

Overview of CNC Milling

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Computer Numerical Control (CNC) milling is a subtractive manufacturing process that uses computer-controlled rotating tools to remove material from a workpiece and produce precise parts. The following notes outline the key concepts, components, operation steps, and typical applications.

1. Basic Concepts

Term	Definition
CNC	A system that interprets a digital program (G-code) to move machine axes automatically.
Milling	A machining operation where a rotating multi-cutting-edge tool removes material by advancing into the workpiece.
Subtractive manufacturing	Material is removed (as opposed to additive processes where material is built up).
Axes	Directions of motion: X (horizontal), Y (horizontal perpendicular to X), Z (vertical). Multi-axis machines add rotary axes (A, B, C).
Toolpath	The programmed trajectory that the cutter follows to achieve the desired geometry.

2. Main Components of a CNC Milling Machine

Component	Function
Spindle	Holds and rotates the cutting tool at variable speeds (rpm).
Tool changer (ATC)	Automatic system that stores multiple tools and swaps them during a job.
Workholding	Fixtures, vises, clamps, or vacuum tables that secure the workpiece.
Control unit	Computer (often a PC-based controller) that reads G-code and drives the drives/servos.
Linear axes (X, Y, Z)	Ball-screw or linear motor drives that translate rotary motion into precise linear motion.

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Component	Function
Coolant system	Delivers cutting fluid to reduce heat, improve surface finish, and prolong tool life.
Enclosure & safety interlocks	Protect operators from chips, coolant, and moving parts; ensure compliance with safety standards.

3. Types of CNC Milling Machines

Machine Type	Typical Features	Typical Use Cases
3-axis mill	Fixed spindle, motion in X, Y, Z only.	Simple parts, prototyping, batch production.
4-axis mill	Adds a rotary A or B axis (usually around X).	Machining around a fixed axis, e.g., pockets, slots on cylindrical parts.
5-axis mill	Two rotary axes (A & B or A & C) plus X, Y, Z.	Complex geometries, aerospace components, molds, reduced setups.
Vertical mill	Spindle vertical; workpiece on a horizontal table.	General-purpose machining, PCB drilling, small parts.
Horizontal mill	Spindle horizontal; better chip evacuation, deeper cuts.	Large, heavy parts, aerospace, automotive components.

4. CNC Milling Workflow

1. Design & CAD

- Create 3D model of part in CAD software (e.g., SolidWorks, Fusion 360).

2. CAM Programming

- Import CAD model into CAM software.
- Define stock size, tool library, machining strategies (roughing, finishing).
- Generate toolpaths and simulate to detect collisions.

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3. Post-Processing

- Convert toolpaths into machine-specific G-code using a post-processor.

4. Machine Setup

- Install workpiece in the fixture.
- Load required tools into the automatic tool changer or manually.
- Set work