The Manufacture of Spherical Titanium Alloy Powder in Plasma

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Abstract. In this study, the preparation technology of spherical titanium alloy powder (tc4) was studied by using continuous induction plasma powder synthesis system. The flow-ability, particle size and impurity content of the powder before and after plasma treatment were measured and compared. The result showed that, by applying induction plasma preparation technology, the powder’s flow-ability was improved by 20% while oxygen and carbon content were decreased significantly. The powder’s sphericization rate and recovery rate were above 95% and 90% respectively with plasma spherical treatment.

1. Introduction

The material of titanium alloy has many excellent properties such as high strength, low density, good corrosion resistance, and so on. Titanium is becoming a very important material in automobile manufacturing, because of the energy saving and emission reduction projects in China. However, there is a critical problem limiting the titanium alloy’s usage—its high cost. Many researches are focused on reducing the price of titanium, and the results of them show that the near net shape technology through the powder metallurgy and laser rapid prototyping is the best research direction and technology. The spherical titanium alloy powder is the best raw material for the near shape technology, and the demand for this type of powder keeps increasing [1-4].

Currently, the spherical Titanium alloy powder can be obtained by spray method, but the oxygen content of the powder will increase to a level of 1000 ppm, because of the high affinity between oxygen and titanium. In this study, we manufactured spherical titanium alloy powder through induction plasma technology, and controlled the particle size distribution and the oxygen content of powder by adjusting parameters.

2. Experiments

Material: normal titanium alloy powder (tc4);
Plasma gases: argon and hydrogen;
Quench gas: recycle gas of plasma gas;
Power: 40–60 KW;
Feeder rate: 2~4 kg/h.

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We can collect the spherical Titanium powder from two positions. We added oxygen in this system to passivate the powder.

We can get the spherical Titanium alloy powder’s properties by testing of laser particle size, SEM, oxygen content, hall flow-ability.

The number of parameters of induction plasma manufacture powder technology is more than 130. In this study, we adjusted six parameters, including feeder rate, the power of plasma, reactor pressure, particle size of raw powder, flow of quench gas, and position of probe.

### Table 1. Processing parameters and value ranges

| Parameter                  | Range                                      |
|---------------------------|--------------------------------------------|
| Flow of center gas        | 30 slpm                                    |
| Flow of sheath gas        | 80〜90 slpm(argon) + 40〜50 slpm(hydrogen)  |
| Reactor Pressure          | 85〜120 KPa                                 |
| Powder of the plasma      | 40〜60 KW                                   |
| Feeder rate               | 2-5 kg/h                                    |
| Flow of quench gas        | 800〜2000 slpm                              |

### 3. Results And Discussion

#### 3.1 Flow-ability of the powder

In this study, we selected two types of raw Titanium alloy powder to treat, and we collected the powder from two positions. The flow-ability is as follows.

### Table 2. The flow-ability testing result

| No.1 | No.2 |
|------|------|
|      | Raw powder | Position 1 | Position 2 | Raw powder | Position 1 | Position 2 |
| Average size (μm) | 3 | 0.7 | 0.2 | 2.6 | 0.42 | 0.17 |
| Hall flow-ability | 25s/50g | 14s/50g | 20s/50g | 26s/50g | 17s/50g | 20s/50g |

![Figure 1. SEM of treated powder](image)

It is well known that when the powder’s size becomes smaller, its flow-ability becomes much worse. However, we found that the flow-ability of the powder manufactured through plasma technology becomes better than that of raw powder, even though the powder’s particle size is much smaller than that of raw powder. The reasons for the better flow-ability are the powder’s smoothness, spherical morphology and high sphericization rate.
3.2 Oxygen content of the powder

In this study, we selected two types of raw titanium alloy powder to treat. One was with oxygen content of 0.063%, the other with oxygen content of 0.12%. And the parameters are: plasma power: 40~60 KW; quench gas: 1500 slpm; plasma gas: Argon and Hydrogen; feeder rate: 0.5~1.0 kg/h

The results of oxygen content test are as follows.

Table 3. Oxygen content testing result

|       | No.1         | No.2         |
|-------|--------------|--------------|
|       | Raw powder   | Position 1   | Raw powder   | Position 1   |
|       |              |              |              |              |
| Average size (μm) | 3 | 0.497 | 0.327 | 3 | 0.448 | 0.181 |
| Oxygen content(%) | 0.063 | 0.039 | 0.051 | 0.12 | 0.043 | 1.03 |

It can be found that the oxygen content of the last sample is very high, because its particle size is too small and there are oxidation happening on its surface. There is a very important factor leading to the increase of the powder’s oxygen content, which is the oxygen adsorption. In fact, the oxygen content of the powder treated by induce plasma technology is lower than that of raw powder. There are two reasons behind the increase of the powder’s oxygen content:

1) The powder’s particle size becomes small, and small particle size will make the powder’s surface increase. Its surface activity becomes very high, thus oxidation will happen easily.

2) The process of passivation will make the oxygen content increase. We always use passivation treatment to prevent oxidation, and the passivation treatment will generate an oxide film about 2~3 nm in thickness.

3.3 Particle size of the powder

The parameters for manufacturing the powder and the particle sizes are listed in Table 4.

Table 4. Particle size testing result

| The NO. of sample | Parameter                   | Particle Size(nm) |
|-------------------|-----------------------------|-------------------|
| 1                 | Position 2, Feeder rate 0.5kg/h | 38.4              |
| 2                 | Position 1                  | 780.0             |
| 2                 | Position 2, Quenching gas 1200slpm, raw powder size<74um | 191.0 |
| 3                 | Position 1                  | 448.0             |
| 3                 | Position 2, Quenching gas 800slpm, raw powder size<74um | 209.7 |
| 4                 | Position 1                  | 467.1             |
| 4                 | Position 2, Power 40KW, Feeder rate 0.5kg/h | 138.0 |
| 5                 | Position 1                  | 890.1             |
| 5                 | Position 2, H2 50slpm, Quenching gas 1500slpm, power 40KW | 152.2 |

Figure 2. PSD of the powder collected in NO.1
We can find that this technology has the capacity of controlling the powder’s particle size. There are four rules in the process of manufacturing the powder, including (1) The powder’s particle size will significantly decrease by increasing the plasma power; (2) The powder’s particle size will significantly decrease by adding Hydrogen, because the Hydrogen can increase the plasma’s power; (3) The powder’s particle size will significantly decrease by decreasing the feeder rate; and (4) The powder consists of three parts, big particle of unvaporization, nano-powder and residual particle after vaporization. We can conclude that the powder’s pretreatment and post-treatment will help control the particle size more precisely.

4. Conclusions

First, the flow-ability of the spherical powder manufactured through induction plasma technology was better than that of raw powder. On the basis of particle size decreased to 1/10, the flow-ability of the spherical powder increased by 20% than that of raw powder.

Secondly, manufacturing the powder through induction plasma technology can decrease the powder’s oxygen content.

Thirdly, the size distribution of the power manufactured through induction plasma technology is uniform. We can control the particle size and get power of desired size in an interval by adjustment of the parameters.

References

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