Influence of as-built surface topography on the fatigue behavior of SLM Inconel 718: experiments and modeling

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ABSTRACT

One of the most important qualification challenges of structural parts produced by selective laser melting (SLM) is their fatigue strength. Specimens of SLM metals with machined surfaces typically achieve comparable fatigue strength to conventionally produced counterparts [1]. When considering the unlimited part complexity associated with SLM production, however, post-fabrication surface machining is often impractical or even impossible. The high roughness characterizing the as-built surfaces (ABS) compared to machined surfaces introduces local stress concentrations that favor fatigue crack initiation at relatively low stresses. The fatigue strength of ABS SLM specimens is therefore significantly lower than that of polished specimens. Fatigue design and qualification of SLM parts should account for their effective surface quality, which is known to depend on many factors such as powder, process parameter, surface orientation, etc..

In this study, the fatigue behavior of ABS SLM Inconel 718 as obtained by testing directionally-fabricated specimens is presented and discussed together with characterization of surface topography of the specimens using green light interferometry. Three sets of smooth specimens were manufactured using a SLM® 280HL system (SLM Solution Group AG, Germany) equipped with 2x400W lasers. Gas atomized Inconel 718 alloy powder was processed using a layer thickness of 50 µm and a fluence F = 54.82 J/mm^3. After fabrication, the specimens were heat treated with a solution treatment plus a two-step aging treatment.

Specimens with the test axis in three different directions with respect to the build direction were subjected to plane cyclic bending and the respective S/N curves generated [2]. The fatigue data clearly showed a directionality effect. Different topography parameters of the specimen surfaces were examined and correlated to the directional fatigue response.

A modeling approach based on transformation of the measured surface topography into a 3D finite element (FE) model of the surface layer subjected to tensile loading was then developed to quantify the effect of surface roughness on the surface stresses. Tetrahedral elements were used and the material behaviour was assumed to be linear elastic. The FE mesh was fine, with surface nodes corresponding with data obtained from the optical profiler. The elastic surface principal stress was divided by the nominal stress to quantify the surface distribution of stress concentration, identifying potential locations of fatigue crack initiation.

REFERENCES

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