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Experiment Report Form

	DCT, TT & 3DXRD in-situ study of strain partitioning in 316L additive manufacturing microstructure during fatigue lifetime	**Experiment number**: MA4763
Beamline: ID11	**Date of experiment**: from: 2021/06/13 to: 2021/05/14	**Date of report**: 2021/09/03
Shifts: 3	**Local contact(s)**: Wolfgang LUDWIG	*Received at ESRF:*

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Introduction

Metals obtained by additive manufacturing (AM) are organized at different length-scales and show particular grain structures compared to conventional parts. The fatigue crack initiation mechanisms are strongly influenced by the microstructure, and more especially by the grain orientations, and organizations. From an experimental point of view, the study of fatigue crack initiation mechanisms requires the use of diffraction to separately identify grain behaviour. However, diffraction methods like Diffraction Contrast Tomography (DCT) or far-field method (3DXRD) still show limitations which limits their uses for AM materials which presents large intragranular misorientations and small grains. The limitations are proposed to be surpassed by using particular heat treatments in order to optimize the microstructure to the diffraction methods. There are very few results for individual grain behavior in a polycrystal of AM metals, and still less concerning fatigue loadings. This proposal consists in an *in-situ* monotonic and fatigue loading experiments for 316L stainless steel coupling DCT, 3DXRD and topo-tomography (TT).

Experimental method:

The studied alloy was AISI 316L SS obtained by laser powder bed fusion process. Heat treatments were realized prior to the experiment in order to obtain coarse grains with low internal misorientations. Three different microstructures were used during the experiment in order to study the effect of microstructure on the fatigue behaviour at the grain scale. Grain size, morphology and positions were captured with the DCT method before loading for each sample. An in-situ monotonic loading test was performed on one specimen and was stopped at different loading point to access strain/stress state with the far-field method (3DXRD). Then, in-situ fatigue experiment was performed on a new specimen. It consisted on the application of a block of fatigue cycles, then the loading was stopped in order to perform 3DXRD and TT measurements, and supplementary cycles applied. The TT was realized on three grains. Ten measurements points were realized during the first 100 000 cycles at a given stress level, then the experiment was repeated at a higher stress level.

Results, analysis and future works

- DCT:

DCT data was supposed to allows the reconstruction of the numerical polycristalline grain structure. However, the numerous twins paving the material after heat treatment hindered numerical reconstruction. Future developments about DCT reconstruction code could help to surpass these difficulties.

- TT:

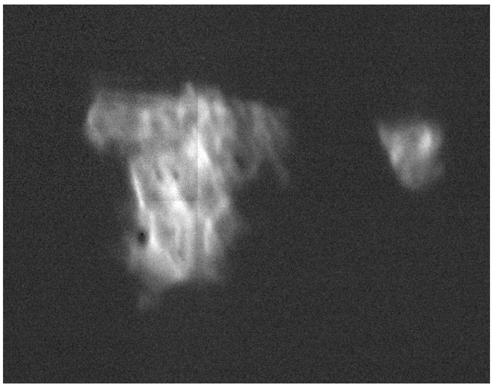
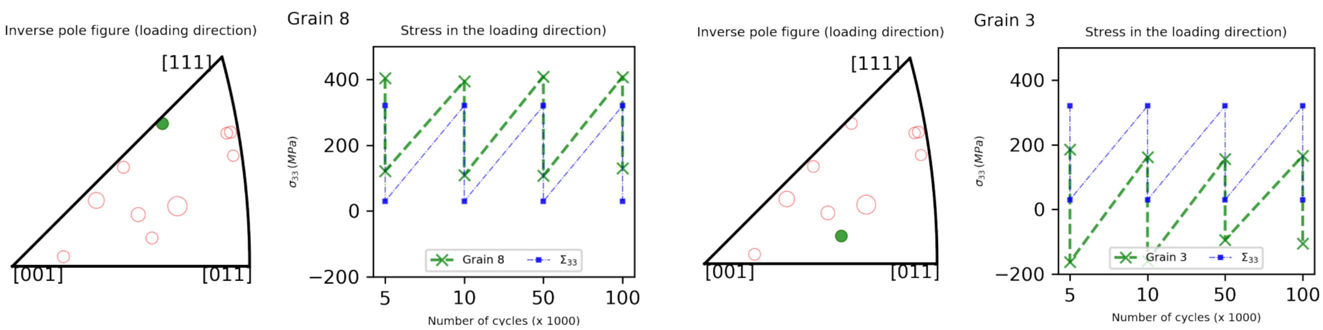


Fig.1: TT reconstruction of one grain after fatigue loading

Three grains were followed in TT during the fatigue loading. These grains were chosen for their specific orientations along the building direction. Two of these grains were twinned before loading, which limits their observation in TT. The third grain (Fig 1) showed a high intragranular misorientation prior to the loading. This misorientation didn't evolve significantly and no strain localization (like slip band) have been observed during the entire fatigue loading. This local approach remains very interesting as it gives experimental information about strain localization in polycristal and it should be re-used on more grains.

- **3DXRD:** Figures below indicate the local stress evolution in two grains with different orientations during the fatigue loading. The same type of data has been obtained for the monotonic loading. These results show that there is a high heterogeneous stress distribution between grains in 316LSS obtained by AM. Grains are showing more than 200 MPa of stress differences and some of them are in compressive state whereas the average polycristal is in tensile state. On the other hand, it has been shown that for grains with comparable orientations, the stress state can be completely different. This hypothesize a probable effect of grain surroundings. However, our results do not allow to conclude what parameters are the most influencing on the stress distribution of grains.



Further works

Besides the continuation of preliminary analysis presented before, a comparison between results obtained during the in-situ fatigue experiment and the in-situ monotonic loading have to be realized in order to conclude if the loading mode affect distribution state. Moreover, the final goal is to understand more clearly how and why stresses/strains are localized in few grains and leads to fatigue crack initiation.