IOP Conference Series: Materials Science and Engineering

Study on the Formability of 3D Printed TC4 Alloy Powder by EIGA

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Abstract. TC4 (Ti-6Al-4V) powder prepared by electrode induction melting gas atomization (EIGA) was used as raw material and SEM was used. The morphology, microstructure, particle size, distribution and phase composition of the powder were characterized by laser particle size analyzer and X-ray diffraction analyzer. At the same time, the influence of the powder properties of TC4 alloy for 3D printing was studied. The results showed that the powder prepared by EIGA was mainly spherical with good fluidity. The main particle size distribution of the powder is in the range of 50 ~ 180 μ m, which meets the requirement of laser 3D printing. When the pressure is 6.0MPa, the loose density of powder is 2.96g / cm^3, and the fluidity is 2.24g / s. Staggered acicular martensite α '-phase composition.

1. Introduction

Three Dimensional printing technology is based on the digital model file, using powder metal or plastic and other adhesive materials. The preparation of solid parts by layer printing has attracted much attention because of its high speed [1~4], low cost, high flexibility and high integration.

Titanium alloys have the advantages of high strength, low modulus of elasticity and low density, excellent fatigue resistance and corrosion resistance, and are the leading materials in the laser 3D printing industry [2]. Titanium alloy can be divided into three types according to the annealed microstructure: α type, β type and α+β type. For example, TA4~TA8 denotes α type titanium alloy; TB1~TB2 means β-type titanium alloy; TC1~TC10 indicates that the strength of α+β titanium alloy is lower than that of α+β titanium alloy at room temperature (σ b is about 850 MPA), However, the high temperature strength and creep strength are the top of titanium alloy.The alloy has stable microstructure, excellent corrosion resistance, good plasticity and processing formability, and excellent welding and low temperature properties. β-titanium alloy has good ductility and cold forming property in quenched state. However, the alloy has high density [5~6], unstable microstructure, poor heat resistance, and is not widely used. α+β type titanium alloy has the characteristics of both α type and β type titanium alloys. It has very good comprehensive properties and is the most widely used titanium alloy.

The composition of TC4 titanium alloy is Ti-6Al-4V, which belongs to (α+β) titanium alloy. It has good comprehensive mechanical properties, high specific strength and good corrosion resistance. Because of its good biocompatibility, it has been widely used in aerospace, petrochemical, biomedical and other fields. In this paper, EIGA method was used to prepare 3D printed titanium alloy powder, and scanning electron microscope (SEM) was used. The morphology, microstructure, particle size, distribution and phase composition of the powder were characterized by laser particle size analyzer and X-ray diffraction analyzer. At the same time, the influence of powder properties of TC4 alloy powder for 3D printing was studied, and the evolution law of microstructure was studied [7]. It provides the necessary theoretical basis for the application of TC4 titanium alloy in 3D printing technology [8].

2. Experimental part

The TC4 alloy powder prepared by vacuum induction melting with rotating electrode was prepared by chemical analysis, carbon and sulfur analyzer, oxygen and nitrogen analyzer and so on. The chemical composition and impurity element content of the alloy powder were determined, such as Table 1. Using Scott volumeter, the loose and vibrational density of the powder was determined. The fluidity of powder was measured by FT-102 Hall flow meter. OLYMPUS-GX71 inverted optical microscope (OM) was used to observe the percentage and microstructure of hollow spheres. The surface morphology and sphericity of the powder were observed by Shimadzu-SSX-550 scanning electron microscope (SEM). Phase analysis was carried out by using SmartLab-9000 type X-ray diffractometer in Japan.

Table. 1 Content of elements in TC4 alloy powder

element	Ti	Al	V	C	N	O	S
numerical value	88.7	6.05	3.89	0.013	0.006	0.045	<0.001

3. Results and discussions

3.1. TC4 alloy powder morphology

As can be seen from figure 1, the spherical degree of the powder prepared in the experiment is over 98%, the surface of the powder is flat and the finish is good. In the process of laser 3D printing, the alloy powder has good fluidity and good formability, but the oval powder has poor fluidity. The forming of spherical powder is divided into three stages [9-10]. In the first stage, the molten metal droplets are impinged by high pressure gas to tear and elongate into wavy metal film, which is far away from the center of gas at high speed. In the second stage, the wavy metal film cannot be kept stable because of the movement of the air flow around it. Under the action of liquid surface tension, the thin metal film will shrink and tear again to form a slender rod droplet in the smaller thickness of the film. In the third stage, the long rod droplets continue to be torn by tension and gas flow in the furnace for the third time. The thin rod droplets are divided into several small droplets, and the droplets shrink into spherical shape under the action of surface energy [11]. The specific surface increases and the cooling rate is accelerated, and the surface section of the single particle surface of the spherical. TC4 powder is mostly cellular, and there are a small amount of special-shaped particles and hollow powder. As shown in Fig. 2, this is because the higher the pressure, the higher the kinetic energy, the higher the secondary fragmentation, and the higher the probability of partial gas being trapped inside the droplet, so that the pressure increases and the hollow sphere rate increases.

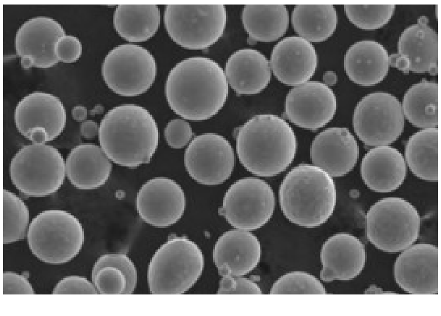

Fig. 1 SEM image of TC4 alloy powder

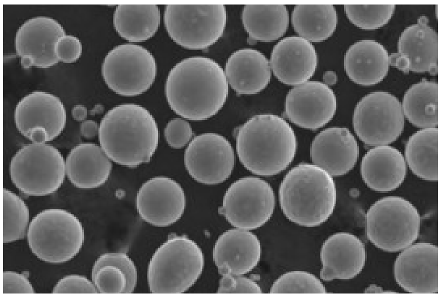

Fig. 2 Cross Section Morphology of TC4 Alloy Powder

3.2. *Effect of particle size of alloy powder*

Figure 3 shows the particle size distribution of TC4 alloy powder prepared by experiment. It can be seen from fig. 1 that the powder prepared by EIGA method is mainly spherical and has good dispersibility [12]. The particle size distribution is more uniform, and the main particle size distribution is in the range of 50 ~ 180 μ m, which meets the requirement of laser 3D printing. The solidification structure of titanium alloy powder is mainly determined by cooling rate. The temperature gradient G and the solidification rate R in the liquid phase are determined together, and the value of G / R decreases with the increase of the cooling rate. The morphology of the crystal surface changes from plane crystal to cellular crystal, and the smaller the size of molten metal droplets, the larger the specific surface area and the faster the surface cooling rate.

It can be found that the morphology of the powder is related to its particle size, the smaller the particle size, the better the spherical degree, the more smooth the surface. On the contrary, the larger the particle size, the more rough the surface is, and with the decrease of the particle size. The number of crystal boundary is reduced obviously.

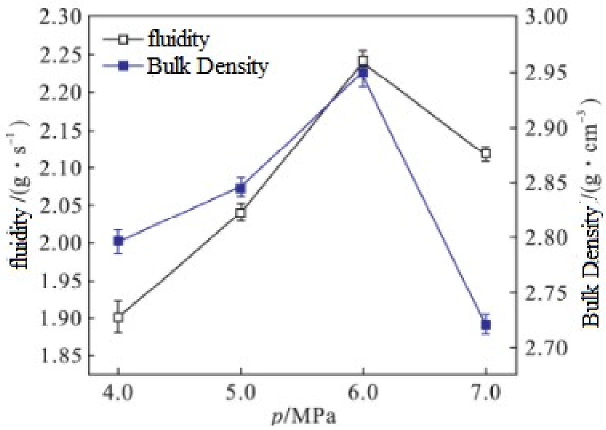

Fig. 3 Particle size Distribution Diagram of prepared from TC4 Alloy

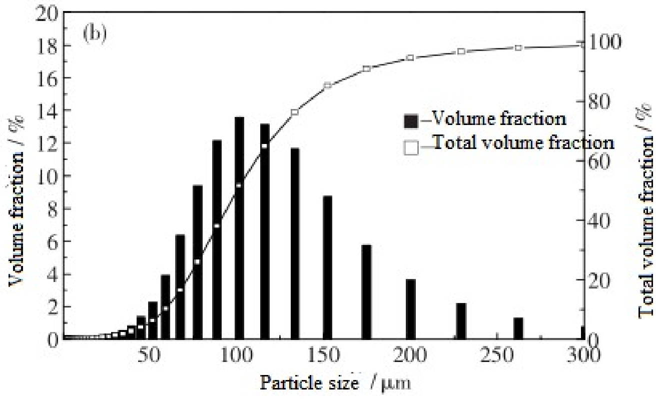

Fig. 4 Curves of fluidity and loose spherical density with pressure

3.3. Powder feeding density and fluidity

The stability of the loose density directly affects the forming quality of the molten pool and ensures the matching of the molten pool after melting and solidification, thus affecting the accuracy and interlaminar quality of laser 3D forming [13].

Figure 4 shows that the density and fluidity of the powders vary with the pressure. It can be seen from the diagram that with the increase of atomization pressure, the fluidity and the loose density of the titanium alloy powder first increase and then decrease, which is due to the increase of the pressure. The particle size of the powder decreases and the spherical degree of the powder decreases, the gap between the powders decreases, the powder passing through the funnel increases in unit time, the flow of the powder accelerates and the loose density increases [14~15]. When the air pressure is 6.0 MPA, the powder flow is increased. The density of loose powder is 2.96g / cm3, the fluidity is the best, 2.24g / s. The density requirement of TC4 alloy powder for laser 3D printing was achieved. When the pressure of powder exceeded 6.0MPa, the agglomeration of broken powder and fine powder increased, so the fluidity of powder decreased. Loose density is reduced.

3.4. Powder phase structure

The microstructure of TC4 alloy powder prepared by EIGA was observed by OLYMPUS-GX71 inverted optical microscope (OM). The cross section of alloy powder is mainly arranged in fine arrangement. The interlaced acicular martensite α 'phase consists of 2 ~ 3 acicular martensite sequences in one particle. The reason is that the high temperature β phase in the solidified powder changes rapidly to the acicular martensite phase.

4. Conclusion

(1) The powder prepared by the EIGA method is mainly spherical, with good fluidity, good formability and uniform particle size distribution. The main particle size distribution of the powder is in the range of 50 ~ 180 μ m, which meets the requirement of laser 3D printing.

(2) With the decrease of the particle size range, the sphericity of the powder increases, the surface is brighter, the fluidity and loose density decrease with the particle size, and the pressure is 6.0MPa. The loose powder density is 2.96g / cm3 and the fluidity is 2.24 g / s.

(3) The internal structure of TC4 alloy powder prepared by EIGA is consistent, mainly composed of fine and interlaced acicular martensite α'phase.

Acknowledgments

The authors are grateful to Project Anhui Department of Education (Project Number: KJ2018A0581) for supporting of this research.

IOP Conf. Series: Materials Science and Engineering **493** (2019) 012134 doi:10.1088/1757-899X/493/1/012134

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