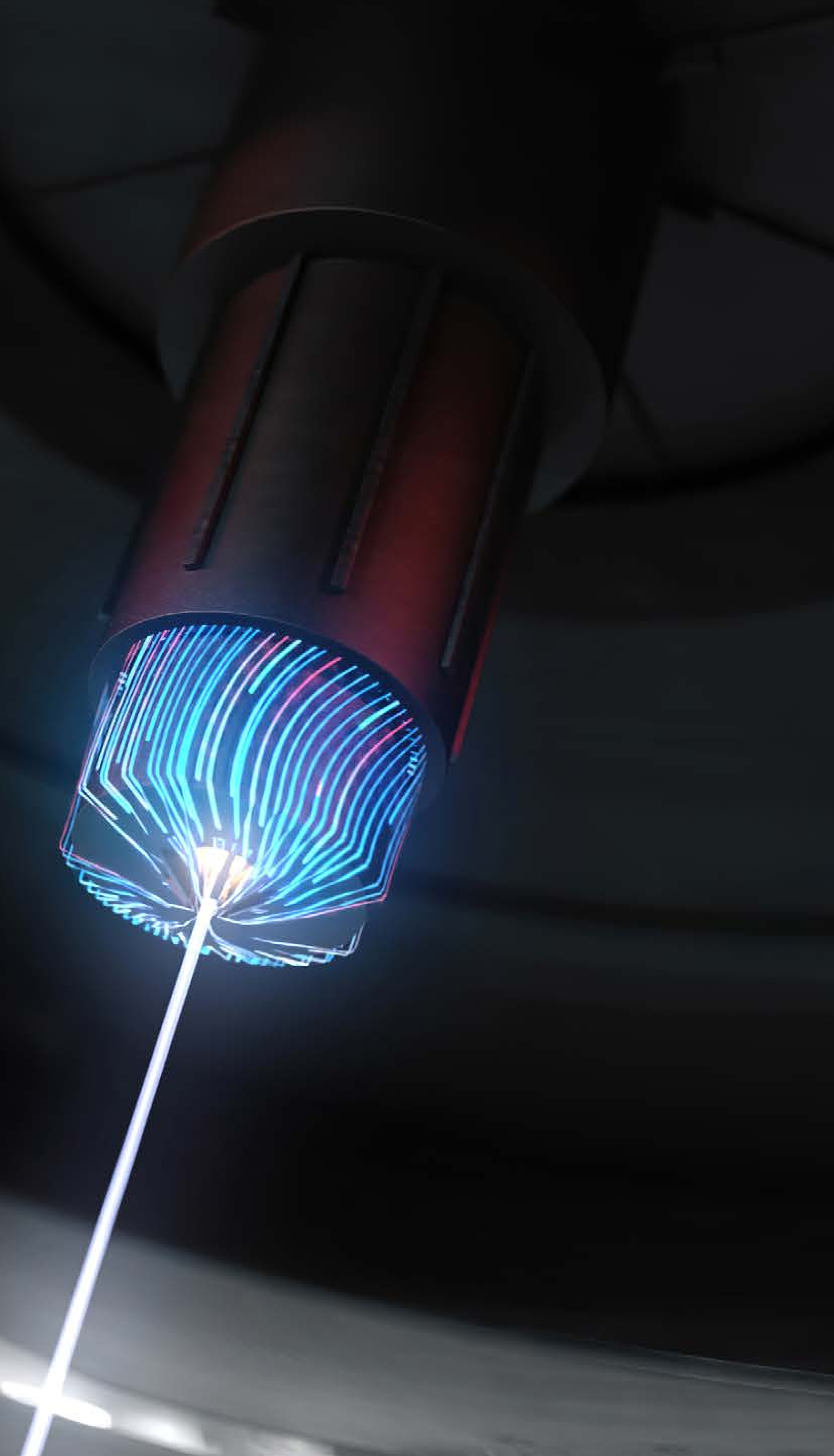
e.Guide

Design for Additive Manufacturing with FDR

Introduction

Fine Detail Resolution (FDR) functions in a manner very similar to Selective Laser Sintering (SLS), but at a much greater level of precision. The 55 watt CO laser type creates an ultra-fine beam with a focus diameter of 200 μm, about half the size of those seen in current SLS 3D printing systems. The thinner laser beam helps to create new exposure parameters, resulting in the development of super-fine surfaces. It is ideal for 3D printing applications involving delicate structures, those requiring tiny surface details and those designed with ultra-thin wall thicknesses, offering dimensional accuracy down to +/- 40 microns.

Thus far, the FDR process has been qualified for use with PA 1101 polymer. This Polyamide 11 (PA 11) material, commonly known as nylon, is processed in layer thicknesses of 40 μm. It's a sustainable material that is made entirely from renewable castor beans. Also, it is both chemically and mechanically heat-resistant, making it ideal for highly technical applications thanks to its durability.



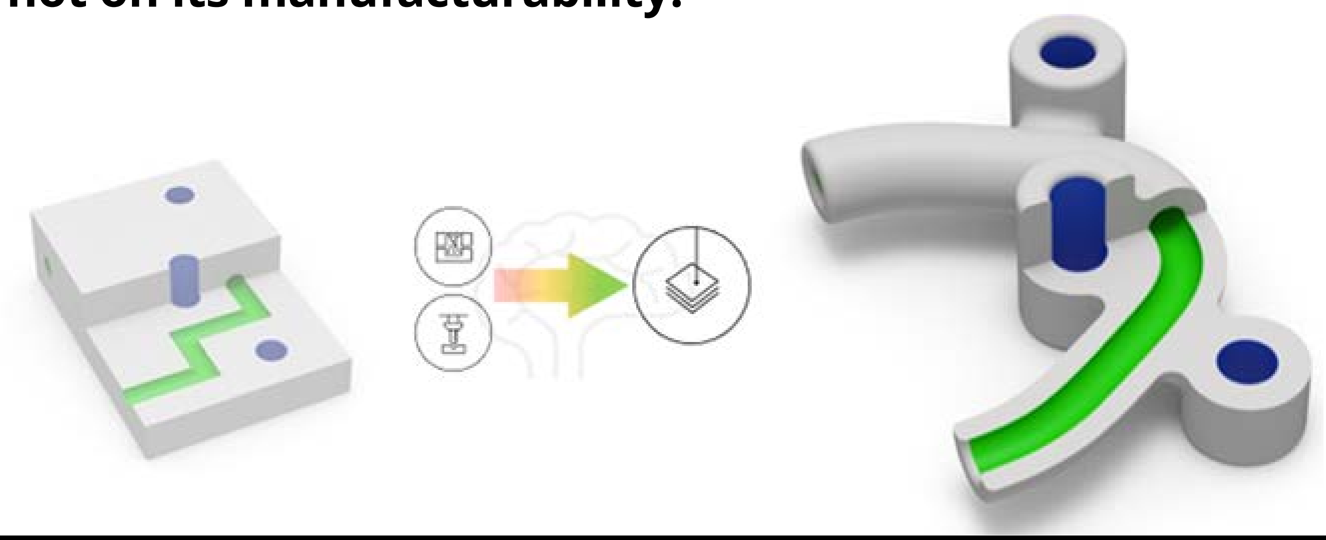
FUNDAMENTAL DESIGN PRINCIPLES

Fundamental Design Principles

While far from the only factors that matter when designing polymer parts for industrial 3D printing, the following four principles will form the basis of a foundationally strong design workflow.

1. Function-focused design

Focus on the part's function during design — not on its manufacturability!

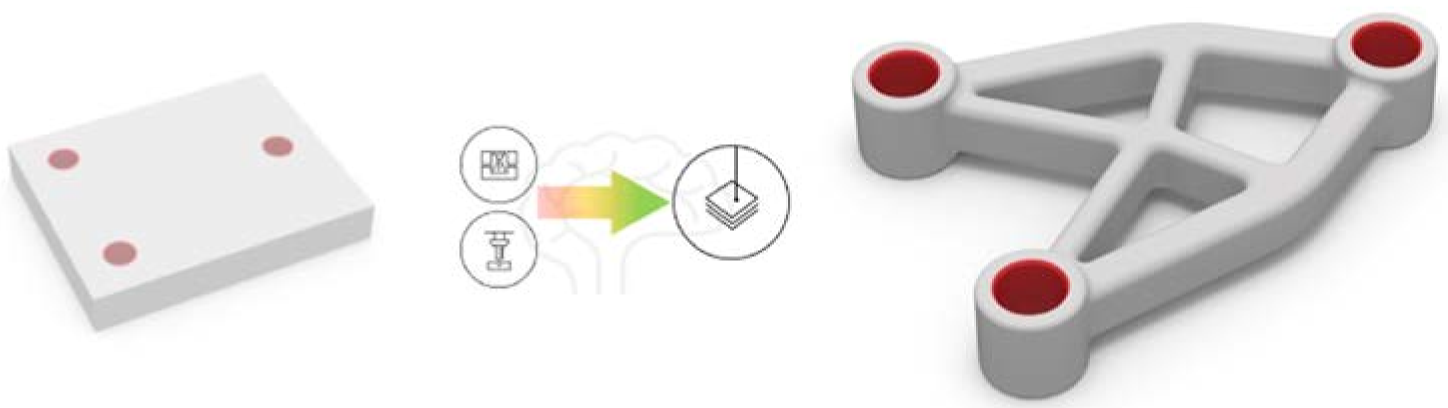


2. Material minimalism

Use material only when it is necessary to fulfill a core function of the part.

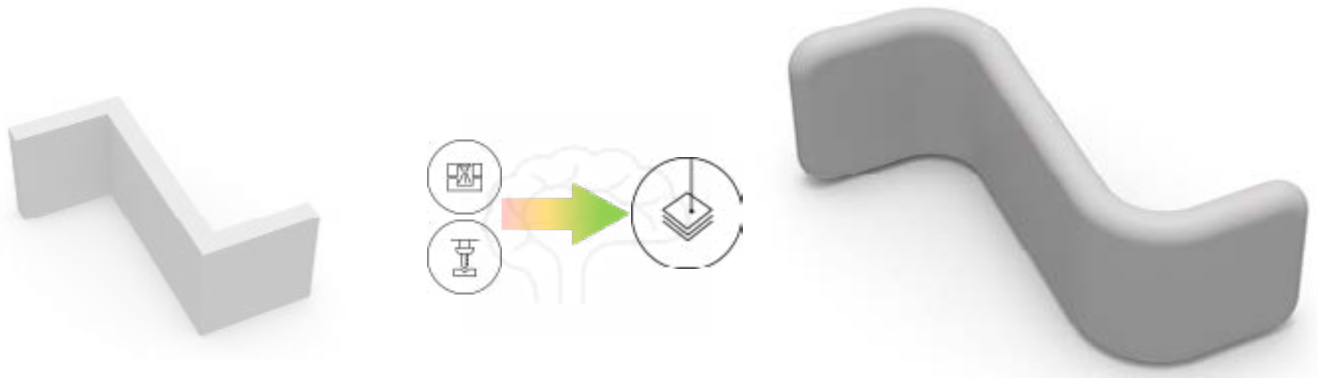
3. Force flow design

Use material only when it is needed to meet a part's strength requirements.



4. Soft edges and corners

Round off any sharp edges and corners — unless their angularity is integral to part function!

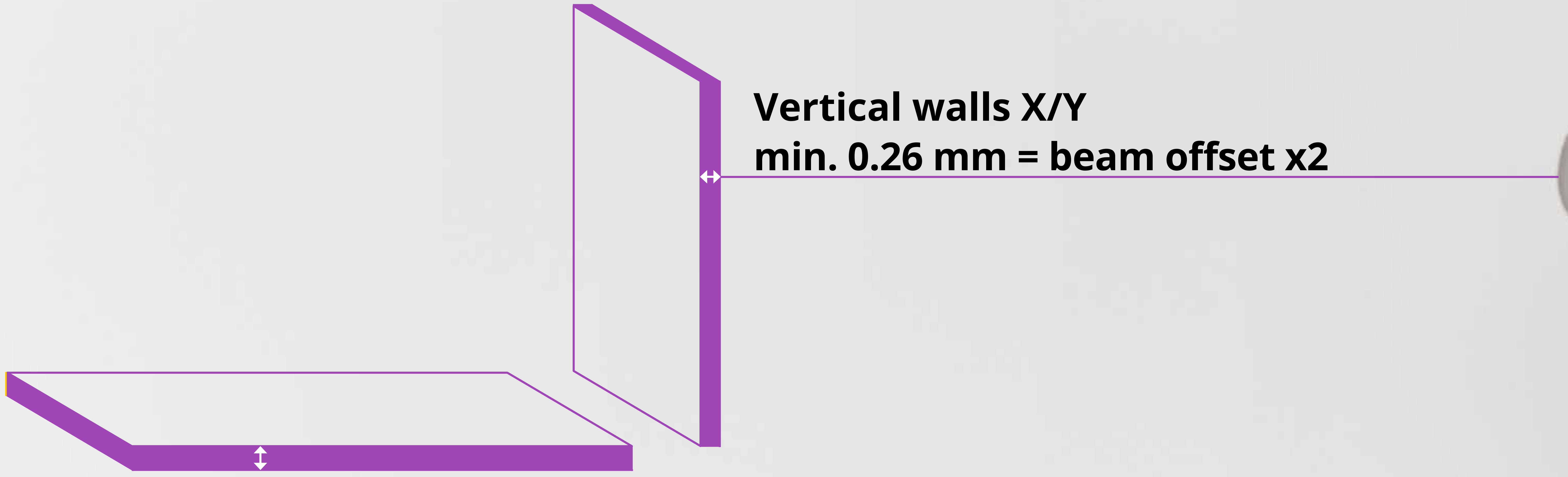


DESIGN
GUIDELINES

Wall Thickness

Vertical walls should consist of at least one contour. The minimum vertical wall thickness is therefore specified by the focus diameter (including the melting pool), equivalent to double the beam offset. Beam offset is the distance (radius of melting pool) between the path of the laser beam and the part boundary.

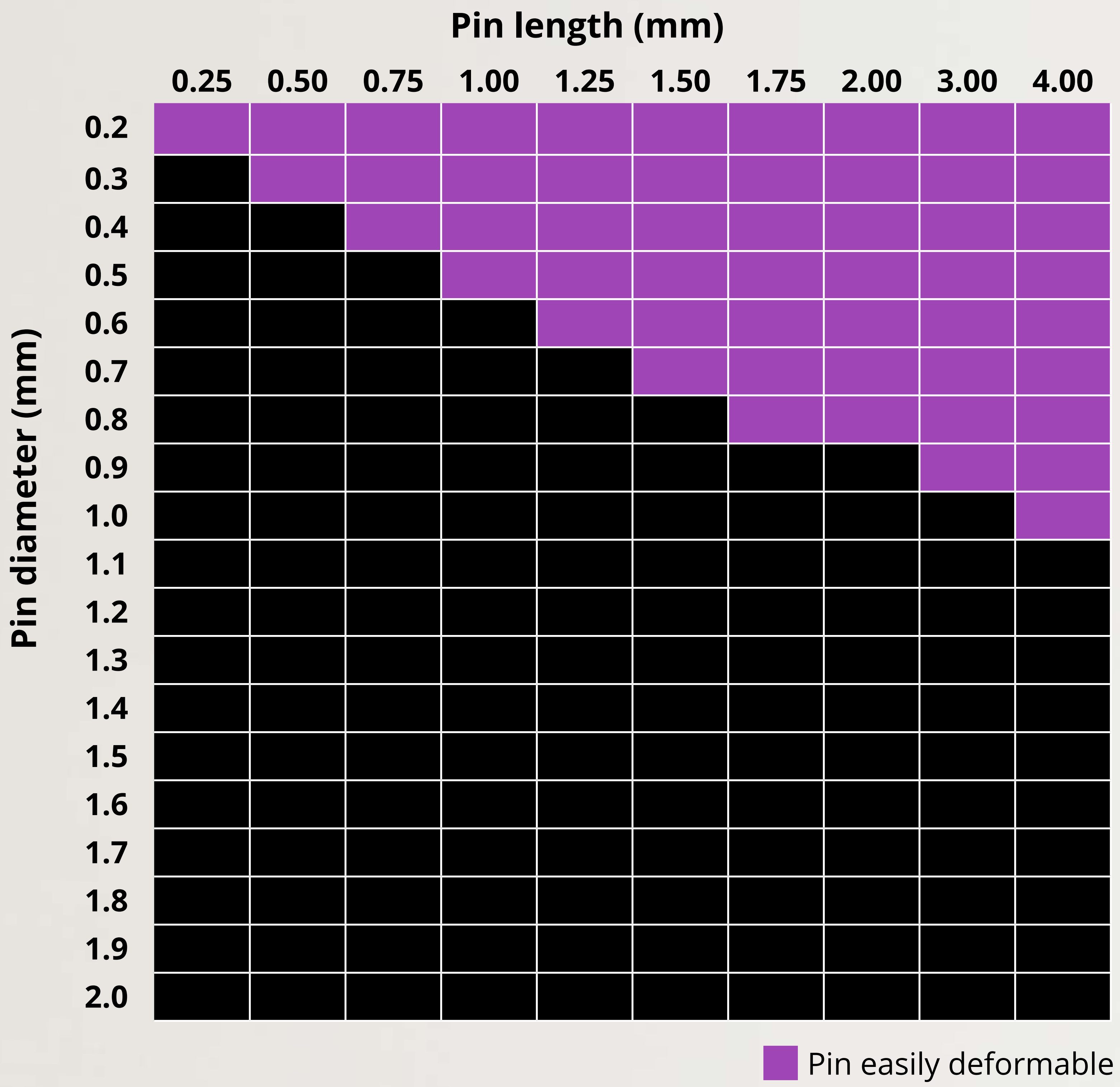
If horizontal walls are to be pushed to their limits, then the following must be observed. Walls can be designed with a thickness of just one layer (40 µm), but due to the overcure effect (see page 22 for explanation), this wall is thickened to 120 µm (3 layers). In this extreme case, the Z-compensation should definitely be avoided — otherwise, the component will disappear in Materialise Magics or alternative data preparation software.

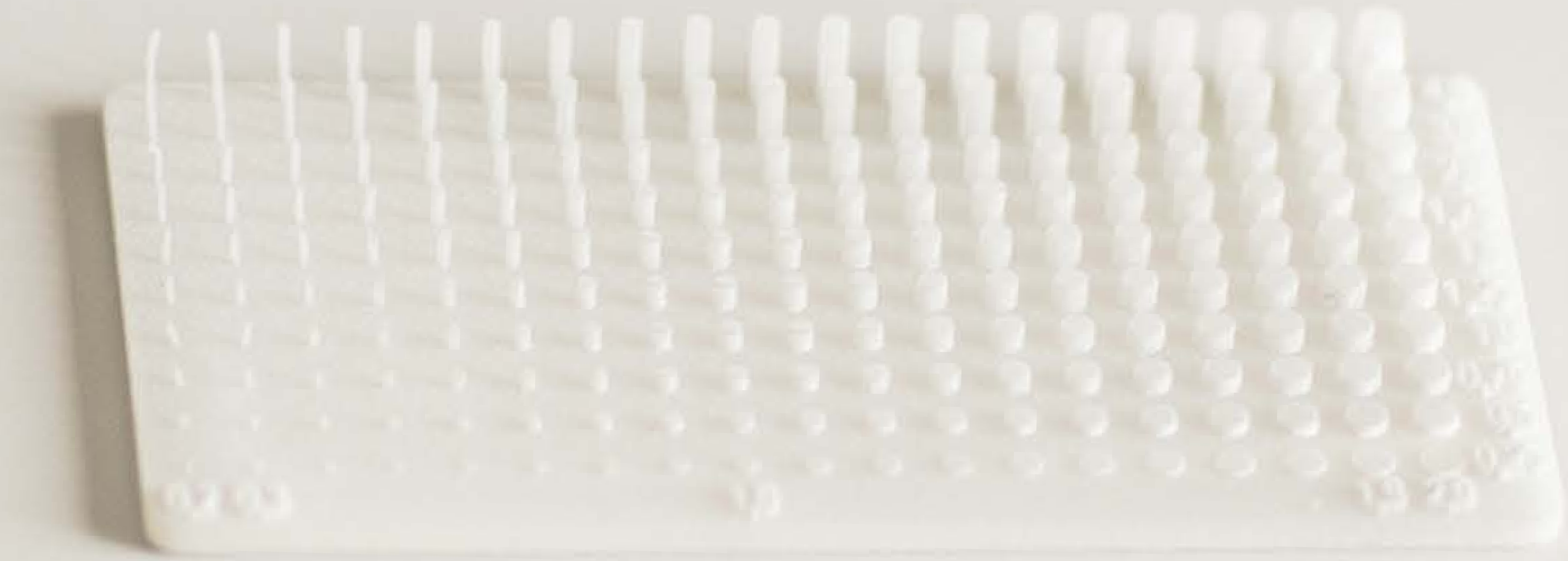


Pins

Pins should be oriented vertically whenever possible for optimal roundness. From a technological point of view, even pins with a diameter of just 0.2 mm can be printed with a length-diameter ratio of up to 20. But the cross-section (in combination with the length) significantly influences the strength of the pin. Therefore, pins up to a diameter of 0.4 mm are generally fragile, especially those that have a higher length-diameter ratio. However, due to the exemplary mechanical properties of PA11, especially its high elongation at break, the pins do not break off — they only can be deformed. Pins become more resistant with a maximum length-diameter ratio of 3.

Min. possible Ø 0.2 mm
Recommended length-diameter-ratio: 3



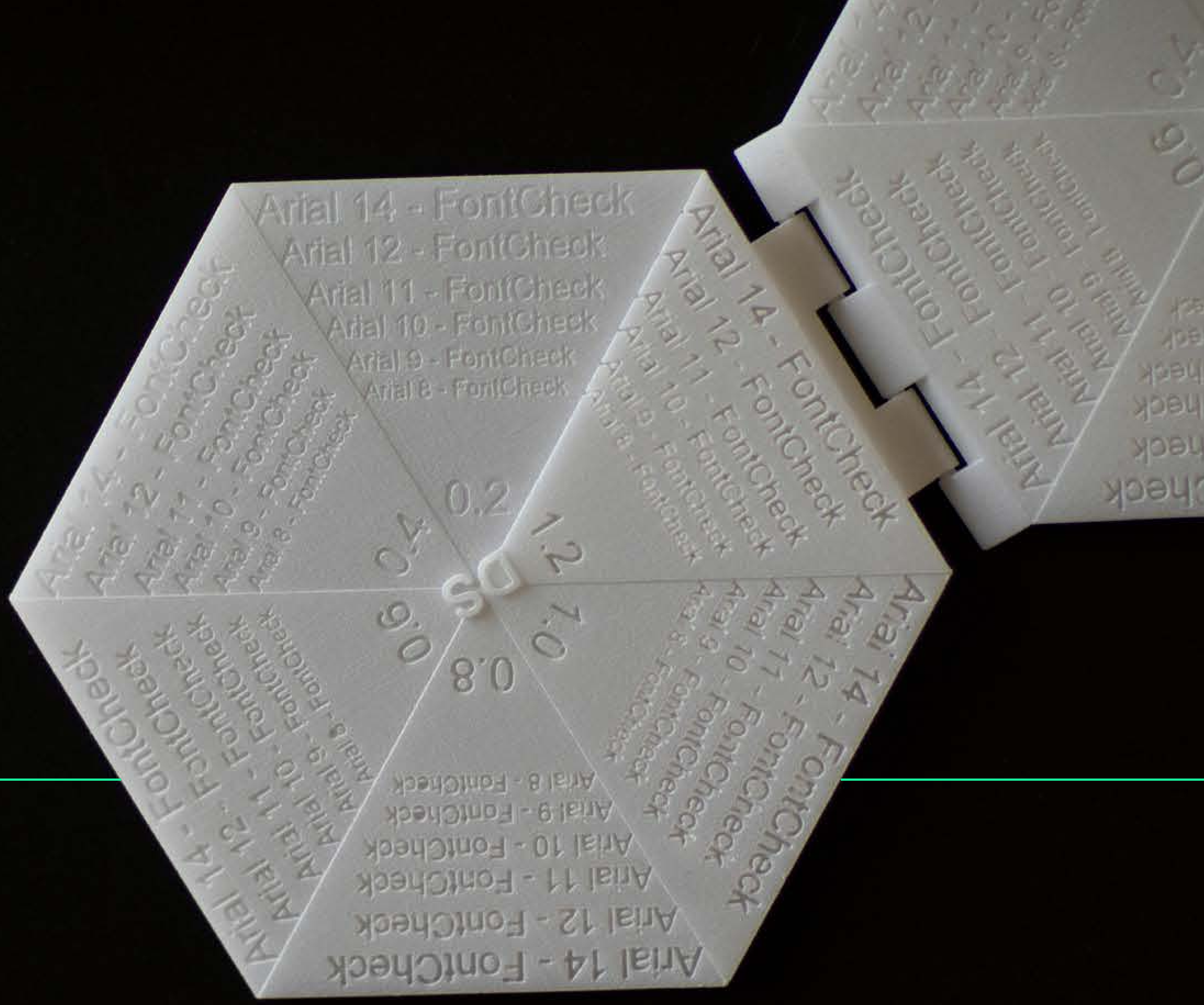


Application: Pin test sample, System: FORMIGA P 110 FDR,
Material: PA 1101, Orientation: horizontal

Font

To ensure legible print on a polymer part, orientation is just as important as choosing the right font and properly calculating height and depth measurement, depending on whether you are embossing (to create a raised font) or debossing (engraving the font into the part's surface).

Upskin (the upward-facing part surface) is ideal for fonts due to its edges, which are slightly sharper by comparison to the downward-facing surface (downskin). If the values below are undercut, both readability and level of detail will suffer.

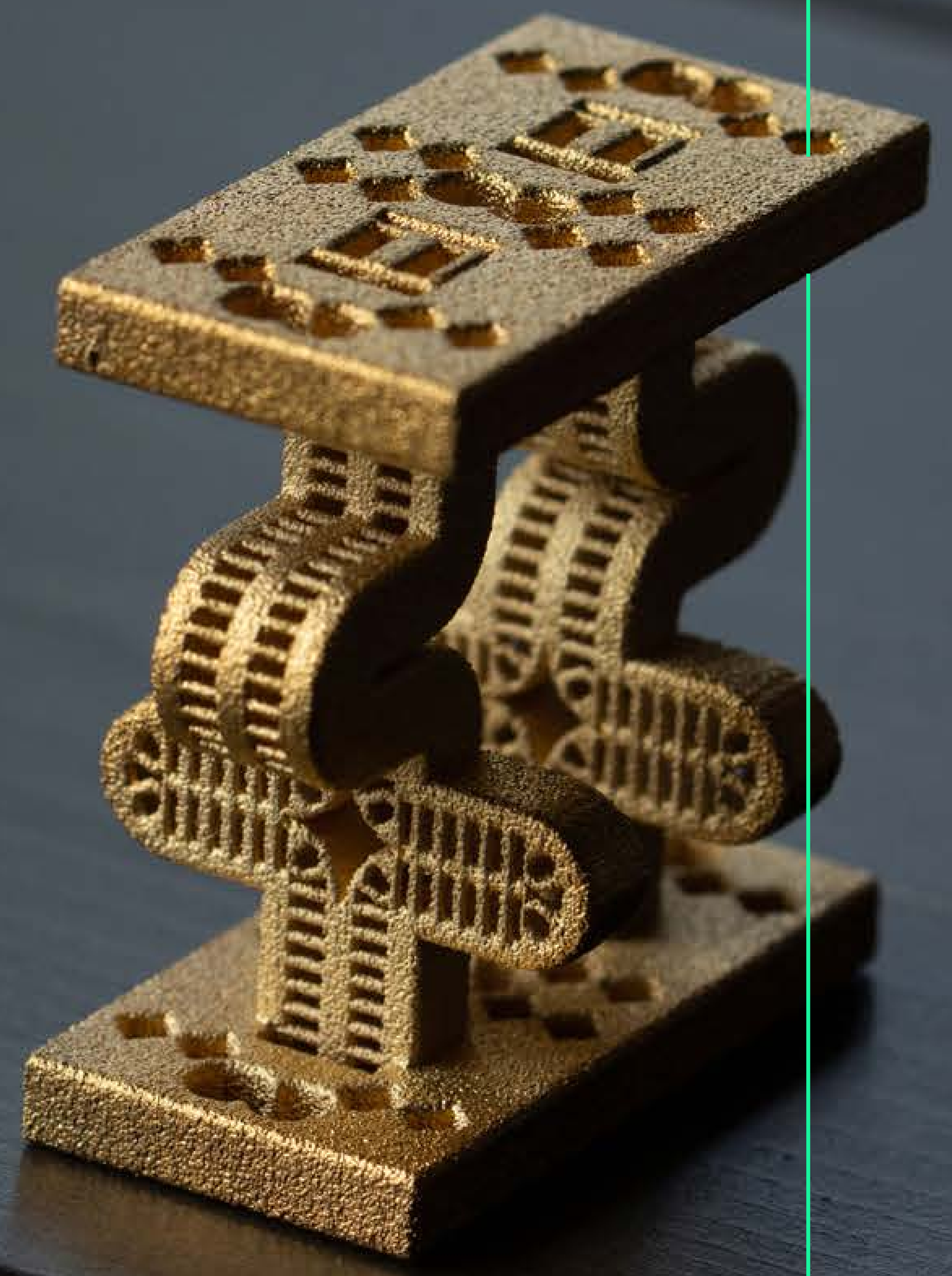


Emboss/raised: height 0.4 mm; size 2 mm
Deboss/engraved: depth 0.4 mm; size 2 mm

Holes

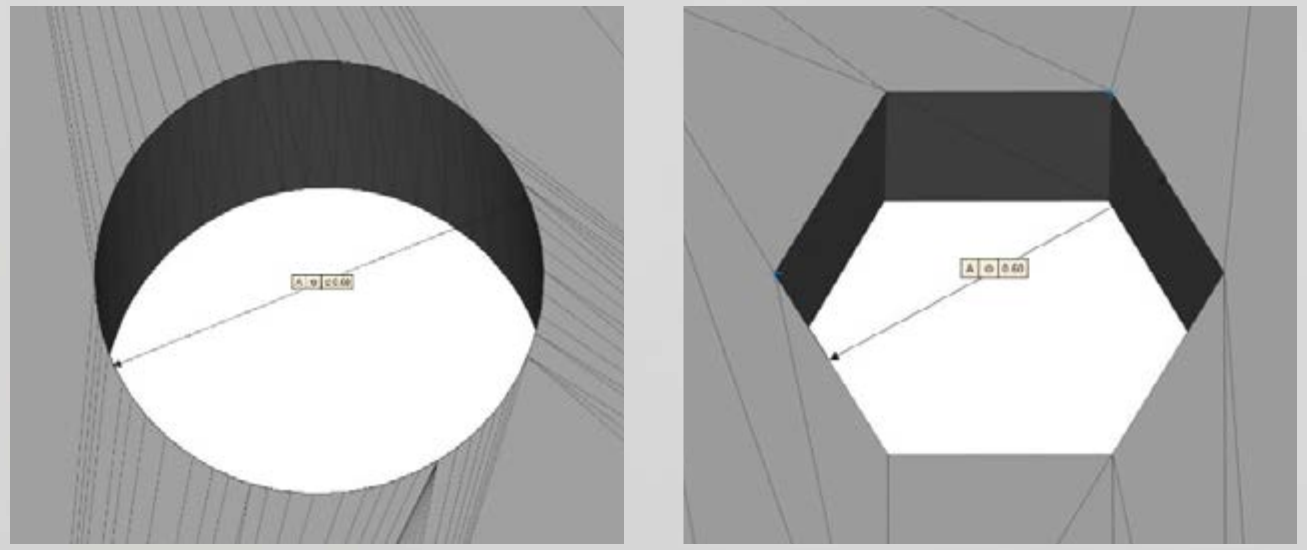
The minimum hole diameter for any particular part depends very much on its intended depth, the material surrounding the hole and whether it goes all the way through the part (i.e., a through hole) or is a blind hole that stops partway through the surface. Through holes are ideal for the additive manufacturing process because they are easier to depowder during the post-processing phase, and it's generally wise to ensure any hole is vertically oriented to ensure optimal roundness of the part. A great example of how a small hole runs through a thicker wall is illustrated by the nozzle application. The diameter of a hole can be reduced to a minimum by making the hole tapered.

Ø 0.5 mm (through hole depth ≤ 10 mm)
Ø 1.0 mm (through hole depth ≤ 20 mm)

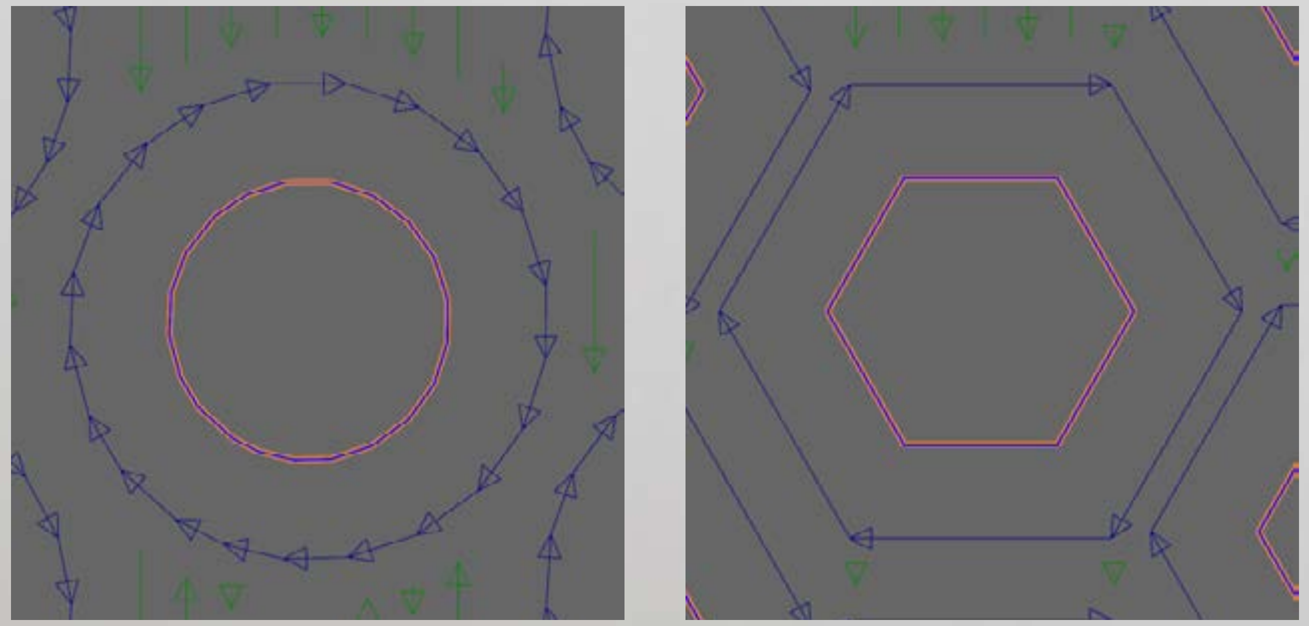


Holes

Another recommendation, especially for very small openings, is to change the geometry of a hole into a hexagon to reduce the number of vector moves. With FDR, the laser moves in vectors at each layer. Based on the triangulation, each hole is displayed as a polygon (see screenshot below showing triangles in Materialise Magics). With a high resolution, a hole is displayed with a larger number of triangles, in contrast to a low-resolution STL file. If the polygons are translated into vectors, which the laser traces, a large number of vectors will be required to trace a hole with a diameter of, for example, 0.6 mm. If you replace the hole with a hexagon you can reduce the number of vectors and achieve better results, especially at holes with a small diameter.



Triangle display of a hole and hexagon with a diameter of 0.6 mm in Materialise Magics.



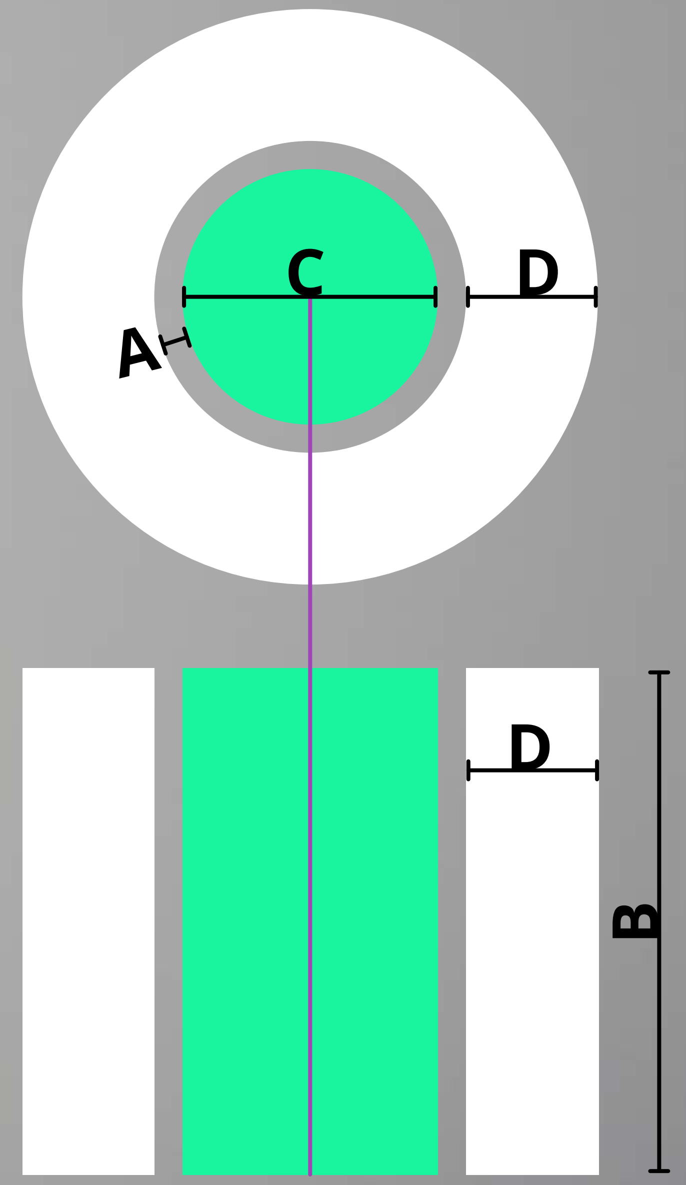
Differentiation of vector directions between hole and hexagon in EOSPRINT 2.

Application: “Nozzle“
Dimensions: 28 x 28 x 30 mm

Hinges (without assembly)

Part consolidation is one of the major advantages of powder bed-based AM technologies. Moving assemblies such as hinges can be printed in one piece, as long as the appropriate gap size is considered during design. In addition to the gap, you must ensure accessibility between the moving components to enable depowdering. You can design holes in the surface of the part assembly‘s outer body and remove loose powder through them. Very small gap dimensions can be realized, but these must be adjusted if necessary because the gap size is influenced by the following factors: wall thickness (D), accessibility of the gap (to remove loose powder), shaft diameter (C), distance of the connection (B) and size of the play (A)

Gap size (A):
X/Y (vertical) ≥ 0.30 mm (depending on variables B, C, D)
Z (horizontal) ≥ 0.22 mm (depending on variables B, C, D)



Film Hinge

In addition to non-assembly hinges, film hinges represent a good opportunity for movable parts. This type of hinge is not that durable, but investigation has shown that cycles up to 10,000 are possible without any noticeable signs of wear and tear.

Thickness for film hinge: 0.3 mm

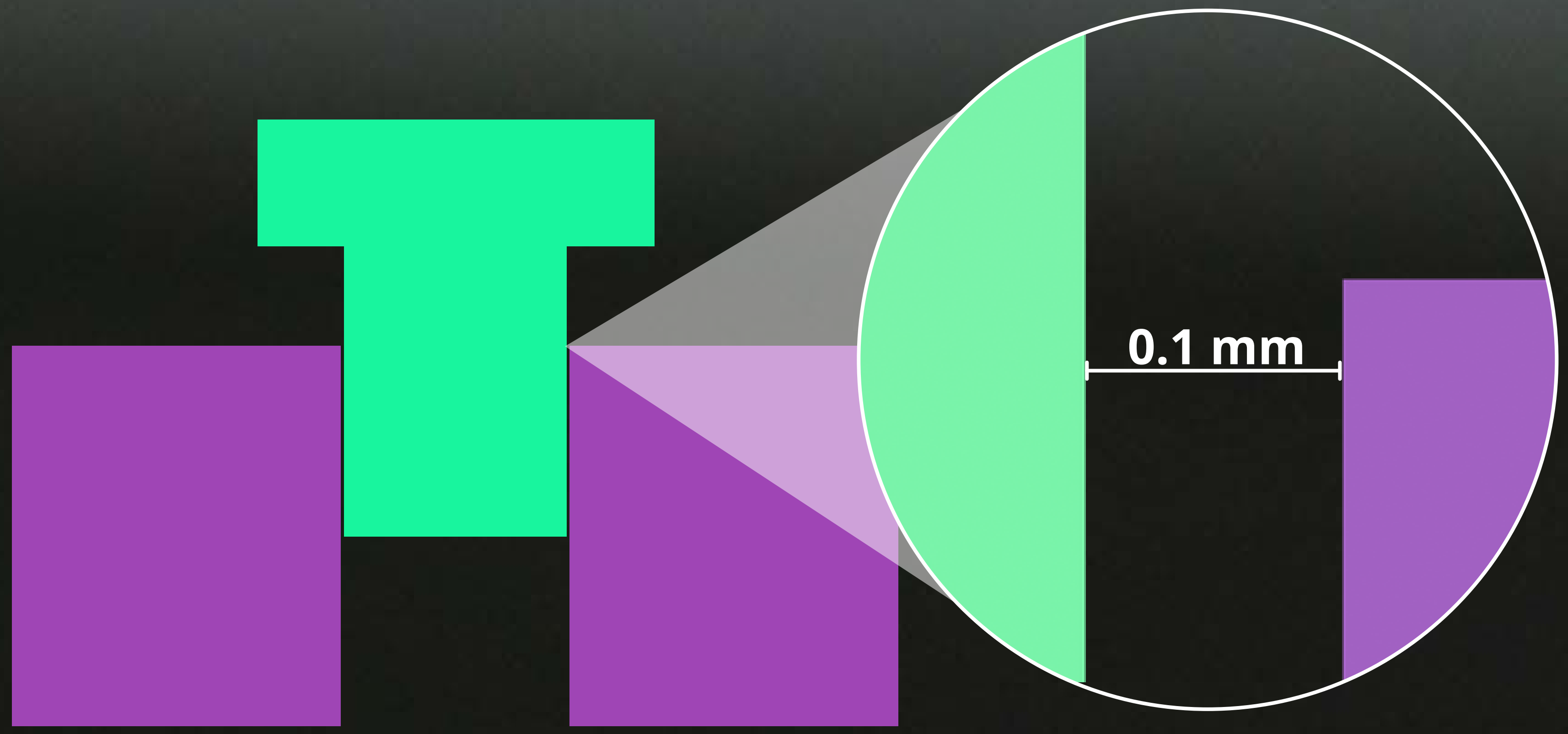
Fittings (assembled)

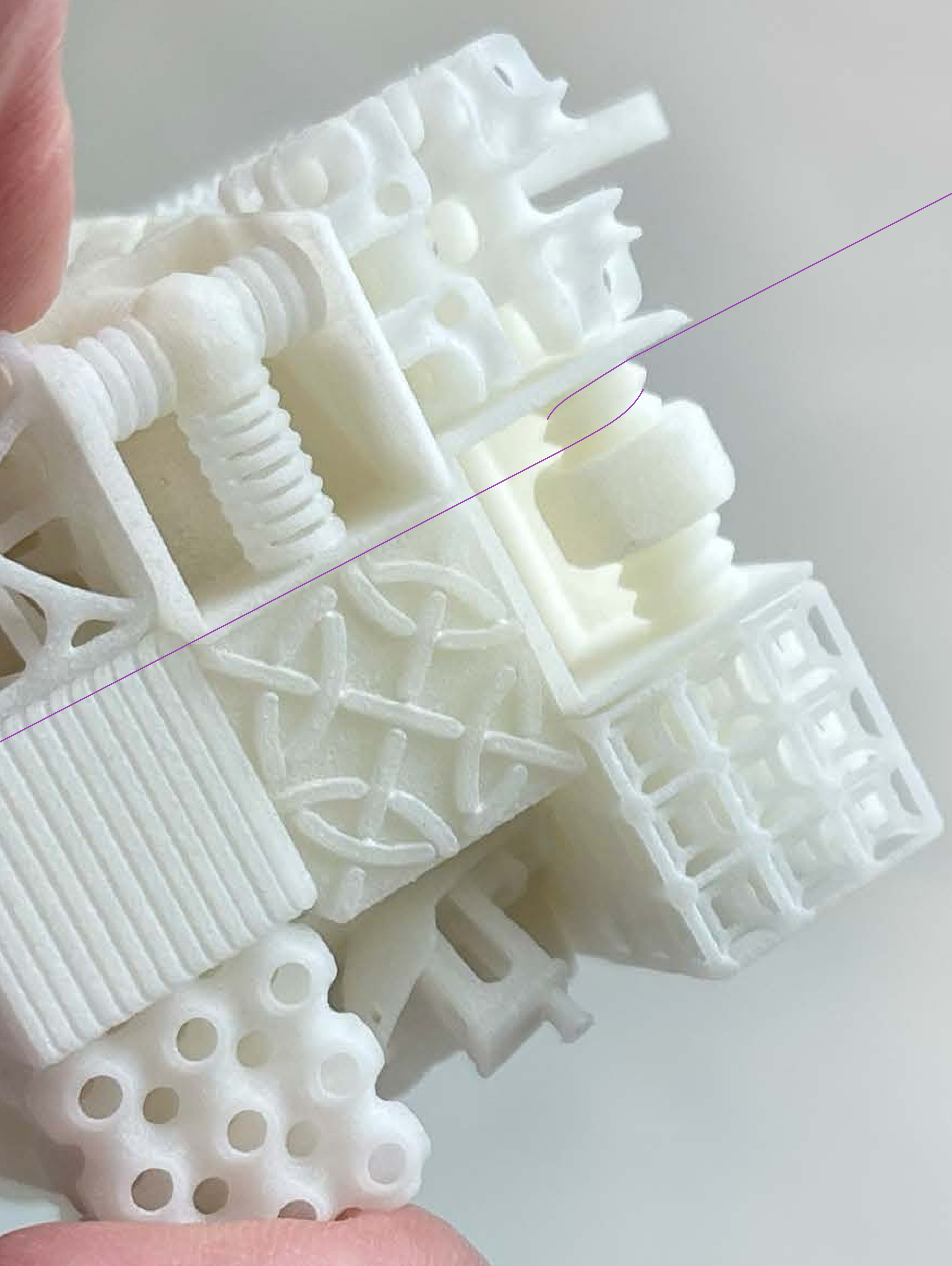
Fits are used to establish tolerances between inner and outer features of bearings, bushings, shafts or drilled holes. Fits are often represented as a shaft and a hole, although they include other parts that are not strictly cylindrical. The two fitting types are:

Clearance fit: With this fit, the shaft can slide and/or rotate in the hole when assembled, requiring no force — because the hole diameter is larger than the shaft diameter.

Interference fit: The hole diameter of an interference fit is smaller than the shaft diameter. This means significant force is required during assembly and disassembly, but it also provides a reliably strong connection.

Min. gap clearance fit: 0.1 mm





Screws and Threads

If plastic threads will be sufficient for your polymer 3D printing application, you can print them directly with your FDR system. This will eliminate a notable time-consuming step in the process. Alternatively, threads can be conventionally cut into the material.

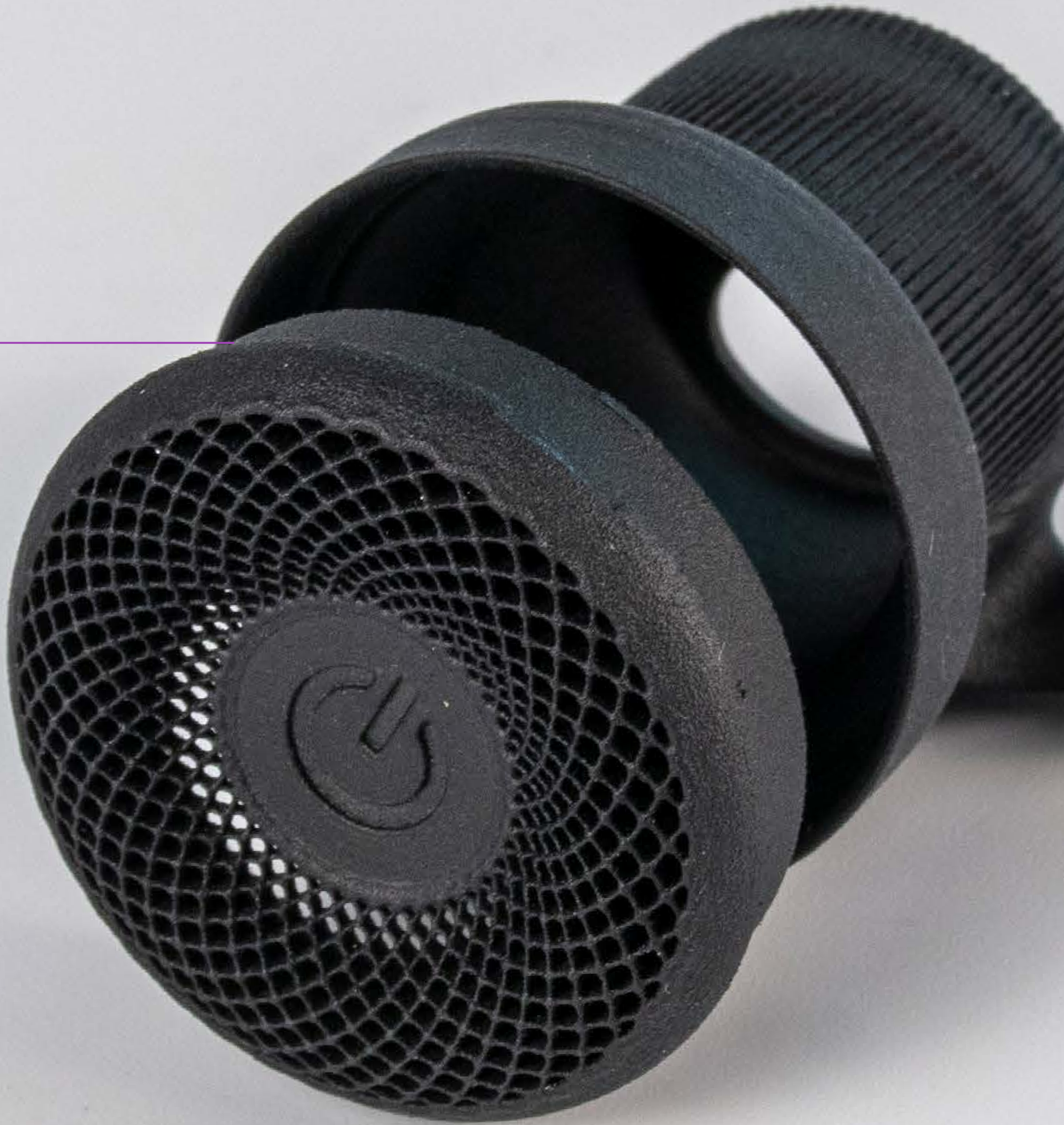
Size of threading	M3	M4	M5	M6	M8	M10
Recommended thread lash (S)	0.05	0.05	0.05	0.05	0.10	0.15

Typically, we recommend a hybrid solution: Threaded metal inserts provide a strong, reusable and permanent thread in plastic parts, and they are typically used when frequent assembly and disassembly are required for service or repair. These inserts are often available in brass, stainless steel and aluminum, and can be installed in the polymer 3D-printed part using various techniques (heat-staking, ultrasonic vibrations or a self-threading insert).

Snap-fit Connections

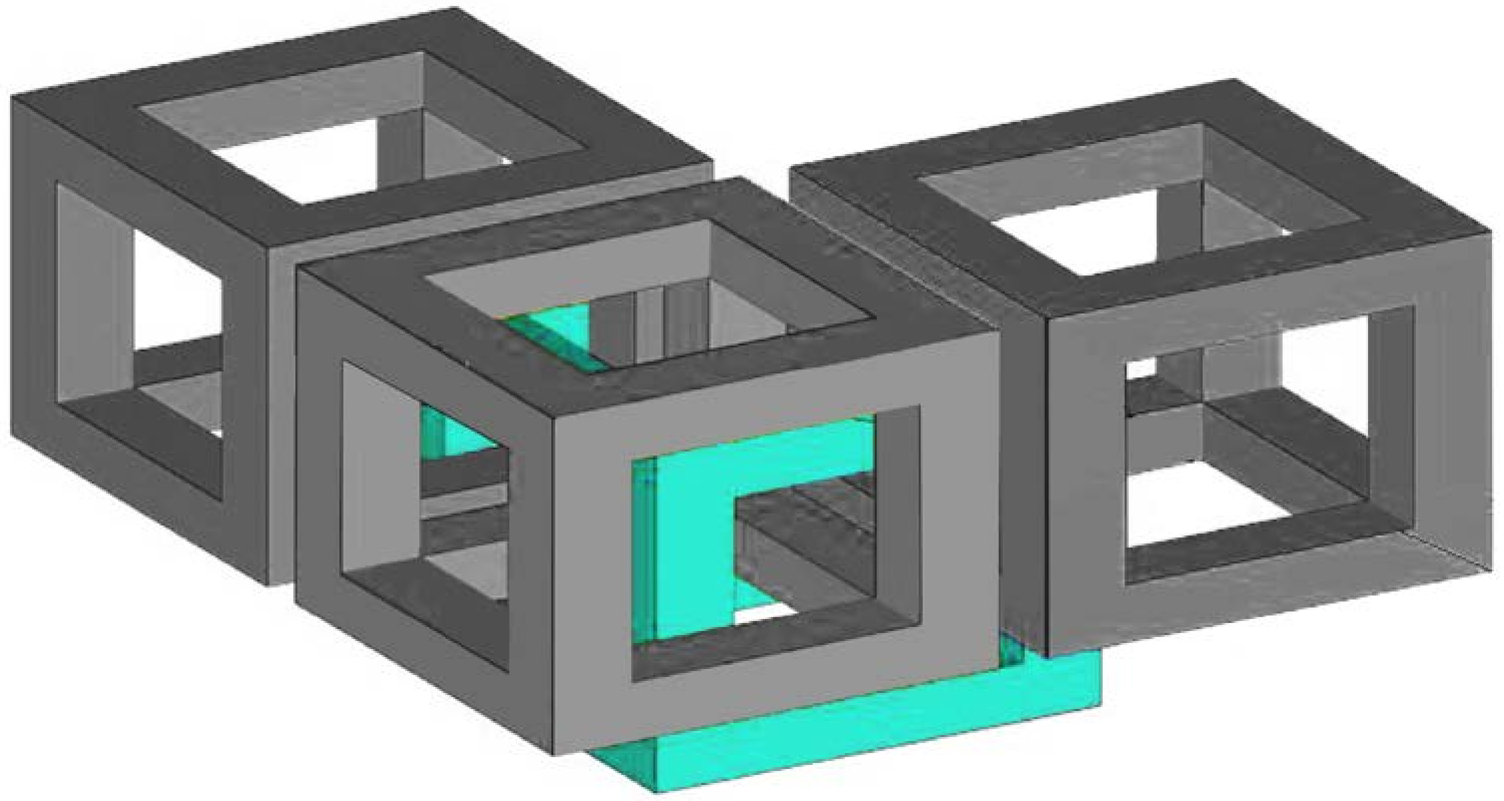
In a snap-fit, a feature that sticks out from one part, such as a hook, moves from its original position to be fitted into a slot of another part, allowing the two parts to be attached. The component then returns to its starting position. Snap-fits make the assembly process much faster and more efficient. Design has a major influence on snap-fits — specifically on their ability (or lack thereof) to be assembled and reassembled. The following two applications show two different snap-fits: annular and cantilever.

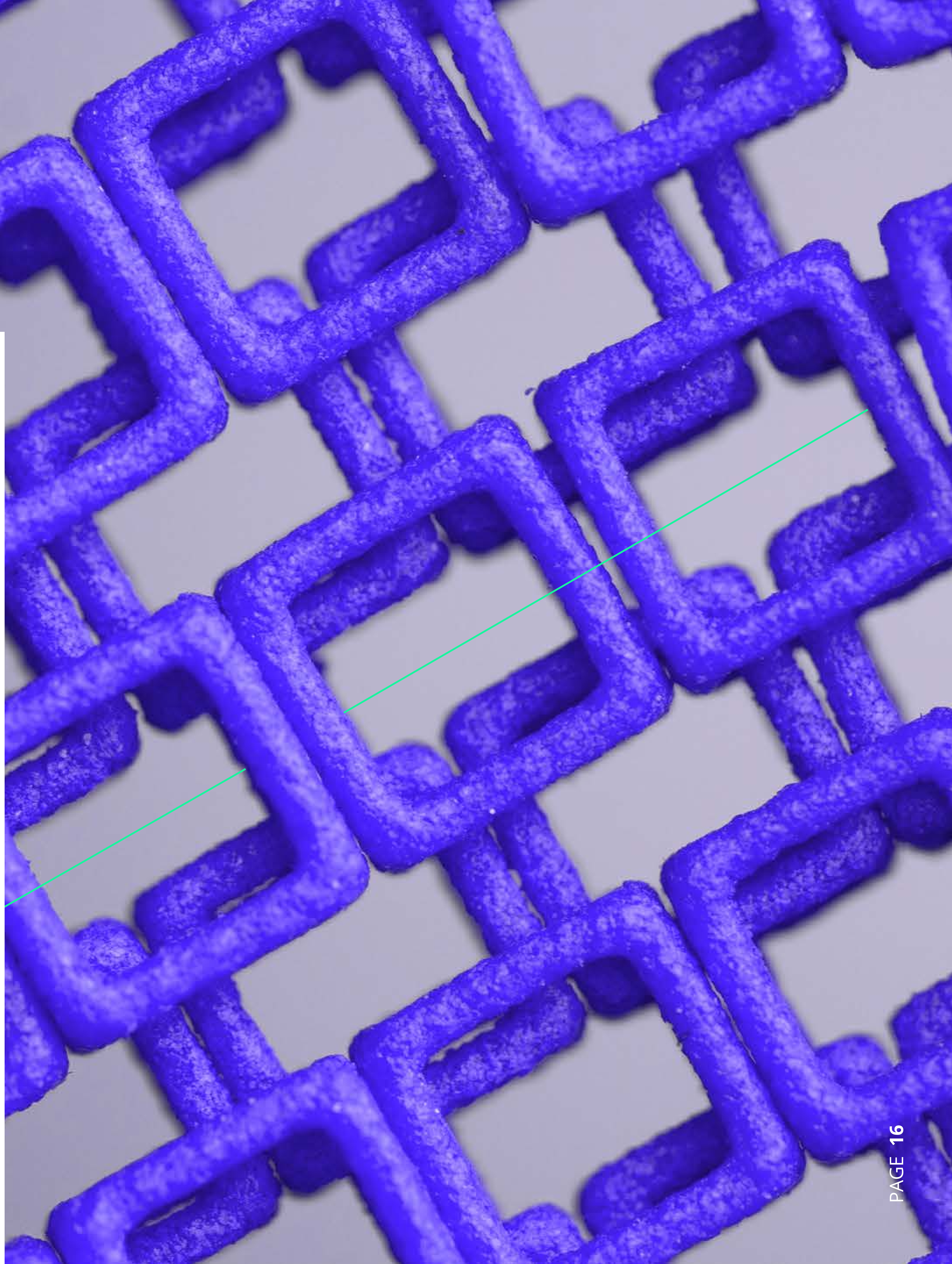
The annular snap-fit uses one part that features a mating lip and another with an undercut to allow them to connect. It typically involves two circular or cylindrical parts or two parts that are rotationally symmetrical. The counterpart to the ball should be conical or smaller than the diameter of the sphere so that the connection snaps into place. A cantilever snap-fit ends in an overhang. It is the most common snap-fit, and its strength depends on a sturdy assembly. It is important to ensure that the overhang is rounded and that the counterpart into which it snaps is not rounded, so that the connection can be released again.



Interlocking Parts

Interlocking parts are ideal for the design of numerous products, ranging from jewelry and clothing to carpets. With FDR, there is no limit to the shapes you can realise, which means there are no limits on the creativity of designers. The minimum distances can be compared to the values of hinges without assembly.





DATA
EXPORT

STL Export – Triangulation

When exporting a part design from the file type of its original software to the STL format, resolution plays a major role in the part‘s ultimate surface quality and accuracy. Generally speaking, a high resolution means a large number of triangles and a greater file size. Striking a strong balance between resolution and data size is always wise. Typically, the STL file size is between 1 MB and 30 MB, dependent on the complexity of the component.

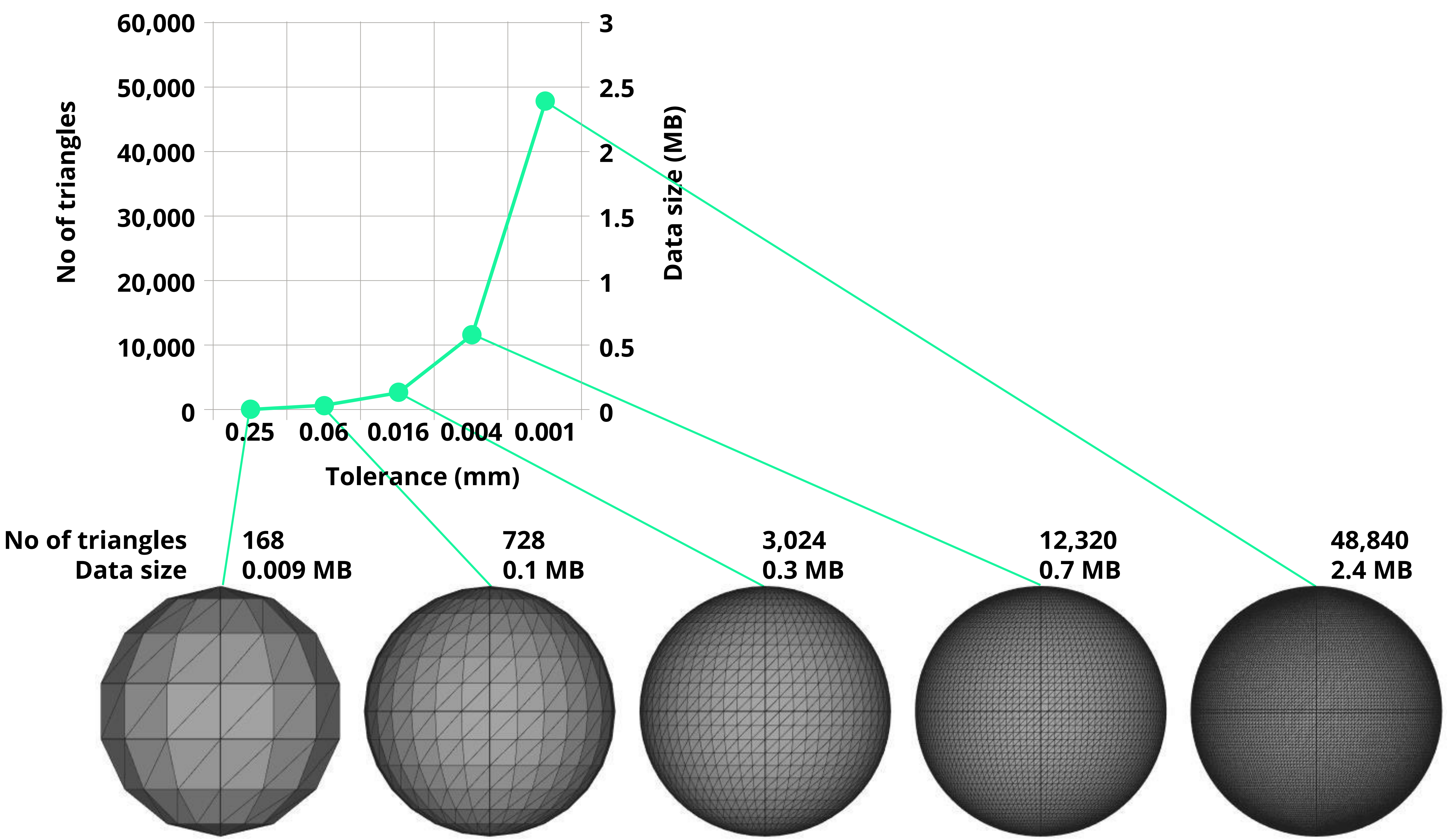
The parameter settings for exporting an STL file vary based on the design and data preparation software you are using. Parameters such as output type (Binary, ASCII, etc.), deviation chord tolerance and angle tolerance may require manual entry. The recommended export settings are:

Output type: Binary
Deviation chord tolerance: 0.01 mm
Angle tolerance: 1.5°

STL Export – Triangulation

The values must be adjusted if the file size becomes too large.

Effects of resolution on surface quality (Diameter: 20 mm)

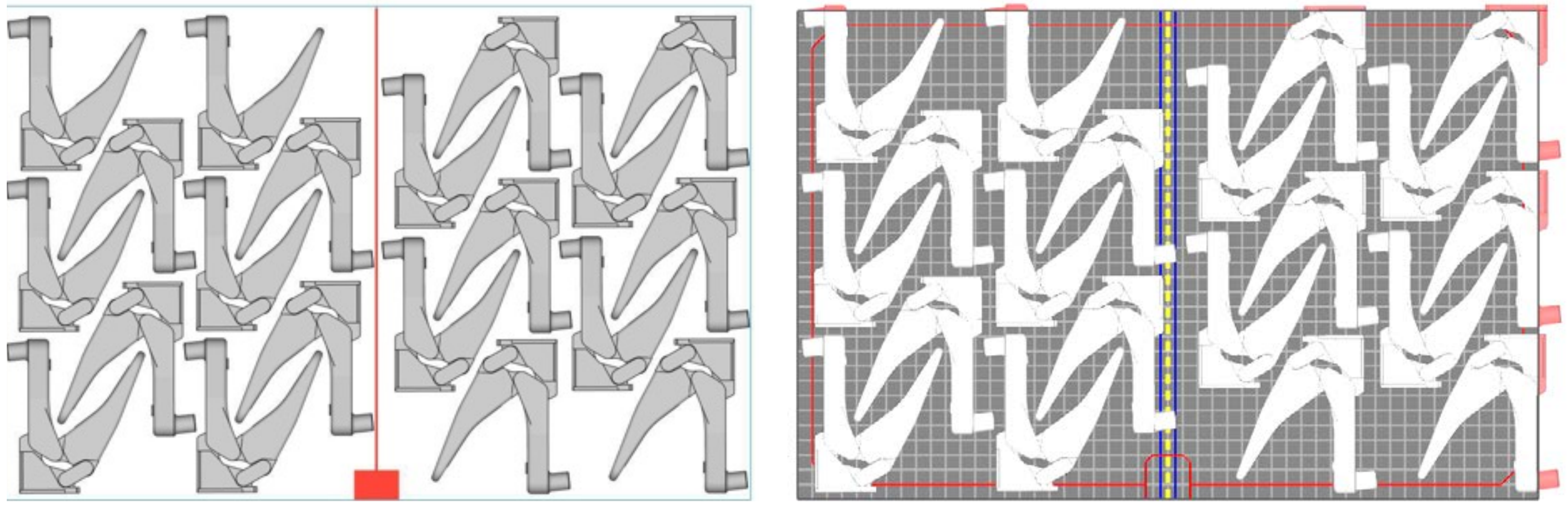


DATA PREPARATION/ ORIENTATION

Scaling

During the SLS printing process, polymer material will expand as it grows hot, but then begin to shrink during cooling — as per the natural behavior of virtually all polymer materials in hot and cool environments. To guarantee that the final component is produced at the desired size, it must be scaled per appropriate dimensions to compensate for any shrinkage. Proper shrinkage values depend on material, machine, part geometry and properties. They are specified in EOS parameter sheets and can be adjusted if necessary.

To ensure all components fit into the build space after scaling, we recommend working with downscaled build spaces when preparing the build job in Materialise Magics and making final data preparation adjustments in EOSPRINT 2. Therefore, the effective build volume will differ slightly from the physical printable area. You can tackle that issue by prescaling in Materialise Magics (based on the global scaling information from an EOS parameter sheet) and then scaling in EOSPRINT 2, even if dealing with bulky parts.

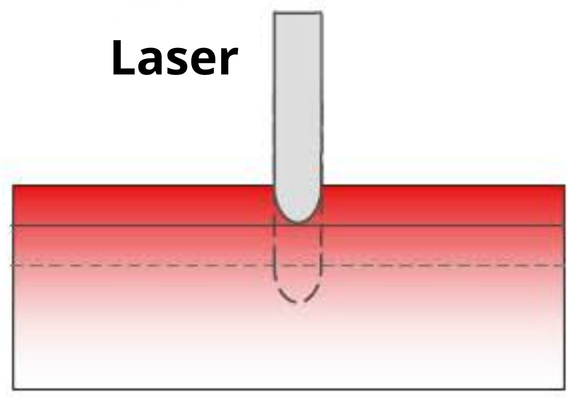


Build job preparation in Materialise Magics (left) **without** pre-scaled build space.
After scaling in EOSPRINT 2 (right), the parts no longer fit into the printable area.

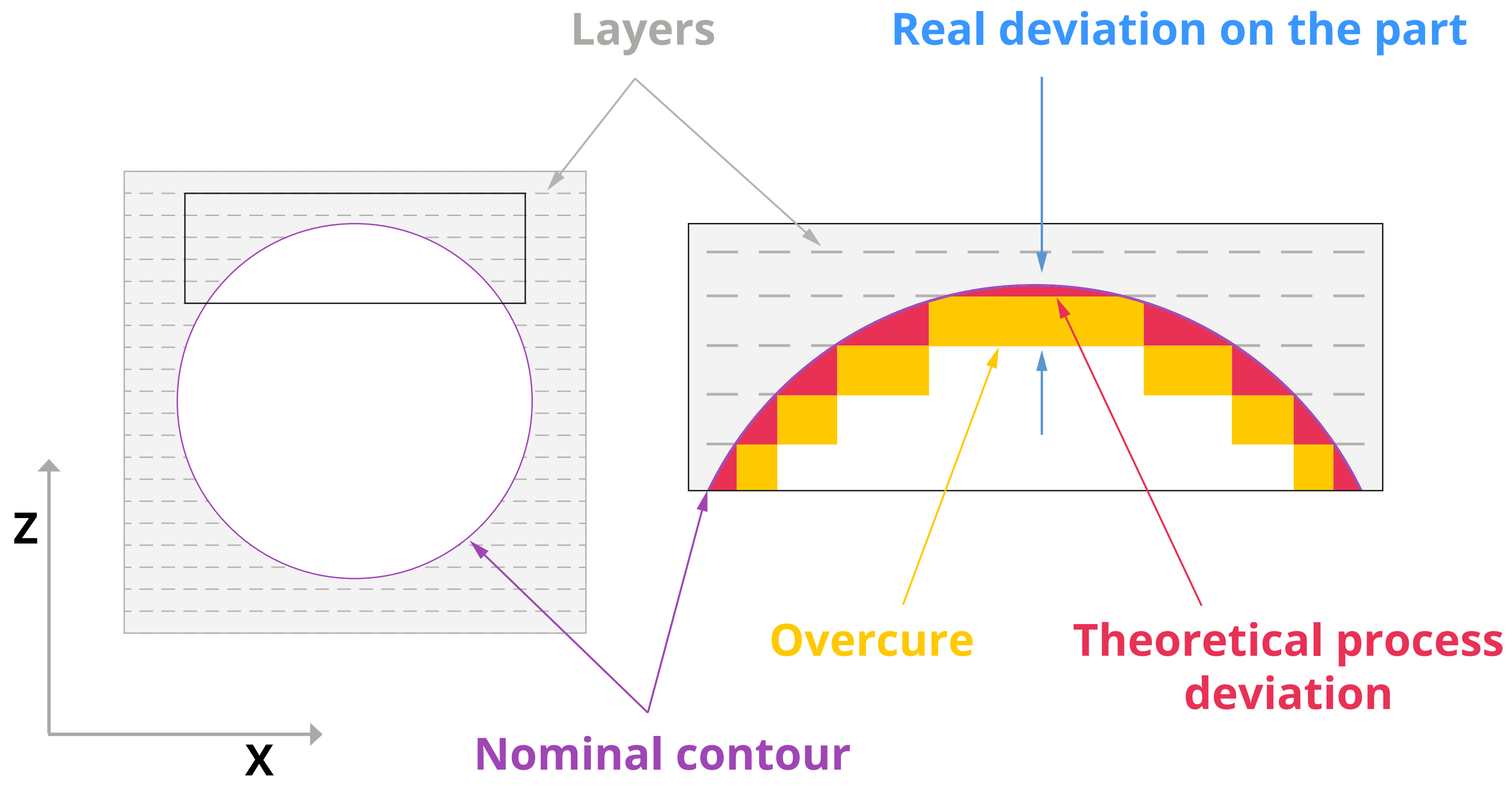
Overcure Effect

Like in SLS, the laser in an FDR system will penetrate deeper than the last recoated layer and reach the loose powder bed. As such, the first layer turns out thicker than required. This so-called overcure effect can be prevented by Z-compensation in Materialise Magics or an equivalent software platform.

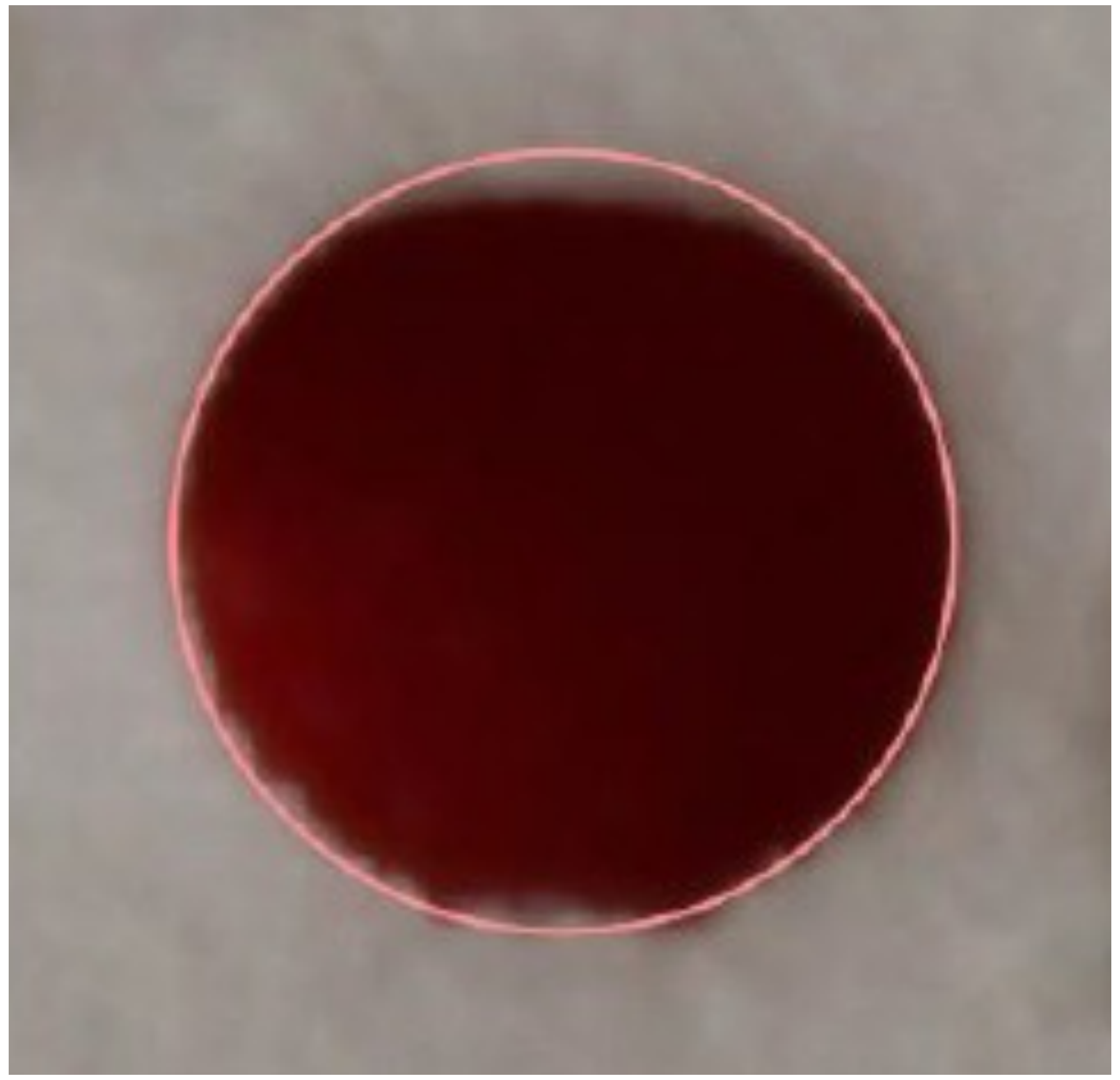
The downskin surfaces in the Z-direction will be shortened by a certain value, depending on the machine, the material and the parameters. For FDR, a 3-layer Z-compensation is recommended. Also, keep in mind that you must repair the STL files after data manipulation to whatever degree is necessary before the build begins.



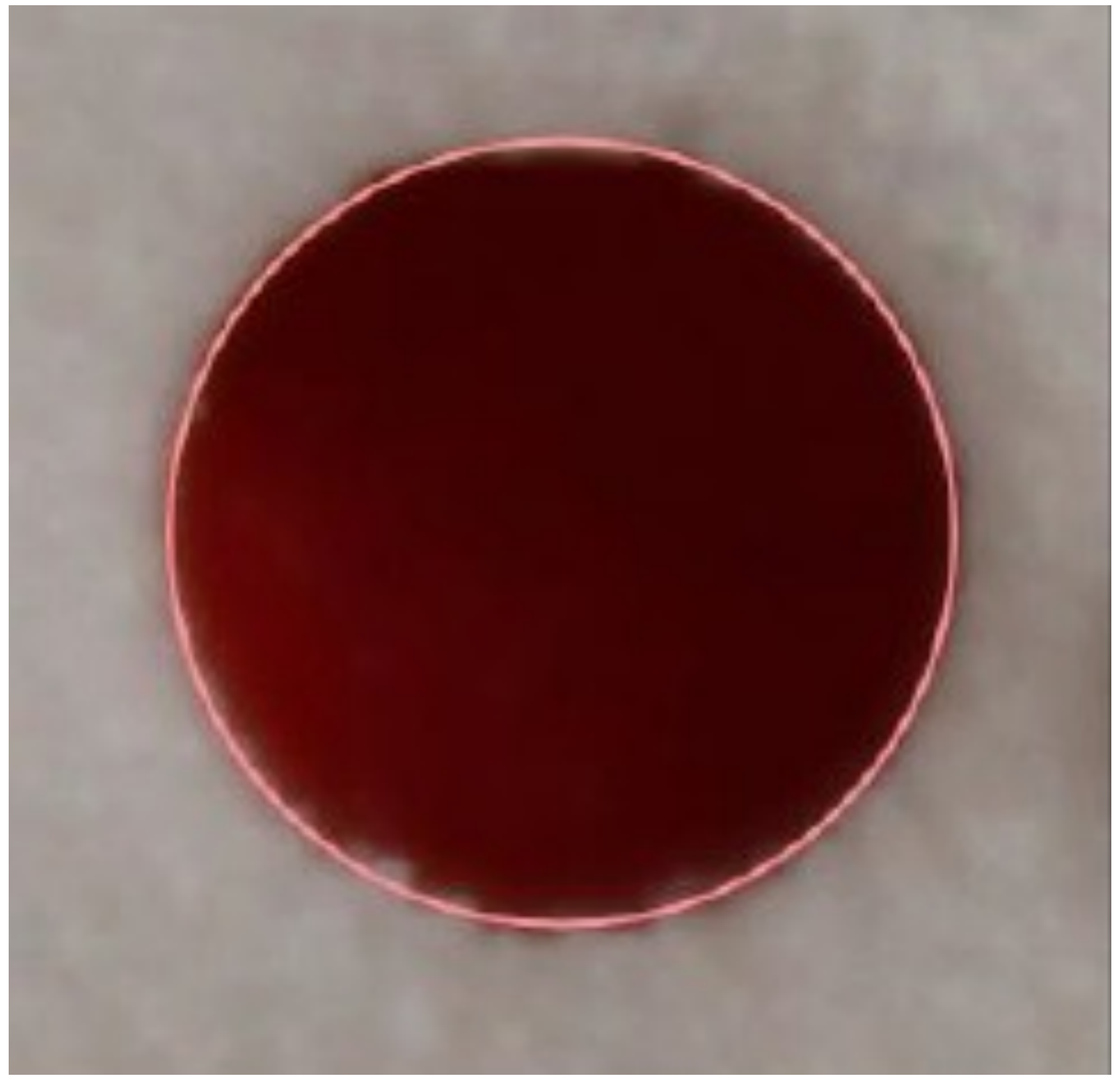
Schematic sketch of the overcure effect



Recommendation: 3x layer thickness, 120 µm



without z-comp

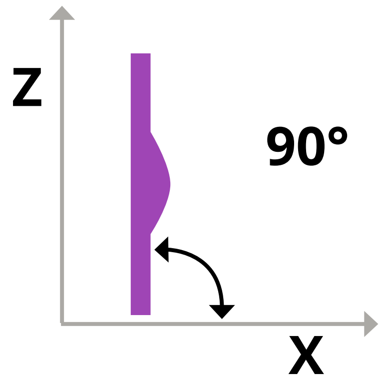


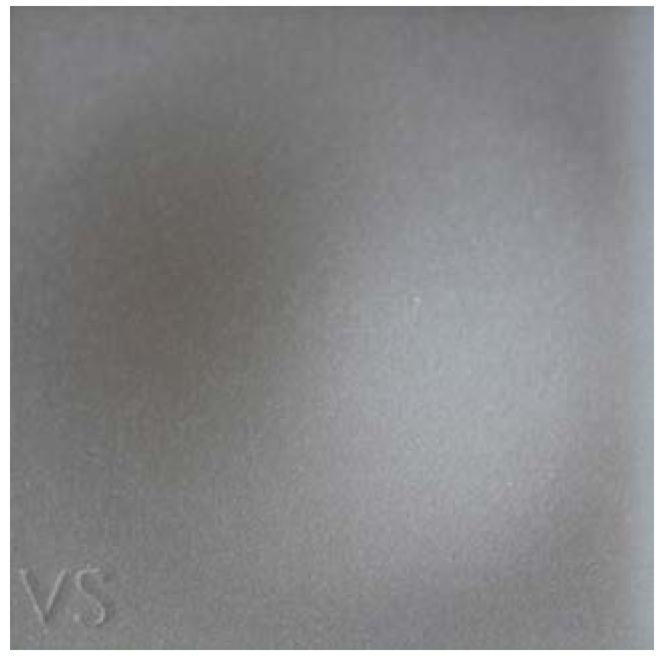
with z-comp

Stair Stepping

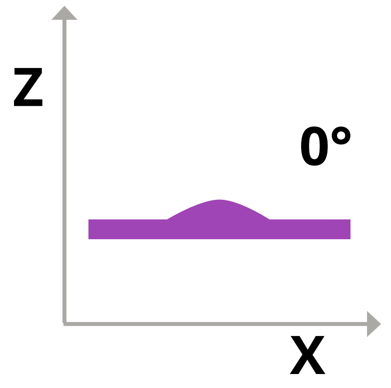
With a layer thickness of just 40 µm, the haptic and visual effect of steps on the surface of a component is reduced many times over. The difference between upskin and downskin is negligible, and even at very flat angles, it is difficult to see the stair stepping effect. If there should be no steps visible on a surface, then a flat orientation or an angle greater than 20 degrees is recommended.

Vertical Skin

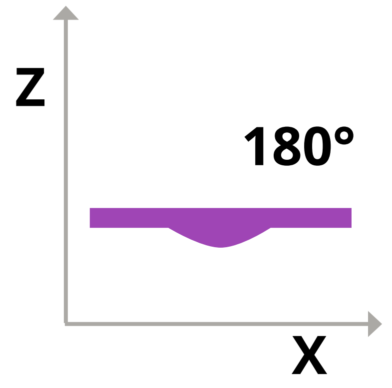




Upskin



Downskin

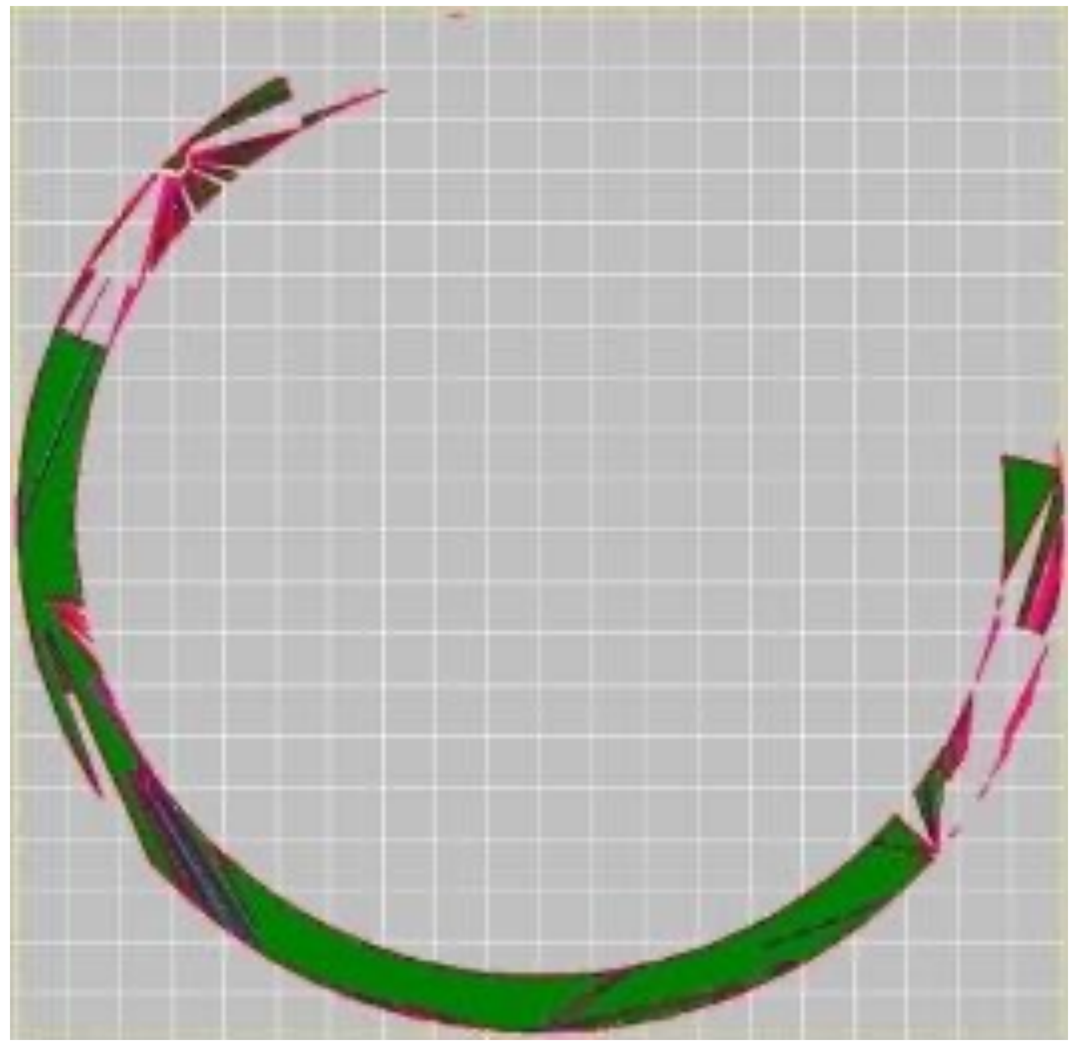


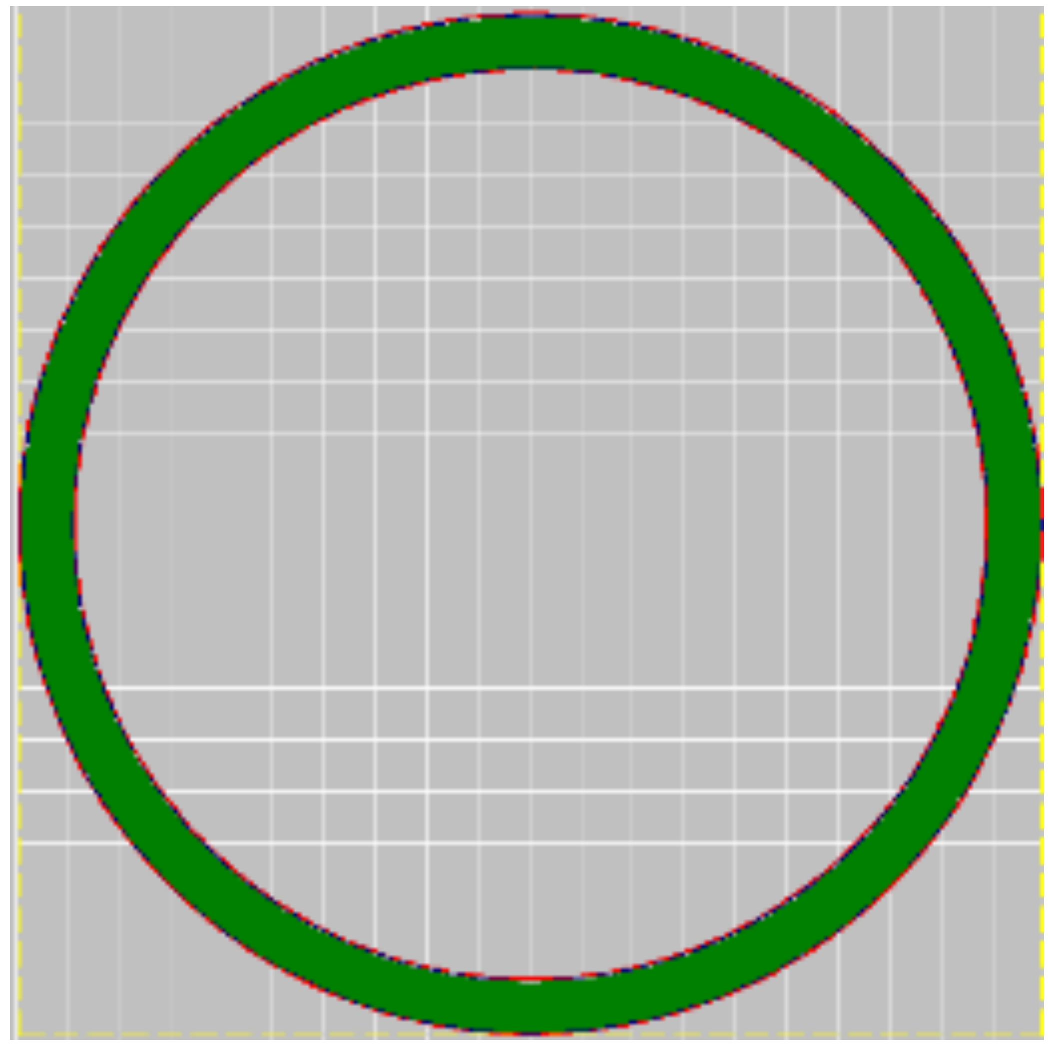
Stair stepping effect hardly visible. No difference between upskin and downskin. Avoiding the effect completely angle between part surface and X/Y-plane: 0° or ≥ 20°.

Slice Error

These „Slices“ appear as defective triangles in the top or bottom layers of a component and result from algorithm miscalculations, creating an uneven surface.

To avoid this problem, it is best to place the components at an initial height of 6.013 mm instead of 6.0 mm at a layer thickness of 40 µm. The recommended starting height may vary and depends on the material and system (see EOS application notes for more details.)





While FDR is currently in its nascent stages, research and development into this additive manufacturing technology continues unabated at EOS. In the not-too-distant future, it could be compatible with various other polymers, which will only broaden its use cases and create more new possibilities for designers and engineers alike.

As FDR is initially rolled out, it will only be natural for either new or current AM adopters to have certain questions beyond the scope of this introductory guide, but EOS experts can readily answer them. Contact the award-winning Additive Minds Consulting team for general and strategic advice on everything from early planning and design to the build and post-processing phases.

GET IN TOUCH

www.eos.info

EOS3DPrinting

EOS3DPrinting

EOS