What is dimensional accuracy in 3D printing and how do you achieve it?

What is dimensional accuracy in 3D printing and how do you know which technology will yield the most accurate results? This article compares the expected dimensional accuracy of various 3D printing technologies to help designers and engineers choose the right solution for their application.

Dimensional accuracy in 3D printing refers to how closely the measurements in your CAD design match those of the part once it's printed. It's a key consideration if your components need to fit together precisely or if you're manufacturing sizable assemblies.

Many factors can positively (or adversely) affect the dimensional accuracy of your 3D printed parts, including the quality of your filament , thermal contraction and/or over- or under-extrusion (for FDM specifically). Other factors, including the quality of the machine, machine calibration, quality of resin and post-processing , can also affect the dimensional accuracy of your parts.

When it comes to achieving dimensional accuracy, each additive manufacturing technology has its strengths and weaknesses. The two most important factors that govern whether your printed part will match its design specifications, apart from the technology itself, are its design and materials.

In this article, we'll compare the expected dimensional accuracy of the 3D printing technologies we offer to help designers and engineers choose the right solution for their applications.

3D Printing for Beginners - Make perfect parts every time

Knowledge base ⌄

How do materials affect dimensional accuracy?

Accuracy in 3D printing depends in part on the materials you use. In many cases, enhancing specific material properties will mean sacrificing accuracy. For instance, a standard SLA resin will produce more dimensionally accurate parts than a flexible resin.

For parts where high accuracy is critical, we recommend you use standard printing materials. High-quality, industrial materials, such as Nylon and Ultem, are both strong and accurate will be more expensive.

How do you measure dimensional accuracy in 3D printing?

To quantify the dimensional accuracy of 3D printed parts, we use the following parameters.

parts. These are defined with respect to well-designed parts on well-calibrated machines.

- *Warping or shrinkage* - the likelihood a part will warp or shrink while printing. While design plays a big role in determining whether parts will warp or shrink, some processes are inherently more prone to warping or shrinkage than others.

- *Support requirements* - for many 3D printing technologies, the number of supports you have to remove after printing will affect the accuracy of a part's surfaces and features.

Dimensional accuracy of FDM 3D printing

FDM (fused deposition modeling) is ideal for low-cost prototyping, where form and fit are more important than function. It's the most accessible form of 3D printing, and one of the most widely used across most industries.

FDM machines produce parts by extruding a thermoplastic material onto a build plate one layer at a time, from low-cost PLA or ABS for prototyping to industrial aerospace parts made from high-strength thermoplastics like Nylon and Ultem.

Typically, small parts are limited by extrusion spot size and gantry positioning accuracy. On the flip side, large parts are limited by shrinkage due to non-uniform cooling that comes from the temperature gradient mid-build.

For large parts, this can lead to big variations in temperature across the build platform. As different areas of the part cool at different rates, internal stresses cause the print to deform, leading to warping or shrinkage. Solutions like printing rafts, heated beds and radii at sharp edges and corners help to reduce this effect.

Lastly, FDM parts require support structures. Even though build prep software takes into account the supported sides and will often make adjustments to hit the ideal dimensions, post-processing can introduce some dimensional inaccuracy for parts that require a significant amount of support material.

Of course, different materials are more prone to warping than others. [ABS](#) is more susceptible to warping than [PLA](#) , for instance.

Finer points for dimensional accuracy of FDM

Parameter	Finer details
Dimensional tolerance	prototyping (desktop): ± 0.5% (lower limit: ± 0.5 mm) industrial: ± 0.15% (lower limit: ± 0.2 mm)
Shrinkage/warping	Thermoplastics that require a higher print temperature are more at risk. Adding a radius on the bottom edge in contact with the build plate or a brim is recommended. Shrinkage usually occurs in the 0.2 - 1% range depending on the material.
Support requirements	These are essential to achieve an accurate part. Required for overhangs greater than 45 degrees.

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Dimensional accuracy of SLA 3D printing

SLA (stereolithography) printers use lasers to UV cure specific areas of a resin tank to form solid parts one cross-section at a time. These cured areas, however, are not at full strength until post-processing with UV. As well, the typical printing angles and orientations of SLA can lead unsupported areas to sag.

This effect is especially prevalent in taller SLA parts, which have dimensional discrepancies thanks to the layer-by-layer build process. Dimensional discrepancies can occur because of the peeling process used by some SLA printers.

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Resins that have higher flexural properties (less stiff) are at a greater risk of warping and may not be suitable for high-accuracy applications.

SLA parts also require the parts to be anchored to the build plate and that angles lower than 45 degrees be supported. Support removal from SLA parts can often be considered an art and requires highly skilled technicians to remove supports and provide light sanding to those surfaces.

Finer points for dimensional accuracy of SLA

Parameter	Finer details
Dimensional tolerance	Prototyping (desktop): ± 0.5% (lower limit: ± 0.10 mm) Industrial: ± 0.15% (lower limit: ± 0.01 mm)
Shrinkage/warping	Likely for unsupported spans.
Support requirements	Essential to achieve an accurate part.

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Dimensional accuracy of SLS and MJF 3D printing

SLS (selective laser sintering) produces parts with high accuracy and can print designs with complex geometry. A laser selectively sinters powder one layer at a time to form a solid part.

HP's Multi-Jet Fusion (MJF) is similar to SLS, in that they both use heated build chambers, are powder-based and can produce parts with high accuracy using production-grade powders. The biggest difference between the two technologies is that MJF uses a solution to bind the powder and a heat lamp to cure the powder layer by layer.

To restrict the likelihood of parts warping or shrinking during printing, MJF and SLS printers use heated build chambers that heat up the powder to just below the sintering temperature.

MJF and SLS parts do not need to be anchored to the build plate and are suspended in the powder during the build. The heated powder allows for slower temperature changes and aids in dimensional accuracy. This results in temperature gradients in large SLS and MJF parts where the bottom of the part has cooled while the recently printed top layers remain at an elevated temperature. To further mitigate the likelihood of warping occurring parts are left in the powder to cool slowly (often for 50% of the total build time).

Finer points for dimensional accuracy of SLS/MJF

Parameter	Finer detail
Dimensional tolerance	± 0.3% (lower limit: ± 0.3 mm)

| Shrinkage/warping | Shrinkage usually occurs in the 2 - 3% range however most SLS and MJF print providers allow for this in the design.|

| Support requirements | Not required. |

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Frequently asked questions

Why is dimensional accuracy important? ⌄

How can you improve dimensional accuracy? ⌄

Which 3D printer offers the highest accuracy? ⌄


What are dimensional tolerances? ⌃

Dimensional tolerances are the numerical ranges of measurements that you assign to the dimensions of a part. These indicate how much a manufacturer can differ from the design's nominal measurement. They are essential to the manufacturing process.

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More resources for engineers

Product development & manufacturing: how do you source parts for the initial prototyping stage
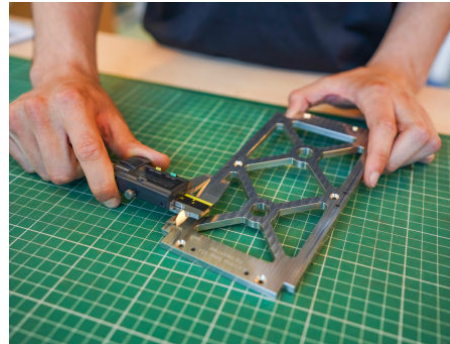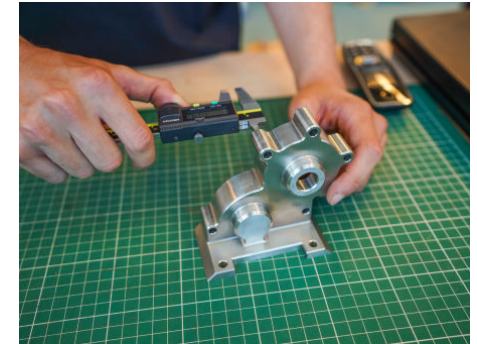

What is GD&T? How to reduce manufacturing errors and improve quality

What is Geometric Dimensioning and Tolerancing (GD&T) and how

How do you design parts for MJF (Multi Jet Fusion) 3D printing?

Multi Jet Fusion (MJF) 3D printing can create highly accurate, complex industrial parts more

What is design for manufacturability (DFM)?

Design for manufacturing (DFM) means taking a design-first approach to manufacturing. In this

What are the best manufacturing processes for creating initial prototypes? This article covers the key benefits of prototyping with ~~~~ these processes.

is it used? This article explores the basics of how and when to use GD&T to get the best results out of custom part manufacturing

efficiently - and potentially more cost-effectively - than other industrial 3D printing processes. This article covers how to design

article, we look at the overall DFM process, the necessary steps for a successful outcome, examples of DFM done right and how to get

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