DEFECT QUANTIFICATION OF ADDITIVELY MANUFACTURED METALLIC MICROLATTICE

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Summary: The inherent defects of additively manufactured microlattice structures, their size/shape distribution has been presented in this work with the aid of sub-micron scale tomography. The results showed that the build angle strongly influences the generation/distribution, as well as the spatial morphology of defects.

1. INTRODUCTION

Additive manufacturing of metallic microlattice has become popular in recent years, due to the possibility of realizing complex topology without the pitfalls of traditional cutting/tooling approach [1]. However, the parts produced from this method suffer from internal porosity due to the inefficiency rooted in the production mechanism, especially laser Powder-Bed Fusion (PBF) manufacturing [2]. This porosity, spanning on a length scale from micro- to nano-meters, would cause the parts to fail rather early should they be used for structural application, especially under fatigue loading conditions [3]. To investigate the effect of the voids on the overall response of the bulk structure, the characteristics data is needed first, which warrants sub-micron scale tomography.

In this research, the volumetric information about the internal structure of the built parts (individual struts) in as-manufactured condition has been acquired at sub-micron scale resolution in the National Laboratory for X-ray Micro Computed Tomography at Australian National University (ANU). Thermo Scientific™ Avizo™ software has been used to conduct 3D image analysis on tomography based reconstructed image stack.

2. EXPERIMENTAL METHOD

Individual strut with length close to node-to-node distance in the unit cell was collected from the lattice block by wire-cut Electrical Discharge Machining (EDM) to avoid inducing stress during the extraction procedure and placed vertically in the hollow strut holder. The nano-scale CT data acquisition was done in an in-house developed helical CT scanner where individual 316L stainless steel struts were exposed to 100 keV X-ray energy for 6 seconds at a sample-to-detector distance of 10.896 mm. The sample rotates in a helical fashion (combination of vertical and rotational traveling) during the data acquisition phase, and typically takes ~24 hours to finish. The temperature and humidity of the data acquisition room was carefully controlled, to avoid nano-scale expansion or contraction, and compensated in both day and night time to maintain constant climate parameters during the entire experiment.

The advantage of helical scanning over traditional circular scanning strategy (e.g. synchrotron radiation tomography) are two folds – (i) it involves a single continuous scan for taller samples where no stitching is needed in post-processing, thus resulting in complete elimination of artefacts that are common in multi-scan stitching paradigm, (ii) acquired images provide high signal to noise ratio. The iterative reconstruction procedure yielded a resolution of 371.917 and 329.131 nm for the 35.26° and 90° strut, respectively.

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3. RESULTS

Two types of unit cell topology were used to manufacture lattice blocks, one with inclined struts forming a Body-Centered Cubic (BCC), and another with BCC plus a vertical pillar at the center (BCC-Z). The resulting 3D tomogram of the individual struts and the porosity residing inside is shown in Figure 1, the fine resolution of nano-CT was able to resolve lone powder particles attached to the surface and capture minute details of voids with different shape and size ranging from micro- to nano-meter scale. The main results are listed below:

1. The defect distribution was found to be build angle dependent, sample with vertical build angle retaining larger voids (high volume fraction) and aspect ratio than inclinedly oriented sample.

2. Both build angles had high occurrence of voids size in 0~5 μm range, with the aspect ratio being mostly within 1~2 for both.

3. The widely reported stair-case surface morphology for inclined build angle is apparent. As a result, the surface roughness is also found to be higher for inclined samples.

References

[1] M.G. Rashed, R.A.W.M. Mahmud Ashraf, P.J. Hazell, Metallic microlattice materials: A current state of the art on manufacturing, mechanical properties and applications, Mater. Des. 95 (2016) 518–533. doi:10.1016/j.matdes.2016.01.146.

[2] M.G. Rashed, M. Ashraf, P.J. Hazell, Manufacturing issues and the resulting complexity in modeling of additively manufactured metallic microlattices, Appl. Mech. Mater. 853 (2017) 394–398. doi:10.4028/www.scientific.net/AMM.853.394.

[3] A. Yadollahi, N. Shamsaei, Additive manufacturing of fatigue resistant materials: Challenges and opportunities, Int. J. Fatigue. 98 (2017) 14–31. doi:10.1016/j.ijfatigue.2017.01.001.

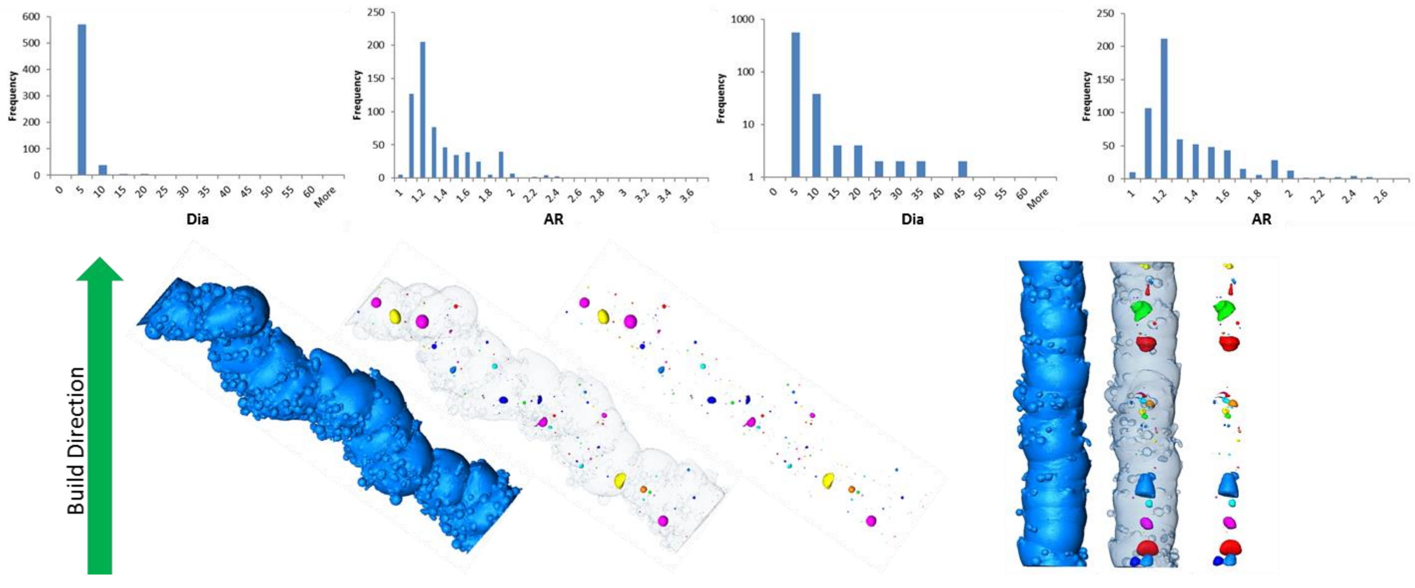

Figure 1: Defects distribution.