Dry sliding wear behavior of Powder Metallurgy Al 2014 Hybrid composite

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Abstract - Aluminium alloys have been used in the main airframe materials in aerospace industry and also in other industries of specific applications. The attractiveness of aluminium is that it is a low cost, light-weight metal. Alloying elements such as to the Copper, Mg, Tungsten, Boron Carbide, Sic and Graphite with Aluminium Alloy 2014 make the alloy with improved properties and can be applicable in various engineering applications.

In view of this it is proposed to manufacture the Al 2014 hybrid composite by adding the Silicon carbide of varying 6%, 8%, 10% and 2% Graphite constant through-out in the form of powders by using powder metallurgy process. Process consist of three steps blending of powders, consolidation of powders to the green compact and sintering at a temperature below the melting point of material and further finishing process. There after the prepared samples were examined for quality analysis through EDAX and SEM was performed for composition analysis. In addition to that on the prepared samples wear test have been conducted and the results are discussed and compared.

Keywords: ***Aluminium, Graphite, Hardness test, Powder metallurgy, Sintering, Silicon carbide, SEM images, Wear behavior.***

I. INTRODUCTION

Aluminium alloy composites which have become the most widely usage for the better combinations of properties such as stiffness, hardness, strength, thermal and electrical conductivity, and wear resistance. And alloy is mostly for its low density and its ability to resist corrosion. Aluminum 2014 alloy is an aluminum-based alloy it is the second popular of the 2000-series aluminum alloys, after 2024 series aluminum alloy. Which is used in an aerospace industry and also it is machined easily in certain heat treatment condition, and it is the strongest aluminum alloys, and has high hardness. But, it is difficult to weld. The present experimental investigations are on Al components. The effect of SiC in Al-SiC alloys proven better wear resistance, lower density and co efficient of thermal expansion, improved specific strength and stiffness compared to base Aluminium. The current scenario is demanding wear resistance along with high specific strength and stiffness. With all the variations in parameters with the AMC an emerged a wide range of wear resistive material. Based on the importance of this material and metal matrix composite this project is proposed to investigate the properties of Al2014-SiC-Gr i.e. hybrid composite which is prepared by powder metallurgy method. And the results are proposed to validate by using experimentation results.

In this project the materials used are Aluminium 2014 series and composites used are graphite and silicon carbide in the form of powders. And the metal matrix composites are prepared by powder metallurgy process by which adding silicon carbide powder and graphite powder by varying the weight percentage. In which the graphite of 2% is being kept constant and silicon carbide varied by 6%, 8% and 10%.

Wear is the phenomenon of material removal from a surface due to interaction with a mating surface and when a mechanical action is exerted. Mostly all machines lose the durability and reliability due to wear loss, and the possibilities of advanced machines are reduced because of wear problems. Mechanical wear plays a major part in a machines low performance in industry. It is a process which occurs when the surface of engineering components are loaded together and are subjected to sliding and rolling motion. Due to utilization and equipments, the reduction takes place in the dimension of parts slowly and continuously as the change in shape and surface finishing is known as Wear. It is progressive loss of material from the surface of a solid body caused by mechanical action.

From the references available, it is evident that many attempts had made to understand and predict the behaviors of materials that include the study of tribology and its evolution, the response of metal matrix composites to reduce wear rate, and to improve the properties correlation to its mechanical properties and possible application.

Ch.Mohana Rao [1] in this paper he stated and focuses on abrasive wear behavior of Al 6061 composites. The Al6061-T6 sheet which is fabricated after friction stir process with TiB_2 is subjected to abrasive testing

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performed on pin-on-disc. By adding TiB_2 in to the metal which leads to increase in wear resistance has been observed.

A. Pramanik [3] investigated the effects of load, sliding speed and longtime continuous friction on the friction and wear properties of Al−5% Si−Al_2O_3 composites. Experimental the materials were 6061 A1 matrix alloy and its composites reinforced by 10% angular shaped Al_2O_3 particles. Both of the materials were first direct chill cast and then hot-extruded. Which results reveal the roles of the reinforcement particles on the wear resistance for a better control of their wear and also found that with the increase of load, wear loss and coefficient of friction increased.

C.Antony vasantha kumar [9] in which he investigated processing of samples to carry through the wear study, the following composites were prepared: 1) Pure Al, 2) Al/15%SiC, 3) Al/15%SiC/ 4%TiO_2, 4) Al/15%SiC/8%TiO_2, 5) Al/15%SiC/ 12%TiO_2. The proposed composite samples were manufactured using powder metallurgy technique. Mixing powders with the support of rolling steel balls reduce agglomeration of particles. Powders were cold compacted at 800 MPa. The green compacts were sintered at 650 °C in an electric muffle furnace for 2h as hinted by YUSUF [4].

For this reason many attempts are made by varying the parameters, operation conditions and reinforce materials used.

II. Preparation of Samples

Samples were prepared by using powder metallurgy process in which the steps involved are blending of powders, consolidation of powders and sintering process.

Mixing of Powders: Initially the preparation of parts by using powder metallurgy process is blending; In which the powders are measured according to the weight percentage by using digital weighing machine and in which silicon carbide is added by varying the composition percentage of 6%, 8% and 10% and the graphite powder of 2% is being kept constant and added to alluminium 2014 powder the weight percentage is measured by considering the die dimensions used for compaction is diameter of 24 mm and length of 45 mm. The mixing of powders is been carried out in a planetary mixer finely till the size of powders is reduced. The powder is filled completely inside die without dropping powders with the help of funnel and then again the plunger is placed after the die is filled with powders. Dimensions of die are 24 mm diameter; 45 mm length.

Compaction or consolidation of powders: And the dies filled with required powders are compacted under the force required to compact the specimen. The die is placed on the UTM machine fig (2a) between the two jaws of UTM machine and the force of 3000 Kgf of force is applied which the maximum force required for the specimen to be compacted and for all the specimens the force used is constant and the time duration taken to compact each specimen is about 15 minutes with the support of both plungers the powders get compacted and the volume of specimen is reduced and the density increases specimen after compaction is called as green compact as shown in fig 2b

Figure 2a Universal tensile machine (For compaction)

Figure 2b Compacted specimen (green compact)

Sintering: The specimens after compaction is called green compact i.e. half finished part only for strength and bonding purpose sintering is been proceeded. Sintering is a heat treatment process and shaping process which does not have to reach the melting point of the base material. It is required to obtain strength and integrity of the compacted specimens. Before sintering process to be carried the specimens are coated with the aluminum paint and kept for drying in the atmosphere and the purpose of coating is because the temperature in a furnace should not directly exposed on the specimens by happening of this the cracks may be formed inside the specimen.

Figure 2c Muffle furnace is used for sintering

And the furnace used for sintering process is Muffle furnace shown in fig (2c) and the temperature is made to setup till 500ºC. Specimen placed inside the furnace after heating it is kept for cooling for a day. Mostly sintering

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process is used in powder metallurgy and ceramics. Sintering temperature is taken as 70% to 90% of melting temperature of metal. And due to which particles form into mass and strengthens voids are reduce and the bonding between each particle is enhanced and melting occurs in between each particle. The specimen after powder metallurgy process that is after sintering image is shown in fig (2d).

Figure 2d Specimens obtained by powder metallurgy process

And the levels and parameters used for the wear test are mentioned below table no.2.

Table no. 1 Parameter used for wear test

And the levels are;

(1)Al 2014+2%Graphite+6%SiC

(2)Al 2014+2%Graphite+8%SiC

(3)Al 2014+2%Graphite+10%SiC

Parameters	**Units**	**Level 1**	**Level 2**	**Level 3**
Load	N	3	6	9
Sliding velocity	RPM	400	500	600
Composition Percentage(SiC)	Wt %	6%	8%	9%

III. EXPERIMENTAL WORK

Preparation of samples for wear test: For the preparation of specimens the wire-cut EDM machine is used to obtain required dimensions to proceed further for the wear test. For which the specimens are fixed in the jaws of machine and the brass wire is cut through the work piece about 8 mm diameter and 30 mm length fig (3a) are the specimens obtained by wire-cut EDM process and further used for the wear test.

Figure 3a Pins obtained from wire cut EDM and used further for wear test

The experiments are repeated and conducted for all the specimens for wear test.

Figure 3b Pin-on-disc machine

Wear test are being carried out on pin-on-disc machine shown in fig (3b) to know the wear performance and to study the mechanism of wear. Dry sliding wear tests for different number of specimens i.e. 27 experiments were conducted by using pin-on-disc wear testing machine, from which the wear path is described by the machine from the digital board on the machine. The pins of 8 mm diameter and 30 mm length are fixed in a chuck against the disc through a dead weight loading. And the disc is of material steel EN 31. The machine is used to evaluate the wear and frictional force properties of materials under dry sliding conditions.

Initially, the surfaces of the pins are made flat by using emery paper such that it can support the load. And in first step the pin is fixed in the chuck and then loads.

The second step is in which the track diameter or sliding distance is kept constant of 60 mm. And then the time duration is being kept constant and adjusted about 5 minutes and also the speed.

In the third step the machine is switched on and the readings from the display of the machine are noted after the 5 minutes of duration the machine is stopped and the experiments are repeated for all the specimens.

Below mentioned is an Experimentation table:

S.No.	Load(N)	Sliding velocity(RPM)	Wear(μm)	Friction force(N)
1	30	400	57	26
2	40	400	78	32
3	50	400	111	35.3
4	30	500	67	28
5	40	500	90	36.5
6	50	500	117	38.3
7	30	600	110	32
8	40	600	125	41.9
9	50	600	180	46.2

Table no. 2.1 Experimentation table value for 6% SiC

S.No.	Load(N)	Sliding velocity(RPM)	Wear(μm)	Friction force(N)
1	30	400	55	24.1
2	40	400	74	30.1
3	50	400	103	33
4	30	500	64	25

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5	40	500	83	32
6	50	500	105	38
7	30	600	73	26.8
8	40	600	97	34
9	50	600	124	40

Table no. 2.2 Experimentation table value of 8%SiC

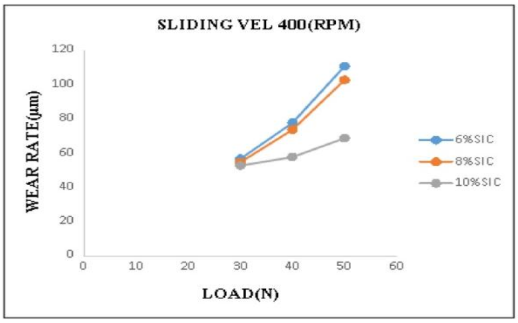
S.No.	Load(N)	Sliding velocity(RPM)	Wear(μm)	Friction force(N)
1	30	400	53	20.1
2	40	400	58	29.3
3	50	400	69	31.2
4	30	500	60	22.7
5	40	500	80	30
6	50	500	99	33.3
7	30	600	70	23.8
8	40	600	94	31.5
9	50	600	119	36.3

Table no. 2.3 Experimentation table value for 10% SiC

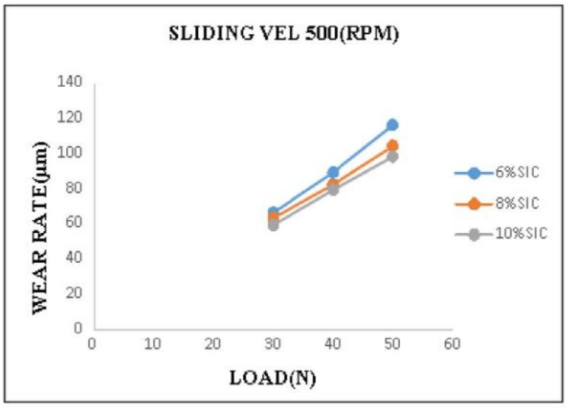
IV. RESULTS AND DISCUSSION

The below graphs plotted are shows the wear rate and friction force of all the three levels 6% (wt), 8% (wt) and 10% (wt) SiC with varying loads, speed and composition.

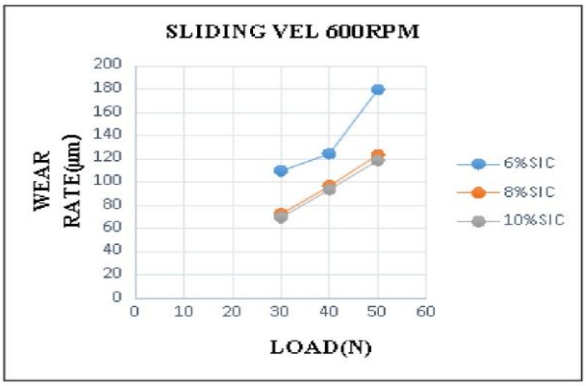
(1) Effect of load on wear rate of aluminum 2014 alloy binary composite at different sliding velocity fig 4.1(a, b, c).



(a)

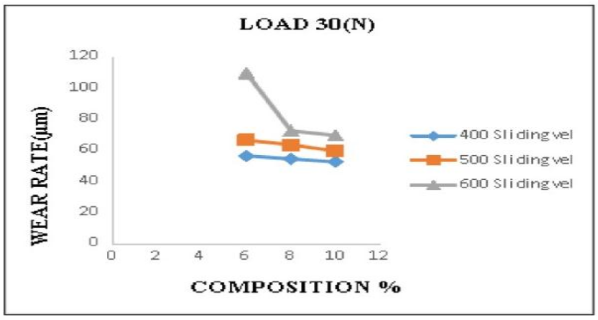


(b)

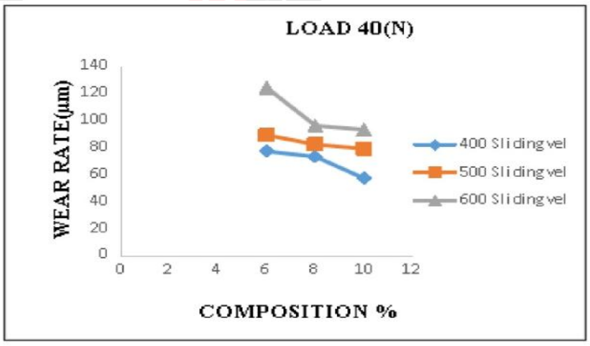


(c)

(2) Effect of wear rate on composition percentages of Silicon Carbide of aluminum 2014 alloy binary composite at different loads fig 4.2(a, b, c).



(a)



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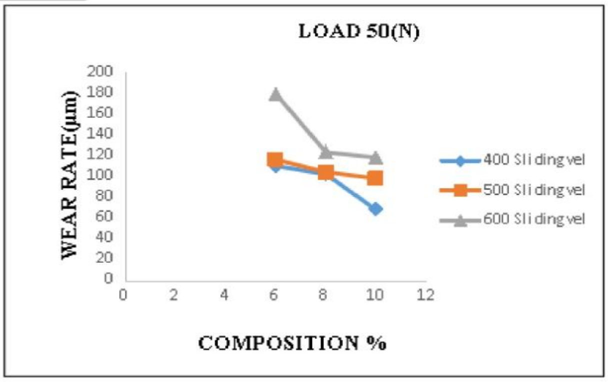

(c)

(3) Effect of wear rate on sliding velocity of aluminum 2014 alloy binary composite at different loads fig 4.3(a, b, c).

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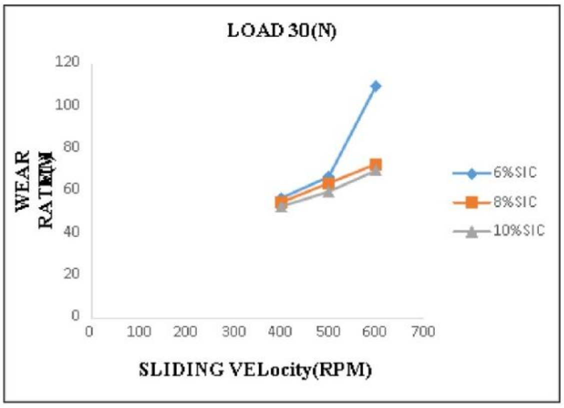
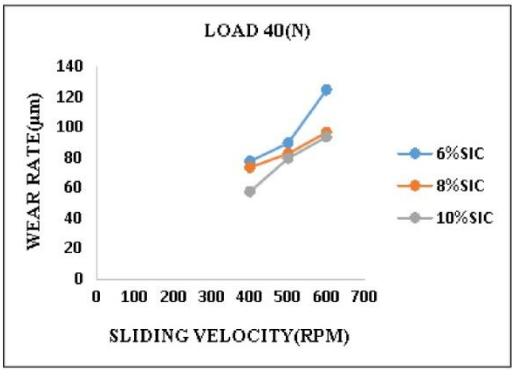
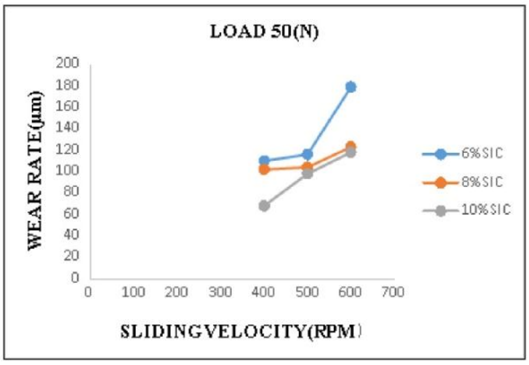


(a)

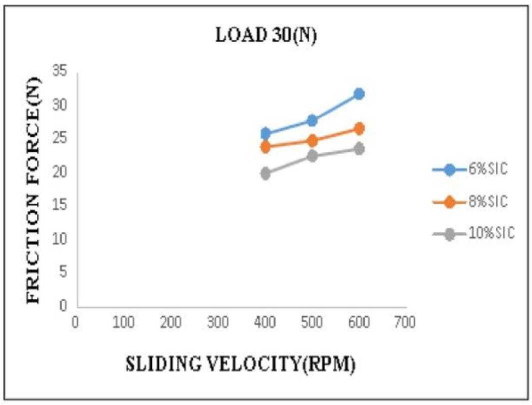


(b)

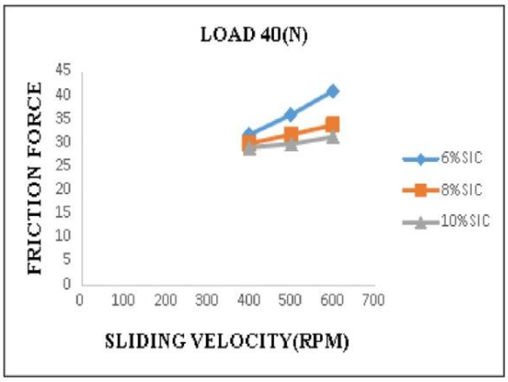


(c)

(4) Effect of frictional force on sliding velocity of aluminum 2014 alloy binary composite at different loads fig 4.4(a, b, c).



(a)



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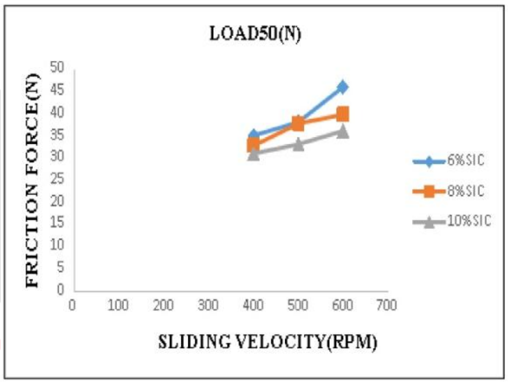

(c)

The graphs plotted above are the effects of hybrid composites. The hybrid composites used are Graphite and Silicon-Carbide in which; SiC and Graphite are used for bonding, strengthening agent and lubricant. And also it was found that increase in load increases the wear rate but as SiC and graphite are being added which are hard material so, the wear rate reduces as the percentage ratio of Silicon carbide increases. Effect of sliding velocity on friction force of aluminium 2014 alloy binary composite at different loads in which as the sliding velocity increases rate of producing oxidation increases while friction force increases and decreases because of effects of work hardening.

V. MICROSTRUCTURE CHARACTERIZATION

After wear tests, worn surface of pin sample is prepared for the analysis of microstructure using scanning electron microscope (SEM). The ZESIS EVO18 machine is used to take the SEM images of worn surface. The samples after wear tests microstructure study are conducted on the surface of the specimen on the worn-out area and the analysis is done the Scanning Electron Microscope.

And by the SEM images the mechanisms can be studied of wear loss. The fig 7(a, b, c) mentioned below are the SEM images of specimen containing 6% 8% and 10% Silicon carbide.

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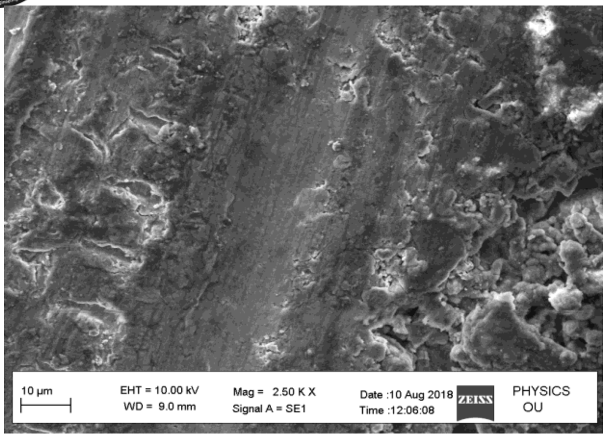
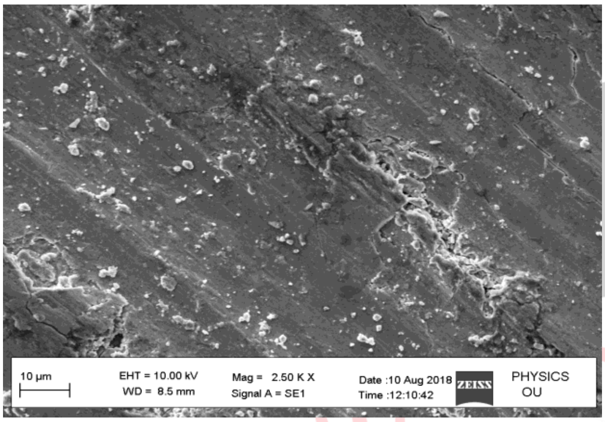
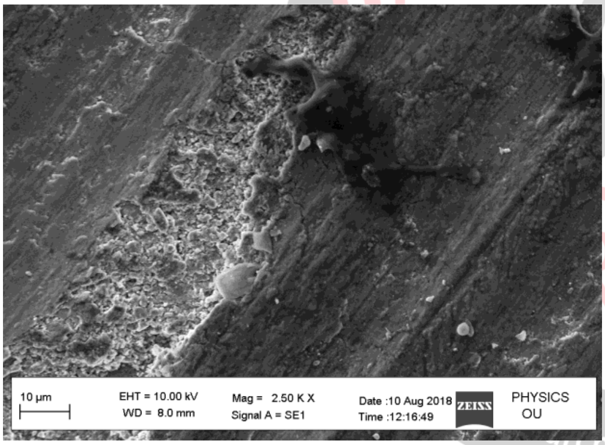


(a)



(b)



(c)

Fig 7 (a) Al 2014+2%Gr+6%SiC (b) Al 2014+2%Gr+8%SiC (c) Al 2014+2%Gr+6%SiC

The SEM images are been taken after wear test and it reveals the microstructure in which the white colored layer observed is silicon carbide particles and the black layers observed in the figures indicates the presence of graphite. And to analyze the composition ratio EDAX spectrum is been conducted.

VI. HARDNESS TEST

Hardness is a measure of the resistance against the surface indention. Rockwell hardness method was used to measure the hardness of the work piece of cylindrical section. The surface should be flat and perpendicular to the indenter. And before the hardness test the specimens are polished by using emery paper. Hardness tests are carried out by Rockwell hardness tester under the load of 100 Kgf. The measurement of hardness was taken at three different places on each work piece to get average value of hardness restrict the movement of dislocations there by hardness of composite is high.

S.NO	Specimen	Hardness Values			Average
		Value 1	Value 2	Value 3	
1	6%SiC	42	54	64	53.33
2	8%SiC	56	63	69	62.66
3	10%SiC	60	68	70	66

Table 4 Specimen hardness

The hardness values has been increased gradually by addition of SiC composite as it is hard abrasive so the values of hardness has increased at 10%SiC than 6%SiC. The addition of SiC particles to AMC is restricting the movement of dislocations so; the hardness value is increased as SiC percentage increases.

VII. CONCLUSIONS

Wear behavior of powder metallurgy Aluminum metal matrix composite and Al-SiC-G were investigated and following conclusions are drawn.

- As sliding velocity increases the value of coefficient of friction increases for silicon carbide.
- Increase in loads, the value of coefficient of friction decreases for silicon carbide-based from the experimentation table it is observed.
- As sliding velocity increases the value of volume of wear loss for silicon carbide composite increases.
- Volume of wear loss increases with increase in applied load for silicon carbide-based aluminium metal matrix composites.
- As the silicon carbide particles are added for which it is useful for bonding purpose and also improves the wear resistance.
- By adding metal matrix to aluminium the wear rate observed is reduced.
- As no wet lubricant is added during sintering the addition of Graphite acts as lubricant for strengthening agent.
- By comparison of hardness also among all the three compositions hardness values have been increased for aluminium metal matrix
- As no wet lubricant is added during sintering the addition of Graphite acts as lubricant for strengthening agent.
- And also the addition of Graphite acts as lubricating oil and specimen is ejected smoothly from the compaction die.
- SEM images shows that the wear occurs mainly due to mechanical action and the parallel layers of wear

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track indicate the presence of adhesive and abrasive wear.

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