Blended Elemental P/M Synthesis of Titanium Alloys and Titanium Alloy-based Particulate Composites

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Abstract

Titanium alloys and Titanium alloy-based particulate composites were synthesized using the blended elemental P/M route. First, processing conditions such as the fabrication of master alloy powder were investigated. Ti-6Al-4V, Ti-5Al-2.5Fe, Ti-6Al-2Sn-4Zr-2Mo, IMI685, IMI829, Timetal 1100 and Timetal 62S, and Ti-6Al-2Sn-4Zr-2Mo/ 10%TiB and Timetal 62S/10%TiB were then synthesized using the optimal processing conditions obtained. The microstructures and mechanical properties such as tensile strength and high cycle fatigue strength were evaluated.

Keywords : Titanium alloys, Particulate composites, Powder metallurgy, Microstructure, Mechanical properties

1. Introduction

Titanium alloys are attractive structural materials for aircraft and automobile applications due to their high strength-to-weight ratio and excellent corrosion resistance. However, the use of titanium alloys in various industrial areas is still limited due to the high manufacturing cost of forging and machining difficulties. Blended elemental (BE) powder metallurgy (P/M), which uses cold press and sinter techniques, as well as hot pressing for further densification, is a promising method for the mass production of relatively small alloy parts, and has been successfully applied to the fabrication of titanium alloys and titanium alloy-based particulate composites. However, information on its processing conditions and mechanical property data is still lacking. So in the present study, processing conditions such as the fabrication of master alloy powder were first investigated. In the next stage, a variety of titanium alloys such as Ti-6Al-4V, and titanium-based particulate composites such as Ti-6Al-2 Sn-4Zr-2Mo(Ti-6242)/ 10vol.%TiB were produced using the optimal processing conditions obtained, and mechanical properties such as tensile strength, Young's modulus and high cycle fatigue (HCF) strength were evaluated. Special attention was paid to improve the HCF strength of these materials by the modification of matrix microstructures.

2. Processing conditions

1. Type of titanium powder used

It has been well established that the porosity present in the BE P/M compacts, which is attributed to the retained chlorides inheritted from the titanium sponge, degrades mechanical properties, especially HCF strength. Therefore, extra low chlorine (ELCL) hydride-dehydride (HDH) titanium powder with a chlorine level less than 20 ppm was used in this study.

2. Fabrication of master alloy powder

In the BE titanium P/M method, alloying elements such as aluminum and vanadium are usually added in the form of a master alloy powder. Master alloy powders are usually made by mechanically crushing master alloy ingot. However, in the case of most titanium alloys, the master alloy ingots are very hard or tough and thus are difficult or impossible to crush into fine powder. To overcome this difficulty, compositions of each master alloy were divided into two parts. For example, in the case of Ti-6242 alloy, the master alloy ingot of the composition 6Al-2Sn-4Zr-2Mo was divided into 2.5Al-2Sn-1Mo-2Ti and 3.5Al-4Zr-1Mo. Each of these two master alloy ingots was very easy to crush.

3. Selection of the reinforcing particulates

Among the many possible candidates, which include TiC, TiN, TiB_2, TiB, SiC and B_4C, the most promising is thought to be TiB. Thus, in the present study, only TiB was selected as a reinforcing particulate. In order to disperse TiB in-situ during the sintering process, TiB_2 ceramic powder was used as the starting powder material.

4. Effect of titanium powder size on the sintered density

The ELCL HDH titanium powder smaller than 45 μm was used. It was found that a pressure of 2 ton/cm^2 was sufficient for matrix alloys to obtain 95 % density after sintering. For composites, the sintered density was lower than that for matrix alloys throughout the entire pressure range. Nevertheless, a pressure of 4 ton/cm^2 was enough to achieve a density greater than 95 %. By subsequent HIP'ing, a 100% density was obtained for both alloys and composites.

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Table 1. Room temperature mechanical properties of BE P/M titanium alloys and TiB-reinforced composites

Alloy	Method and Heat treatment	Matrix Microstructure	0.2%P.S. (MPa)	T.S. (MPa)	El. (%)	E (GPa)	σ_f (MPa)
Ti-6Al-2Sn-4Zr-2Mo	Conventional P&S+HIP	Colony	982	1059	15	119	330
(Ti-6242)	P&S+β-WQ+HIP	Fine acicular α	1046	1109	15	119	550
Ti-6Al-2Sn-4Zr-2Mo-0.1Si	Conventional P&S+HIP	Colony	970	1058	18		
(Ti-6242S)	P&S+ β -WQ+HIP	Fine acicular α	1020	1117	13		
Ti-6Al-2Sn-4Zr-2Mo/10TiB	Conventional P&S+HIP	Colony	1202	1253	2	140	490
	Conv.+ β -WQ+1203K/ 5.4ks	Fine acicular α	1220	1273	2	140	590

β-WQ: Water quenching from above the β transus temperature.
P&S+ β -WQ+HIP: new BE P/M method developed by the authors [1]

5. Sintering and HIP conditions

Sintering was done at 1573 K for 10.8 ks. A cooling rate of 0.3 K/sec was used to cool from the sintering temparature to 873 K in the sintering furnace. A subsequent HIP treatment was performed at 1203 K and 200 MPa for 10.8 ks.

6. Microstrauture modification of matrix microstrucrure

It is known that the matrix modification from a colony to a fine acicular microstructure is effective in improving the HCF strength of the Titanium alloys and their composites. So in addition to the conventional BE P/M titanium alloys with a coarse colony microstructure, titanium alloys with a fine acicular matrix microstructure were produced using the new BE P/M method developed by the authors, in which a water-quench step is added before final HIP'ing [1]. In the composites, the acicular α microstructure could be obtained by quenching the HIP'ed composites from above the β transus temperature followed by annealing at temperatures in the α-β two phase range.

3. Results

As typical examples, the tensile and other property data at room temperature obtained for Ti-6242(s) alloy and its composites are summarized in Table 1. Ti-6242 alloy produced by the new BE P/M method, shows considerably higher HCF strength compared with its corresponding conventionally processed BE P/M alloy. It is also obvious that the matrix microstructure modification from a colony to a fine acicular microstructure was successful in further imroving the HCF strength of the composites. For example, the HCF strength of the heat treated Ti-6242/10%TiB composites at 10^7 cycles was increased to 590 MPa, from 490 MPa for the conventionally processed composites.

4. Conclusions

Titanium alloys and titanium-based particulate composites were successfully produced by the BE P/M method using ELCL HDH titanium powder smaller than 45 m in diameter. Titanium alloys produced by the new BE P/M method, in which a water-quenching step was added before final HIP'ing, showed improved HCF strength compared with their corresponding conventional BE P/M alloys. The modification of the matrix microstructure from a colony to a fine acicular microstructure by the post-HIP heat treatment was successful in further improving the HCF strength of the composites.

5. References

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