Critical assessment of the defect tolerance of beta-metastable titanium alloys processed by additive manufacturing compared to cast alloys

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Titanium alloys constitute a very attractive choice for aerospace, aeronautics and biomedical applications mainly due to their excellent strength-to-weight ratio. Classical alloys, such as Ti-6Al-4V, exhibit a high strength but a low hardening capacity, ductility and fracture toughness. Much efforts have been made to develop new titanium alloys, called beta-metastable titanium alloys, in which the simultaneous activation of Transformation-Induced Plasticity (TRIP) and Twinning-Induced Plasticity (TWIP) effects increases significantly the hardening capacity and the resistance to plastic localization.

It has been demonstrated that Ti-12 wt % Mo presents a uniform deformation 3 to 4 times larger than classical Ti-6Al-4V alloy and a true fracture strain twice higher than the true fracture strains of other classical titanium alloys. Moreover, an extraordinary resistance to damage has been observed in this alloy as well as a unique fracture mechanism through shear bands instead of the common ductile fracture, dictated by nucleation-growth-coalescence of cavities.

On the other hand, additive manufacturing is commonly used to elaborate complex geometries to reduce even more the weight of the designed parts. However, defects such as porosity are almost inevitable during additive manufacturing process such as L-PBF causing a considerable decrease in the mechanical properties. Recent work has demonstrated that 3D printed Ti-12 wt % Mo maintains its improved mechanical properties even when defects are present from the beginning of straining due to a large resistance to coalescence.

In this study, additively manufactured samples as well as cast-and-wrought samples were considered to assess the influence on the mechanical response of Ti-12wt %Mo (such as the uniform elongation and the true fracture strain). This study deals with the influence of the process and the resulting microstructure on the mechanism of localization of the deformation (characterized by Digital Image Correlation) and the subsequent fracture mechanisms. The L-PBF process parameters, i.e. the volumetric energy density, have been tuned to also assess the influence of density on the mechanical behavior, and determine the defect tolerance of Ti-12 wt % Mo.