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COMPARATIVE STUDY OF COPPER BASED METAL MATRIX COMPOSITES

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Abstract- *In this present work an effort has been made to fabricate and compare the properties of copper based metal matrix composites. Two specimens were made by adding 2wt% of Feand 2wt% of Fe, 1wt% of SiC with copper metal matrix. The specimens were fabricated by using Powder compaction with hot pressing technique. X-ray diffraction analysis was carried out for phase analysis. EDX analysis confirms the presence of Fe and SiC in Cu-Matrix. Morphology of the fabricated composite reinforced with Fe and Fe-SiC were studied in detail by optical microscopy to analyse the particle distribution in copper metal phase. Microstructural analysis of samples was studied by using scanning electron microscope. The hardness test was carried out to find the hardness of composites by using a Rockwell hardness tester, which shows the hardness of Cu-2Fe-SiC is approximately 24% more than Cu-2Fe Composite. Wear test was carried out to study the wear resistance behaviour of Composites. Wear test analysis proves that wear resistance behaviour of Cu-2Fe-SiC composite is higher than Cu-2Fe composite. AFM results confirm that the Cu-2Fe-SiC composite has better roughness behaviour than Cu-2Fe composite.*

Key words*-Metal matrix composite, Fe, SiC, Hardness, Wear*

I.INTRODUCTION

The biggest advantage of modern composite materials is that by choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. [1] Composites can be excellent in applications involving sliding friction, with tribological (“wear”) properties approaching those of lubricated steel. [1] Cu-matrix composites are promising candidates for applications in electrical sliding contacts such as those in homopolar machine and railway overhead current collection system, where high thermal /electrical conductivity and good wear resistant properties are needed.

Pure copper exhibits high electrical and thermal conductivities but it has low hardness, low tensile and creep strengths. Copper is ductile and has low hardness because of that it has poor wear resistance. The development of Cu-based alloys with high tensile strength and hardness is of primary importance. The mechanical strength and wear resistance of copper is increased by introducing dispersed particles in its matrix. Dispersed particles such as oxides, carbides, borides are insoluble in the copper matrix, and are thermally stable at high temperatures. [2]

Powder metallurgy (sintering) and infiltration techniques are used for fabricating copper matrix composite. Copper metal matrix composite possesses Low coefficient of thermal expansion, High stiffness (modulus of elasticity), Good electricalconductivity, High thermal conductivity, Good wear resistance. The advantages of using Fe as reinforcement are their high friction coefficient, good heat resistance and low cost. [3]

Most often reinforcement materials for MMCs are ceramics (oxides, carbides, nitrides, etc.) Which are characterized by their high strength and stiffness both at ambient and elevated temperatures. Examples of common MMC reinforcements are SiC, Al2O3, TiB2, B4C, and graphite. Metallic reinforcements are used less frequently. [1] Few works were carried out to introduce SiC as an outstanding reinforcement with Copper metal matrix. This is due to the fact that SiC reveals outstanding features such as high melting point (2730^{o}C) Low Density, High hardness and high elastic modulus, excellent thermal shock resistance and Superior chemical inertness. [5] Previous study shows that Cu Metal matrix composites reinforced with SiC particulate possess high stiffness, superior room and elevated temperature strengths, improved wear resistance and low coefficient of thermal expansion. (4)S.C. Tjong et al [3]worked on synthesization of copper and its composites reinforced with SiC particles by hot isotactic pressing (HIP). Reported that hot isostatically pressed SiC–Cu composites exhibit good strength, electrical and mechanical properties. The HIP process consisting of sintering the blended powders under the applications of high pressure and high temperature. A new effort has been taken to fabricate composite reinforced with Fe and SiC using powder compaction and hot pressing technique. This work deeply compares and analyse the tribological properties of both composite specimens reinforced with Fe and Fe-SiC, and analyze the effect of using SiC as additional reinforcement in Cu matrix reinforced with Fe.

II.EXPERIMENTAL PROCEDURE

Commercially pure copper (99.5%), Iron (99.5%) and Silicon carbide powder of 20µm was selected for the preparation of Cu-2Fe and Cu-2Fe-SiC composites.Powders was weighed in the set of composition mentioned in the table.1 by chemical balance. Then put in electric agate pestle mortar, machine for 2 hours in order to obtain mixing and blending. The blended powder was filled in the bore of the die and cold compacted with the help of pressing machine for uniform compaction. Split Die of high chromium steel is used for compaction of powder. Die with cold compacted powder placed inside the muffle furnace at the temperature of 850 °C with the help of a clamp. After two hours die was taken out from the furnace and immediately hot pressed by a hammer. Then remain cool in the room temperature. Hot pressing of sample is done in order to avoid porosity. The cooled sample is taken out from the die with the help of pressing machine and hammer, because of the split we opened the die and get the sample out easily. Same procedure repeated for the preparation of second specimen. Image and Specification of prepared specimen are shown in Table.2 and Fig 1.
(a) And (b)

***Table 1** Composition of sample*

Sr.No.	Copper(in gm)	Iron(in gm)	Silicon carbide(in gm)	Remark
1	19.6	0.4	Nil	Cu 98%, Fe2%
2	19.4	0.4	0.2	Cu 97%, Fe 2%, SiC 1%

***Table 2** Specification of prepared sample*

Sr.No.	Sample ID	Diameter (In mm)	Height (In mm)	Volume (In mm^3)	Weight (in gm)	Density gm/mm^3
1	Cu-2Fe	10.65	33.24	2.962	19.275	6.507
2	Cu-2Fe-Sic	11.57	31.46	3.305	18.483	5.592

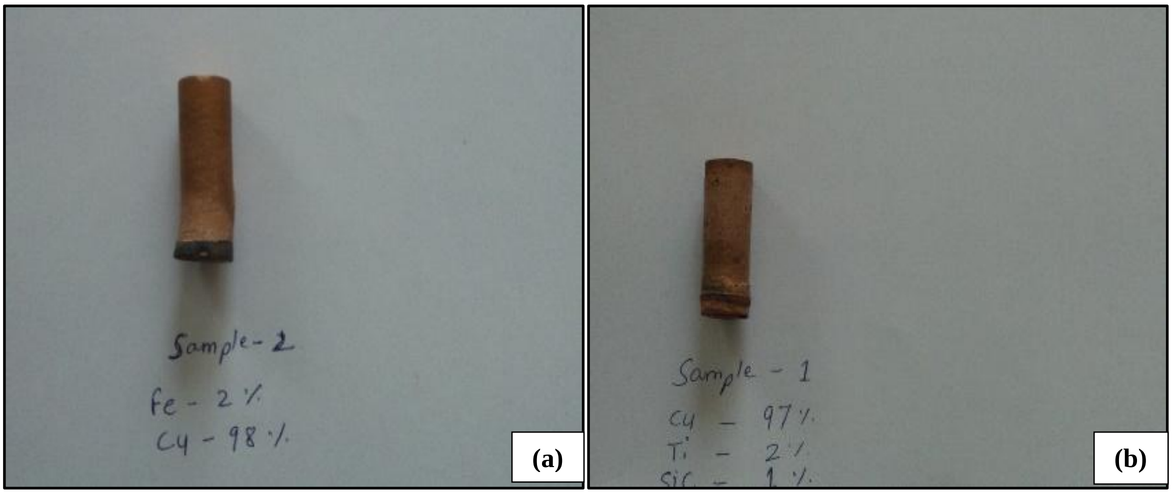


***Figure 1**Images of prepared sample in the order mentioned in Table 2 (a) Cu-2Fe (b) Cu-2Fe-SiC*

Both sample was sectioned in the form of pellets with the help of hacksaw blade and Cutting machine and polished properly with the help of grit paper in sequence of 240,320, 400, 600, 1000, 1200, 1500, 2000 grit. The fine disc polishing was done by cloth polishing machine.

XRD was studied in PAN analytical XRD equipment. The diffraction patterns were recorded over a scan range of 20 – 80 ◦ at a step size of 2◦/min using the copper target. The phases present at different sample and crystal structures of the product phases were identified from the peak positions (2Θ) values of the XRD pattern. The compositional analysis of a section was investigated by electron dispersive X-ray (EDX)Morphology of both the specimen was studied by optical microscope. Microstructural characterization of polished samples was carried out by scanning electron microscopy (JEOL SEM Equipment). Ferric chloride solution (5 g $FeCl_3$ and 50 ml HCl in 100 ml distilled water) was used as an etchant to selectively attack the grain boundaries. [6] Micrographs were taken at 20KV accelerating voltage. The morphology of the reinforcement particle, particle distribution, reinforcement particle-matrix integrity, matrix cavitation and grain size was observed from the SEM micrographs.The roughness behaviour of the samplewas determined by the help of AFM. Polished sample were prepared for AFM. AFM of the sampleare proceeding in semi contact mode.Hardness testing was done by Rockwell hardness tester. Rockwell hardness was measured on polish surface of the sample using the B scale in the Rockwell hardness tester. A steel ball indenter with fixed indentationload of 100kgf was used for all the tests. At least three indents were made on polished surfaces both the sample and average hardness was determined. For the study of tribologicalbehaviour wear analysis of prepared specimen is done. A pin-on-disk wear testing machine was employed to evaluate wear resistance of samples of different composition. Wear tests were conducted at room temperature. AISI 52100 steel disc (60HRC hardness) was employed as the counter face. Wear tests were carried out under varying loads and sliding distance, Sample having a diameter of 8 mm and length 24 mm was prepared in order to maintain perfect length to diameter ratio of specimen. In this experiment, the load varies from 10 to 25 N, velocity is 0.75 m/s, time is 20 min., and track radius is 50 mm for both samples.Samples of the worn out surface were studied in SEM for further analysis.

III.RESULT AND DISCUSSION

3.1. Metallographic Analysis

XRD analysis was conducted for both the sample and analysis is done by software “HIGH SCORE PLUS” by PAN’alytical. XRD pattern and XRD analysis of both the sample are shown in Figure 2, Table 3 and Figure 3 Table 4 respectively. Further confirming the presence of iron and SiC in the composites, energy depressive X-ray analysis (EDAX) was also used. Figure 1 and 2 shows the EDAX monographs of composite with two different compositions. In the monograph shows in figure 4.largerpeaks correspond to Cu and smaller ones to iron similarly in figure 5. large peak correspond to Cu and smaller one to Fe and SiC. It confirms the presence of iron in the Cu-Fe and SiC in Cu-Fe-SiC composite.

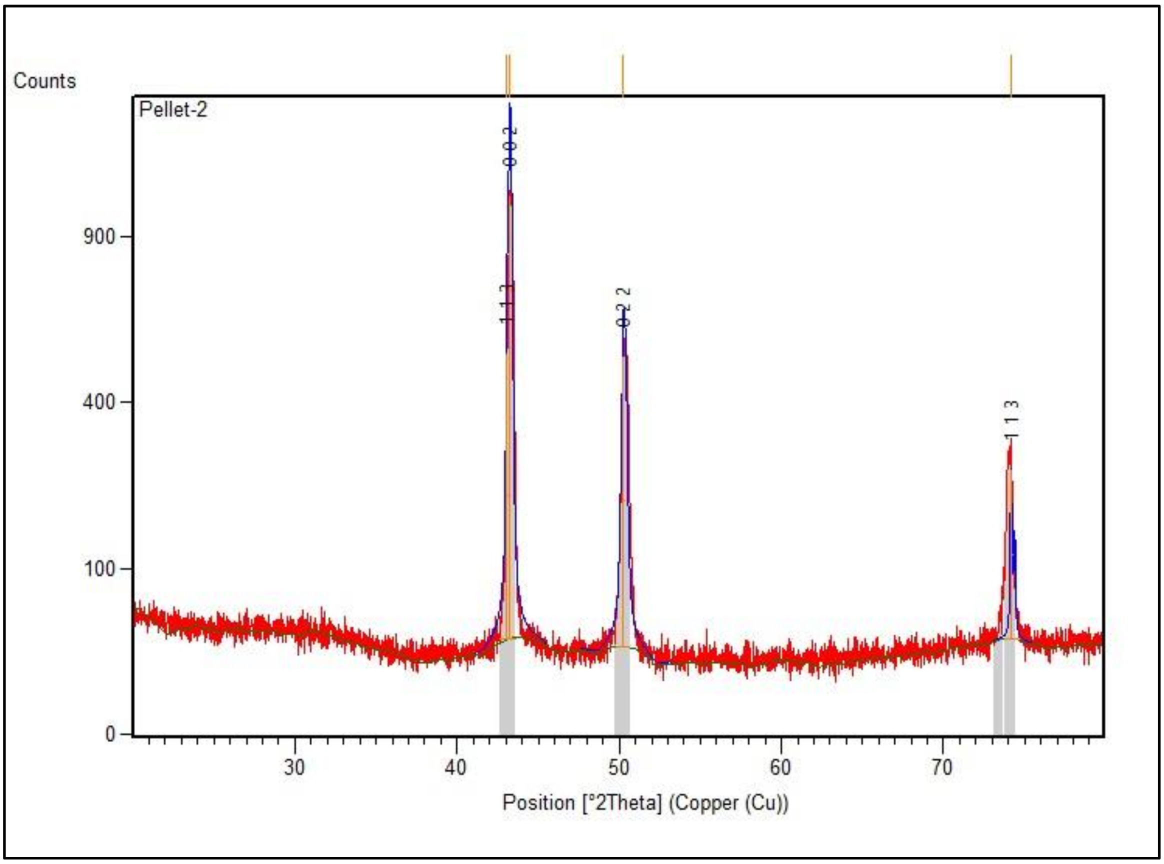


Figure 2.*XRD pattern of Cu-2Fe composite*

Table 3.*XRD Analysis of Cu-2Fe composite*

Ref. Code	**Score**	**Compound Name**	**Crystal Structure**	**Scale factor**	**Chemical Formula**	**Semi Quant [%]**
ICSD-98-005-3757	75	Copper	Cubic	0.997	Cu1	93
ICSD 98-063-1730	31	Iron	Cubic	0.067	Fe1	7

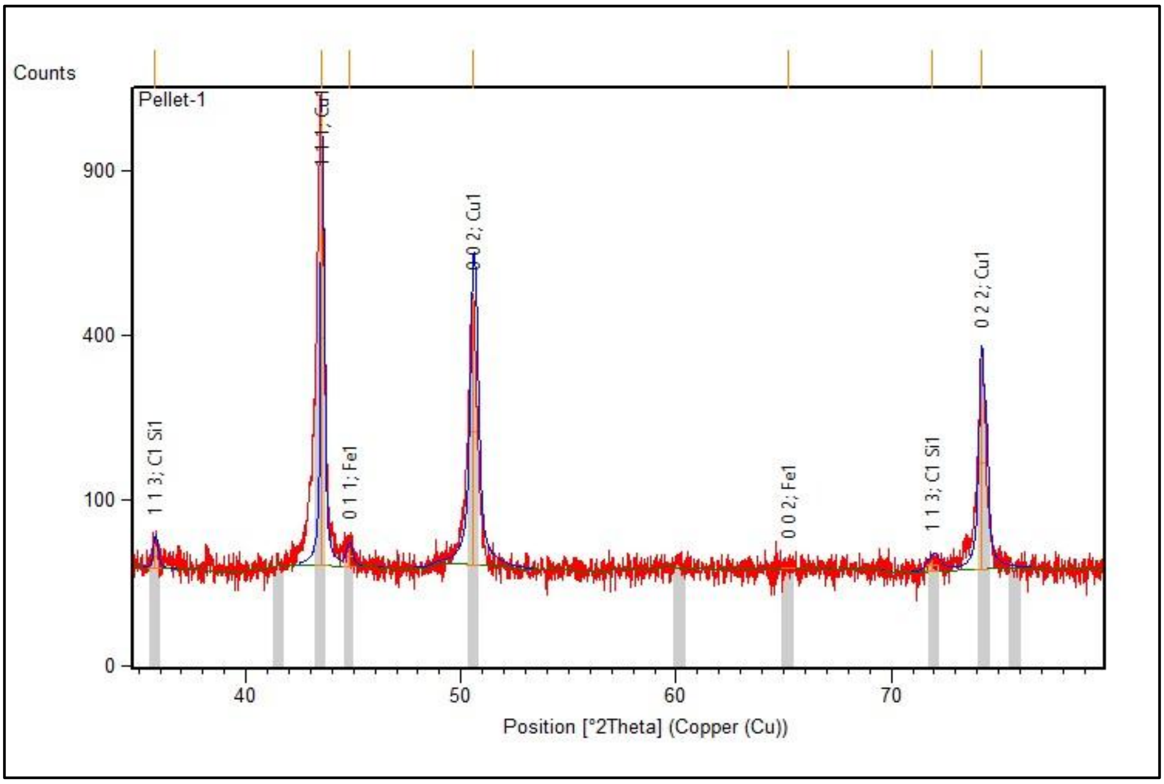


Figure 3*XRD pattern of Cu-2Fe-SiC composite*

Table 4*XRD Analysis Cu-2Fe-SiC composite*

Ref. Code	Score	Compound Name	Crystal structure	Scale factor	Chemical Formula	Semi Quant [%]
ICSD 98-062-7117	45	Copper	Cubic	0.872	Cu1	95
ICSD 98-006-4999	66	Iron	Cubic	0.018	Fe1	2
ICSD 98-002-4217	30	Moissenite 3C	Cubic	0.011	C1 Si1	3

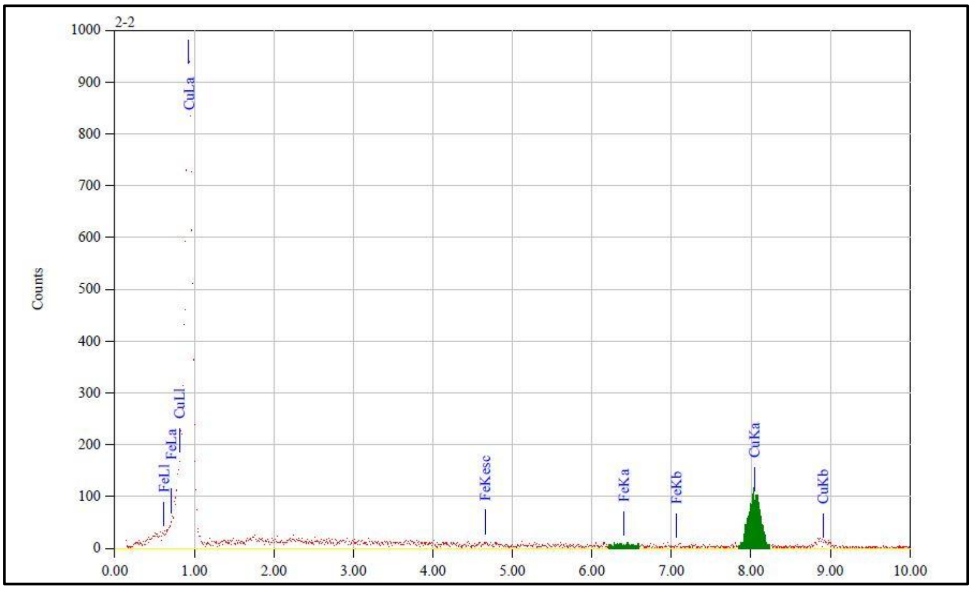


Figure 4*EDAX Result Cu -2Fe composite*

ZAF Method Standardless Quantitative Analysis

Fitting coefficient: 0.3488

***Table 5** EDAX result of Cu-2Fe Composite*

Element	(Kev)	Mass %	Error %	Atom %	K
Fe K*	60389	0.20	1.00	0.23	0.2347
Cu K*	8.040	99.80	2.73	99.77	99.0329

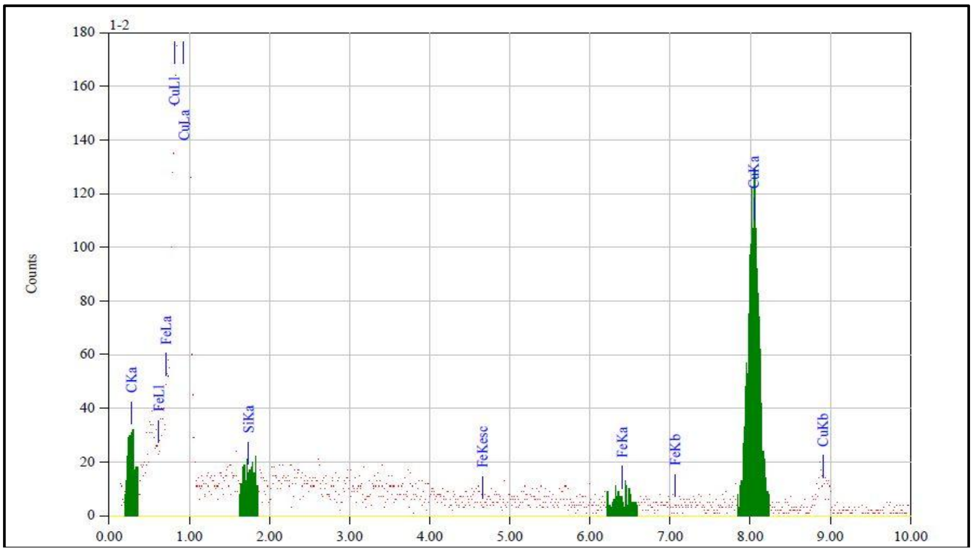


***Figure 5**EDAX Result Cu -2Fe-SiC composite*

Method Standardless Quantitative Analysis
Fitting coefficient: 0.3488

***Table 6** EDAX result Cu-2Fe-SiC Composite*

Element	(Kev)	Mass %	Error %	Atom %	K
C K	0.277	7.63	0.21	30.40	1.7558
Si K*	1.739	0.30	0.26	0.52	0.2066
Fe k*	6.398	0.51	0.75	0.44	0.6343
Cu K	8.040	91.01	2.03	68.50	95.5148
Lu M	1.581	0.54	1.26	0.15	0.3185

Optical Micrograph of Cu-2Fe shows in figure 6 (a) clearly shows the presence of Fe particle and its distribution in Copper matrix. Figure 6 (b) shows the optical micrograph of Cu-2Fe-SiC which shows the presence of Fe particle which was black and SiC particle which are gray in color.SiC particles are visible in the optical micrograph. Both the samples were also studied under SEM for further investigation of microstructure. The microstructure shows in SEM imagesshow in figure 7 (a) and (b) revealed that the bonding has taken place between copper,Fe and SiCparticles. Some amount of porosity is also visible in the micrographs.As is depicted from the optical and SEM micrographs that all the reinforcement particles are well enwrapped by the copper matrix, indicating that the bonding between the particles and the copper is quite satisfied.

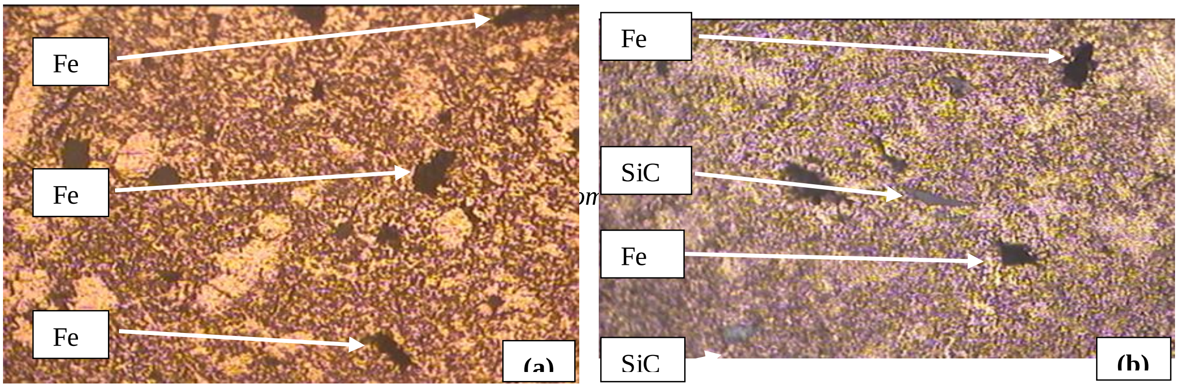


***Figure 6** Optical images of (a) Cu-2 Fecomposite (b)Cu-2Fe-Sic composite*

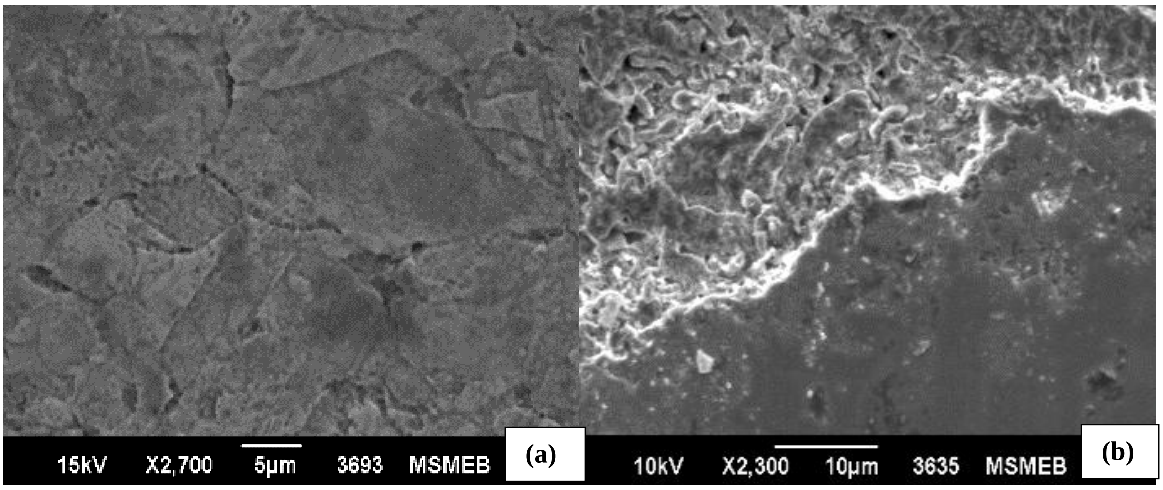


Figure 7*SEM image of* ***(a)*** *Cu-2Fe composite* ***(b)*** *Cu-2Fe-SiC composite*

3.2Hardness measurements and results:-

The Rockwell Hardness test was performed by taking the preload as 3 kgf and the major load as 100 kgf. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery. This major load is then released and the final position is measured against the position derived from the preload, the indentation depth variance between the preload value and major load value. This distance is converted to a hardness number. Here, HRB readings are taken as the steel indenture balls are used and three readings of each sample were noted and the average of the reading is considered are shown in the Table7 drawn below in figure 8: As it is clear from the plot shown in figure 8 that the hardness of Cu-2Fe sample is found to be 18.5HRB.However the hardness of second sample Cu-2Fe-SiC increases up to 23HRB due to reinforcement of SiC.Hence hardness of Cu-2Fe-SiC is approximately 24% more than Cu-2Fe composite.

Table 7 *Reading of Rockwell Hardness test*

Sr.No	**Sample**	**1st reading (HRB)**	**2nd reading (HRB)**	**3rd reading (HRB)**	**Average reading (HRB)**
1	Cu-2Fe	B15	B23	B21	B18.5
2	Cu-2Fe-SiC	B18.5	B27	B23	B23

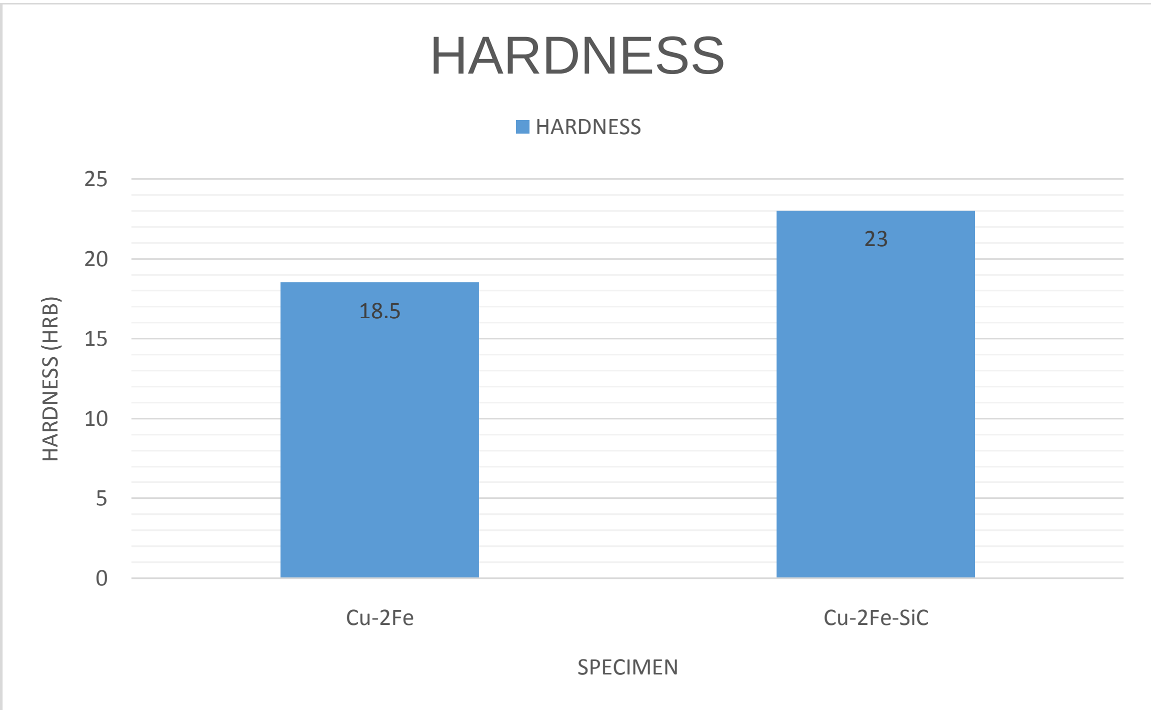
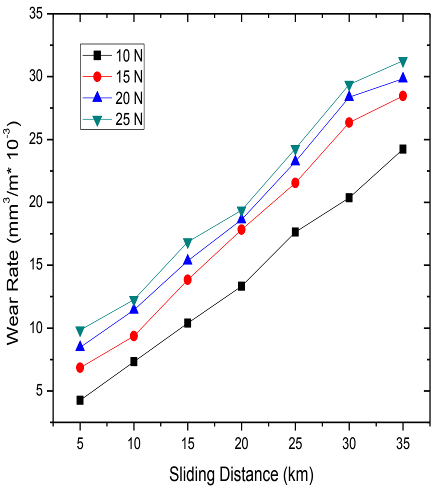


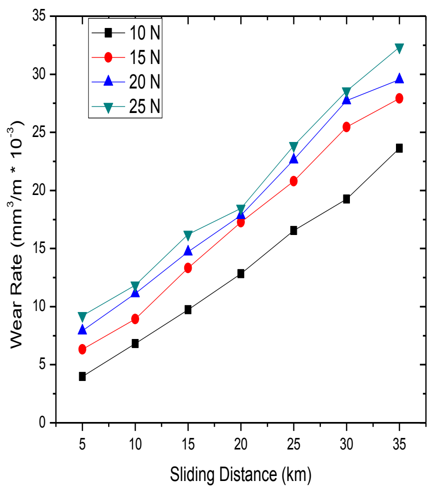
Figure 8 *Plot shoeing hardness results of specimen*

3.3 Wear test analysis

Wear test analysis was carried out separately in order to evaluate the wear resistance of the composites and a graph fig- and fig- is plotted using experimental result. The variation of cumulative wear rate with sliding distance was studied at the different load. Figure 9 (a) and(b) shows the results of the cumulative wear volume with sliding distance at the different load and fixed sliding velocity i.e., 0.75 m/Sec for Cu-2Fe and Cu-2Fe-SiC. It is observed the cumulative wear volume increase linearly with an increase the sliding distance at fixed load and the sliding velocity. It is evident from figure9. (a) And (b) that the initial running in periods is followed by the steady state wear, seen in both the composite. In steady state wear, it shows a linear relationship between the wear volume and sliding distance. The cumulative wear volume also increases with an increase the normal load. However the cumulative wear lost is observed to be less in Cu-2Fe-SiCcomposite materials than that from the Cu-2Fe as clear from Figure 9 (a) and (b). The relation found here is in accordance with the pattern for most metallic materials derived theoretically as well as observed experimentally. The wear rate, i.e.Volume loss during wear per unit sliding distance at a given load is calculated from the slop of the best fitted line on a specific curve shown in Fig.9 (a) and (b). [7-8]

The studies conducted, to see the effect of applied load on wear rate, reveal that wear rate increases continuously with load in a linear manner, as it is evident from Figure 10 at a particular velocity. Composite Cu-2Fe-SiC shows the lowest wear rate at the higher load while Cu-2Fe composite shows the higher wear rate even at the lowest load. From the curve between average wear rate and normal load, we observed that the wear rate of composite material decreases with enhancement of SiC with Fe in copper matrix, in the materials due to increase hardness of the composite and corresponding decrease in real area of contact. [9-10]





(a) (b)

Figure 9 *Variation of average wear rate with sliding distance (a) Cu-2Fe (b) Cu-2Fe-SiC*

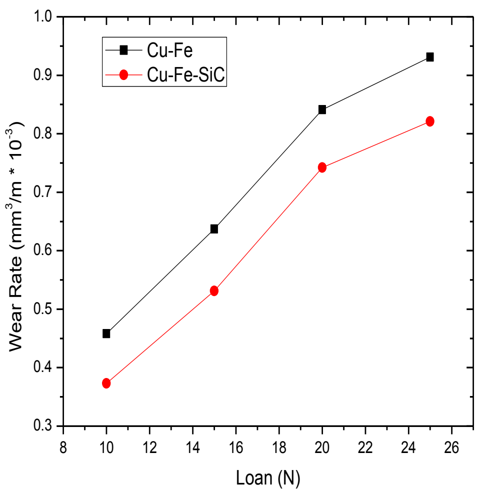


Figure 10 *Variation of average wear rate with normal load*

For the surface examination, we were studied the worn out surface of Cu –2Fe and Cu-2Fe-SiC composite in SEM shown in Figure 11 (a) and (b). With the help of micro structural analysis we observed that with increasing the load in duration of wear test the deep grooves are formed in the sample by the removal of either metallic or oxide layer. Generally, the parallel ploughing grooves and scratches can be seen over all the surfaces in the direction of sliding. These grooves and scratches resulted from the ploughing action of asperities on the counter disc of significantly higher hardness.

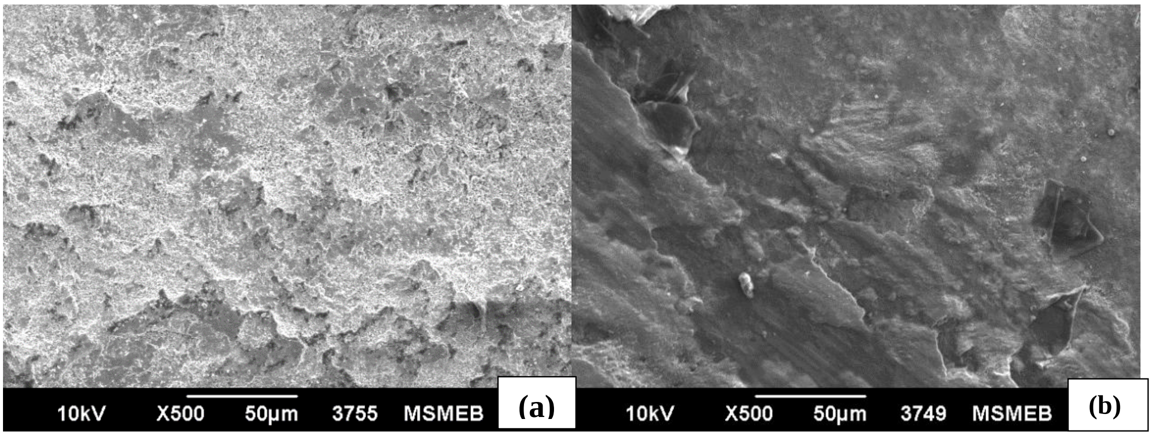


***Figure 11** SEM image of worn pin surface of (a) Cu-2Fe and (b) Cu-2Fe-SiC*

3.4 Roughness behaviour with the help of AFM Results

Firstly the AFM of polished sample is taken and its 2D and 3D images of area 10 x 10 μm^2 are captured. As it is clearly observed by Figure 14roughness profile of the Cu-2Fe composite that the maximum peak of high profile rises up to 150 NM where as it rises less in height profile of Cu-2Fe-SiC Composite up to 60 names shown in Figure 15 which is less in the comparisons of both the composite.

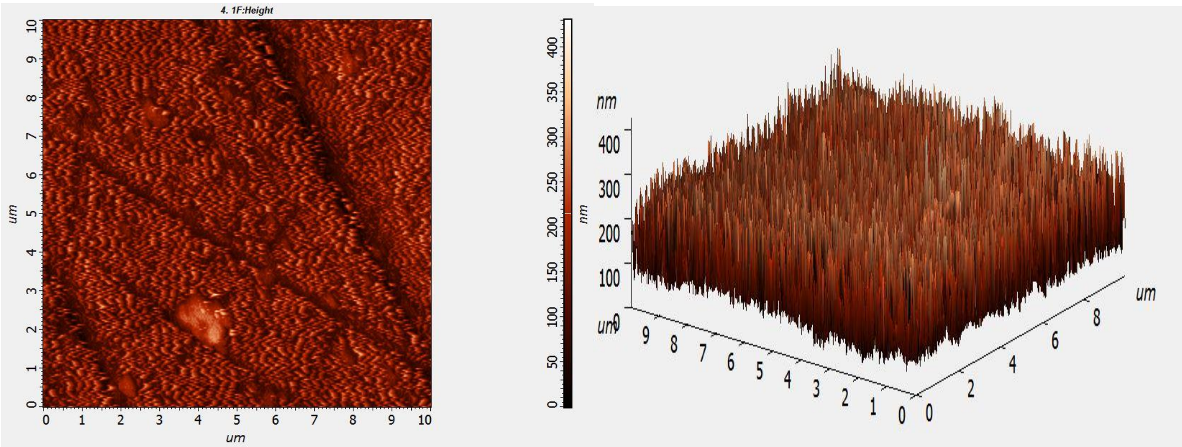


***Figure 12** 2D and 3D AFM image of Cu –2Fe Composite (10 x 10 µm2)*

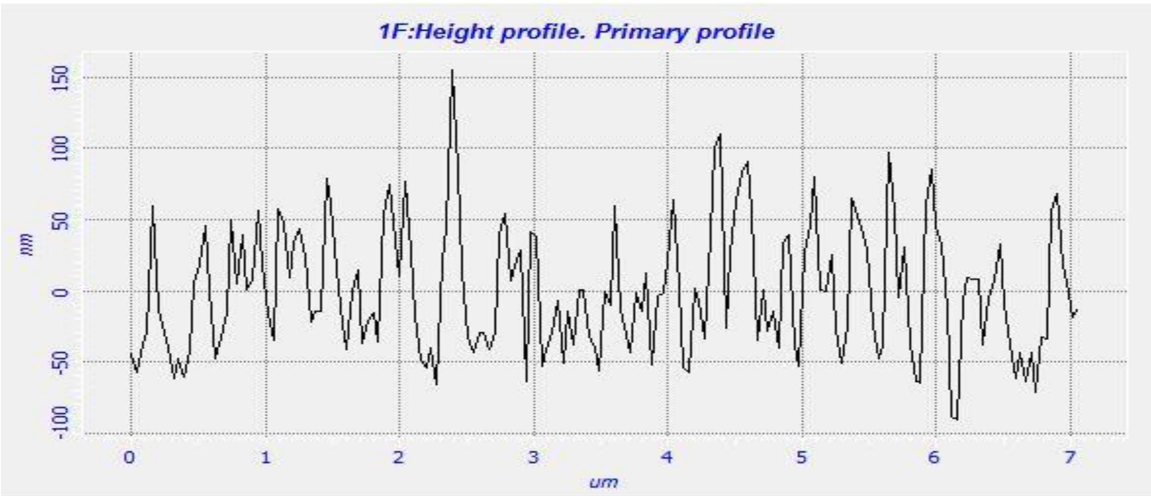


***Figure 13** Height profile, roughness profile of Cu –2Fe Composite (10 x 10 µm2)*

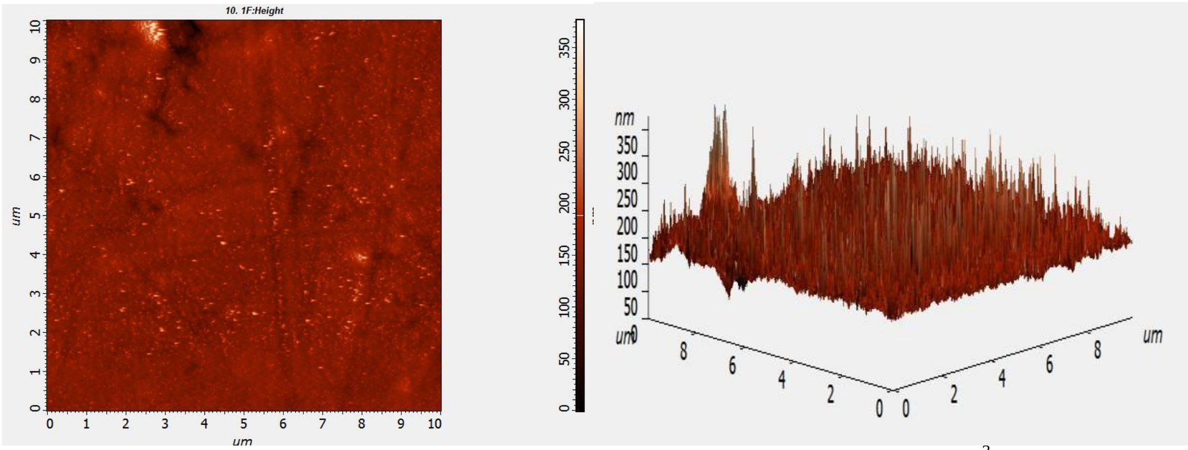


Figure 14 *2D and 3D AFM image of Cu-2Fe- SiC Composite (10 x 10 μm^2)*

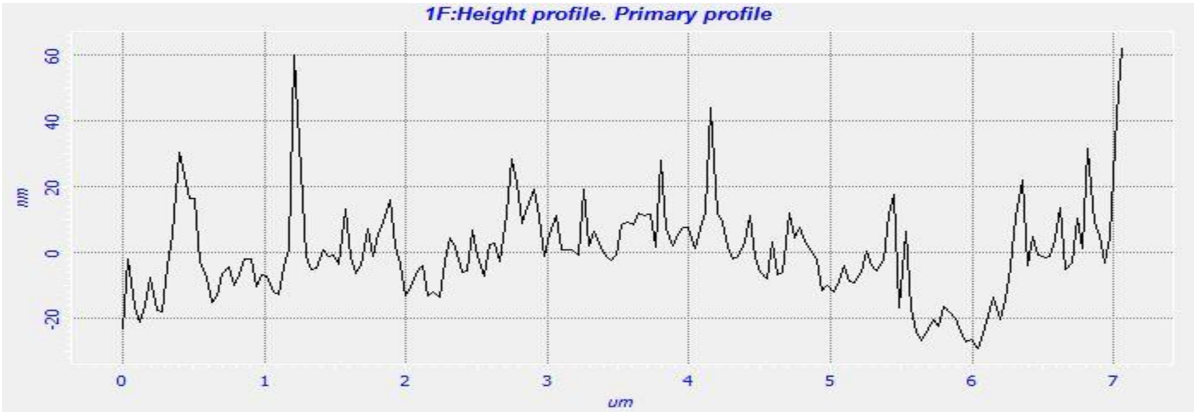


Figure15 *Height profile, roughness profile of Cu-2Fe-SiC Composite (10 x 10 μm2)*

IV. CONCLUSION

1. Copper based metal matrix composites can be successfully fabricated by powder compaction and hot pressing technique.
2. Microstructural analysis shows the presence and well distribution of Cu and SiC particles in copper matrix.
3. XRD analysis reveals the presence of Fe and SiC in composites which is also confirmed by EDAX analysis.
4. With the application of SiC as a reinforcement additionally with Fe in Copper matrix Hardness of composite increases approximately 24%, which results in decreasing wear rate.
5. Cu-2Fe-SiC Composite possesses better tribological properties than Cu-2Fe composites.
6. AFM result revealed that Cu-2Fe-SiC Composite has better roughness behavior than Cu-2Fe Composite

REFRENCES

1. Chawla, Krishan Kumar, Composite Materials: Science and Engineering, second edition.
2. C.C. Leong, L. Lu, J.Y.H. Fuh, Y.S. Wong, " In situ formation of copper matrix composites by laser sintering" Materials Science and Engineering A ,volume 338 Issue 1-2, pages 81- 88, 2002
3. S.C. Tjong, K.C. Lau,"Tribological behavior of SiC particle reinforced copper based metal matrix composites" Materials Letters 43 ,pages 274–280, May 2000
4. Moustafa S.F., Abdel-Hamid Z., Abd-Elhay A.M. "Copper matrix SiC and Al2O3 particulate composites by powder metallurgy technique." Material Letters, 53,pages 244–249, 2002
5. Sanjeev Das, Sidhart Das,Kabir das "Composite Science and Technology" 67, Pages746-751, 2007.
6. ASM Metal Handbook, Vol 09, Metallography and Microstructures
7. Zhang Yijie, Ma Naiheng, Yi Hongzhan, Wang S., And Wang H., "Effect of Fe on grain refinement of commercial purity aluminium" Materials and Design 27 ,Pages 794-798, 2006
8. Skrotzki W., Keegler K., Tamm R., AndOertel C.G., "Grain structure and the Texture of cast iron aluminides" Cryst. Res. Technol.40, No.1/2, Pages 90-94, 2005.
9. García-Cordovilla C., Narciso J., Louis E., "Abrasive wear resistance of aluminum alloy/ceramic particulate composites" , Wear, 192, 1-2, Pages 170-177, 1996.
10. Korkut M.H.,"Effect of particulate reinforcement on wear behavior of aluminum matrix composites" , Materials Science and Technology, 20, 1, Pages 73-81, 2004.