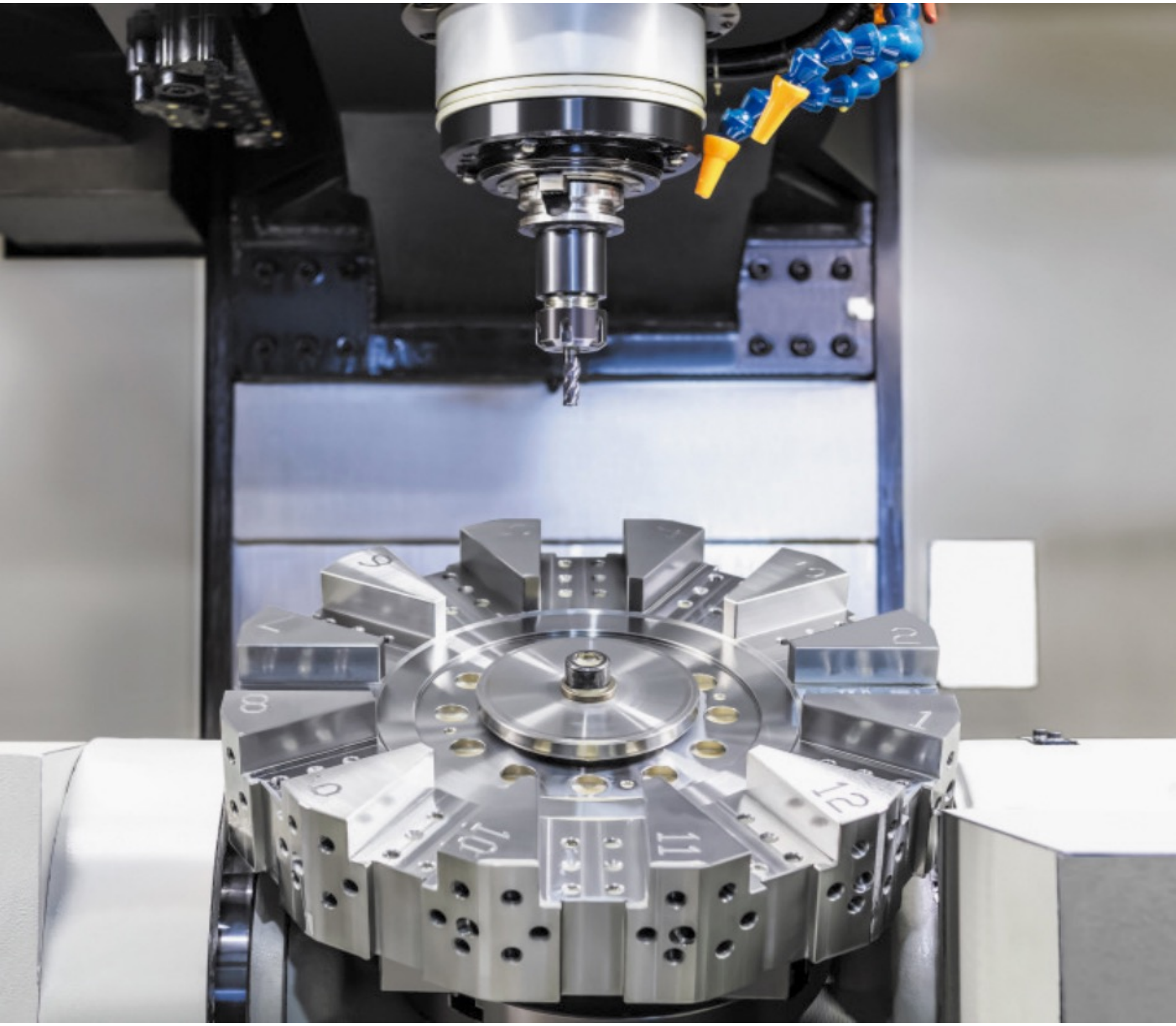
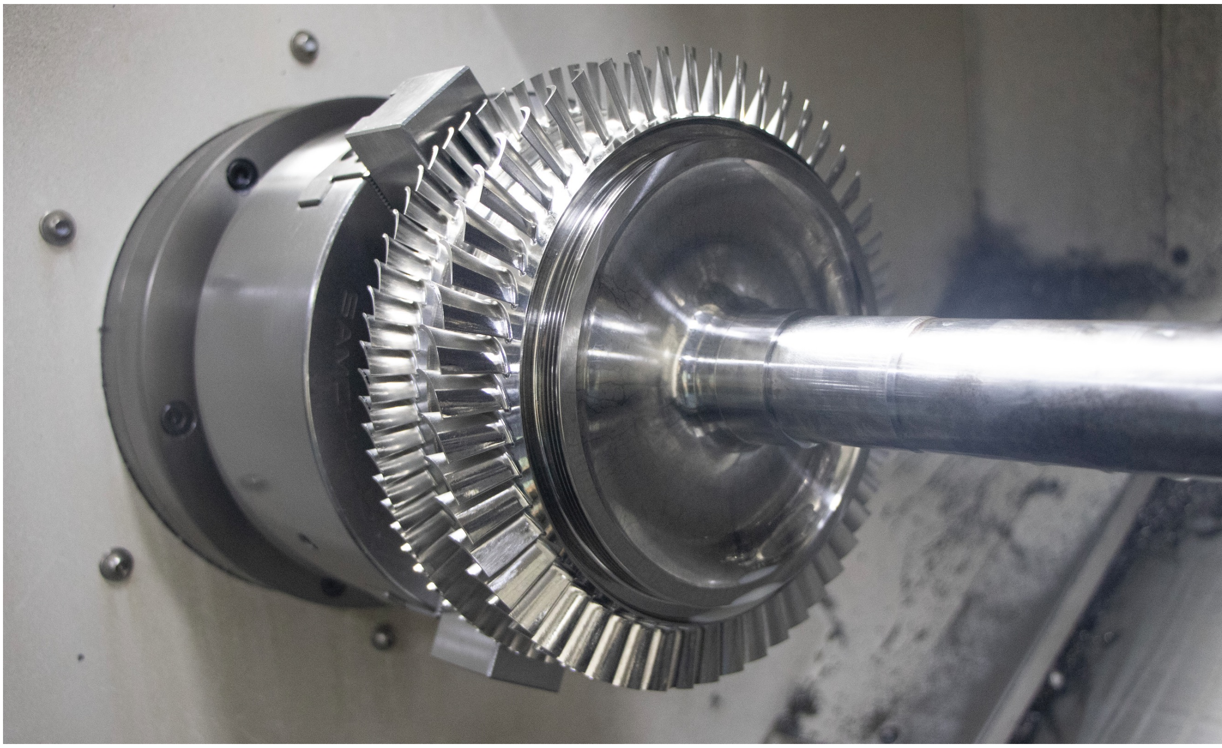


CNC Machining Design Guide

Understand every detail of your components with precision

A thorough understanding of the capabilities and limitations of the machinery is required to design parts for CNC machining. This guide outlines key design considerations and guidelines to ensure the best results for CNC machined parts.

Contents



What is CNC Machining

CNC machining is a computerized manufacturing technology that relies on pre-programmed codes and software functions to control the operation of machines, including grinders, milling machines, and lathes. These machines are used for cutting, shaping, and producing prototypes and finished components.

CNC machinists apply their expertise in mechanical systems, mathematics, and technical drawing interpretation to create a wide range of metal and plastic components.

In **CNC machining**, a part design is first developed using a CAD (Computer-Aided Design) software. This design is then converted into machine-readable code (G-code) and uploaded into the CNC machine. The CNC machine uses cutting tools to accurately remove material from the raw stock, shaping it into the final desired component.

CNC production machining is extensively utilized in the manufacturing sector to create high-precision, intricate parts from a variety of materials, including metals, plastics, and composites. Known for its speed, automation, and enhanced accuracy, CNC machining is also a highly scalable process, making it suitable for prototypes, small-batch production, and large-volume manufacturing alike.

CNC machines, such as vertical and horizontal milling machines and lathes, are capable of operating along multiple axes. Traditional 3-axis CNC machines can manipulate parts along three linear axes (X, Y, and Z) to produce relatively simple components. In contrast, **5-axis CNC machining** operates along the three linear axes while also incorporating two rotational axes, enabling the creation of more intricate and complex parts.

CNC Machining Process

1. Process design and production scheduling
2. Design and program
3. Product machining
4. Quality control
5. Surface finishing
6. Inspection before shipping
7. Packaging and shipping

Type of CNC Machining

Small batch CNC machining

Small-batch CNC machining refers to facilities focused on producing a limited quantity of complete production parts. In most cases, this applies to production runs of fewer than 10 to 1,000 parts. Small-batch (also known as low-volume) CNC machining has become increasingly popular.

•Bridges the gap between the original product design concept and prototype mass production.

•Reduces costs.

•Makes it accessible to more companies in the early stages of product development.

•Performs well for products with short life cycles.

•Makes customized designs relatively easy to implement.

Mass production CNC Machining

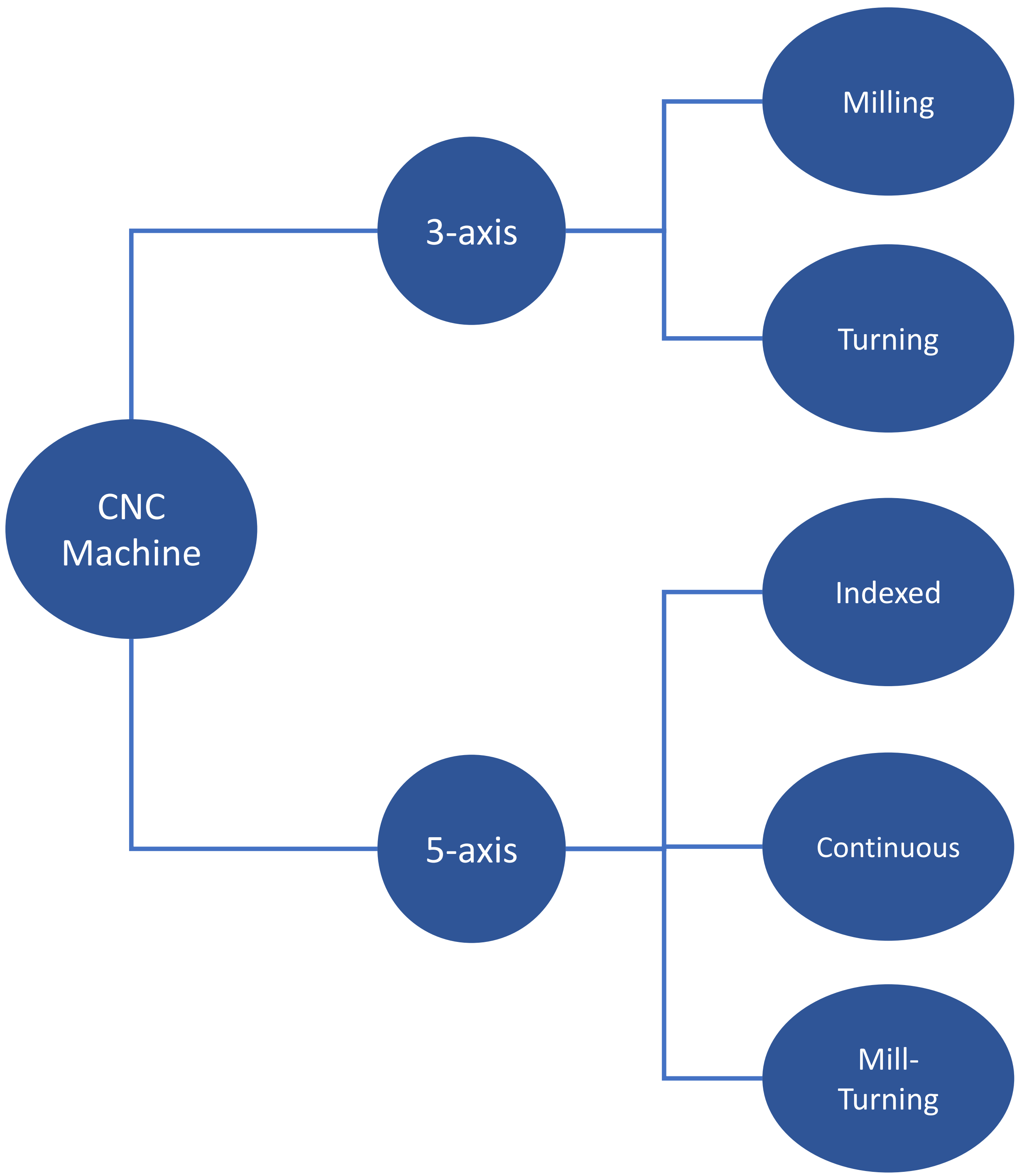
Mass production or large-scale CNC machining is used for high-volume, high-quality material production, capable of producing 1,000 or more parts. It is the preferred manufacturing method for many businesses, as it allows cost reduction while ensuring a sufficient supply of parts. Large-scale CNC machining is a widely used production technology due to its lower costs, reduced dependence on labor, and greater accessibility.

Custom or prototype CNC machining

Custom or prototype CNC machining is typically used for low-volume production during new product development (NPD). Advanced CNC machining and custom manufacturing technologies enable clients to use CNC machining for prototyping. This means that CNC prototypes can be created early in the design process, providing functional prototypes with the same look, feel, and functionality as the final product.

CNC machining is a popular choice for custom part manufacturing. Modern technological advancements have made CNC machining an excellent option for prototyping, as well as making it highly suitable for custom part production. CNC machining offers an affordable solution for producing custom and prototype parts.

Type of CNC Machine

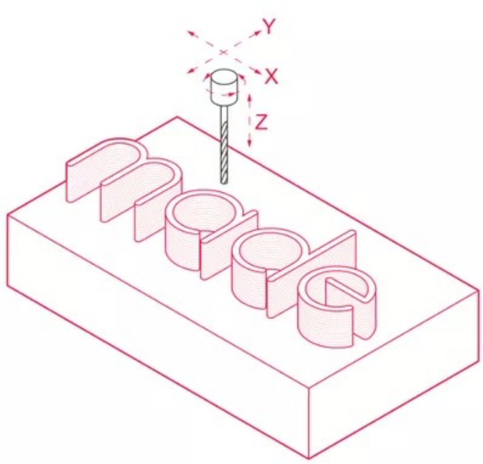


3-axis CNC Machine

CNC Milling

3-axis CNC milling is a subtractive machining process that uses a high-speed rotating cutting tool to remove material from a fixed workpiece. The tool is mounted on a spindle and can move along three linear axes.

CNC milling is the most widely used of all CNC machining processes, as it allows for high-precision machining of most simple geometric shapes. With relatively simple setup and operation, it offers low initial processing costs. However, as geometric complexity increases, 3-axis CNC milling has limitations. With only three axes available, there may be areas that the cutting tool cannot reach. As a result, 3-axis CNC milling has certain design constraints, which will be discussed in the design guidelines section later.

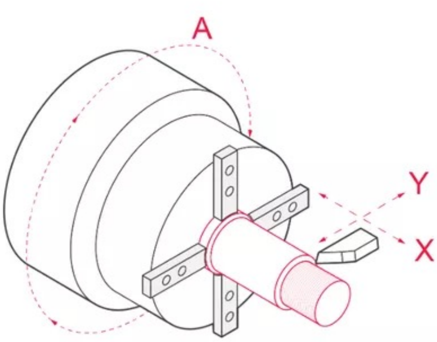


- ✅ Can manufacture simple geometries efficiently
- ✅ Parts can be produced to high tolerances
- ❌ Limited tool access creates design restrictions
- ❌ Manual repositioning of workpiece increases cost

CNC Turning

CNC turning is a subtractive machining process where the workpiece is clamped in a chuck and rotated, while the cutting tool is fed into the workpiece to remove material. The tool is programmed to trace both the external and internal shapes of the part to create the desired geometry. Unlike milling, the tool does not rotate but moves radially and longitudinally around the workpiece.

CNC turning allows for faster production of parts, making it more cost-effective compared to CNC milling. The increased machining speed also enables large-scale production. However, the main limitation of CNC turning is that it is only suitable for geometries with rotational symmetry. To overcome this design limitation, CNC milling is often used as a secondary operation to create additional features. By using a 5-axis machine, both processes can be integrated into a single operation.



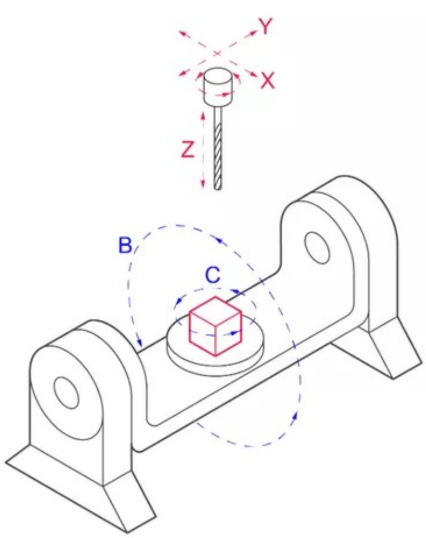
- ✅ Lower cost per unit compared to other CNC processes
- ✅ High part production capabilities
- ❌ Can only machine symmetrical geometries

5-axis CNC Machine

5-axis indexing CNC milling (3+2 machining)

5-axis indexed milling, or 3 + 2 machining, operates by rotating the workpiece to the desired position around the B and C axes. The workpiece then remains stationary while the tool moves along the three linear axes to perform the required cuts. When the cutting position changes, the B and C axes reposition the workpiece, which then stays stationary to adapt to the new cutting position. This machining method is also referred to as 3 + 2 CNC milling, as the additional two degrees of freedom do not work simultaneously with the three linear axes of the tool.

The main advantage of this method is that it eliminates the need for manual workpiece repositioning. Compared to 3-axis milling, this reduces manufacturing time and improves the precision of CNC parts with complex geometries.

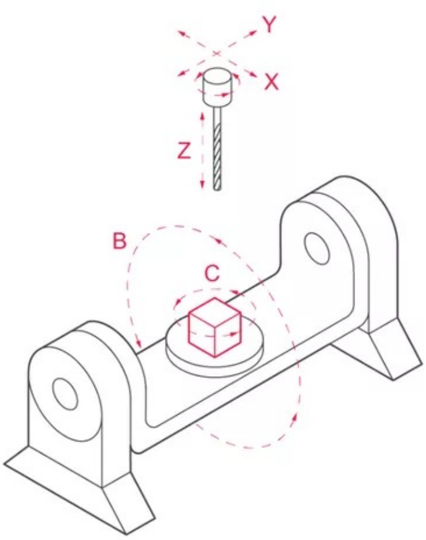


- ✅ Eliminates the need to manually reposition the workpiece
- ✅ Reduced manufacturing time compared to 3-axis CNC machining
- ❌ Cannot cleanly machine contoured faces
- ❌ Increased cost compared to 3-axis CNC machining

5-axis continuous CNC milling

A 5-axis continuous CNC milling machine is similar to a 5-axis indexed CNC milling machine, but it allows the workpiece to continuously rotate around the B and C axes during the machining process.

Both the workpiece and cutting tool can move simultaneously along five different axes, enabling the machining of complex features. This allows for the production of highly precise, smooth contour surfaces, such as the blade contours on turbine blades, making this method especially popular in the aerospace industry. However, the high cost of the machinery and the demand for highly skilled machinists significantly increase the cost of this method.



✅ Ability to machine complex features and smooth surfaces in a single setup

✅ Produce complex parts to an accuracy that is not achievable with any other process

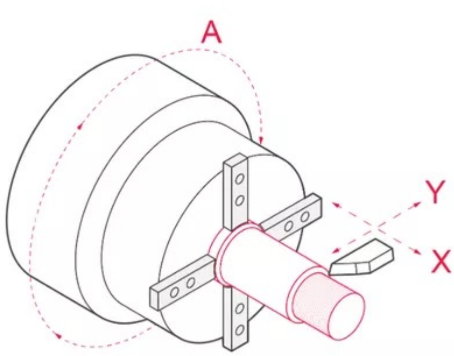
❌ Most expensive CNC machining method

❌ Certain tool restrictions still apply

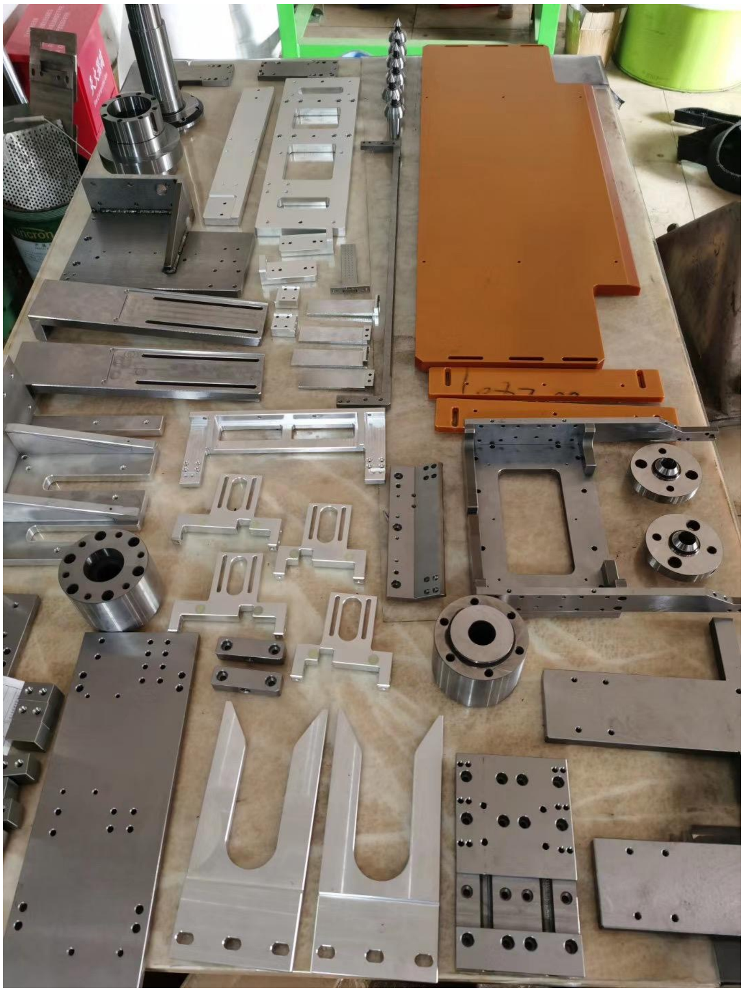
Turn-mill center

A turn-mill center, also known as a turn-mill machine, is a combination of a CNC lathe and a CNC milling machine, as the name suggests. The workpiece can be rotated at high speeds on the rotational axis for CNC turning operations, then rotated and held at precise angles for CNC milling operations.

Turn-mill machines offer manufacturers a combination of higher productivity from CNC turning and design flexibility from CNC milling. These versatile CNC machines are ideal for parts that require multiple machining operations. Processing the part in a single cycle speeds up production and improves accuracy, as it eliminates the need for additional setups. Due to the increased efficiency of CNC turning, the cost of part production is significantly lower than with other 5-axis machines.



- ✅ Lower cost per unit compared to other CNC processes
- ✅ High part production capabilities
- ❌ Can only machine symmetrical geometries



Material Selection for CNC Machining

Material selection is a crucial factor in CNC machining design. The material's characteristics influence its machinability, cost, and the final quality of the part. When choosing materials for CNC machining, it is important to take into account factors such as machinability, mechanical properties, cost, material availability, and environmental considerations.

Metals

Some of the common metals used in CNC machining include:

- Aluminum
- Stainless steel
- Mid steel
- Brass
- Copper
- Alloy steel
- Tool steel
- Titanium
- Inconel
- Carbon fiber

Plastics

Some of the common plastics used in CNC machining include:

- POM(Delrin/Acetal)
- Nylon
- ABS
- PEEK
- PTFE(Teflon)
- Polycarbonate
- Polyethylene
- PVC
- PMMA(Acrylic)
- PET

Surface Finishes Selection for CNC Machining

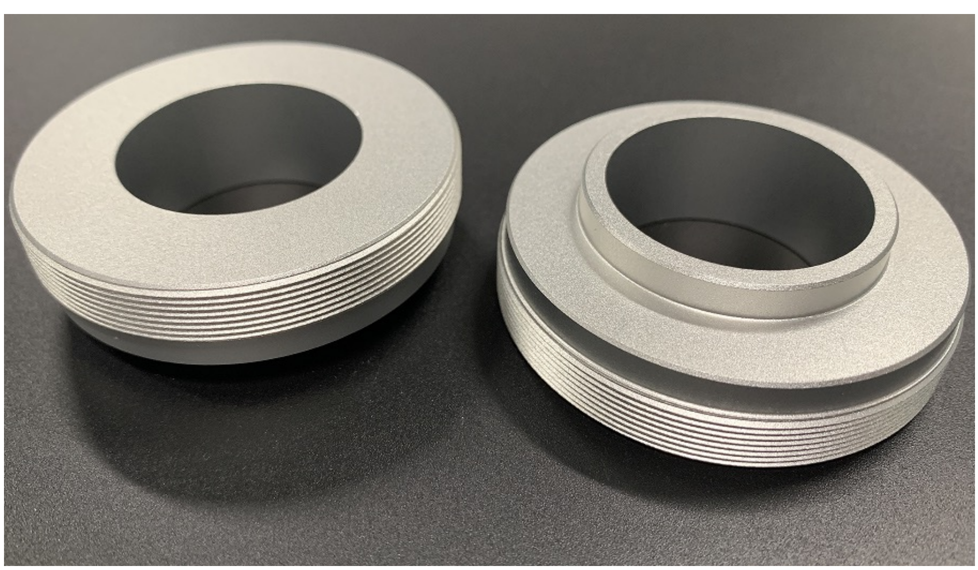
Surface finish is a key factor in CNC machining, as it impacts the appearance, performance, and longevity of the final product. There are various surface finishing techniques available to refine CNC-machined parts, ensuring they meet both aesthetic and functional specifications.

As Machined

This is the initial surface finish produced by the CNC machining process. An as-machined part typically has a finish around 125 µin Ra, although finer finishes with tighter tolerances, such as 63, 32, or even 16 µin Ra, can be requested. The surface may display visible tool marks, and the finish may not be entirely uniform.

Sand Blasting

This is the initial surface finish produced by the CNC machining process. An as-machined part typically has a finish around 125 µin Ra, although finer finishes with tighter tolerances, such as 63, 32, or even 16 µin Ra, can be requested. The surface may display visible tool marks, and the finish may not be entirely uniform.



Anodizing (Type II or Type III)

Anodization is a versatile and popular surface treatment for CNC machined components, offering superior resistance to corrosion, increased hardness, wear resistance, and improved heat dissipation. It’s widely used for painting and priming due to its high-quality finish. At HL Parts, we offer two forms of anodization: Type II, known for its corrosion protection, and Type III, which provides an additional layer of wear resistance. Both processes can be tailored to produce a range of color finishes to suit your specific needs.

Aluminum and Aluminum alloy

40-160 HV

Anodic oxidation

250-300 HV

Hard anodizing

350-420 HV

HL PARTS

Ultra-precision mechanical machining manufacturer

Ultra-high precision mechanical machining manufacturer

+86-0752-3776106
sales@hlparts.cn
www.hlparts.cn