Study on Microstructure and Mechanical Properties of Powder Metallurgy TA15 Titanium Alloy

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Abstract: TA15 pre-alloyed powder chosen in this paper is made by plasma rotating electrode method. The powders were used to prepare fully dense TA15 alloy ingots by the means of hot isostatic pressing(HIP) forming technology. The optimum parameter of the HIP process is 900℃ /120MPa/3h. After the process of hot isostatic pressing, the powders were pressed into a fully dense ingot. An optital microscope was used to observe the microstructure of the ingot specimen and its formation mechanism was analyized. The microstructure of the TA15 alloy prepared by hot isostatic pressing of pre-alloyed powder is composed of fine α-equiaxed grains along lamellar colony boundaries. The mechanical properties exceed that of the casting level, which is close to the forging level. A typical TA15 alloy component was finally produced by HIP-PM process.

Key words: Powder metallurgy; TA15 alloy; Microstructure; Mechanical properties

1. Introduction

Powder metallurgy(PM) can produce titanium alloy components with high performance and low cost, it has advantages of defects free, homogenious microstructure, low inner stress[1-5]. High performance PM components have been applied in business. Hot isostatic pressing PM generally use nitrogen and argon as pressure transfer medium, pre-alloyed powders were compacted under high temperature and high pressure. HIP-PM titanium alloy has no macrosegregation, and the mechanical properties can reach the forged level[6-9], secondly, HIP PM can produce components with a high stock utilization. Compared to other processings such as casting and forging, the stock utilization can increase from 10~20% to above 50%, and the cost can be reduced by 50~80% [10-12]. Therefore, powder metallurgy have been becoming a promising near-net-shape forming method.

For titanium alloys, mechanical properties are influenced by microstructures, different processing methods will lead to various microstructures, due to intrinsic difference of PM compared to casting and forging. The forming mechanism of microstructures will change dramatically.

In this paper, TA15 alloy was selected to study PM microstructure and mechanical properties by hot isostatic pressing technology. The alloy has a nominal compositon of Ti-6.5Al-2Zr-1Mo-1V(wt.%), which is a near α alloy and have medium strength, cast and forged components of this alloy have been widely used in aerospace and aircraft industries. PM TA15 ingots and typicall components was produced by HIP, the microstructure formation mechanism and mechanical properties were studied.

2. Material and experiments

Plasma rotating electrode method was used to produce TA15 alloy powders, the dimension of powders ranged from 45-105μm, the powders were spherical, and had smooth surface(Fig.1). the oxygen, hydrogen and nitrogen contents were 0.13%, 0.004% and 0.008%(weight fraction).

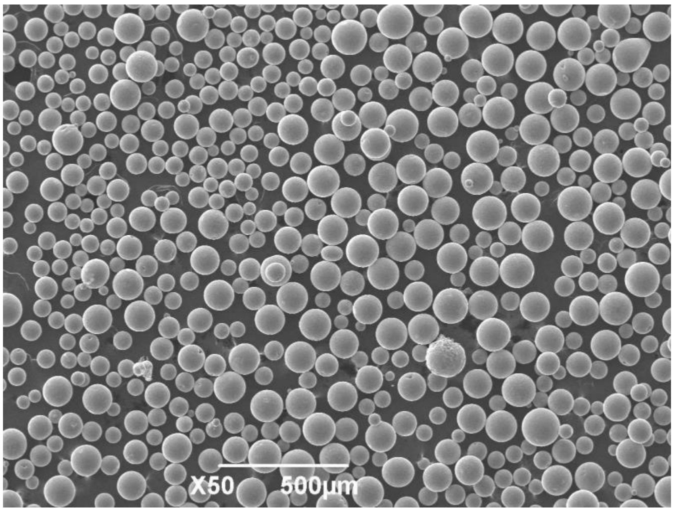

Fig.1 SEM image of pre-alloyed TA15 alloy powders

The flowchart of HIP-PM process was shown in Fig.2, TA15 pre-alloy powders were firstly sealed into low carbon steel capsule, the capsule was pumped to 3.4 ×10-3Pa in order to eliminiate gas contamination, then the capsule was closed by welding. HIP process was 900℃ /120MPa/3h, the steel coats were machined away to obtain PM TA15 ingots. The production of TA15 component was the same as the ingot.

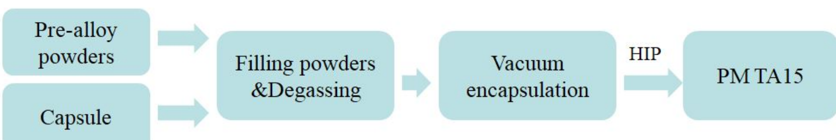

Fig.2 Flowchart of HIP-PM process

An optical microscope was used to examine microstructure of PM TA15 alloy, standard tensile test bars were cut from the ingot and machined to test tensile properties. Finally, the production of PM TA15 component was introduced.

3. Results and discussion:

3.1 Microstructure of PM TA15 alloy

Fig.3 showed the microstructure of PM TA15 alloy, it consist of lamellar α and β, fine equiaxed α grains distributed along grain boundaries, the mean lamellar colony size was 70μm, and the mean equiaxed α grains were 5μm. The formation of fine grained microstructure mainly ascribed to the pre-alloyed powders size, because the powders size ranged from 45 to 105 μm, during HIP process, the powders in the capsules connected point to point firstly, the powders were compacted under high temperature and high pressure, deformation of powder boundaries increased and formed high strain zones along the boundaries(Fig.4), fully dense microstructure formed at the same time, the high strain energy of powder boundaries lead to recystallization of fine equiaxed α grains, and there was no recystallization at the center of powders because of low strain, lamellar α and β grew and formed basket-weave microstructure.

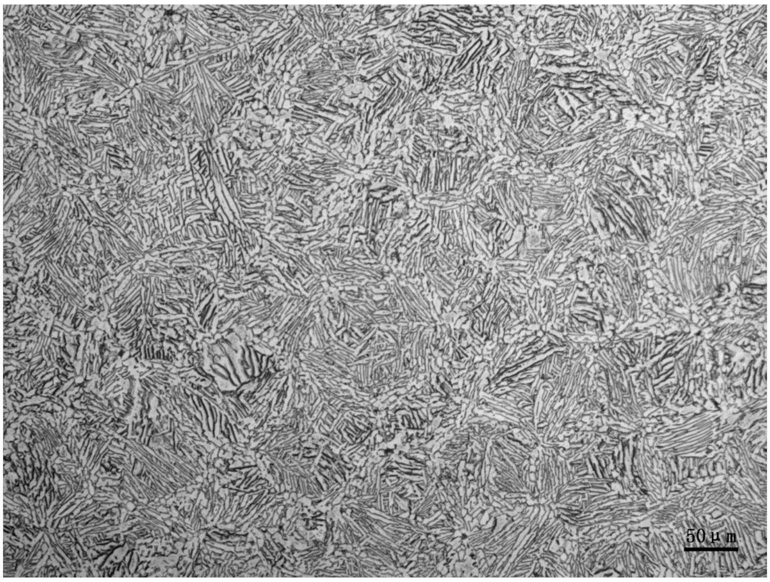

Fig.3 microstructure of PM TA15 alloy

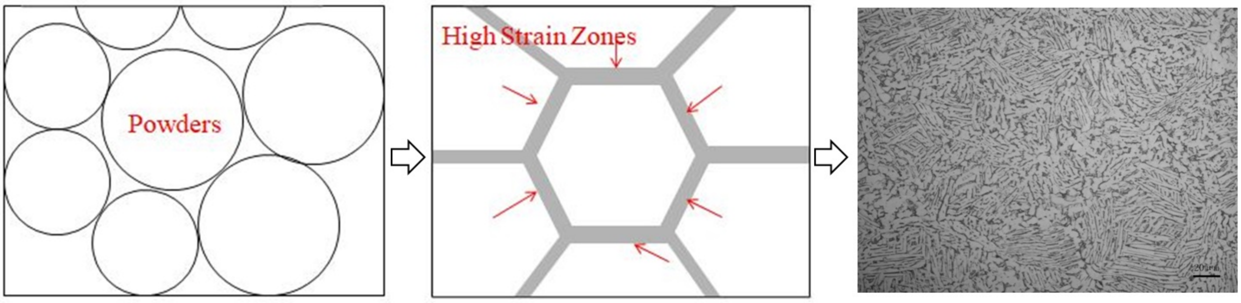

Fig.4 Microstructure forming of PM TA15 alloy

3.2 Tensile properties of PM TA15 alloy

Room temperature tensile properties of PM TA15 alloy was tested and shown in Table 1, compared to cast and forged TA15 alloy, PM TA15 alloy have a higher elongation, tensile strength and yield strength were higher than that of cast alloy, and reach the forged level. Refinement effect was thought to contribute the high elongation.

Table 1. Tensile properties of PM/Cast/Forged TA15 alloy

Material	σb/MPa	$\sigma_{p0.2}$/MPa	A/%	Z/%
PM TA15	937	850	18.5	40
Cast TA15	920	814	15	29
Forged TA15	948	865	13.8	41.5

3.3 Pilot production of PM TA15 alloy component

A typical shell component was produced by HIP-PM process, the 3D model of the component was shown in Fig.4, the dimension is φ180mm×83mm, the thinnest part is 3mm, the capsule for HIP-PM was designed and contained upper/bottom moulds and three cores, which were shown in Fig.5. In order to control dimensional accuracy of inner channels, solid steel cores were finish machined.

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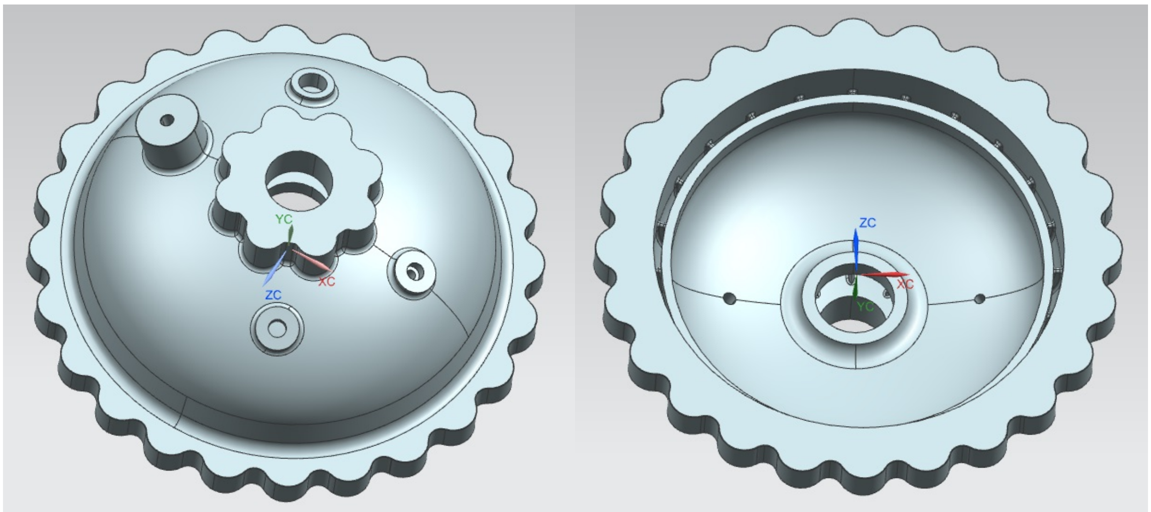

Fig.5 3D model of the shell component

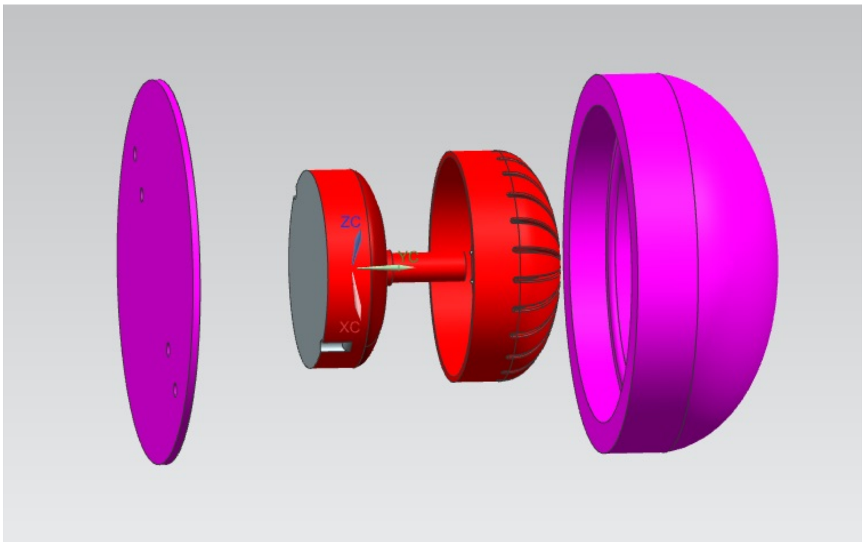

Fig.6 The capsule structure of PM TA15 component

After HIP process, the capsule was removed by machining and acid pickling, and dense TA15 alloy component was produced, the appearance of PM TA15 product and the inner quality detected by X-ray flaw detection were shown in Fig.6, it showed no inner defects by the X-ray detection. The density of the component was calculated and reached above 99.6%. X-ray images also showed no obvious deformation in the channels. The dimensions reached requirement for further machining.

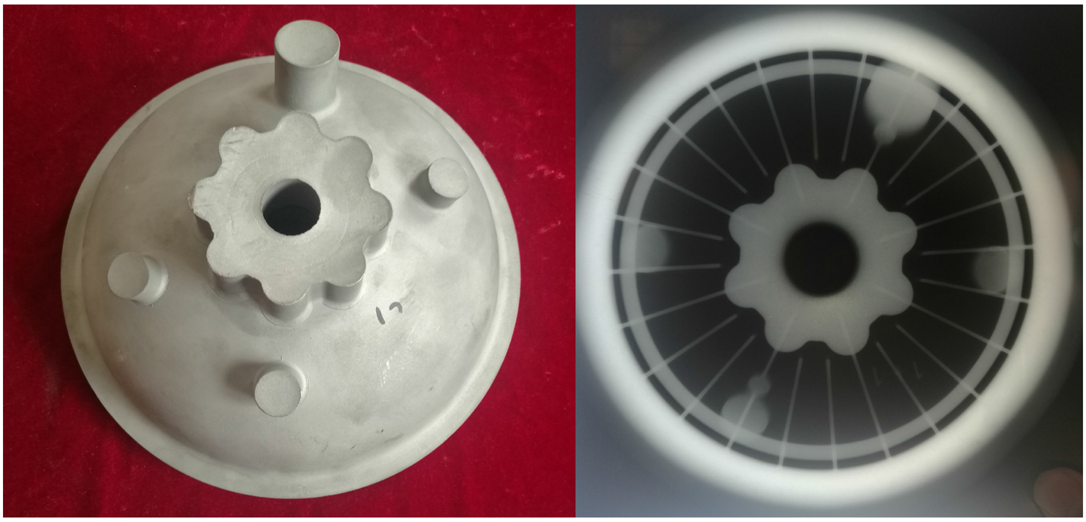

Fig.7 Appearance of PM TA15 component and its X-ray image

4. Conclusion:

(1) The microstructure of PM TA15 alloy consist of fine lamellar (α+β) colonies with mean size of 70 μm, fine exquixed α grains of mean 5 μm distribute along grain boundaries.

(2) Room temperature tensile properties of PM TA15 alloy was higher than that of cast TA15 alloy, and reached the forged level.
(3) A typical component of PM TA15 alloy was successfully produced, X-ray detection shows no inner detection, there was no obvious deformation happened in the channels.

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