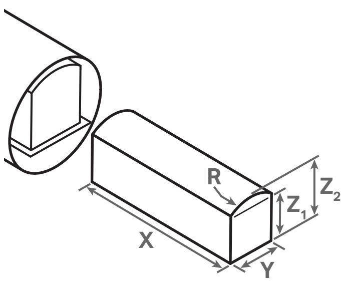
Metal X Design Reference Sheet

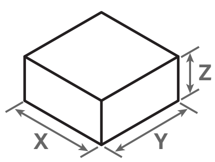
Listed dimensions are as designed for your final part unless otherwise specified. These guides serve as recommendations and may not reflect all implementations, since 3D printing is a geometry dependent process.



Maximum Part Size with Sinter-1

X: 235.0 mm (9.25")
Y: 68.3 mm (2.69")
Z_1: 65.5 mm (2.58")
Z_2: 80.0 mm (3.19")
R: 55.5 mm (2.18")

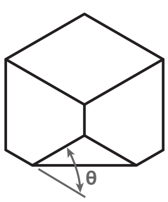
These dimensions account for all aspects of the Metal X system using the Sinter-1, including scaling factors, your part raft, and the setter tray. Software limits parts to a bounding box of X, Y, Z_1. Due to the shape of the Sinter-1 tube, taller parts can extend up to Z_2 in height if their top surface fits within a radius of R centered along the part.



Minimum Part Dimensions

X: 2.8 mm (0.110")
Y: 2.8 mm (0.110")
Z: 1.7 mm (0.067")

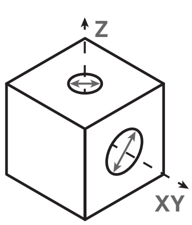
Elements with dimensions smaller than these may not print well due to the size of the filament and the structural weakness of thin walls.



Maximum Unsupported Overhang

θ: 45°

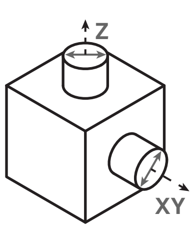
An overhang is a feature that has no material beneath it, and the overhang angle refers to the angle between the horizontal build plate and the overhang feature. Under a certain angle, printed overhangs may break off due to gravity, so the model should be rotated or supports should be used.



Minimum Hole Diameter

XY: 1.5 mm (0.059")
Z: 1.0 mm (0.039")

A hole with too small a radius may be closed off during printing. Horizontal surface holes (Z) may be slightly smaller than vertical surface holes (XY).



Minimum Post Diameter

XY: 3.0 mm (0.118")
Z: 3.0 mm (0.118")

A post with too small a radius may not print straight. The ratio of height-to-diameter should be considered, as tall skinny features may wave or break off.

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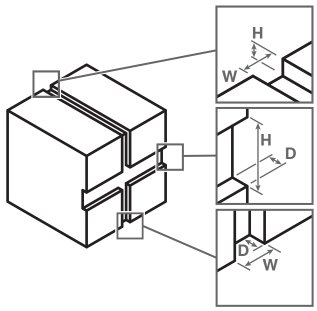


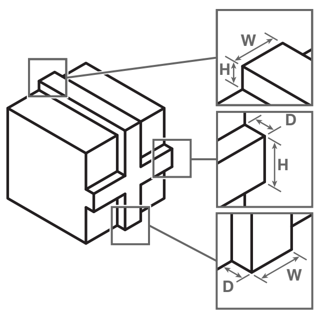
Minimum Engraved Features

H: 0.17 mm (0.007”)
W: 0.50 mm (0.019”)

H: 2.0 mm (0.079”)
D: 0.5 mm (0.019”)

W: 0.5 mm (0.019”)
D: 0.5 mm (0.019”)

An engraved feature is one that is recessed below the surface of the model. Engraved features may blend into the rest of the model if they are too small. Common examples include text and texture.



Minimum Embossed Features

H: 1.50 mm (0.059”)
W: 0.17 mm (0.007”)

H: 1.7 mm (0.067”)
D: 0.5 mm (0.019”)

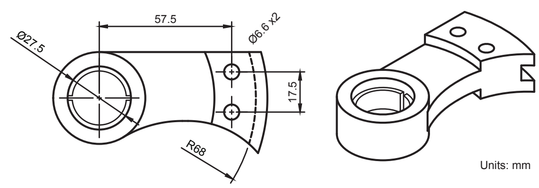
W: 1.5 mm (0.059”)
D: 0.5 mm (0.019”)

An embossed feature is one that is raised above the surface of the model. Embossed features may blend into the rest of the model if they are too small. Common examples include text and texture.

Markforged

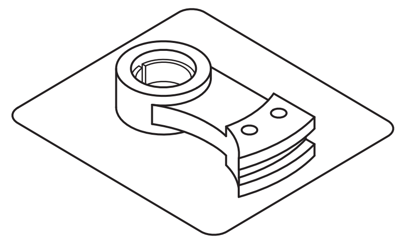
Optimize For Printing

As you design your part, consider how it can be optimized for the printing process. Below are four considerations to keep in mind when designing:



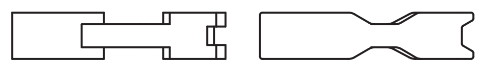
1. Identify Critical Dimensions

3D printers have higher precision in planes parallel to the build plate. What are your critical dimensions or features?



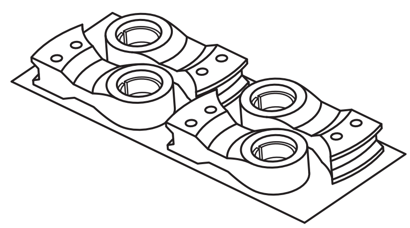
2. Maximize Bed Contact

Greater surface area on the print bed minimizes supports and improves bed adhesion. Which face of your part contacts the bed?



3. Reduce Supports

Fewer supports reduce printing and processing time. How can you design to minimize supports? Are the supports in your part accessible?



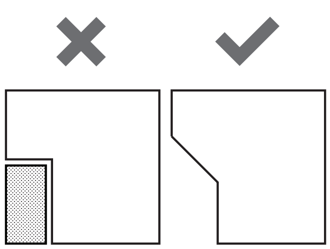
4. Consider Batch Processing

The more parts you can pack into a sintering run, the lower batch cost you have per part. How will your part pack among others in the furnace?

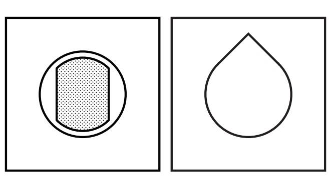
Modify Overhangs to Optimize Supports

Supports are necessary to prevent overhang collapse during printing and sintering. Consider where your parts will require supports and what you can do to minimize supports to decrease print time. Ensure the supports on your part are easy to access and remove before you print. If not, consider modifying overhangs to improve support removal.

Eliminate Supports

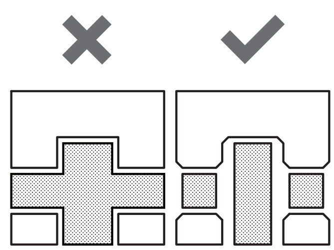


Chamfer small overhangs at 45°

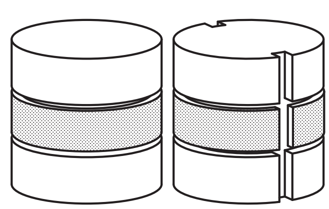


Teardrop XY holes to clear channels

Simplify Support Removal

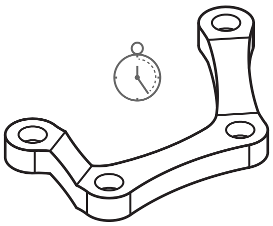


Break up supports with 45° chamfers on edges

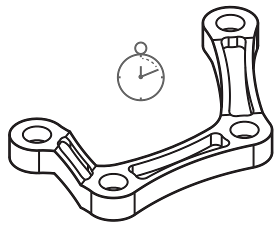


Add slits to separate segments

Optimize For Washing



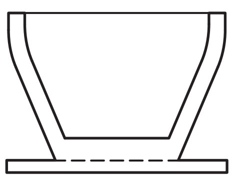
Thicker part sections increase wash time



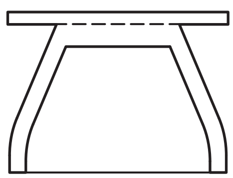
Shell parts for a faster wash time

Shell Out Thick Parts

The thicker your part is, the longer it will take to wash. Shell out large volumes and increase surface area to minimize the time your parts spend in the wash. Try to maintain consistent wall thickness across your part.



Slower wash time in printed orientation

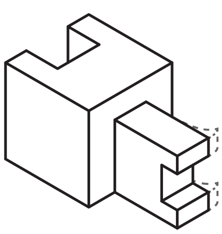


Faster wash time when inverted

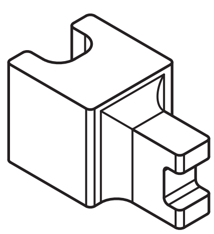
Wash Bowls Upside Down

Wash bowl-shaped parts upside down (no need to change print orientation) because the washing solvent is lighter than the binder material. When upside-down, the solvent permeates up into the bowl, resulting in a faster wash time.

Optimize For Sintering



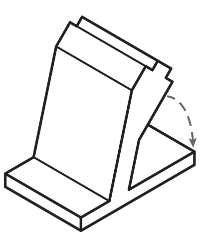
Sharp edges may cause deformation during sintering



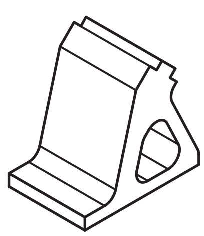
Smooth transitions reduce deformation

Reduce Stress Concentrations

Parts undergo thermal stresses when sintering because they are pulling themselves together as they shrink. Reduce stress concentrations by filleting your edges and designing gradual instead of sharp changes in thickness.



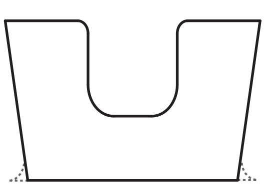
Cantilevered features may topple when sintered



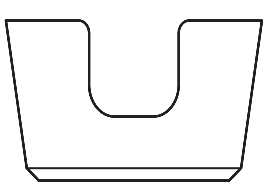
Balanced features stay supported during sintering

Ensure Features are Well Balanced

As parts go through the sintering process, the heat induces a clay-like state that makes them malleable. If your parts don't need supports, ensure they are inherently stable in their printed orientation. Avoid top-heavy, cantilevered, or tall and thin features.



Straight bottom edges can splay out during sintering



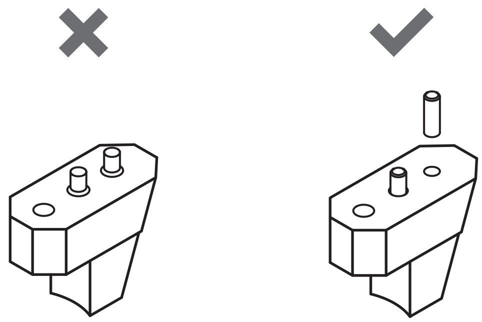
Splaying avoided with chamfered bottom edge

Chamfer Bottom Edges

The bottom edge of your part may splay out during sintering. Adding a 0.5-1.0 mm (0.02"-0.04") chamfer to the bottom edges of your part will prevent splayed edges, especially on small features like holes and channels.

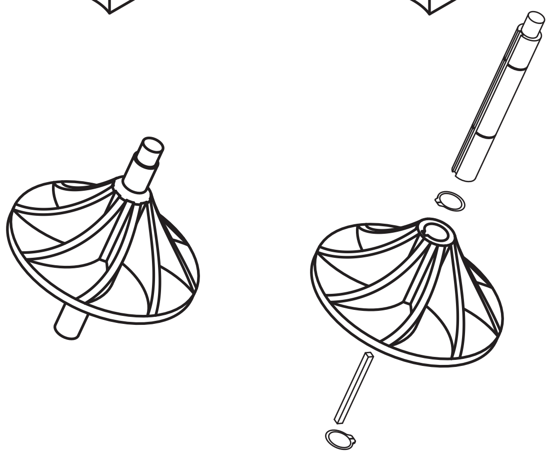
Strategic Metal Printing Practices

Think critically about what aspects of your design need to be 3D printed. Some features could be implemented more efficiently with other manufacturing methods. When appropriate, integrate other parts into your design to save on print time, design complexity, and cost. Below are some examples:



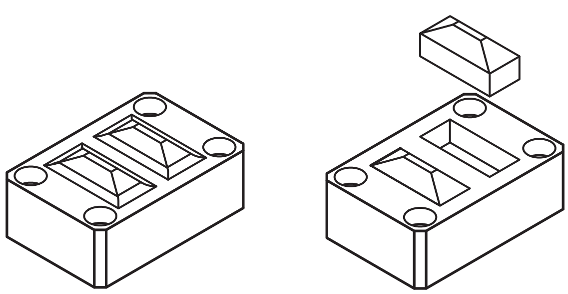
Use Pins for Alignment Features

Improve alignment precision and save material and print time by pressing dowel pins into your parts or using shoulder bolts for location. Dowel pins pressed into this gripper jaw locate it on a robotic arm. This design change reduces supports and simplifies print orientation.



Separate Printed from Simple Features

Isolate complex part features for metal 3D printing. Printing an impeller with an integrated shaft will sacrifice optimal print orientation for furnace orientation — it can only fit in the Sinter-1 sideways. Instead, the impeller can be printed apart from a turned shaft to decrease print time and part complexity. The retaining rings locate the impeller on the shaft, and the key acts as a shear point that can be swapped if it fails.

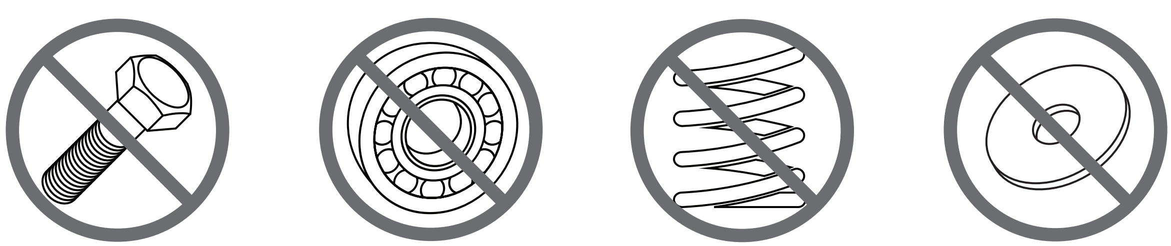


Isolate Properties with Modular Features

This sheet metal stamp consists of a blank with metal printed inserts. Isolating the metal inserts as separate parts localizes metal properties to only the region they are required, so you don't need to print an entirely new tool for every revision. This also makes maintenance and tool repair easy.

DON'T PRINT YOUR HARDWARE

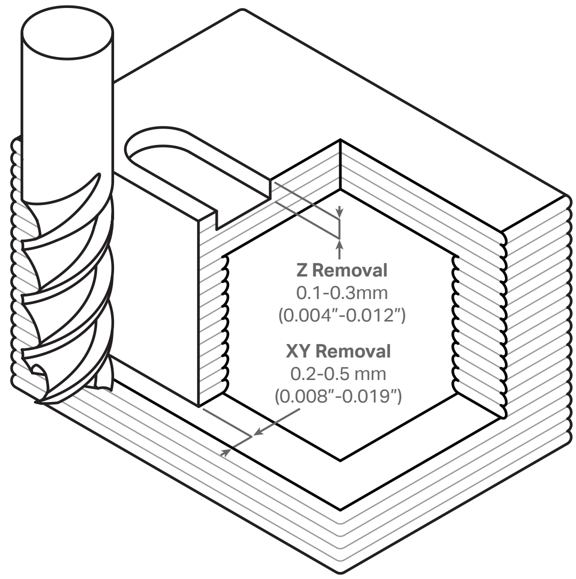
Printing hardware is a poor use of the Metal X technology — purchasing off-the-shelf hardware is almost always more cost- and time-efficient and produces better results. Hardware like bushings, bearings, and springs are produced with specialized manufacturing processes and will not behave the same way when printed. Washers, nuts, bolts, and similar hardware are cheaper and more effective to purchase than to print.



Post-Processing Metal Parts

Green State Sanding

If you value surface finish over precision, wet sanding green parts under warm water with 240-320 grit sandpaper or Scotch-Brite leaves a smooth matte finish once sintered. Modifying green parts may affect sintering performance, so be cautious if applying other techniques in the green state. Sand green parts over a receptacle or filter to prevent sink clogging, and use proper PPE.



Machining and Polishing Sintered Parts

The diagram on the right serves as a guide for post-processing parts to remove layer-line deviations without running the risk of exposing infill. Offset faces you wish to machine in your design so that when material is removed you can meet your tolerances.

Threads

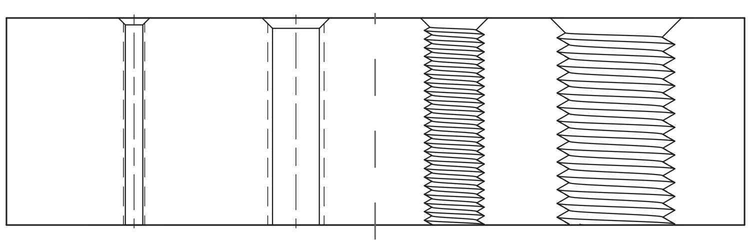
Tapped Threads

Tapped threads will be tighter tolerance than printed threads. Use 50% thread engagement for your tapped hole size in steels and other hard metals.

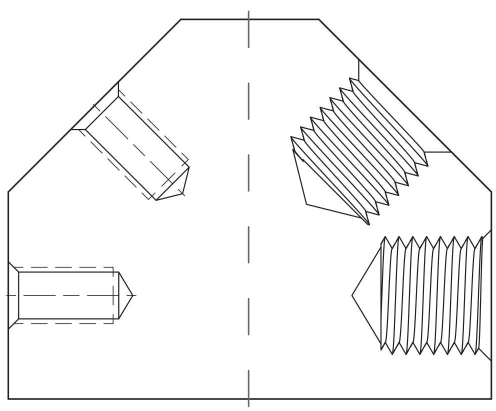
Printed Threads

Printed threads may need to be chased with a tap or need lapping compound for an even thread.

Vertical Threads



Angled and Horizontal Threads



Some metal printed parts may be difficult to fixture for machining or tapping due to their complex geometry. You can use Markforged composite printers to create conformal workholding to hold the metal parts in these cases.