Simulation of residual stresses due to SLM fabrication and correlation with directional fatigue behavior of AlSi10Mg

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ABSTRACT

Selective laser melting (SLM) is a layered manufacturing process that allows the building of complex, lightweight and customized parts by consolidating successive layers of powder via melting with a laser. During the SLM process, the material experiences large localized temperature fluctuations in a short time. This causes high thermal-induced residual stresses that may result in unwanted part distortion and may affect fatigue strength of the part.

Conventional thermo-mechanical FEM simulations show that distortion of AM parts tends to be a macroscopic phenomenon, which is mostly dependent on the hatching strategy and the geometry of the manufactured part. Since stress and temperature in a layer are affected only by a few neighbouring layers, a computationally-efficient multiscale method for the prediction of residual stresses and deformation for AM parts has been developed in [1]. The strains determined in the mesoscopic hatching model are applied as inherent strain in the macroscopic layer model via the inherent strain vector.

Residual stresses due to SLM process should be accounted for when designing for fatigue in the absence of suitable post fabrication heat treatments. Generally, residual stresses are expected to be either detrimental on fatigue strength when tensile or positive when compressive. The complex link between the SLM process, induced residual stresses and fatigue response would benefit from the irreplaceable insight provided by experiments: this contribution integrates SLM process simulation for residual stresses and fatigue experiments.

The residual stresses due to the fabrication of directional fatigue specimens are simulated using the inherent strains approach as implemented in the SIMUFACT software. A preliminary calibration phase of the scan strategy parameters is performed on cantilever specimens of prescribed geometry. A gas-atomized AlSi10Mg powder is processed in a SLM 280HL system (SLM Solutions Gmbh, Germany) to 3D print the cantilever beam specimens. Then they are separated from the build plate by cutting and the resulting deformation measured to compute the specific inherent strains simulation parameters.

Four batches of miniature fatigue specimens oriented in four different directions with respect to build are produced with the SLM system with the frozen process parameters for AlSi10Mg. The as-built specimens of SLM AlSi10Mg are then tested in cyclic plane bending establishing a distinct directional fatigue behaviour, [2]. The directional fatigue behaviour is discussed considering the magnitude and sign of the simulated residual stresses in the crack initiation locations.

REFERENCES

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