SLIDING WEAR BEHAVIOUR OF Fe-Cr-TiC COMPOSITES

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Abstract

Ferrous matrix composites materials containing titanium carbide are produced by the direct reaction of pure titanium with molten Fe-Cr-C alloy. TiC particles were formed in liquid iron solution by the reaction between pure titanium and carbon available in molten Fe-Cr-C. The microstructure, wear behavior of Fe-Cr-TiC composites is discussed. Examination of the composite microstructure revealed a near uniform distribution of the particulate reinforcement through the metal matrix. The effect TiC on sliding wear analyzed. Results indicate that micro structural parameters play an important role in improving wear resistance of the composite material. Sliding wear increases with increasing carbide volume fraction.

Keywords: *ferrous, Fe-Cr-TiC, Wear, Microstructure, etc.*

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1. INTRODUCTION

Ferrous based metal matrix composites [MMC’s] have attracted the considerable attention of researches in the field of material science in recent years as they posse’s potential improved properties over commercial metals and alloys. In recent years, particle reinforced iron matrix composites have been a core of attention within the range of new materials [1-2]. Based on earlier investigations, incorporation of ceramic particles i.e. Al2O3, SiC, TiB2, WC and TiC in an iron metal matrix give great improvement on the mechanical and wear properties of iron and its alloys. Among these ceramic particles, TiC had drawn much attention as reinforcements in iron matrix due to its high hardness, wear resistance, high chemical stability, high thermal and shock resistance.[3] Iron based composites with reinforcement of TiC particles have received interest in these classes of materials. [4-5] although, most of the work on iron based composites are centred on low and medium carbon steel to improve upon their wear resistance, strength and stiffness of the composites.

TiC particles with high hardness are widely used as the reinforcing phase for iron matrix due to good wettability with liquid iron [6]. The TiC phase strongly influences the mechanical, wear and corrosion properties by bonding with matrix of iron [7]. Bandyopadyay and Das synthesis the TiC reinforced ferrous based composites for wear resistance application [5]. The ferrous matrix prepared is having high wear resistance but, high brittleness. Prarashivamurthy et al [8] also developed TiC reinforced composites by In-Situ technique and observed in improved wear and erosion properties along with reduced tensile properties. But, in many industrial applications, ferrous matrix composites essential to provide combination of wear properties with toughness gives high service life of the components [9]. The various alloying elements like Ni, Cr, Mn etc. enhances the properties in the matrix of iron. The alloying elements like chromium, up to 12% increases toughness and wear resistance of the steel [10].

In-situ casting method for synthesizing the TiC crystals in the molten iron is observed by reacting titanium along with carbon in molten iron. TiC precipitation is occurring is based on the thermodynamically first order of kinetic reaction . The synthesizing the TiC particles in Fe-Cr molten alloy Cr promote the formation of TiC along with toughened matrix austenite face. Thus. No much of literature is available for understanding fracture behaviour of Fe-Cr-TiC composite. The present study was undertaken with the primary objective of influence of TiC on wear behaviour of Fe-Cr-TiC composite produced by casting method.

2. EXPERIMENTAL PROCEDURE

The induction furnace of 20kg capacity was used to melt the alloy. The charge material used was clean steel scrap, Chromium13% and petroleum coke. Petroleum coke was used to adjust the carbon content, and 3.5, 7, 10.5 and 14 weight percent of titanium were added respectively. High temperature refractory crucible was used as the reaction container. The crucible was heated via water-cooled copper coils in an induction furnace. The reaction time and temperature are 15 minutes and 1620^{o}C respectively. For TiC formation, a calculated weight of titanium bar was plunged in to the liquid Fe-Cr melt to form titanium carbide. After completion of reaction, the power was turned off and melt was poured into sand mould and allowed to solidify. The chemical composition of the base metal was determined using vacuum emission spectrometer, carbon content in the sample were analysed by wet method and composition of the alloy is tabulated as shown in table 1. The microstructure of composites was examined using optical microscope and scanning electron microscope (SEM). The castings are designated as 1, 2, 3 and 4 for reference based on the volume fraction of TiC in each of them.

Table 1: Chemical analysis of Fe-Cr-TiC composites in (wt %)

Sample no	C	Mn	Ni	Cr	Ti	Fe
1	0.83	0.66	0.11	13.58	0.036	Balance
2	0.85	0.52	0.94	12.58	3.99	Balance
3	1.37	0.56	0.00	12.48	7.56	Balance
4	1.63	0.73	0.00	12.36	10.36	Balance
5	2.14	0.36	0.00	12.24	14.51	Balance

3. MICROSTRUCTURE

Four different grades of Fe-Cr-TiC composites were prepared as described in section 2. Table 1 gives the chemical composition of the Fe-Cr-TiC composites. The castings are designated 1, 2, 3, 4 and 5 for future reference based on the volume fraction of TiC in each of them.

Typical microstructures of Fe-Cr-TiC composites in as-cast condition are shown in figure 1 to 4 at two magnification of 100X and 400X for sample 3and 5. The structure shows the carbide distribution in the matrix with well defined grain boundary. The size of the carbide increases with increasing carbon and titanium contents

Table 2: TiC grain size measurement of Fe-Cr-TiC composites

Sample no	Minimum grain size in µm	Maximum grain size in µm	Mean grain size in µm	Aspect ratio (H/W)	% of pearlite Area	Volume Fraction of TiC
2	13.1	17.0	15.0	0.92	2.3	4.62
3	15.6	19.8	17.7	0.94	2.6	8.26
4	21.3	23.9	22.6	0.94	4.5	12.67
5	23.3	26.2	24.5	0.94	4.8	14.87

The aspect ratio of the Fe-Cr-TiC composites between 0.92 to 0.94 shows (Table 2) the crystals are nearly equiaxed. The structure shows that pearlite in the matrix. The bonding between TiC and Fe-Cr matrix is good.

The Fe-Cr-TiC composites were examined in the scanning electron microscope. Typical high magnification micrographs of sample 3 and 5 are shown in fig 5 and 6. The structure shows that the TiC particles are nearly rectangular in shape with occasional coalescence of a few carbides.

Energy dispersive X-ray analysis was carried out on all the composites. The fig 9, 10 and 11 shows the X-ray mapping of Chromium, Titanium, and iron respectively. From the X-ray mapping, it is clear that no chromium is uniformly distributed in the matrix. The X-ray profile data of the Fe-Cr-TiC matrix (Fig 12) shows that 14.87 Chromium is dissolved in the matrix of steel for sample no 4 which is in comparable in with the chemical analysis data.

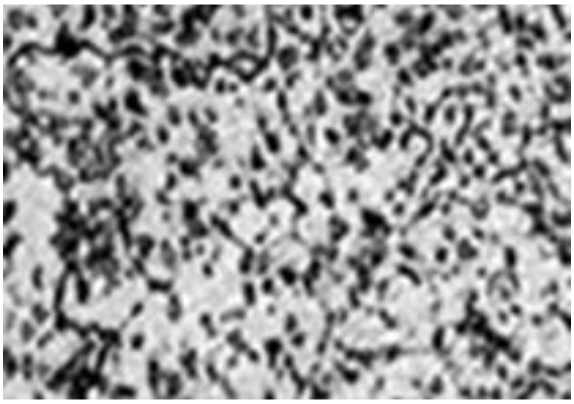


Fig 1: Optical microstructure of sample 3 with lower magnification (100X)

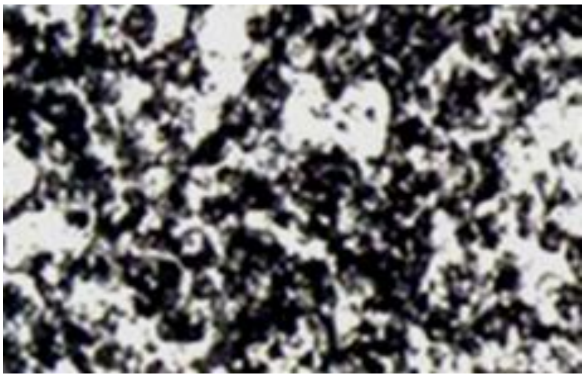


Fig 2: Optical microstructure of sample 3 with higher magnification (400X)

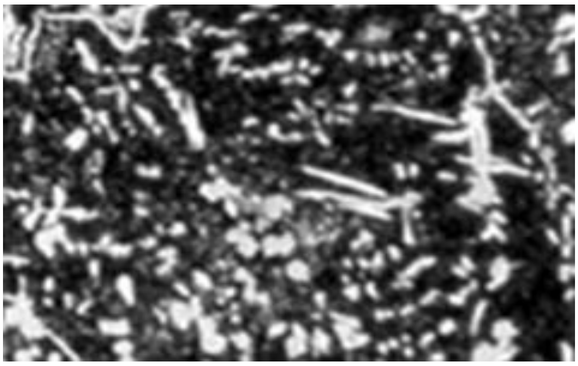


Fig 3: Optical microstructure of sample 5 with lower magnification (100X)

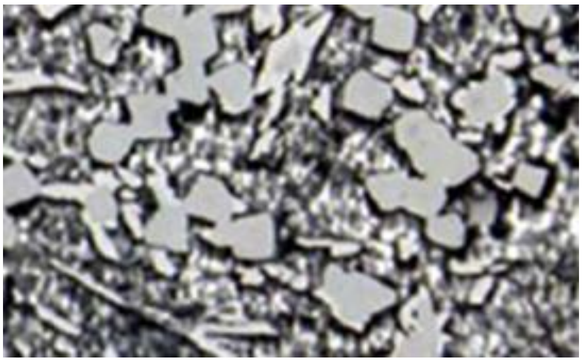


Fig 4: Optical microstructure of sample 5 with higher magnification (400X)

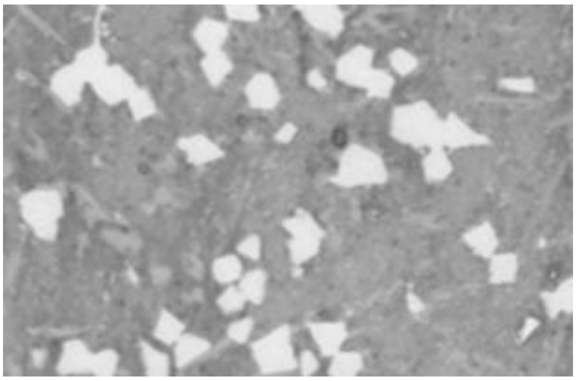


Fig 5: Scanned electron micrograph of Sample 3 with a lower magnification

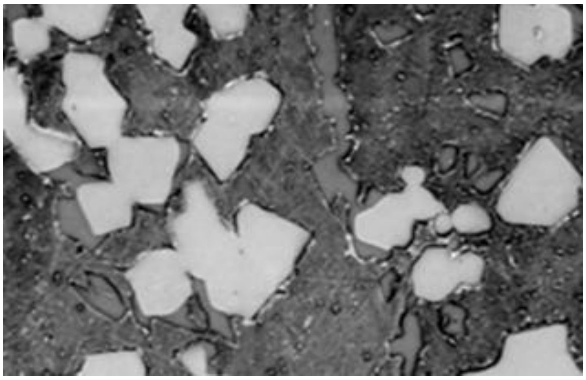


Fig 6: Scanned electron micrograph of sample 3 with a higher magnification

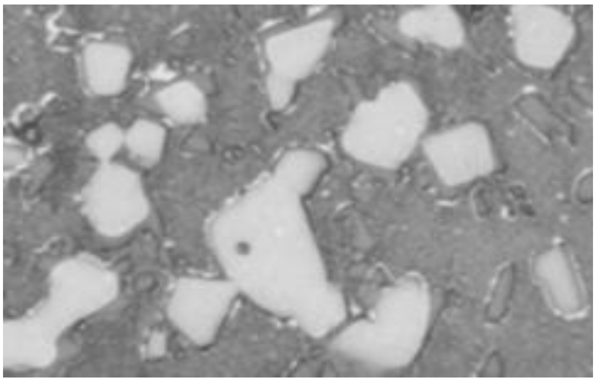


Fig 7: Scanned electron micrograph of Sample 5 with a lower magnification

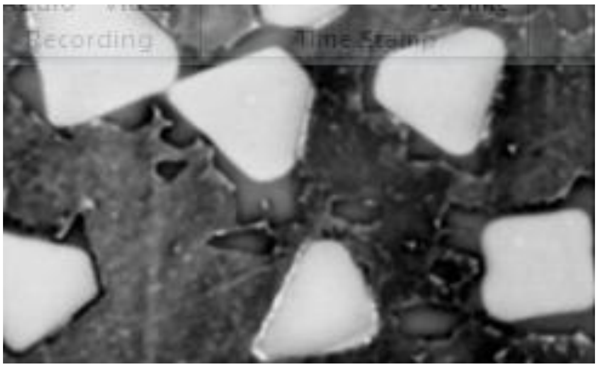


Fig 8: Scanned electron micrograph of sample 5 with a higher magnification

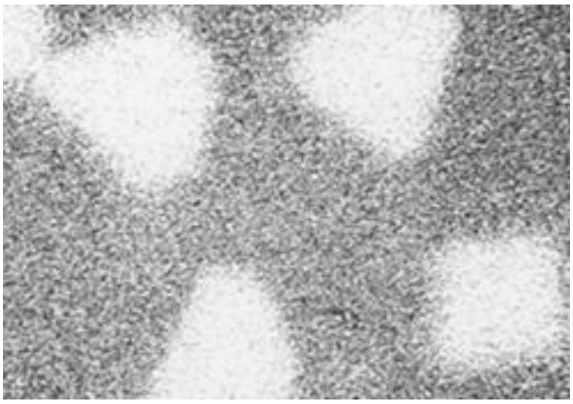


Fig 9: X-ray mapping of Chromium

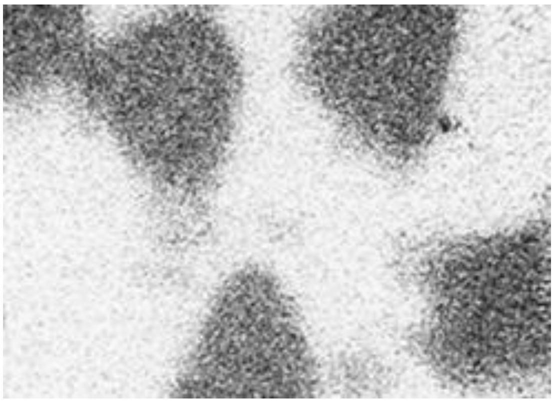


Fig 10: X-ray mapping of Titanium

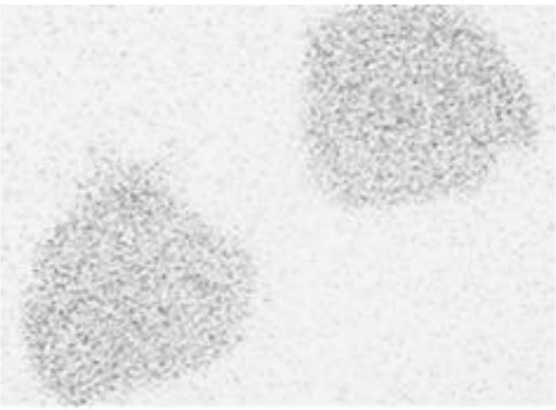


Fig 11: X-ray mapping of iron

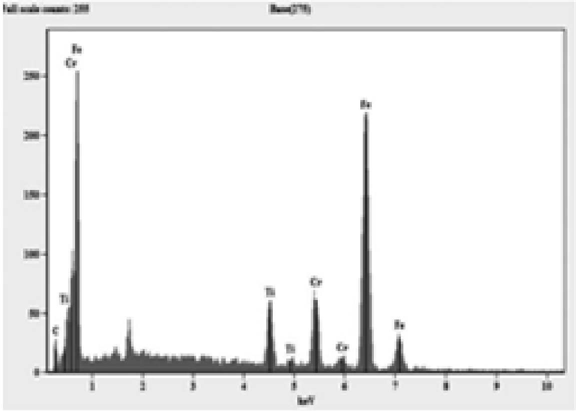


Fig 12: Shows X-ray diffractogram of Sample 3

4. HARDNESS

The Rockwell hardness of all the samples were measured using hardness testing machine at a test load of 1471 N and a diamond cone indenter. Rockwell-C hardness values are reported taking the average of five readings. Micro hardness increases with increasing amount of carbide as shown in Table 3. Fig 13 shows that Rockwell-C hardness increases with increasing volume fraction of carbide.

Table 3: Rockwell hardness and micro hardness data

Sample no	**Rockwell hardness in Rc**	**Micro hardness HV-30**
1	40.9	316
2	42.5	825
3	43.9	920
4	45.2	970
5	47.8	1020

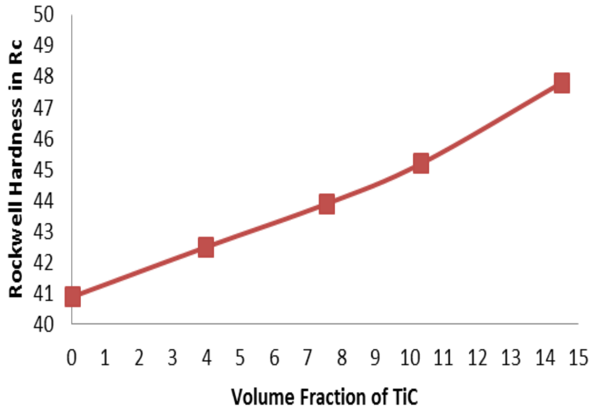


Fig 13: Rockwell-C Hardness v/s Volume fraction of TiC

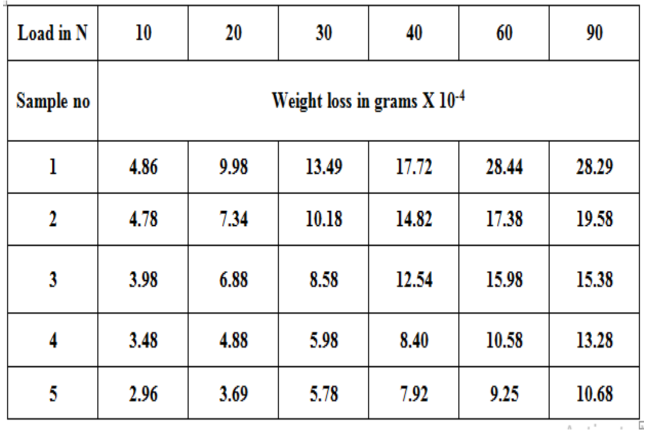
5. WEAR TEST

The adhesive wear resistance of the alloy and composites were studied using instrumented pin-on-disc equipment. The disc used for evaluation was a high hardened cast iron disc with hardness 52 HRc. The specimens of 4mmX4mm cross section were ground using 600 grit emery paper, weighed accurately up to 0.005 decimal points and mounted on the specimen grip. The machine was started and frictional force as indicated by the load cell was noted. After completion of the test, the burrs at the edges of the specimens were carefully removed and the specimens were weighed again accurately. The wear rates were then calculated using weight loss method.

Table 4: Pin-on-disc wear loss at loading 50N .15min at 200 rpm

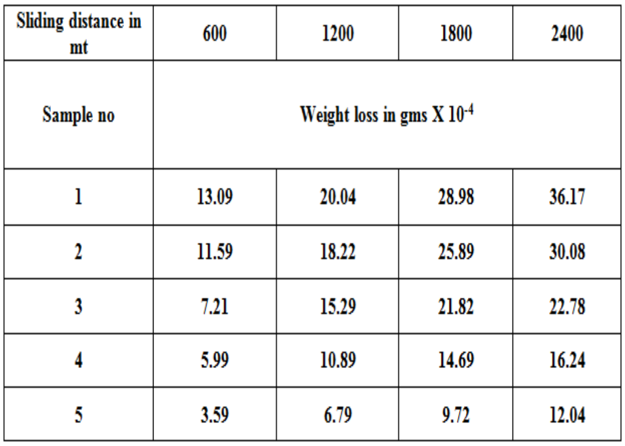
Sample no	**Wear in grams**
1	0.0076
2	0.0069
3	0.0037
4	0.0018
5	0.0007

Table 5: Pin-on-disc wears loss at different loading condition, 250rpm, and 15 min



Load in N	10	20	30	40	60	90
Sample no	Weight loss in grams X 10^{-4}					
1	4.86	9.98	13.49	17.72	28.44	28.29
2	4.78	7.34	10.18	14.82	17.38	19.58
3	3.98	6.88	8.58	12.54	15.98	15.38
4	3.48	4.88	5.98	8.40	10.58	13.28
5	2.96	3.69	5.78	7.92	9.25	10.68

Table 6: Pin-on-disc wear at varying sliding distance at 50 N



Sliding distance in mt	600	1200	1800	2400
Sample no	Weight loss in gms X 10^{-4}			
1	13.09	20.04	28.98	36.17
2	11.59	18.22	25.89	30.08
3	7.21	15.29	21.82	22.78
4	5.99	10.89	14.69	16.24
5	3.59	6.79	9.72	12.04

The wear in grams of the pin-on-disc tests, conducted on Fe-Cr-TiC samples are given in tables 4 to 6. The tests were conducted under varying loads (10N to 90N at 250 rpm and 15 min), varying sliding distance 600m to 2400m at load 50N) and applied load of 50N and sliding velocity of 3.43m/s. Figure 14 to 16 show the variation of weight loss with load, with sliding distance and with varying TiC volume fraction in samples 1 to 5. Figures 17 show the variation of pin-on-disc wear with Rockwell-C hardness. It is evident from the above data that the wear resistance increases with increase in volume fraction of TiC and with increasing Rockwell-C hardness.

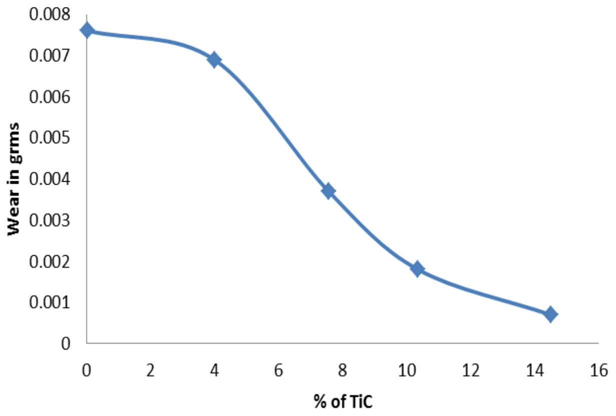


Fig 14: Wear Rate v/s Volume fraction of TiC

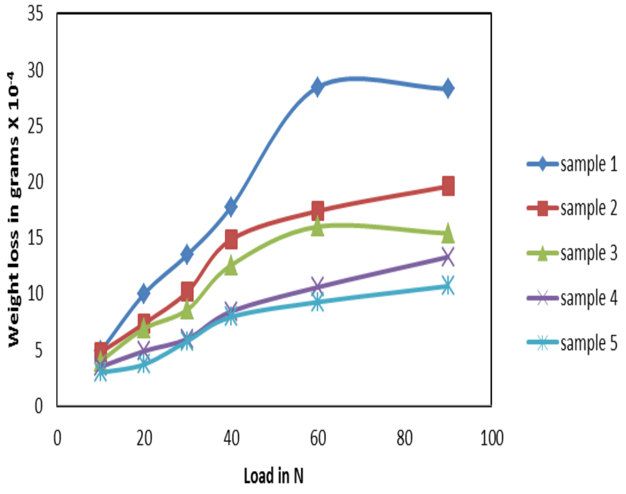


Fig 15: Weight loss v/s load

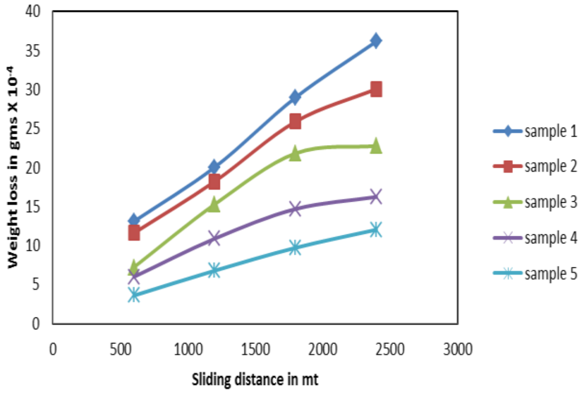


Fig 16: Weight loss v/s Sliding distance

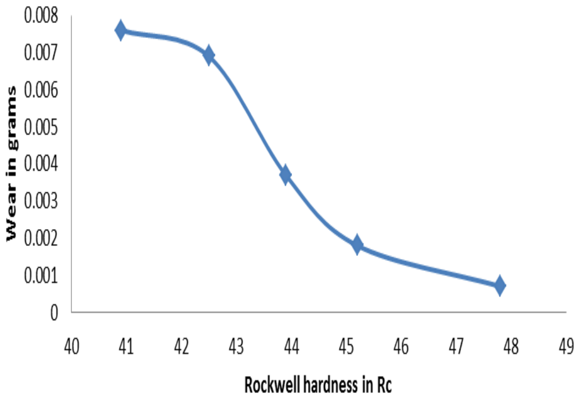


Fig 17: Wear Rate v/s Rockwell Hardness

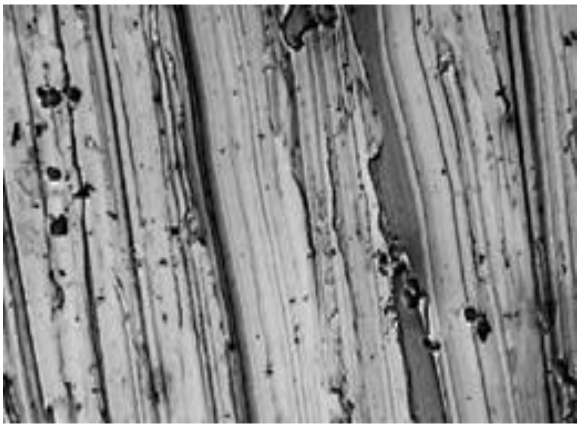


Fig 18: Scanned electron micrograph of wear surface of sample 3

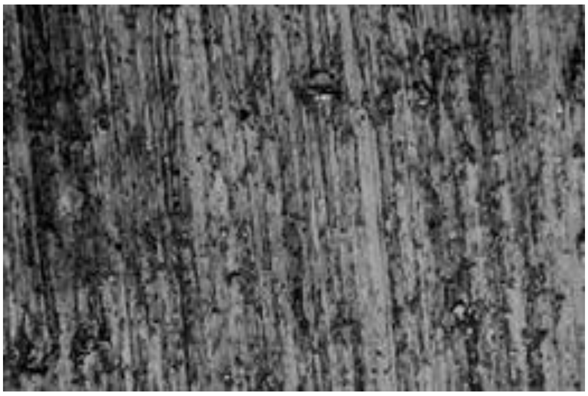


Fig 19: Scanned electron micrograph of wear surface of sample 5

6. CONCLUSION

Based on the result of this investigation on the wear behavior of TiC reinforced with Fe-Cr matrix, the following observations were made

1. Direct addition of pure titanium rod under protective cover of lime holds good promise for producing Fe-Cr-TiC composites.
2. The size, shape and distribution of TiC are mainly dependent on the titanium and carbon content in the matrix. High titanium and carbon contents lead to large TiC size in composites.

3. As the percentage of titanium carbide increases hardness is also increases.
4. Adhesive wear experiments using pin-on-disc technique showed that the addition of TiC improves considerably the wear properties in all the composites.

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