3D Printing vs. CNC Machining: Differences & Comparison

Xometry

Table of Contents

Introduction	3
3D Printing Definition and Comparison to CNC Machining	4
Advantages of 3D Printing Compared to CNC Machining	6
Disadvantages of 3D Printing Compared to CNC Machining	7
CNC Machining Definition and Comparison to 3D Printing	8
Advantages of CNC Machining Compared to 3D Printing	9
Disadvantages of CNC Machining Compared to 3D Printing	
Comparison Table Between 3D Printing and CNC Machining	10
Lead Cost and Speed Comparison	11
Volume Comparison	12
Materials Comparison	13
Alternatives to 3D Printing and CNC Machining	14
Other Alternatives for CNC Machining Besides 3D Printing	15
Summary	16

Introduction

3D printing, or additive manufacturing, builds 3D files as a series of co-bonded slices. These are constructed like a stack of pictures of finite thickness. The term 3D printing covers a range of methods and an even wider range of materials, accuracies, and costs. CNC (Computer Numerical Control) machining achieves similar results through subtractive manufacturing. It cuts the net shape of a part out of a block of material using rotating tools or rotating the workpiece or both.

CNC machining has design limitations but can be used with a variety of materials. If the material is rigid and can be cut, the chances are it can be CNC machined. Some flexible materials, rubbers, for example, can even be processed while cryogenically stabilized. Geometric restrictions apply, and enclosed hollows may require the assembly of two or more parts.

While the processes differ in almost every respect, they are direct competitors for the provision of solid parts. Both differ in very fundamental regards as CNC machining is subtractive, while 3D printing is additive. In this eBook, we will dive deeper into the comparison between 3D printing and CNC machining, their advantages, disadvantages, and alternatives.

3D Printing Definition and Comparison to CNC Machining

3D printing is a family of processes that have a common thread of methodology. Virtual models of 3D parts are software-rendered as slices. The thickness is determined to suit a particular machine or setting, and each layer is printed sequentially. The stacking of these slices and their co-bonding, both internally and to the other slices allows the construction of a part from finite 2D steps.

Some systems use a variety of materials including extruded polymer filaments, light sensitive resins, laser-melted powders, filament feedstock, waxes, and biological materials to print slices. In order for a 3D Printing process to take place, several tools are required, including CAD software to define the part design and export an STL file, a slicer software (such as PrusaSlicer or Cura) to turn the 3D file into a sequence of 2D machine instructions, and a 3D printer setup. The earliest commercially viable 3D printing systems began to come to market in the late 1980s. The technologies have broadened both in method and materials at an accelerating pace since then.

Compared to CNC machining, 3D printing offers improved cosmetics and more effective use of materials. It also requires no direct handwork in executing complex parts. Figure 1 below is an example of an FDM 3D printer:

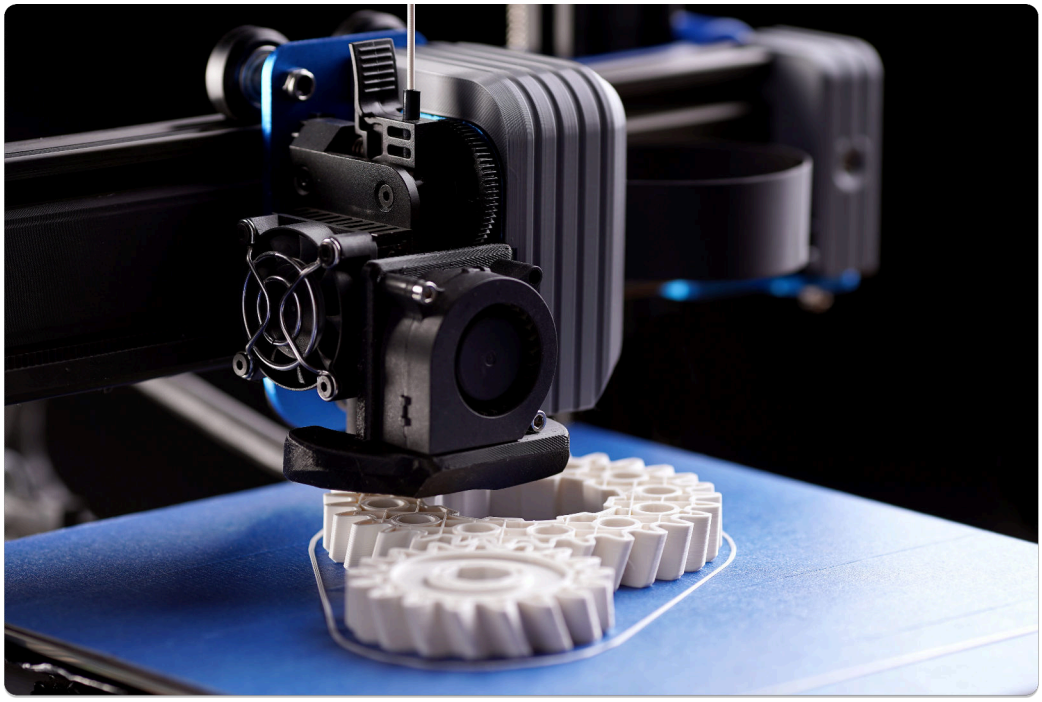


Figure 1. An FDM printer

What Are the Advantages of 3D Printing Compared to CNC Machining?

The advantages of 3D printing compared to CNC machining are:

1. 3D printing delivers net shape parts quickly, whereas CNC machining requires individual setup and (generally) manual programming plus supervision.
2. 3D printing is generally a lower-cost method than other ways of making complex net shapes. It requires minimal setup and operational intervention. It’s common for CNC components to be 10x the price of 3D printed parts.
3. 3D printers that are office-friendly and require only modest skills in setup and maintenance. They are also increasingly capable of satisfying the majority of needs. CNC remains a heavy-engineering and highly skilled process requiring constantly operators to maintain a high level of skillset.

What Are the Disadvantages of 3D Printing Compared to CNC Machining?

The disadvantages of 3D printing compared to CNC machining are:

1. Various 3D printing processes can vary in strength output compared with the “native” properties of the materials. For example, as low as 10 % of material UTS (Ultimate Tensile Strength) for FFF (Fused Filament Fabrication) in ABS is reported, and as much as 100% for SLS of nylon. CNC machining produces parts in undisrupted native materials, so the strength is generally high.
2. 3D printing can achieve good dimensional accuracy, but where high precision is required it can be challenging. CNC machining is highly precise and allows improved accuracy by slower processing.
3. 3D printing is generally affected by process mechanics concerning surface finish. Z-resolution in particular brings stepped surfaces and visual disruptions. CNC surface finish is as machined; it can be extremely uniform and highly precise if cutter paths are programmed for a smooth finish.

CNC Machining Definition and Comparison to 3D Printing

CNC machining is a computerized manufacturing process that uses preprogrammed software and codes to control the movement of machine tools. It is a technology that uses a range of complex machines such as lathes, mills, and grinders to accurately and precisely cut, create, and shape different parts.

In 1949, John T. Parsons introduced the first numerically controlled machine, focusing initially on helicopter and aircraft blades. By 1952, J.F. Reintjes and his MIT team developed the first prototype CNC milling machine. The commercial breakthrough came in 1958 when Richard Kregg, with MIT, launched the Cincinnati Milacron Hydrotel, making it the first available CNC machine on the market.

CNC machining requires a complex setup and expensive outcomes. However, if the parts require long-term wear properties, strength, smooth surface, and high precision, it's preferable compared to 3D printing. Figure 2 is an example of a CNC milling machine:

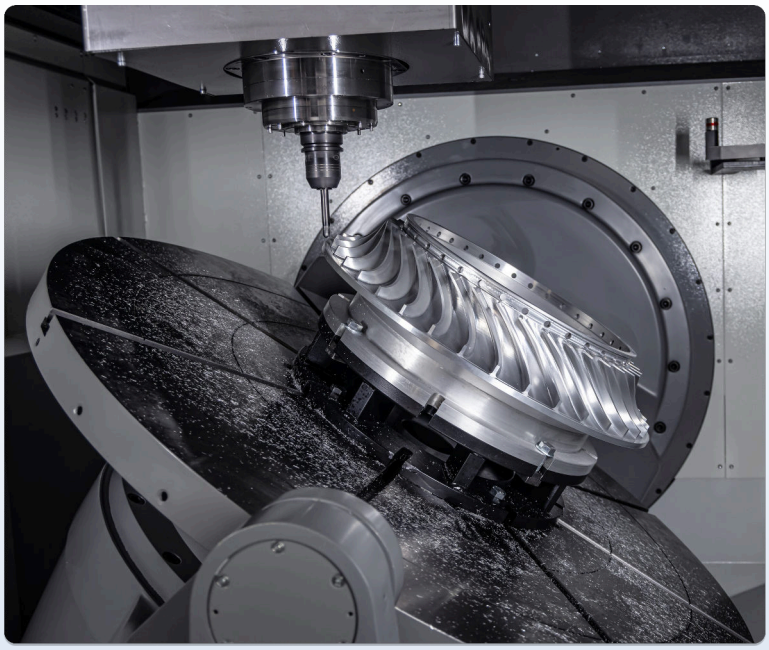


Figure 2. A CNC milling machine

What Are the Advantages of CNC Machining Compared to 3D Printing?

The advantages of CNC machining compared to 3D printing are:

1. CNC machining uses engineering materials and delivers the full properties of the materials, undisrupted by the process. 3D printing, on the other hand, can sometimes achieve this, but generally uses weaker material approximations.
2. CNC parts are more precise, as machine tolerances can be held closer than 3D print tolerances.

What Are the Disadvantages of CNC Machining Compared to 3D Printing?

The disadvantages of CNC machining compared to 3D printing are:

1. CNC machining often requires mounting tools to be made. This complicates the job considerably, whereas 3D printing makes free-floating parts built on a table or scaffold.
2. CNC machining removes material that is not required, creating ‘waste’ in the cutting process. 3D printing is characterized as a ‘low waste’ option.

CNC Machining Definition and Comparison to 3D Printing

Table 1 compares the attributes of 3D printing and CNC machining:

Attribute	3D Printing	CNC Machining
Unlimited material availability	No	Yes
Part Design	Unrestricted by process constraints	Limited by undercut and internal access, tool path and tool type, axis-defined minimum radii, and the need for repositioning mid-task
Precision	Processes vary from 0.016 resolution to 1 mm+. Typically around 0.2 mm	0.005 mm precision, where slow feeds, new cutters, and shallow cuts are employed
Operator Skill	Generally relatively low	Very high
Surface Quality	Grained, rough, and stepped; features are often blurred	Can deliver very high surface quality by using longer cut times
Strength	Often 10–20% of native material	Generally 100% of native material
Cost	Assume a cost of €X	Generally €5X to €10X

3D printing offers advantages in terms of cost and time to build parts. CNC machining, on the other hand, can deliver a close correlation to mass production characteristics whenever the precision of the part is a critical factor.

3D Printing vs. CNC Machining: Lead Cost and Speed Comparison

CNC machining will carry all of the programming and setup costs and it will be expensive in comparison to 3D printing – often five to ten times the price. However, whenever a series of prototypes with small adjustments are required, the modified CNC-cut parts will carry a much lower setup cost, whereas a second 3D printed part will cost the same as the first.

Preparation for the printing of a 3D component requires little time to set up before a print can commence. Although printing is slow by some measures, most prints will likely be completed within a few hours and be ready to use. CNC machining, on the other hand, requires skilled preparation of programming for cutter selection and cutter path. 3D printing offers advantages in terms of cost and time to build parts. CNC machining, on the other hand, can deliver a close correlation to mass production characteristics whenever the precision of the part is a critical factor.

3D Printing vs. CNC Machining: Volume Comparison

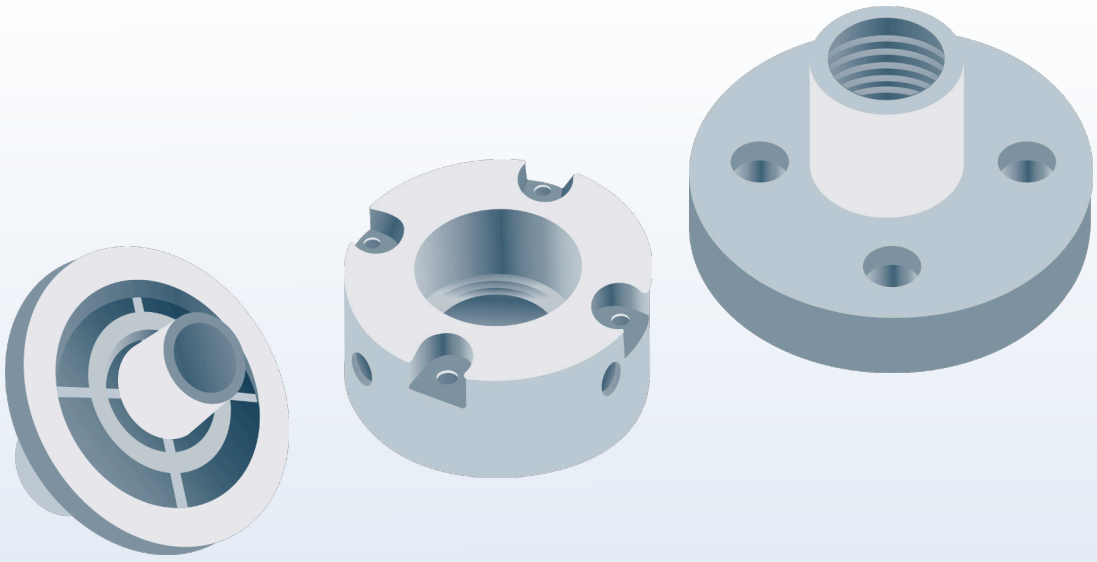
When the extensive setup effort can be shared over multiple parts, CNC machining can produce more cost-effective parts compared to 3D printing. 3D printing has fewer volume advantages, as each part takes the same material and machine costs, irrespective of volume and requires custom or modified jigs to retain the part during processing (including possible repositioning of the part). This can consume considerable time before the first cut.

Cutting, however, is generally fast, and complex parts can generally be completed in an hour (or less) of machining. Total time for preparation and machining can run into a day or more, depending on complexity.

3D Printing vs. CNC Machining: Materials Comparison

In material selection (and successful delivery of material properties), CNC offers better options. Essentially the material choice is open to all engineering materials, up to and including spark-erosion CNC machining of pre-hardened tool steels. CNC-machined parts deliver the native properties of the billet material, largely undisturbed by processing characteristics. 3D printed parts are restricted to those supported by particular processes.

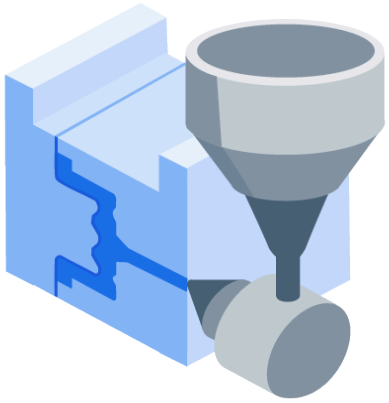
The construction methods of the particular 3D print technology impose severe restrictions on the delivery of properties. Prints are often weakened by anisotropic “grain” in the construction method, porosity, poor layer bonding, and the substitution of printable but non-engineering materials.



What Are the Alternatives to 3D Printing and CNC Machining?

An alternative to 3D printing and CNC machining is **injection molding**.

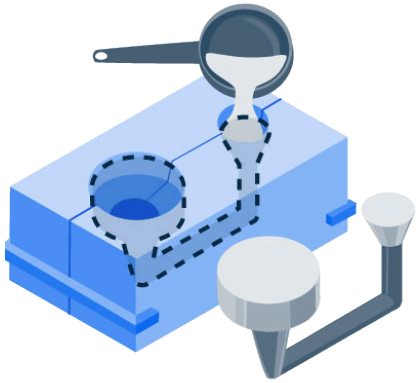
Injection molding can be considered an alternative to 3D printing and CNC machining of parts, in that it is a single-operation process to produce a net shape part that is identical to the 3D file. In reality, the tool-making process rules out the use of injection molded parts as a substitute for most 3D print applications – unless the required production volume is sufficiently high.



What Else Compares to CNC Machining Besides 3D Printing?

Another alternative to CNC machining is **die casting**.

Die casting, like CNC machining, is another method of producing a complex net shape in metal. However, there are considerable tooling costs in manufacturing a die-cast metal part. Nevertheless, as volumes rise, the case for die casting improves.



Summary

This article presented a comparison of 3D printing to CNC machining, explained what they are, and discussed their different attributes. To learn more about **3D printing** and **CNC machining**, contact a Xometry representative.

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