ТЕЗИСЫ ДОКЛАДОВ

МЕЖДУНАРОДНАЯ КОНФЕРЕНЦИЯ

«Физическая мезомеханика. Материалы с многоуровневой иерархически организованной структурой и интеллектуальные производственные технологии»,

посвященная 90-летию со дня рождения
основателя и первого директора ИФПМ СО РАН
академика Виктора Евгеньевича Панина

в рамках
Международного междисциплинарного симпозиума
«Иерархические материалы: разработка и приложения для новых технологий и надежных конструкций»

5–9 октября 2020 года
Томск, Россия

Томск
Издательство ТГУ
2020

DOI: 10.17223/9785946219242/360

Ti-6Al-4V ALLOY BIMODAL POWDERS FOR POWDER INJECTION MOLDING

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Titanium alloys are widely used and promising materials for military, aerospace and biomedical applications due to low density, high specific strength, high corrosion resistance and biocompatibility. To produce small-sized items with a complex configuration of titanium alloys, powder injection molding (PIM) method is well suited. Commonly, for PIM are used powders ranging in size from 10 to 100 μm or more, both spherical [1] and irregular [2] shaped. The metal powders selection to produce feedstock is critical for PIM method. A prospective trend is the use of bimodal powders comprising both nano- and microparticles. Most preferred approach for the preparation of the bimodal powders is direct preparation by electric explosion of wires (EEW), which provides their high homogeneous distribution of the particles and a better processability for PIM. An advantage of the EEW method is the ability to regulate the ratio of nano- and microparticles by adjusting device operating parameters. The aim of the present work is to identify the conditions for the preparation of Ti-6Al-4V alloy bimodal powders, comprising both nano- and microparticles by the EEW method and their application for PIM.

Ti-6Al-4V alloy bimodal powders were prepared by EEW method in argon medium. For electric explosion Ti-6Al-4V alloy wire with diameter 0.4 mm and length 80 mm was used. Alloy samples represent a mixture of nano- and microparticles (fig. 1). An increase energy input into wire E/E_c from 0.64 to 1.0 leads to decrease of nanoparticle size from 210 to 137 nm, while maximum of microparticle size distribution varies slightly from 1.92 to 1.82 μm. At the same time, the oxygen content decreases from 2.13 to 3.86 wt.% in the samples. The oxide film on the particles surface prevents low-temperature sintering of the particles, resulting in an increase in porosity and a decrease in the mechanical strength of the products. Therefore, it is necessary to minimize the oxygen content in bimodal powders.

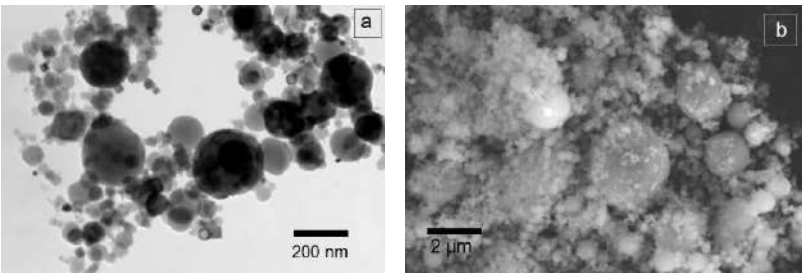

Fig. 1. TEM (a) and SEM (b) images of the Ti-6Al-4V particles

To prevent a high chemical activity of the nanoparticles and their tendency to agglomerate, bimodal powders were treated with 8-hydroxyquinoline as a surfactant resulting in the destruction of agglomerates and the formation of a lyophilic sorption layer on the surface of nano- and microparticles. This treatment improves the wetting of particles by a polymeric binder. In granular materials the binder serves to enhance the feedstock melt fluidity when molding the parts and holds the alloy particles until the sintering process begins. To obtain a homogeneous granular material, the binder components consisting of viscowax 10 wt.%, 8-hydroxyquinoline 0.5 wt.% and PE-LD as main component, and bimodal powder were mixed for 30 min and extruded twice. Bimodal powder content in the feedstock was 93 wt.%. The study of the feedstock granule fracture has shown a uniform distribution of nano- and microparticles over the volume of the samples.

"Green" parts were formed from feedstock and sintered in vacuum. In thermal debinding, the low-boiling components of the binder are removed and the pores and channels are formed, which are necessary for the release of gases formed and uniform shrinkage of the samples when sintering. Sintering of "brown" parts at 1350 °C leads to a decrease in porosity and an increase in the density of samples up to 98% of the theoretical density of the alloy. Examination of the microsection of the sintered sample did not reveal the presence of a significant number of pores. When analyzing the composition of the sample, the main elements were found to be titanium, vanadium and aluminum, similar to the composition of the original wire. Oxygen and carbon were not detected. Carbon content is an important indicator, because the residual carbon in the sample could form a fragile structure of titanium carbide [1].

The mechanical properties of sintered samples depend on the ratio of nano- and microparticles in the bimodal powders. In addition, the mechanical properties of the samples are significantly affected by the regimes of debinding and sintering of "green" samples, including temperature, heating rate, and the exposure time of samples when debinding and sintering. The Vickers microhardness of the samples, determined on polished microsections, was 3.1 ± 0.3 GPa. The highest microhardness was obtained for samples sintered at 1350 °C and dwell time of 30 min. A certain proportion of nanoparticles in a bimodal powder should provide, on the one hand, low-temperature sintering of micro- and nanoparticles with each other, and on the other hand, dense pack of particles and filling the space between microparticles, thereby reducing shrinkage of parts when sintering. When using nano- and microparticles, almost complete compaction of the material can be achieved.

The work was performed according to the Government research assignment for ISPMS SB RAS, project No. III.23.2.5.

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