Structure-Property Relationship Development for Additive Manufacturing

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Academic Disciplines:
MECHANICAL ENGINEERING, MATERIALS SCIENCE

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RESEARCH OBJECTIVE

Additive manufacturing (AM) processes, while versatile, generate high degrees of toolpath-dependent microstructural inhomogeneities not observed in traditional manufacturing methods. The goal of this project is to characterize the **relationship between microstructure** (such as grains, porosity, surface roughness) **and mechanical properties** (such as strength, ductility, fatigue) through image-based reconstruction and simulation.

MICROSTRUCTURE

Grains

SEM image

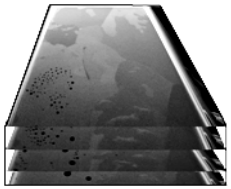
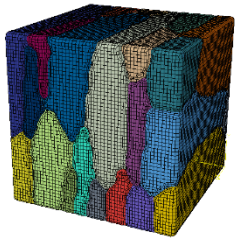


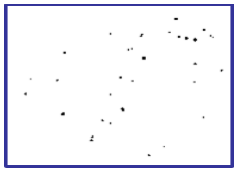
Image stacking in Dream.3D



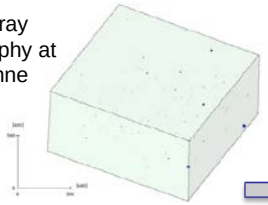
Grains, explicit hex-meshing done in Bolt

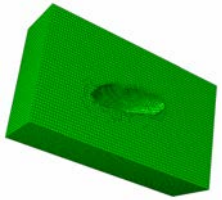
Porosity

OM image



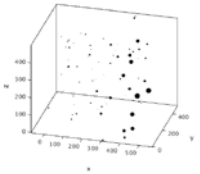
3D x-ray tomography at Argonne



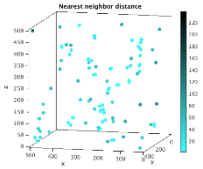


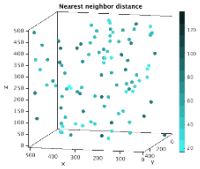
Defect, explicit hex-meshing done in Bolt

Statistical analysis and 3D reconstruction



R(x,y,z)

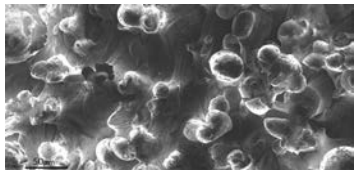


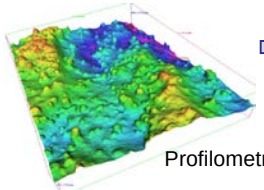


Nearest neighbor distance reveals clustering vs. regularity

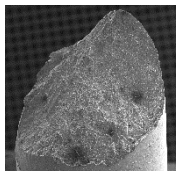
Surface roughness and fractography

SEM image





Profilometry



Fatigue fracture surface

CONSTITUTIVE MODELING

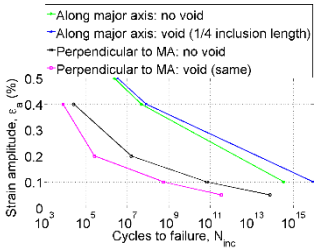
Mesoscale to macroscale

Mesoscale: Crystal plasticity and explicit defect modeling
Macroscale: Anisotropic plasticity and homogenized defect modeling

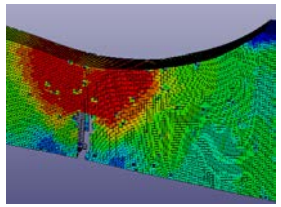
$$\gamma_f\left(2N^{inc}\right)^c = \frac{\Delta\gamma^p}{2}\left(1+\kappa\frac{\sigma_n}{\sigma_y}\right) = FIP$$

FIP (Fatigue indicating parameter) calculation from plastic strain accumulation

MECHANICAL BEHAVIOR



Fatigue: FIP is related to the fatigue incubuation life, the longest stage of fatigue occuring before crack initiation



Strength and Ductility: grain structure and defects can cause strengthening through dislocation pinning, but defects can increase or decrease elongation depending on size scale

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