International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13 (2015) pp 33389-33392
© Research India Publications. http://www.ripublication.com

Effect of Sintering Temperature on Microstructure and Mechanical Properties of Powder Metallurgy Titanium Composites

PapaRao Mondi[1], R. Mariappan[2], C.Raj Kumar[3], S.Jayavelu[4], G.Dharmalingam[5]

[1]*Assistant Manager, Jindal SouthWest steels Limited, Ballery, Karnataka.*
[2] *Professor, Department of Mechanical Engineering, Vel Tech University, Avadi, Chennai.*
[3, 4&5]*AssistantProfessor, Department of Mechanical Engineering, Vel Tech University, Avadi, Chennai*

ABSTRACT

Titanium 6242 alloy and three different composites containing 5%TiC, 10%TiC and 15% TiC have been developed from elemental powders. Green compacts of titanium alloys and composites were made at a pressure level of 560MPa in a Universal Testing Machine. These compacts were sintered at three different sintering temperatures such as 1350, 1400 and 1450°C in an argon atmosphere for 2 hours. Sintered compacts were subjected in to densification studies, micro structural examination and mechanical properties evaluation. Higher sintered density has been exhibited for the Ti6242 alloy sintered at 1450°C. Higher hardness and tensile strength have been attained for the composite containing 15 % TiC. Addition of reinforcement enhanced the strength and hardness.

Keywords: Powder metallurgy, Sintering, Titanium, composites

1.0 INTRODUCTION:

Titanium based alloys and composites are the promising materials for wide range of applications. Some important properties possess by these alloys have made them suitable material in applications such as aerospace, bio-medical, marine, automobile, and other applications where corrosion resistance is most important. These materials having combination of properties such as low density, high strength, excellent corrosion resistance, good biocompatibility and retention of useful mechanical properties at high temperatures[1]. The high specific properties (strength/density, stiffness/density, and modulus/density), creep resistance, and corrosion resistance of titanium, make it suitable for many applications. To reduce the cost, several net shape manufacturing techniques such as super plastic forming, isothermal forging, diffusion bonding, and powder metallurgy have been developed. Of these, the blended elemental (BE) P/M approach appears to be one of the most suitable for producing titanium-alloy/ceramic particle composites have been developed. Commonly used titanium powder includes sponge Ti fines and the hydrogenation and dehydrogenation (HDDH) [7] Ti powder. Recently, significant progress has been made in lowering the cost of processing Ti powder. These attempts would lead to further lower cost of PM Ti alloys. Another aspect of cost reduction is the feasibility of achieving nearly fully dense Ti alloys by a single compressing-sintering step. In most cases, HIPping is always involved in processing PM Ti alloy parts using pre-alloyed powder, and this makes the materials processing much more costly. Titanium can be alloyed with iron, aluminium, vanadium, molybdenum, among other elements to produce strong light weight alloys for aerospace, military, industrial process, automotive, agri– food, medical prostheses, orthopedic implants, dental and endodontic instruments and files and other applications.

Ti6242 titanium alloy[3] is a promising material for the manufacturing of helicopter turbine components submitted to moderate stresses and temperatures. In addition to titanium, the alloy contains aluminum – 6 wt %, tin – 2 wt %, zirconium – 4 wt % and molybdenum – 2 wt %. It is composed of Al-stabilised phase and of a small amount of Mo – stabilized phase. Tin and Zirconium act as hardeners and combined with aluminum, they render the alloy creep resistant upto 873 K. In the present investigation titanium alloy (Ti-6242) and three different composites have been developed from elemental powders and subsequently sintered in three different temperatures such as 1350, 1400 and 1450°C.Densification and mechanical properties have been evaluated after sintering.

2.0 EXPERIMENTAL PROCEDURE

The powders used in this study were procured from Alfa Aesar Ti powder (150 µm), Al powder (100 µm), Zr powder (75 µm), Mo powder, Si powder and TiC powder (10 µm). Chemical composition of Ti6242 is shown in Table1. Three different titanium green composites such as Ti+5%TiC, Ti+10%TiC & Ti+15%TiC and Ti6242[5] have been prepared from Universal testing machine with a pressure level of 560±10MPa. These green compacts were sintered at various sintering temperatures 1350, 1400 and 1450°C in argon atmosphere for 2 hours. The flow rate of argon gas was 2000 ml. The rate of heating is 20°C per minute. After sintering the density of the compacts were measured by Archimedian's principle. Microstructural observation was taken by Image Analyser. Hardness of the sintered titanium alloy and composites were taken Rockwell hardness tester in A scale. The sintering cycle is shown in the Figure1.

Table 1-Chemical composition of Ti6242

Element	Al	Sn	Zr	Mo	Si	Ti
Mass rate	6.0	2	4	2	0.01	balance

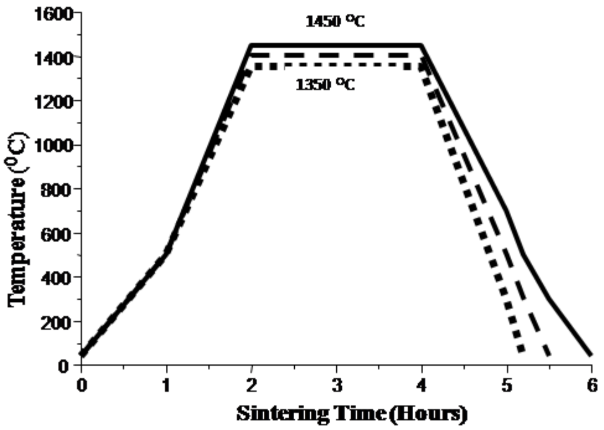

Fig.1 Sintering Cycle Titanium alloy and Composites

3.0RESULTS AND DISCUSSIONS

3.1 DENSITY MEASUREMENTS

Green densities and sintered densities of titanium alloy and composites sintered at various temperatures such as 1350, 1400 and 1450°C are shown in the Table 2. The sintered densities varies from 90 to 96 percent of it's theoretical density. From the results it is clear that the sintering temperature plays a vital role in increasing the sintered density. Hence, the compacts sintered at 1450°C shows higher sintered density irrespective of composition compared with lower sintering temperature. Higher sintering temperature [6] enhances material transport mechanisms between the adjacent particles. Similarly alloying additions in composition also makes the changes in density. Especially titanium alloy is having the densities in the range of 93 to 96 percent of it's theoretical density. Composite containing 10 and 15 % TiC have lower sintered density than it's base alloy. This effect is due to more addition of TiC reinforcement reduces the diffusion kinetics between the adjacent particles.

Table 2 Densities of green composite and sintered one.

Condition	Ti6242	Ti6242/5% TiC	Ti6242/10% TiC	Ti6242/15% TiC
Green Compact	77	76	76	77
Sintered at 1350^{o}C	93	93.5	93.7	90
Sintered at 1400^{o}C	93.5	94	94.2	92
Sintered at 1450^{o}C	96	94.5	94	93

3.2 MICROSTRUCTURAL EXAMINATION

Fig.2 have shown the microstructure of titanium alloy sintered at three different sintering temperatures such as 1350, 1400 and 1450°C. The microstructure of titanium alloy[2] sintered at 1350°C shows the uniform distribution of α platelets in a matrix in random direction. The microstructure obtained is in the form of lamellar and alpha platelet structure which contains white contrast α-phase plates and dark contrast β phase. Moreover small amount of porosity [8]exhibited at the platelet interface. But platelets thickness and length increased with the effect of temperature, higher sintering temperatures influenced the length and thickness of the platelets.

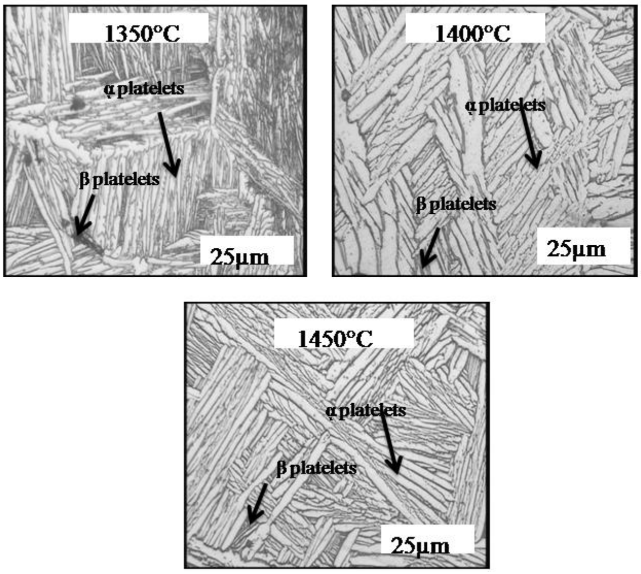

Fig.2 Microstructure of Titanium 6242 alloy sintered at 1350, 1400 and 1450°C

From the Figure 2, the thickness of the alpha platelets is 5.2μm, 6.0μm and 6.5μm for 1350^{o}C, 1400^{o}C and 1450^{o}C respectively. The length of the platelets varies from 52μm to 65μm for three different sintering temperatures. The width and length of the platelets was measured by Image Analyser. In the Ti-6Al-2Mo-4Zr-2Sn-0.1Si, at 1000 °C, begins the formation of the two-phase lamellar structure starting from the molybdenum, silicon particles, that act as beta-phase nucleator agents. It can be observed that the lamellar and alpha platelet structure grows with the dissolution of the β-stabilizer particles by increase of the sintering temperature[10]. The furnace-cooling produced a coarse lamellar microstructure[4] characterized by colonies of α platelets oriented along crystallographic variants. The size of the α-platelets increased as the alloy compositions became comparably richer in α stabilizing aluminum. This increase in α platelet size reflects an reduction in the growth kinetics of the β-phase with increasing α stabilizer. Figures 3 to 5 have shown the microstructure of titanium composite containing 5%wt, 10%wt and 15%wt TiC reinforcements. From the figure 3 uniform distribution of TiC particles are observed, but the microstructures of 10% TiC and 15%TiC have revealed more TiC clusters.

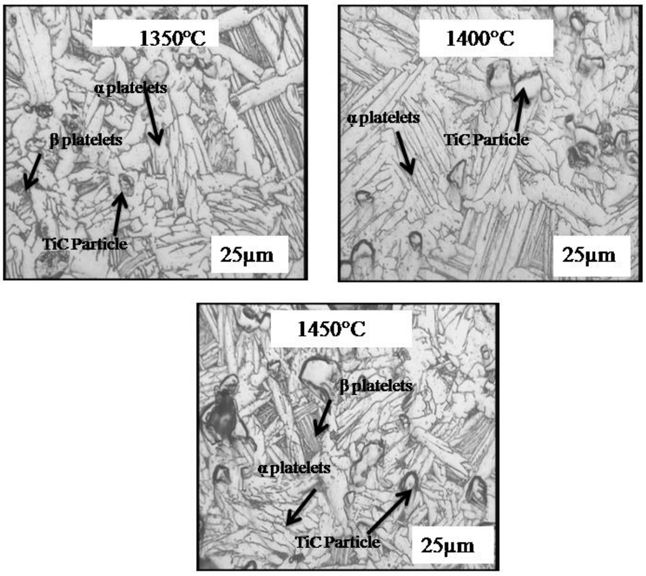

Fig.3 Microstructure of Ti6242-5%TiC composites sintered at three different Temperatures

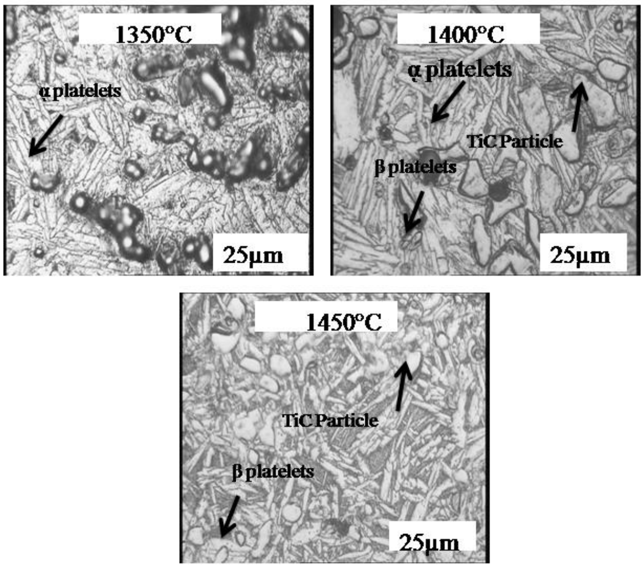

Fig.4 Microstructure of Ti6242-10%TiC sintered at three different temperatures

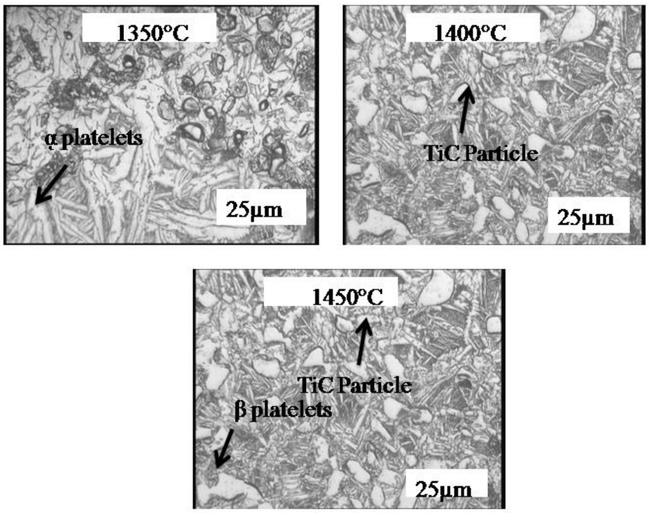

Fig.5 Microstructure of Ti6242-15%TiC sintered at three different temperatures

3.3 MECHANICAL PROPERTIES EVALUATION

Mechanical properties of sintered titanium alloy[9] and composites have been evaluated by Hounsfield Tensometer and Rcokwell hardness tester in A scale. The results showed that the alloy is having lower Tensile strength and better elongation compared with the composites. Figure 6 have shown the tensile properties of titanium alloy and composites sintered at three different sintering temperatures. From the figure tensile strength is varied from 810 MPa to 862 MPa. The highest tensile strength of 862 MPa has been exhibited for Ti6242 with 15%TiC composites sintered at 1450°C. Lower tensile properties have been exhibited for titanium alloy and composites sintered at 1350°C. The materials sintered at 1400°C have shown intermediate tensile strength which varies 830 MPa to 858 MPa. Higher sintering temperature enhanced material transport mechanisms during sintering. Percent elongation and hardness properties are shown in the figure 7 and 8 respectively.

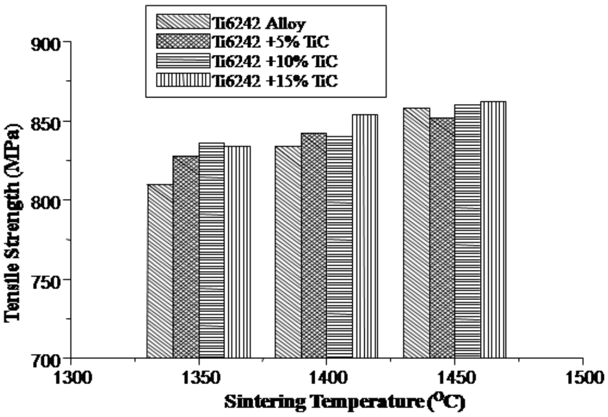

Fig.6. Tensile properties of sintered titanium 6242 alloy and composites

Highest elongation of 9.2 percent has been observed for Ti 6242 alloy sintered at 1450°C. More pore closure and incremental in density are responsible for higher ductility. But the addition of reinforcement reduces the ductility, hence titanium carbide containing composites have poor elongation compared with the alloys. But the trend of hardness bar charts are different from the elongation graphs. From the Figure.8 addition of reinforcement such as TiC enhanced the hardness. Titanium alloy with 15 percent TiC has shown highest hardness of 74HRA for the samples sintered at 1450°C.

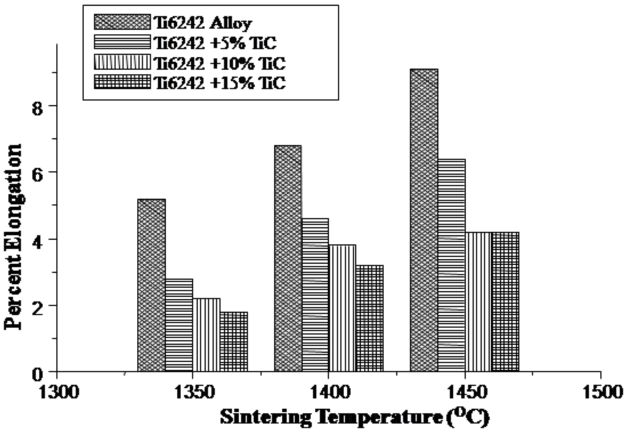

Fig.7. Ductile Properties of sintered Titanium 6242 Alloy and composites

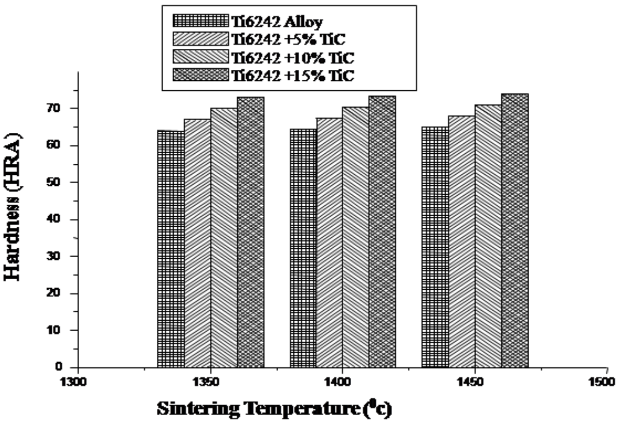

Fig.8. Rockwell Hardness values of sintered Titanium 6242 alloy and composites

CONCLUSIONS

- Higher sintered density of 96 percent of its theoretical density has been obtained for Titanium 6242 sintered at 1450°C.
- Uniform distribution of TiC particles has been observed for the Ti6242 with 10%TiC composite.
- Alpha platelets width and length have been enhanced with the effect of sintering temperature.
- Higher strength and hardness have been exhibited for the Titanium composite containing 15%TiC.

ACKNOWLEDGEMENTS

The authors would like to thank Hon'ble President Dr.R. Rangarajan, Vel Tech Dr.R.R. and Dr. S.R. Technical University, Avadi, Chennai, India for permitting to publish this research paper.

REFERENCES

[1] Z. Sun, Y. Zhou, M. Li, 2001"High temperature oxidation behavior of Ti_3SiC_2-based material in air ".Acta Materialia, Vol. 49 pp. 4347–4353.

[2] R. Pederson, 2002 "Microstructure and Phase Transformation of Ti–6Al–4V", Licentiate Thesis, Lulea University of Technology.

[3] Liu y, Chen l F, Tang H P, Liu C T, LIU B, Huang B Y, 2006"Design of powder metallurgy titanium alloys and composites", Materials Science and Engineering A, Vol.418, pp.25−35.

[4] Das, J., et al., 2007 "Bulk ultra-fine eutectic structure in Ti-Fe-base alloys". Journal of Alloys and Compounds, Vol.435, pp. 28-31.

[5] O.F. Ochonogora, C. Meacockb, M. Abdulwahaba, S. Pityanaa, b, A.P.I. Popoolaa, 2012"Effects of Ti and TiC ceramic powder on laser-cladded Ti–6Al–4V in situ intermetallic composite" Applied Surface Science, Vol.263, pp. 591–596.

[6] J.R. Lu, Y. Zhou, Y. Zheng, S.B. Li, Z.Y. Huang, H.X. Zhai, 2012"Effects of sintering process on the properties of Ti_3SiC_2/Cu composite Key Engineering Materials", Vol.515, pp. 377–381.

[7] J.-M. Oh, K.-H. Heo, W.-B. Kim, G.-S. Choi and J.-W. Lim, 2013 "Sintering Properties of Ti-6Al-4V Alloys Prepared Using Ti/TiH2 Powders", Materials Transactions, Vol. 54, No. 1, pp. 119-121.

[8] F. Xie, X. He, S. Cao, M. Mei, X. Qu.2013"Influence of pore characteristics on microstructure, mechanical properties and corrosion resistance of selective laser sintered porous Ti-Mo alloys for biomedical application", Electrochimica Acta, Vol.105, pp.121-129.

[9] Hiroshi Fujiwara, Takeshi Kawabata, Hiroyuki Miyamoto1 and Kei Ameyama, 2013 "Mechanical Properties of Harmonic Structured Composite with Pure Titaniumand Ti-48 at%Al Alloy by MM/SPS Process Materials Transactions", Vol. 54, No. 9 pp. 1619-1623.

[10] W. N. S. Wan Nawai, N. Awang Kasani, R. Nordin, Z. A. Ahmad, S. Shamsuddin, 2014, "Effect of Sintering Temperature on Microstructure and Mechanical Properties of Ti-Nb-Sn-HA Composites Produced by Powder Metallurgy", Applied Mechanics and Materials, Vol.625, pp. 180-183.