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Wear Properties of Al Based Hybrid Metal Matrix Composites Prepared By Stir Casting Method

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Abstract - In the past few years the global need for low cost, high performance and good quality materials has caused a shift in research from monolithic to composite materials. In case of MMC's, aluminum matrix composite due to their high strength to weight ratio, low cost and high wear resistance are widely manufactured and used in structural applications along with aerospace and automobile industry. Metal matrix compositions (MMC) have become a leading materials and particles reinforced aluminum MMCs have received considerable attention due to their excellent mechanical properties like high hardness, high tensile strength etc. In this study, homogenized (2%, 4%, and 6%) by weight of alumina & (3%,6, and 9%) by weight of graphite aluminium metal matrix composite materials were fabricated and selected as work piece for experimental investigations of hardness, wear behaviour, XRD & SEM. X-Ray Diffraction test shows degree of angle is between 35 to 45. Scanning Electron Microscope test shows electron variation at different magnification it also shows the distribution of Alumina and Graphite particles in aluminium alloy. It has been observed that increase of reinforcement element produced better mechanical properties such as hardness & tribological properties such as wear. A pin on disc tribometer was used for wear test. Wear test were carried out by different sliding distance, speed and load. After wear test scanning electron microscope was used to examine the wear mechanism on the worn surfaces of the composites.

Index Terms –conclusion, hardness, SEM, Stir casting, Warn surface after wear, wear behaviour, XRD.

1 INTRODUCTION

Metal matrix composite (MMC) are widely used composite materials in aerospace, automotive, electronics and medical industries. They have outstanding mechanical properties like high strength, low weight, low ductility, high wear resistance, high thermal conductivity and low thermal expansion. These desired properties are mainly manipulated by matrix, the reinforcement element and the interface. Aluminium-based Al2O3 particle reinforced MMC material have become useful engineering materials due to their properties such as low weight, heat resistant, wear-resistant and low cost. By reinforcement of one material, there is a small improvement in all properties but dominated by one properties. But the properties of hybrid composites are more specific. The primary objective of the present work is to form metal matrix hybrid composite within the Al melt by addition of Alumina & Graphite. In the first part of the work attempt is made to prepare the composites and to characterize them by identifying the various compounds that has been formed with in the matrix. In the second part, the physical and mechanical properties of the composites are reported. In this study aluminium metal matrix composite made by stir casting method. After preparation of aluminium composite material there are investigate its Microstructural characterization such as XRD & SEM & investigate its mechanical properties such as hardness & wear behaviour.

Vencl A et al., (2010) and Yung C.K et al., (2004) [1-2] Metal–matrix composites (MMCs) are most promising materials in achieving enhanced mechanical properties such as: hardness, Young's modulus, yield strength and ultimate tensile strength due to the presence of micro-sized reinforcement particles into the matrix. Vencl A et al., (2010) and Sajjadi SA et al., (2011) and C.S. Ramesh et al., (2005) [3-5] A number of materials such as SiC, Al2O3, B4C, TiB2, ZrO2, SiO2 and graphite are being used as reinforcements to improve the properties of 6061Al alloy.Yung C.K et al., (2004), Salleh SA et al., (2010) [6-7] the mechanical properties of MMCs are very sensitive to the method of processing being used. Considerable improvements may be achieved by applying science-based modeling techniques to optimize the processing procedure. Several techniques have been employed to prepare the composites including powder metallurgy, melt techniques and squeeze casting.

Straffelini et al. (1997) [8] found that the matrix hardness has a strong influence on the dry sliding wear behavior of Al2O3 particulate Al6061 MMC. Martin et al. (1999) [9] investigated tribological behavior of Al6061 reinforced with Al2O3 particles and described that a characteristic physical mechanism exists during the wear process. When a sufficiently high load is applied on the contact, the matrix phase is plastically deformed, and the strain is partially transferred to the particulates, which are brittle with small failure strains. Modi et al. (2001) [10] showed that the effect of applied load on the wear rate of both zinc alloy and the 10 wt. % Al2O3 particle-reinforcement composite using statistical analyses of the measured wear rate at different operating conditions. Effect of applied load on the wear rate of composite was found to be more severe. Winert [11] attributes

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the wear of the carbide tool to abrading Al2O3 particles that forms on the surface and rub the tool in the direction of the chips flow.

Al-Qutab and Allan [12-13] studied wear and friction of AMCs containing 10, 20 and 30 % alumina. They concluded that an increase in reinforcement decreases wear rate. They also concluded that coefficient of friction (COF) decreases with increasing sliding speed. Hosking [14] studied wear behavior of alumina particles reinforced aluminum alloy using pin-on disc type machine for wear properties measurement. They found that increase in contents of reinforcement reduces its ductility and improves wear properties. Pin-on-Disc testing technique has been reported for measurement of wear of aluminum composites. Pin-on-Disc uses volumetric loss, and is evaluated from decrease in length of pin.

Yilmaz [15] produced hybrid composites of Al-10 wt. % Al2O3-x wt. % Gr (x = 0, 1, 2, 3, 4 and 5 wt. %) and observed that the surface texture parameters are decreasing as graphite content increases in the matrix. However, the hardness of hybrid composites started to decrease when the graphite content in the matrix was more than 1wt%. Ted Guo and Tsao [16-17] concluded that addition of Gr particulates facilitates easy machining and results in reduced wear of Al Gr composites compared to Al alloy. But high amount of Gr may result in increase of wear due to decrease in fracture toughness with increase in percentage of reinforcement of Gr particulates. Yang [18] observed that hardness of aluminum composite was increased. Improved hardness results in decrease in wear rate.

It can be understood that only less research work was carried out based on Al alloy reinforced with Al2O3 and Gr hybrid composites and found that 1% wt. of Gr will be suitable for easy wear behaviour. The main objective of the present work is to manufacture the Al reinforced with x wt.% of Al2O3 (x=2,4,6)& x wt. % of Gr (x = 3, 6, 9) hybrid composites via stir casting method, and investigate its mechanical behavior in terms of hardness,& investigate its wear behaviour.

The main objectives of this study are:

1) To prepare the Al2O3 & Graphite reinforced Al composite by stir casting.
2) To characterize the composite material and find the hardness.
3) To optimize weight % of reinforced metal for best wear properties.

2 EXPERIMENTAL WORK

The primary objective of the present work is to form reinforcing particles within the Al melt by addition of Alumina & Graphite into the base metal in the liquid state. In the first part of the work attempt is made to prepare the composites and to characterize them by identifying the various compounds that has been formed with in the matrix. In the second part, the physical and mechanical properties of the composites are reported. Commercially pure Al was taken on the matrix at the first stage of experiment. In this study Al2O3& Graphite are used for as reinforcement. In pure aluminium melt Al2O3 (2, 4, & 6 % & wt. %) & Graphite (is 3, 6 & 9 wt. %.) are add in liquid stage. For improving wettability and this to facilitate reaction, small quantity of Mg (0.02 wt. %) added in this molt.

2.1 MELTING AND CASTING:

The pure aluminum metal matrix composite was prepared by stir casting route. For this we took 500gm of commercially pure aluminum sheet, melted in resistance furnace at 660°C for 30 minutes. The reinforced particle alumina & graphite preheated to 650°C for 30 minutes to remove moisture. The melt temperature maintain 650°Cto660°C for 30minutes. Then the melt was stirred manually with the help of iron rod as 80 rpm approx for 8- 10 minutes. The melt temperature maintained 650-660°Cduring addition of reinforced particles and Mg. The dispersion of reinforced particles was achieved by the vortex method. The melt with reinforced particulates were poured into the preheated permanent metallic mold. The melt was then allowed to solidify in the mould.

TABLE 1: COMPOSITIONS OF SAMPLES

Sample No.	Aluminium (gm)	Alumina (%)	Graphite (%)	Mg (gm)
1	500	2	3	2
2	500	4	6	2
3	500	6	9	2

Fig. 1 Stir casting setup

Fig. 2 Specimens after casting

2.2 SCANNING ELECTRON MICROSCOPE (SEM):

Microstructural characterization studies were conducted to examine distribution of reinforcement throughout the matrix. This is accomplished by using scanning electron microscope. The composite samples were metallographically polished prior to examination. Characterization is done in etched conditions. Etching was accomplished using Keller's reagent. The SEM micrographs of composites were obtained using the scanning electron microscope. The images were taken in secondary electron (SE) mode. The SEM images for different wt. % of reinforcement at different magnification are shown in Fig.3, 4 & 5.

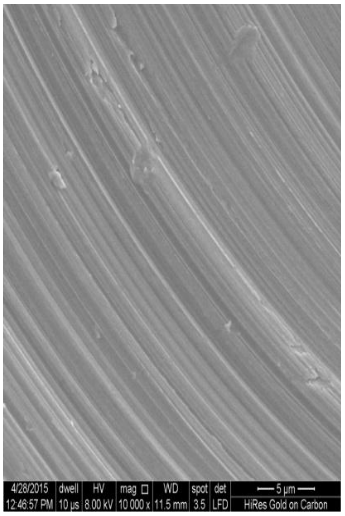

Fig.3 (a)

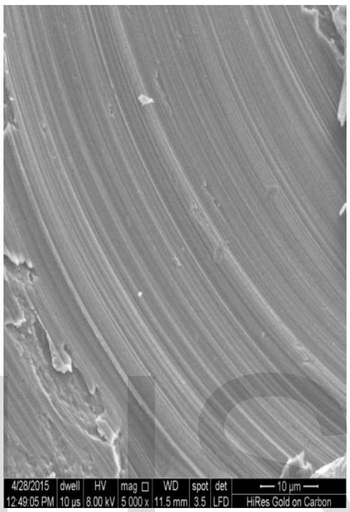

Fig.3 (b)

(a) : sample -1 [Al 2% Al2O3 3% Gr at 10,000 mag.]
(b) : sample -1 [Al 2% Al2O3 3% Gr at 5,000 mag.]

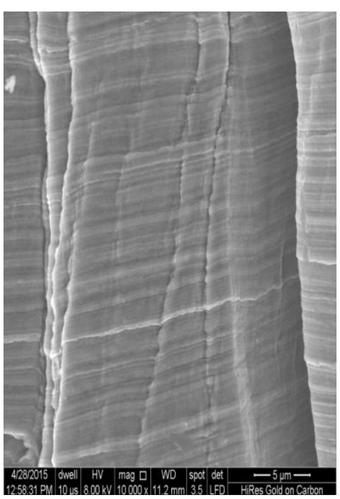

Fig.4 (a)

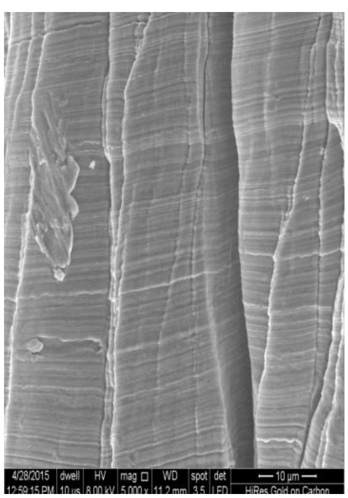

Fig.4 (b)

(a) : sample -2 [Al 4% Al2O3 6% Gr at 10,000 mag.]
(b) : sample -2 [Al 4% Al2O3 6% Gr at 5,000 mag.]

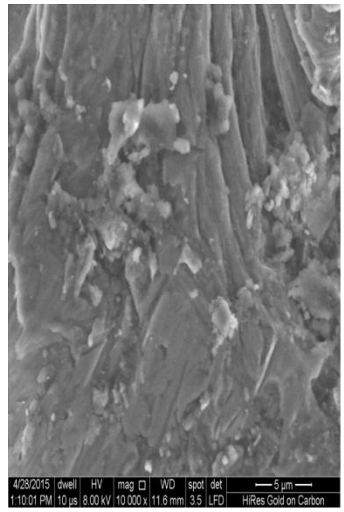

Fig.5 (a)

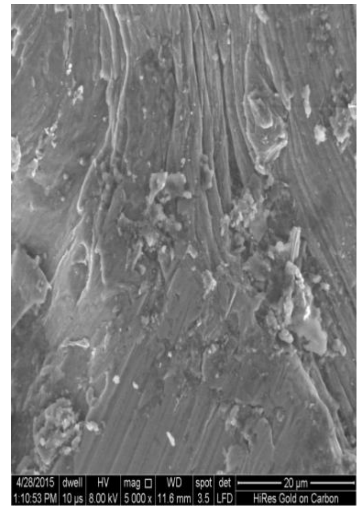

Fig.5 (b)

(a) : sample -3 [Al 6% Al2O3 9% Gr at 10,000 mag.]
(b) : sample -3 [Al 6% Al2O3 9% Gr at 5,000 mag.]

2.3 X-RAY DIFFERACTION (XRD):

X-ray diffraction relies on the dual wave/particle nature of X-rays to obtain information about the structure of crystalline materials. A primary use of the technique is the identification and characterization of compound based on their diffraction pattern. The composites samples were in powder form to examination of XRD test. The XRD graphs are shown in Fig. 6, 7 & 8.

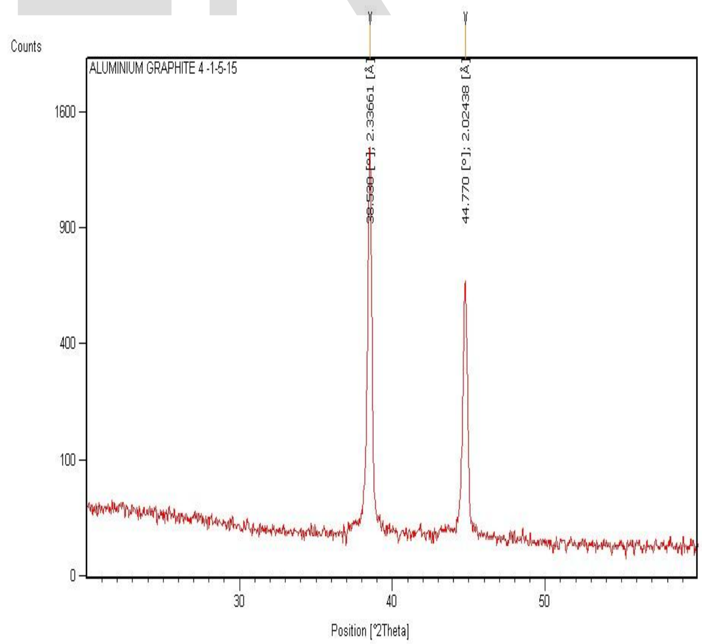

Fig. 6: sample – 1 [Al 2% Al2O3 3% Gr]

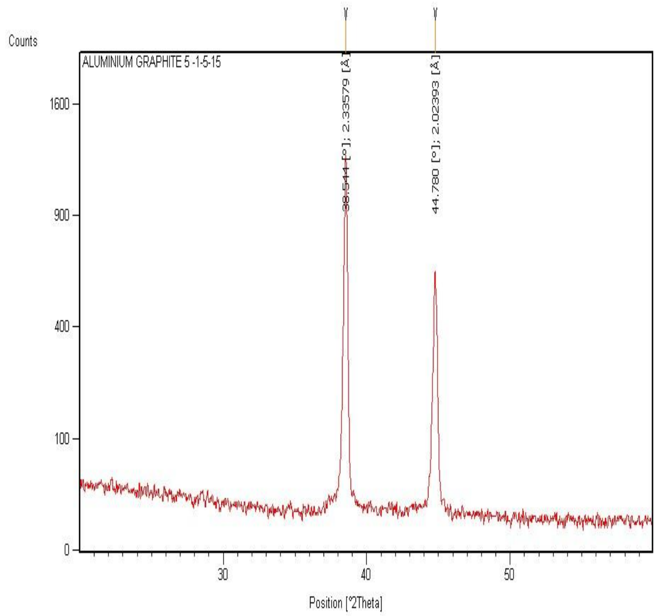

Fig. 7: sample – 2 [Al 4% Al2O3 6% Gr]

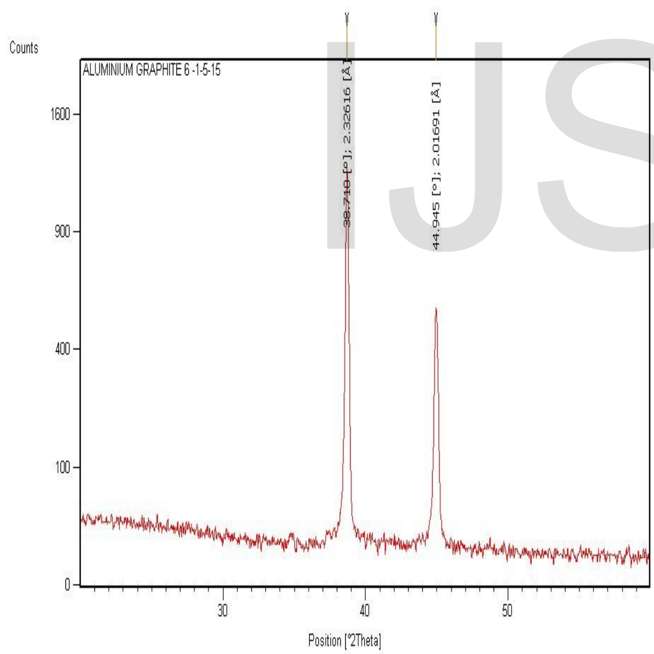

Fig. 8: sample – 3 [Al 6% Al2O3 9% Gr]

2.4 HARDNESS:

Hardness measurements were carried by using standard Rockwell hardness test machine. The composite sample is used for this measurement was cylindrical length of 10mm and the load applied was 100 kg/f for 10 seconds .Steel ball indenter dia. of 1.58 mm. Its uniform time interval in indenter was 10 second. Fig.9 is after hardness of the specimens.

Fig. 9 Specimens after Rockwell hardness

2.5 WEAR BEHAVIOUR:

The wear testing was carried out at a different sliding distance with different normal loads & different sliding speed. A cylindrical pin of size 10 mm diameter and 20 mm length, prepared from composite casting, was loaded through a vertical specimen holder against horizontal rotating disc. The rotating disc was made of carbon steel of diameter 80 mm and hardness of 64 HRC. The weights were measured before and after each test segment to determine the abrasive wear loss of each sample. Scanning electron microscopy was used to analyze the morphology of the worn surfaces of sample.

Fig. 10 specimens use for wear analysis (pin diameter=10mm & length=20mm)

3 RESULTS AND DISCUSSION

3.1 SCANNING ELECTRON MICROSCOPE (SEM):

SEM results are shown in Fig. 3, 4 & 5.Its shown that different wt. % of reinforcement SEM results shown in Fig. 3, 4 & 5 respectively. Its shown that 10,000 & 5,000 magnification use for it and its spots are at 3.5 respectively.

3.2 X-RAY DIFFRECTION (XRD):

XRD result graphs shown in Fig. 6, 7 & 8.X-ray diffraction test shows that the images found at nearly same degree of angle are as (38.530, 38.544, 38.710) respectively. The result also shows from the figure that the counts of the reinforcement increases towards 1600.

3.3 HARDNESS:

Hardness measurements were carried by using standard Rockwell hardness test machine. Fig. 9 shows specimen after Rockwell hardness test done. Hardness test shows that increasing reinforced % hardness is increase. Table 2 shows the average hardness.

TABLE 2: ROCKWELL HARDNESS TEST RESULTS

Sr. No.	Material	Rockwell Hardness Number					Avg. hardness
		1	2	3	4	5	
1.	sample - 1 [Al 2% Al2O3 3% Gr]	74.6	75	74.5	77	76.5	75.52
2.	sample - 2 [Al 4% Al2O3 6% Gr])	75.5	77	80	76.4	81	76.3
3.	sample - 3 [Al 6% Al2O3 9% Gr]	82	81	82	82	84	82.2

3.4 WEAR TEST:

Wear test were carried out on pin on disc machine. Fig. 10 shows specimens use for wear analysis.Fig.11 shows main effects plots for SN ratio. It shows that increase reinforcement decrease wear rate.

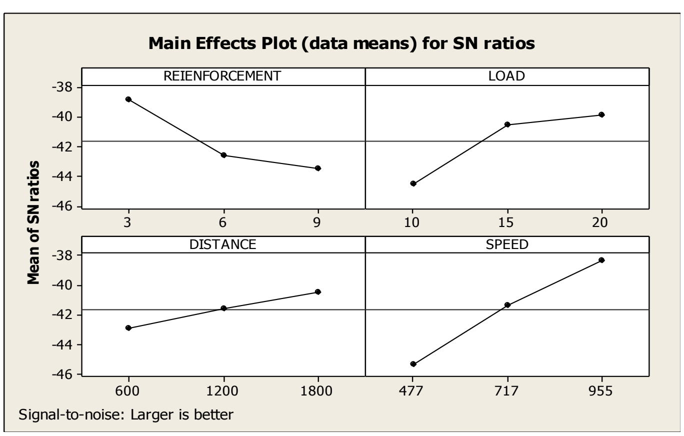

Fig. 11 Main effects plots for SN ratio.

Fig, 12 shows the result of wear vs reinforcement, load, distance & speed.

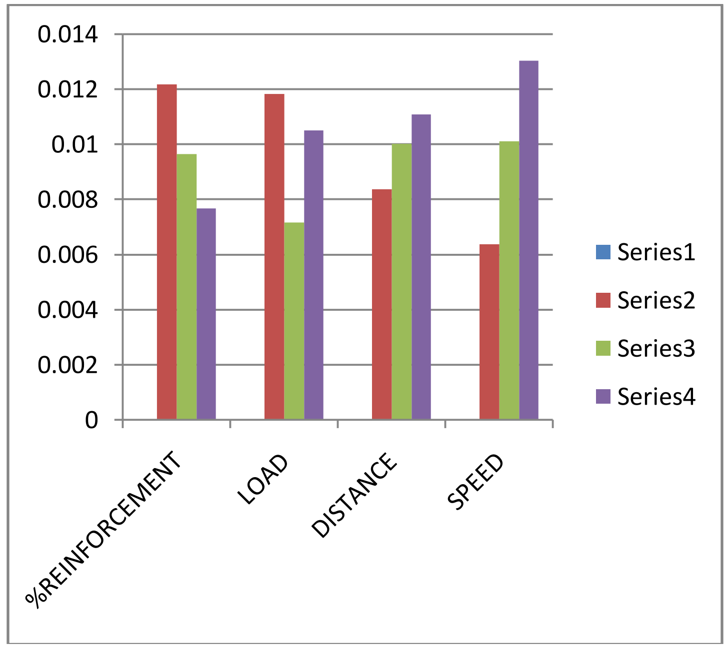

Fig. 12 Wear vs reinforcement, load, distance & speed

3.5 WORN SURFACE AFTER WEAR:

Worn surface after wear shown in fig. 13, 14, & 15.

Fig.13 (a)

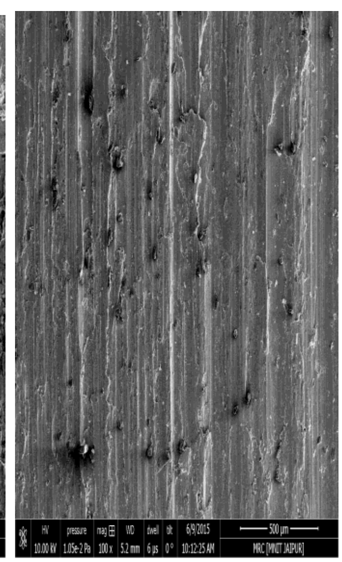

Fig.13 (b)

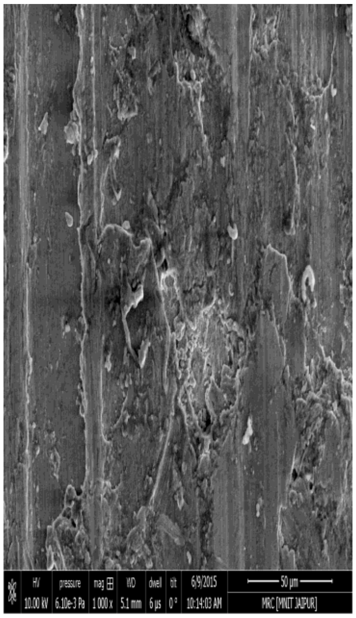

Fig.13 (c)

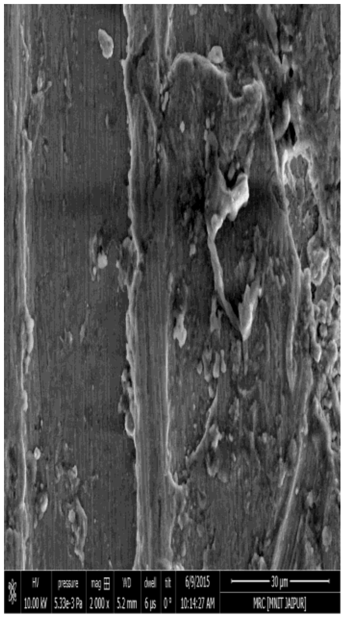

Fig.13 (d)

(a) : sample -1 [Al 2% Al2O3 3% Gr at 100 mag.]
(b) : sample -1 [Al 2% Al2O3 3% Gr at 500 mag.]
(c) : sample -1 [Al 2% Al2O3 3% Gr at 1,000 mag.]
(d) : sample -1 [Al 2% Al2O3 3% Gr at 2,000 mag.]

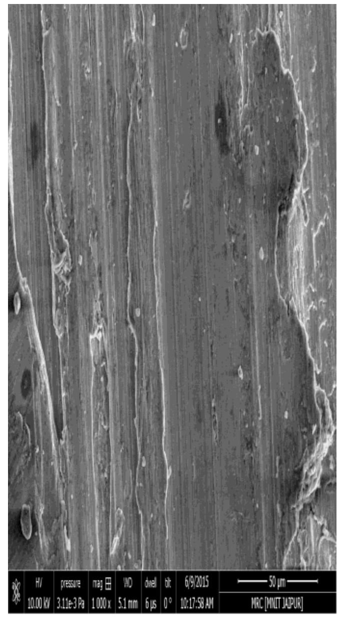

Fig. 14 (c)

Fig. 14(d)

(a) : sample -2[Al 4% Al2O3 6% Gr at 100 mag.]
(b) : sample -2 [Al 4% Al2O3 6% Gr at 500 mag.]
(c) : sample -2[Al 4% Al2O3 6% Gr at 1,000 mag.]
(d) : sample -2 [Al 4% Al2O3 6% Gr at 2,000 mag.]

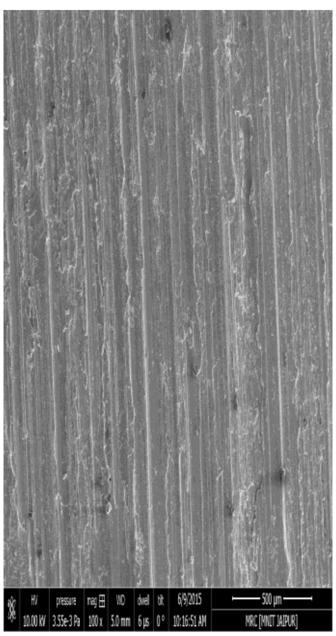

Fig.14 (a)

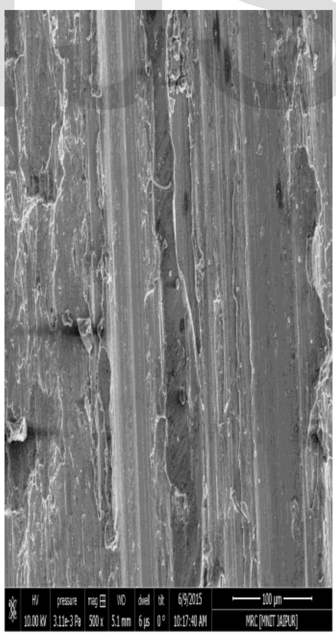

Fig. 14 (b)

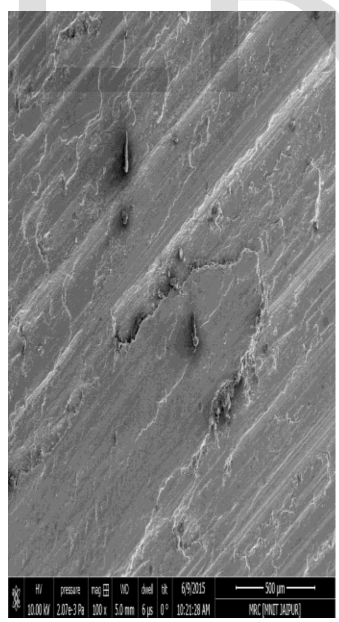

Fig. 15 (a)

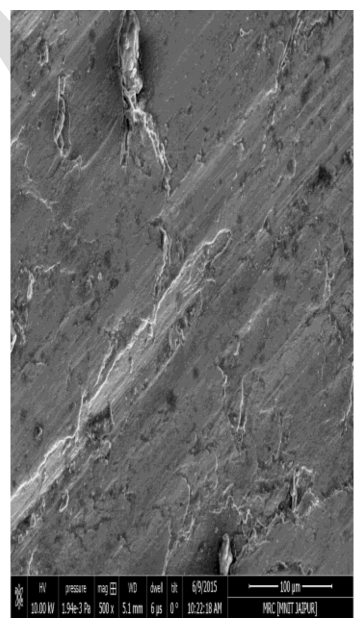

Fig. 15 (b)

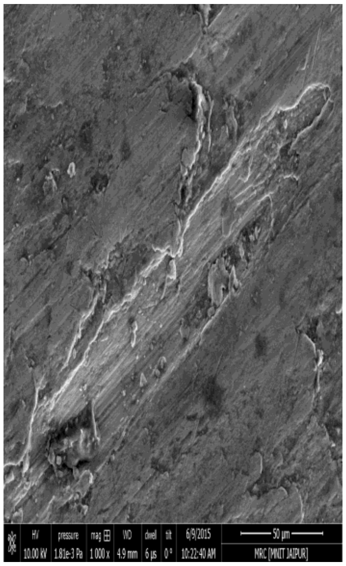

Fig. 15 (c)

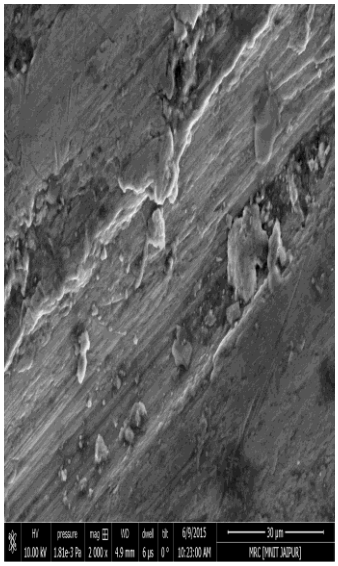

Fig. 15 (d)

(a) : sample -3[Al 6% Al2O3 9% Gr at 100 mag.]
(b) : sample -3 [Al 6% Al2O3 9% Gr at 500 mag.]
(c) : sample -3[Al 6% Al2O3 9% Gr at 1,000 mag.]
(d) : sample -3 [Al 6% Al2O3 9% Gr at 2,000 mag.]

4 Conclusion

In this experimental study, Al HMMCs of varying Al2O3 content (2, 4, and 6 wt. %) & Graphite content (3, 6 and 9 wt. %) were prepared using stir casting fabrication technique. Microstructural aspects, hardness, and wear characteristics of the prepared composites were studied. Based on experimental evaluation, following conclusions can be expressed-

1) The results confirmed that stir formed Al alloy with (Al2O3 and Gr) reinforced composition is clearly giving the best results in XRD.

2) The hardness increase on increments of reinforcement (Al2O3 & Graphite).

3) XRD result shows that the reinforcement particles Al2O3 & Graphite mixture are in uniform rate.

4) Wear resistance of Al2O3 & Graphite reinforced Al based HMMCs decrease with increasing Al2O3 & Graphite content in Al matrix. Sample-3 [Al 6% Al2O3 9 % Gr] reinforced Al HMMC showed minimum wear resistance & sample-1 [Al 2% Al2O3 3% Gr] reinforced Al HMMC showed maximum wear resistance. The result also reveals that when % of graphite increase more than 6 % then wear rate does not decrease abruptly.

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