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FEATURES OF TITANIUM POWDERS FOR ADDITIVE MANUFACTURING

Titanium alloys are widely used in the aerospace and medical industries due to their improved resistance to oxidation, high stiffness, low density, and biocompatibility [1]. Additive manufacturing (AM) of titanium alloys offers numerous advantages over traditional manufacturing methods. It is possible to create highly complex designs and geometries that are not achievable with conventional manufacturing techniques. Furthermore, AM facilitates the easy customization of products to meet individual customer needs. Also, it is a highly efficient process that minimizes material waste. One of the key advantages of AM is its ability to fabricate parts quickly, without the need for costly moulding and tooling. But the success of this technology relies on the careful selection and preparation of the powders used in the process. The powder properties, such as particle size and its distribution, particle shape and oxygen content have significant effect on the surface roughness, volumetric defect content and mechanical behavior of printed parts.

Particle size is a critical factor in the AM of titanium powders. Powders with median particle sizes, typically in the range of 20-60 μm are used. Fine particles are beneficial for packing behavior, especially in powders with a broad particle size distribution, as they provide high bulk density and produce high-quality finished components with minimal flaws. However, finer particles have poor flowability due to increased forces of attraction between particles resulting from their decreased size. Parts manufactured from the coarse powder have slightly higher ductility and fatigue resistance. Though they contain more defects due to the inferior packing state and lower heat absorptivity of coarser particles but the maximum defect size is still larger in the fine powder parts [2]. However, it is important to note that using powders with extremely small particle sizes can also result in an increase in oxygen contamination, which can negatively affect the mechanical properties of the printed parts.

In addition to particle size, the shape of the titanium powder can also affect the properties of the printed parts. By manipulating particle shape, it is possible to offset the low flowability associated with fine powders to enhance AM process efficiency. Furthermore, smooth spherical particles also tend to pack efficiently and so can be additionally advantageous from the perspective of achieving high bulk densities. The utilization of powder composed of highly spherical particles can enhance powder flowability, spreadability, and packing state by reducing interparticle friction [3].

The particle size distribution of titanium powder used in AM has a significant effect on the microstructure, mechanical properties and surface quality of the printed parts. A narrow size distribution can improve the flowability, mechanical resistance and hardness of printed parts by reducing the formation of voids and defects [4].

The effect of oxygen content in titanium powder is particularly significant in additive manufacturing processes, such as selective laser melting and electron beam melting, which use powdered titanium alloys to build up parts layer by layer. High oxygen content in the powder can lead to an increase in porosity and decrease in mechanical properties due to the formation of TiO_2 oxide inclusions [5].

The high cost of titanium powders makes it necessary to search for suitable powder recycling strategies. The powder after recycling has larger average particle size because small particles and satellites are removed. Additionally, particles contain a higher concentration of oxygen. Parts made with recycled powder show a noticeable increase in surface roughness, so their fatigue strength is lower compared to ones made with new powder [6].

Controlling and optimizing particle properties (such as finding a balance between particle size and oxygen content) is crucial for achieving high-quality and reliable AM processes and products. Powder recycling should be closely controlled and studied because excessive reuse could imply changes in the morphology of the powder and alterations in the mechanical properties of the obtained parts.

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