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INTRODUCTION

Laser Powder Bed Fusion (LPBF aka, Selective Laser Melting, Direct Metal Laser Sintering, etc.) uses laser energy to selectively melt metal powders in a layer-by-layer process to build up a three-dimensional part. LPBF is the leading additive manufacturing (AM) process for complex metal parts requiring excellent mechanical properties. Compared to other metal AM processes, LPBF has superior dimensional accuracy with minimal post-processing requirements (e.g., no debinding or sintering). A wide range of materials are available, with significant ability for application-specific customization.

Benefits:
- high density parts (> 99 %)
- mechanical properties comparable to traditional production technologies
- high resolution
- part shape complexity
- functional complexity - multi-part assemblies in a single build
- feedstock re-usability

Characteristics:
- minimum feature size 0.04 - 0.2 mm
- accuracy + / - 0.05 - 0.1 mm
- layer thickness 0.02 - 100 mm
- typical surface finish 4 - 10 microns RA

NOTE: these values are indicative and strongly depend on feedstock and process parameters

Materials:
- Aluminum alloys (AlSi10Mg)
- Bronze
- Cobalt Chrome (Co-Cr-Mo)
- Copper
- Nickel Superalloys (In 625, In718)
- Refractory Metals & Alloys (W, WC-Co12, Ta, W-Cu)
- Stainless Steel (316L, 15-5, 17-4, 400 series)
- Titanium (TiCP, Ti64)
- Tool Steel (Maraging M300, H13)

Applications:
- Aerospace - brackets, air ducts, impellers, etc.; reduction of part count, complex geometry, lightweighting
- Manufacturing - small volume production runs for niche markets
- Medical - custom prosthetics & implants, dental bridges & crowns
- Prototyping - functional prototypes for aerospace, medical, & automotive industries
- Tooling - conformal cooling inserts
PROCESS OVERVIEW

(1) Powder supply is raised placing feedstock material in front of recoater

(2) Recoater moves across the powder bed, distributing a layer of powder on the build platform

(3) A laser locally melts the powder, creating the cross section of the part

(4) The build platform lowers one layer and the powder supply is raised to deliver the next layer of powder

(5) The process is repeated until part fabrication is complete

(6) The build platform is raised and the build plate with the part is removed
GENERAL DESIGN LIMITS

Part Shape
- vertical extruded shape is the most effortless to fabricate geometry
- avoid sharp edges and features (theoretical minimum radius is 0.045 mm; recommended minimum radius is 0.075 mm)

Part Orientation
- flat surfaces should not be parallel to the re-coater blade; allow minimum 5° angle with the blade for gradual contact with re-coater
- avoid large area fusing within a single layer

Staircase Effect
- both up- and down-facing surfaces exhibit staircase effect which contributes to the increase of the surface roughness
- down-facing surfaces display higher roughness with decrease of overhang angle

Supports
- supports perform the following functions:
  - fix the part on the build platform
  - support overhanging structures
  - heat dissipation & residual stress reduction
  - prevent part deformation
- post fabrication process, the support structure has to be removed mechanically
- use of supports must be minimized to reduce build time and post-processing steps
- ideally part will be designed to eliminate supports
COMPONENT DESIGN LIMITS

**Clearance**

- 0.5 mm recommended
- < 0.5 mm may cause parts to fuse
- 0.3 mm clearance is achievable on PANDA system for certain materials & process parameters

Photos show clearance test component; clearance varies from 1 to 0.3 mm

**Supported/Un-Supported Wall Thickness**

- 0.4 mm recommended
- 0.1 mm is achievable for certain materials and process parameters

Photos show supported and unsupported wall test component; wall thickness varies from 0.3 mm to 0.1 mm for supported and 0.35 mm to 0.15 mm for unsupported walls; wall height is 13 mm and 10 mm for supported and unsupported walls, respectively

**Pin Diameter**

More torque is applied to the part as it gets taller which may cause part to bend & potentially damage the recoater, resulting in build termination

- 1 mm minimum recommended
- < 1 mm is achievable but will affect contour sharpness
- recommended height:width ratio is 8:1

**Alternative strategies:**

- bridge multiple vertical sections with arches
- add offset support structure

Photo shows pin diameter test component; pin diameter varies from 5 mm to 0.5 mm and height of 10 mm (aspect ratio up to 20)
COMPONENT DESIGN LIMITS

Supported Overhang - Bridge
• 1 mm maximum recommended; > 1mm requires support structures

Photos show bridge test specimen; bridge size varies from 0.8 to 1.2 mm

Unsupported Overhang
• 0.5 mm maximum recommended (up to 1 mm can be built depending on material & process parameters)
• > 1 mm requires support

Mitigation strategies:
• Strut-like supports
• Alter geometry (if acceptable)

Photo shows unsupported overhang test specimen; overhang length varies from 0.6 to 1.4 mm

Overhang Angle
Reducing angle between part surface and build platform increases the area of unsupported material and melt pool begins to sink partly into the powder bed
• < 30° requires supports (lower angles are possible in certain cases)
• 30-45° self supporting, part may have rough downward facing surface
• > 45° self supporting, good surface finish
COMPONENT DESIGN LIMITS

Minimum Embossed & Engraved Detail

- 0.5 mm recommended
- embossed details down to 100 µm are achievable on PANDA system
- 0.3 mm engraved details are achievable on PANDA system

Photos show embossed and engraved test specimens; Embossed detail height varies from 0.06 to 1.4 mm; Engraved channel depth varies from 0.3 to 0.6 mm

Horizontal Hole Size

- 0.5 mm to 6 mm range recommended
- 0.2 mm is a practical limit
- up to 25 mm can be built without supports. However sagging of the top surface will occur as diameter increases

Mitigation strategies:
- alter cross-section to diamond, teardrop, or oval for larger diameters

Photos show horizontal hole test specimen; hole diameter varies from 5 to 15 mm; Alternative cross-sections shown on photo on the left

Vertical Hole Size

- ≥ 0.4 mm recommended
- < 0.4 mm is achievable for certain materials and process parameters
- 0.2 mm is practical limit

Photos show vertical hole test specimen; hole diameter varies from 1 mm to 0.3 mm