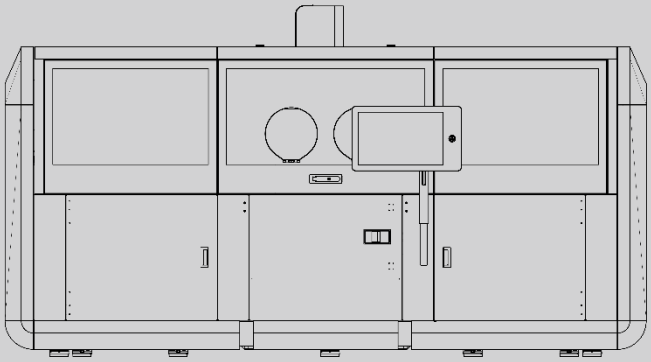
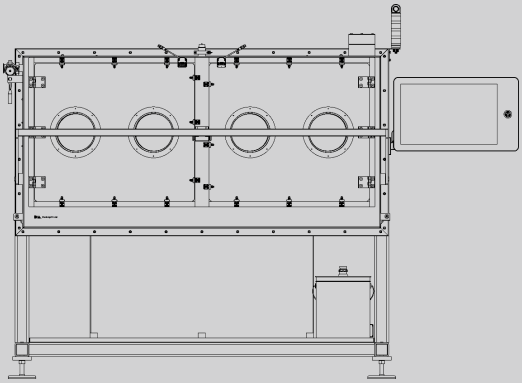
Binder Jet Design Guide

For Production System P-50™, Production System™ P-1, Shop System™, X160Pro, X25Pro, InventX



Production System™ P-50



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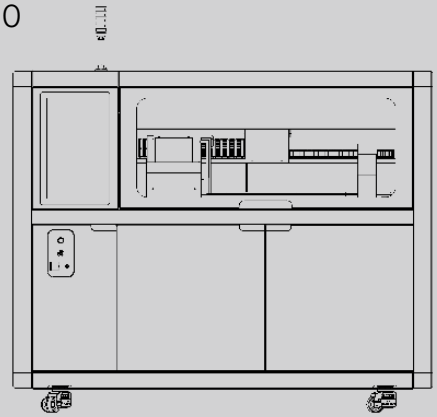
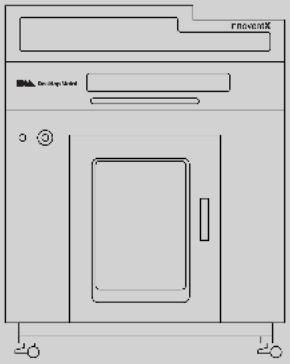


Shop System™



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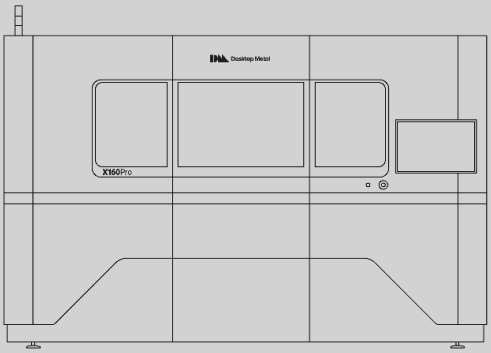
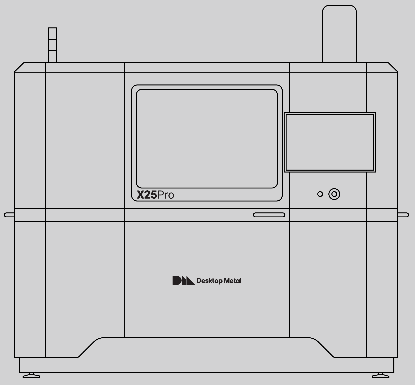


X160Pro



X25Pro

Desktop Metal

Table of Contents

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Binder Jet Design Guide: 81-00239_Rev01_EN, December 2022

About This Guide

This guide explains part geometries that are well-suited for fabrication with binder jet additive manufacturing and how to design parts to maximize fabrication success. It guides you through the recommended workflow - from picking the right type of parts for binder jet to designing corners and text features. A detailed discussion of design for additive manufacturing is beyond the scope of these instructions.

General Considerations When Designing Binder Jet Parts

Shrinkage

Parts produced with binder jet additive manufacturing shrink during the sintering process due to the consolidation of metal particles. Depending on the specific material, shrinkage may be as high as 20%. Desktop Metal® Fabricate® MFG and Live Sinter™ software automatically calculate shrinkage, eliminating the need for you to address it.

Supports

During the sintering process, parts are heated to near-melting temperatures, becoming very ductile and susceptible to deformations from gravity, friction, shrinkage, and other forces. Sintering supports can be used from below to control sagging and other deformations. When designing the part, avoid large overhangs (>10-15 mm length) unless incorporating a support into the design.

Setters

Setters are ceramic objects that help maintain the shapes of parts while they sinter. They are created in CAD alongside the part and inserted as a base or into parts prior to being placed in the furnace. Setters do not shrink during sintering.

Optimize Design of Binder Jet Parts

The most important design considerations for optimizing printing with binder jet are for:

- Part size
- Wall thickness
- Minimum wall thickness
- Aspect ratios

Part Size

Binder jet parts may shrink as much as 20%, so parts may need to be scaled up to 25%, especially in the Z direction and must be a consideration when choosing an ideal part size for specific Desktop Metal machines. For best results in printing and sintering, refer to the following table:

System	Build Box	Build Envelope	Ideal Maximum Part Size
Shop	4L	350 x 222 x 50 mm	120 x 80 x 40 mm
	8L	350 x 222 x 100 mm	150 x 100 x 50 mm
	12L	350 x 222 x 150 mm	
P-1	-	200 x 100 x 40 mm	100 x 65 x 32 mm
P-50	-	440 x 330 x 250 mm	150 x 100 x 50 mm
InnoventX	-	160 x 65 x 65 mm	130 x 50 x 50 mm
X25Pro	-	400 x 250 x 250 mm	150 x 100 x 50 mm
X160Pro	-	800 x 500 x 400 mm	150 x 100 x 50 mm

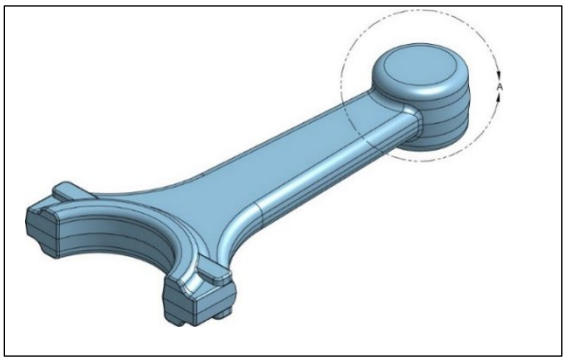
Important: The above table refers to the *as modeled size*, not the size after scaling. Adhering to the recommended part dimensions ensures the scaled part stays within the print parameters of the printer and sinters without cracking.

Maximum Wall Thickness

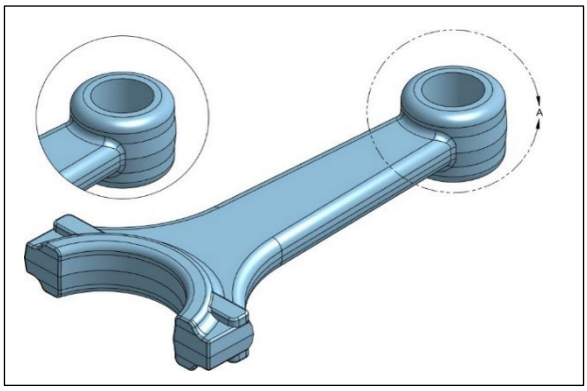
The upper limit of the wall thickness is determined by the ability of the binder to diffuse through the wall during the debinding process.

For successful removal of binder during the debind step of sinter, Desktop Metal® recommends:

- maximum wall thickness of 25 mm
- not to exceed 25 mm in more than two axes



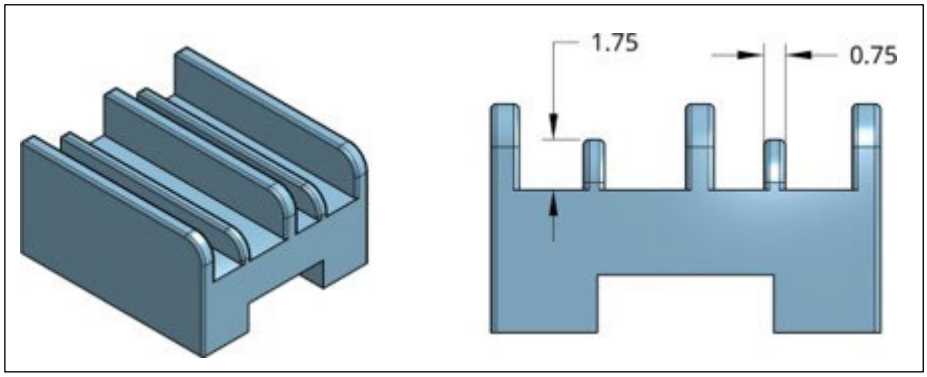
Detail View A: *Length and width (X and Y axis) exceed 25 mm. Thickness on most of the part is <25 mm.*
Thickness in Detail View A is >25 mm in all three axes.



Detail View B: *Shows material removed in Detail View A allowing overall linear dimension to exceed 25 mm.*

Minimum Wall Thickness

Wall thickness under 0.75 mm results in insufficient strength in the green part. Thicknesses between 0.75 mm and 2 mm may still be fragile during the depowdering stage, so be careful when handling parts.



Aspect Ratios

Aspect ratios drive allowable feature size. Specifically, the size or width of the feature limits the maximum achievable wall height, slot depth, and hole depth.

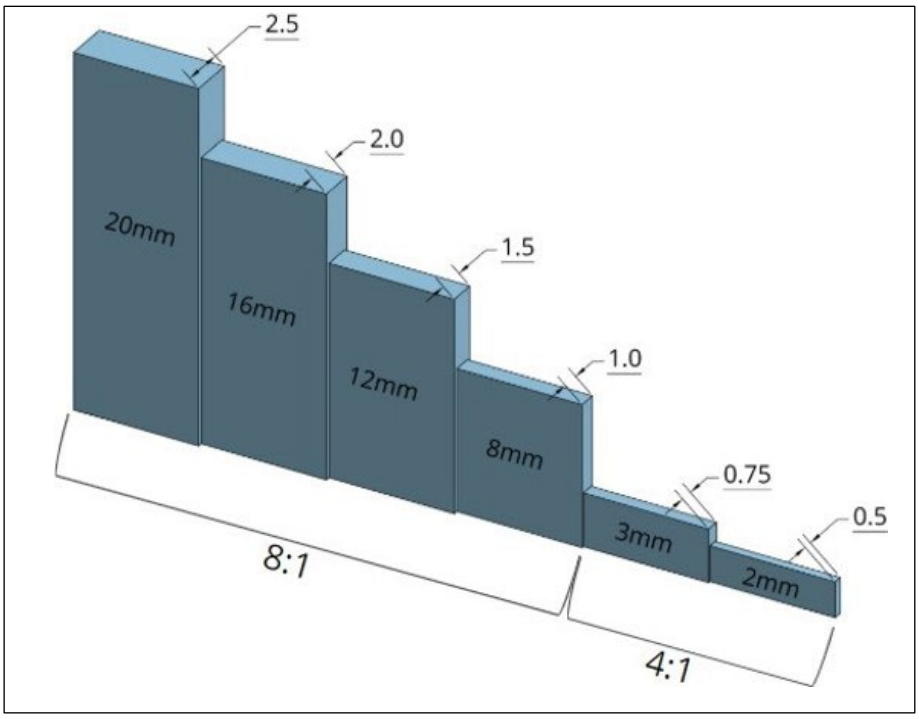
Pillar and Wall Height to Width

The width of the wall or pillar limits its height. The aspect ratio for the wall is defined as the ratio of the height to width.

Walls between 0.75 and 2 mm in thickness can be very fragile and care should be taken during depowder. Aspect ratio requirements are split into two categories depending on wall thickness:

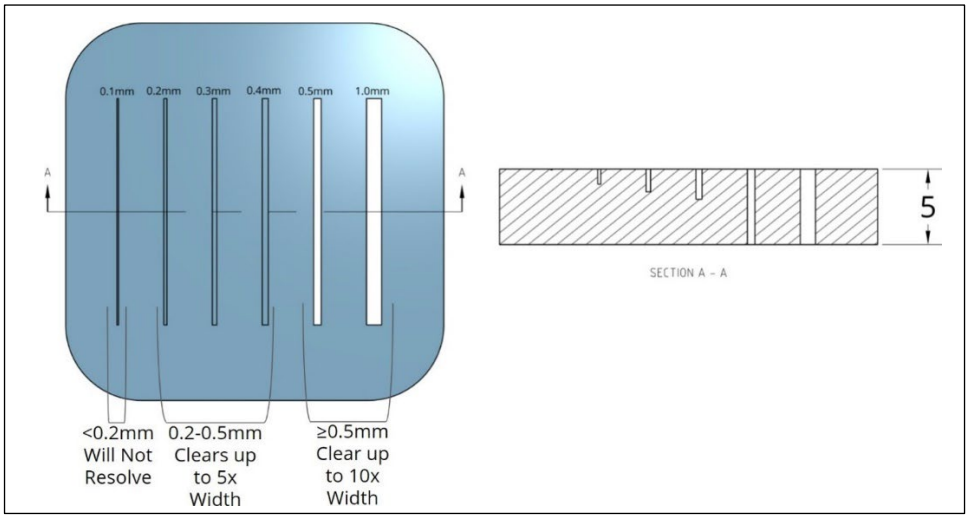
- Walls widths <1 mm not to exceed 4:1
- Walls widths >1 mm not to exceed 8:1

Closed loop designs, where one or more end of a wall is supported, will have a greater allowable aspect ratio.



Slot Depth to Width

To fully depowder and be visible in the sintered part, the width of a slot must be ≥0.5 mm. Slots with widths >0.2 mm and <0.5 mm are visible on the surface of the part, but may not achieve the designed depth on the surface of the part. For slots that project through an entire surface, a depth to width ratio of 8:1 should be maintained to remove powder from slots during depowdering without the use of special tools.

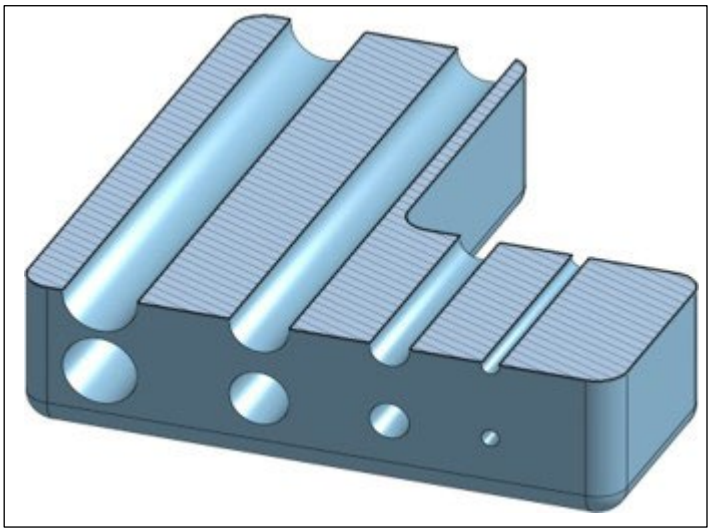


Hole Depth to Diameter

The diameter of a hole must be ≥0.75 mm to resolve and be visible in the sintered part.

Hole aspect ratio cannot be >8:1, meaning the depth of the hole cannot be greater than 8x its diameter.

If the design does not meet this standard, problems may occur during depowdering because the powder is inaccessible in long, thin channels. For holes of smaller diameters (2 mm or less), the aspect ratio is lowered to 4:1, meaning the depth of the hole cannot be greater than 4x its diameter.

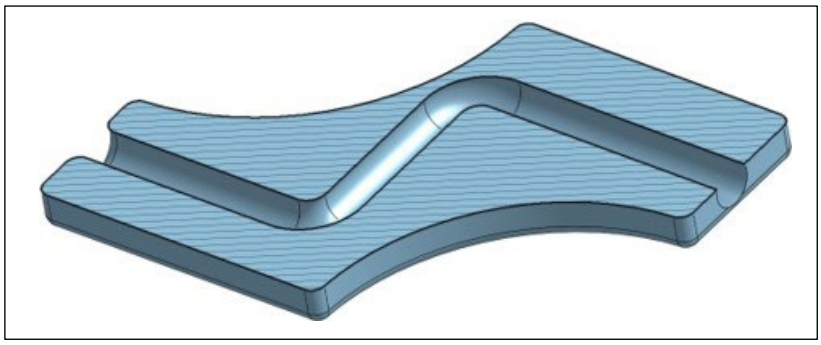


From left to right:

- *Hole >2 mm in diameter, aspect ratio exceeds 8:1: Will resolve and depowder successfully.*
- *Hole 2.0 mm in diameter, aspect ratio equal to 8:1: Will resolve and depowder successfully.*
- *Hole <2.0 mm in diameter, aspect ratio equal to 4:1: Will resolve and depowder successfully.*
- *Hole <0.75 mm in diameter, aspect ratio less than 4:1: Will not resolve and will not depowder successfully.*

Internal Channels

Internal channels should meet the aspect ratio design guidelines for holes, however, sharp turns should be avoided and may require use of custom air depowdering attachments to free channels of powder.



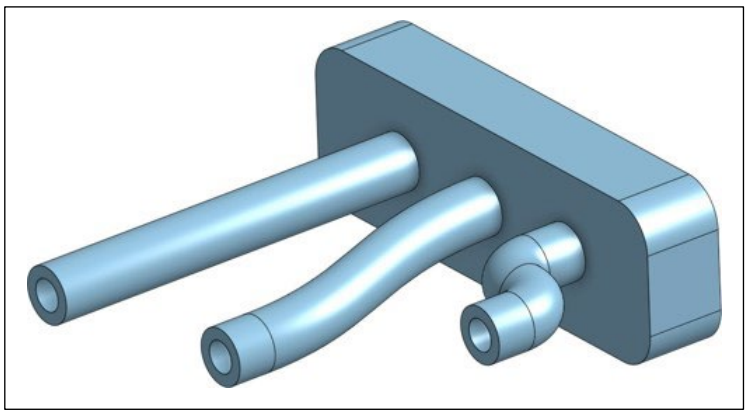
This channel may not fully clear of unbound powder, due to the sharp turn limiting access to the channel.

Tubes

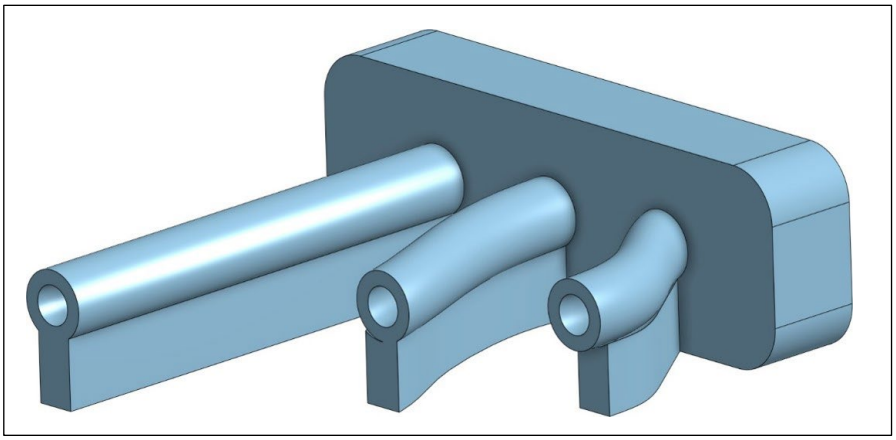
Standalone tubes are some of the most difficult features to process during depowdering. Tubes have long aspect ratios and small internal diameters.

Tube thicknesses should meet the aspect ratio guidelines for wall height to thickness and should avoid sharp turns.

Features should be added to tube support, aiding the ability to both depowder and sinter them.



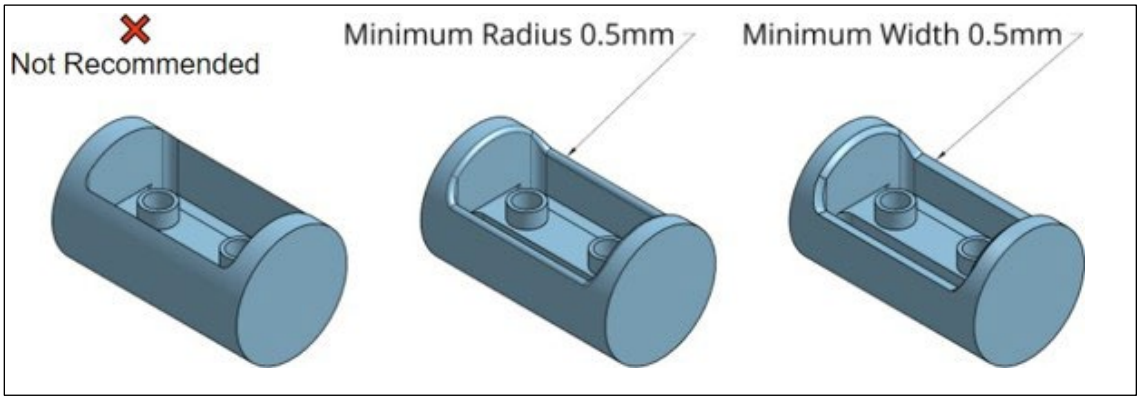
Sharp turns in channels inhibit ability to depowder.
Long unsupported channels are likely to slump during sinter without proper supports or breaks in handling in the green state.



Gradual changes in tube patch direction facilitate depowdering. Adding geometry beneath tubes prevents slumping during sinter.

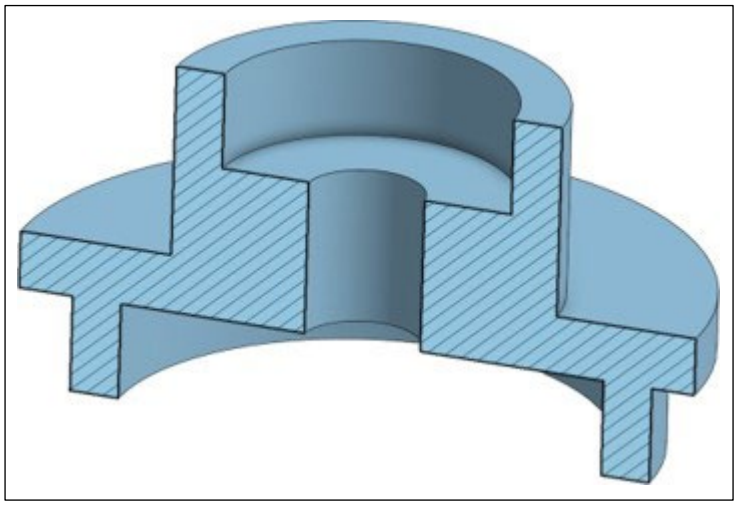
Remove Knife Edges

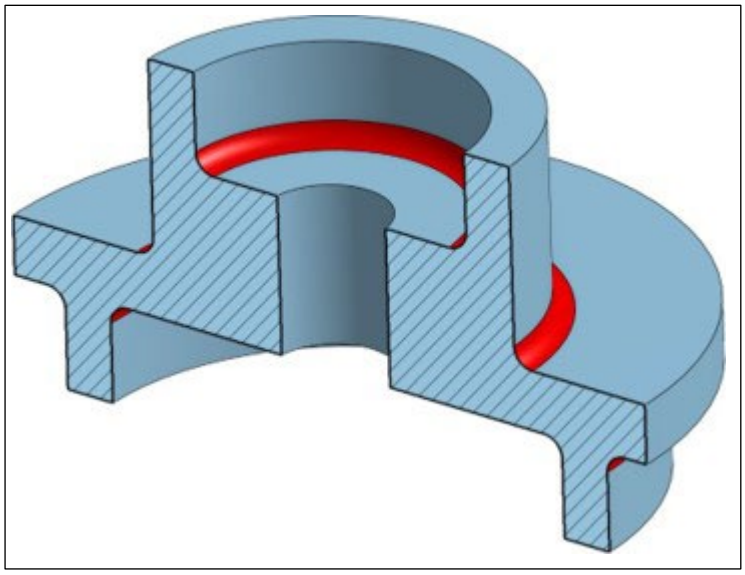
Avoid sharp edges and points with acute angles <70 degrees. Terminate sharp edges with a flat or radius of at least 0.5 mm to avoid chipping and breaking during the depowdering process.



Design Internal Corners

For internal corners, use a fillet with a radius approximate to the thickness of connecting walls and >1 mm. Filleted corners enhance the green part's strength and help prevent distortion and cracking during sintering.





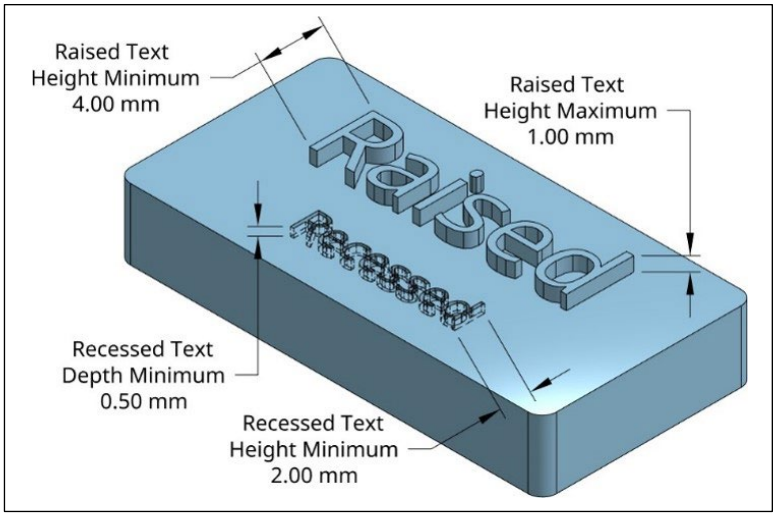
Design Text Features

Text features have minimum and maximum specifications to prevent breakage of fragile features. Raised and recessed text have different specifications.

Recommended Minimum/Maximum Dimensions for Text Features

Recessed Text	Raised Text
• Minimum 2mm in text height (~6 point font size) • Minimum 0.50 mm in recess depth	• Minimum 4 mm in text height (~12 point font size) • Maximum 1 mm in raise height

Use caution when depowdering text, especially raised text. Small features, like the small dot on an i or j, are effectively tall thin pillars that could exceed the design guide aspect ratio. Avoid recessed text that passes all the way through part geometry, which may leave free-floating entities such as the centers of an o and d. Favor simple sans serif fonts. Prevalence of thin sections causes unnecessary feature fragility. In general, recessed text and sans serif fonts provide the best results.



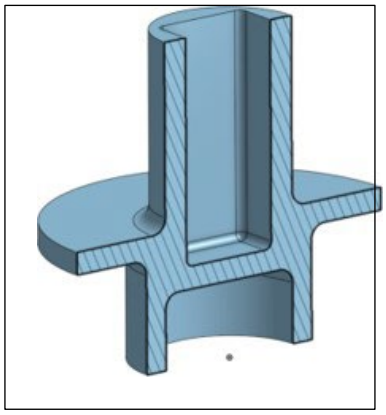
Use Sintering Supports

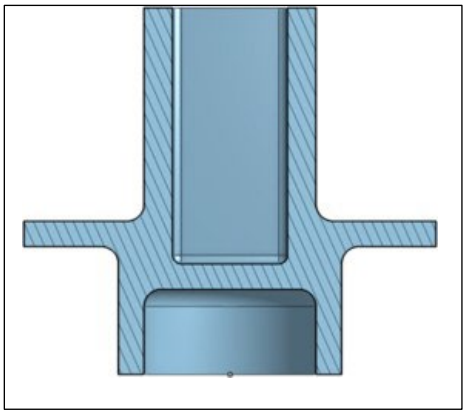
While supports are not necessary for shape retention during the printing process, they are critical during sintering when the material approaches its melting point. Powdered metal parts are sintered at high temperatures and have very little strength. The force of gravity is enough to distort parts unless they are properly supported. Parts that do not have flat bottom-facing surfaces require part-specific sintering supports. Primitive supports can be manufactured out of ceramic or form fitting supports can be printed in tandem with parts. Printed or *live* supports are of the same material as parts and require an anti-sintering agent to be separable after sintering.

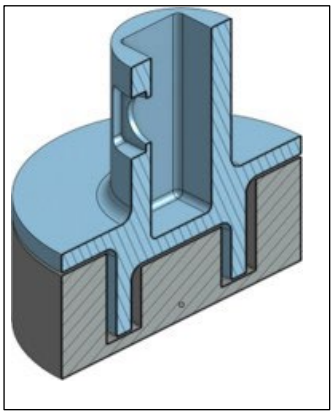
Part Features Requiring Sintering Supports

Bridges and Overhangs

Bridged features greater than 20 mm and overhangs greater than 7.5 mm require the use of a sintering support.

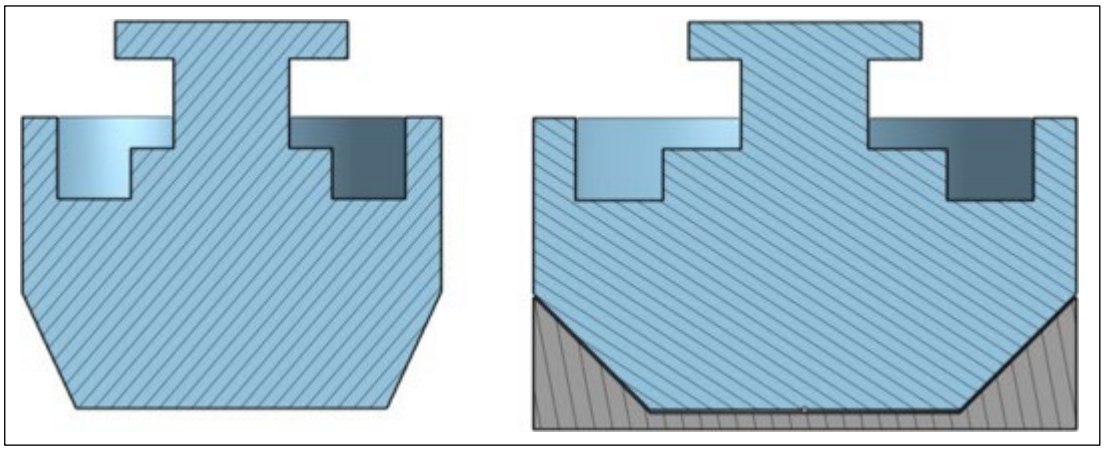






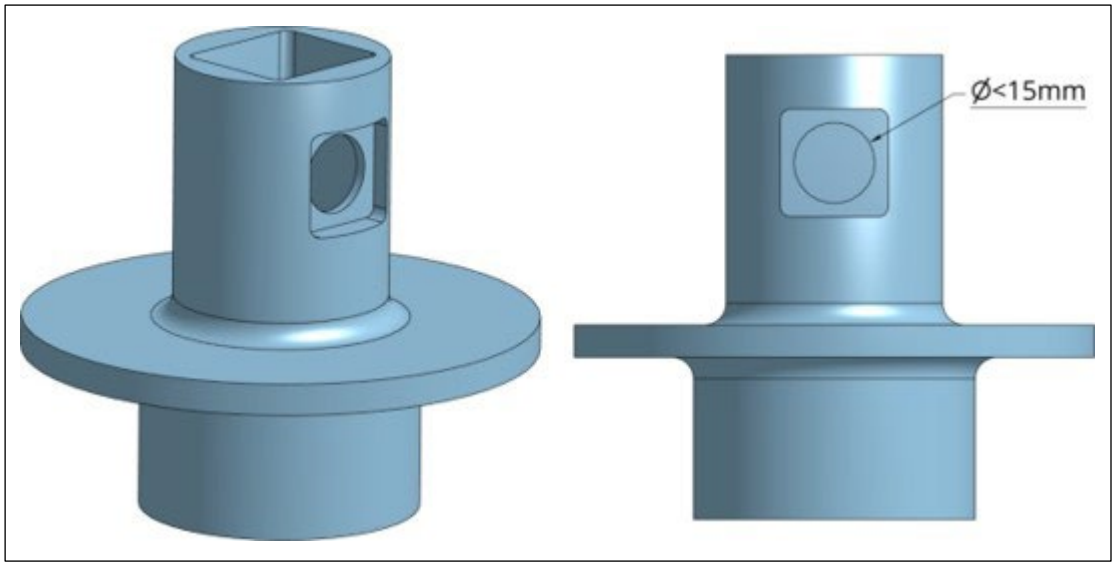
Angles

Overhanging features which deviate more than 30 degrees from vertical require a sintering support.

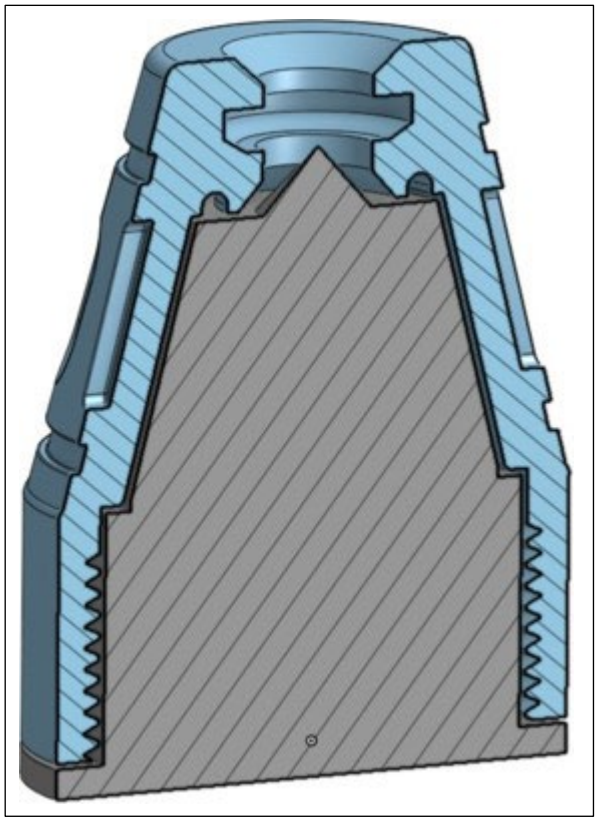


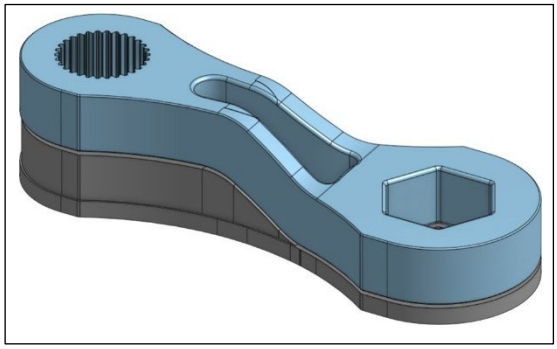
Horizontal Holes

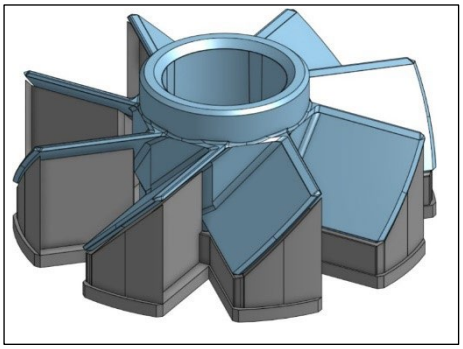
Holes in the horizontal axis of the part with diameters greater than 15 mm require Live Sinter processing.



Other Examples of Sintering Supports







Quick Reference for Designing Binder Jet Parts

Feature	Recommendation	Consequence of Not Following Recommendation
Part size	See Part Size.	• Part is larger than recommended maximum size. • During sinter, part will shrink large physical distances and will be subject to frictional and/or compression forces. • It may result in drag marks and cracks.
Wall thickness	• Maximum wall thickness = 25 mm • Minimum supported wall thickness = 0.75 mm	• Wall thickness will be larger than recommended maximum. • Large walls will be unable to release binder thoroughly and excess binder may remain in the part. • During sinter, binder that is unable to leave part may cause cracks. • Wall thickness will be smaller than recommended minimum. • Small walls will be extremely fragile in depowder. • It can lead to breaks or failures from cracking.

Wall aspect ratio	• 8:1 for wall widths greater than 1 mm • 4:1 for wall widths under 1 mm	• Wall aspect ratio will be higher than recommended maximum. • During sinter, tall walls will be unstable. • It can lead to distortion, sagging.
Minimum hole width	.075 mm	• Hole width will be smaller than recommended minimum. • During depowder, powder removal of small holes will be difficult. • It can lead to incorrect geometry.
Hole aspect ratio	• 8:1 for holes of diameter greater than 2 mm • 4:1 for holes of diameter less than 2 mm	• Hole aspect ratio will be higher than recommended maximum. • During depowder, powder removal of holes will be difficult. • It can lead to incorrect geometry.

Pillar width	• Minimum pillar width – 0.75 mm • Maximum pillar width = 25 mm	• Pillar width will be smaller than recommended minimum. • Small pillars will be extremely fragile in depowder. • It can lead to brown part breaks. • Larger pillars will be unable to debind thoroughly and excess binder may remain in the part. • During sinter, binder will be unable to leave part and can lead to cracking.
Pillar aspect ratio	Aspect ratio should not exceed 8:1. Example: The height of the pillar should be less than 8x its width.	• Pillar aspect ratio will be higher than recommended maximum. • During sinter, tall pillars will be unstable. • It can lead to distortion and sagging.
Overhang		• Overhang length longer than recommended maximum. • During sinter, large overhangs will be unsupported in the sinter temperature range. • It can lead to distortion and sagging. • Overhang angle will be greater than recommended maximum. • During sinter, improperly supported overhangs will be malleable in the sinter temperature range. • It can lead to distortion and sagging.

Binder Jet Glossary

Wall aspect ratio	Wall height : Wall width
Slot Depth to Width	Slot depth : Slot width
Hole aspect ratio	Hole depth : Hole width
Pillar aspect ratio	Pillar height : Pillar width

Desktop Metal, Inc.
63 3rd Avenue
Burlington, MA 01803
https://www.desktopmetal.com/

Desktop Health
c/o Desktop Metal, Inc.
63 3rd Avenue
Burlington, MA 01803
https://health.desktopmetal.com/

EnvisionTec US LLC (ETEC)
15162 Commerce Dr. S
Dearborn, MI 48120
https://etec.desktopmetal.com/

EnvisionTec GmbH
Brusseler Str. 51
45968 Gladbeck
Germany

ExOne Operating, LLC
127 Industry Boulevard
North Huntingdon, PA 15642
https://www.exone.com/

ExOne GmbH
Daimlerstrasse 22
86368 Gersthofen
Germany

ExOne KK
161-5 Haneo
Odawara-shi, Kanagawa
Japan 256-0804