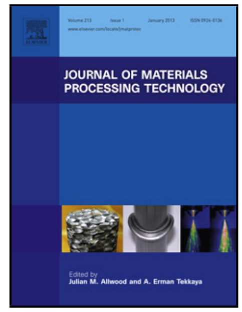
Accepted Manuscript



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PII: S0924-0136(17)30501-0
DOI: https://doi.org/10.1016/j.jmatprotec.2017.10.052
Reference: PROTEC 15472

To appear in: *Journal of Materials Processing Technology*

Received date: 1-5-2017
Revised date: 22-9-2017
Accepted date: 29-10-2017

Please cite this article as: Kreitcberg, A., Brailovski, V., Prokoshkin, S., New biocompatible near-beta Ti-Zr-Nb alloy processed by laser powder bed fusion: process optimization.Journal of Materials Processing Technology https://doi.org/10.1016/j.jmatprotec.2017.10.052

New biocompatible near-beta Ti-Zr-Nb alloy processed by laser powder bed fusion: process optimization

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Abstract

The laser powder bed fusion parameters were determined for a novel biomedical Ti-18Zr-14Nb (at%) alloy using both analytical and experimental approaches. An analytical model was used to calculate the laser powder bed fusion parameters such as laser power, scanning speed and hatching space providing the energy density on the powder bed surface ranging from 9 to 85 J/mm^3, and the build rate – from 12 to 52 cm^3/h. A technological processing window corresponding to a 25-45 J/mm^3 energy density range and a 10-25 cm^3/h build rate range is recommended for the fabrication of the fully dense Ti-18Zr-14Nb alloy with improved surface roughness.

Keywords: Additive manufacturing; selective laser melting; laser powder bed fusion; Ti-based alloy; biocompatible superelastic alloy; processing parameters

1. Introduction

Metals and metallic alloys are widely used for load-bearing biomedical applications such as orthopedic and dental implants. Material selection, implant design and manufacture depend on the functional requirements of an intended medical application. Two main criteria are applied when selecting materials for such applications: inertness of the material to the body's environment and similarity of the material's mechanical behavior to that of biological tissue. In this context, Ti-based alloys can be divided into three groups. The first group comprises pure titanium (Ti-CP) and titanium alloys, such as Ti-6Al-7Nb and Ti-6Al-4V, which are characterized by excellent corrosion and mechanical resistance, but also a significant stiffness mismatch with bone tissue as shown by Geetha et al. (2009). The second group comprises alloys with excellent biomechanical compatibility, such as superelastic Ti-Ni intermetallics, but which pose a risk of corrosion and release of toxic nickel in the body's environment (Davis, 2004). Finally, the third group comprises near-beta titanium alloys exhibiting relatively low elastic modulus and having only non-toxic elements in their composition. The following titanium alloy systems belong to the third group: Ti-Mo (ASTM, 2013b), Ti-Nb-Zr (ASTM, 2013a), Ti-Nb (Xu et al., 2013), Ti-Nb-Ta-Zr (Geetha et al., 2009), and Ti-Nb-Ta-Sn (Hao et al., 2007). Song et al. (1999) found that among the multitude of alloying elements, Zr, Nb and Ta contribute the most to the reduction of the elastic