International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 981-984 www.ijaem.net ISSN: 2395-5252

Effect of TiC contents on the microstructure and mechanical properties of Fe-TiC composite

Ha Bach Tu[1], Hoang Anh Quang[2]
[1,2]*Mechanical Engineering Faculty, Thai Nguyen University of Technology, Thai Nguyen, Vietnam*

Submitted: 10-05-2022 Revised: 15-05-2022 Accepted: 18-05-2022

ABSTRACT: Titannium carbide (TiC) reinforced metal matrix composite with many advantages such as high hardness, toughness and wear resistance can be widely used in various industries including of mining, rail tracks and cement production. In the present work, TiC reinforced metal matrix composite was fabricated by powder metallurgy method. The TiC contents were varied from 3% to 7%. The powder mixture after 2h milling was pressed in stainless steel mold at an uni pressure of 400 Mpa and sintered at different temperature of (1200-1300)^{o}C for 2h. Phase component of the samples before and after sintering was analyzed by X-Ray diffraction method (XRD). The porosity was measured by Archimedes method and the microstructures were analyzed by scanning electron microscopy (SEM). Effect of TiC contents and sintering parameters on porosity and mechanical properties of samples were discussed. The results showed that with 6% TiC content, sintering at 1300^{o}C, combined with post-sintering plastic deformation, the porosity of the composites decreased sharply (2.18%), the best mechanical properties (Compression strength: 625MPa, Hardness: 345HV).

KEYWORDS: Iron matrix composite, Dispersed durable, Mechanical properties.

I. INTRODUCTION

TiC with high hardness and thermal stability is one of the best choices as reinforcement material for Fe-based composites. The existence of hard TiC particles evenly distributed in the Fe matrix increases the wear resistance, elastic modulus, shear modulus. Therefore, Fe-TiC composites can be used for applications requiring high wear resistance and thermal stability such as in the plastic industry, in the high temperature working industry (Mei et al., 2003[1]); Panchal et al., 1990[2]; Robisch & Slagle, 1989[3]; Dogan & Hawk, 1995[4]).

Manufacturing technology of TiC/iron composites can be divided into two methods: solid phase synthesis and molten casting [5,6,7]. Solid-phase synthesis methods include powder metallurgy, high-temperature self-propagation, mechanical alloying, and thermal carbon reverts [8-16]. The hot melt casting method has the advantages of low cost, large-scale production, can make large parts, complex shapes, but this method requires high temperature, is prone to organizational segregation. 17,18]. Powder metallurgy method is a simple method to synthesize materials from powdered materials, easy to apply to manufacture composites with high TiC content, accuracy, stable particle size, evenly distributed in the steel matrix and does not cause material loss, so this method is commonly used to fabricate metal-based composites.

In this study, powder metallurgy method is used to make Fe-TiC composite. TiC content and sintering temperature were changed to study their influence on the structure and mechanical properties of the composite.

II. EXPERIMENTS

In this study, Fe powder (purity 99.5%; average particle size 100µm) and TiC (99% purity, particle size 2µm ÷5µm) were used to make Fe-TiC composite.

The manufacturing process of Fe-TiC composite was selected as shown in Figure 1. The mixture of Fe and TiC powder (2÷10%) was ground for 2 h in hexane by a planetary ball mill with a ball/powder ratio of 5/1, at speed of 300 rpm. The powdered mixture after grinding is pressed and shaped in a steel mold ϕ15x80 mm under pressure of 400MPa.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 981-984 www.ijaem.net ISSN: 2395-5252

The sample after pressing was sintered in a resistance furnace with Ar shielding gas at 1200÷1300^{o}C for 2h. After sintering, the sample was tested for porosity and then deformed under 700MPa pressure, then annealed at 1200^{o}C for 2h. The final product is measured for porosity, hardness and compressive strength.

The phases were examined by X-ray diffraction (XRD, D8 ADVANCE, Germany). The microscopic organization and distribution of TiC in the composite were observed through SEM images (JEOL JSM-7600F Scanning Electron Microscope, Japan).

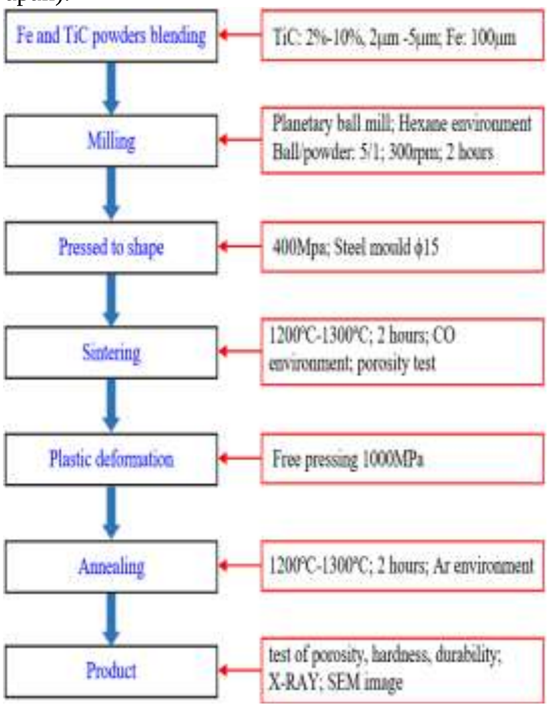

Figure 1. Technological process for making Fe-TiC composite

III. RESULTS AND DISCUSSION

3.1. Effect of TiC content and sintering temperature on the porosity of composites

Figure 2(a) shows the influence of TiC content and sintering temperature on porosity of the composite after sintering. Porosity increases with increasing TiC content, because TiC is a hard phase, so it is difficult to achieve high density when pressed, moreover, the small fine TiC hinders the diffusion of the substrate (Fe) when sintering. After pressing and sintering at 1200^{o}C, the porosity of the material is 12.66%÷17.42%%. Increasing the sintering temperature to 1300^{o}C, the diffusivity of Fe increases, the porosity decreases to 9.55%-13.98%. To further reduce porosity, plastic deformation and annealing of the material are carried out.

Figure 2(b) shows the influence of TiC content and sintering temperature on the porosity of the material after plastic deformation and annealing. The porosity decreased sharply to 2.18-4.5%, the cause of the reduction in porosity is that after sintering in a CO atmosphere, the oxide film on the surface of the Fe particles was reverted, increasing the compressibility, combining with plastic deformation under high pressure reduces the volume of pores.

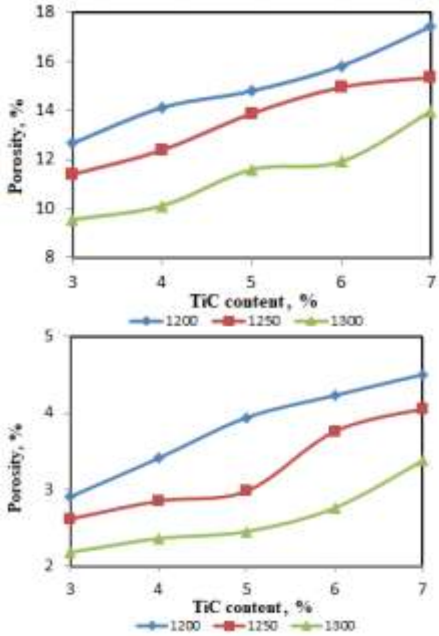

Figure 2. Effect of TiC content and sintering temperature on the porosity of the composite
(a) – After sintering; (b) – After deformation and annealing

3.2. Effect of TiC content and sintering temperature on the hardness of composites

Figure 3 shows the influence of TiC content and sintering temperature on the hardness of the material. As the TiC content increases, the hardness increases, which is completely consistent with the theory. On the other hand, increasing the sintering temperature also increases the hardness of the material due to a decrease in porosity.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 4, Issue 5 May 2022, pp: 981-984 www.ijaem.net ISSN: 2395-5252

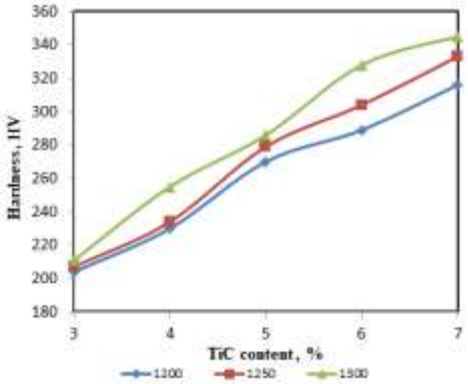

Figure 3. Effect of TiC content and sintering temperature on the hardness of composites

3.3. Effect of TiC content and sintering temperature on the compressive strength of the composite

From Figure 4 shows the influence of TiC content and sintering temperature on the strength of the material. The strength increases rapidly when the TiC content increases from 3-5%, this proves that the Fe substrate has been reinforced by fine and evenly distributed TiC particles. With the sintering temperature of 1200^{o}C, 1250^{o}C, if the TiC content continues to increase, the strength tends to decrease, due to the decrease in material density. Increasing the sintering temperature, promoting the diffusion process also increases the strength and reaches the maximum value of 625MPa with 6%TiC content when sintering at 1300^{o}C.

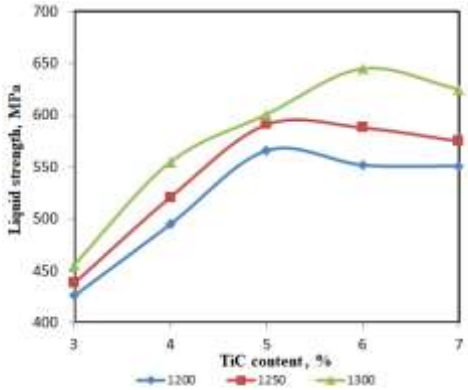

Figure 4. Effect of TiC content and sintering temperature on the strength of the composite

3.4. Microorganism and phase composition of composites

X-Ray diffraction image of sample 6%TiC (sintered at 1300^{o}C) (Figure 5) shows that the composite consists of two phases Feα and TiC, no foreign phases or oxides are seen, this proves that the input material meet the requirements. The sintering process did not produce foreign phases and is not oxidized.

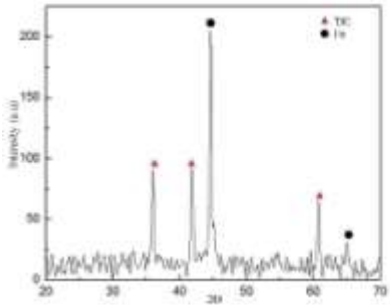

Figure 5. X-ray diffraction pattern of Fe-TiC composite with 6% TiC

Figure 6 is the microorganization image of the Fe-TiC composite samples. Gray TiC particles, light Fe background. Samples of 5%TiC, 6%TiC showed a uniform distribution of TiC particles on the Fe substrate, which explains the increase in mechanical properties of Fe-TiC composite when TiC content increases. When TiC content is large (7%), TiC particles are seen to have clustering and uneven distribution, which can be one of many causes of reduced strength of the material.

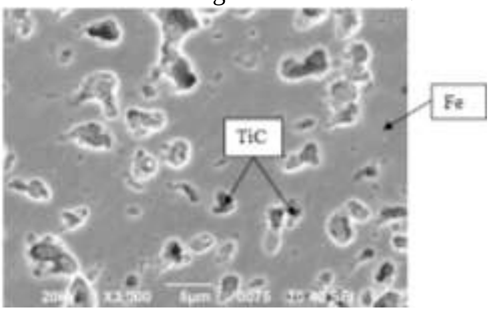

Figure 6. Microstructure image of Fe– 5%TiC composites with magnification X 3000

IV. CONCLUSION

The mechanical properties of Fe-TiC composites are enhanced when reinforced by TiC. With 6% TiC, sintering at 1300^{o}C, combined with plastic deformation after sintering, the mechanical properties of the composite are the best: Liquid strength: 625MPa; Hardness: 345HV.Compared with the properties of the Fe substrate (liquid strength: 120 MPa; hardness: 60.8 HV), the obtained Fe-TiC composite material can be applied as an alternative structural material for C steel such as gears without requiring heat treatment.

ACKNOWLEDGMENT

This work was supported by the Thai Nguyen University of Technology

REFERENCES

[1]. Mei, Z., Yan, Y.W., Cui, K., 2003. Effect of matrix composition on the microstructure of in situ synthesized TiC particulate reinforced iron-based composites. Materials Letters 57, 3175–3181.

[2]. Panchal, J.M., Vela, T., Robisch, T., 1990. Ferro-TiC metal matrix composites for high performance tooling and engineering applications. Fabrication of Particulates Reinforced Metal Composites, Montreal, Quebec, Canada, pp. 245–260.

[3]. Robisch, T., Slagle, P., 1989. Steel-bonded carbides for wear problems. Materials and Design 10, 258–261.

[4]. Dogan, O.N., Hawk, J.A., 1995. Abrasion resistance of in situ Fe–TiC composites. Scripta Metallurgica et Materialia 33, 953–958.

[5]. F. Akhtar, S.J. Askari, J.A. Shah and S.J. Guo (2007). Processing, microstructure and mechanical properties of TiC-465 stainless steel/465 stainless steel layer composites. J. Alloys Compd, 493, pp. 287-293.

[6]. J.J. Park, S.M. Hong, M.K. Lee and C.K. Rhee (2013). Effects of metal additions on refinement behavior of TiC particles during a very high speed milling process. Powder Technol, 249, pp. 126-133.

[7]. R. Mansour, S.Y. Maziar, R.R. Mohammad and S.R.T. Seyed (2010). The effect of production method on Fe-TiC composite. Int. J. Min. Process, 94, pp. 97-100.

[8]. B.H. Li, Y. Liu, J. Li, H. Cao and L. He (2010). Effect of process on the microstructures and the properties of in situ TiB2-TiC reinforces steel matrix composites produced by spark plasma sintering. J. Mater. Process. Technol, 210, pp. 91-95.

[9]. C.L. Han and M.G. Kong (2009). Fabrication and properties of TiC-based cermet with intra/intergranular microstructure. Mater. Des, 30, pp. 1205-1208.

[10]. D.H. Bacon, L. Edwards, J.E. Moffatt and M.E. Fitzpatrick (2013). Fatigue and fracture of a 316 stainless steel metal matrix composite reinforced with 25% titanium diboride. Int. J. Fatigue, 48, pp. 39-47.

[11]. F. Akhtar and S.J. Guo (208). Microstructure, mechanical and fretting wear properties of TiC-stainless steel composites. Mater. Charact, 59, pp. 84-90.

[12]. H. Kwon, C.Y. Suh and W. Kim (2015). Microstructure and mechanical properties of (TiC,W)C-Ni cermet prepared using a nano-sized TiC-WC powder mixture. J. Alloys Compd, 639, pp. 21-26.

[13]. O.R. Wiedemanm, C. Weck, U. Martin, A. Muller and H.J. Seifert (2012). Spark plasma sintering of TiC particle-reinforced molybdenum composites. Int. J. Refract. Met. Hard Mater, 32, pp. 1-6.

[14]. R.H. Md, Z. Hussain and R. Sivakumar (2014). Mechanism and optimization of titanium carbide-reinforced iron composite formation through carbothermal reduction of hematite and anatase. J. Alloys Compd, 587, pp. 442-450.

[15]. W.F. Zhang, X.H. Zhang, J.L. Wang and C.Q. Hong (2004). Effect of Fe on the phases and microstructure of TiC-Fe cermets by combustion synthesis/quasi-isostatic pressing. Mater. Sci. Eng, A381, pp. 92-97.

[16]. Y. Yang, H. Wang, R. Zhao, Y. Liang, L. Zhan and Q. Jiang (2008). Effects of C particle size on the ignition and combustion characteristics of the SHS reaction in the 20 wt%Ni-Ti-C system. J. Alloys Compd, 460, pp. 276-282.

[17]. T. Z. Kattamis and T. Suganuma (1990). Solidification Processing and Tribological Behavior of Particulate TiC Ferrous Matrix CompositesSolidification Processing and Tribological. MaterialsScience and Engineering, A128, pp. 241-252.

[18]. O.N. Dogan, J.A. Hawk, and K.K. Schrems (2006). TiC-Reinforced Cast Cr Steels. JMEPEG, 15, pp. 320-327