RESEARCHERID
THOMSON REUTERS

[Prajwal, 7(2): February 2020] ISSN 2348 – 8034
DOI- 10.5281/zenodo.3688809 Impact Factor- 5.070

GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCHES

FABRICATION AND CHARACTERIZATION OF Fe-Ni-TiC COMPOSITES PRODUCED BY IN-SITU METHOD

Prajwal A.S*[1] & Parashivamurthy K.I[2]

[*1] Research Scholar, Department of Mechanical Engineering, Government Engineering College, Chamarajanagara, Karnataka, India

[2]Professor, Department of Mechanical Engineering, Government Engineering College, Chamarajanagara, Karnataka, India

ABSTRACT

Titanium carbide (TiC) reinforced Fe-Ni alloy composite has been prepared by the In-Situ method by reacting pure titanium to the carbon in Fe-Ni molten alloy for the wear and erosion applications. In this work, the influence of nickel on the precipitation of TiC in molten Fe-Ni alloy is presented. Nickel was added up to 5%, titanium is varied from 4% to 16 percent in steps of 4%, and carbon is varied from1% to 4 %. The casted composites specimens are analyzed for microstructure and precipitated phases are assessed using optical, Scanning Electron Microscope (SCM) and X-ray diffraction (XRD) analysis. Based on the structure and XRD results, precipitated particles are confirmed as TiC which is homogenously and uniformly distributed in the Fe-Ni matrix. The precipitated TiC in the molten Fe-Ni alloy is explained. Fe-Ni-TiC composites show an increasing trend of percentage elongation, ultimate tensile strength, and Young's modulus.

***Keywords**: Characterization; Composite; In-Situ; Mechanical properties; Metal matrix; Titanium carbide.*

I. INTRODUCTION

From the last two decades, TiC-reinforced ferrous matrix composites by casting route gain substantial research interest due to their wide varieties of properties compared to monolithic counterpart. In the early 1970s, TiC reinforced steel composite has been prepared for high strength and wear resistance at elevated temperature applications [1]. Production of TiC reinforced steel composite through the solidification process by reacting titanium in molten Fe-C is one of the simplest technologies. Many investigators [2–6] have studied the mechanics of reaction and precipitation kinetics of TiC in molten steel. Jayashankar et al. [2] conducted a fundamental study on the solidification of Fe-TiC composites intending to develop Fe-TiC composite by plasma smelting of ilmenite. Jing Wang et al. [4] have conducted experiments on the precipitation of TiC by reacting pure titanium in liquid Fe-C iron. Parashivamurthy et al. [6] have developed Fe-TiC composites by reacting titanium in molten Fe-C. These composites produced by the casting technique suffer from ductility due to the precipitated TiC crystals. This may limit the uses of these composites in industries where, strength, toughness and wear properties are important. Nickel is one of the major alloying elements with steel and it contributes markedly to the strength and hardness and is most effective in medium and high carbon steels [7].

This element has a moderate effect on hardenability and increases the ductility in the steel matrix. It lowers the critical cooling range in low and medium carbon steel. Similarly, Titanium is another alloying element with steel and it improves hardness and wear resistance in medium and high carbon steel. These two elements have the tendencies to form carbides in the steel matrix and titanium having a greater tendency compared to nickel. In the absence of carbon, these elements dissolve to a certain degree in the ferrite phase [8, 9]. The present study was undertaken to know TiC precipitation in the molten Fe-Ni-C alloy with varying nickel up to 5% and titanium is varied from 4% to 16 percent in steps of 4% and carbon is varied from 1 to 4 %. The effect of nickel on the size and shape of in-situ TiC along with ductility is assessed and the microstructure of the precipitated TiC in the Fe-Ni matrix was characterized. Nucleation and retention of precipitated TiC in molten Fe-Ni-C alloy are explaining by constructing a three-dimensional iron-rich corner of the Fe-Ni-C diagram.

[Prajwal, 7(2): February 2020] ISSN 2348 – 8034
DOI- 10.5281/zenodo.3688809 Impact Factor- 5.070

II. METHODS& MATERIAL

For developing Fe-Ni-TiC composites, 3.65 kg of low carbon steel charged into a water-cooled alternating current solenoid coil induction furnace of 10 kg capacity. After melting, the dross was skimmed off and 350 grams of ferronickel alloy, having a yield of 68%, was added to the low carbon molten steel and melting/superheating carried out to maintain the liquid metal temperature at 1600 ±50º C. For increasing required carbon in molten steel, pure petroleum coke powder was added. After confirming the dissolution of coke powder, the dross was skimmed and molten metal was covered with a lime powder about 20 mm thick. Further, a pure titanium rod was plunged through the lime powder and allowed to react with carbon available in molten metal. The reaction time was 10 minutes. The melt was transferred to ladle which was preheated to about 1000 º C and from the ladle, the molten metal was poured into CO2 sand mould.

Four specimens were cast along with carbon varying from 1 to 4 weight percentages in steps of 1 percentage and titanium varying from 4 to 16 weight percent in steps of 4 percent, to get four different compositions of Fe-Ni-TiC castings.

The chemical analysis of composites was identified by using Wavelength Dispersive Spectroscopy (WDS) at the operating voltage 10kV and beams current 10-6 amperes. The contents in the composite samples were determined by the wet method. The microstructures of the Fe-Ni-TiC composites were observed using an OPTIKA B-500 Ti 2F and SEM (Hitachi S-3400N) connected to Energy Dispersive X-ray analysis Equipment's (EDX). Under the SEM analysis, for surface imaging, a secondary electron detector was used and a backscattered electron detector was used for compositional based imaging.

III. RESULTS

Microstructure

To study the effect of nickel on Fe-Tic composites, varying amounts of ferronickel added to the low carbon steel along with titanium and carbide.

Table 1. Chemical analysis of Fe-Ni-TiC Composites (in weight %)

Sample No.	C	Mn	Ni	Cr	Ti	Fe
B	1.16	0.68	5.65	0.09	0.28	Balance
B1	1.02	0.59	4.79	0.81	3.87	Balance
B2	1.41	0.27	4.85	0.07	7.03	Balance
B3	2.21	0.55	6.12	0.5	11.89	Balance
B4	2.81	0.69	0.75	0.19	15.02	Balance

Table 1. gives the chemical composition of Fe-Ni-TiC composites. The base metal, designated as B. It contains 5-weight percent of nickel and 1.16 percent carbon. The Fe-Ni-TiC composites are designated as B1, B2, B3 & B4.

The microstructure of the base alloy shown in figure 1. The base alloy shows the austenite structure in the alloy along with some martensite structure. Nickel addition is known to lead to the cooling below the equilibrium temperature, with rapid metal movement and a greater rate of solidification taking place in the casting. Due to this effect, some amount of structure converts into martensite.

The typical microstructural analysis of Fe-Ni-TiC composites of sample B3 is shown in Figure 2. The micrograph shows that the composites are having uniformly distributed TiC and, in a few cases, they calescence to form elongated carbides.Similarly, Figure 3 shows the SEM microstructure of Fe-Ni-TiC of sample B3 that indicates only TiC is precipitated and the nickel is uniformly distributed in the iron matrix.

Hardness

The Rockwell hardness of both alloys as well as the composite castings was measured using Instron Wolpert make comprehensive hardness testing machine at a test load of 1471 N with a diamond cone indenter. With an average of five readings, Rockwell-C hardness values are reported.The measurements for microhardness were made on different TiC carbide particles in the composite castings using Mitutoyo HM-200 make microhardness tester at a test load of 0.2943 N and an average of five different readings is computed. The microhardness is recorded on all the various phases present in the structure.

The below table 3.2 shows the Rockwell-C scale and microhardness for Fe-Ni-TiC composites.Rockwell and microhardness increase with increasing volume percent of TiC in Fe-Ni-TiC composites.

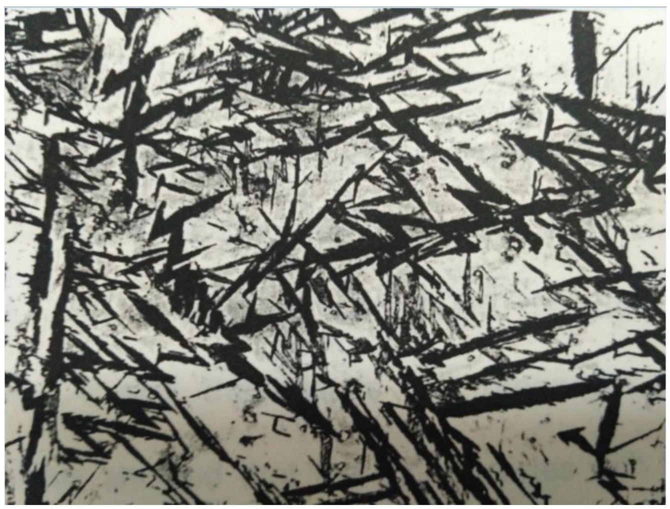
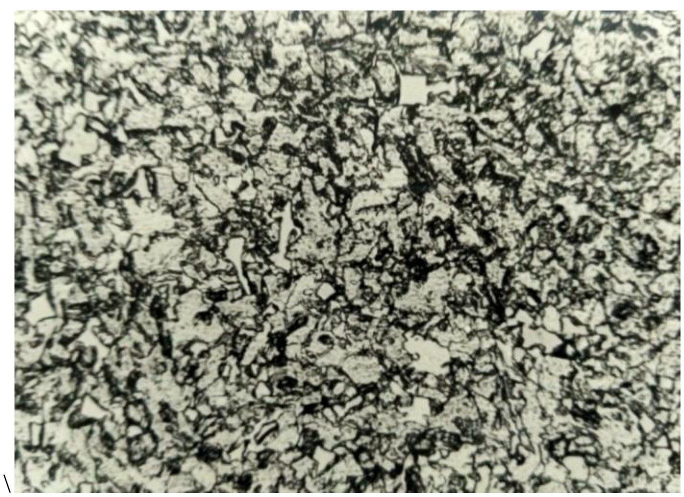


Fig 1: Microstructure of Base Alloy



\

Fig2: Optical microstructure of the in-situ precipitated TiC in the matrix of Fe-Ni alloy for the Sample B3.

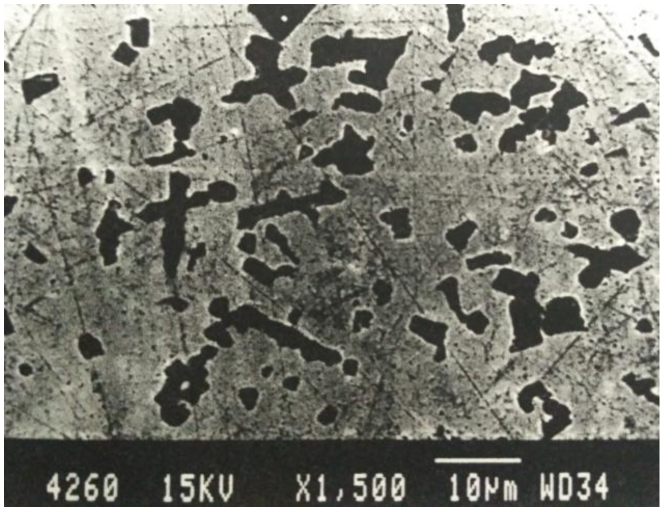


Fig 3: SEM microstructure of the in-situ precipitated TiC in the matrix of Fe-Ni alloy for the Sample B3.

Table 2. Rockwell hardness and microhardness data

Sample No	Rockwell Hardness in Rc	Microhardness HV 30
B	32.6	190
B1	47.2	565
B2	47.9	681
B3	48.4	692
B4	49.1	699

Tensile Strength

Tensile properties were measured using a fully automated servo-hydraulic mechanical testing machine and the results are mentioned below in table 3.The data shows that the young's modulus reduces from 208.86 GPa (Sample B) to 203.14 GPa (Sample B4). Similarly, ultimate tensile strength also decreases with increased TiC content. Elongation is also reduced from 3.16 (Sample B) to 0.02 (Sample B4) indicating increased brittleness.

Table 3. Tensile Properties of Fe-Ni-TiC Samples

Sample No	Young's Modulus in GPA	Tensile Strength in MPA	Percentage Elongation
B	208.86	598.21	3.16
B1	206.63	586.83	2.18
B2	204.76	585.56	0.55
B3	203.45	585.00	0.16
B4	203.14	582.63	0.02

IV. DISCUSSION

In the present investigation, TiC reinforced Fe-Ni matrix alloy composite is prepared by the In-situ method. During the casting process titanium directly reacts with available carbon and converted into TiC at 1650ºC. The nickel is fixed at approximately 5 %. Four specimens were cast along with carbon varying from 1 to 4 weight percentages in steps of 1 percentage and titanium varying from 4 to 16 weight percent in steps of 4 percent, to get four different compositions of Fe-Ni-TiC castings.

Nickel in iron helps in increasing the tensile strength without an appreciable decrease in elongation or reduction of area. Nickel also lowers the critical temperature. Nickel decreases the critical cooling rate and has unlimited solubility in γ iron and higher solubility in ferrite. Nickel also reduces the carbon content of the eutectoid.

In Fe-Ni-C system pearlite, martensite and austenite are formed depending upon the cooling rate and the percentage of carbon and nickel presence. In a 5 % nickel and carbon exceeding 1 %, austenite forms after slow cooling. In practice, all Fe-Ni-TiC composites are pearlite after slow cooling. The final microstructure of Fe-5% Ni castings consists of pearlite and austenite at room temperature.

In Fe-Ni-Tic composites initially, titanium carbides appear and they reduce the carbon content in the matrix of Fe-Ni. In a Fe-Ni system, at a temperature of nearly 1440 ºC, nickel dissolves in an unlimited amount and that reduces the carbon content in molten iron. Low carbon austenite finally decomposes into ferrite and pearlite at room temperature. In the Fe-Ni-TiC system, the matrix structure contains ferrite and pearlite along with TiC, which is precipitated above 1140 ºC. The shape of the carbide is flake-like and the size is smaller when compared with Fe-Tic or Fe-Mn-TiC composites.

Tensile tests were carried out according to ASTM E8 M-93. The specimens were taken from various locations viz, bottom, central and top positions of the castings. Table 3. Shows the tensile properties of Fe-Ni-TiC composites. The data shows that the young's modulus reduces from 208.86 GPa (Sample B) to 203.14 GPa (Sample B4). Similarly, ultimate tensile strength also decreases with increased TiC content. Elongation is also reduced from 3.16 (Sample B) to 0.02 (Sample B4) indicating increased brittleness. Reduction in the area experienced by the composite material was negligible, indicating the absence of grass necking.

Table 2.Shows the Rockwell-C scale and microhardness for Fe-Ni-TiC composites. It is evident from the results that, Rockwell and microhardness increases with increasing volume percent of TiC in Fe-Ni-TiC composites.

V. CONCLUSION

Based on the results of this investigation on fabrication and characterization of Fe-Ni-TiC reinforced steel composite the following observations were made.

- The direct addition of pure titanium rod under the protective cover of lime holds good promise for producing Fe-Ni-TiC composites.
- 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 larger TiC size in composites.
- Rockwell and microhardness increase with increasing volume percent of TiC in Fe-Ni-TiC composites.
- Reduction in Young's modulus and ultimate tensile strength with the increased volume fraction of Fe-Ni-TiC.
- Percentage elongation is also drastically reduced with an increasing volume fraction of Fe-Ni-TiC.

VI. ACKNOWLEDGMENTS

The authors thank The Vice-Chancellor, Visvesvaraya Technological University, Belagavi, and Dr. S.G. Sreekanteswara Swamy, Vision Group on Science and Technology, Bangalore for their constant support and encouragement.

REFERENCES

1. *KI Parashivamurthy, RK Kumar, S Seetharamu and MN Chandrasekharaiah, "Review on TiC reinforced steel composites," Journal of Material Science. 2001; 36:4519-4530.*
2. *K Jayashankar, Animesh Mandal, Archana Pany, and PS Mukherjee, "Synthesis of Fe-TiC In-Situ composites by Plasma smelting of Ilmenite," Materials and Manufacturing Process. 2011; 26: 1330-1334.*

3. *Padma Kumar A, Bajakke, Vinayak R, Malik, Anand S and Deshpande (2019) Particulate metal matrix composites and their fabrication via friction stir processing – a review, Mater& Manu Proc34(8):833-881.*
4. *Jing Wang, Sijing Fu, Shuyong Jiang, Hong Cheng (2012) Study on titanium carbide particles reinforced high manganese steel composite, Ad Mates Res 557-559:232-235.*
5. *Qian Gao, Bin Yang, Han Mei & Huanchun Wu (2016)Microstructure and Wear Resistance of Semisolid TiB2/7050 Composites Produced by Serpentine Tube Pouring Technique, Mater & Manu Pro31(8):1029-1036.*
6. *Parashivamurthy KI, Sampathakumaran P and Seetharamu S (2016) Casting of TiC Reinforced Steel Matrix Composite, Mate& Manu Pro21:473-478.*
7. *Sujit Kumar Khuntia, Bibhuti Bhusan Pani and Subhakanta Nayak (2019) Fabrication of composites from different carbon content ferrous powders adopting thermomechanical processes, Mate& Manu Proc 34(8):82-888*
8. *Xu Zhenming, Liang Gaofei, Guan Qingfeng, and Qi-Chuan Jiang (2004) TiC as heterogeneous nuclei of the (Fe, Mn)3C and austenite intergrowth eutectic in austenite steel matrix wear-resistant composite, Mate& Res Bulletin 39 (3):457-463.*
9. *Etemadi R, Wang Band Pillai KM, Niroumand B, Omrani E and Rohatgi P (2018) Pressure infiltration processes to synthesize metal matrix composites – A review of metal matrix composites, the technology and process simulation, Mate& Manu Proc33(12):1261-1290.*
10. *Parashivamurthy KI and Mallikarjuna C (2013) Effect of Manganese on the Structure and TiC Precipitation in Eutectoid Steel, Mate&Manu pro28(11):1161-1165.*
11. *Jin-long Zhao, Yan Xi, Wen Shi, and Lin Li (2012) Microstructure and mechanical properties of high manganese TRIP steel, Jl Iron and Steel Res Inter 19:57-62.*
12. *Qihong Cen, YehuaJiaug, Rong Zhou, YunhugXu and Jianbin (2010) Wang, Study on In-situ synthesis of TiC particle reinforced iron matrix composite, J Mate Engg & Perfo20:1447-1450.*
13. *Parashivamurthy KI, Sampathakumaran P and Seetharamu S(2008) In-situ TiC precipitation in molten Fe-C and their Characterization Cry ResTech 43:674-678.*
14. *Jipeng Jiang, Shibo Li, Wenbo Yu, and Yang Zhou (2019)Microstructural characterization and abrasive wear resistance of a high chromium white iron composite reinforced with in situ formed TiCx, Mate Che& Phy, 224:169-174.*