The plasma atomization process for the Ti-Al-V powder production

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Abstract. The paper presents brief information on the characteristics of the spherical powder of the Ti-Al-V alloy, produced by the method of plasma atomization of the wire. The scheme of the equipment and the results of studying the powder of the Ti-Al-V alloy are shown.

1. Introduction

During the last decade the manufacturing of Ti alloys using different additive manufacturing technologies emerged as one of the most important areas of Ti alloys application. Further development of these manufacturing technologies is to have high-quality and low-cost spherical Ti alloy powder. The critical characteristics of spherical Ti powder include particle size and size distributions, flowability, and chemical compositions, especially gaseous impurities. The Ti alloy powder used for additive manufacturing are produced by gas atomization, plasma atomization, and plasma rotating electrode process. The particle size of powder produced by plasma rotating electrode process is typically ranged from 50 μm to 350 μm, which is coarser than desired for selective laser melting or electron beam melting applications. In case of gas atomization and plasma atomization process particle sizes powders range from 10 μm to 300 μm [1].

One challenge for the production of titanium powder is the control of gaseous impurities (oxygen and nitrogen) content in the powder, especially fine powder. In general, the oxygen content of Ti powder is inversely proportional to the particle sizes [2]. The plasma-atomized Ti powder has high purity because the liquid metal does not contact any refractory metals or other solid materials that may contaminate the powder before solidification. The purpose of this work is to develop the equipment for plasma atomization process and to produce the spherical powder of Ti-Al-V alloy.

2. Methods and materials

Plasma atomization process was developed to produce fine and spherical powder in 1996 [3]. The equipment consists of a plasma torch, spraying chamber, cooling zone, feeding wire mechanism, powder collector. The most important equipment in these process is the plasma torch where the plasma jet is produced. Pre-alloyed wire is fed into plasma jet zone, where is melted and broken into droplets that would cool rapidly. Figure 1 shows a scheme of the apparatus. The Ti-Al-V wire with a diameter of 1.6 mm was used. The composition of the wire is shown in Table 1. High purity argon (99,997%) was used as a plasma-forming and shielding gas.
Table 1. The Ti-Al-V wire composition (wt. %).

|   | Ti  | Al  | V   | Fe  | Si  | C   | N   | H   | O   | the rest |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|----------|
| base | 3.80 | 3.01 | 0.12 | 0.014 | 0.009 | 0.012 | 0.0008 | 0.065 | 0.082 |          |

Figure 1. Plasma atomization equipment.

Metallographic specimens with powder were formed by using a hot mounting press IPA Evolution Ø25 mm. Surface of a metallographic specimen is prepared by a grinding-polishing machine Buehler Phoenix 4000. Wet etching is used of 5% hydrofluoric acid, 15% sulphuric acid, and 80% water solution. Microscopic examination of properly polished and etched specimens was carried out by light microscope.

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The Leco TC-600 is a software-controlled instrument that measures both nitrogen and oxygen in a wide variety of metals, refractories, and other inorganic materials. The inert gas fusion principle is employed. A weighed sample, placed in a high-purity graphite crucible, is fused under a flowing helium gas stream at temperatures sufficient to release oxygen, nitrogen, and hydrogen. The oxygen in the sample combines with the carbon from the crucible forming primarily carbon monoxide (CO). In some instances, depending upon sample type and furnace temperature, some oxygen can be released directly as carbon dioxide (CO). The nitrogen present in the sample releases as molecular 2 nitrogen, and any hydrogen present is released as hydrogen gas.

Funnel method using Hall-flow meter HFLOW-1 was carried out to identify the fluidity and bulk density of the powder.

3. Results and Discussion

As a result of the Ti-Al-V wire plasma atomization, a spherical titanium alloy powder was produced. There are three zones in the plasma atomization process. A similar process for producing a powder is described in [4]. The only difference is in the first zone, where the wire melts due to the heat-affected plasma. The solidified droplets are collected in a powder collector. Before the start of the process, the chamber was purged with high-purity argon. Ti-Al-V powder produced by plasma atomization on the developed equipment has a very good sphericity, as shown in Figure 2. There are no satellites on the surface of particles.
Figure 2. SEM Image of Ti6Al4V powder.

The image of surface of a metallographic specimen obtained by light microscope demonstrates low internal porosity of powder particles (Figure 3).

Figure 3. Optical image of Ti-Al-V powder.

The content of oxygen, nitrogen and carbon impurities in the Ti-Al-V powder are demonstrated in the following table 2. Although the chamber was purged with argon, the particles have the increased oxygen content. For this reason, the chamber must be additional vacuuming before spraying.

Table 2. The content of oxygen, nitrogen and carbon impurities in the Ti-Al-V powder (wt. %).

|     | oxygen   | nitrogen  | carbon  |
|-----|----------|-----------|---------|
|     | 0.370    | 0.06565   | 0.03    |
Figure 2 clearly shows the different structure on the powder particles. Some particles have a pronounced dendritic structure, while others have a smooth surface. It has been suggested that the difference is due to different ratios of elements in the particles. The results of investigating the chemical characterization of two particles with different structures are given in Figure 4.

![Figure 4. Elemental composition of powder particles with a smooth surface.](image)

Bulk density of produced powder is 2.36 g/cm³. Flowability of powder evaluated using Hall flowmeter is 29±0.5 seconds, that is comparable to commercial powder produced by different methods [5].

4. Conclusion

The tests on Ti-Al-V wire atomization by means of plasma spraying were carried out. Produced powder has spherical shape without defects and satellites on the surface of particles. The plasma-atomized Ti-Al-V powder has high conditioned bulk density and flowability due to a good sphericity of powder particle. Good sphericity of powder particles allows to achieve more efficient packing to favoring the formation of a highly dense powder bed.

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