

ABSTRACT

Titanium based Ti-6Al-4V is the most common alloy, having a high strength to weight ratio and good corrosion resistance, which is suitable for aerospace and biomedical applications. This alloy is kept in a difficult-to-cut material category because of poor thermal conductivity and low elastic modulus. Therefore, additive manufacturing of Ti-6Al-4V alloy has become popular in fabricating complex and customized components in the fields of aerospace and biomedical devices. But, one of the most difficult aspects of additive manufacturing is fabrication of components with reproducible metallurgical and mechanical properties in different build orientations.

In this work, one of the additive manufacturing processes called Laser-Powder Bed Fusion (L-PBF) process has been used to fabricate Ti-6Al-4V components in 0°, 45°, and 90° build orientations. The as-built components have been heat-treated at 800°C for 1.5 h in an argon atmosphere and then cooled in furnace to relieve the residual stress induced during fabrication by the L-PBF process. The combined effect of build orientation and heat treatment on surface roughness, residual stress, microstructure, tensile properties, corrosion, wear, and biological behaviour has been examined on the L-PBF Ti-6Al-4V samples. In the as-built condition, the 0° build-oriented flat sample exhibited high tensile strength (1202 MPa) as well as high microhardness (481 HV), but low ductility due to the presence of fine acicular α' martensite. The 90° build-oriented samples had the largest elongation of 8% and high tensile residual stress of 163 MPa. After heat treatment, the α' martensitic phase transforms into α and β phases, therefore, 0° build oriented samples showed the largest ductility (10.8%) and highest tensile strength (1081 MPa).

Surface grinding setup has been used to finish the L-PBF Ti-6Al-4V samples under dry, wet, and cryogenic environments and found that the surface roughness under cryogenic condition can offer a better surface finish (reduced from 5.94 μm to 0.259 μm). Corrosion

tests have been carried out in Ringer's solution by potentiodynamic polarization and electrochemical impedance spectroscopy (EIS) techniques. Scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS) analyses have been done on the surface of corroded samples. In as-built samples, the corrosion rate decreases when build orientation increases from 0° to 90°. The heat-treated samples showed higher corrosion resistance than the as-built samples. After heat treatment, the corrosion rate of L-PBF Ti-6Al-4V samples is comparable with conventionally manufactured Ti-6Al-4V samples.

Dry rotary wear test has been performed on L-PBF Ti-6Al-4V samples to study the effect of build orientation and heat treatment, at different sliding velocities and loading conditions. The wear rate exhibited by the heat-treated samples was lower than those of respective as-built samples but comparable with those of conventional samples. Biological test has also been carried out on the L-PBF fabricated Ti-6Al-4V samples by using human osteosarcoma cell line named MG-63. Maximum number of cells were found to adhere on the 45° oriented samples, followed by 0° oriented sample and lowest number of cells were adhered on the 90° oriented samples. This study points out the necessity of considering build orientation as an important variable in the process of optimization.