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Production and Characterization of Titanium Matrix Composites by VHP Route

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A B S T R A C T

Discontinuous particulate reinforced metal matrix composites (MMC)'s due to their low cost, ease of manufacturing and relatively good isotropic mechanical properties, form one of the major and important applicative class of composite materials. Titanium being one among the matrix materials (other important ones including Al, Mg, Cu and their alloys) widens its scope of usage due to its high strength to weight ratio, high stiffness, good corrosion resistance and high creep resistance. In the present work discontinuously reinforced titanium matrix composites (TMCs) were synthesized by using CP Ti powder (13µm) and B4C powder of varying particle sizes (165µm, 49µm, 8µm) through powder metallurgy. The blended powder were consolidated by VHP at 1000˚C for 1hr. XRD analysis was carried out to conform the extent of the reaction and the types of phases present. Microstructural analyses were carried out. The strength of the composites were evaluated by the three point bend test. The test revealed that the composites have high flexural strength with respect to unreinforced titanium. The fractography of the bend tested samples was carried out using SEM which revealed a mixed mode of fracture for the composites

Introduction

Titanium matrix composites (TMCs) are a subclass of metal matrix composites, consisting of at least two chemically and physically distinct phases-one being titanium matrix and other a suitable reinforcement both separated by an interface. The end properties being totally unique to the individual constituent phases. The reinforcements can be either fibrous or particulate distributed in the Titanium metallic matrix. TMCs owe importance with respect to unreinforced titanium because of major weight savings due to higher strength-to-weight ratio, significantly improved cyclic fatigue characteristics, exceptional dimensional stability, and higher elevated temperature stability, i.e., creep resistance [1]. They stand competitive to other composites because of their higher strength and stiffness, higher service temperatures and good mechanical properties, all of which emphasis on their usage in automobiles, armours and aerospace industries [2]. The boron carbide (B4C) ceramic reinforcements combine high strength and elastic modulus with high temperature capability [3] which enables for their usage in defense armor applications [4]. They are also relatively less expensive than continuous fibers. The variation in their vol.% within the composite severely affects final composite mechanical properties [5], thus becoming a critical factor in composite manufacturing. Many novel methods are in use for the synthesis of metal matrix composites [6]. The powder metallurgy route is one of the most preferred method for synthesis of titanium matrix composites.

2. Experimental Work:

Ti-B4C composites were synthesized by vacuum hot pressing at a temperature 1000˚C and at a pressure of 30MPa for 1hr. Required amount of titanium and B4C powders were blended in stoichiometric proportions to get the final composite. The present work consists of blending of three different B4C particle sizes (165µm, 49µm and 8µm) with titanium (13µm) in a rubber roller mill at 30 rpm for 24 hrs. The.blended powder mixtures were hot pressed in vacuum to obtain compact discs of 100 mm dia and 5 mm height. Phillips PW 3020 diffractometer with Cu Kα radiation was used to conduct X-ray diffraction studies on hot pressed compacts of titanium and composites for confirmation of phases. Microstructures of the specimens were studied using optical microscope after the specimens were cut to the required size and etched with Kroll's reagent. Three point

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bending test was conducted to determine the flexural strength of the un-reinforced titanium and composite specimens. Fractography of the bend tested samples was carried out using SEM to find out the mode of fracture.

3. Results and Discussion:

3.1 Microstructure:

The micrographs of the VHP composites are shown in Fig. 1 (a) to (d) at a magnification of 100X. From the micrographs it can be seen that there are no new phases except for simple B4C reinforcements being embedded uniformly in the titanium matrix. It can be observed that no reaction was initiated between the Ti and B4C at 1000°C.

3.2 XRD:

Figure 2 reveals the XRD patterns of both blended powder and composite sample having reinforcement B4C particle size of 165μm. It can be observed that the blended mixture of Ti and B4C powders has no new chemical species except for the initial parent phases which confirmed the absence of impurities, foreign species or any oxide formation during the raw material processing or blending. Similar results were observed in case of composite which focused no new compound formation like TiB, TiB2 which confirmed the absence of any interfacial reaction between the Ti and B4C matrix. Similar trend was observed with composites having reinforcement B4C particle sizes of 49μm and 8μm.

3.3 Three point bend test:

Flexural strength of the composites and unreinforced titanium are shown in the Table 1. Unreinforced titanium revealed flexural strength value of 234 MPa. The flexural strength of the composites varies from 375 MPa to 760 MPa. Thus there is a relative increase in the strength values of composites from 60% to 225%. It can be clearly seen that the strength of the finer B4C (8μm) reinforced titanium matrix composite is higher compared to the coarser 49μm and 165μm B4C reinforcement. This is due to higher resistance offered to deformation by the fine dispersed B4C particles in titanium matrix.

Table1: Flexural strength of unreinforced titanium and Ti – B4C composites

Material	Flexural Strength (MPa)
Titanium	234
Ti + 165μm B_4C	375
Ti + 49μm B_4C	545
Ti + 8μm B_4C	760

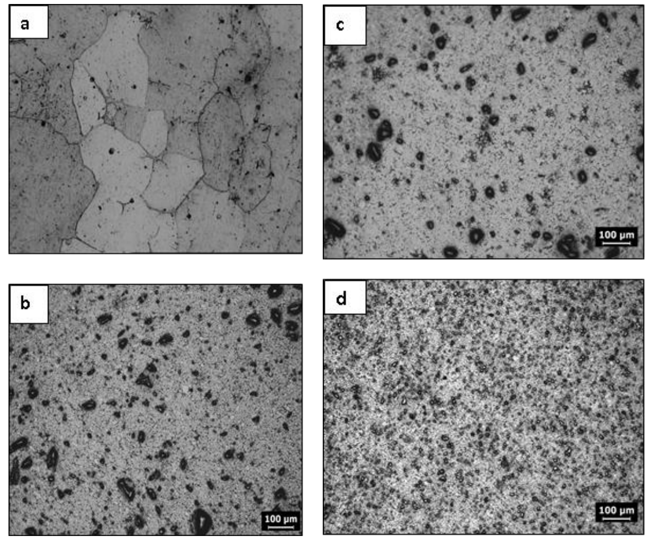

Figure 1: Optical images of:
(a) Pure Titanium (b) Ti+B4C (165μm)
(c) Ti+B4C (49μm) (d) Ti+B4C (8μm)

3.4 Fractography:

The fractographs of the bend tested samples are shown in Fig. 3 (a) to (d). The fractographs revealed a relative mixed mode of fracture in the case of composites while the unreinforced titanium showed a plastic mode of fracture.

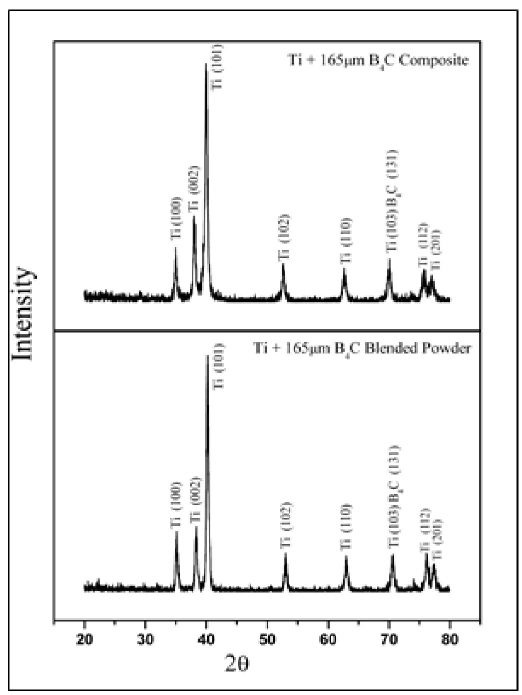

Figure 2: X-ray diffraction patterns of TMC with 165 μm B4C before VHP (bottom) and after VHP (top)

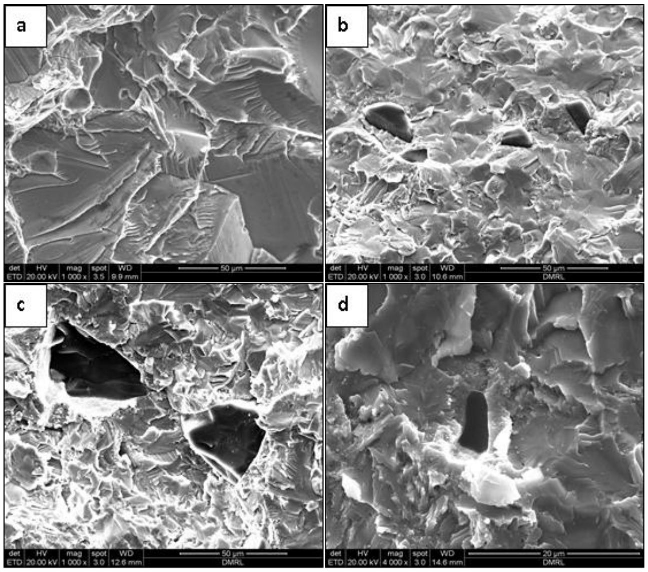

Figure 3: SEM fractographs of (a) Pure titanium (b) Ti+B4C (165µm) (c) Ti+B4C (49µm) (d) Ti+B4C (8µm)

4. Conclusions:

The following conclusions emerged from the present study:

1. Metallography studies revealed the absence of any reaction between titanium and the B4C particles.
The finer B4C particles are more uniformly distributed in the titanium matrix.
2. XRD studies confirmed the absence of any new phases and absence of reaction between titanium
and B4C particles at 1000°C.
3. The flexural strength of the composites are higher than unreinforced titanium.
4. The fractographs revealed a relative mixed mode of fracture

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