Lattice Introduction to Address Hotspots Formed During Metal Additive Manufacturing

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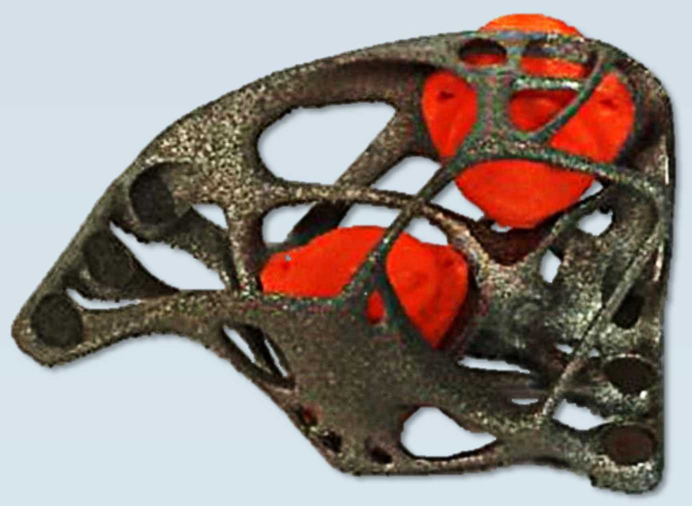
Introduction

There is a great demand for lightweight and customized components that can be reliably designed and manufactured, particularly in the aerospace industry. This has drawn designers to computer-aided optimization, as well as additive manufacturing, also called 3D printing, which can build complex 3D geometries.

Selective Laser Melting (SLM) uses a laser to melt and fuse metal powder into a solid part. However, **hotspots** during manufacturing can create severe local deformation and weak or damaged regions. Prevention of hotspots is a major goal for manufacturers and designers who need high-quality parts.

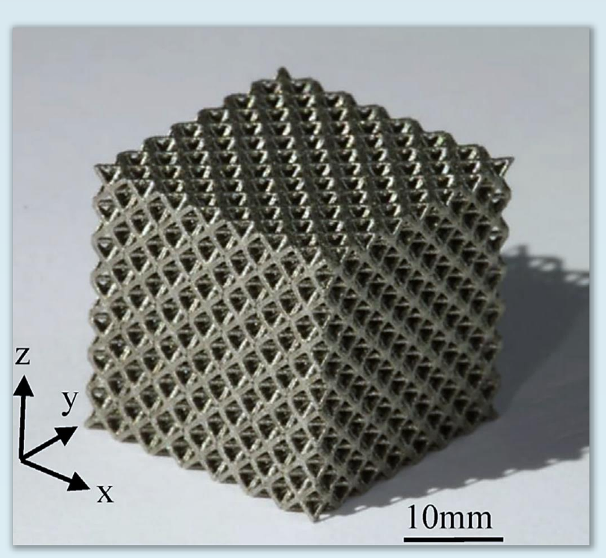
This project explores the use of cellular lattice structures that are selectively inserted into the volume of the part in order to prevent hotspots by dissipating excess heat. Potential hotspot locations are predicted using manufacturing process simulations, and lattices are introduced nearby.



Accelerometer bracket with complex geometry

Hotspot predicted by process simulation

Approach



Latticed volume made through SLM

Lattices are complex structures consisting of repeating patterns of small beams or walls. They can be used as a lightweight alternative to solid materials.

Lattices have also shown to be effective at heat transfer to ambient air due to their high surface area. As a result, they have the potential to transfer heat from nearby hotspots during manufacturing.

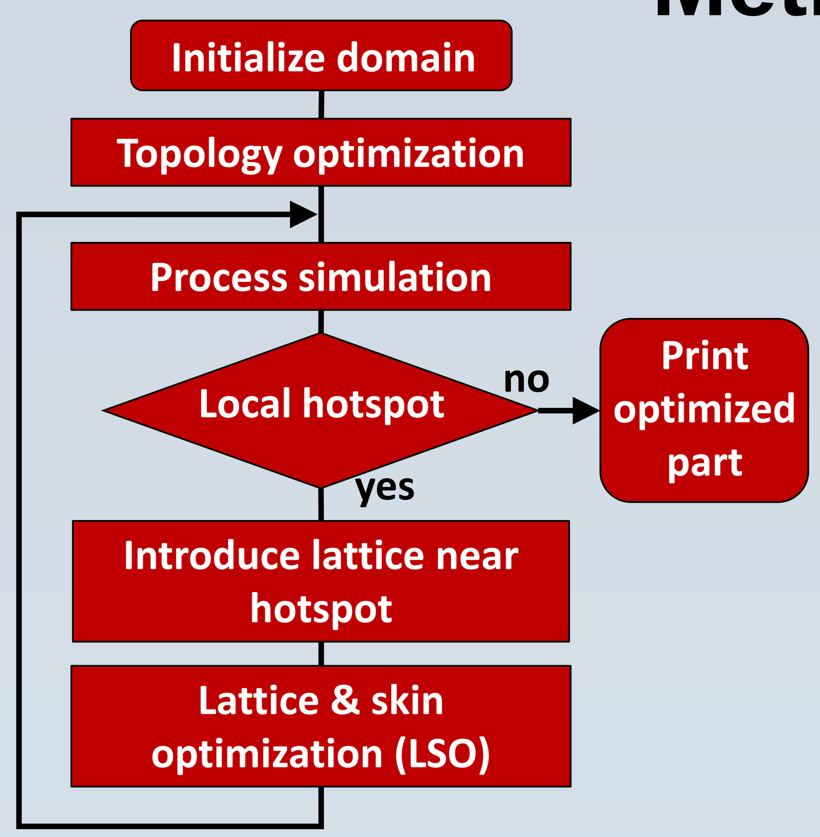
The use of lattices for mechanical optimization has been explored in SLM parts due to lattices' high strength and low weight, but they have yet to be used for their thermal advantages.

Additively manufactured piston using cellular lattices

Process simulations use detailed models of manufacturing conditions to identify potential complications.

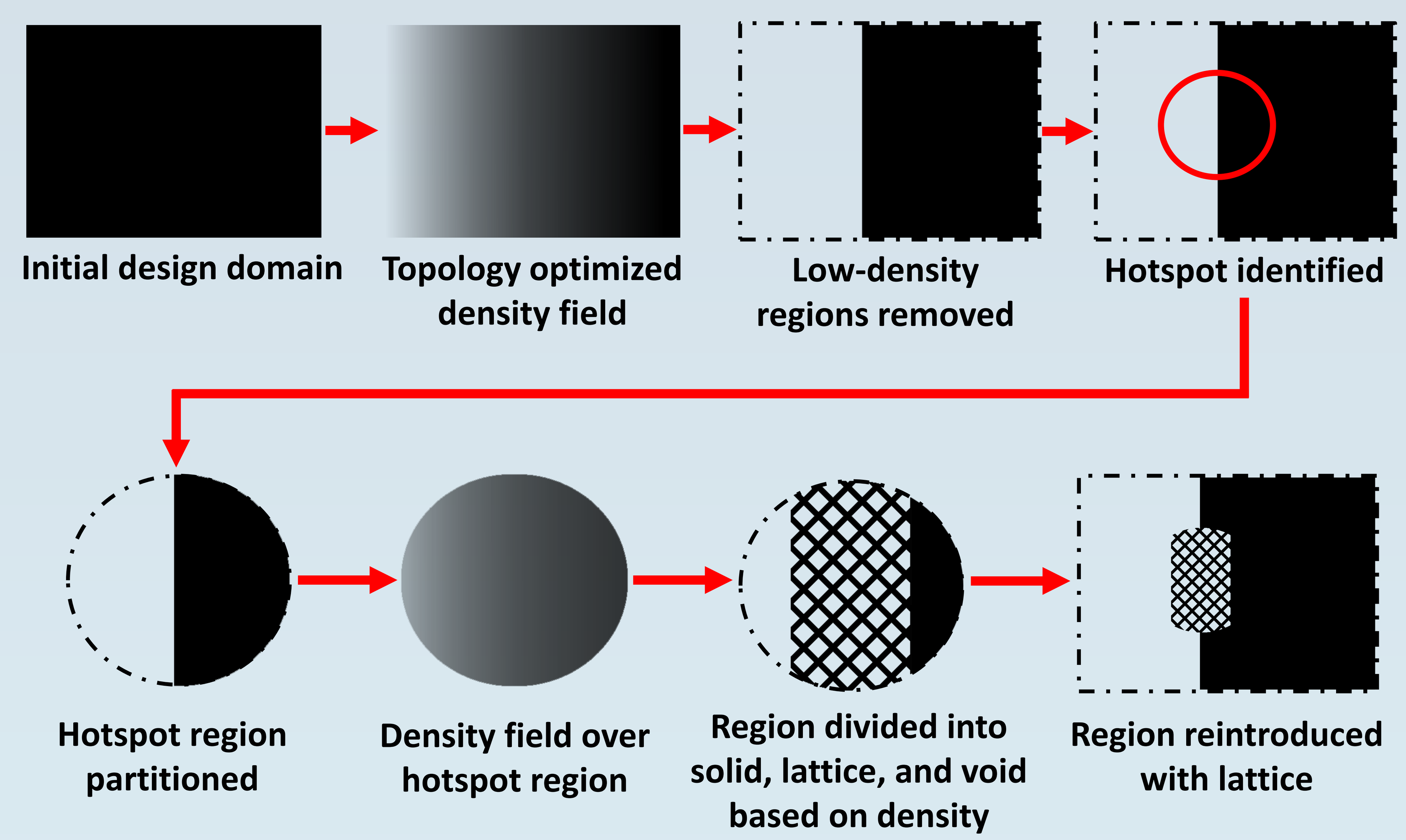
Topology optimization determines the ideal shape of a part for its expected loading conditions, removing unnecessary material.

Methods



Optimization for SLM components follows the workflow on the left. Topology optimization computes an ideal material density for every point over the volume of the part, and only regions with density above a specified threshold value are preserved. Process simulations are then used to predict hotspots during printing, and lattices are introduced to reduce these hotspots.

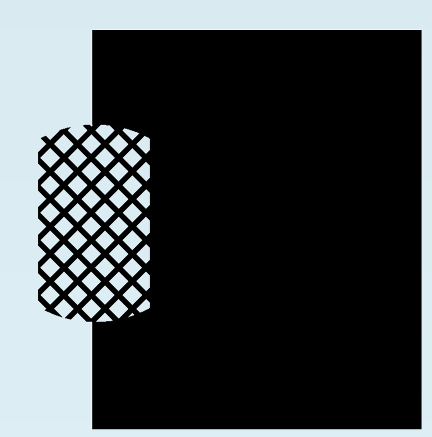
Lattice Introduction Procedure



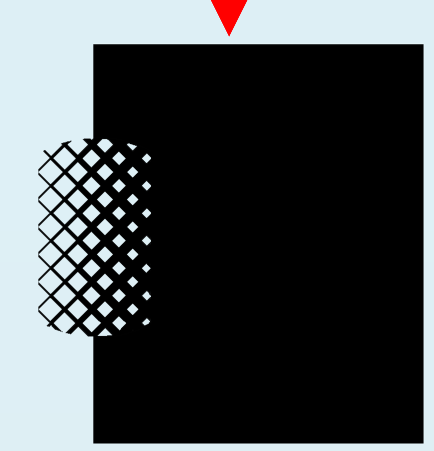
To introduce lattices, regions surrounding hotspots are manually partitioned from the model. Hotspot regions are then divided based upon the optimized material density field. High densities become solid, intermediate densities become lattice, and low densities are removed.

Lattice parameters such as cell structure and beam diameters are determined next. Beam diameters are given an initial value which is then altered through another optimization process. Material is distributed to the most crucial beams for mechanical stability, creating a functionally graded lattice.

This procedure was attempted on an aerospace component to demonstrate the advantages and challenges of the approach. Abaqus CAE was used for topology optimization, and Autodesk Netfabb was used to run process simulations and to generate and optimize graded lattices.



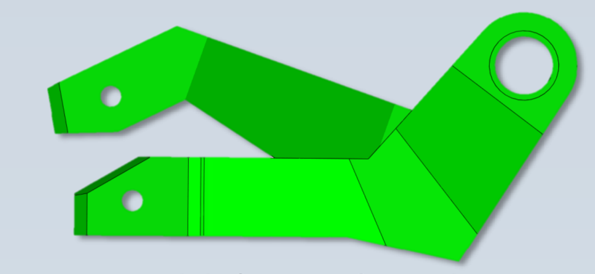
Initial latticed part



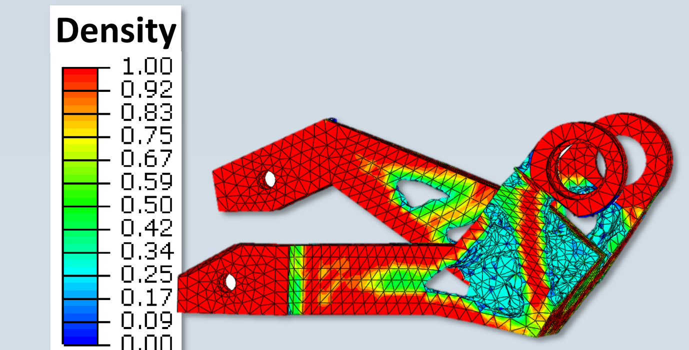
Graded lattice after optimization

Results

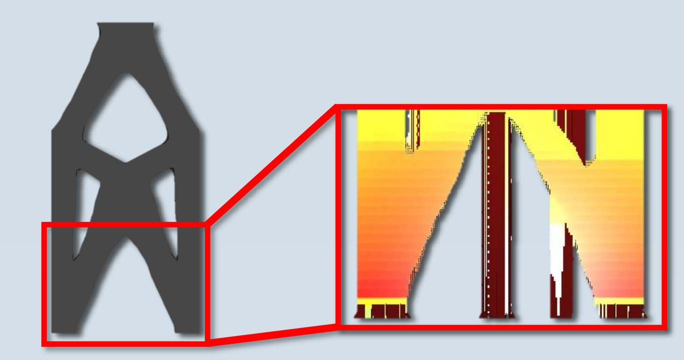
Lattices successfully reduced the severity of hotspots when introduced in a simple beam. The complex part caused process simulations to fail, so results were inconclusive. Neither part could be mechanically simulated or graded through optimization due to mesh complications.



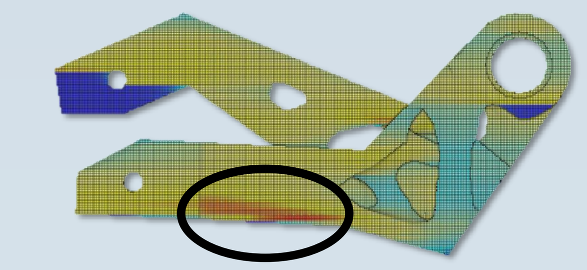
Initial part domain



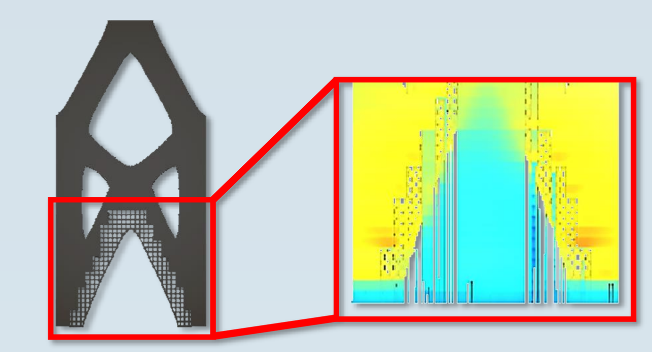
Topology optimization



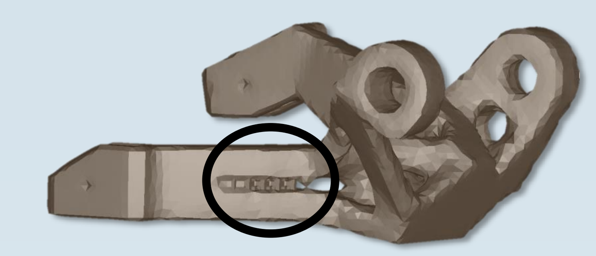
Hotspot in beam



Hotspot in process simulation



Lattice resolves hotspot



Lattice introduced

Conclusions

The success of this methodology on the simple part proves the potential of the approach. However, current software is still very limited in its ability to handle complex parts, and this provides a significant barrier to applying this process to parts in industry. Solving these issues through mesh repair tools is possible but time-consuming.

Future Work

Future work will begin with the use of mesh repair tools to make the latticed parts suitable for optimization and simulation. This will allow for further simulations to confirm the success of this method.

Later research will focus on quantifying the thermal effectiveness of lattices for heat dissipation, such that the extent and type of lattice needed can be easily determined for a given hotspot.

References

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