Mechanical Property Variation in Metal Lattice Structure

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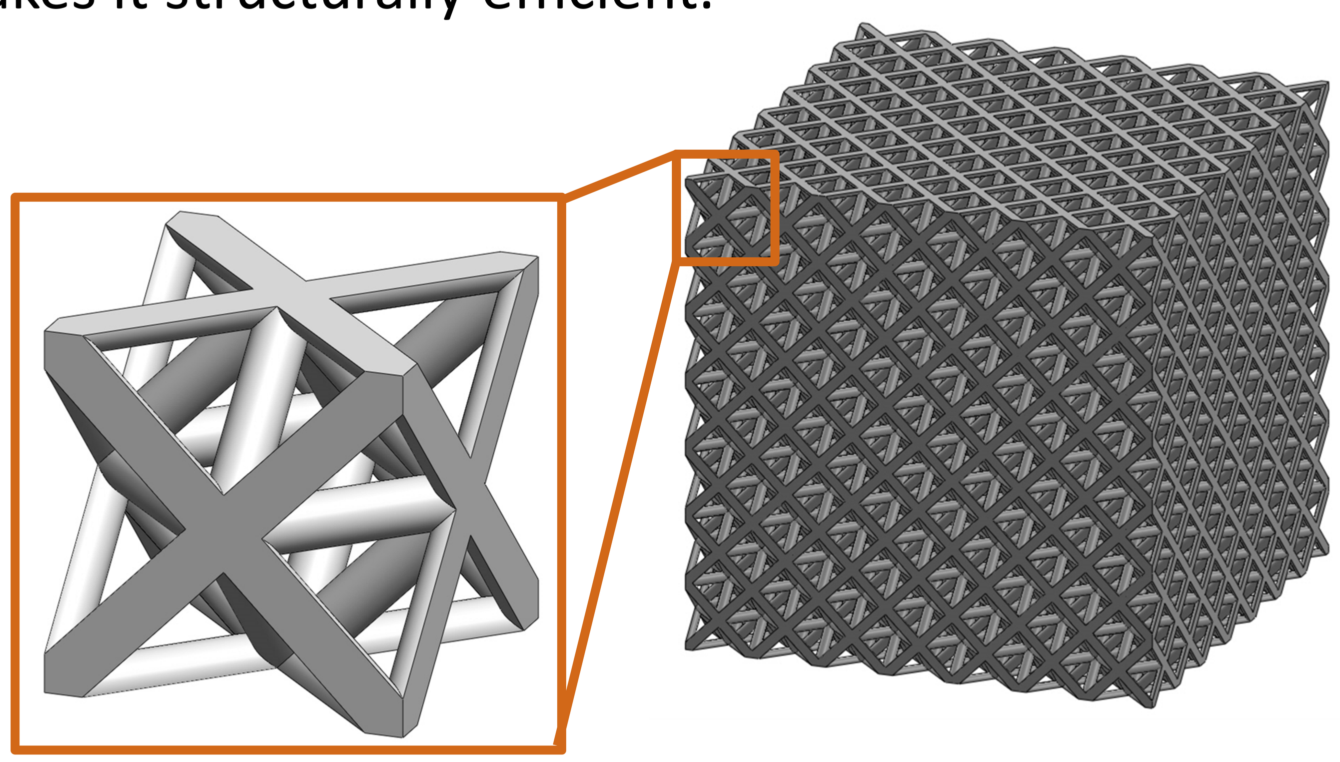
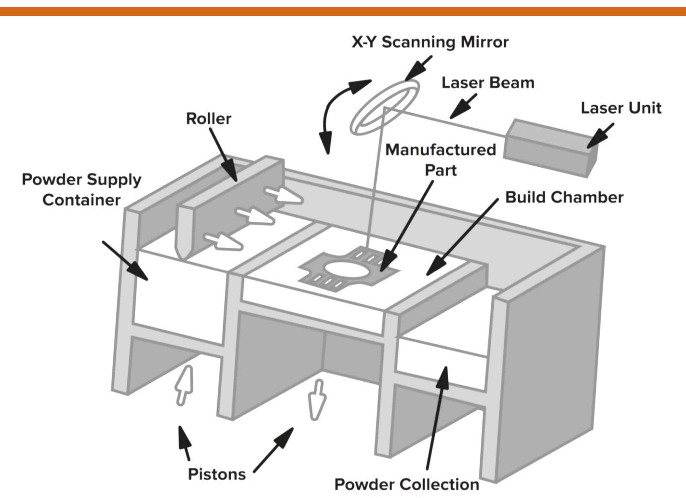
Lattice Structures

Lattice structures are composed of repeated unit cells. These structures are of interest due to their high strength-to-weight ratios. While there are many types of unit cells, this research is focused on the octet truss, below. The nodal connectivity in an octet truss unit cell makes it structurally efficient.



Manufacturing and Defects



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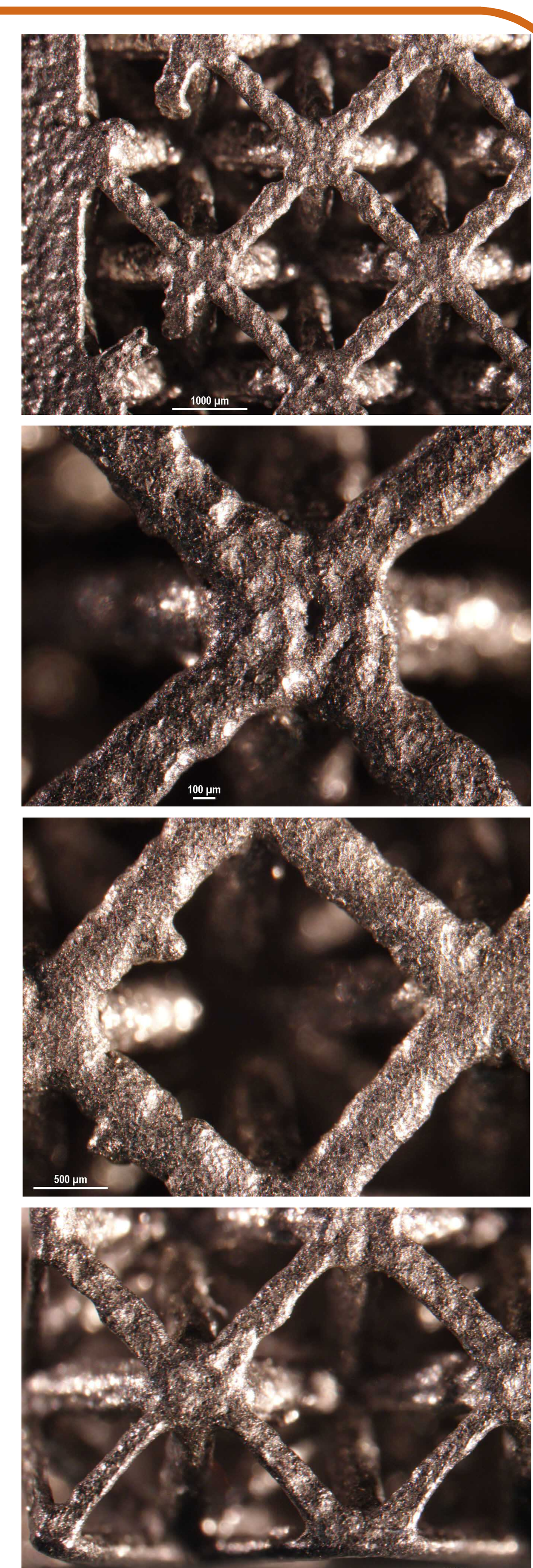


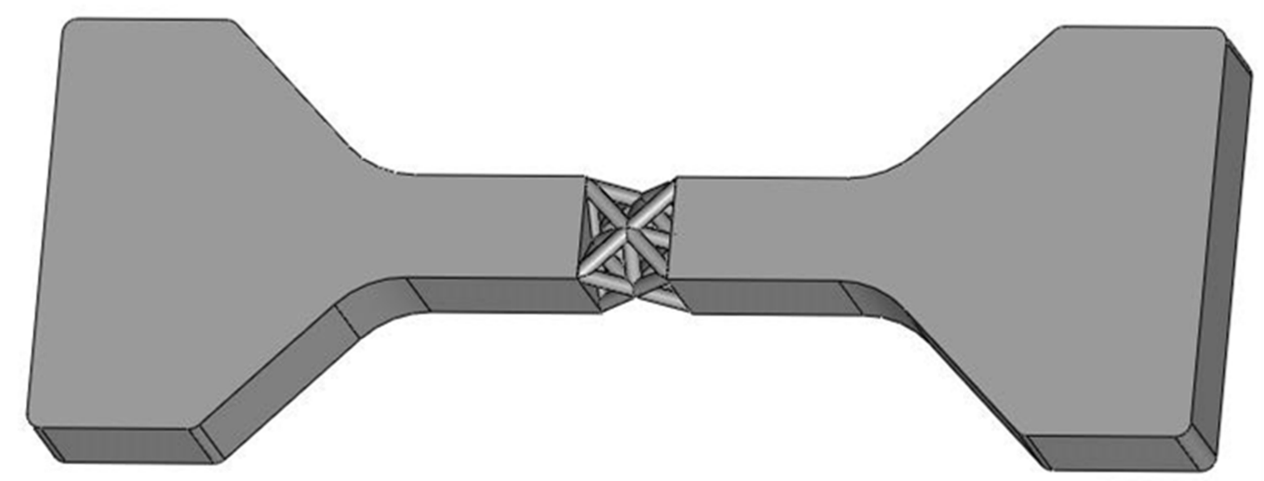
The lattices are additively manufactured with direct metal laser sintering, DMLS. A laser sinters metal power into 3D objects.

Many types of manufacturing defects can be present in DMLS parts. These defects include porosity, unresolved features, geometric inaccuracy, surface flaws, and surface roughness. Understanding the impact of defects on mechanical properties will increase the applicability of metal lattice structures

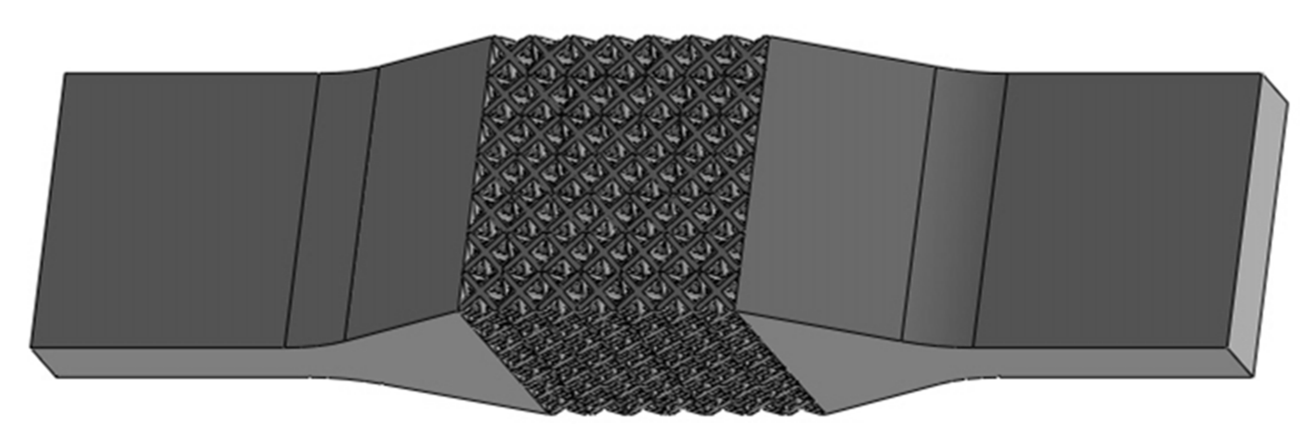
Planned Experiments

Two types of tensile bars will be built for these experiments. One bar will have a single unit cell in the gage section while the other has a 7x7x7 unit cell lattice. All tensile bars will be manufactured at Stratasys Direct Manufacturing in 17-4 PH stainless with stress relief and HIP treatment.

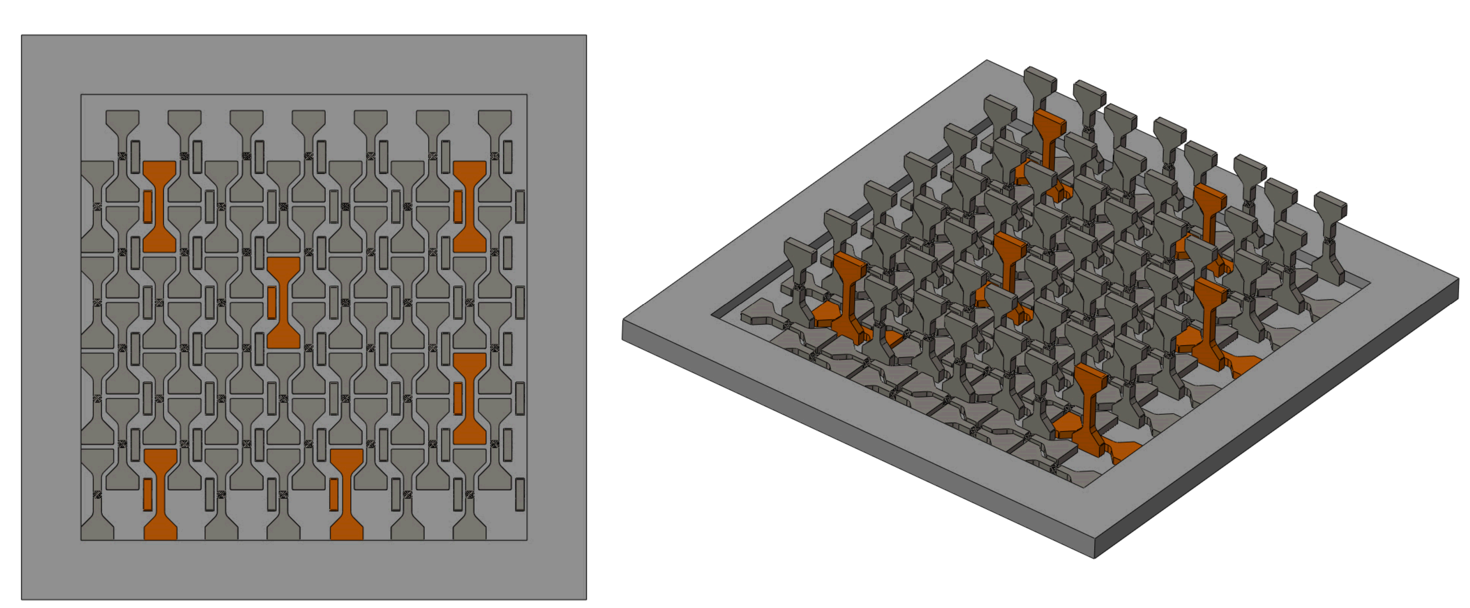
Single cell tensile bars, below, are tested to investigate how struts are failing within the unit cell. The strut failure mechanisms will inform failure behavior of the full lattice structure.



To achieve lattice properties, seven unit cells are joined in each direction within the gage section of the tensile bar, below.

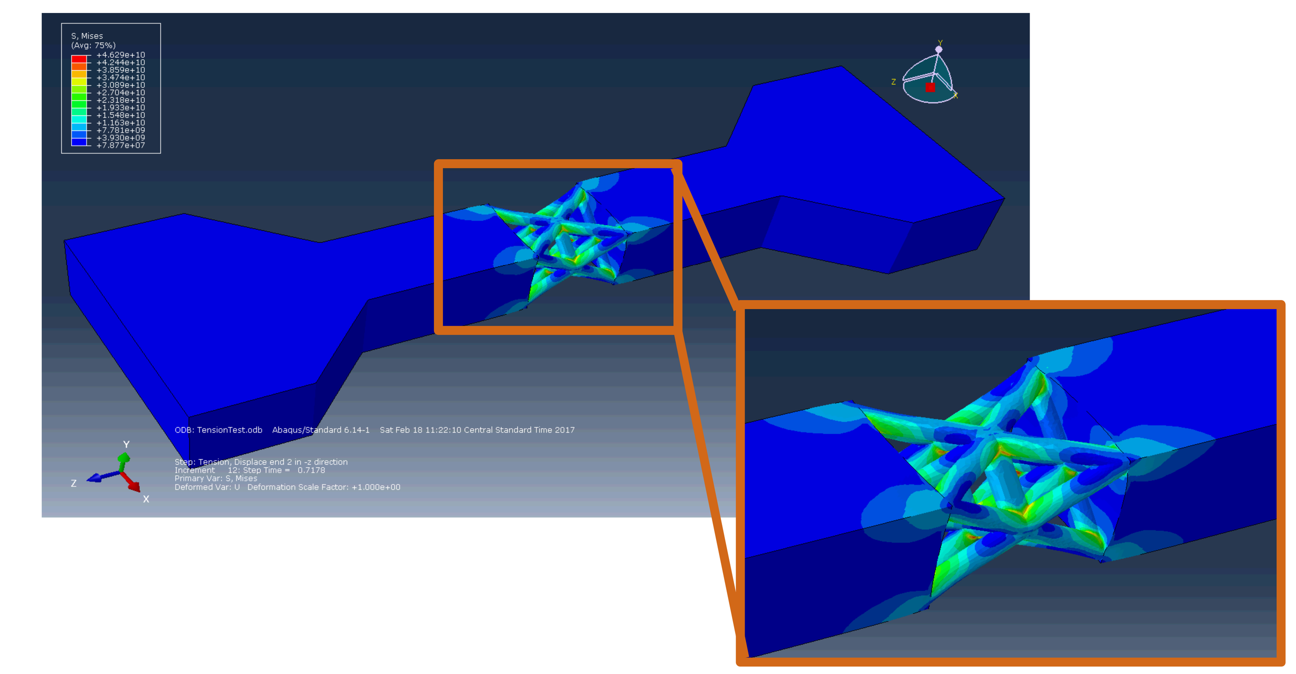


In order to limit variation from building on different days or different machines, horizontal and vertical tensile bars will be packed onto the build platform. A few solid tensile bars, in orange, will be built for comparison to the unit cell tensile bars. A similar packing method will be used for the lattice tensile bars.



Simulations

Prior to manufacturing tensile bars, stress concentrators and ultimate failure of the struts are predicted using finite element analysis. Currently, the model does not account for plasticity in the steel. Next steps are to account for plastic deformation and validate the results.



Testing and Expected Results

Both non-destructive and destructive testing will be used to analyze the mechanical properties of the unit cell and lattice structures. The non-destructive testing includes optical imaging and computed tomography (CT) scanning. Optical imaging will help determine the amount of edge defects on the unit cells that could lead to stress concentrations resulting in failure of the structure. CT scanning will show the porosity within the tensile bars created during manufacturing. For destructive testing, each bar will be tension tested to gain quantitative property data. After destructive testing, the facture surfaces will be analyzed with a scanning electron microscope to look for defects resulting in failure.

A large amount of variation is expected in the quantitative mechanical property data due to various manufacturing defects. The goal is to understand the impact of defects on mechanical properties in order to design around the expected variation.

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