Effect of Rapid Cooling of High Temperature Laser Fabricated Ti/B_4C/BN Coating on Ti-6AL-4V alloy

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Abstract— **A hybrid Ti-6Al-4V based metal matrix composites characterized of martensitic structure was formed using three hoper system. Different volume percentages used were as follows: 3.0 vol. % of Ti-6Al-4V, 3.2 vol. % of Ti-6Al-4V and 3.4 vol. % of Ti-6Al-4V respectively while an equal amount of BN and B_4C mixed with the Ti-6Al-4V powder particle was fed through the hoper systems at a constant laser power 2000 W and scanning speed of 1.0 m/s. The influence of rapid cooling and varied powder particle at constant coating temperature on the surface morphology and hardness property of Ti-6Al- 4V/B4C/BN alloy systems was however investigated. The hardness result of experimental showed a general improvement. Further result showed that the Ti-6Al-4V/B_4C/BN system fabricated at 3.0 Ti Vol. percent had a hardness improvement as high as 986.9 $HV_{O.5}$ compared to the as receive Ti-6Al-4V substrate Hardness value of about 357.3 $HV_{O.5}$. 3.2 Ti Vol. percent systems recorded a hardness value of 723.4 $HV_{O.5}$ and 3.2 Ti Vol. percent system recorded a hardness value of 609.6 $HV_{O.5}$. Optical microscope (OM) Scanning electron microscope (SEM) was also carried out for microstructural evaluation and Energy Dispersive Spectroscopy (EDS) to confirm the elemental composition of coating when necessary.**

Index Terms— **Ti6Al4V Substrate alloy, Martensite, Ti-6Al-4V, B4C and BN powder. Laser Coating**

I. Introduction

Rapid cooling (quenching) of high temperature laser fabricated Ti-6Al-4V alloy do not allow carbon atoms enough time to diffuse out of the microstructure forming martensitic structure [4]. Martensite structures are formed in most cases in a non-equilibrium phase. This process has been demonstrated to have effect on the microstructure, hardness and other mechanical properties. In this paper, the effect of rapid cooling on the microstructural formation, variation of powder particle reinforcement and its effect on the microstructure and microhardness property was considered**.**

Hardness of Martensite in titanium alloys is regarded as a change in crystalline structure of alloy which is determined by its carbon constituent [6]. However at beta-phase, solid solutions can be controlled by factors such as the amount of dissolved element, secondary phases and their distribution, grain size and boundaries etc [7]. Due to difference in particle size some reinforcement particles which are un-melted reach higher hardness value than Martensitic structure [8].

There are two different kinds of Titanium martensites, alpha prime (hex) and alpha double prime (orthorhombic). Beta phase can only be present at room temperature if beta stabilizers like V, Nb, Mo or Fe are present in the alloy [9]. These beta stabilizers diffuse into the beta phase during cooling to form higher amount of beta stabilizers in the beta phase compared to the nominal composition of the alloy [10].

The martensitic beta to alpha transformation induced by rapid cooling may lead to the formation of alpha prime phase [11]. The lattice parameter of alpha prime can be different from "normal" (diffusion controlled beta to alpha transformation).

Cooling therefore makes the B phase to exhibit non equilibrium conditions; as it becomes instable and reduces the Gibbs free energy transformation to martensite.

II. Experimental Procedure

Rofin Sinar of 3 KW Nd: YAG laser controlled system created a laser beam fixed with a fibre optic to a focused lens. The three hopper plasma spray type powder feeder was employed to enable supply of a combination of Ti-6Al-4V, B4C and BN powder particles. The flow rate however depended on the rotational speed of the powder supply mechanism that allows for the delivery of powder particles from the hoppers into a stream of inert argon gas [1].

A hybrid Ti-6Al-4V/ B4C/BN system was fabricated at 2000W. The Scanning speed was kept constant at 1.0 and

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powder flow rate for three systems as follow: 3.0 Vol. % of Ti-6Al-4V, 0. 5Vol. of B4C and 0.5 Vol. BN, 3.2 Vol. % of Ti-6Al-4V, 0. 4Vol. of B4C and 0.4 Vol. BN and 3.4 Vol. % of Ti-6Al-4V, 0.3 Vol. of B4C and 0.3 Vol. BN. The cooling/reinforcement variation was investigated as it influenced the microstructure, surface roughness and hardness of the three hybrid systems formed.

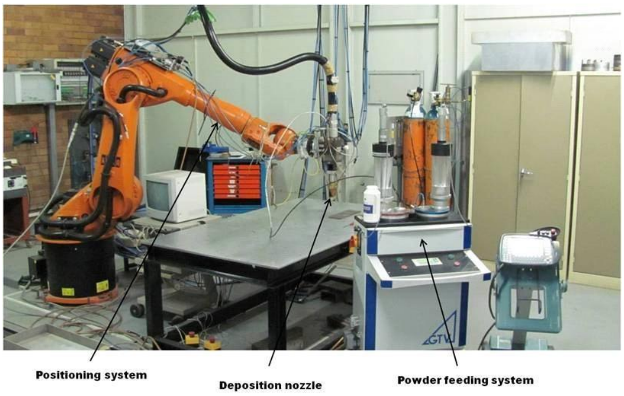

Fig. 1 Photograph of the laser metal deposition facility [5]

TABLE I

PROCESSING PARAMETERS

Sample	Laser power	Scanning Speed (m/s)	Powder flow rate (Ti64)	Powder flow rate (B_4C)	Powder flow rate (BN)
1	2000	1.0	3.0	0.5	0.5
2	2000	1.0	3.2	0.4	0.4
3	2000	1.0	3.4	0.3	0.3

TABLE II

PROCESSING PARAMETERS AND AVERAGE HARDNESS VALUE OF FABRICATED COMPOSITE.

Sample	Laser power	Scan Speed	Ti Powder flow rate	B_4C Powder flow rate	BN Powder flow rate	$HV_{0.5}$
1	2000	1.0	3.0	0.5	0.5	986.9
2	2000	1.0	3.2	0.4	0.4	723.4
3	2000	1.0	3.4	0.3	0.3	609.6

III. RESULTS AND DISCUSSION

Fig. 2 Presents a microstructure of 3.0 Ti-6Al-4V/B4C/BN system obtained by a Scanning Electron Microscopy. The microstructure revealed a spectrum of dark sport and the elemental constituent was determined by EDS to be predominantly Boron and carbide. The X-ray microanalysis shows the formation of martensitic microstructure and un-melted Boron Carbide. At 2000W with combined particle distribution of 3.0 Ti-6Al-4V/ B4C/BN. Fig. 3 (a) shows strong bond strength between the coated layer and the substrate with a little crack defect initiated by un-melted carbide. This could be due to the force exerted on the un-melted carbide during sample preparation (machining) see Fig. 3 b. Fig. 4 (a) revealed strong bond strength between the coated layer and the substrate as well as a homogenized structure. This was also revealed in Fig. 4 (b) and 4 (c) showing clearly acicular martensite formed at the Heat affected Zone (HAZ) [2] and better distribution of reinforcement particles compared to the 3.2 Ti-6Al-4V/ B4C/BN in Figure 3. The formation of martensite within the matrix was as a result of rapid cooling to room temperature [3].

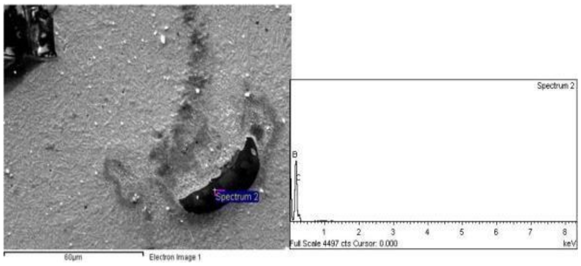

Fig. 2. SEM/EDS: 2000W, 3.0 Ti-6Al-4V/B4C/BN showing dark sport

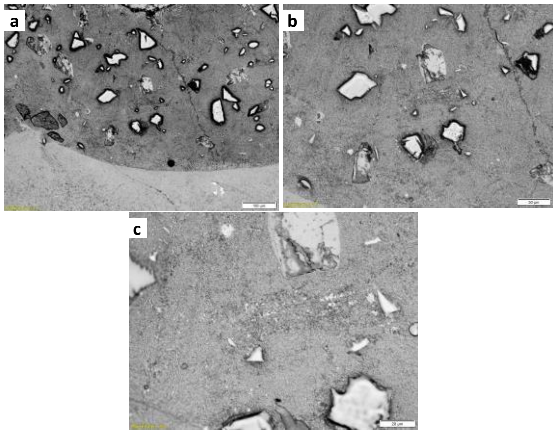

Fig. 3 2000W, 3.2 Ti-6Al-4V+ B4C+BN showing strong bond strength between the coated layer and the substrate with a little crack defect

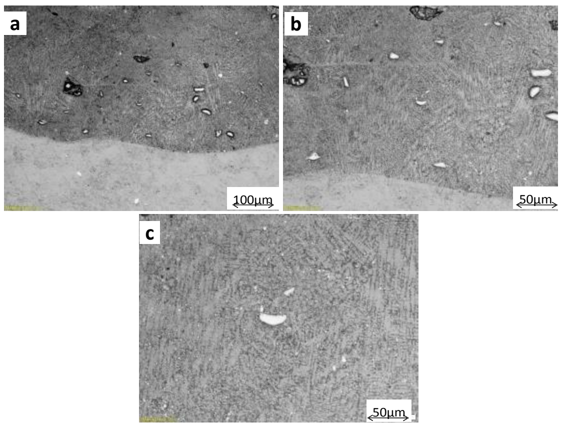

Fig. 4 2000W, 3.4 Ti-6Al-4V+ B4C+BN showing strong bond strength between the coated layer and the substrate with homogenized martensitic structure

IV. HARDNESS RESULT

Microhardness of hybrid titanium alloy metal composite was evaluated. The hardness indent was done from the top layer of the cladded zone down to the substrate which was in accordance to the ISO standard 3878 using MH-3 (Melkon) hardness tester with a load of 500g and dwell time of 15 seconds micro. The spacing between two indentations of the Vickers microhardness of the samples was 100 µm.

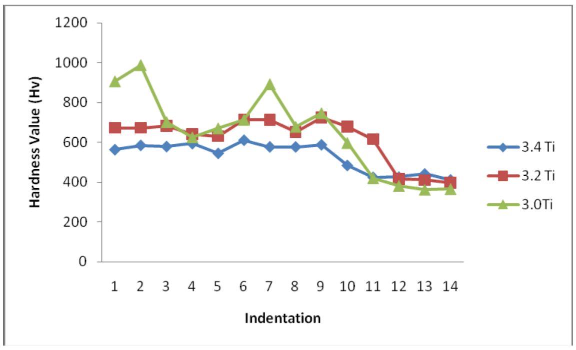

Fig. 5 Hardness value of Ti-6Al-4V/ B4C/ BN at different at different variations.

All three systems investigated revealed a general improvement in hardness value. However the hardness profile at lower variation of Ti powder particle revealed the highest hardness value which could be attributed to a higher volume of boron carbide and Boron Nitride powder particle deposited of the Ti-6Al-4V substrate as reinforcement particle. Therefore the higher the quantity of Ti-6Al-4V reinforcement powder particle the lower the hardness value in this case.

V. CONCLUSION

Martensitic structures were formed due to rapid cooling observed from the experiment.

The influence of variation of Ti-6Al-4V powder particle on the surface morphology, hardness property was successfully investigated. Results showed that the more in Vol. percent of Ti-6Al-4V, the lower in reduction of hardness value. This was due to the reduction of harder reinforcement materirials as the Ti-6Al-4V alloy powder increases. The bonding strength and particle distribution of the fabrication was generally excellent. This research has however developed an improved, hybridized and excellent Ti-6Al-4V alloy required in an extreme temperature condition.

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