ANSYS Simulation solution from Topology Optimization to Metal Additive Manufacturing Process

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ANSYS Vision for Additive Design
AGENDA: Design for AM with ANSYS

1. Complete Design-to-Print Solution
2. Increased Confidence without Trial-and-Error
3. Truly Successful AM Production
Design for Additive Manufacturing
Topology Optimization Overview

- **Given**
  - Design space
  - Applied load cases, frequency constraints, and other engineering requirements

- **Determine**
  - Geometry with maximum stiffness and minimal mass

- **Subject To**
  - Stress and/or displacement constraints
Topological Optimization for Additive Example

• Wheel

In cooperation with TH Ingolstadt / AUDI
Lattice Design Using Topology Optimization

Optimize Lattice Density Distribution

- Homogenization-based approach
- Support library of lattice cell templates
- Validate design
- Construct detailed lattice geometry

Structural Problem Set up
Lattice Density Optimization
Design Validation on Homogenized Model
Generate Lattice Structure, Validate Manufacturability
Print
Topology Optimization Workflow

Topological Optimization

Geometry

Validation

Print

Enables superior designs via physics-driven free-form design optimization

Is this design printable?
Additive Manufacturing
What is Additive manufacturing?

Additive Manufacturing (or 3D printing) builds 3D objects by adding a layer-upon-layer of material.
The AM Promise

- Impossible to Manufacture
- Part Consolidation
- Distributed Production
- New Material Properties
- Replacement parts
The AM Promise

• *Impossible to Manufacture*

• Part Consolidation

• Distributed Production

• New Material Properties

• Replacement parts
The AM Promise

- Impossible to Manufacture
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Removal of Joints
The AM Promise

• Impossible to Manufacture
• Part Consolidation
• Distributed Production
• New Material Properties
• Replacement parts
The AM Promise

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The AM Promise

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Understanding the problem
Build Issues

It can take multiple build tries until a successful build is obtained
Build Issues

DISTORTION

• Due to the high thermal strains and induced plastic strains, parts distort when removed from the build plate

BLADE CRASH

• The part can distort out of the top of the powder bed during the build
  − At worst, the build will stop
  − At best, the part will be deformed or the powder bed altered leading to a defect in the part

CRACKING

• The high residual stresses and high strains can lead to cracking in either the part or its supports

Figure courtesy of Dr. Tim Simpson (Penn State University)
How to avoid a bucket filled with failed prints, sitting right next to a million-dollar machine.
Current AM Build Workflow

Design → Build → Measure
Why simulation is key to realizing full potential of Additive Manufacturing?

Need Process Simulation to Get it Right the First Time!
Process Simulation Goals

Answer the questions about the design:

• Is this buildable?
• What is the thermal distortion?
• How do I compensate the design for the distortion
• What is the best built orientation?
• What are the best support to use, and where?
Different Types of Customer need AM Simulation
ANSYS AM products

**ANSYS Additive Print**

Lightweight, Standalone application

Delivered outside of Workbench
  • Desktop and Cloud availability

Includes SpaceClaim

Targeted at Designers and Machine Operators

Predict build quality, part distortion, reduce build failures...
maximize productivity of your AM machine
ANSYS AM products

**ANSYS Additive Suite**

Includes All ANSYS AM capabilities

- ANSYS Workbench & Mechanical Enterprise Additive Capabilities
  - Process Simulation
  - Topological Optimization
  - Lattice Optimization
- Additive Science
  - Scan-vector-level thermal analysis
  - In-depth material behavior
- Additive Print

FEA analysts, AM experts and material researchers

Industry leading analysis tool for AM processes and materials
Workflow Overview

**DESIGN**
- Static Structural
- Engineering Data
- Geometry
- Model
- Setup
- Solution
- Results

**OPTIMIZATION**
- Topology Optimization
- Engineering Data
- Geometry
- Model
- Setup
- Solution
- Results

**VALIDATION**
- Static Structural
- Engineering Data
- Geometry
- Model
- Setup
- Solution
- Results

**PROCESS SIMULATION**
- Transient Thermal
- Engineering Data
- Geometry
- Model
- Setup
- Solution
- Results

Optimized Geometry

Original Assembly

Optimized Part

Validate Design

Asses Printing Process
Features of ANSYS AM Suite

• Options for Simplified Thermal Analysis AND Detailed Thermal Analysis
• Topology / Lattice Optimization
• Distortion / Residual Stress / Failure Prediction
• Automatically Compensate Geometry for Distortion
• Four Strain Mode Options
• STL File Repair / Manipulation
• Location-Specific Microstructure Output
• Geometry-based Support Generation
• Physics-based Support Generation
• Porosity Predictions
• Simulate using Machine Scan-Vectors
• Thermal Sensor predictions

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Additive Manufacturing Application Examples
The Pitfalls

Simulation with ANSYS Additive Print

(red – shows where the part deforms upwards)

On the Build Plate
Why Simulate

Accurately printed part

Simulation accurately predicts distortion

Distortion Compensated simulation results (blue) overplayed on STL file
Application example: Distortion compensation

Original Geometry

Compensated Geometry
Comparison of Support Failure Prediction to Experiment

- Support Failure Prediction
  - Prediction of support failure for default supports show excellent correlation to experimental results
  - Strengthened supports were also correctly predicted to fail
Summary
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