IN-SITU TIC PRECIPITATION IN MOLTEN FE-CR-C AND THEIR CHARACTERIZATION

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Abstract

Tic particles were formed in liquid iron solution by the reaction between pure titanium and carbon available in molten Fe-Cr. TiC particles have been precipitated in steels with four different carbon content by in-situ reaction during melting. The influence of titanium, carbon and chromium concentration on the precipitation of TiC and effect of chromium on TiC was studied. The samples were studied by means of optical microscopy, scanning electron microscopy and X-ray microanalysis. The morphology of the obtained crystals was studied and correlated with carbon and titanium and chromium. It was found that TiC crystallises as primary crystals at 1600°C during solidification of the Fe-Cr melt. The obtained crystals were of cubic, rectangle and had maximum of 27.2µm the size and shape of the carbides increases with increasing carbon and titanium in molten Fe-Cr.

***Keywords**: TiC, X-ray, Chromium, Optical Morpology. etc.*

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1. INTRODUCTION

Composites are leading candidate for applications where a good combination of strength and plasticity required. **[1]** Metal matrix composites [MMCs] are currently one of the focuses of intense research and development worldwide. Although much of the metal matrix composites [MMCs] interest in centred on lighter structural material like Ti, mg, and aluminium primarily to attain improved strength and stiffness. **[2]** In recent years metal matrix composites reinforced with ceramic particulates have received considerable attention, For example, Particulate reinforced steel matrix composites have been proposed for use as wear and corrosion resisted parts in the chemical process industry.**[3-4]** Metal matrix composites dispersed with discontinuous particulates gain a considerable amount of attention as an important engineering material in automotive, aerospace and defence sectors and also to an extent in general engineering because of their improved properties and much lower cost of production.**[5]**

TiC is one of the most important compounds among transition metal carbides, due to its promising physical properties, such as high melting temperature(3140°C), a high boiling temperature(4820°C), high Vickers hardness (25-35 Gpa) high young's modulus (410-450 Gpa) low density (4.93 g-cm^3), high flexural strength (240-400N/mm^2), good thermal conductivity (21W/m2XK), high resistance to corrosion and oxidation, high abrasion resistance, high thermal shock resistance. So it is widely used for cutting material, abrasion, anti-wear and aerospace materials.**[6-7]** Fe-Cr-TiC can be produced by various technologies, some of these technologies include exothermic dispersion(XD), liquid-solid or liquid-liquid reactions, and self-propagation high- temperature synthesis (SHS).Patrick person et al.**[8]** produced Fe-TiC composites, however, manufacturing of Fe-TiC composites using SHS will encounter large difficulties handling the intrinsic porosity during reaction. S.C.T Jong G.S Wang **[9]** produced metal matrix composites through Ex-Situ process of fabricating MMCs posses some inherent defects, such as residual micro porosity, uneven distribution of reinforcement, non wetting of the reinforcement and control of matrix reinforcement interface. Scaling up of the process for industrial utilization and processing cost. K.I Parashivamurthy et al **[10]** produced Fe -TiC composites through in-situ technique by reacting Fe- C molten alloy with 4, 8, 12, and 16 percent of titanium. The evaluation of size, shape and distribution of TiC particles was carried out on all the samples. Kattamis and suganuma **[11]** have developed Fe-TiC composites by reacting titanium in molten Fe-C and mixing of carbides in high carbon steel, and achieved well dispersed carbides in a steel matrix. Y.L. REN, X.L.HAN **[12]** produced Fe-TiC by in-situ synthesized 10% TiC in iron matrix composites. The results shows that TiC is in two kinds of morphologies, i,e, spherulic and rod-like ones. It is thought that the spherulic TiC is a proeutectic phase and the rod-like one is a eutectic.

The phase diagram (Figure 1) describes the composites consisting of reinforcements of TiC in the matrix of iron-Chromium. In the reaction, initially TiC nucleates because titanium has an affinity for carbon when compared to iron and chromium, and the distance A-TiC gives the associated free energy, when TiC precipitates first. The residual driving free energy for the formation of iron carbide and chromium carbide decreases, and it is represented by B-CrC and C-Fe_3C. As the driving free energy is reduced by the nucleation of TiC, it may be presumed that the Fe_3C and CrC will not nucleate during the composite formation because of kinetic difficulties. As a result, iron carbide and chromium carbide will not appear in the composite casting.

Therefore, TiC alone will nucleate and stabilize in the matrix. Furthermore, X-ray diffraction analysis confirms the non-precipitation of iron carbide and chromium carbide in the matrix of iron chromium

In the present work, we highlight in-situ techniques were used to produce Fe-Cr-TiC matrix composites. This article gives particular attention to the reaction path and the microstructure of the final product is characterized.

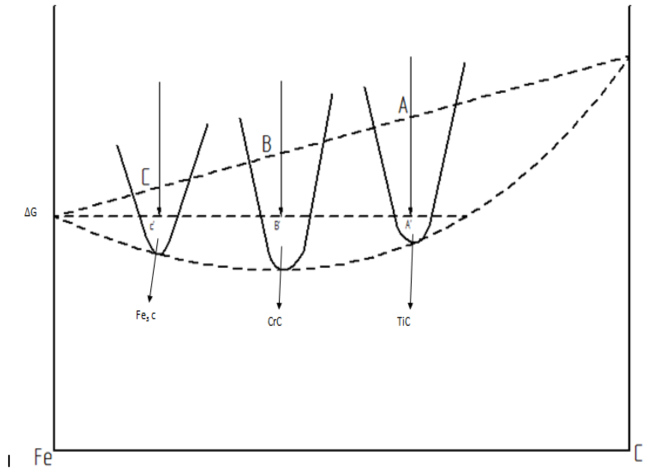

Fig 1: Schematic Free Energy Diagram for Hypothetical Composites

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

As the chromium is added to iron, amount of carbon solubility in austenite decreases. The carbon content of the eutectoid is diminished and the temperature of the eutectoid reaction is raised. Due to changing temperature effect, chromium reduces the rate of cooling.

Typical microstructure of Fe-Cr-TiC composites is shown in fig 1 and 2 at two magnifications of 100X and 400X for sample 2 and 4. The structure shows the carbide distribution in the matrix with well-defined grain boundary. The size of the carbide increases with increasing carbon with titanium contents.

The size and shape of the carbides is evaluated and are presented in table 2. The morphology showed that the carbide particles below 6µm are drastically reduced and the number with grain size between 20 to 30 µm is increased. The size, aspect ratio and volume fraction of TiC in the Fe-Cr-TiC are presented in table 2.

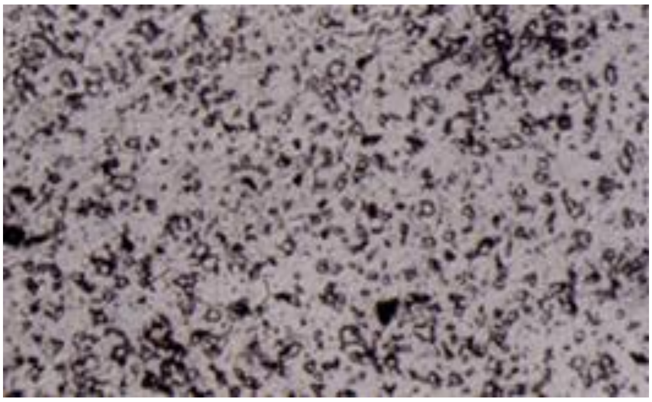

Fig 1: Optical microstructure of sample 2 with lower magnification (100X)

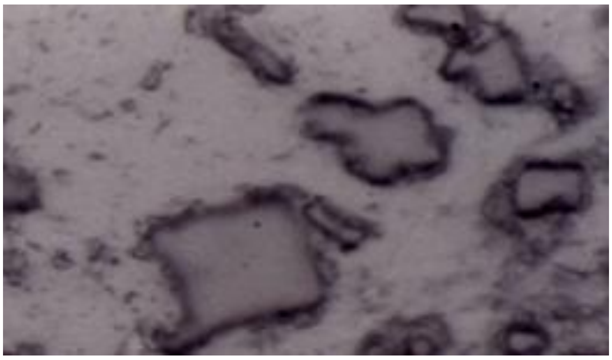

Fig 2: Optical microstructure of sample 2 with higher magnification (400X)

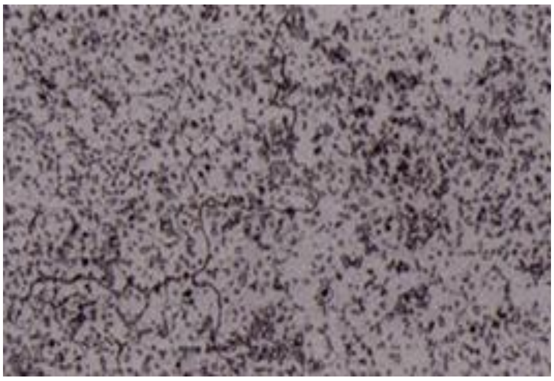

Fig 3: Optical microstructure of sample 4 with lower magnification (100X)

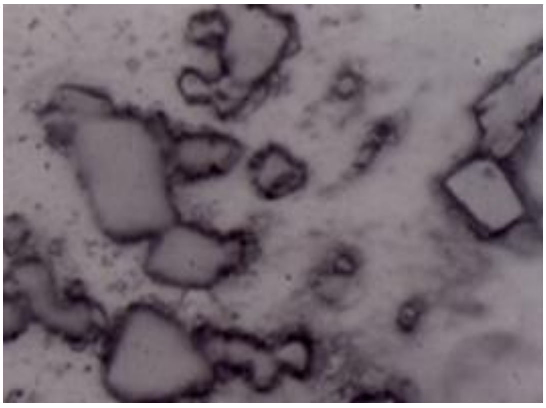

Fig 4: Optical microstructure of sample 4 with higher magnification (400X)

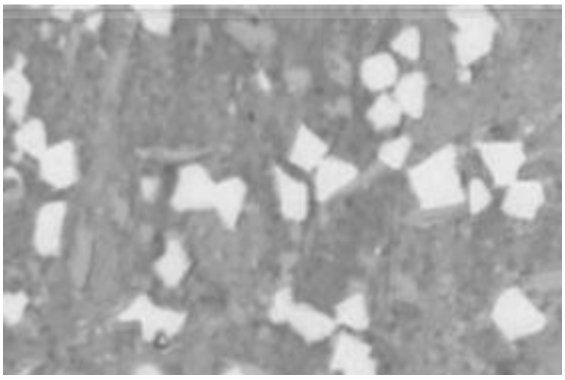

Fig 5: Scanned electron micrograph of Sample 2 with a lower magnification

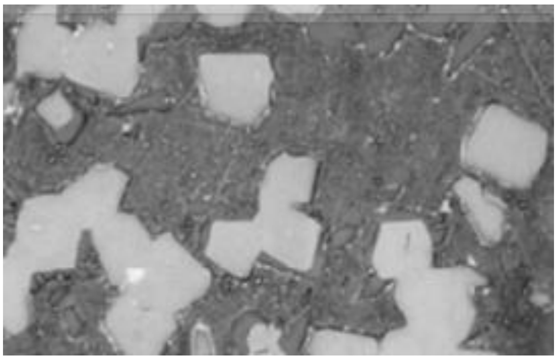

Fig 6: Scanned electron micrograph of sample 4 with a higher magnification

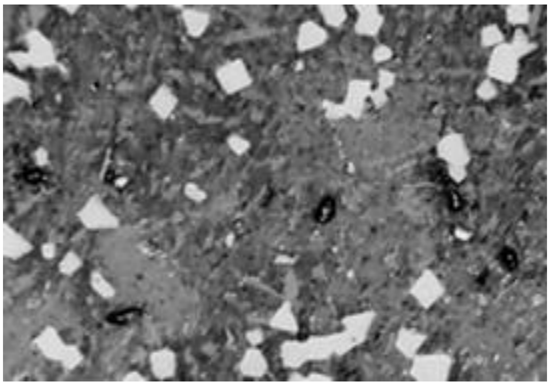

Fig 7: Scanned electron micrograph of Sample 4 with a lower magnification

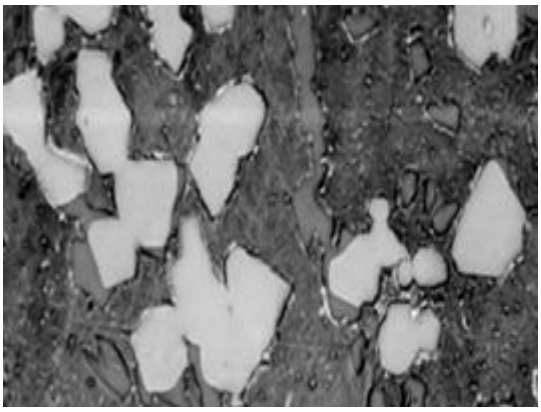

Fig 8: Scanned electron micrograph of sample 4 with a higher magnification

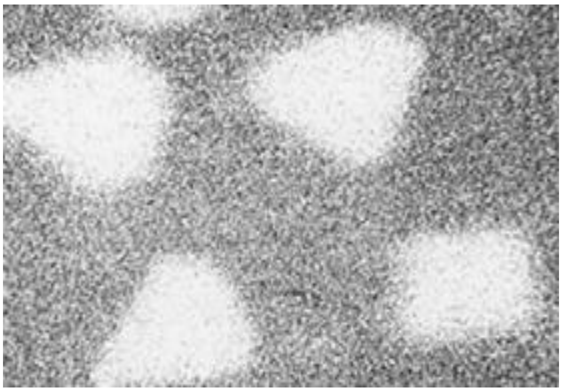

Fig 9: X-ray mapping of Chromium

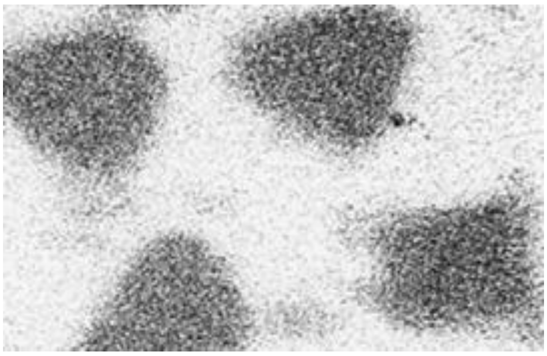

Fig 10: X-ray mapping of Titanium

Fig 11: X-ray mapping of iron

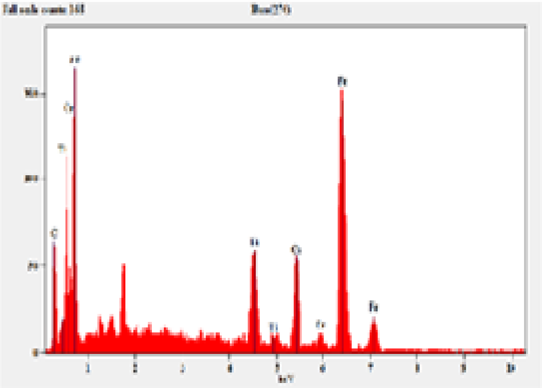

Fig 12: Shows X-ray diffractogram of Sample 4

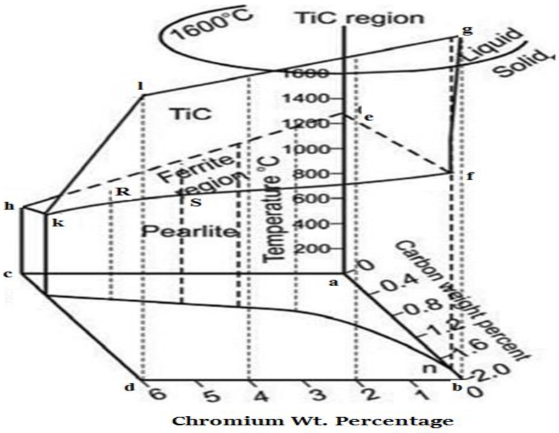

Fig 13: Three-dimensional iron-rich corner of in-situ TiC precipitated Fe-Cr-C phase Diagram

Fig 13 shows a three dimensional drawing of the Tic precipitated in Fe-Cr-C phase diagram. In this diagram, eh represents lowering of ɤ→α change in carbon less alloys, fk represents movement of the eutectoid steel, and nm is the projection fk on to the base triangle; efhk is the surface on which ferrite begins to form in hypo eutectoid alloys, and fglk indicates which ferrite begins to form in hypo eutectoid alloys, and fglk indicates which TiC begins to separate in the hypo eutectoid alloys. The TiC crystals nucleate at around 1600°C and grow constantly as temperature decreases. At some stage in this process 4% titanium reacts with 1% carbon, and the carbon content continuously decreases and and reaches 0.84% in the residue liquid. As soon as the temperature decreases, the primary TiC gets enlarged. Further more, at below 1320°C ferrite begins form when the austenite is cooled to the appropriate point on the surface fghk. Formation of ferrite precedes and the composition of the austenite moves over this surface until it reaches the eutectoid line bc. At eutectoid temperature the residue austenite is transferred into pearlite.

During the solidification, TiC crystallize in the matrix, of Fe-Cr varies with cooling rate. The TiC nucleate at 1600°C will be in regular shapes like rectangle, square, and the TiC Precipitate later will be in irregular with varying shapes in the matrix.

4. CONCLUSION

Fe-Cr-TiC composites are casted through the in-situ casting route on a small scale by varying TiC in Fe-Cr. The additions of chromium to iron-carbon improve hardenability, strength and wear resistance. In Fe-Cr-TiC composites, TiC is uniformly distributed in the matrix of Fe-Cr. No chromium carbide is precipitated due to the prior formation of TiC above the liquidus temperature, thus reducing the carbon content of the pro-eutectic phase and subsequent rise in the M_s Temperature. The TiC crystals often have cubic and rectangular shapes and their maximum size does not exceed 25.5µm. Nucleation and retention in-situ TiC is understood by constructing the three dimensional iron-rich corner of Fe-Cr-C phase diagram.

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