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Prediction of Residual Stresses in L-PBF Ti-6Al-4V Fatigue Specimens Using a Thermo-Mechanical Finite Element Model

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LASER POWDER BED FUSION (L-PBF) OF TI-6AL-4V FATIGUE SPECIMENS

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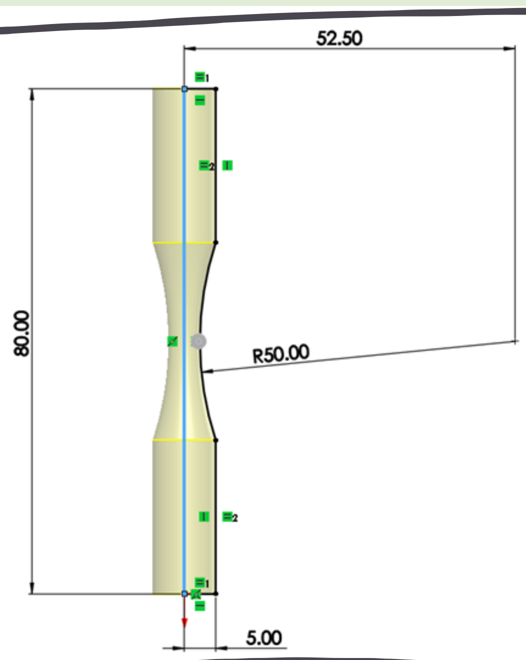


L-PBF

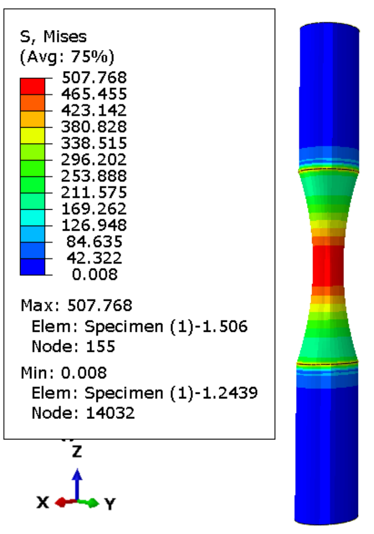
Laser powder bed fusion is an additive manufacturing process used to create metallic parts by melting metal powder with a high powered laser. The laser selectively melts the powder around the geometry of the part in a layer by layer fashion until the part is complete.

TEST SPECIMEN

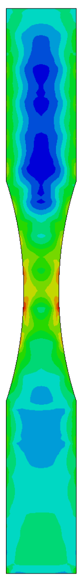
Using a cylindrical test specimen from ASTM-E466 "*Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials.*" This cylindrical specimen is typically used in fatigue testing. This is due to the lack of sharp angle in the geometry, allowing for more evenly distributed stress within the part.

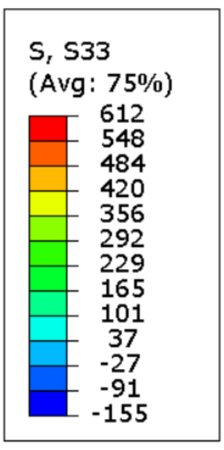
WROUGHT FATIGUE TESTING

First, the fatigue life of a wrought as-built part was determined so that it could be compared to the life a L-PBF produced specimen. The top grip section of the specimen was axially loaded with 9817.477 N, and the bottom grip section remained fixed in all three directions. The specimen was then simulated to have a cyclic loading applied at 1 Hz to find the fatigue life of the material/specimen. 1 Hz was used because time is not a factor in fatigue life in this study. The fatigue life of the wrought specimen was found to be 193489.875 cycle. This is comparable to other Ti-64 fatigue life with similar stress ranges.



Units in MPa





Units in MPa

THERMO-MECHANICAL MODELING

Thermo-mechanical finite element modeling is used to predict the residual stresses that arise within a part during the additive manufacturing process. Residual stresses can drastically reduce the fatigue life of a part, or even cause part distortion if the stresses are great enough. The thermal model uses the heat input from the laser and temperature dependent material properties to calculate the temperature at each node of the model. These temperatures are then read into a mechanical model, where the resulting stress state is predicted.

FATIGUE ON L-PBF PART

For this part the stress range that will be used is 500 MPa. The load and frequency was applied identically to the wrought specimen. The fatigue life of the L-PBF part was found to be 98,223 cycles, which is significantly less than that of the wrought specimen. This is most likely a result of the increased stress state due to the residual stresses that remained in the additively manufactured part. Being able to accurately predict these stresses by simulating the L-PBF process can play a major role in determining what the performance of a part will be before it is even manufactured.