Corrosion Science 224 (2023) 111495

Contents lists available at ScienceDirect

Corrosion Science

journal homepage: www.elsevier.com/locate/corsci

Microstructure and corrosion behavior of differently heat-treated Ti-6Al-4V alloy processed by laser powder bed fusion of hydride-dehydride powder

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ARTICLE INFO

Keywords:
Additive manufacturing
Titanium
Heat treatment
Passive film
XPS

ABSTRACT

This study investigates the use of hydride-dehydride non-spherical Ti-6Al-4V powders in laser powder bed fusion process and the effects of post-heat-treatments on additively manufactured parts. As-built parts show anisotropic microstructure with α' martensite and some β phases. Post heat-treated parts exhibit $\alpha + \beta$ phases, with characteristics dependent on the heat treatment. Heat treatment below β-transus leads to homogenized grain structures with improved corrosion resistance. Electrochemical analysis reveals a very stable corrosion rate due to faster formation of a protective passive layer aided by the fine-structured β phase. X-ray photoelectron spectroscopy examines corrosion behavior and film growth mechanism in saline water.

1. Introduction

Powder bed fusion (PBF) processes have garnered substantial attention across various industries due to the multitude of advantages they offer over traditional manufacturing techniques. These benefits encompass exceptional design flexibility, diminished post-processing requirements, and minimized material wastage [1]. The Ti-6Al-4V alloy stands out as a particularly well-suited material for PBF methods such as laser or electron beam techniques, primarily due to its outstanding weldability [2]. This alloy is in high demand owing to its highly favorable attributes, including remarkable strength, biocompatibility, and corrosion resistance [1,2].

Traditionally, conventional feedstock for the Ti-6Al-4V alloy was prepared using melting methods like plasma rotating electrode processes and atomization [3], resulting in the formation of spherical powder morphology. The use of spherical particles in powder bed additive manufacturing (AM) is deemed crucial owing to their capacity to enhance powder flow, spreadability, packing density, and reproducibility. These advantages ultimately contribute to the improvement of final part density and overall performance [1,4–7]. Fusion-based AM methods, including laser or electron beam powder bed fusion (L-PBF or EB-PBF), predominantly rely on spherical atomized powders, despite concerns related to entrapped gas within particles and the costs associated with powder production.

In recent times, a misconception has arisen that non-spherical particles are unsuitable for achieving fully dense parts through L-PBF. Nevertheless, technological advancements have led to the commercialization of several cost-effective powder production methods [8,9]. These techniques involve refining recycled metal scrap, machine turnings, or milled sponge in conjunction with blended elements. Non-spherical powders offer notably greater cost efficiency, with costs reduced by approximately 40–50 % compared to pre-alloyed powders possessing spherical morphologies produced by atomization [9–13].

The hydride-dehydride (HDH) process represents an economical production method that employs hydrogen as a temporary alloying element, presenting more environmentally friendly alternatives. Some studies have explored the application of non-spherical HDH Ti-6Al-4V powder in powder bed fusion (PBF) processes. For instance, Varela et al. [14] achieved a relative density exceeding 98.9 % using HDH Ti-6Al-4V powder with particle sizes ranging from 50 to 120 μm in the

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https://doi.org/10.1016/j.corsci.2023.111495
Received 6 July 2023; Received in revised form 27 August 2023; Accepted 3 September 2023
Available online 9 September 2023