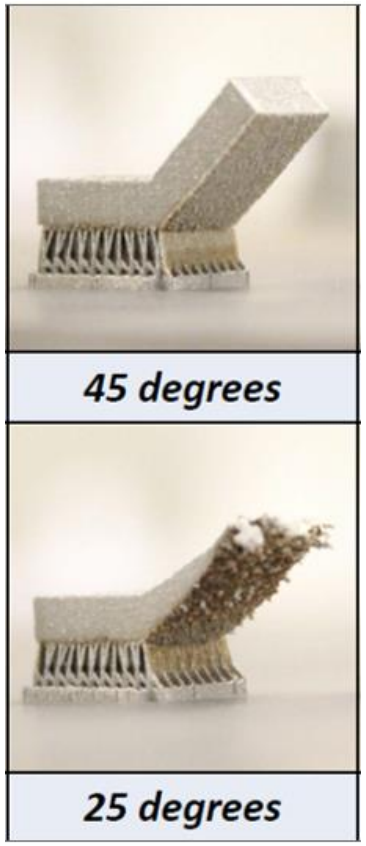
Design for DMLM

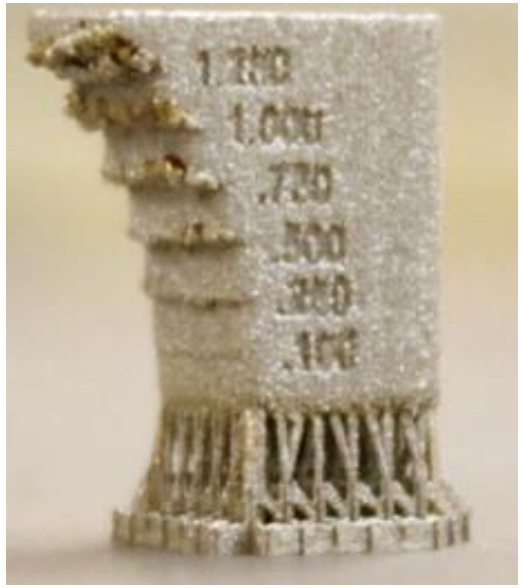
March 18, 2020

Examples of troublesome geometry

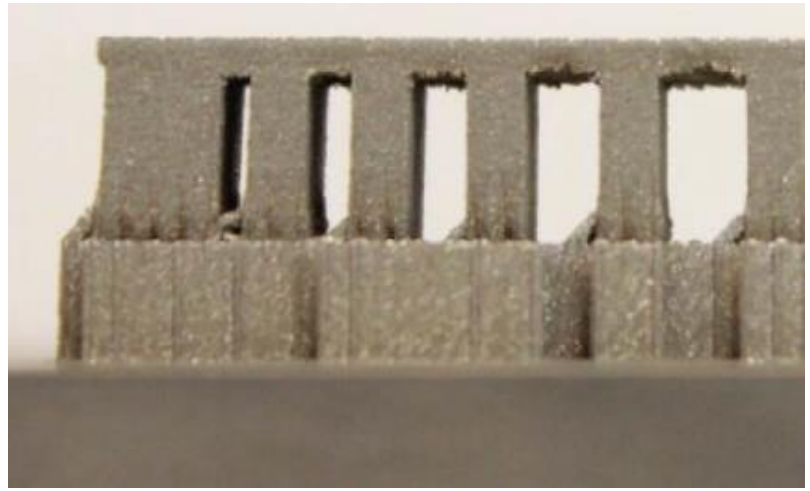
Analogy



Unsupported Angles

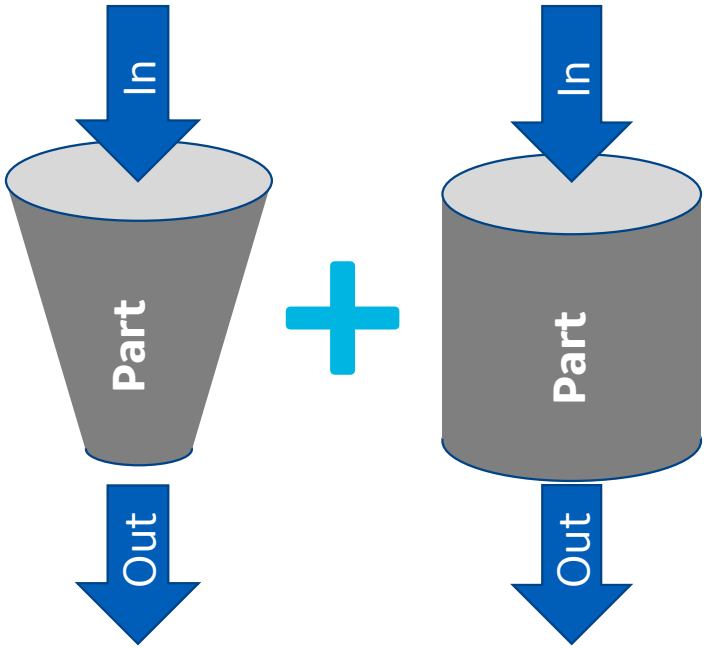


Unsupported Overhangs

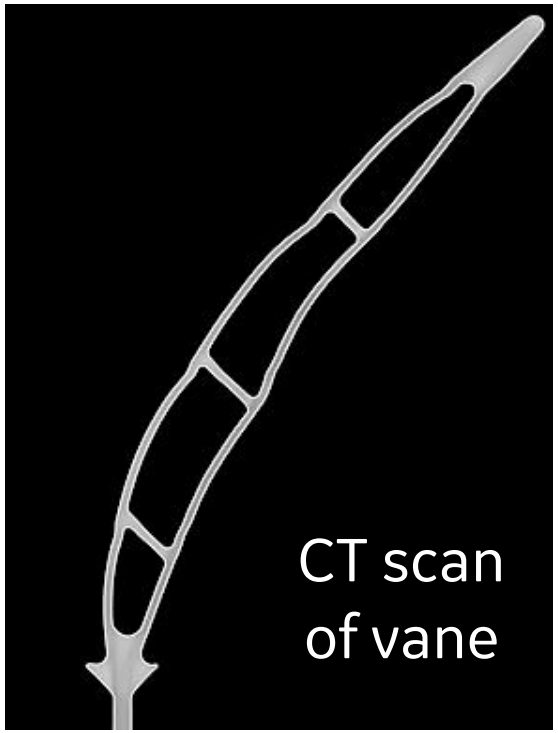


Unsupported Bridges

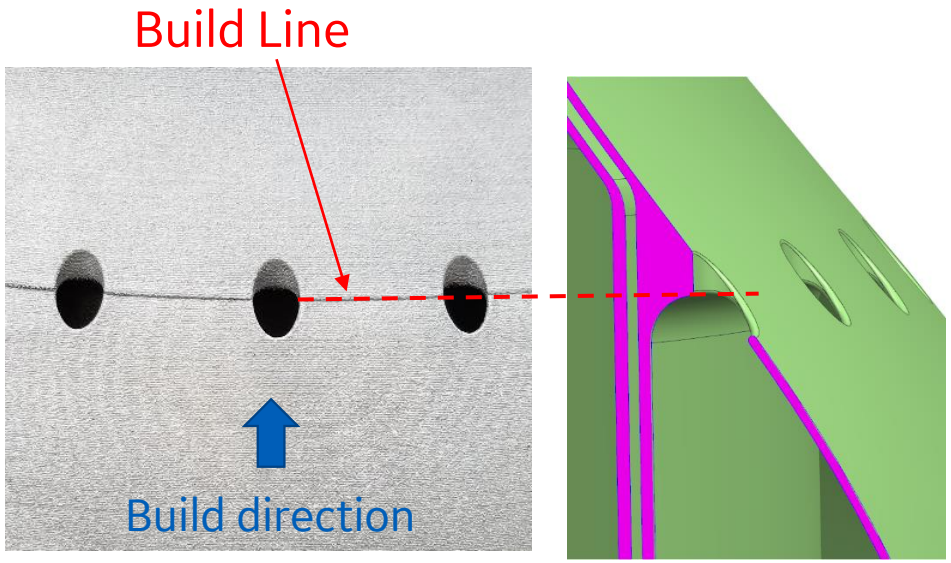
More examples of troublesome geometry



Analogy



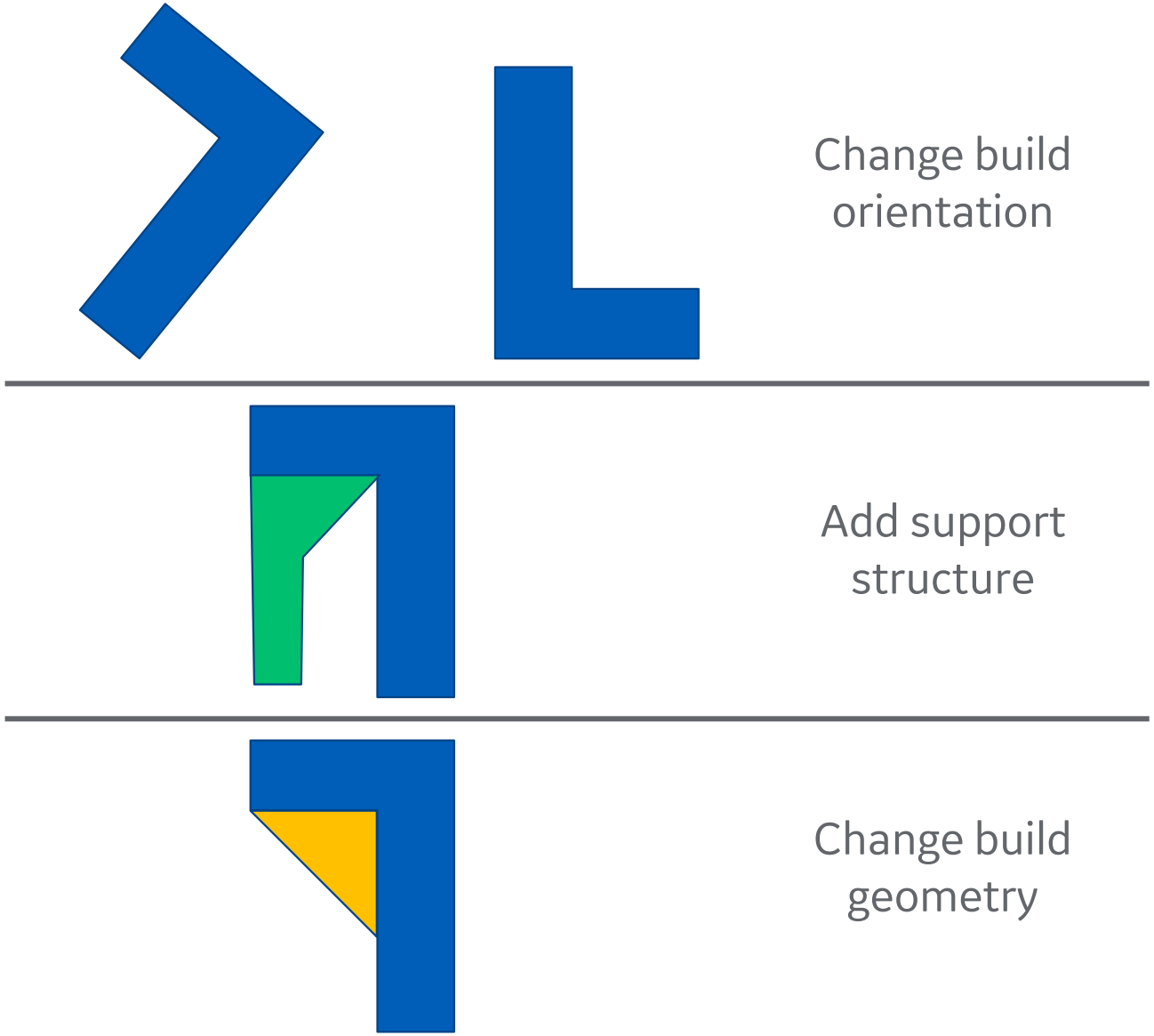
Build Orientation



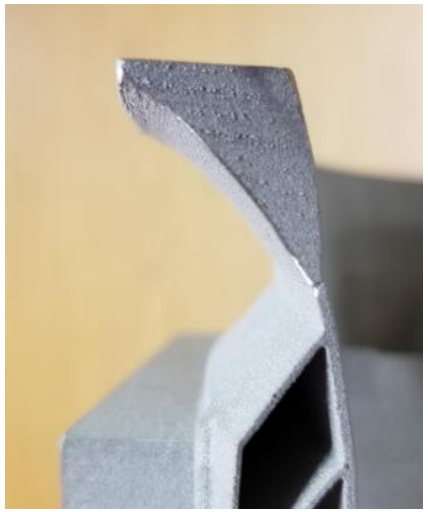
Non-uniform areas

Overhung flanges

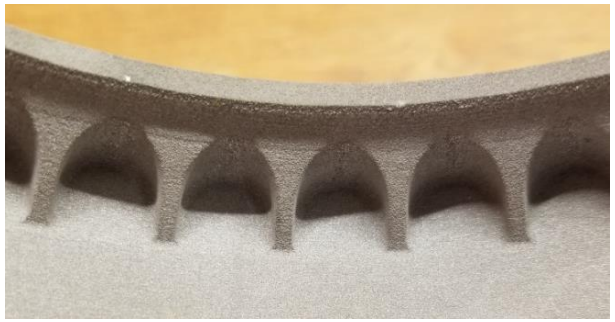
You want this...



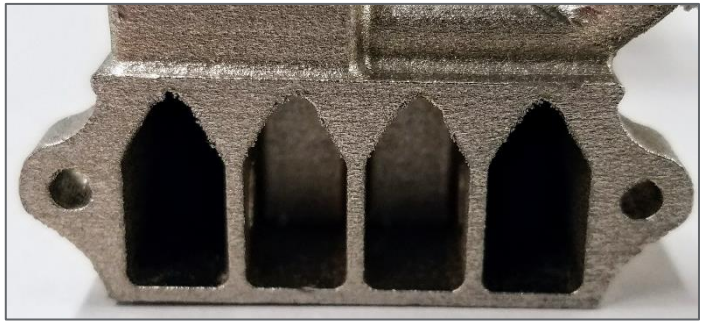
Build geometry options for overhangs



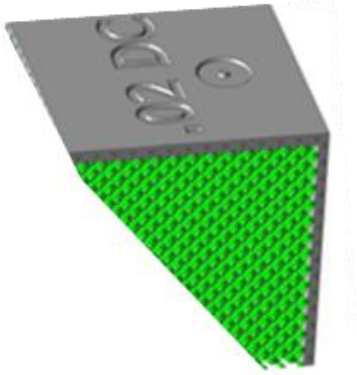
Wedge



Arched Roofs



Angled Roofs



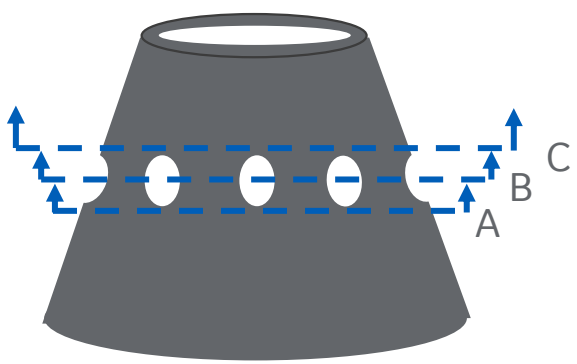
Lattice Wedge

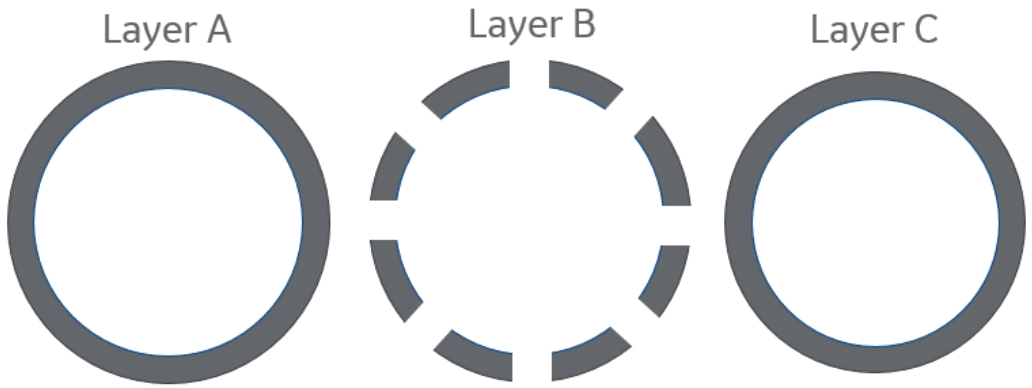
If self supporting geometry is chosen, then geometry chosen should be a balance between build time, distortion control and the machining of the part

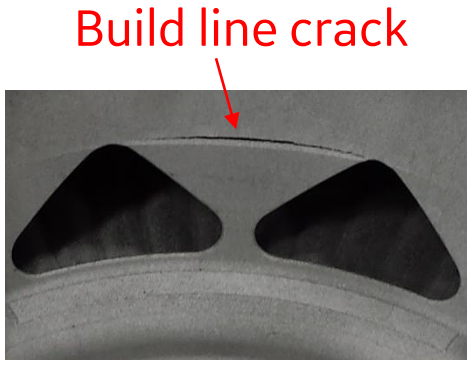
- Build time & distortion control: Arched Roofs, Angled Roofs, Lattice Wedge
- Machining of the part: Wedge (uninterrupted cut for a lathe)

Transition between area changes

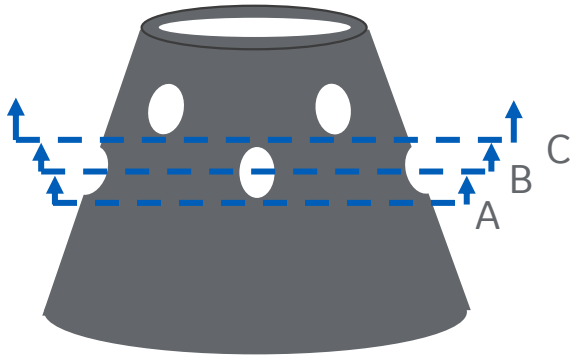
Problem: Features like holes on a cone can result in abrupt area changes that can impact your buildability (excessive build lines)

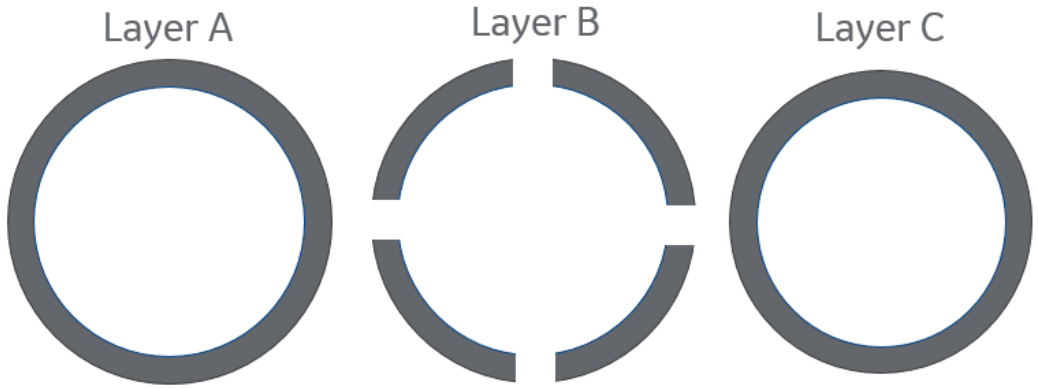




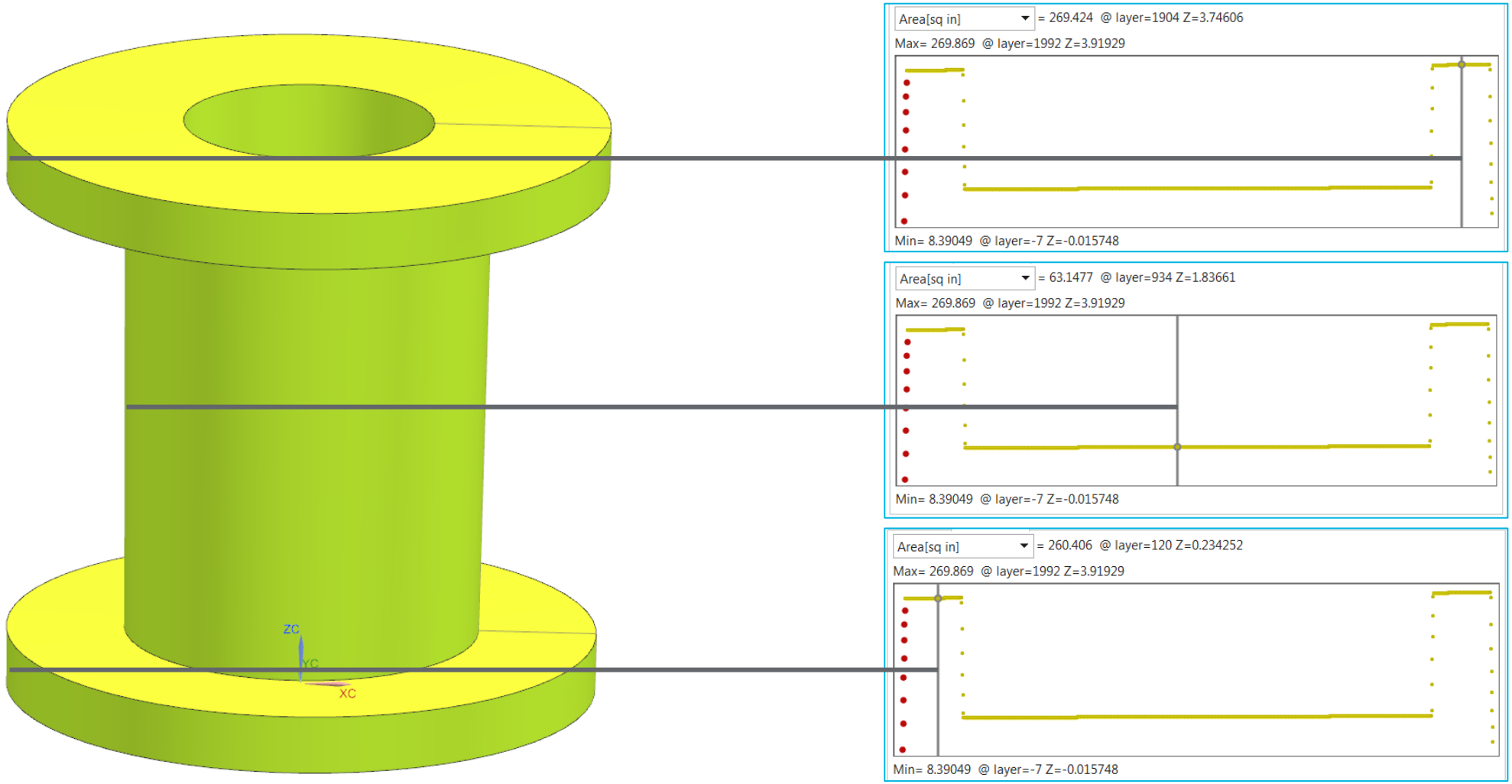


Solution: Use staggered holes and teardrop holes can help have a slow transition of area changes throughout the build



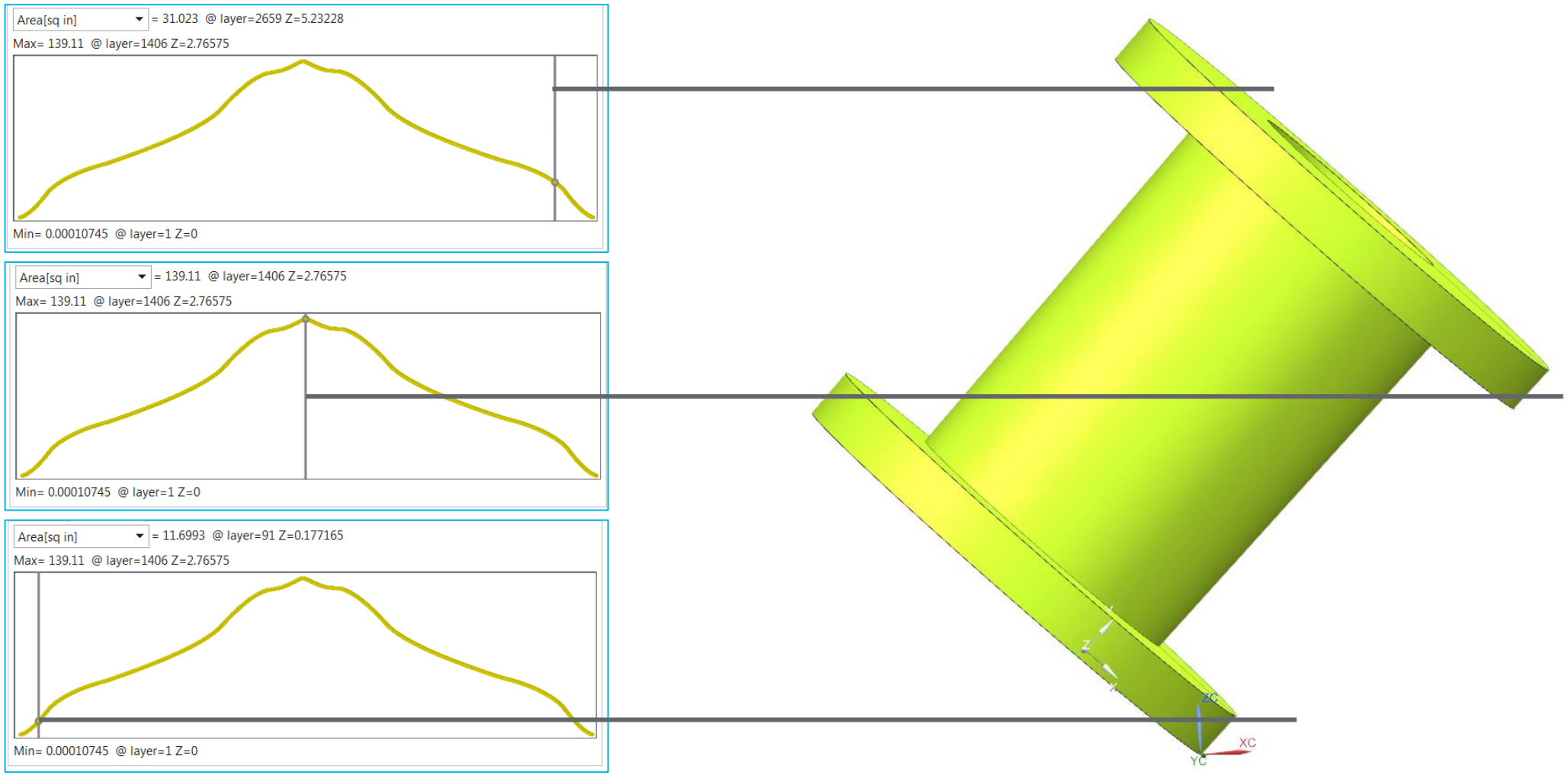


Area transitions



Rapid area transitions can cause defects (cracking, build lines…) in the part due to the high thermal gradients created by uneven energy inputs and dissipations

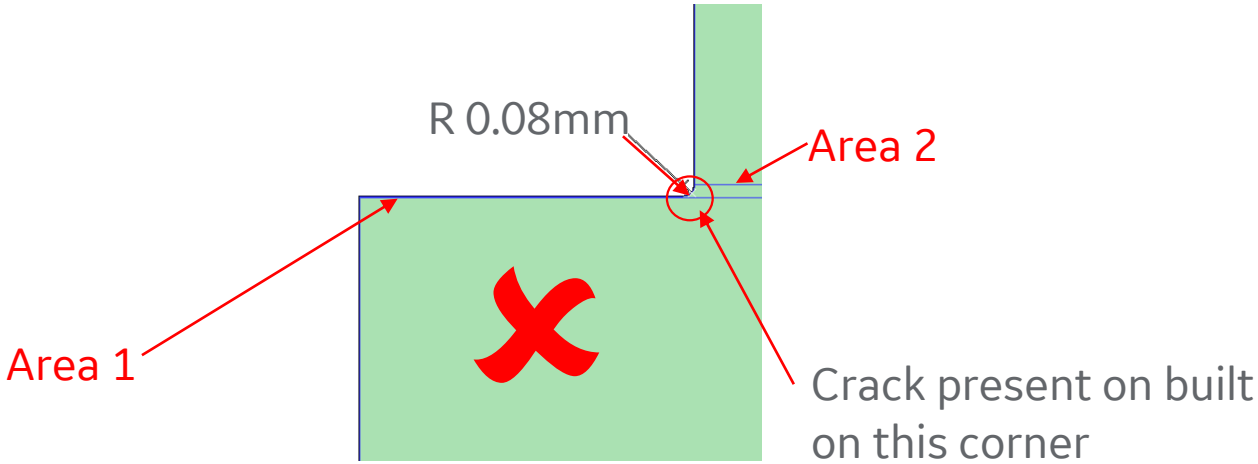
Improved area transitions



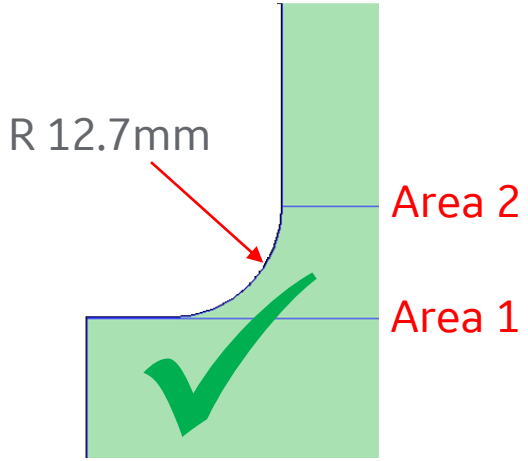
Same part, but orientation improves area transitions

Transitions between area changes

Rapid area changes are susceptible to cracking



Area Change Ratio: 33%
Change occurred within 2 layers



Area Change Ratio: 57%
Change occurred within 250 layers

Avoid combinations of high area sections next to low area sections and sharp corners/small radii
Allow large fillets between these sections for internal stresses to get redistributed evenly.
Consider Radius > 1mm for these cases.

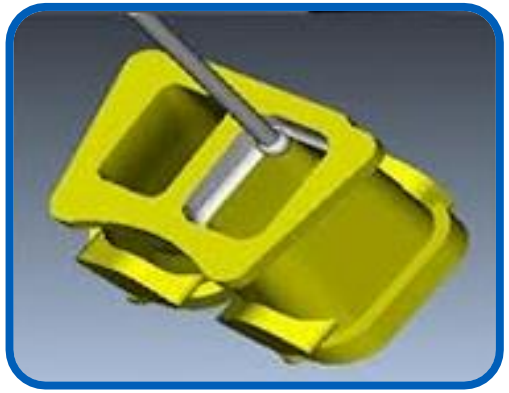
DMLM – Design considerations

Do both an inlet and an outlet with a Dia > 1.5mm exist for all cavities exist for powder removal?
Are all unsupported build angles ≥ 45° relative to the build plate surface?
Are all of the unsupported flat roofs < 2mm?
Do all of the unsupported arched roofs have R ≤ 6mm?
Is the maximum unsupported overhang < 0.5mm?
Is the minimum distance between features > 0.25mm?
Is the minimum inside corner blend or radius ≥ 0.25mm on the additive component?
Have all sharp corners/points on exterior edges subject to handling been avoided? (R 0.13mm min break edge)
Has a R 2mm minimum been added to the base support and the build plate for build plates > 250mm per side in size?
Has 5mm minimum of material been added to the base of the part(s) to be band saw cut from the build plate?
Do holes greater than Dia 13mm and oriented within +/-45° to horizontal (plane of base plate) have internal supports?
Have compensations been applied to critical holes/passages to account for shrinkage, warpage, pressure loss or flow?

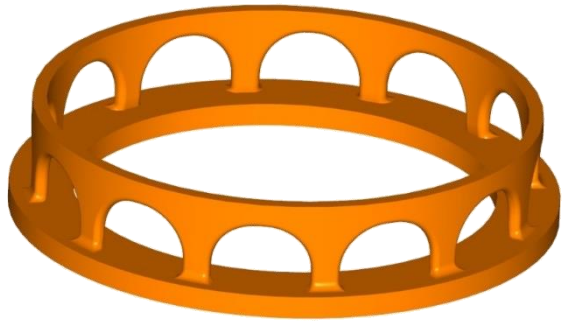
Minimum wall thickness for Aluminum is 0.66mm

Holes and Passages

Design approach to additive



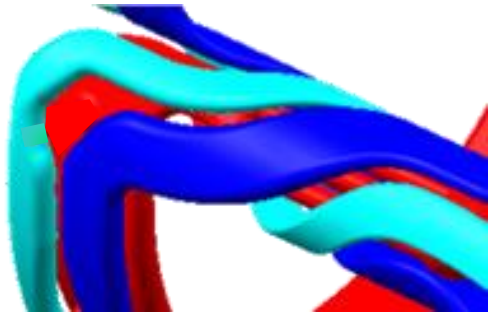
Design Paradigm Shift



Conventional Design rules determined by tool path and joining technology

Additive Design rules based on a bottom-up layer-upon-layer self supporting technology with arches and controlled build angles.

Optimized Designs

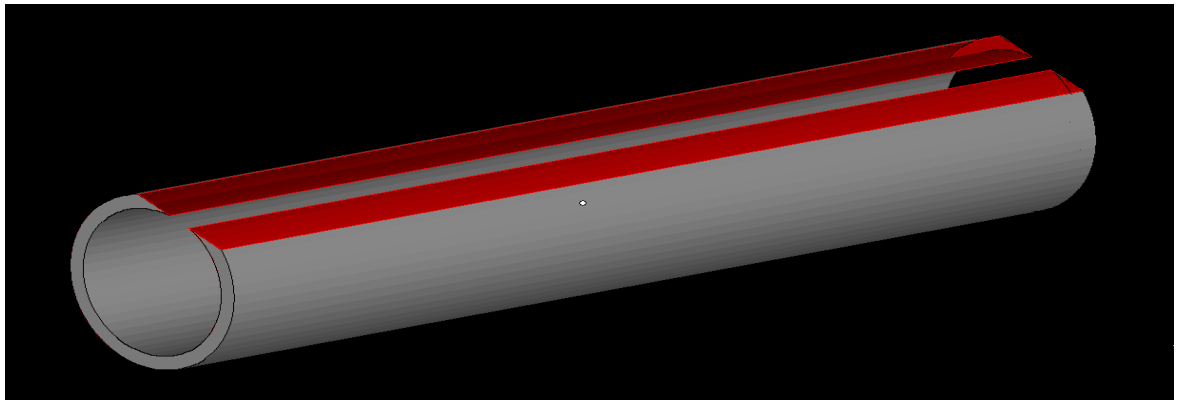


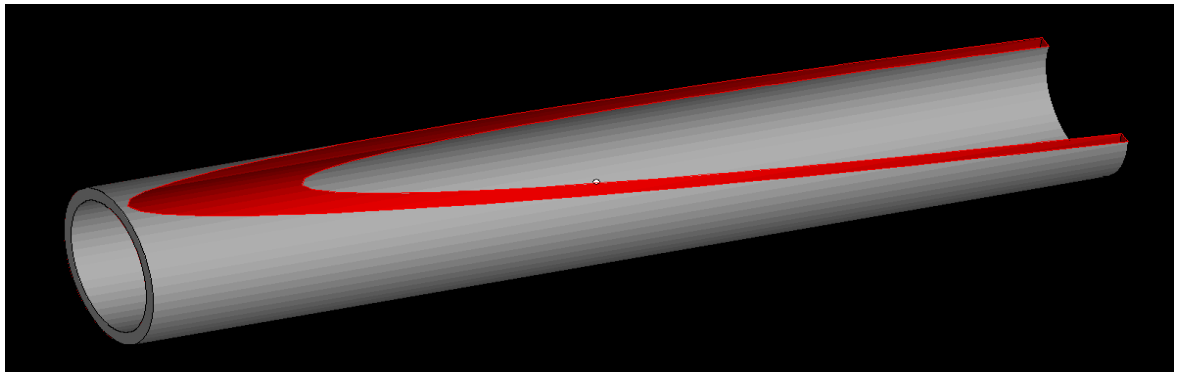
Additive Design frees designer to create a more optimal physics based geometry

No penalty for complexity
Designs tend to mimic nature

Build orientation/direction

- Consider thermal geometry challenges:
  - Thick to thin walls
  - Sink marks
  - Narrow unsupported geometry
- Building parts with large areas that close up at once should be considered to build on slight angle
- No faces of a part should be parallel to the re-coating arm



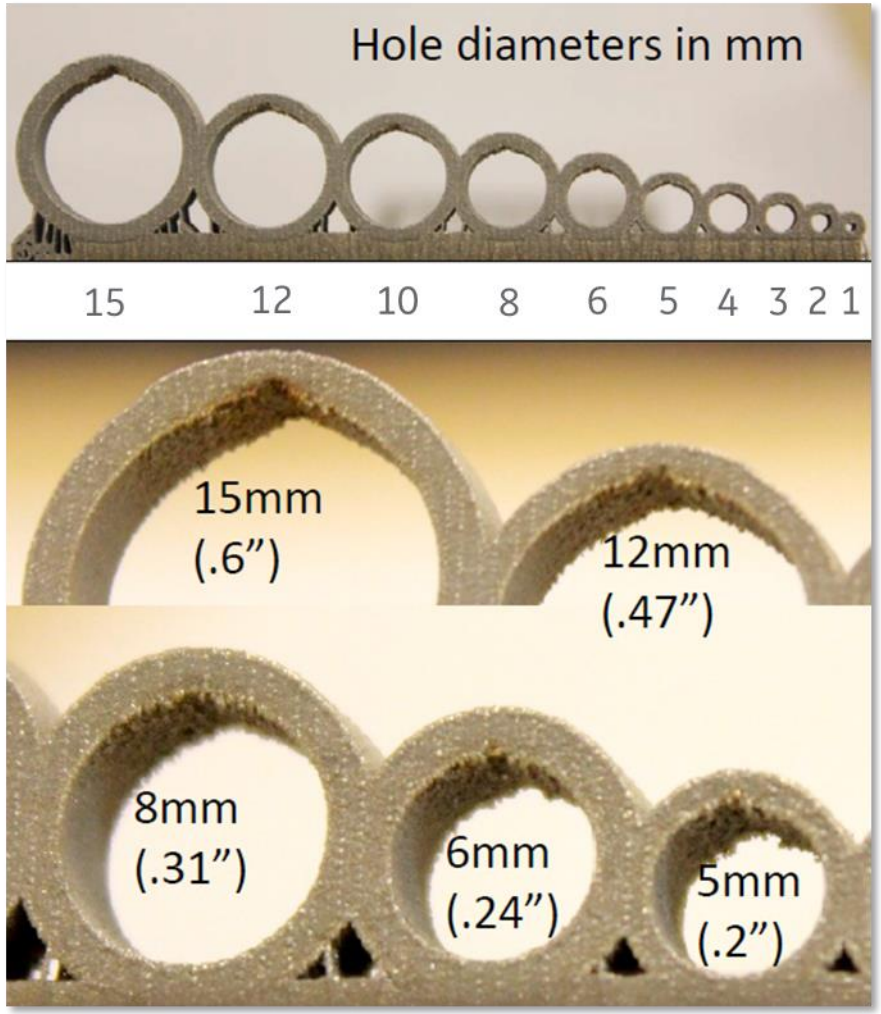


Passages and holes

As the hole diameter increases, the overhang or unsupported surface increases near the closing of the hole

Unsupported holes Dia > 12.7mm will suffer downfacing distortion and potentially create build issues

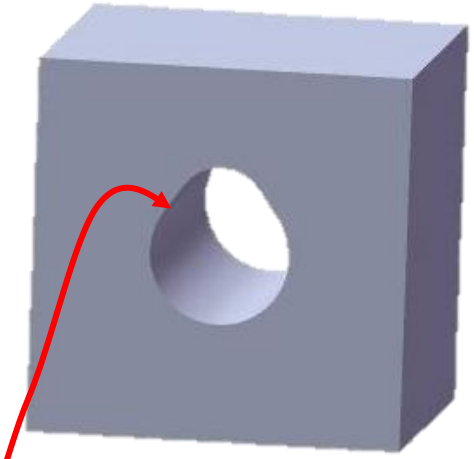
Design Tip: Use diamond, teardrop or elliptical passages to replace round holes. Initially size by equivalent hydraulic diameter to the round hole

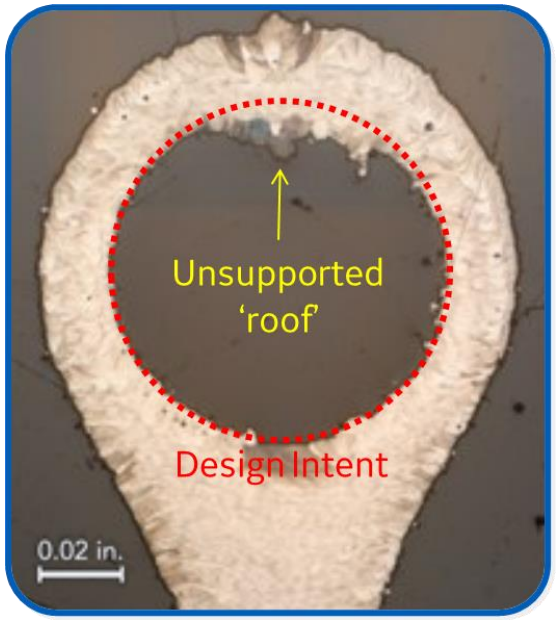


Tricks of the trade: holes and passages

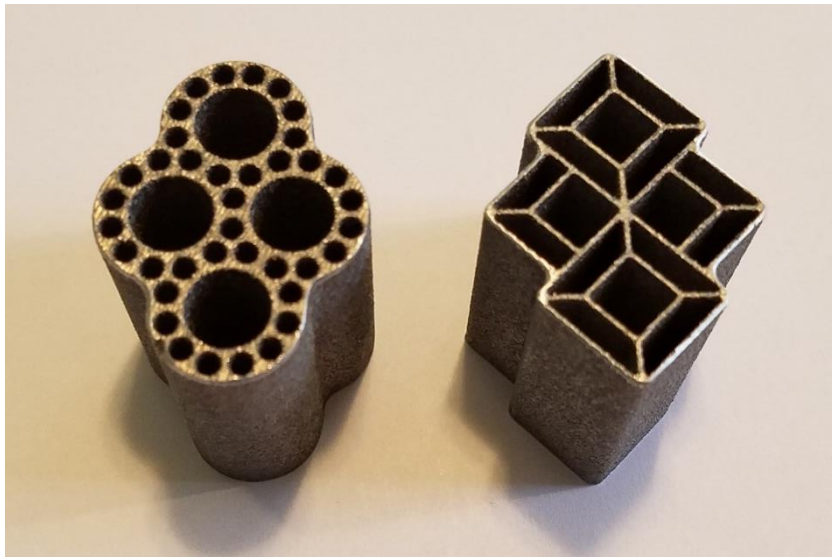
Horizontal holes and passages will ‘pill’ at the top due to laser penetration

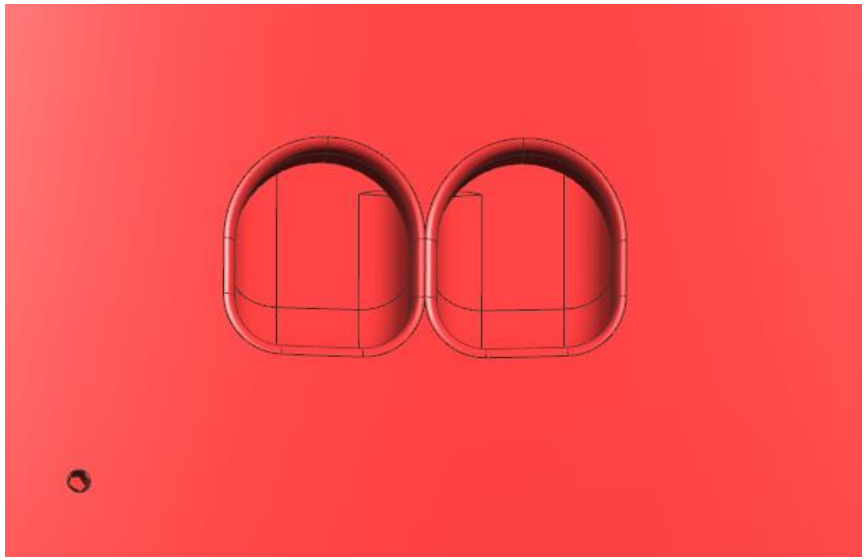
- To countermeasure the unsupported roof effects, pent roof shapes can replace holes
- With build trials, pre-build compensation can achieve usually acceptable results
- Engineer must plan for some amount of area loss; build trials

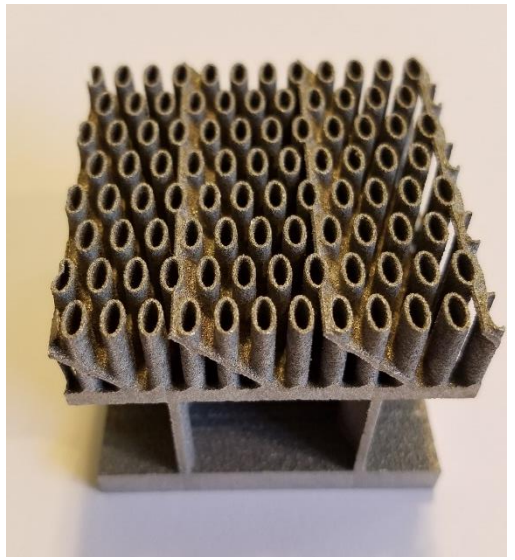




Do Holes / Passages Need to Be Round?







If the size or orientation of circular passages is not possible, then different passage geometries can be sized by the hydraulic diameter

Hydraulic Diameter = $D_h = 4*A/P$

Where:

A = cross sectional area of the fluid flow

P = the wetted perimeter of the cross section