Particle variations and effect on the microstructure and microhardness of Ti6al4V Hybrid metal matrix system.

Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 7 (2017) 616 – 621

Procedia MANUFACTURING

International Conference on Sustainable Materials Processing and Manufacturing, SMPM 2017, 23-25 January 2017, Kruger National Park

Particle Variations and Effect on the Microstructure and Microhardness of Ti6al4V Hybrid Metal Matrix System

O. F. Ochonogor [a,*], E.T. Akinlabi[a], K. D. Nyembweb, Sisa Pityana[c] and M. B. Shongwe[d]

[a]*Department of Mechanical Engineering Science, University of Johannesburg, Johannesburg,South Africa*
[b] *Department of Engineering Metallurgy, Doornfontein Campus University of Johannesburg, Johannesburg,South Africa*
[c]*Council for Scientific and Industrial Research, Pretoria ,South Africa*
[d]*Metallurgical and Materials Engineering, Tshwane University of Technology, Pretoria, South Africa.*

Abstract

Manufacture of hybrid Ti6Al4V alloy systems for application specifically in hot parts of turbine engines has been a challenge in recent years. This is due to the need to increase efficiency and reduce combustion rate and emission. In this work, three reinforcement powders namely Ti6Al4V, B4C and BN were fed through three different hopper systems to create a melt pool on the surface of Ti6Al4V alloy substrate. Three percentage variations of these powders with equal amount of B4C and BN were obtained as follow: 3.0 Ti6Al4V, B4C and BN, 3.2 Ti6Al4V, B4C and BN, and 3.4 Ti6Al4V, B4C and BN systems. Laser coating experiment was done at 1400W. The influence of difference in variation of powder on the microstructure and hardness values was investigated. The hardness value improved significantly in the following order. 971.1 HV0.5, 971.1 HV0.5 and 1161.8 HV0.5 respectively. The overall coatings of layers were characterized by good microstructural homogeneity, excellent bonding with a metal substrate.

Peer-review under responsibility of the organizing committee of SMPM 2017

Keywords: Ti6Al4V alloy, Microstructure, Laser Coating, Thermodynamics, Hardness Property

1. Introduction

There has been an increase in the manufacture of hybrid systems of Ti6Al4V alloy for applications in hot turbine parts. Clean interface, excellent metallurgical bond, good hardness strength of fine ceramic particles can be

*Corresponding author. phone: +27 61 0564 124
E-mail:engr.frankiebaba@gmail.com

Peer-review under responsibility of the organizing committee of SMPM 2017
doi:10.1016/j.promfg.2016.12.092

uniformly dispersed in the matrix system in-situ fabrication of TMCs [1-2]. This paper investigates in situ formation of Ti6Al4V, B_4C and BN-reinforced MMCs coatings on Ti-6Al-4V alloy surface using a laser coating process. The microstructural formation, and microhardness property of the composites coating was observed.

Several metal matrix material systems that have been studied in the past and some of which has continued to form a major research focus are highlighted as follows: Ti-C-N, Ti-Si-Ni, B_4C, TiC, TiB, BN [3-11]. These investigations resulted to laser coatings and formation of metal matrix composites system with some un-melted hard ceramic particles on titanium alloy surfaces as revealed by microstructural observations. Titanium matrix composites (TMCs) are favorable materials in the aerospace industry due to good wear resistance. However, a major distinction in hardness between these ceramic reinforcement materials and titanium matrix may lead to difficulty in machining of the TMCs fabricated, as a result of their very hard properties they are categorized as cutting tool. The wear mechanism on the harder part of the un-melted particles experienced during preparation of samples for microstructural investigation might extend to the surrounding surface [12] as observed in this experiment which is mostly experienced at the harder and un-melted ceramics zone. This paper investigated in situ formation of TiC, TiB and TiN reinforced MMCs coatings on Ti-6Al-4V alloy surface by laser coatings using Ti-6Al-4V, B_4C and ultrahard cubic boron nitride β-BN powders as the starting materials. Microstructural investigation was carried out, formation mechanisms determined and the microhardness profiles of the composites coating were also obtained.

2. Experimental Procedure

Laser cladding experiments were carried out , various depositions were produced and characterized. Particle size of Ti6Al4V between 45 and 90, BN varied between 150 and 200 µm, B_4C of -45 µm.

Ti6Al4V substrate with dimensions of 102 mm x 102 mm x 7 mm, analysis of feedstock powders and their microstructural characterization.

The microstructural examination of the as received powders and the fabricated materials was carried out using an optical microscope (OM) and a scanning electron microscopy (SEM) combined with energy dispersive. Microhardness profile was carried out using a Vickers hardness machine on each sample from table 1, sample 1 to 3 starting from the top of the coatings cross section down to the substrate. Ti-6Al-4V alloy was used as the as received material, with the size of samples was 102 mm x 102 mm x 7 mm. The powder particle mixtures used as coatings for reinforcement materials were prepared from pure titanium (99.6 wt. %) B_4C (97.13 wt. %) and BN powders, supplied by Industrial Analytical House. The size of the powder particle was 45 and 90 µm for Ti and -45 µm for B_4C. A 3-kW Nd: YAG laser was used to provide a laser beam directed onto the sample surface. The parameters of laser processing were as follow; laser output power P = 1.4 kW, laser scanning speed V = 1.0 mm/s and laser beam diameter D = 3.0 mm. Microstructural characterizations of the coated layers was performed with the BX51M Olympus optical microscope and Super Scanning Electron Microscope SSX-550 EDX with an integral energy dispersive X-ray fluorescence spectrometer (EDXRF) for the observation of metallographic specimens, the surface sample of the coatings were prepared by grinded and polishing and etched with Krolls reagent. The microhardness was measured with a load of 0.5 N and a holding time of 15s by using a Vickers microhardness tester.

Table 1Processing parameters

Sample	Laser power	Scanning Speed (mm/s)	Powder flow rate(Ti)
1	1400	1.0	3.4
2	1400	1.0	3.2
3	1400	1.0	3.0

Table 2 Processing parameters and hardness value of Ti6Al4V/B_4C/BN system

Sample	Laser power	Scanning Speed (mm/s)	Powder flow rate (Ti)	$HV_{0.5}$

1	1400	1.0	3.4	643.8
2	1400	1.0	3.2	1161.8
3	1400	1.0	3.0	971.1

3. Results and Discussion

3.1. Microstructure of starting powder particles

The powder morphology of the as received powders is shown in Fig. 1 with spherical Ti-6Al-4V fine powder particle that is spherical in shape with 99.6 % purity and average Hardness (Hv) of 349.

Fig. 1b shows an extremely hard boron–carbon ceramic and covalent material. Whereas BN was identified in Fig. 1c which has been regarded as one of the highest abrasion resistance particle. The morphology of the powders was analyzed using scanning electron microscopy (SEM) (Fig. 2). Fig. 2a to 2c reveal the presence of un-melted hard particles with very good metallurgical bond at the HAZ region. The martensitic transformation and formation became noticeable as the resolution increased from 100 µm to 20 µm. Fig. 3a to 3c reveal un-melted hard particles with very good metallurgical bond at the HAZ region (Fig. 3a and 3b). Martensitic transformation and formation is revealed in Fig. 4b and 4c.

3.2. Chemistry of hybrid MMC formed

A chemical combination resulting in the formation of a very fine and thermodynamically balance reinforcement ceramic phase in a metal matrix was formed. In the design of TMCs, an important factor that was considered in this experiment is the wetting property. The compound combination or reaction that may occur between the reinforcement phase and the matrix is also important. Ti, B_4C, and BN produced a stable compound and great combination due to the covalent bond that exists between boron and titanium in equilibrium state. Ceramics and boride are used in TMCs for wear resistance and high-temperature application. Under laser irradiation, the chemical reactions (1) and (2) between the BC particles and molten Ti might take place and novel phases is created in this case. The possible novel phases created, their morphology and distribution in their matrix system was determined using the laser-processing parameters represented in this experiment.
Reaction in the investigated system could be:

$$3Ti + B_4C + 2BN = TiC + 3\ TiB_2 + 2\ TiN \tag{1}$$

$$4Ti + 2B_4C + BN = TiC + 3TiB_2 + TiN \tag{2}$$

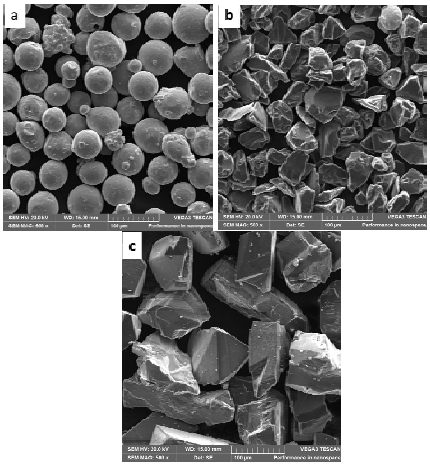

Fig 1: SEM micrographs of (a) Titanium alloy (b) Boron carbide and (c) Boron nitride powder

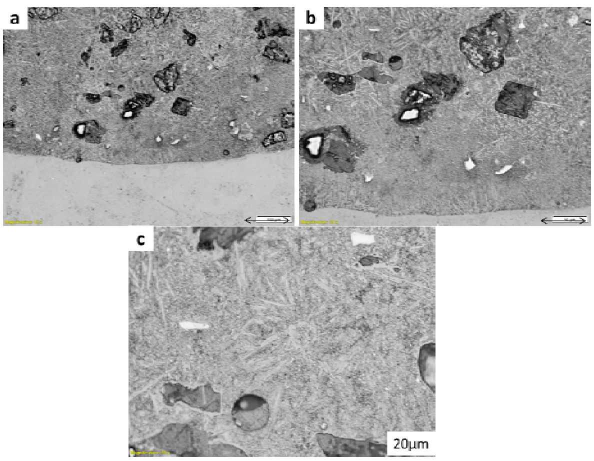

Fig.2. 1400W, 3.0 Ti-6Al-4V+ B4C+BN showing showing Martensitic transformation and formation.

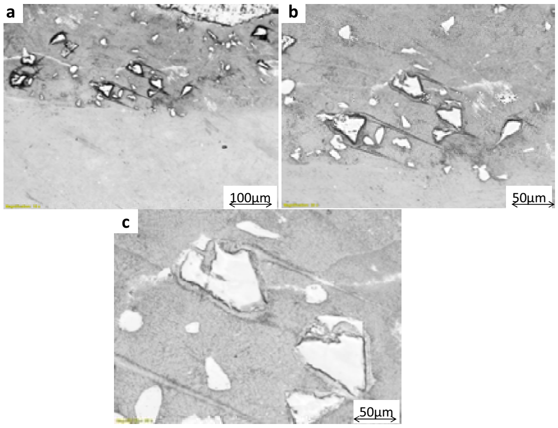

Fig.3. 1400W, 3.2 Ti-6Al-4V+ B4C+BN showing a good metallurgical bond and un-melted hard particles.

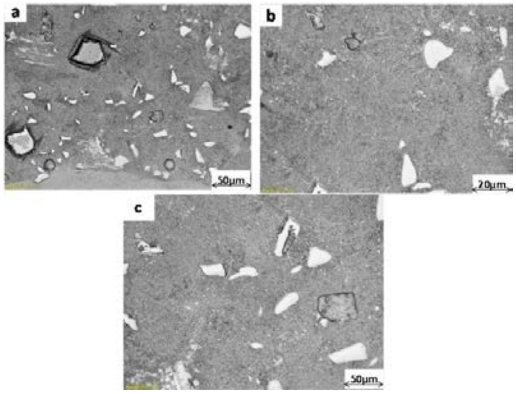

Fig. 4. 1400W, 3.4 Ti-6Al-4V+ B4C+BN good metallurgical bond and well dispersed reinforcement carbides Particles.

3.3. Hardness Result

The hardness profile (3.2 vol. % Ti) represented in red revealed a general increase in the hardness value of the coated area. A sharp increase was also observed at the third point of indentation and could be attributed to the un-melted solid carbide particle embedded in the matrix as represented in fig. 5. It also had the highest average hardness value. The other profile (3.0 vol. % Ti) represented in black dotted line also followed a similar trend. The third profile (3.4 Vol. % Ti) represented in blue dotted line showed a lower hardness value and was more uniform as the hardness decreased. The steady decrease could be attributed to more uniformly dispersed carbide in the matrix.

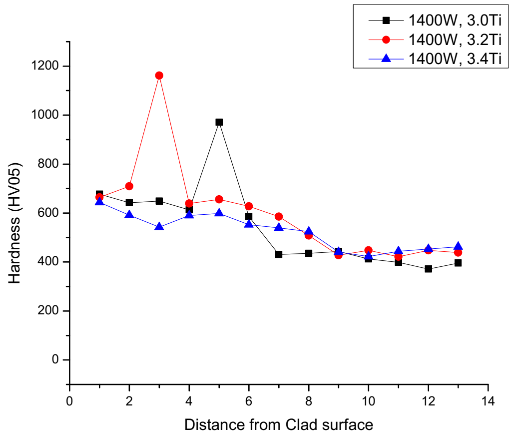

Fig. 5 Hardness Profile of Ti-6Al-4V/ B_4C

4. Conclusions

This work focused on laser coated composite formed using Ti- 6Al-4V, B4C and BN particles.

Laser metal deposition (LMD) process has been used to successfully produce a reinforced titanium matrix composites.

The influence of percentage variation on the laser power was evident from the hardness profile.

Microstructural features of hybrid composite and the influence of particle dissolution on the composite microstructure formed was studied. The characterized overlap cladding of Ti-6Al-4V/B4C/BN composite in terms of microstructure and microhardness.

The microstructural evolution of the Ti-6Al-4V/ B4C/BN composite produced; assess the formation of the ceramic phases formed with respect to changes in variation parameters, substrate dilution and influence on composite microhardness.

Acknowledgements

The financial support of the global excellence and stature (GES), University of Johannesburg and CSIR for the experimental are acknowledged.

References

[1] M.J Dutta. and B.L Mordike, Friction and wear behavior of Ti following laser surface alloying with Si, Al and Si + Al, Wear, 2000, 242: 18.

[2] S. Zhang , W.T. Wu and M.C Wang, In-situ synthesis and wear performance of TiC particle reinforced composite coating on alloy Ti6Al4V, Surf. Coat. Technol., 2001, 138: 95.

[3] S. Zhang ., W.T Wu., and M..C. Wang , In-situ synthe-sis and wear performance of TiC particle reinforced composite coating on alloy Ti6Al4V, Surf. Coat. Technol., 2001, 138: 95.

[4] B.J Kooi. And Y.T Pei, The evolution of microstruc-ture in a laser clad TiB-Ti composite coating, Acta Mater., 2003, 51: 831. Vreeling J.A., Ti-6Al-4V strengthened by laser melts injection of WCp particles, Acta Mater., 2002, 50: 4913.

[5] H.C Man., S Zhang., and F.T Cheng, Microstructure and formation mechanism of in situ synthesized TiC/Ti surface MMC on Ti-6Al-4V by laser cladding, Scripta Mater., 2001, 44 (12): 2801.

[6] R.L Sun., D.Z Yang., and L.X Guo., Laser cladding of Ti-6Al-4V alloy with TiC and TiC+NiCrBSi powders, Surf. Coat. Technol., 2001, 135: 307.

[7] S. J Senthil., K Subramanian., and A.K Nath., Laser boronising of Ti-6Al-4V as a result of laser alloying with pre-placed BN, Mater. Sci. Eng. A, 1999, 260: 178.

[8] H.M. Wang and Y.F Liu, Microstructure and wear resistance of laser clad Ti5Si3/NiTi2 intermetallic composite coating on titanium alloy, Mater. Sci. Eng. A, 2002, 338: 126.

[9] Y.S Tian., C.Z Chen., and S.T., Li, Research pro-gress on laser surface modification of titanium alloys, Appl. Surf. Sci., 2005, 242: 177.

[10] F Ochonogor, E. T. Akinlabi, K. D. Nyembwe, A review on the effect of creep under elevated temperature of Ti6Al4V alloy for Turbine engine Application. 5th International Conference on Materials Processing and Characterization. 12TH -13TH March, 2016.

[11] F Ochonogor, E T. Akinlabi, Member, IAENG, and K. D. Nyembwe, Effect of Laser Power on the Microstructure and Microhardness Property of Hybrid Fabricated Ti6Al4V Based Metal Matrix Composite

[12] Vlastimil Brožek, Jan Doležal, Michal Novák, Pavel Ctibor, Blahoslav Kolman Ceramo-Metallic materials of the Ti-B-C and Ti-B-N systems. Institute of Chemical Technology, Technická 5, 166028 Praha, Czech Republic.

[13] Y. F. Ge, J. H. Xu and Y. C. Fu, Mater. Sci. Forum 770 (2013) 3944.