Design for Additive Manufacturing:
Topology Optimization using GENESIS and Current Challenges

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Acknowledgment
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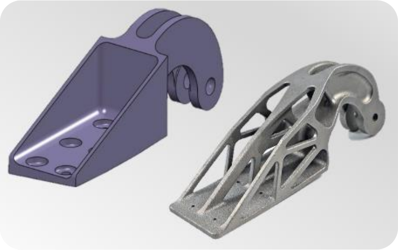
Overview

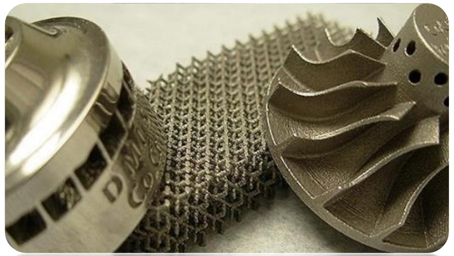
- Design for Additive Manufacturing (DfAM) and CAE's role
- DfAM Process Flow
- Where does GENESIS fit in?
- Generative Design
- Design Example Studies
- Current Challenges

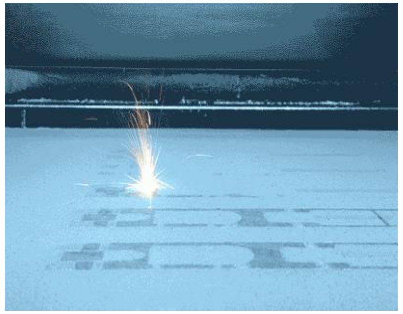
What is Additive Manufacturing?

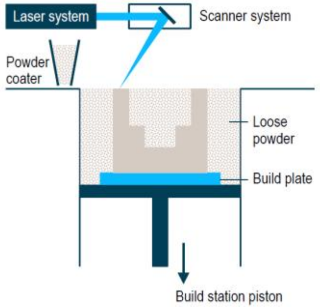
Additive manufacturing (AM) is the process of making 3D objects from computer model data by joining materials layer by layer (additive process) under computer control using 3D printer.

*AM name given by ASTM F42 committee





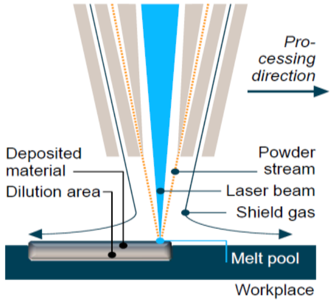




POWDER BED AM

AM = 3D-prining

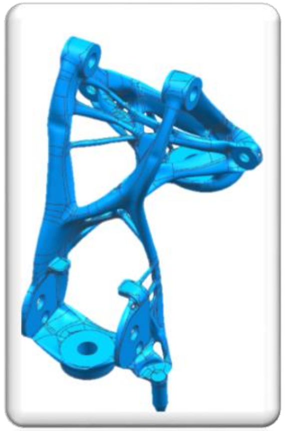
Not limited to Lattice-structure



DIRECT METAL DEPOSITION

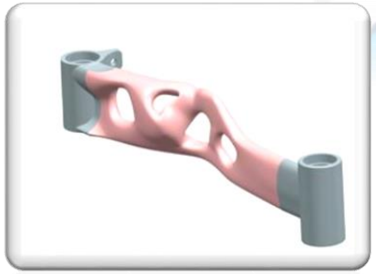
Why Design for Additive Manufacturing (DfAM)?

- Design and manufacture complex geometries to meet mass/performance goals
  - > Optimized designs – light weighting, lattice design, internal channels for air and fluid flow, etc.
- Reduce assembly complexity: consolidate multiple parts
- Reduce development time: fast design optimization iterations
- No tooling required: minimal DFM rules



CAE IS CRITICAL FOR DfAM

- 3D-printing existing design has no advantage
- DfAM could be so complex that traditional design process does not work
- CAE optimization provides a way to take advantage of design and manufacturing freedom (explain and switch)
- CAE Optimization tool is needed to generate "**best design for meeting the performance requirements with minimum mass and cost**"



DfAM Tools and Strategy

- AM Design for Performance is an exciting new emerging field
  - > Ability to design and manufacture parts, which are optimized for mass and performance, with minimal DFM rule
  - > Lots of opportunities: software tools can help
- CAE optimization tool supporting DfAM
  - > VR&D GENESIS | Altair Inspire/Optistruct
  - > Strong optimization and FEA capabilities
  - > Need more DfAM specific features (objective / constraint / realization)
- CAD tools are adding limited CAE optimization capabilities
  - > Siemens NX-Nastran/UG | Autodesk Generative-Design/Fusion360
  - > Strong design (design space generation / integration / smoothing) capabilities
  - > Need improvement in FEA and Optimization capabilities
- Need stronger CAD-CAE interface for quicker design iteration & integration
  - > Compatible file formats for data transfer and integration
  - > Graphical and visualization tools to fully integrate topology optimization, design and manufacturing
- Process Simulation
  - > Post-print Thermal Distortion / Print Failure / Print Direction / Support Structure

DfAM Process Flow

Packaging/Tooling Requirement ⇄ **Design Optimization** ⇄ **Design Integration** ⇄ **Print Simulation and Preparation** → **Manufacturing**

Design Optimization:

AM Material Modeling
Aluminum, Steel, Plastic

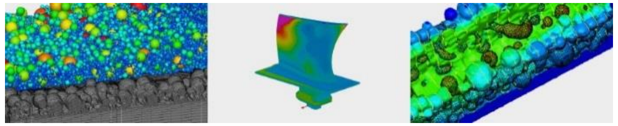
Topology Optimization
Organic vs Lattice, Nonlinearity, Print Direction, Supports

CAD-CAE interface
Unified Platform vs Software Integration

Print Simulation and Preparation:

Post-print Thermal Distortion

Print Direction
Support Structure
Print Failure



Generative Design using Topology Optimization

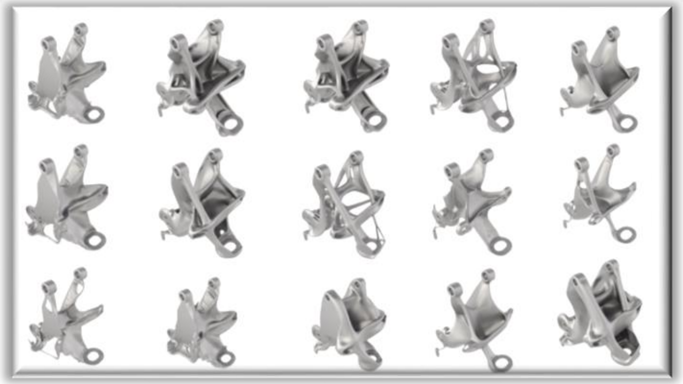
OEM part design space is constrained due to Packaging and Tooling requirements.
Traditional Topology Optimization with fixed Performance Target can lead to single design output.

Generative Design enables the generation of multiple design concepts!

Organic vs Lattice

Material Options

Aluminum vs Steel



Print Direction

Support Structure

Interface/Attachment Options

Performance Balance: Strength vs Stiffness

Print Time & Cost

DfAM Examples

For Live Presentation Only

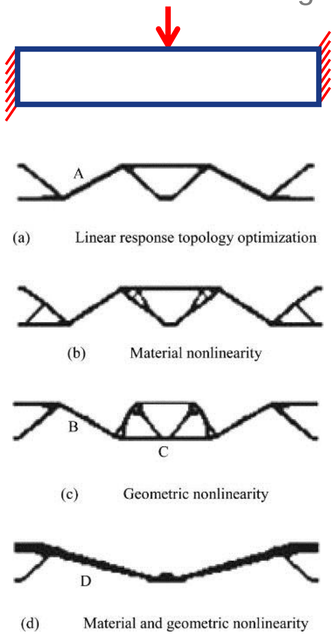
Current Challenges

- Topology Optimization with nonlinear loadcase/requirements

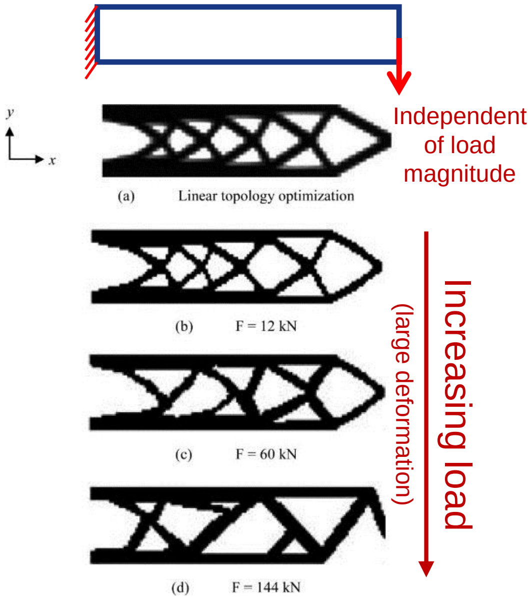
  > Traditional design with linear/component loads and fine-tune the design later to meet sub-system/system-level nonlinear requirement strategy is not very effective for DfAM

  > Framing the design problem is very critical!

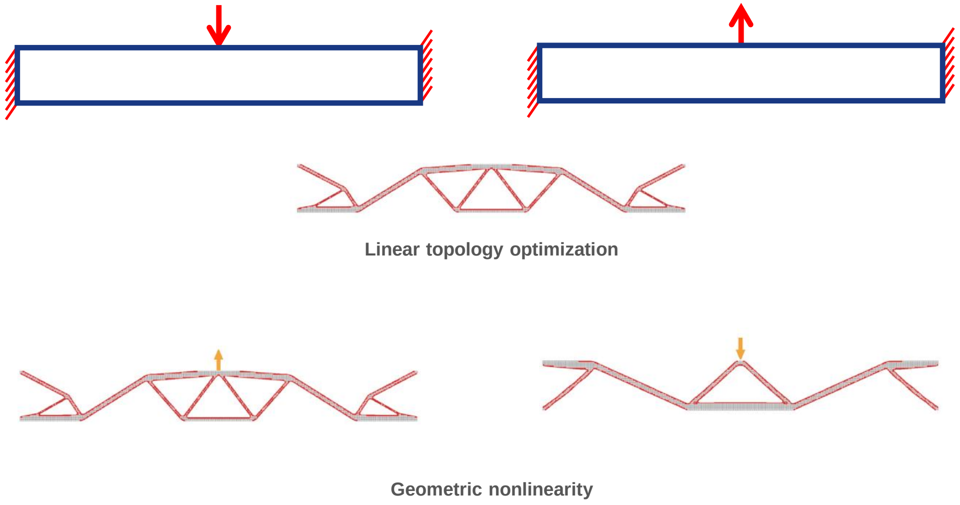
  > Post-design fine tuning might not be effective in meeting all requirement without changing the basic organic loadpath



Fully nonlinear and dynamic ?



Dynamic load ?



Stiffness in one direction and compliance in the other ?

Lee HA and Park GJ, Topology Optimization for Structures With Nonlinear Behavior Using the Equivalent Static Loads Method, J. Mech. Des 134(3), 031004, Feb 18, 2012.

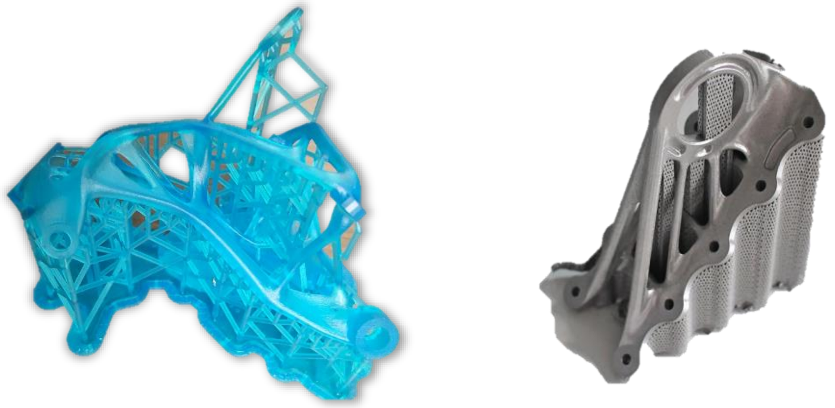
Abdi M et al., Topology Optimization of Geometrically Nonlinear Structures using an Evolutionary Optimization Method, Engineering Optimization, Vol. 50, Issue 11, DOI: 10.1080/0305215X.2017.1418864, 2018.

Current Challenges

- Topology Optimization with AM specific constraints
  - > Print Direction
  - > Overhang Angle
  - > Support Structure

Topology result will vary based on print direction

Print direction may effect performance and #of parts getting printed together



✓ Removal of support structure makes DfAM complex and adds cost
✓ Topology design with minimal support structure (overhang angle)?
✓ Self supported structure / Use support structure as structural loadpath

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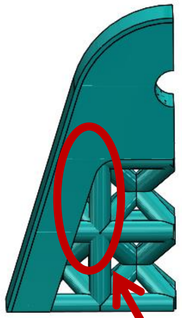
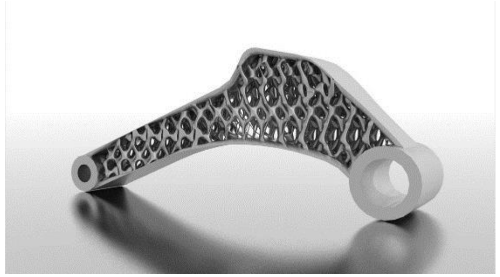
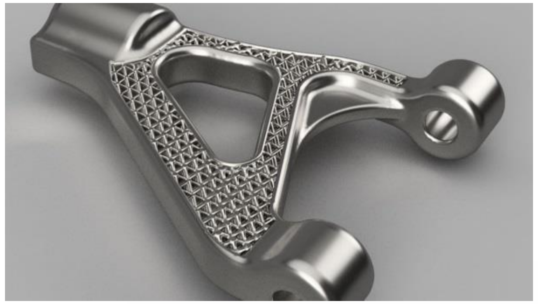
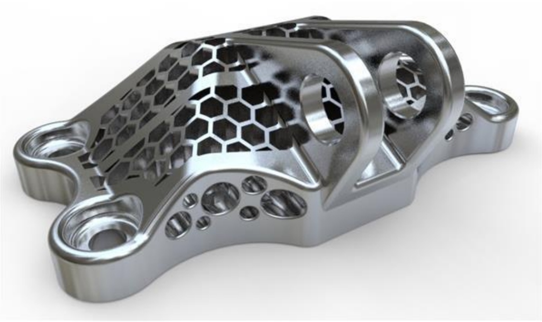
Current Challenges

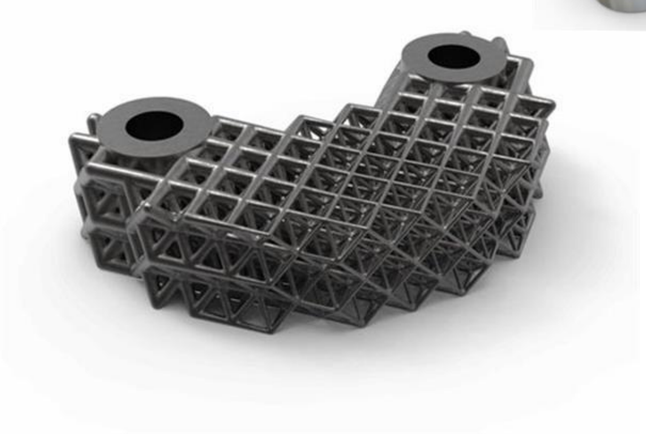
- Optimizing lattice type and design











- ✓ **What lattice type is optimal for the performance/mass?**
- ✓ **Can tool design optimal lattice instead of user choosing a type?**
- ✓ **Chopped lattice along surface not desirable – auto resizing of unit cell for smoothing?**

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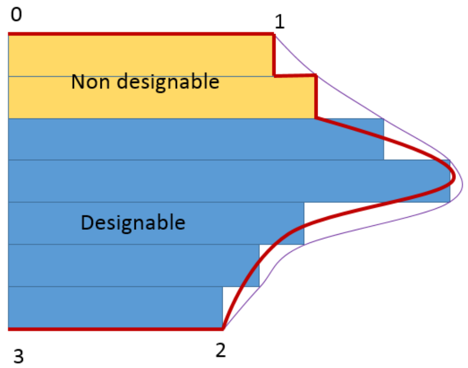
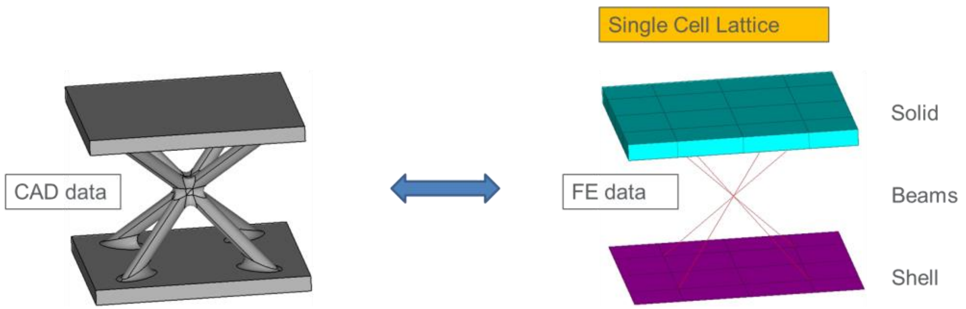
Current Challenges

- CAD-CAE integration
  - > Interpretation of topology result
  - > Generating smooth shrink-wrap from topology result
  - > Topology result to CAD Math data (NX UG solid body)





✓ **CAE mesh data to CAD feature based data and vice versa ?**

Key Takeaways

- CAE is critical for DfAM: “Synthesis Tool” rather than “Analysis Tool”
  > Topology Optimization a synthesis approach to generate new concepts
- Requirement driven design
  > Framing the design problem is very critical
  > Optimization with nonlinear loadcase/requirements
- DfAM specific features in Optimization tools
  > Objective | Constraint | Realization
- Stronger CAD-CAE interface for quicker design iteration & integration
  > Quicker design iteration & integration
- Process Simulation
  > CAM-CAE integration
- Generative Design
  > Explore multiple design options

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Thank You!

Question?

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