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Effect of Sliding Velocity and Normal Applied Load on Wear Behavior of Al-Ti- Sic Composites for Automobile Brake Pad System Under Dry Sliding Condition

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***Abstract:** The wear and coefficient of friction (COF) behaviour of aluminium titanium (Al-Ti) alloys with varying of silicon carbide (SiC) are used as reinforcement material in the present research work. Automobile brake pads were developed by stir casting technique with 15, 20 and 25wt.% of SiC in Al-Ti alloys, respectively, instead of the traditional CI (cast iron) brake drum used for a chase machine. The normal applied load and sliding velocity varied to simulate vehicle running condition. It has been observed from the results the wear and COF for silicon carbide MMC is effectively than the CI material. The wear is varied with both sliding velocity and normal applied load. The experimental results reveals that the low wear was observed at 25wt.% of SiC than 15 and 20 wt.% of SiC. With increase of normal applied load, the wear was observed to increase whereas the COF decreases.*

***Keywords :** Al-Ti- SiC (HMMCs) , brake material, stir casting route, COF, SEM*

I. INTRODUCTION

Aluminium based MMCs are widely utilized as a part of utilizations auto spot gearbox actuators, rocker arms for racing engines, fuel pumps for racing engines, connecting rods, airways, mineral processing components and other industries due to its low density, and high thermal conductivity, However, they suffer from poor wear properties. To overcome this hard reinforced particulates are using, which are well know the for the high stiffness, high specific strength, have been uniformly distributed [1,2]. The objective of having reinforcement is to take advantage of superior properties of both materials without compromising on the weakness of either. Sahin et al. [3] studied a few manufacture techniques accessible to fabricate MMCs with different wt. % of TiC. Sahin [4] developed Al/TiC MMCs with different wt.% of TiC and studied their densities. Gopalakrishana et al. [5] developed AA6061/ TiC MMCs using stir casing technique and observed that, specific strength and wear resistance of composite has been increased with increase of wt. % of TiC. Ranjithkumar and Velmurugan [6] performed dry sliding wear experimental studies on aluminum hybrid metal matrix composites. The results reveals that increasing the applied load, sliding velocity and sliding distance the wear reate was also increasing. Ramakoteswara Rao et al. [7] prepared the Al/TiC MMCs with various wt. % TiC rangin 2-10% in step of 2%, and conducted wear test from the experimental observation it is observed that low wear was observed in MMC with wt.8% of TiC. RajneshTyagi [8] fabricated Al-TiC MMCs at different volume factions of TiC by melt reaction method and performed dry sliding wear test on pin-on-disc tester at different load and at a constant sliding velocity. The experimental results reveal that the wear rate decreases linearly with increasing volume fraction of TiC. Ramakoteswara Rao et al. [9] fabricated AA7075 / TiC MMCs with various weight fractions of TiC. From the experiments, it is observed that the wear rate increases by diminishes the wt. % of TiC. But decrease in density, hardness and wear resistance of the composite by increasing the wt. % of TiC. The experimental results reveal that the wt. % of TiC has the highest influence followed by speed on wear rate. Baskaran et al. [10] worked on AA 7075 / TiC (4% and 8% wt. % of TiC) MMCs, they observed the wear behavior under dry sliding condition. The experimental results reveal that the applied load has the highest influence followed by sliding velocity. Basavarajappay et al. [11] studied the wear behavior of AA 7075/ TiC castings are developed with various wt. % of TiC under dry sliding condition. and they observed that, the wear rate is diminishes by increasing the wt. % of TiC the experimental results reveal that the sliding distance has the highest influence followed by wt. % of TiC and COF (coefficient of friction) diminishes gradually with increasing normal loads and wt. % of TiC [12].

The friction processes in a disc brake pads are rather complex and not yet understood in detail [13]. This is mainly due to the complexity of the brake disc pad material formulation that consists of a wide several of components, and the complexity of the various chemical reactions occurring at the interface between brake disc and brake pad.

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In the present research, tribological characteristics of Al–Ti/SiC are widely used in various automobile brake pad system under dry sliding conditions were studied in pursuit of effect of reinforcement weight fraction and normal applied load and sliding velocity over wear parameters of the system. Pin-on-Disc test rig was used for evaluating wear behavior. Test parameter conditions were chosen such that they can used in real time on a brake pad materials [14,15,16].A schematic view of disk brake are shown in Figure 1.

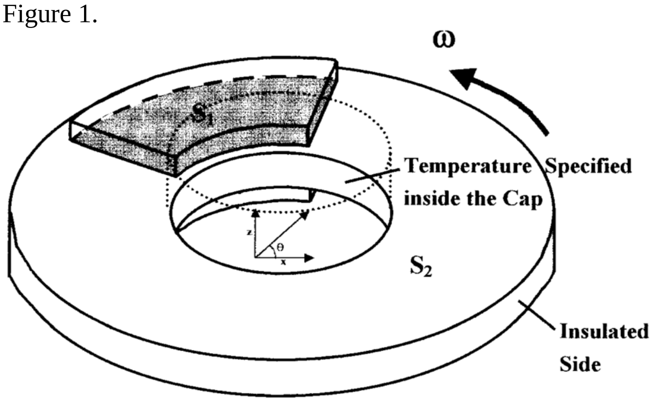


Fig. 1.A schematic view of a disc brake [17].

MMCs of different formulations (containing various wt.% normal applied load and sliding velocity) were used in this present investigation. The micro structural analysis was carried out using SEM and *EDX*, which revealed fairly uniform distribution of reinforcement in a matrix.

II. MATERIALS AND METHODS

Disc materials are used in present research are Al based MMCs of various formulations. Al- MMCs are used in the present investigation are reinforced with 5% of Ti particles and SiC with 15 and 20 and 25wt.% with angular SiC particles. Formulation details of the composites are presented in Table 1.

Table 1. Composition of Al-Ti-SiC

Elements	Composition
Si	4.3
Fe	0.5
Cu	2.2
Mn	0.2
Mg	0.16
Cr	0.01
Ni	0.03
Zn	0.30
Ti	0.028
Pb	0.02
Ca	0.007
Al	92

III. PIN MATERIAL

Pins are developed for the brake material, because of its low resistance and low scratch are against to harder disc material. A study coefficient of friction is maintained and consists of metallic disc brake and pads, it helps to transfer the kinetic energy into heat energy during the uses of brakes apply to slow the moving automotives and it is subjected to high pressure. Thus, it needs to possess i.e., high resistance to brake pad materials, good resistance and low compressibility to the materials.

The brake pad materials are divided into a various categories [16-19]: Binder, SiO_2, $BaSO_4$, brass, Al_2O_3, MoS_3, Sb_2S_3, Sn, Sb, Cu, Sb_2O_3, and aluminum hydroxides to protect the pad from fire.

A. Preparation of Brake Disc Pads

MMCs are developed using stir casting technique, the AA 6061 were fed into a crucible and heated up to a temperature of 780^{0}C. After melting the matrix the magnesium ribbons are added into a molten metal for removing the dirt and increasing wettability of AA-6061, and adding 15wt.% Ti mixed in a molten metal, pre-heated up to 300^{o}C. Simultaneously the liquid metal was stirred completely at a consistent speed 300 RPM with a stirrer for 15 minutes to enchsure uniform mixture of matrix and reinforcement. The experimental setup for the stir casting is shown in Figure 2.Discs were then faced on a lathe machine using diamond tipped tool to a thickness of around 6 mm, and a central hole of 8 mm diameter was drilled into each disc so that it could be fixed onto the Pinon-Disc wear-testing machine.

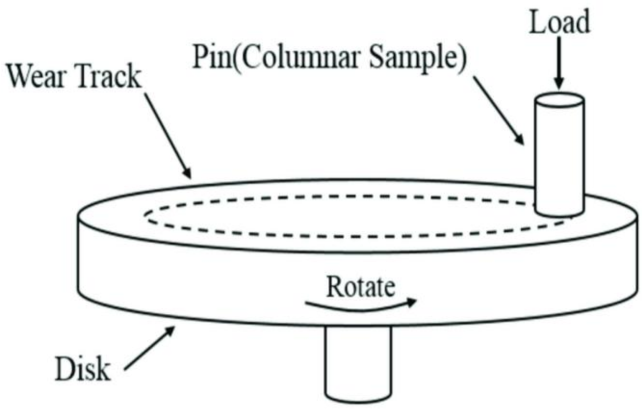


Fig. 2: A Schematic view of a pin-on-disc

B. Preparation of Pin

Brake pad materials are prepared in 5×5mm square with a height of 15mm. The square cross-section was chosen for two reasons:

a) Use the specimen in square/rectangular cross-section which results reveals that the low wear, COF and scatters [20].

a) Secondly it is difficult to machine pin of circular cross-section from fibrous brake pad material.

VI. MECHANICAL PROPERTIES OF THE COMPOSITE MATERIALS.

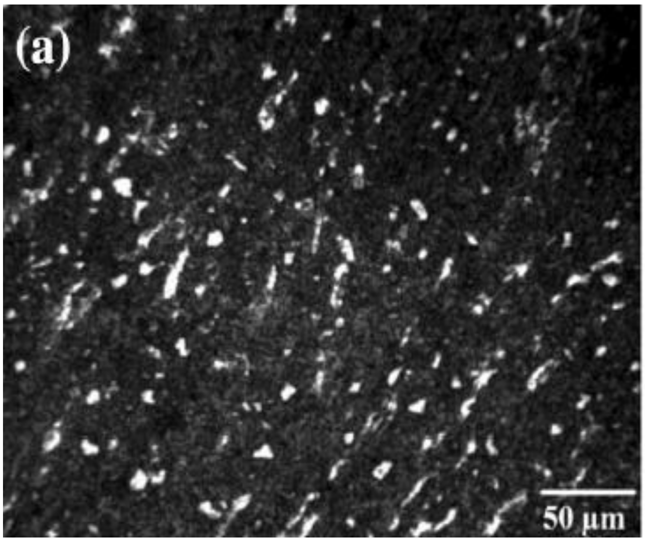
Micro hardness of the composite is carried out using Vickers harness tester for HMMCs. The specimens are prepared with a length of 20mm were cut from the specimen and polished the specimen using emery papers. The load was applied on the composite for 30s depending on the intensity of the load and material begin tested. It was noticed that the micro hardness of Al-Ti-SiC of HMMCs is higher with increase of reinforcement content the values of hardness is illustrated in Table 2.

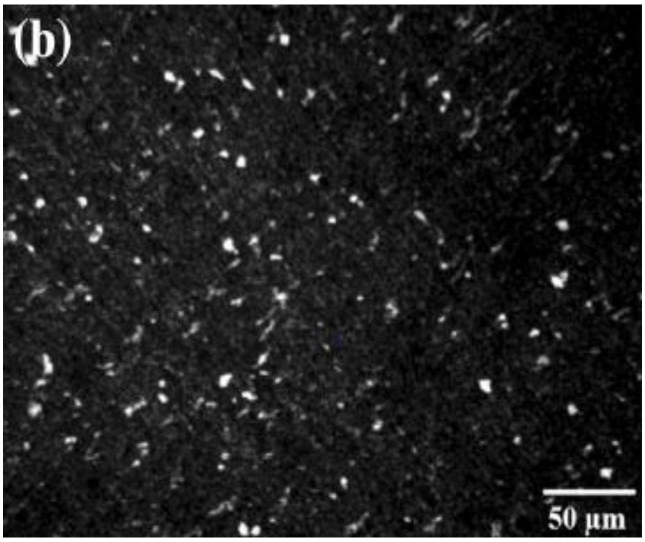
The tensile test was conducted using universal testing machine as per ASTM standard. The load is applied on the composite was 2mm/min and gauge length of the composite is 20mm of the composite material. The maximum tensile strength for Al-Ti-SiC composite. The results of hardness and tensile strength are illustrated in Table 2.

Table 2. Mechanical properties the HMMCs

Sl.no	Composite	Micro hardness	Tensile strength (MPa)
1	80%Al-5%Ti-15%SiC	129	152.63
2	75%Al-5%Ti-20%SiC	137	169.48
3	70%Al-5%Ti-25%SiC	152	186.72

The reinforced particles are analyzed in matrix material using microstructure analysis are shown in Figure 3. From the analysis the reinforced particles is highly segregations and agglomerations, the dispersion of the particles in the matrix material and causes a localized agglomerations. A good interfacial bonding in between the reinforcement particles of Ti and SiC with a matrix material was observed. Form the figure 3 (a-c) confirms that the interfacial integrity of reinforcement and matrix material of Al, and no traces of the reaction interfacial product.





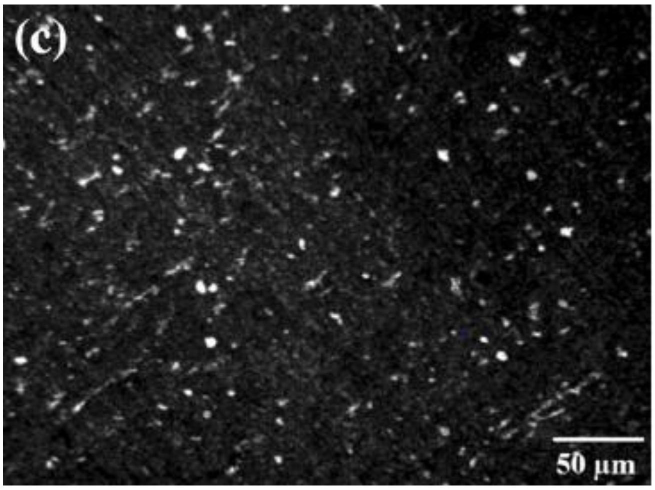


Fig. 3. Microstructure of the Inner surface of HMMCs (a) 80%Al- 5%Ti-15%SiC (b) 75%Al-5%Ti-20%SiC (c) 70%Al-5%Ti-25%SiC.

V. PIN-ON-DISC TESTER

In present research, pin-on-disc machine were used for experimental work to analyze the tribological behavior. Test methods are as follows: pin surface are prepared as a flat because it will supports the over load on entire section. The test was conducted for 20mins which applies a small loads and speeds on 800-grit emery paper it is attached to a disc surface, to avoid the turbulent period, friction and wear curves. Before testing and after testing the disc material and pin material was cleaned using ethanol soaked cotton and measured the weight of the pin material with an accuracy of 0.001gm. For each experimental run, precautionary steps are taken, that the applied load direction is in normal condition; friction forces and wear of the pin material are recorded with the help of LVDT. And time taken for each experimental run is 5min and sliding distance is 15Kms. Each experiment is run at 3times and average values are recorded for COF and wear are presented in next sectin. Figure 2 shows the schematic view of Pin-on-Disc test.

Surface textures of the pins and discs of the materials and wear debirs were analyzed using SEM, and also performed using EPMA and XRD technique.

VI. RESULTS AND DISCUSSION

A. Wear behavior of Al-Ti- SiC

The influence of normal applied load and sliding velocity with the wt.% of reinforcement on dry sliding condition of Al-Ti-SiC hybrid metal matrix composites (HMMCs) are discussed here.

A/I Effect of Normal applied load wear rate and coefficient of friction Tribo-test results are the variation of applied load with respect to wear is shown in Figure 4. It is noticed that the disc with high friction of reinforced particle, by the increase the applied increases the wear of the reinforcement particle of the composite. On the other hand, the lower wt.% of reinforcement is effect on wear was observed at lower wt.% of reinforcement particle in the matrix material are shown in Figure 4.

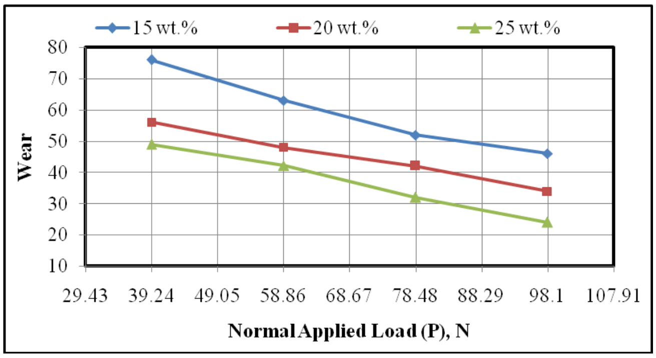


Fig.4. Effect of applied load with respect to wear on wt.%

The friction coefficient is measured a friction in between the contact surfaces. The frictional force is always exerted in a direction that potential movement between the two mating surfaces. It is a ratio between reaction force and frictional force. The frictional force during sliding is to be the power function of normal applied load and the sliding velocity at a different temperature ranges.

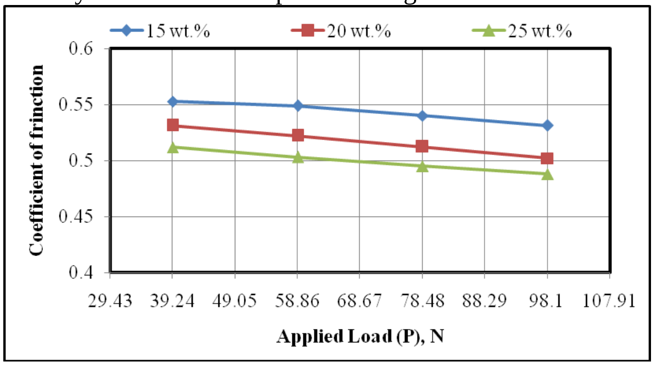


Fig. 5. Effect of applied load with respect to coefficient of friction on wt.%

Figure 5 shows the influence of applied load on the coefficient of friction, it is observed that the coefficient of friction is decreases gradually with increases of applied load and wt.% of reinforcement in to the matrix material. The applied load is varying from 29.43N to 98.1N, the plot is drawn with the help of response surface model by keeping the one parameter is constant and other parameter is in variation. The load is increases the coefficient of friction increases for all the wt.% of reinforcement particles, as well as monolithic alloy regardless of applied load with the addition of Mg particles into a molten metal it reduces the heat generated because of to friction by its intrinsic lubricity. The COF reduces with increase in SiC reinforcement and a similar observation was reported by Deuis et al. [21].

A/II Effect of Sliding Velocity on wear and coefficient of friction

The effect of sliding velocity on wear and coefficient of friction with wt.% of reinforcement is shown in Figure 6 for sliding velocity 2.5m/s to 4.2m/s, respectively and other parameters are constant at middle level, the plots are drawn with the help of response surface model. From the Figure 6 it is observed that the wear of the composite as well is decreases with increase of sliding velocity for all range of composites. This is due to high temperature interfacial, oxidation in Al from oxide layers thus supporting the high sliding velocity interfaces by decrease the wear. Alphs and Zhang [22] have been noticed that iron was oxidized in the process of wearing and has shows the oxide layer in the composite, during wear test iron layers are generated at particular positions and acts as solid lubricant and it reduces the wear of the composite.

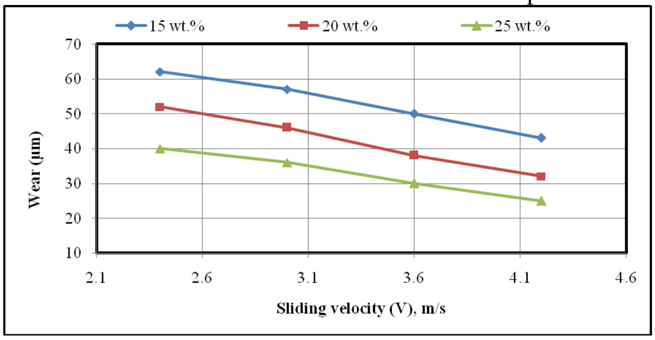


Fig. 6. Effect of sliding velocity with respect to wear on wt.%

Figure shows that Al-Ti-SiC, as the wear decreases with increase of sliding velocity up to 4.2m/sec, the SiC in the hybrid composite wear the disc counter and iron oxide were form by oxidation of iron particles from the disc phase. Results reveal that the sliding velocity with respect to wear of the composite is shown in Figure 6. It is it is inversely proportion was observed in between sliding velocity and wear i.e, wear gradually reduces with increase of sliding velocity. This is in direct contact with effect of sliding velocity over the wear.

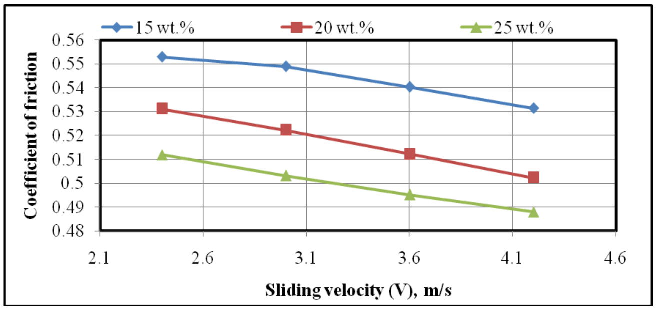
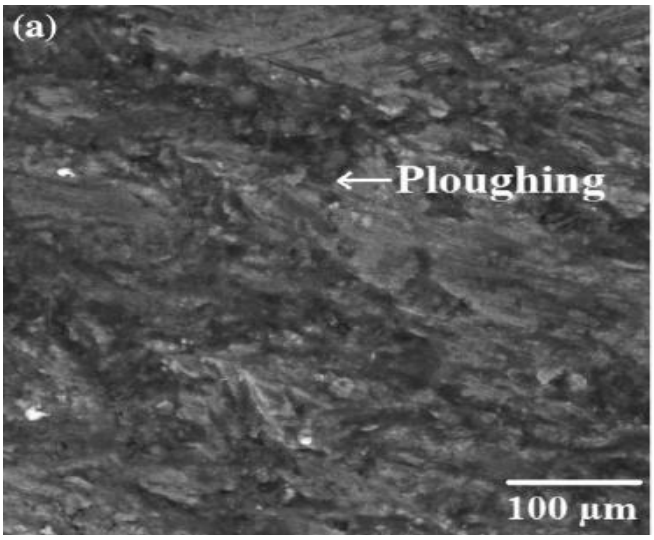
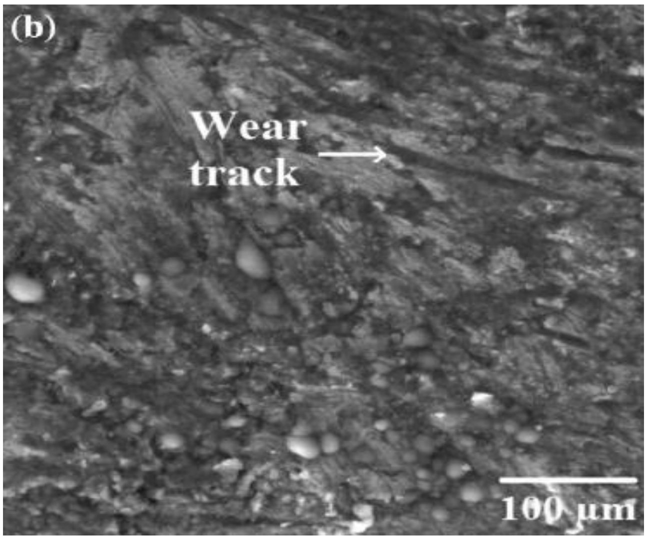
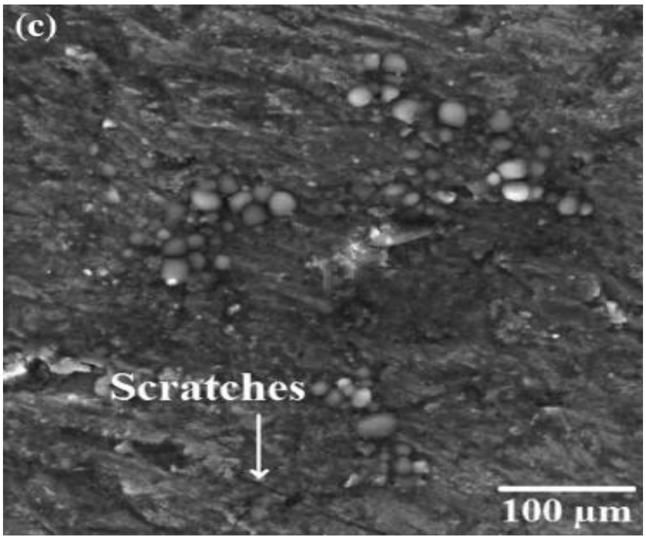


Fig. 7. Effect of sliding velocity with respect to coefficient of friction on wt.%

The variation of COF with varying the sliding velocity form 2.4, 3, 3.6 and 4.2 m/s for all wt.% of reinforced particles with 15%, 20% and 25% in aluminium matrix material are shown in Figure 7. The coefficient of friction (COF) of hybrid composites decrease with increase of sliding velocity. The trend is gradually decreases for all wt.% of reinforced particles and high COF were observed in at low wt.% reinforcement (15wt.%). The COF is mainly affected in by two parameters, by increase the hard particles in the matrix material and it fit reduces with Fe phase in the composite. Because of the formation of Fe rich transfer layers contributed HMMCs to reduce the overall COF [23,24] and also high hardness of the composite material which results that area of contact is increase in between the disc and pin of the material.







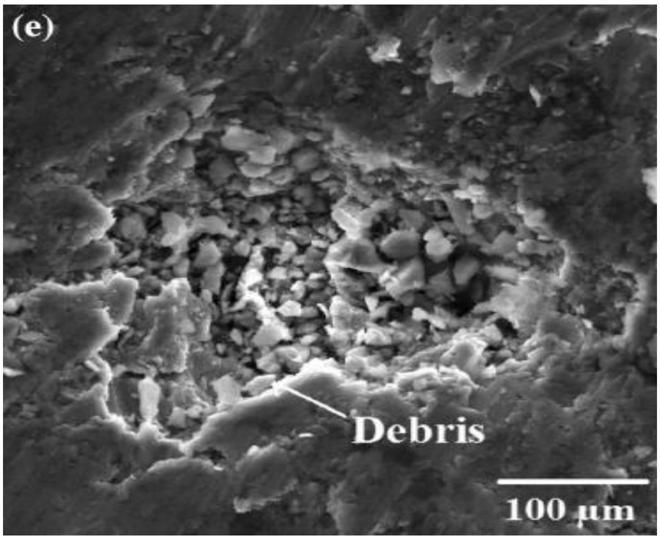


Fig. 8 (a-d).SEM analysis of the worn surfaces.

The SEM studies on the worn out surfaces of the fabricated composites at various sliding velocities of 2.4, 3, 3.6 and 4.2 m/s are shown in Figure 8 (a-d). Figure 8 (a) shows a small amount of abrasive action and cutting action on the surfaces at this way due to the presence of lower amount of reinforcement particles in to matrix material on the surface of composite to the particle rich. Figure 8 (b) results show the mild scratches along with the particle richer and wear tracker at 3m/s sliding velocity. Figure 8 (c) observed that the heavy scratches that the matrix contained a maximum amount of reinforcement and it protects the matrix material from the abrasion ploughing and cutting action actions at 3.6m/s the abrasive sand particles on the wornout surfaces were lower and same results and mechanism was noticed [25].

VII. CONCLUSIONS

Wear and coefficient of friction (COF) behavior of Al-Ti- SiC HMMCs have been investigated against automobile brake pads. The major conclusions shown in below:

- The Pin material are developed using stir casting route.
- Analyze the reinforced particle (SiCp) distribution in matrix material, particle are uniformly distributed and good interfacial bonding in between matrix and reinforcement.
- The mechanical characteristics are improved with the addition of SiCp reinforced particle in aluminum matrix materials.
- Wear and COF were observed with varying of applied load and sliding distance for different wt.% of reinforcement material. By increasing the wt.% of reinforced particles in matrix material the wear loss and COF are decreases gradually.
- The applied load and sliding velocity are increases wear and COF decreases for all wt.% of reinforced particles.
- The worn out surfaces of the pin material were analyzed using SEM analysis that reveals, large number of groves, scratches and ploughing marks

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- are observed with increase of sliding velocity and wear track distance.

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