Additive Manufacturing: Understanding and Applying Key Design Considerations

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Objectives

Explain the process of metal additive manufacturing (LPBF)

Identify key variables that affect the quality of a metal 3D-printed part

Sustainable best practices within additive manufacturing

Workflow strategies to address key variables
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Brian Jeong is a Shop Supervisor at the Autodesk Technology Centers in Toronto, Canada. Brian has a background in automotive and mechanical engineering, additive manufacturing, and project management. Brian has an extensive research and laboratory background in process optimization methods in laser powder bed fusion additive manufacturing and design for additive manufacturing. Brian is passionate about exploring new ways of designing and making.
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Inspired by circularity and biomimicry, Tyson is an avid maker and sustainability advocate. He works directly with residents, innovation communities and researchers to provide technical expertise and fabrication consultation through the Autodesk Outsight Network. A designer and cabinetmaker by trade, Tyson's past work includes everything from additive, subtractive manufacturing, woodworking to CAD/CAM, Generative Design, construction and more recently - robotics.
The Future of Making
Starts Here

The Autodesk Technology Centers Outsight Network brings together pioneers innovating in design, architecture, engineering, construction, manufacturing, and emerging technologies.

Through this network, Autodesk helps bring solutions to life that enable people to do more and make better things with more positive impact on the world.
Additive Manufacturing Fundamentals
Additive Manufacturing

Process of joining materials to make objects from 3D model (CAD) data. A layer-to-layer based system that effectively uses only the raw material required - unlike subtractive.
Types of AM Technologies

- **VAT PHOTOPOLYMERIZATION**
  - SLA
  - DLP
  - CDLP

- **MATERIAL EXTRUSION**
  - FFF

- **MATERIAL JETTING**
  - MJ
  - NPJ
  - DOD

- **BINDER JETTING**
  - BJ

- **POWDER BED FUSION**
  - MJF
  - EBM

- **DIRECT ENERGY DEPOSITION**
  - LENS
  - EBAM

- **SHEET LAMINATION**
  - LOM

- **LPBF**
Laser Powder Bed Fusion

Metal powder + accurate laser + flat bed = layer-to-layer fusion
General AM Workflow

From designing digitally to ending up with an end-use part, a typical additive manufacturing workflow has a couple of key phases and transitionary points.
Our Focus – ‘Key Considerations’

Obstacles that can occur during the different AM phases and can be resolved at distinct transitionary junctions. These ‘gates’ are grounded in computer-aided manufacturing, process simulation and sustainability.
Gated approach

1. SUSTAINABILITY
2. DFAM
3. LPBF VARIABLES

Image courtesy of Briggs Automotive Company Ltd.
Sustainability Fundamentals
Sustainability

Ability for a system to maintain and thrive indefinitely. In manufacturing, this means limiting materials, energy consumption, and embodied carbon.
Sustainability in AM

SUSTAINABILITY

Failed prints = Cost

Carbon Emissions

Image courtesy of Briggs Automotive Company Ltd.
Sustainability in AM

- Material
- Energy
- Run Time

Preparation

Design for Additive Manufacturing
Design for Additive Manufacturing

Synthesis of shapes, sizes, geometric meso-structures, material compositions and microstructures to best utilize manufacturing process capabilities to achieve desired performance and even to maximize product performance (Rosen 2007)
AM Pitfalls

- Many print failures
- No feature scaling
- Long print times
- Overly complex designs
- Heavy post-process
- Not enough post-process
- Wrong process
- Wrong material
- Lack of DFAM
- Lack of calibration
- Lack of maintenance
- Ignoring simulation

Photo courtesy of Alexander Liu
Key Considerations in LPBF

- Residual Stress
- Support Structures
- Part Orientation
Residual Stress

Heat flows during melting

Weld pool
Solidifying metal
Laser
Spot motion
Heat flow

Un-fused powder
Solid metal

Shrinkage after solidification

Cooling solid weld track
Contraction
Contraction
Solid material

Photo Courtesy Of Renishaw Inc.
Netfabb Simulation Demo

LPBF VARIABLES

1. RECOATER

2. SUPPORT STRUCTURE

3. PART DISTORTION
Recoater Interference

Residual stresses during print can cause parts to distort upwards, colliding with the recoater.
Recoater Tolerance

A) 100% Tolerance
(a) 100% Recoater tolerance

B) 85% Tolerance
(b) 85% Recoater tolerance

C) 19% Tolerance
(c) 19% Recoater tolerance

D) -25% Tolerance
(d) -25% Recoater tolerance
Avoiding Recoater Interference

SELECT APPROPRIATE SCANNING STRATEGIES

HEATED BUILD PLATE
Avoiding Recoater Interference

PART ORIENTATION

PART PLACEMENT
Support Structure Failure

Residual stresses during print can cause parts to distort upwards, causing the support structure underneath to yield to the forces of distortion.
Support Structure

Photo Courtesy Of Dr. Ed De Meter
NETFABB DEMO: PREDICTING SUPPORT FAILURE

AUTODESK® NETFABB®
Avoiding Support Failure

RE-DESIGN SUPPORTS

RE-ORIENT PART
Part Distortion

Part distortion is unavoidable due to residual stresses during print. Predicting distortion and applying corrected geometric compensation.
Part Distortion

Geometry Compensation

BEFORE PRINTING

AFTER PRINTING

BEFORE PRINTING

AFTER PRINTING
NETFABB DEMO:
PART DISTORTION & APPLYING
GEOMETRY COMPENSATION
Sustainable Solutions
Sustainable Solutions

**DESIGN**
- Generative Design
- (Dis)Assembly
- Parameters
- Packing
- Simulation

**MAKE**
- In-machine Data
- Material Graduation
- Post-processing
- Prototype Scaling
- Process Selection
Simulation

Complications stem from a lack of foresight. The inability to project downstream pitfalls can cause error to compound incrementally.
Generative Design (Fusion 360)

Lattice Optimization
Packing
List of Resources

- Autodesk Netfabb
- Autodesk Fusion 360
- Generative Design
- Sustainability

Find these resources & more in the handout!
Autodesk Technology Centers
The Autodesk Technology Centers Outsight Network is a global community with resident teams from industry, academic, and entrepreneurial sectors coming together to create a shared vision of the future of making.

The program provides our residents access to a diverse and innovative community, subject matter expertise, and tools at no charge.
Autodesk Technology Centers

Our Technology Centers are equipped with state-of-the-art equipment and machinery to aid our residents as they prototype new ideas. Our facilities are available for use by all of our Outsight Network residents.

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Toronto, Ontario, Canada
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**Advanced machinery**
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**Training and support**
- Expert Consultation
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Our team is available to assist in proposal development and to answer questions.
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