PERFORMANCE EVALUATION AND CHARACTERISATION OF EIGA PRODUCED TITANIUM ALLOY POWDER FOR ADDITIVE MANUFACTURING PROCESSES

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ABSTRACT

Metallic powders are widely used as the feedstock material for many additive manufacturing processes. Titanium alloys in particular are used in aerospace construction as an attractive alternative construction material due to the superior properties they exhibit. This paper highlights the process used to produce titanium alloy powder for additive manufacturing, and the characterisation methods used to qualify the atomised powder against specifications contained in applicable test standards. The electrode composition was compared to commercially available wrought samples, and cylindrical rod structures 13 mm in diameter and 90 mm in length were laser printed.

1. INTRODUCTION

Metallic powders are widely used as the feedstock material for many additive manufacturing (AM) processes. Titanium alloys in particular are used in aerospace construction as an attractive alternative construction material due to the superior properties they exhibit, such as corrosion resistance, use at elevated temperatures and a high strength to weight ratio (Shunmugavel et al. [1]). Due to the high costs of titanium powder, material recycling is recommended to reduce wastage and to achieve a more economical process (Herzog et al. [2]). However, it is necessary to analyse the powder after each use to track the powder chemistry and morphology to identify any changes that may affect powder quality, and hinder processing.

In an investigation by Goso and Kale [3], Ti-6Al-4V alloy powder was produced by the hydride-dehydride (HDH) process in order to make titanium components by blended elemental approach. Chemical analysis revealed that the composition of produced titanium matched specifications of commercially available titanium; however, high carbon content was identified, which reduces the ductility of titanium. Powder production methods such as oxide reduction and water atomization are not preferred for reactive and refractive metals because the processes introduce chemical impurities, and do not produce the particle geometry and morphology required for additive manufacturing processes (ALD Vacuum Technologies [4]). Inert gas atomization is thus a preferred approach for refractive and reactive metals such as titanium, as the desired purity and specifications such as particle morphology required in achieving homogenous microstructures are achievable to a high grade (ALD Vacuum Technologies [4]).

For powder production by means of the electrode inert gas atomisation (EIGA) process, atomisation is achieved through inductive melting of a pre-alloyed bar. The bar is supplied in the form of an electrode, and atomised with an inert gas. This paper highlights the atomisation of Grade 5 wrought Ti-6Al-4V bar to produce feedstock material for AM. Rod structures 13 mm in diameter and 90 mm in length were fabricated using this powder by the directed energy deposition (DED) technique on the LENS™ system. The successful production of powder that compares well with commercially available powders, and can be used to produce AM components with comparable properties could create the opportunity for local titanium alloy powder production. Considerable cost savings would be achieved through such an opportunity. The electrode was analysed to determine chemical composition, while the atomised powder was characterized to determine oxygen and nitrogen content, particle size, and morphology, and the manufactured samples analysed to determine defects. The samples were subsequently put through a hot isostatic pressing (HIP) post-process treatment to improve mechanical properties. Mechanical investigations were performed on as-built samples and HIP treated samples for comparative purposes. Only electrode and powder characterisation results are presented.

2. METHODOLOGY

A Grade 5 wrought Ti-6Al-4V bar sourced from Baoti Titanium Industry in China was used as source material to ensure a reliable electrode with accurate analysis for atomisation was obtained. The bar was prepared to specification for EIGA systems and shipped to TLS in Germany for atomisation. The atomised powder was

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classified using a standard fractional sieve system to achieve a 45 to 100 µm size range. The sieves were equipped with rubber seal rings, and the powder loaded and decanted in a glove box under argon atmosphere. Oxygen in the glove box was 0.2 ppm. Laser processing was performed on a LENS™ system mounted with a 1 kW IPG fiber laser in an argon atmosphere. A laser power of 330 W at a spot size of 1.3 mm was used to melt approximately 2.76 g/min material deposited at a scan speed of 8.47 mm/s.

3. RESULTS

The chemical composition of Ti-6Al-4V bar used for the atomising process compares well with ASTM standard as analyses results obtained fall below the maximum acceptable ASTM standards. This is indicated by Table 1. An inert gas (argon) environment is employed during LENS processing to ensure minimal oxidation due to the high oxygen content reported in Table 1. Only the oxygen and nitrogen content was determined for atomised powders, and was reported as 0.33% and 0.007% respectively for run one. Run two reported amounts of 0.36% and 0.012% respectively. Samples for gas analysis will be machined out of the LENS printed samples to determine the influence of LENS processing as this would give more accurate results.

Table 1: Chemical composition of titanium alloy

Material	***N%***	***C%***	***H%***	***Fe%***	***O%***	***Al%***	***V%***	***Ti% (balance)***
Ti-6Al-4V electrode	0.01	0.01	0.002	0.16	0.2	6.2	4.1	Balance
Wrought Ti-6Al-4V (ASTM F1472)	<0.05	<0.08	<0.015	<0.3	<0.2	5.5-6.75	3.5-4.5	Balance

The process from sourcing of Ti-6Al-4V bar used as electrode for atomising to the final laser printed rod samples for evaluation is indicated by Figure 1.

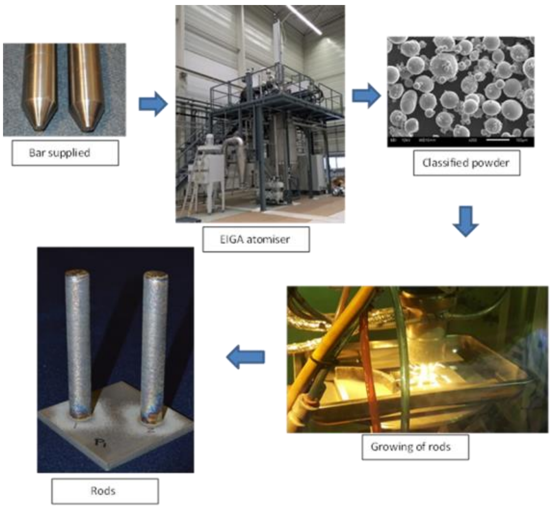

Figure 1: Powder production and sample manufacturing process

4. CONCLUSION

Analysis of the electrode compared well with ASTM requirements, indicating that a reliable source material was obtained. The laser printed rod samples were manufactured without challenges that could arise from particle distribution or flowability of the powder. Characterisation of the samples for defects, porosity and mechanical properties will inform the success of producing rod samples and powder performance.

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