Accepted Manuscript

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PII: S0924-0136(17)30421-1
DOI: http://dx.doi.org/10.1016/j.jmatprotec.2017.09.022
Reference: PROTEC 15399

To appear in: *Journal of Materials Processing Technology*

Received date: 25-11-2016
Revised date: 12-9-2017
Accepted date: 14-9-2017

Please cite this article as: Longhitano, Guilherme Arthur, Larosa, Maria Aparecida, Jardini, André Luiz, de Carvalho Zavaglia, Cecília Amélia, Ierardi, Maria Clara Filippini, Correlation between microstructures and mechanical properties under tensile and compression tests of heat-treated Ti-6Al–4V ELI alloy produced by additive manufacturing for biomedical applications.Journal of Materials Processing Technology http://dx.doi.org/10.1016/j.jmatprotec.2017.09.022

Correlation between microstructures and mechanical properties under tensile and compression tests of heat-treated Ti-6Al-4V ELI alloy produced by additive manufacturing for biomedical applications

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Abstract

As both life expectancy and accidents rates increase around the world, also the number of orthopedic surgeries has growth significantly, together with the need for advances in materials and techniques in order to better produce implants. The Direct Metal Laser Sintering (DMLS) is an additive manufacturing process capable of producing complex geometries and customized parts. In this study, samples of Ti-6Al-4V ELI alloy were produced by DMLS and heat-treated at 650°C for 3h (stress relieving), and at 850°C, 950°C and 1050°C for 1h, all followed by furnace cooling. The microstructural modifications were analyzed by optical microscopy, scanning electron microscopy and X-ray diffraction, and the mechanical properties were analyzed by tensile, compression and Vickers microhardness tests. It was found that the higher the temperature of heat treatment, the higher the ductility and the lower the mechanical strength, due to nucleation and growth of α and β phases. In addition, the values of ductility found for compression tests were higher than for tensile tests, having a different behavior under tensile and compression loads. The heat-treated Ti-6Al-4V ELI alloy at 950ºC and 1050ºC conditions presented the best relation of mechanical properties for use in implants, meeting the requirements of ASTM F136 and ASTM 3001 standards.

Keywords: Ti-6Al-4V ELI alloy, Additive Manufacturing, Heat Treatments, Mechanical Properties, Direct Metal Laser Sintering, Orthopedic Implants.

1. Introduction

One major problem of public health is the growing number of member repair or replacement surgeries, which occur due to the increase in both life expectancy and accidents over the recent decades.