Surface roughness sensitivity of Ti-6Al-4V parts obtained by SLM and EBM: Effect on the HCF

B. Vayssette [a*], N. Saintier[a], C. Brugger[a], M. El May[a]

[a]Arts et Metiers Paristech, I2M, CNRS, Talence 33400, France
*Corresponding author: bastien.vayssette@ensam.eu

ABSTRACT

Selective Laser Melting (SLM) and Electron Beam Melting (EBM) are powder bed fusion processes which allow to build parts by successive addition of layers directly from 3D-CAD models. Among the advantages are the high degree of freedom of design and the small loss of material, which explain the increase of Ti-6Al-4V parts obtained by these processes.

However Ti-6Al-4V parts produced by SLM and EBM contain defects (surface roughness, porosity, residual stresses) which decrease significantly the High Cycle Fatigue (HCF) life. In order to minimize the porosity and the residual stresses, post-processing like Hot Isostatic Pressing (HIP) and Stress Relieving are often conducted. The modification of the surface roughness by machining is very costly and not always possible, especially for parts with complex design. The aim of this work is to evaluate the effect of the surface roughness and microstructure of Ti-6Al-4V parts produced by SLM and EBM on the HCF life.

5 sets of specimens were tested in tension-compression and torsion (R=-1): Hot-Rolled (reference) ; SLM HIP machined ; SLM HIP « As-Built » ; EBM HIP machined ; EBM HIP « As-Built ». For every condition, microstructures characterization, observations of the fracture surface of the specimens and surface analysis were carried out respectively by Optical Microscope (OM), Scanning Electron Microscope (SEM), 3D optical profilometer and X-ray tomograph. The results of the fatigue testing show a significant decrease of the HCF life due to the surface roughness.

Along with experimental testing, numerical simulations using FEM were conducted from surface scans obtained by profilometry and volume scans obtained by tomography. Based on extreme values statistics, a methodology is proposed in order to take into account the effect of the surface roughness on the HCF life.

Finally a crystal plasticity model is introduced to give a better understanding of the mechanisms leading to the crack initiation especially the competition of the stress localization between the microstructure orientation and the surface roughness.