In-situ synchrotron X-ray investigation of 3D microscale strain fields during tensile loading of LPBF AlSi10Mg

Marion Defer*†[1], Alessandro Rocco[2], Tito Andriollo[3], Gabriella Tarantino[4], François Hild[4], Innokenty Kantor[5], and Yubin Zhang‡

[1]DTU Construct, Department of Civil and Mechanical Engineering – Denmark
[2]Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS - Laboratory of Mechanics Paris-Saclay – LMPS - Laboratoire de Mécanique Paris-Saclay – France
[3]Aarhus university, Department of Mechanical and Production Engineering - Mechanics and Materials – Denmark
[4]Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS - Laboratory of Mechanics Paris-Saclay – LMPS - Laboratoire de Mécanique Paris-Saclay – France
[5]MAXIV, DanMAX – Sweden

Abstract

AlSi10Mg is a widely-used alloy for Laser Powder Bed Fusion (LPBF) due to its good processability. Its as-printed refined microstructure, featuring an AlSi eutectic network at the aluminium cell wall boundaries and grain boundaries, results in yield stress and ultimate tensile strength frequently exceeding those of its cast counterparts. Furthermore, its lightweight, low cost, and excellent corrosion resistance, combined with the advantages of LPBF, make the AlSi10Mg alloy particularly interesting for aerospace and transportation applications. However, LPBF often generates high residual stresses along with the presence of matrix porosity in as-printed AlSi10Mg, which significantly lower the ductility. Annealing heat treatment allows the residual stresses to be relieved but also leads to the degradation of the AlSi eutectic network resulting in the formation of Si particles. These particles coarsen further upon longer annealing times, potentially impacting the alloy's mechanical performance. Additionally, the heat treatment may alter the distribution of pores within the material. An in-depth understanding of the influence of the Si particles and pores on the microscale deformation mechanisms is crucial for optimizing heat treatments and achieving enhanced mechanical properties.

To investigate these effects, miniaturized dog-bone samples made of LPBF AlSi10Mg annealed at 520∘C were studied by synchrotron X-ray tomography during uniaxial tensile testing. The fast image acquisition rate combined with superior contrast and spatial resolution (ca. 275 nm) provided by the DanMax beamline at the MAXIV synchrotron enabled the visualization of the pores as well as micro-sized Si-rich particles dispersed within the aluminum matrix.

Using full-field measurements obtained via digital volume correlation, 3D strain fields were

*Speaker
†Corresponding author: mcade@dtu.dk
‡Corresponding author: yubz@dtu.dk

extracted during tensile deformation, and the microscale mechanisms of strain localization which eventually led to fracture, were revealed. The results indicate that the development of strain bands was affected by the alloy microstructure, including structural features of the Si particles, pore distribution and 3D melt pool morphology. The findings are presented, and it is discussed how they may be used to guide the refinement of heat treatments to improve the mechanical properties of LPBF AlSi10Mg.