dry condition. The worn surfaces of the wear out samples were studied under SEM to get an idea about the effect of particulate reinforcement on the wear behaviour of the composite.

Keywords :- Wear , microstructures , SEM, Composite

I. INTRODUCTION

Interest in aluminium based metal matrix composites (MMCs) continues to grow, especially from the transport industries, where component weight reduction is a key objective [1,2,3]. Since the 1980s there had been extensive investigation of aluminium MMCs reinforced with hard ceramic phases, such as Al2O3 or SiC, in an effort to understand and improve the tribological properties of aluminium [4–15]. Whilst to an extent this has been successful, some authors [4,6,9,12,17] have noted that a critical load exists during dry sliding, above which a ceramic based composite offers little improvement in wear resistance compared to an un-reinforced sample. Indeed, others [6,9–11,18] have found.

Particulate reinforced aluminium alloy composites are currently being considered for a number of engineering applications requiring improved strength, modulus and wear resistance compared to their unr**einforced'matrix** counterparts [2]. In terms of the tribological behaviour of Al alloy MMCs, their resistance to both dry and lubricated sliding wear [3-18], has been investigated

B. Venkataraman and G. Sundararajan [32]assess the sliding wear rate and the coefficient of friction of Al matrix SiC reinforced composites as a function of volume of SiC. For this purpose, aluminium with 10, 20, 30 and 40 vol. % of volume fraction of SiC and Aluminium in the size and shape of pins, have been experimentally wear tested against a hardened steel disc at two test applied loads (52 and 122 N) and one sliding velocity (1 m/s).They concluded that the resistance to wear of Al matrix, SiC particulate reinforced composites are better than that of Al. Their resistance to wear increases with increasing volume fraction percentage of Silicon Carbide. On the other hand Satyappa Basavarajappa et.al [33] investigate the wear behaviour of as cast aluminium alloy, reinforced with Silicon Carbide particles and with Silicon Carbide particle–Graphite manufactured by liquid metallurgy route. They concluded that a rate of wear of the Graphite composite is lower than that of the matrix alloy and SiC particle reinforced composite. The rate of wear has been enhanced with the increasing load and decreased with increasing speed up to 4.6 m/s and then increased. M. Singh et.al investigate the consequence of reinforcement of granite on the dry sliding wear behaviour of an aluminium–silicon alloy.

Sliding wear tests were carried out at applied loads and with variation of speeds. They concluded that the composite's rate of wear was less than that of the matrix alloy. The rate of wear increased with applied pressure whereas speed had a mixed effect on rate of wear. Also Manoj Singla et.al. [34] Investigated the wear and friction characteristics of Al–SiC composites under dry sliding conditions and compared with by pure aluminium observations results. Dry sliding wear tests have been conducted using pin-on-disk wear test rate at different normal loads and at constant sliding velocity. They observe that sliding distance has been found to be linear for both pure aluminium and the composites with collective wear loss. M.Ramachandra and K. Radhakrishna [35] studied that aluminium based metal matrix composite containing up to 15% weight percentage of Silicon carbide particles are synthesized using stir-cast method. Friction and wear behaviour is examined by using computerized pin on disc wear testing machine. Wear resistance and hardness has increased with increase in SiC particles. However with increase in normal load and sliding velocity wear has increased.

A general conclusion that can be drawn on the basis of these tests is that as long as the interface between the particulate and the matrix is reasonably strong, the wear rates of the composites are lower than their matrix counterparts.

In spite of the extensive data already available on the dry sliding wear behaviour of Al alloy particulate composites, there is a real need for further study for the following

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

reasons.Study on the effect of volume fraction of the particulate reinforcement in an Al composite on its friction and wear behavior is not yet available. Zam Zam [8] has obtained wear data on Al and Al matrix composites reinforced with Sic particulates upto 40 vol.% However, the coefficient of friction was not monitored in these tests and the main focus of the work was on studying the effect of load, speed and vol conc. of SiC on wear behavior[18-25]. Most of the work carried out earlier has been with Al alloy matrix composites and invariably the composite has been tested in the aged condition. Thus, the strength/hardness of these composites was not only due to particulate reinforcement, but also due to precipitation hardening and solid solution strengthening. In addition, it is well known that precipitation hardening and particulate strengthening interact in a synergistic fashion [22]. Thus, the use of Al alloy based composites, precludes the study of particulate reinforcement on friction and wears behavior. A complete understanding of the deformation and fracture micro mechanisms of the particulate composites under sliding wear conditions\leading to the generation of wear debris is still lacking though some attempts have been recently made in that direction [10].
The objective of this paper is to fulfill may be partially, the above needs. For this purpose 2014 Al matrix composites reinforced with different vol.% of SiC particulates of average size 2.5 micrometer have been chosen as the test material. The friction and wear behaviour of the composites and 2014 Al have been obtained at different test loads along with different sliding speed but with constant track diameter and sliding distance. [26-31]

II.EXPERIMENTAL PROCEDURE

2.1 Materials:

2.1.1 Matrix material

In the present study well known alloy 2014Al is used as matrix material and high puritySilicon Carbide (SiC) as reinforcement. 2014 alloy was found in the form of ingots. The compositional examination of the 2014 Al alloy was done by wet chemical analysis which is given in Table 2.1

Materials	Composition
Aluminium	93.5 %
Copper	4 %
Manganese	1 %
Magnesium	1 %

Table 2.1 Composition (2014 alloy) [36]

2.1.2Reinforcement material

Silicon carbide (SiC) particles were used as reinforcement material. Particle size of as received reinforcement was in the range between 50-200 μm. The reinforcement particle were ball milled to lessen the size and by sieving requisite particle size 20-32 μm were selected for the experimentation.

2.2Preparation of the composite

A graphical representation of stir casting setup as shown in Figure2.1 Consists of a resistance Muffle Furnace and a stirrer assembly, was used to yield the composite. The stirrer assembly comprised of a graphite stirrer, which was coupled to a variable speed vertical drilling machine with range of 80 to 890 rpm through a steel shaft. The stirrer was manufactured by cutting and shaping a graphite block to preferred shape and size manually. The stirrer comprised of three blades at an angle of 120° apart. Crucible made of Clay graphite of 1.5 Kg capacity was placed inside the furnace. About 1Kg of alloy in solid form (hexagonal rod) was melted at 820°C in the resistance furnace. Preheating of reinforcement (Silicon carbide) was done for one hour to eliminate moisture and gases from the surface of the particulates. The reinforcement particles were separated by sieve shaker. The stirrer was then dropped vertically up to 3 cm from the bottom end of the crucible (the total height of the melt was 9 cm). The speed of the stirrer was progressively elevated to 800 rpm and the preheated reinforced (SiC) particles were progressively added with a spoon at the rate of 10- 20g/min into the melt [37, 38].
The speed controller kept a constant speed of the stirrer, since the stirrer speed decreases by 50 -60 rpm due to the increase in viscosity of the melt when particulates were added in the melt. After reinforcement addition, stirring was sustained for 8 to 12 minutes for proper mixing of prepared particles in the matrix. The melt was kept in the crucible nearly for half minute in static condition and then it was transferred in the mould as shown in fig 2.2. Cylindrical samples of 8mm diameter and 30mm height are machined from the as-cast Al-SiC ingot in the lathe machine for sliding wear test .Test samples were obtained from those cylindrical pieces by polishing them.

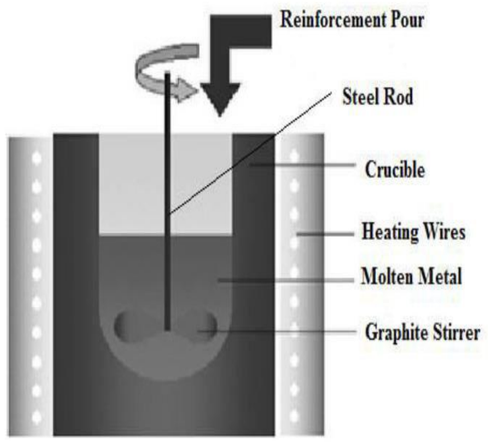


Figure 2.1- Graphical representation of Stir Casting

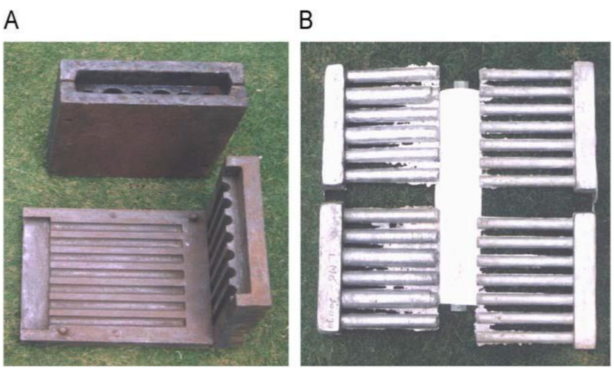


Fig 2.2 Photographs of(a)metallic die for finger casting and(b) finger castings

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016

The flowchart of processing of Al-Matrix Composite has been shown in figure 2.3

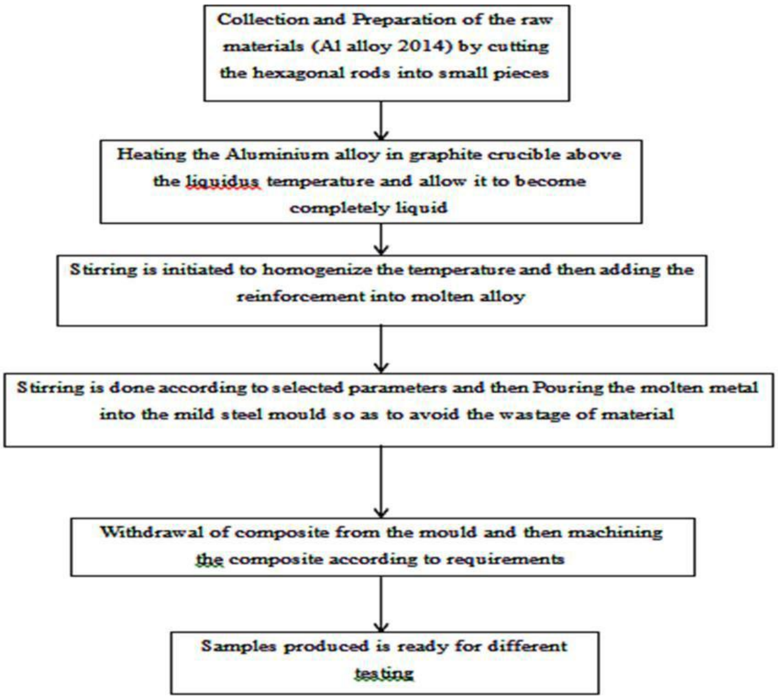


Fig 2.3 Processing Route of Al-SiC Composite

III. WEAR TESTING

3.1 Sliding Wear Test Apparatus

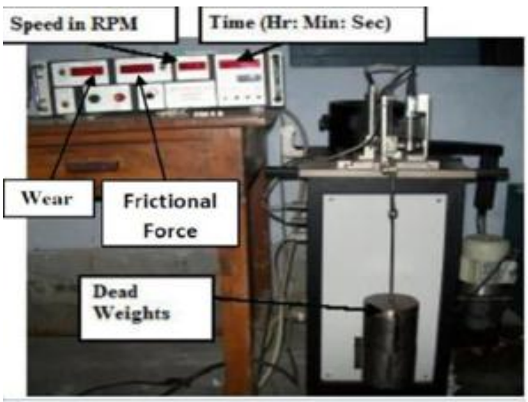


Fig 3.1 Ducom Wear And Friction Monitor

Ducom Wear and Friction Monitor

The machine consists of a pin on disc , loading panel and controller. The sample is put in that hole and screwed with a pin. For rotation of the disc to take place,time period of revolution is set up initially in the control panel. The wear is shown in the monitor in micrometer. The frictional force is shown in KN. The machine is automatically stopped when the given time period is reached

3.1.1 Operating Parameters

The variables involved in wear test are:

- % Si in the Al-Si alloy
- Normal load
- Sliding velocity
- Sliding distance

3.2 Wear Test Procedure

The pin was placed against the counter face of a rotating disc (EN31 steel disc hardened to 60HRc, ground to 1.6Ra surface roughness) with wear track diameter 80mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal loads of 2kg, 3kg, 5kg and 7 kg and with a varying sliding velocity of 1m/s,3m/s,5m/s and 7m/s . Wear tests were carried out for a total sliding distance of approximately 1200 m under analogous conditions as discussed above. The pin samples were 30 mm in length and 8 mm in diameter. The surfaces of the pin samples was rubbed using emery paper (80 grit size) preceding to test in ordered to make sure effective contact of fresh and flat surface with the steel disc. The samples and wear track were cleaned with acetone and deliberated up to an accuracy of 0.0001 gm. using microbalance (Fig 4.13) prior to and after each test. The wear rate was calculated from the height loss technique and articulated in terms of wear volume loss per unit sliding distance.

3.3 SEM examination

The casting procedure was observed under the Scanning Electron Microscope to conclude the reinforcement pattern and structure of the cast. A section was cut out from the castings. They were polished using 100 grit emery paper followed by 220, 400, 600 ,800, 1000,1200,1500 and finally with 2000 grades of emery paper with Alumina paste . Before optical observation the samples were mechanically polished and etched by Keller‟s reagent to acquire better contrast.

IV. RESULTS & DISCUSSION

4.1 Hardness and Density

Rockwell hardness tester (model TRSND, fine manufacturing Industries India) machine by using ball 1/16 inch ball indenter is used to determine hardness. Before each hardness test series, the specimens, which were of diameter 8mm were metallographically polished with a 240 grit SiC paper till the oxide layer was removed and the opposite sides were flawlessly parallel. Load used on Rockwell hardness tester was 100kg with dwell time 20 seconds for each sample. The densities of the Al2014 alloy, Al2014/10%SiC and Al2014/20%SiC composite were measured using Archimedes principle of water displacement

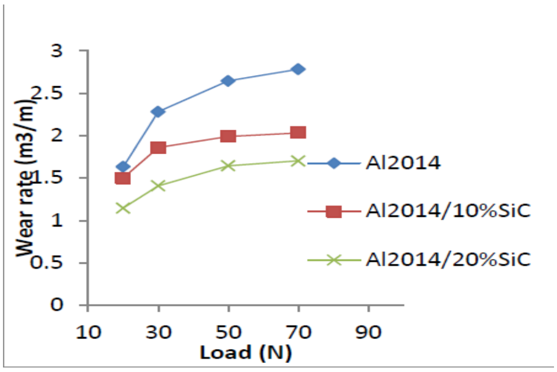
The result of Rockwell hardness test and density for alloy 2014 without reinforcement and the wt .% variation of Different reinforcements Of SiC, , in Al alloy 2014 MMCs are shown in Table

ALLOY	SiC%	Density	Hardness
2014 Al	0%	2.715	80.8
2014 Al	10%	2.74	83.6
2014 Al	20%	2.76	85.8

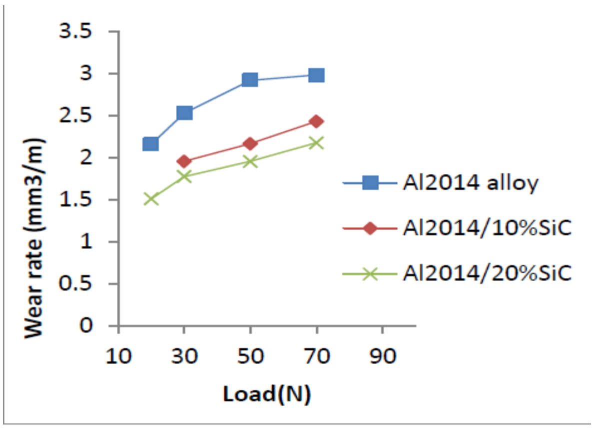
Table 4.1 Hardness and Density of 2014 Al Alloy with Vol% of SiC

4.2 Wear Test Results

4.2.1 Variation of wear rate of 2014Al alloy and Al2014/SiC composite with load (Sliding distance 1200m., track diameter 80m)



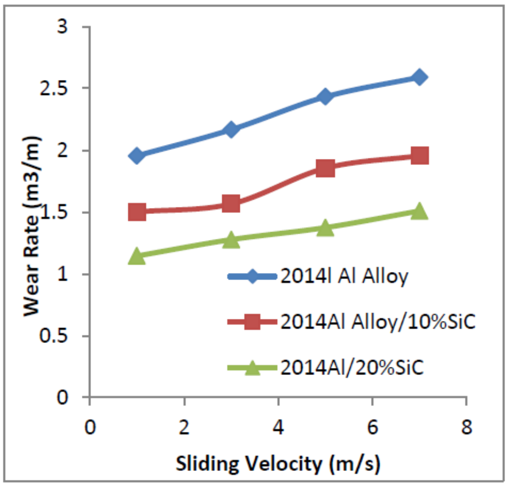
(a)



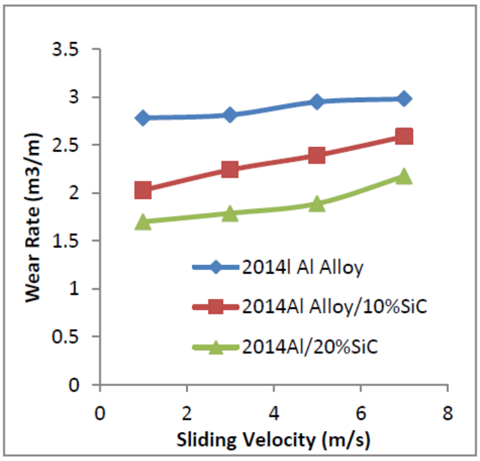
(b)

Figure shows the variation of wear rate with Load for the Al alloy 2014 and composites reinforced with Silicon Carbide at different loads and at constant sliding distance , sliding velocity and track dia of 1200m , 1m/s and 7m/s and 80m respectively. The wear rates of the composite did not increase linearly through the complete applied load range. The wear rate curves illustrates that the change of wear volume with Load is in the form of polynomial function. The wear rate increases as the load increases and also wear rate decreases at SiC % composition increases at constant sliding velocity.

4.2.2 Variation of wear rate of Al2014 alloy andAl2014/SiC composite with sliding velocity (Sliding distance1200m., track dia 80m)



(a) Load 20 N



(b) Load 70N

Figure shows the deviation of rate of wear with Sliding Velocity reinforced with Silicon Carbide at constant sliding distance, load and track dia of 1200m, 20N and 70N and 80m respectively. It is observed that wear rates of the composite did not increase linearly through the applied sliding velocity. The wear rate curves show that the change of wear volume with Sliding Speed is in the form of polynomial function. . The wear rate increases as the sliding velocity increases and also wear rate decreases at SiC % composition increases at constant applied load.

4.3 Microstrucuture Characterization

Microstructure was envisioned with the help of Scanning Electron Microscope. For the specimen preparation, first of all specimen were cut down into small cylindrical pins shapes. Afterwards the different samples were grinded on different grit size papers consecutively by 100, 220, 400, 600 and 1000. Subsequently after grinding, the specimens were polished mechanically by alumina paste and then etched by kellar's reagent to attain better contrast. The

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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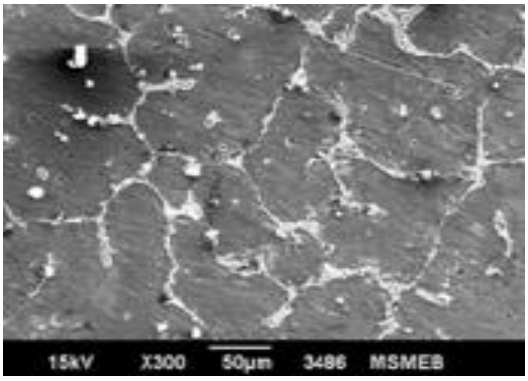
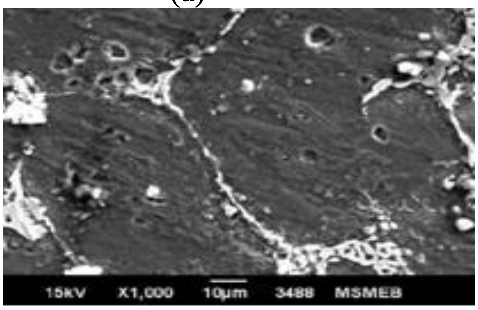
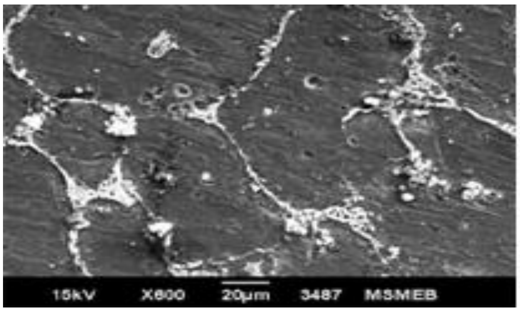
cleaned, dried and etched specimens is prepared and then mounted on specially designed aluminium stubs using (holder). The specimens thus mounted were observed under Jeol, JSM 6390A analytical electron microscope at an accelerating voltage of 15 kV. Figure illustrates the SEM micrograph of Al2014 alloy and it different Aluminium matrix composites at different magnifications (300X, 600X and 1000X)



(a)

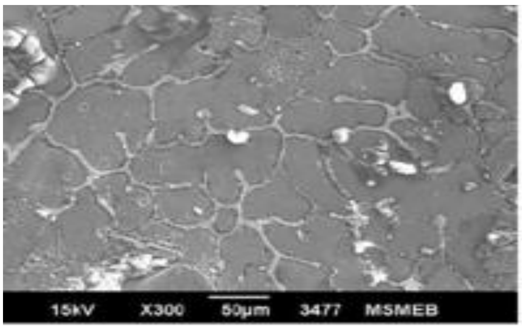


(b)

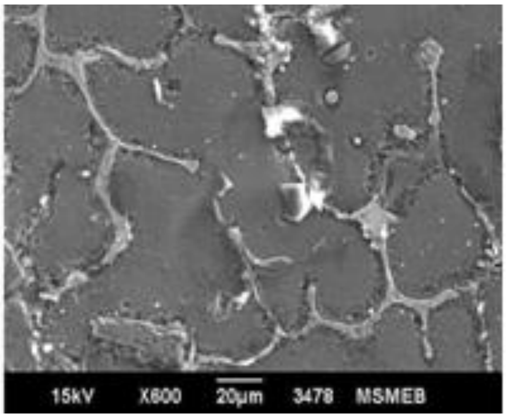


(c)

Fig 4.1 SEM of Al2014 at (a) 300X, (b) 600X, (c) 1000X



(a)



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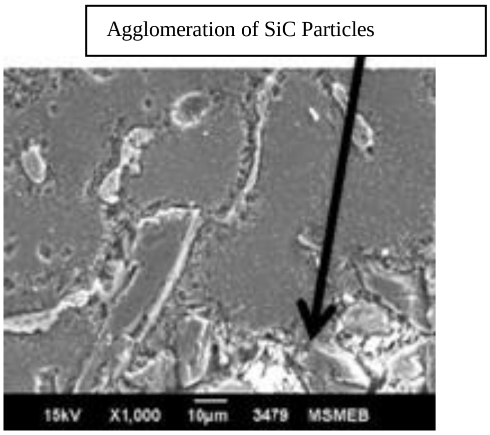
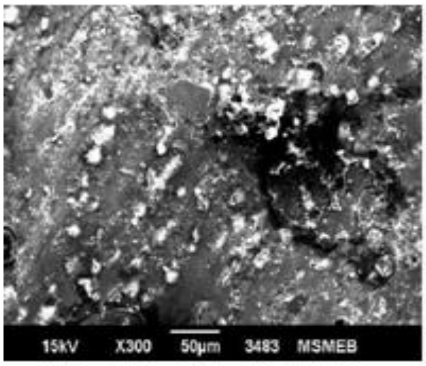
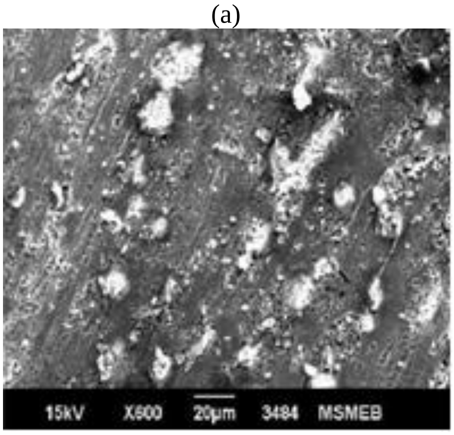


(c)

Figure 4.2- SEM of MMC with 10 wt. % SiC at (a) 300X, (b) 600X, (c) 1000X



(a)



(b)

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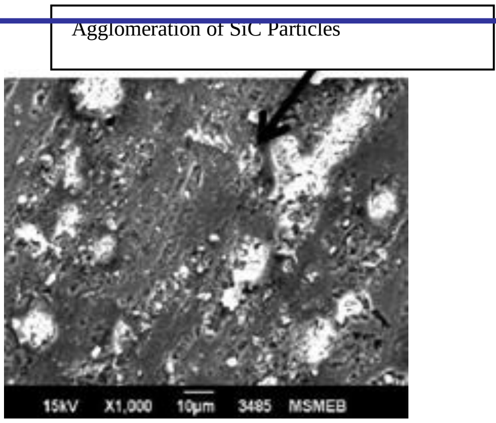
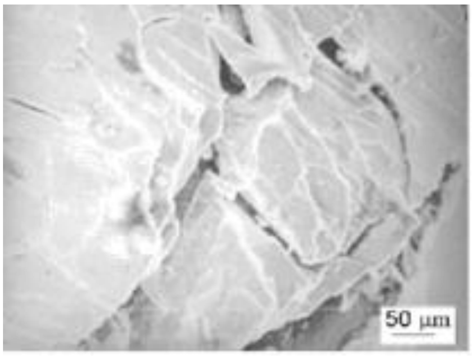
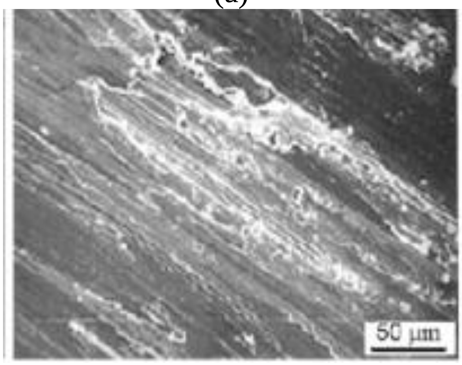
ISSN: 2278-0181
Vol. 5 Issue 06, June-2016



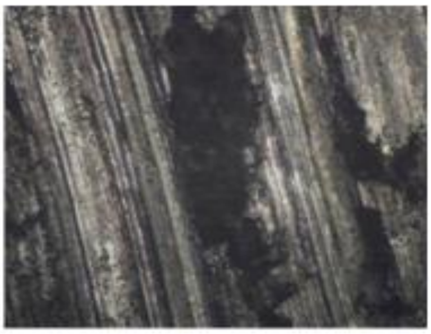
(c)
Figure 4.3- SEM of MMC with 20 wt. % SiC at (a) 300X, (b) 600X, (c) 1000X,



(a)



(b)



(c)

Fig 4.4 SEM of wear surface of Al2014 Al Alloy, Al2014/ 10% SiC and Al2014/20%SiC at 50N and 7m/s Sliding Velocity

Figure 4.1-4.3shows the regular distribution of SiC reinforced particles in alloy matrix. Homogeneous distribution of particles is desired for accomplishing better wear behaviour and mechanical properties settling. However, agglomeration of particles in some regions is clearly noticeable in all cases; this is due to the presence of porosity .The structures of the worn surfaces are greatly dependent on sliding speed, load and hardness of particles (reinforcement). Comparing worn surface figures 4.4 it can be visualized that one of the common features observed in all three MMCs, i.e. the formation of grooves and ridges running parallel to the sliding direction

V.CONCLUSIONS

The unlubricated slidingwear of 2014 Al alloy and stir cast 2014 Al–SiCp processed with different sliding speeds and loads under constant track diameter and sliding distance was studied by pin-on-ring tests using EN-31 steel (hardened to 60HRc, ground to 1.6Ra surface roughness) as counterbody. The following conclusions can be stated:

1. Aluminium based MMC’s have been effectively fabricated by stir casting technique with fairly even distribution, Silicon carbide particulates.
2. For manufacturing of composite by stir casting process, stirrer design and position, stirring velocity and time, particles preheating temperature, particles incorporation rate etc. are the significant process parameters.
3. The results established that stir formed Al alloy 2014 with SiC reinforced composites is clearly superior to base Al alloy 2014 in the comparison of hardness i.e. the hardness increases after dispersion of SiC particles in the matrix. Though, supplementary increase in the hardness has been observed with increasing quantity of SiC in the Al 2014 alloy.
4. The results established that stir formed Al alloy 2014 with SiC reinforced composites is clearly superior to base Al alloy 2014 in the comparison to density i.e. the density increases after dispersion of SiC particles in the matrix. However, further increase in the density has been observed with increasing amount of SiC in the Al 2014 alloy.
5. Dispersion of SiC particles in aluminium matrix develops the resistance to wear of the composites. In other words we can say that the sliding wear behaviour of Al-SiC particle material enjoys superior sliding wear sustainability than that of Al 2014 alloy.
6. It is establish that wear rate tends to decrease with increasing particles wt. percentage (10%-20%), which confirms that silicon carbide addition is advantageous for reducing the wear rate of MMCs.
7. From this study it appears that , the wear rate trend starts decreasing with increase in weight percentage of SiC
8. It is also establish that wear rate trend increases with increase in sliding speed at constant applied load
9. From this thorough study it is evident that wear rate trend increases with increase in applied load at constant sliding speed.

10. It is discovered from SEM images that at some places voids have been occurred before wearing. Also Agglomeration of particles in some regions is clearly noticeable in all cases; this is due to the presence of porosity associated to it.

VI. ACKNOWLEDGEMENT

Author is extremely thankful to research" Prof. Guide Dr.Gajendra Dixit," Maulana Azad National Institute of Technlogy, Bhopalfor consistence inspiration and his valuable support..Iam very thankful to Dr.Appu.Kuttan.K.K Director, MANIT, Bhopal, for their blessings and encouragement. I am also thankful to Dr. Geeta Agmihotri, Dean (Academic) and Dr. Siraj Ahmed HOD (Mechanical Department) for providing all facilities that were needed for this cause

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