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Particle Variations and Effect on the Microstructure and Microhardness of Ti6Al4V Hybrid Metal Matrix System

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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.

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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

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uniformly dispersed in the matrix system in-situ fabrication of TMCs [1-2]. This paper investigates in situ formation of Ti6Al4V, B₄C 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, B₄C, 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, B₄C 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 μ m, B₄C of -45 μ m.

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. %) B₄C (97.13 wt. %) and BN powders, supplied by Industrial Analytical House. The size of the powder particle was 45 and 90 μ m for Ti and -45 μ m for B₄C. 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 Kroll's 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 1 Processing 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/B₄C/BN system

| Sample | Laser power | Scanning Speed (mm/s) | Powder flow rate (Ti) | HV _{0.5} |
|--------|-------------|-----------------------|-----------------------|-------------------|
|--------|-------------|-----------------------|-----------------------|-------------------|

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