Unit- 4

Computer Aided Manufacturing

Introduction to CNC Machining, Advantages and limitations of CNC machining, Types of CNC machines, Components of a CNC machine (e.g. controller, spindle, axes, ATC), CNC machine configurations (e.g., 3-axis, 5-axis). CNC Programming Basics: Introduction to G-code and M-code programming & its basic applications.

What is CNC Machining?
Definition: CNC (Computer Numerical Control) machining is a subtractive manufacturing process that uses computerized controls and machine tools to automate the fabrication of parts. Pre-programmed software dictates the movement of machinery and tools, enabling precision and efficiency in shaping metal, plastic, and other materials.

Key Components of CNC Machining Process:

CAD (Computer-Aided Design): Designing the part using software.
CAM (Computer-Aided Manufacturing): Converting CAD models to machine instructions.
CNC Machine: Performs the material removal.
Diagram: A flowchart showing the CNC process from design to finished product (CAD → CAM → CNC Machine → Final Part).

1. **Advantages of CNC Machining**

High Precision and Accuracy: CNC machines can work with tight tolerances (±0.001 mm) for complex parts.
Consistency and Repeatability: Once a part is programmed, it can be replicated with identical accuracy.
Automation: Minimal manual intervention; reduces errors and allows for 24/7 manufacturing.
Efficiency: Optimized tool paths, automatic tool changes, and minimal downtime.
Complex Geometries: Multi-axis capabilities (up to 5-axis) allow CNC machines to create intricate designs that are impossible with manual machining.
Reduced Waste: More efficient material usage compared to traditional methods.
Scalability: Ideal for both prototyping and mass production.

1. **Limitations of CNC Machining**

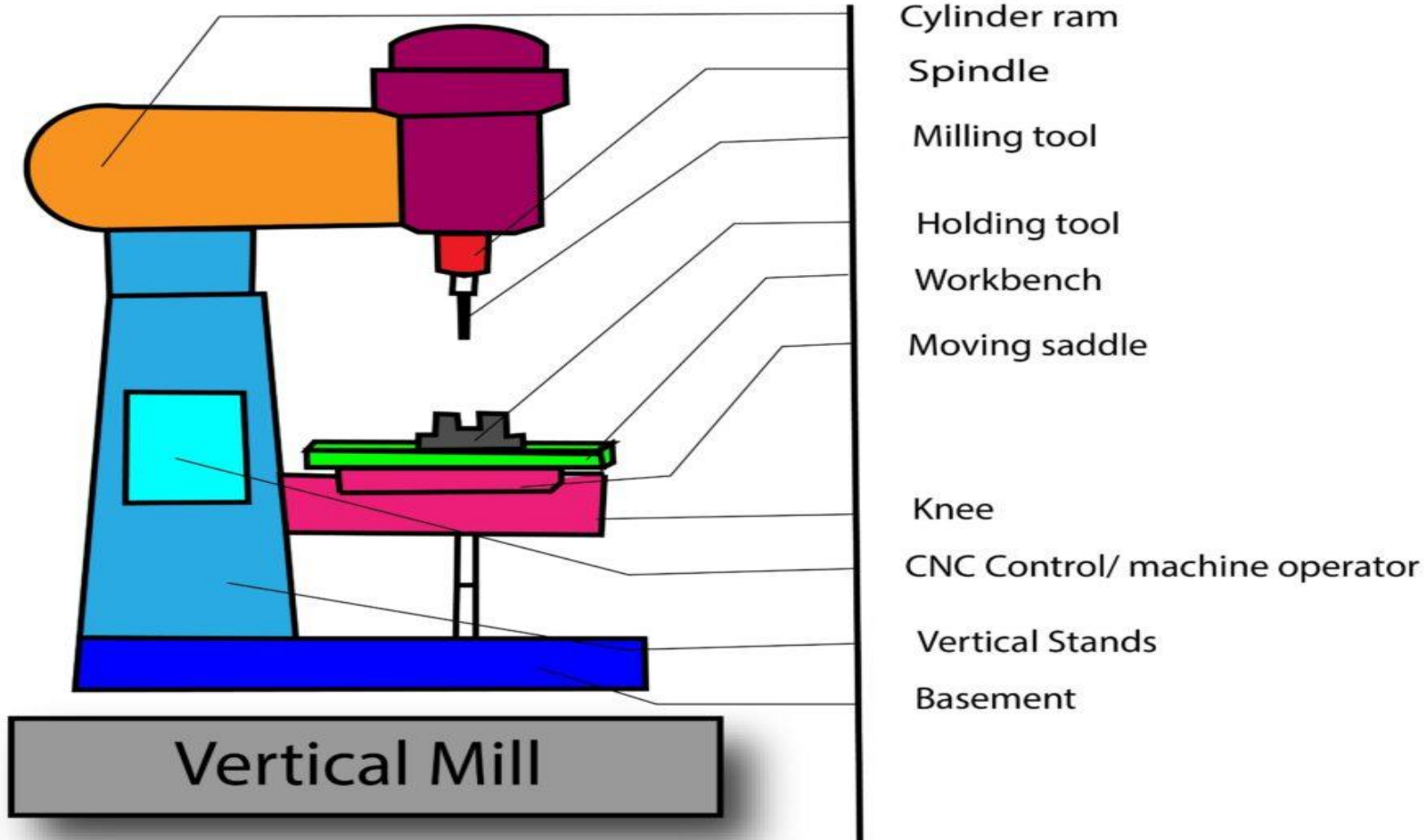
High Setup Costs: CNC machines are expensive, with initial setup including hardware, software, and tooling investment.
Complex Programming: Requires skilled technicians familiar with G-code, M-code, and CAD/CAM software.
Time-Consuming for Low Volume: For small batches, the setup time may outweigh the benefits of CNC machining.
Maintenance and Tooling Costs: Requires regular maintenance and tool wear management.
Material Limitations: While CNC works well with metals and plastics, some materials like certain composites or ceramics may be challenging.

Types of CNC Machines

CNC Milling Machines:

Function: Rotating cutting tools move along multiple axes to remove material.

Applications: Complex parts, molds, dies, and 3D shapes.

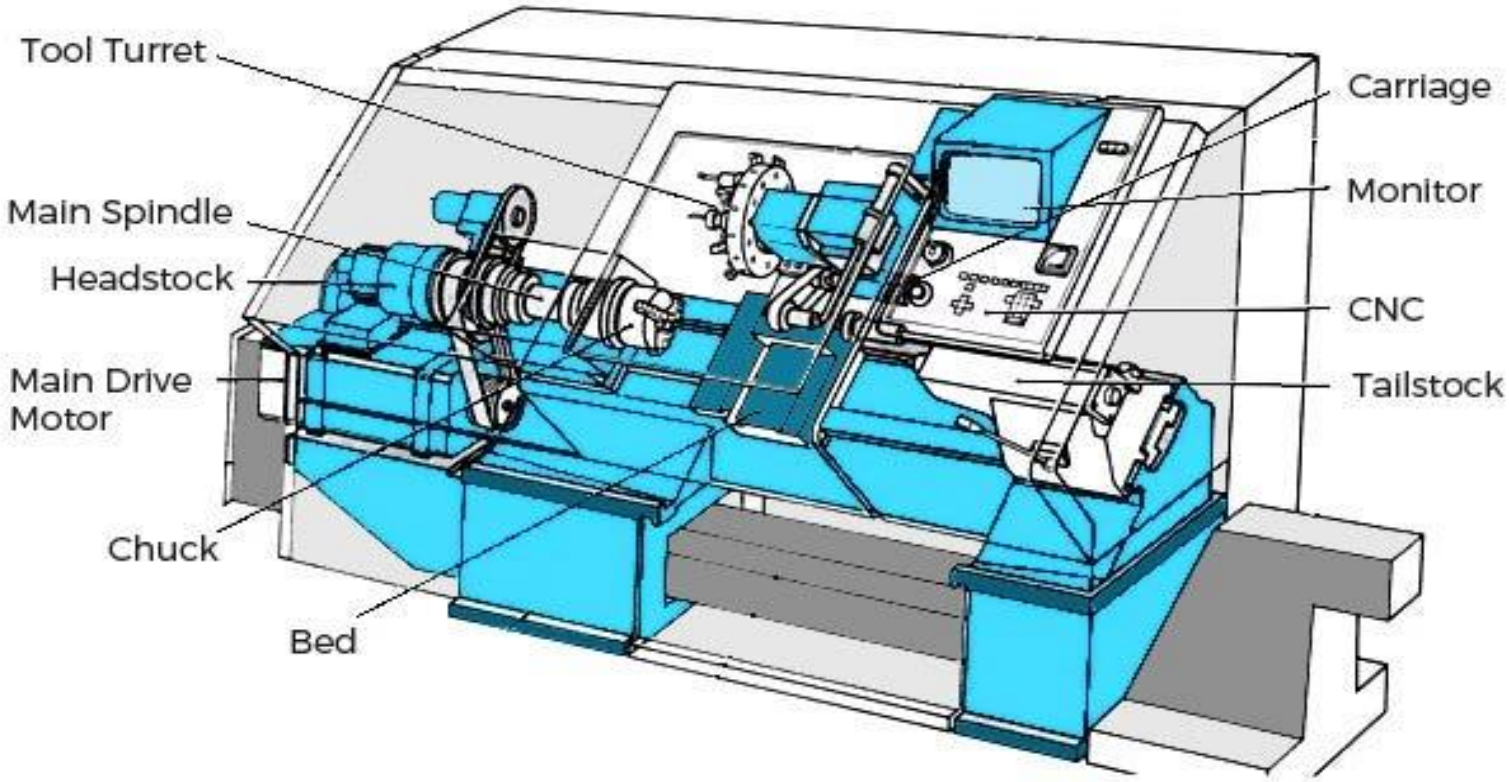


Types of CNC Machines

CNC Lathes:

Function: Rotates the workpiece while stationary cutting tools remove material.

Applications: Cylindrical parts, shafts, bushings.

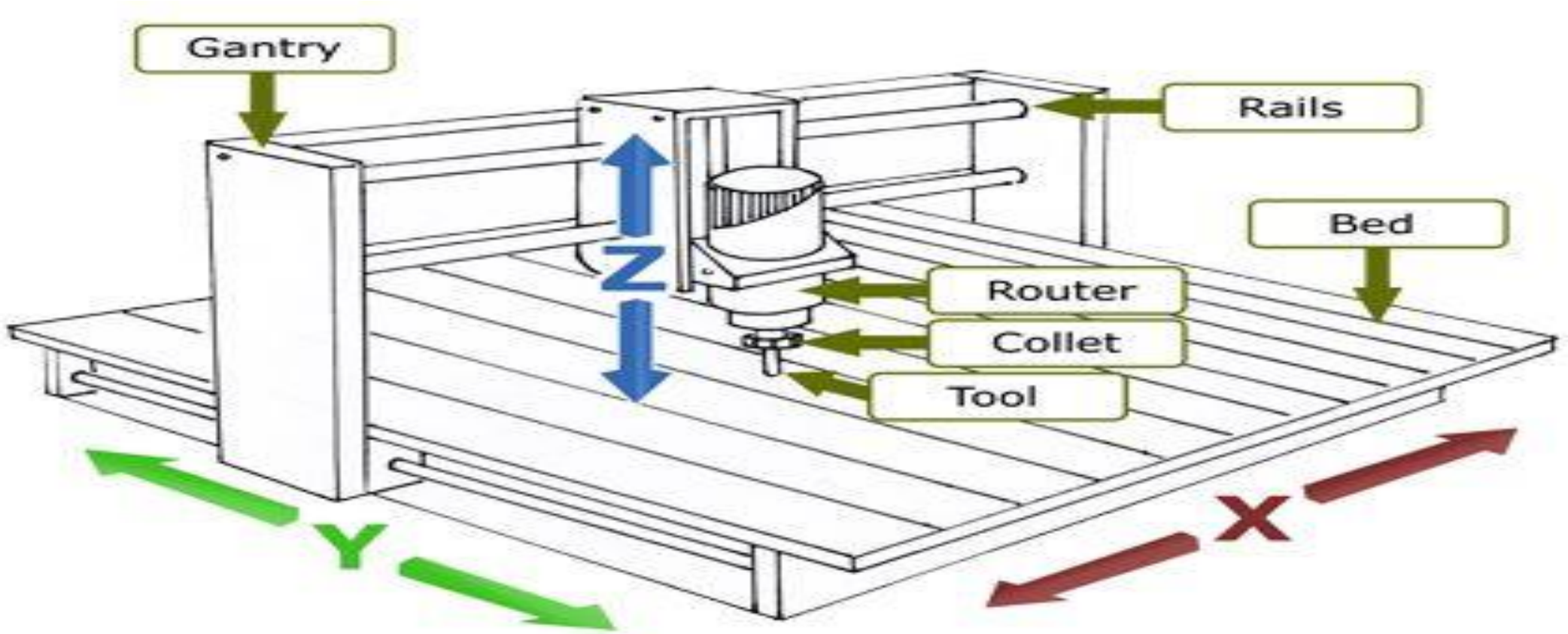


Diag. Main parts of a CNC lathe machine

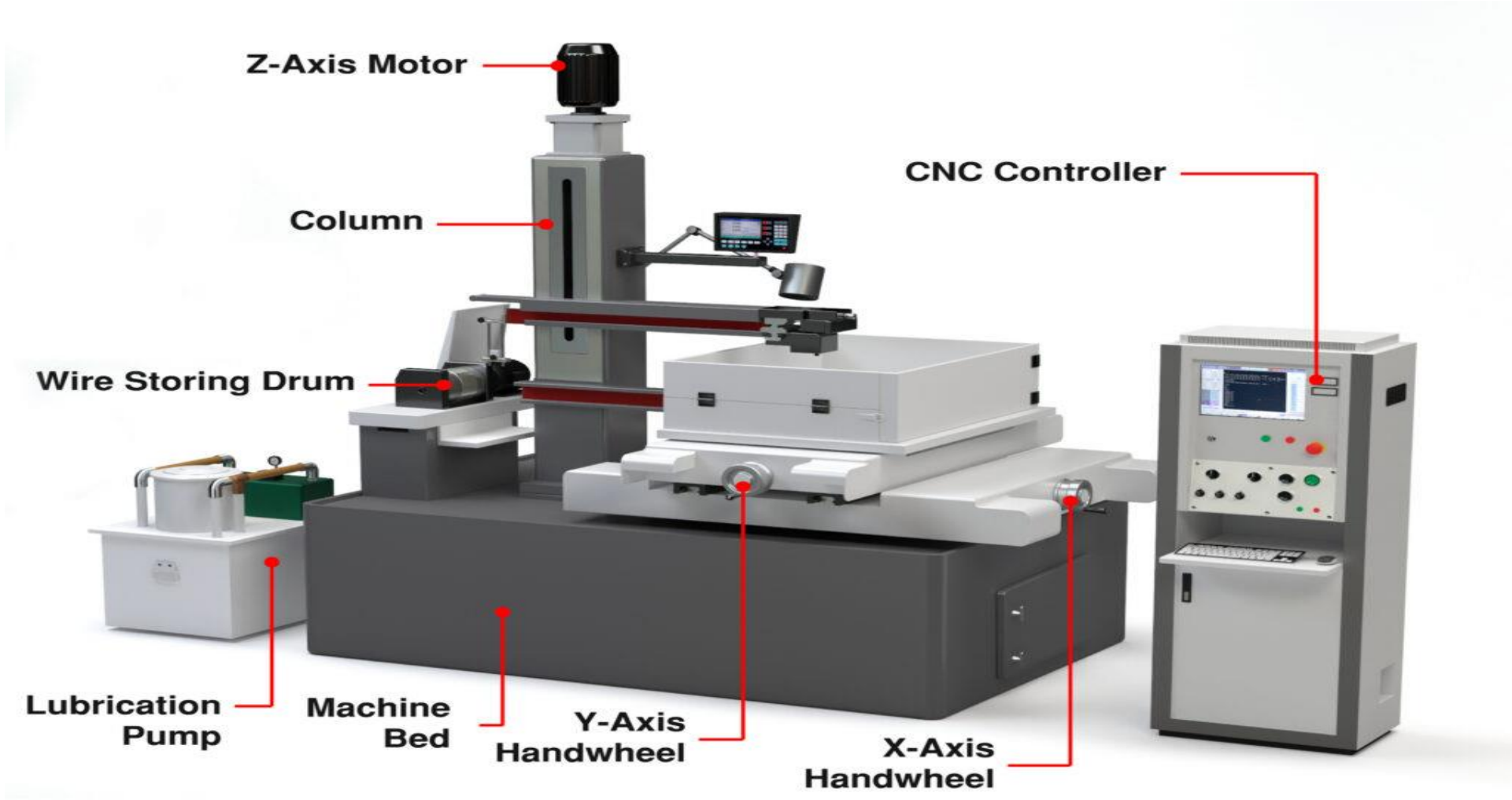
CNC Routers:

Function: High-speed cutters for softer materials (wood, plastic, foam).

Applications: Furniture, signage, and custom products.



CNC EDM (Electrical Discharge Machining):
Function: Uses electrical sparks to erode material, typically for hard metals.
Applications: Tooling, dies, and complex geometries with high hardness.



Major Components of a CNC Machine

Controller (CNC Control Unit): Processes G-code and M-code commands to control the machine's movement and operation.
Spindle: The rotating part of the CNC machine that holds the cutting tool or workpiece.
Axes (X, Y, Z + Optional Rotational Axes): Control the movement of the tool and/or workpiece. In a 5-axis machine, two additional rotational axes (A, B, or C) allow for complex part geometry.
Automatic Tool Changer (ATC): Automatically switches between tools without stopping the process, increasing efficiency.
Workholding Devices (Chucks, Vices): Hold the material in place securely while machining.
Servo Motors and Drives: Responsible for the precise movement of machine axes.
Diagram: A detailed diagram of a CNC machine, with each component labeled (controller, spindle, axes, ATC, motors).

CNC Machine Configurations

3-Axis Machines:

Movement in X, Y, and Z directions (up, down, left, right, forward, and back).

Suitable for flat and basic 3D designs.

4-Axis Machines:

Adds rotation around one axis (often the X-axis) for increased flexibility.

Useful for parts that require machining on multiple sides.

5-Axis Machines:

Adds two rotational axes (around X and Y, or X and Z).

Can create extremely complex geometries, such as aerospace components, turbine blades, and medical devices.

Diagram: Illustration comparing 3-axis, 4-axis, and 5-axis machine configurations.

1. Introduction to G-Code

- **Definition:** G-code (Geometric Code) is a numerical control programming language that dictates the movement of the machine's tool or workpiece. It describes how and where the machine should move (positioning), the speed of movement (feed rate), and the toolpath for machining.
- **Syntax:** G followed by a number, representing different commands.
- **Examples:** G00 (Rapid positioning), G01 (Linear interpolation), G02 (Circular interpolation - CW), etc.

2. Introduction to M-Code

- **Definition:** M-code (Miscellaneous Code) controls various machine operations that are not related to tool movement. These include starting and stopping the spindle, changing tools, or turning the coolant on/off.
- **Syntax:** M followed by a number, representing different machine functions.
- **Examples:** M03 (Spindle on - CW), M06 (Tool change), M08 (Coolant on), etc.

Important G-code Commands and Their Functions:

G-Code	Description	Functionality	Example
G00	Rapid Positioning	Moves the tool quickly to a specified location without cutting.	`G00 X50 Y25 Z10` → Rapid move to coordinates X50, Y25, Z10.
G01	Linear Interpolation (Cutting)	Cuts the workpiece in a straight line at a controlled feed rate.	`G01 X100 Y50 Z0 F200` → Move to X100, Y50, Z0 at feed rate 200.
G02	Clockwise Circular Interpolation	Cuts the workpiece in a clockwise circular path.	`G02 X100 Y100 I20 J0` → Creates a clockwise arc.
G03	Counterclockwise Circular Interpolation	Cuts the workpiece in a counterclockwise circular path.	`G03 X50 Y50 I-20 J0` → Creates a counterclockwise arc.
G04	Dwell	Pauses machine movement for a specified duration.	`G04 P1000` → Pause for 1 second (1000 milliseconds).

Important G-code Commands and Their Functions:

G17	**Select XY Plane**	Sets the active plane to XY for circular cutting.	Used before G02/G03.
G18	**Select XZ Plane**	Sets the active plane to XZ.	Used in turning operations.
G19	**Select YZ Plane**	Sets the active plane to YZ.	Rarely used.
G20	**Inch Units**	Changes unit to inches.	`G20` → All subsequent commands are interpreted in inches.
G21	**Metric Units**	Changes unit to millimeters.	`G21` → All subsequent commands are interpreted in mm.

Important G-code Commands and Their Functions:

G21	**Metric Units**	Changes unit to millimeters.	`G21` → All subsequent commands are interpreted in mm.
G28	**Return to Machine Home Position**	Moves the tool to the machine's home position.	`G28 X0 Y0` → Returns to home position.
G90	**Absolute Positioning Mode**	Coordinates are referenced from a fixed origin point.	`G90` → All positions are relative to the origin.
G91	**Incremental Positioning Mode**	Coordinates are referenced from the current tool position.	`G91` → Move relative to the current position.
G92	**Set Position**	Sets the current tool position as the origin.	`G92 X0 Y0 Z0` → Set current position to X0, Y0, Z0.

4. Detailed G-Code Example for a Machined Part

Objective: Create a 100mm x 50mm rectangular pocket with a depth of 10mm.

Program:

plaintext Copy code

```
G21          ; Set units to millimeters
G90          ; Absolute positioning mode
G00 X0 Y0    ; Move rapidly to start position (X0, Y0)
G01 Z-10 F100 ; Move down to cutting depth of 10mm
G01 X100 Y0 F200 ; Cut to X100, Y0
G01 X100 Y50 ; Cut to X100, Y50
G01 X0 Y50   ; Cut to X0, Y50
G01 X0 Y0    ; Return to starting position
G00 Z10      ; Rapid move back up
M30          ; End program
```

M-code (Miscellaneous Code)

- **Definition:** M-code handles machine-specific operations that are not related to the path or geometry of the tool. It controls functions such as starting/stopping the spindle, turning the coolant on/off, and managing tool changes.
- **Format:** Typically starts with the letter "M" followed by a number. E.g., M03, M06, M30.

Common M-Code Commands and Their Functions

M-Code	Description	Functionality	Example
M00	**Program Stop**	Stops the machine; requires the operator to resume manually.	`M00` → Stop the machine at a specific point.
M01	**Optional Stop**	Stops the machine only if the optional stop switch is on.	`M01` → Stop only if the switch is activated.
M03	**Start Spindle (CW)**	Turns the spindle on in a clockwise direction.	`M03 S1000` → Spindle on at 1000 RPM.
M04	**Start Spindle (CCW)**	Turns the spindle on in a counterclockwise direction.	`M04 S1000` → Spindle on (counterclockwise) at 1000 RPM.
M05	**Stop Spindle**	Stops spindle rotation.	`M05` → Stop spindle rotation.

Common M-Code Commands and Their Functions

M06	**Tool Change**	Automatically changes the tool in the tool holder.	`M06 T03` → Change to Tool #3.
M08	**Coolant On**	Turns the coolant on.	`M08` → Coolant on for cutting.
M09	**Coolant Off**	Turns the coolant off.	`M09` → Coolant off.
M30	**End Program and Reset**	Ends the program and resets to the beginning.	`M30` → End of program.
M98	**Subprogram Call**	Calls a pre-defined subprogram stored in memory.	`M98 P1234` → Call subprogram P1234.
M99	**Subprogram Return**	Returns to the main program after completing the subprogram.	`M99` → Return to main program.

Applications of CNC Machining

CNC Programming Example
Part Example: Create a simple block with a drilled hole.
Programming Sequence:
G00 X0 Y0 Z0: Rapid move to start position.
G01 X100 Y50 F200: Linear cutting to specified coordinates.
G02 X100 Y100 I50 J0: Circular interpolation for a drilled hole.
M06: Tool change for different cutting operations.
M30: End of program.

Applications of CNC Machining

Automotive Industry:

Engine components, transmission parts, custom gears.

Aerospace Industry:

Aircraft structural components, turbine blades, fuel systems.

Medical Industry:

Custom prosthetics, surgical tools, medical implants.

Electronics Industry:

Housings for electronics, PCB fabrication, enclosures.