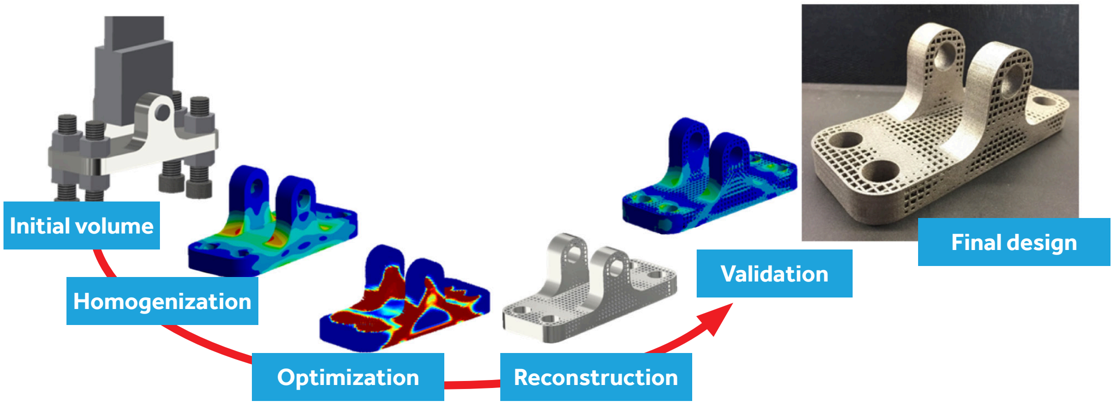
SUCCESS STORY

Utilization of Micromechanics Model Enables Efficient Variable-Density Lattice Structure Optimization Method

Reduce Weight by as Much as 50%, While Improving Mechanical Properties



Application of homogenization-based topology optimization method for a pillow bracket made with Ti-6Al-4V.

PROBLEM

Additive manufacturing (AM) enables the manufacture of parts previously impossible to machine. Complex geometries can be produced as easily as simple shapes. To fully exploit the AM advantage, design tools need to be established to enable component geometry to be optimized for strength and weight by incorporating features such as lattice and porous structures. Current modeling and simulation (M&S) tools lack efficiency in designing these complex geometries for AM. Incorporating M&S in the development of the CAD or STL file will enable an efficient design and optimization of cellular structured AM products.

OBJECTIVE

The goal of this project was to develop robust software for design and optimization of AM structural designs based on cellular structures. The outcome of this project not only enabled efficient design and optimization of cellular structured AM products but also integrated cost modeling and design requirements for several AM processes.

This project included the following specific objectives:

1. Develop experimentally-validated micromechanics models for different cellular structures, which were fully implemented into commercial ANSYS finite element analysis (FEA) software.
2. Develop topology optimization and reconstruction algorithms, which were also fully integrated with ANSYS.
3. Demonstrate and validate capability of design and optimization tools on design of a realistic structural component.

TECHNICAL APPROACH

The key innovation in this technology involved the utilization of micromechanics models to capture the effective behavior of cellular structures in FEA. This enabled solving topology optimization problems via FEA more efficiently.

The homogenization-based topology optimization method to optimize variable-density cellular structures efficiently included the following three steps:

First, homogenization was performed to capture the effective mechanical properties of cellular structures through the scaling law as a function of relative density.

Second, the scaling law was employed directly in the topology optimization algorithm to compute the optimal density distribution for the part being optimized.

Third, Boolean operations were employed to reconstruct the CAD model of the optimal variable-density cellular structure.

AMERICA MAKES TECHNOLOGY DEVELOPMENT ROADMAP

This project aligns to: DESIGN

ASTM PROCESS CATEGORY: Binder Jetting, Directed Energy Deposition, Material Jetting, Powder Bed Fusion

EQUIPMENT: EOS M290, ExOne M-Flex, Optomec LENS, Stratasys Objet

MATERIAL: ABS-like, Verowhite, Ti-6Al-4V, Inconel 718, SS420 or Polymers, Metals

ACCOMPLISHMENTS

The project team developed a topology optimization software to design realistic AM cellular structured components. The software has the ability to take a primitive component design and produce the optimal design in a CAD or a STL file that is ready to be additive manufactured with a number of different process-material combinations.

A beta version of the software was successfully deployed to United Technologies Research Center, ExOne, and Materials Sciences Corporation.

At the close of the project, ANSYS was in the process of implementing the developed technology into their world-leading CAE/CAD software, which is expected to be available in the next release of their software.

Enabling design optimization of AM cellular structures achieved a number of sustainability goals, including direct reduction in material use and process energy in manufacturing cellular structures by 50% as compared to bulk solids, and enhanced mechanical properties (e.g. stiffness increases by >100%; strength increases by >200% .)

PROJECT END DATE

January 2016

DELIVERABLES

- Completed topology optimization software
- Calibrated models for EOS DMLS Ti-6Al-4V structures
- Demonstration of topology optimization tool for allowable stress
- Demonstration of topology optimization tool for large-scale problem
- Demonstration of topology optimization tool for efficiency for large-scale tool
- New graduate degree program for AM (curriculum/course material)
- AM senior design projects in the MEMS1043 senior design project course (curriculum/course material)
- Workshop to introduce high school students to AM (curriculum/course material)

All downloadable deliverables are available to America Makes members via the Digital Storefront

FUNDING

$1.08M total project budget
($438K public funding/$641K private funding)

PROJECT PARTICIPANTS

Project Principal:
University of Pittsburgh

Other Project Participants:
ANSYS, Inc.
United Technologies Research Center
The ExOne Company
GE
ALCOA Inc.
Materials Science Corporation
AMRDEC
ACUTEC Precision Machining, Inc.

Public Participants:
U.S. Department of Defense
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U.S. Department of Energy

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