CNC TECHNOLOGY

1

INTRODUCTION TO CNC AND METAL CUTTING

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HISTORY

- US Air Force commissioned MIT to develop the first "numerically controlled" machine in 1949. It was demonstrated in 1952.
- At 1970-1972 first Computer Numeric Control machines were developed.
- Today, computer numerical control (CNC) machines are found almost everywhere, from small job shops in rural communities to companies in large urban areas.

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DEFINITION

- In CNC (Computer Numerical Control), the instructions are stored as a program in a micro-computer attached to the machine. The computer will also handle much of the control logic of the machine, making it more adaptable than earlier hard-wired controllers.

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CNC APPLICATIONS

- **Machining**
  - 2.5D / 3D
  - Turning ~ Lathes, Turning Centre
  - Milling ~ Machining Centres
- **Forming**
  - 2D
  - Plasma and Laser Cutting
  - Blanking, nibbling and punching
  - 3D
  - Rapid Prototyping

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SAMPLE CNC MACHINES

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CNC TURNING

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CNC MILLING

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CNC LASER CUTTING

9

CNC PLASMA CUTTING

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CNC PRESS

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CNC RAPID PROTOTYPING

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INDUSTRIES MOST AFFECTED by CNC

- Aerospace
- Machinery
- Electrical
- Fabrication
- Automotive
- Instrumentation
- Mold making

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SAMPLE PRODUCTS OF CNC MANUFACTURING

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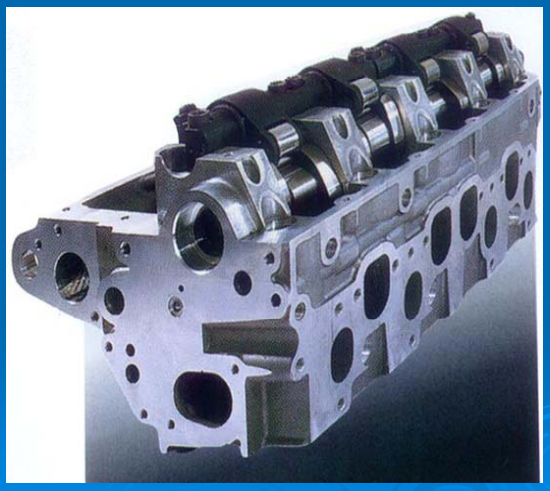
AUTOMOTIVE INDUSTRY
Engine Block



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AUTOMOTIVE INDUSTRY(Cont'd)

Different Products

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AEROSPACE INDUSTRY
Aircraft Turbine Machined by 5-Axis CNC Milling Machine

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CNC MOLD MAKING

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ELECTRONIC INDUSTRY

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RAPID PROTOTYPING PRODUCTS

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ADVANTAGES OF CNC

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Utilization of computers in manufacturing applications has proved to be one of the most significant advantages & developments over the last couple of decades in helping to improve the productivity and efficiency of manufacturing systems.

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ADVANTAGES of CNC

- **Productivity**

  Machine utilisation is increased because more time is spent cutting and less time is taken by positioning.

  Reduced setup time increases utilisation too.

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PROFIT increases as **COST** decreases and as **PRODUCTIVITY** increases.

PRODUCTIVITY through AUTOMATION

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AUTOMATION

- any means of helping the workers to perform their tasks more efficiently
- transfer of the skill of the operator to the machine

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Transferred skill	Results	
muscle power	*engine driven machine tools*	*First industrial revolution*
manipulating skill	*mechanization*	*hard automation*
vision skill	*use of position transducers, cameras*	*increase of accuracy, part recognition*
brain power	*cnc machines, industrial robots, soft automation, computer control of manufacturing systems*	*second industrial revolution*

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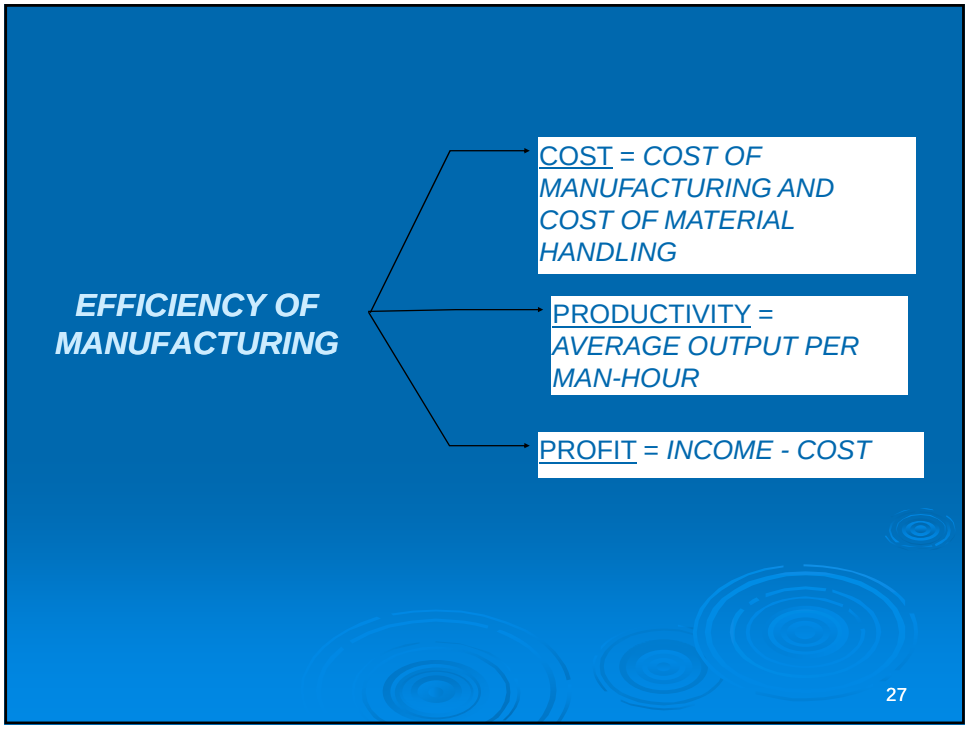

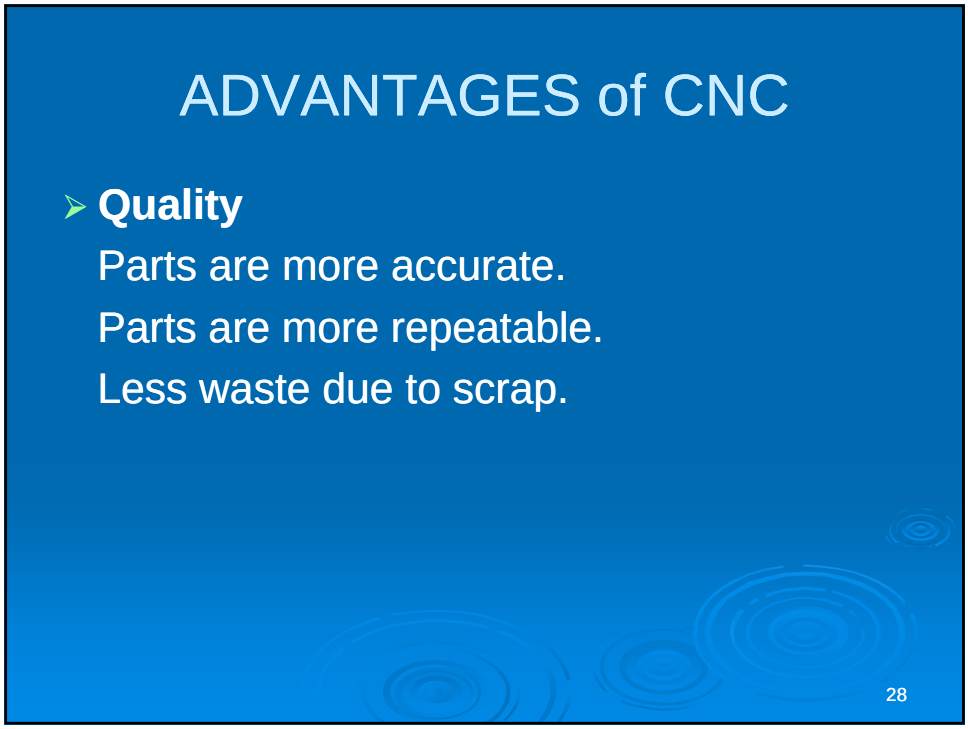

ADVANTAGES of CNC

- **Reduced inventory**

  Reduced setup time permits smaller economic batch quantities.

  Lower lead time allows lower stock levels.

  Lower stock levels reduce interest charges and working capital requirements.

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ADVANTAGES of CNC

- **Machining Complex shapes**

  Slide movements under computer control.

  Computer controller can calculate steps.

  First NC machine built 1951 at MIT for aircraft skin milling.

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ADVANTAGES of CNC

- **Management Control**
  - CNC leads to CAD
  - Process planning
  - Production planning

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DRAWBACKS of CNC

- High capital cost
  - Machine tools cost $30,000 - $1,500,000
- Retraining and recruitment of staff
- New support facilities
- High maintenance requirements
- Not cost-effective for low-level production on simple parts
- As geometric complexity or volume increases CNC becomes more economical
- Maintenance personnel must have both mechanical and electronics expertise

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FUNDAMENTAL OF METAL CUTTING

33

The metal cutting operations *(also called machining)* is one of the most important manufacturing processes in industry today *(as it was yesterday)*.

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MACHINING IS THE REMOVAL OF MATERIALS IN FORMS OF CHIPS FROM THE WORKPIECE BY SHEARING WITH A SHARP TOOL.

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The main function of a machine tool is to control the workpiece-cutting tool positional relationship in such a way as to achieve a desired geometric shape of the workpiece with sufficient dimensional accuracy.

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Machine tool provides:

work holding
tool holding
relative motion between tool and workpiece

primary motion
secondary motion

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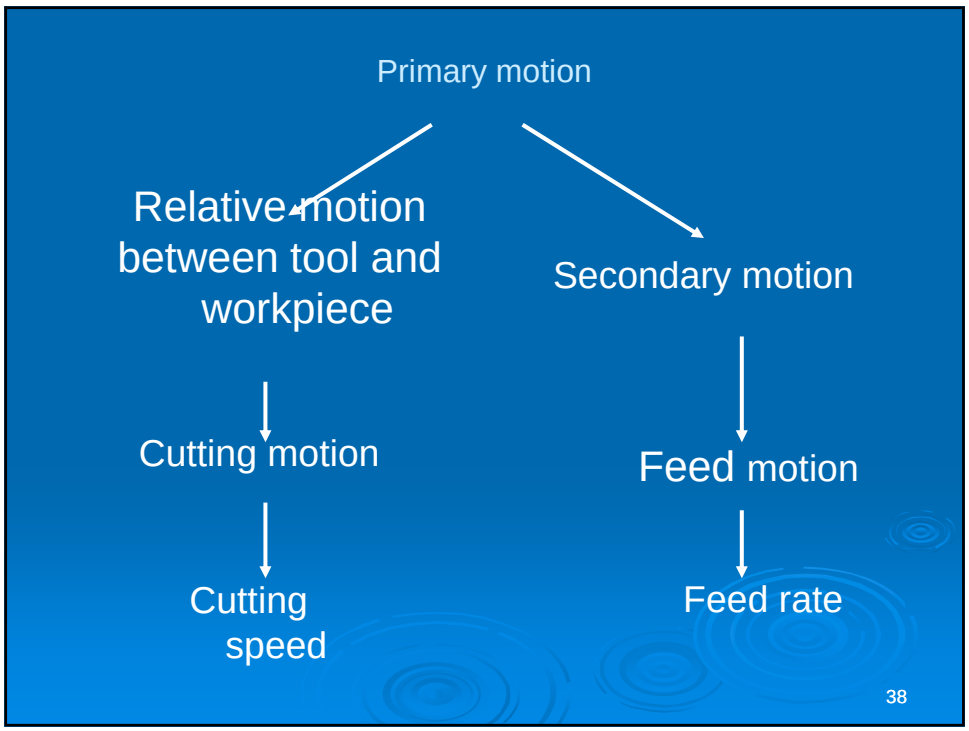

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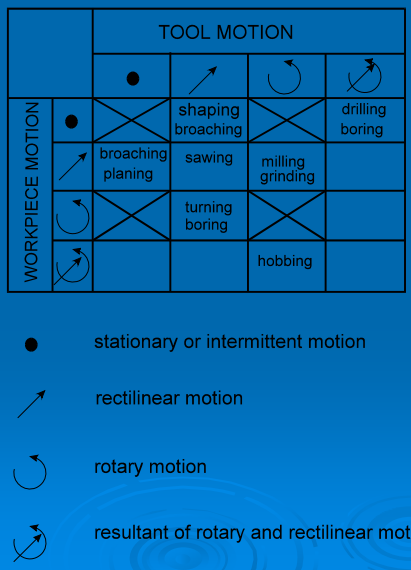
CLASSIFICATION OF THE CHIP REMOVING METHODS ACCORDING TO THE RELATIVE MOTION



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CLASSIFICATION OF MACHINE TOOLS

THOSE USING SINGLE POINT TOOLS	THOSE USING MULTIPOINT TOOLS	THOSE USING ABRASIVE TOOLS
lathes shapers planers boring m/c's etc.	drilling m/c's milling m/c's broaching m/c's hobbing m/c's etc.	grinding m/c's honing m/c's etc.

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BASIC COMPONENTS OF CNC SYSTEMS

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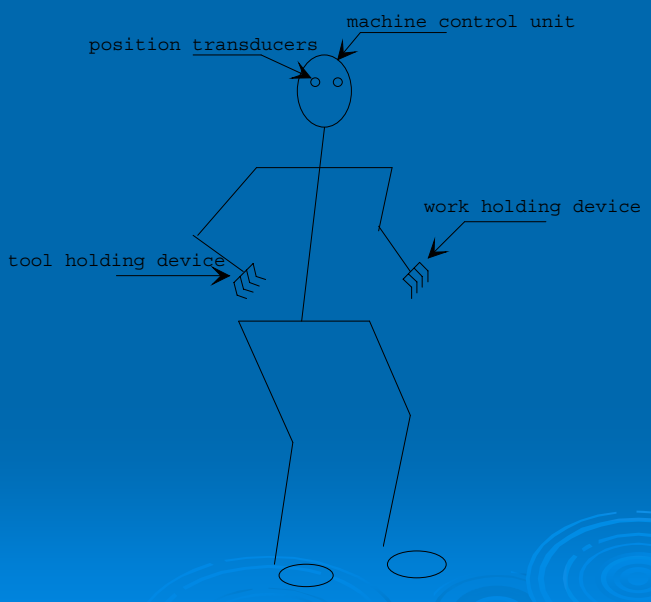

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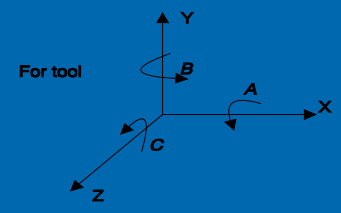
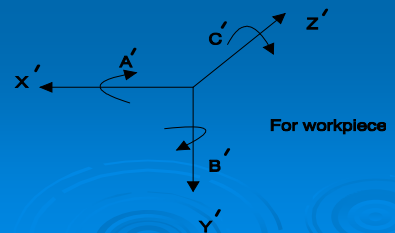
ISO MACHINE TOOL AXIS DEFINITION





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ISO MACHINE TOOL AXES DEFINITIONS

AXIS	*MACHINE TOOL WITH SPINDLE*			*MACHINE TOOL WITH NO SPINDLE*
Z	axis of spindle, (+Z) as tool goes away from the work piece			perpendicular to work holding surface, (+Z) as tool goes away from the workpiece
X	*MACHINE TOOL WITH ROTATING WORKPIECE*	*MACHINE TOOL WITH ROTATING TOOL*		
		HORIZONTAL AXIS	*VERTICAL AXIS*	
	radial and parallel to cross slide, (+X) when tool goes away from the axis of spindle	horizontal and parallel to work holding surface, (+X) to the right when viewed from spindle towards work piece	horizontal and parallel to the work holding surface, (+X) to the right when viewed from spindle towards column	parallel to and positive in the principal direction of cutting (primary motion)
Y	apply right hand rules			

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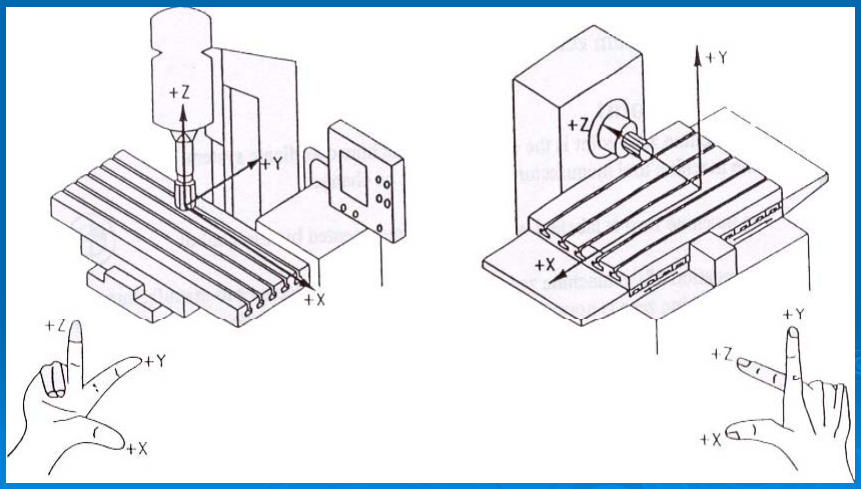
RIGHT HAND RULE

Vertical Machine Horizontal Machine



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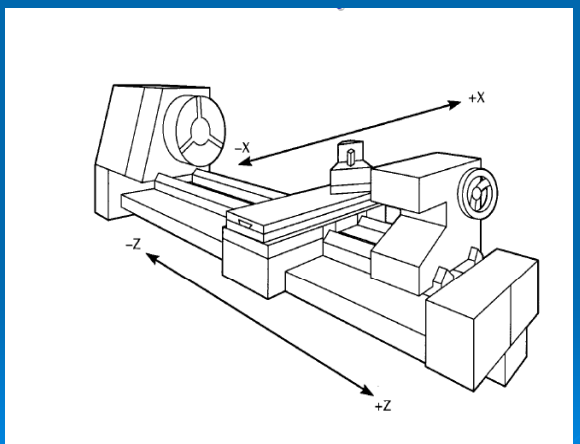
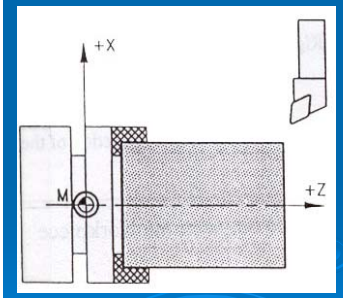
STANDARD LATHE COORDINATE SYSTEM





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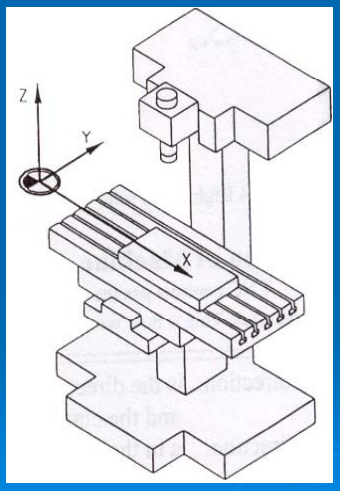
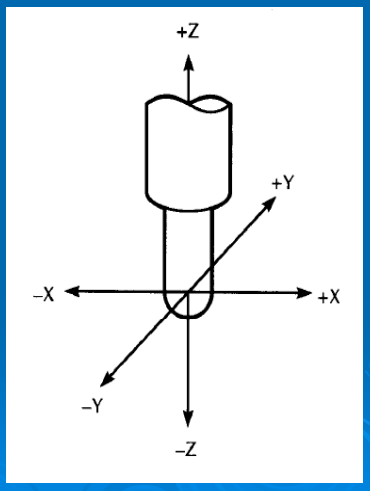
STANDARD MILLING MACHINE COORDINATE SYSTEM





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NUMERICALLY CONTROLLED MACHINE TOOLS:

An NC machine tool is functionally the same as a conventional machine tool. The technological capabilities NC machine tools in terms of machining are no different from those of conventional ones. The difference is in the way in which the various machine functions and slide movements are controlled.

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The functions and motions such as;

turning the spindle on and off
setting cutting speeds
setting feed rate
turning coolant on and off
moving tool with respect to workpiece

are performed by Machine Control Unit (MCU) in NC machine tools.

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MACHINE TOOL AUTOMATION

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CNC SYSTEM ELEMENTS

A typical CNC system consists of the following six elements

- Part program
- Program input device
- Machine control unit
- Drive system
- Machine tool
- Feedback system

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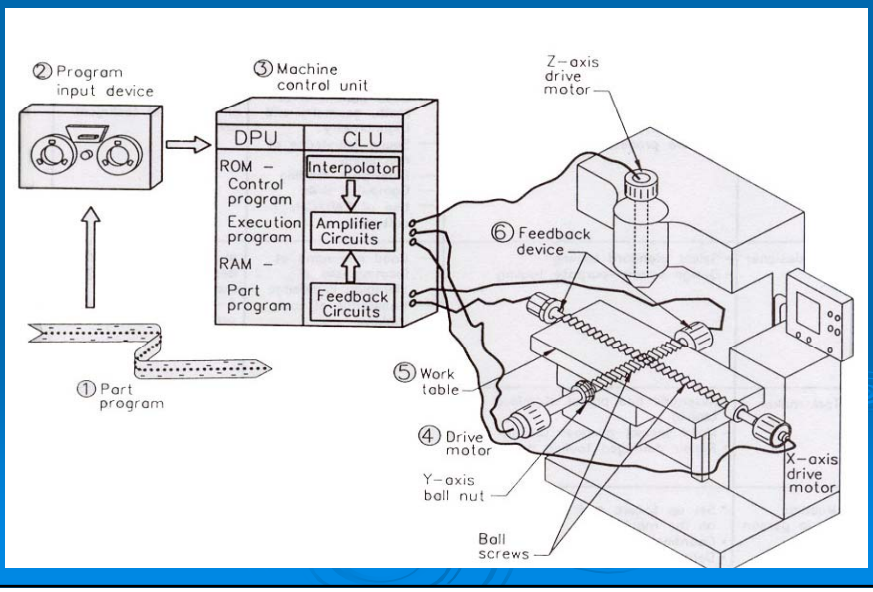
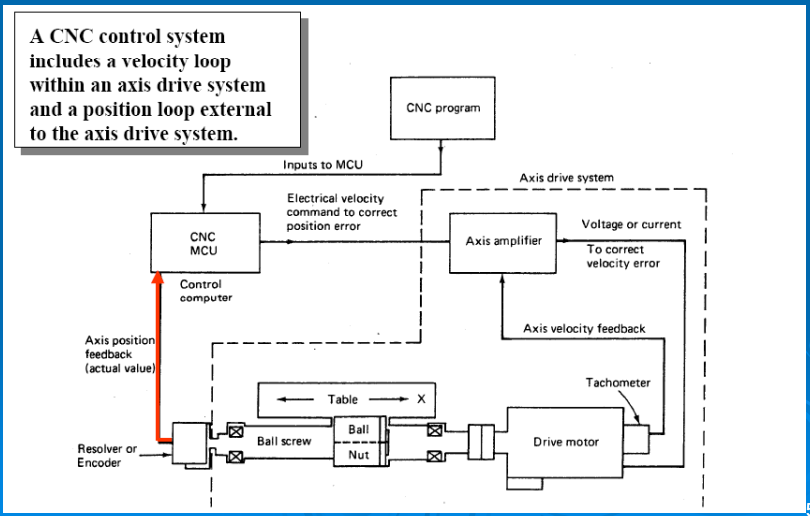
NC SYSTEM ELEMENTS



OPERATIONAL FEATURES of CNC MACHINES



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PART PROGRAM

- A part program is a series of coded instructions required to produce a part. It controls the movement of the machine tool and the on/off control of auxiliary functions such as spindle rotation and coolant. The coded instructions are composed of letters, numbers and symbols and are arranged in a format of functional blocks as in the following example

N10 G01 X5.0 Y2.5 F15.0
| | | | | |
| | | | | Feed rate (15 in/min)
| | | | Y-coordinate (2.5")
| | | X-coordinate (5.0")
| | Linear interpolation mode
Sequence number

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PROGRAM INPUT DEVICE

- The program input device is the mechanism for part programs to be entered into the CNC control. The most commonly used program input devices are keyboards, punched tape reader, diskette drivers, throgh RS 232 serial ports and networks.

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MACHINE CONTROL UNIT

The machine control unit (MCU) is the heart of a CNC system. It is used to perform the following functions:

- Read coded instructions
- Decode coded instructions
- Implement interpolations (linear, circular, and helical) to generate axis motion commands
- Feed axis motion commands to the amplifier circuits for driving the axis mechanisms
- Receive the feedback signals of position and speed for each drive axis
- Implement auxiliary control functions such as coolant or spindle on/off, and tool change

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TYPES of CNC CONTROL SYSTEMS

- Open-loop control
- Closed-loop control

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OPEN-LOOP CONTROL SYSTEM

- In open-loop control system step motors are used
- Step motors are driven by electric pulses
- Every pulse rotates the motor spindle through a certain amount
- By counting the pulses, the amount of motion can be controlled
- No feedback signal for error correction
- Lower positioning accuracy

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CLOSED-LOOP CONTROL SYSTEMS

- In closed-loop control systems DC or AC motors are used
- Position transducers are used to generate position feedback signals for error correction
- Better accuracy can be achieved
- More expensive
- Suitable for large size machine tools

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CONTROL

- Desired path (*p, v, a*)
  - 3-axis position control (encoder feedback)
  - Velocity control (tachometer feedback)
  - Torque control (current feedback)
- Path generator
  - Linear interpolation
  - Circular interpolation
  - Complex path interpolation (contouring)

DRIVE SYSTEM

- A drive system consists of amplifier circuits, stepping motors or servomotors and ball lead-screws. The MCU feeds control signals (position and speed) of each axis to the amplifier circuits. The control signals are augmented to actuate stepping motors which in turn rotate the ball lead-screws to position the machine table.

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STEPPING MOTORS

- A stepping motor provides open-loop, digital control of the position of a workpiece in a numerical control machine. The drive unit receives a direction input (cw or ccw) and pulse inputs. For each pulse it receives, the drive unit manipulates the motor voltage and current, causing the motor shaft to rotate bya fixed angle (one step). The lead screw converts the rotary motion of the motor shaft into linear motion of the workpiece .

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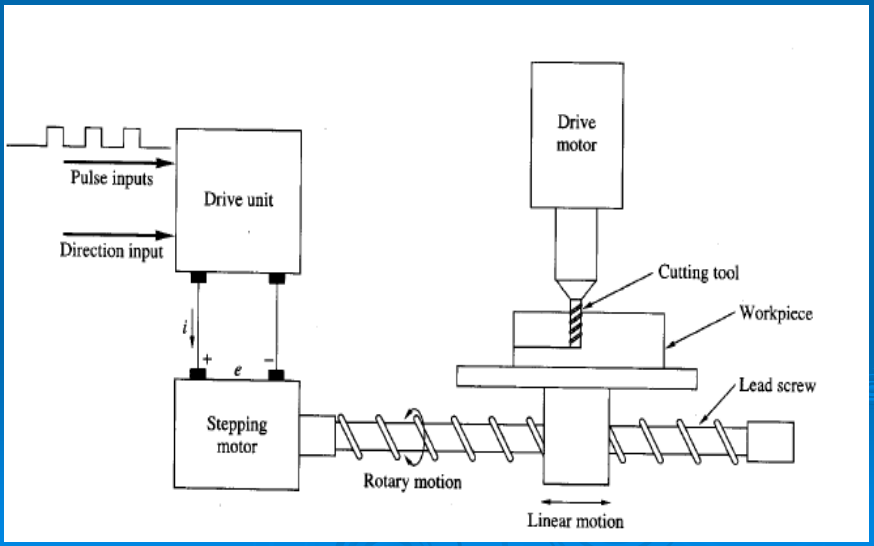
STEPPING MOTORS



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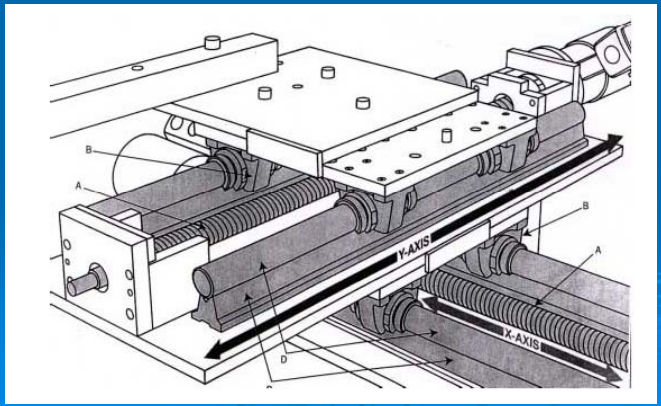
RECIRCULATING BALL SCREWS

Transform rotational motion of the motor into translational motion of the nut attached to the machine table.



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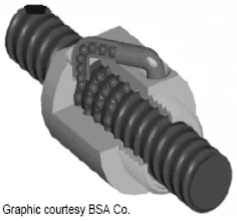
RECIRCULATING BALL SCREWS

- Accuracy of CNC machines depends on their rigid construction, care in manufacturing, and the use of ball screws to almost eliminate slop in the screws used to move portions of the machine.

Photo courtesy Thompson Ball Screw.



Graphic courtesy BSA Co.

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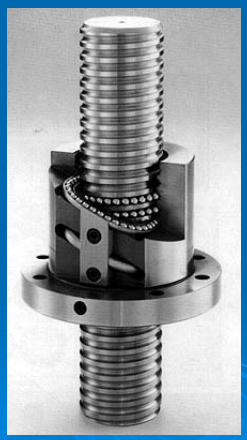
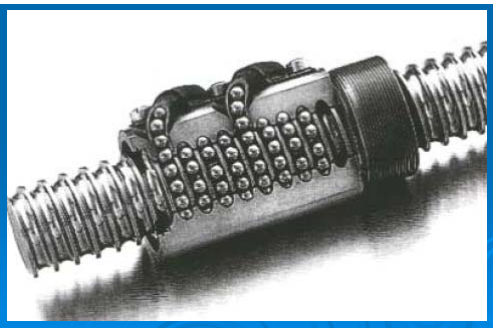
COMPONENTS OF RECIRCULATING BALL SCREWS

- Ball screw
- Ball nut (anti-backlash)
- Ways
- Linear bearings



Advantages of Recirculating Ball Screws

	Ball Screws	ACME Screws	Fluid Power	Belt, Chain	Rack & Pinion	Cam Followers	Pneumatic Cylinders
Inexpensive	●	●		●	●	●	
Low Power Use	●			●	●	●	
Low Maintenance	●						
High Accuracy	●				●		
High Repeatability	●						
High Efficiency	●						
High Load Capacity	●		●				●
Compact Size	●	●			●		



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POSITIONING

- The positioning resolution of a ball screw drive mechanism is directly proportional to the smallest angle that the motor can turn.
- The smallest angle is controlled by the motor step size.
- Microsteps can be used to decrease the motor step size.
- CNC machines typically have resolutions of 0.0025 mm or better.

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MACHINE TOOL

- CNC controls are used to control various types of machine tools. Regardless of which type of machine tool is controlled, it always has a slide table and a spindle to control of position and speed. The machine table is controlled in the X and Y axes, while the spindle runs along the Z axis.

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FEEDBACK SYSTEM

- The feedback system is also referred to as the measuring system. It uses position and speed transducers to continuously monitor the position at which the cutting tool is located at any particular time. The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors.

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CNC MACHINES FEEDBACK DEVICES

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ENCODERS

- A device used to convert linear or rotational position information into an electrical output signal.

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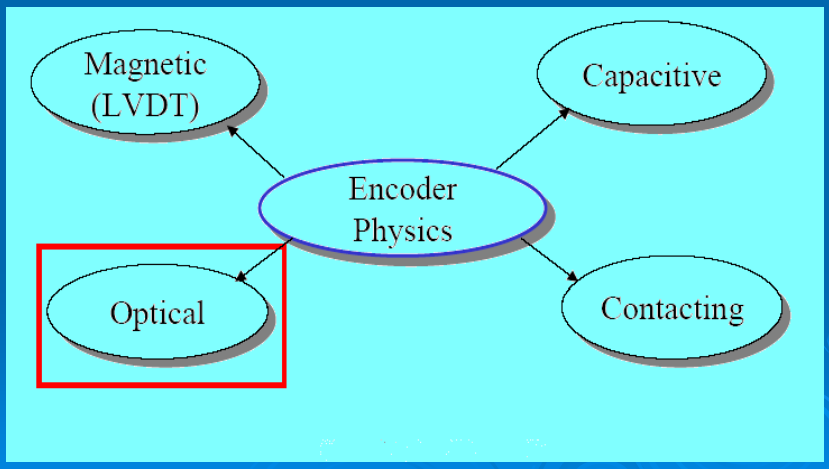
ENCODERS



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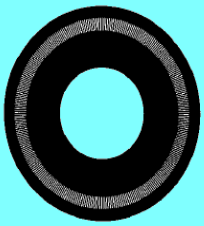
INDUSTRIAL APPLICATIONS of ENCODERS

Rotary Encoders are widely used with robotics.



Linear encoders are widely used with machine tools.

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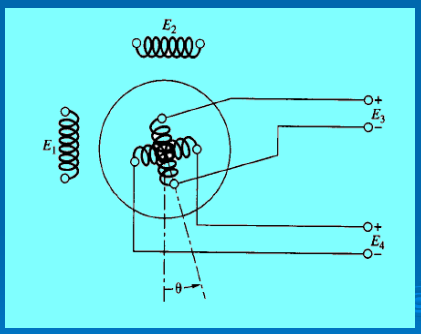
RESOLVERS

- A resolver is a rotary transformer that produces an output signal that is a function of the rotor position.



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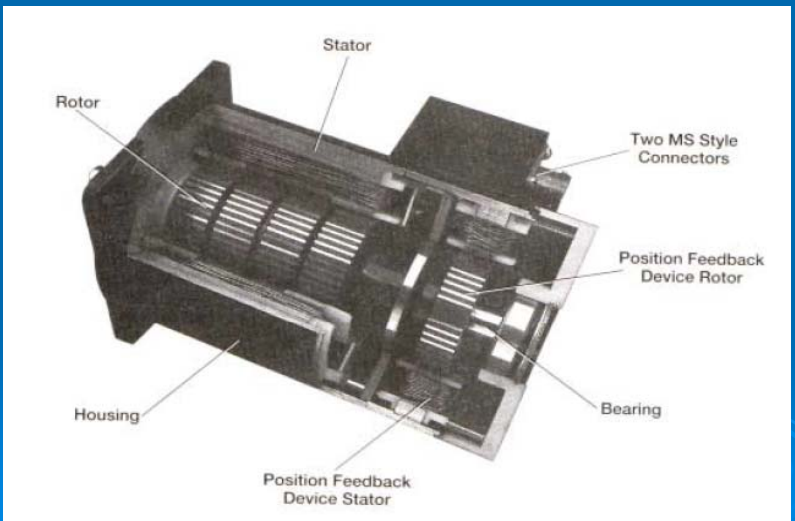
SERVOMOTOR with RESOLVER



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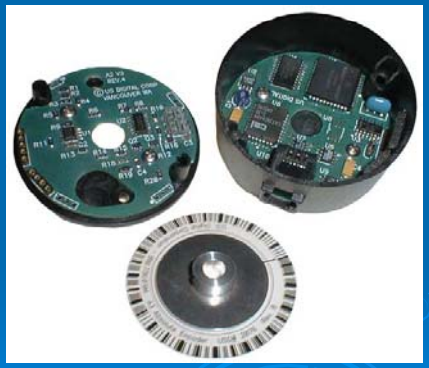
DRIVE MOTORS

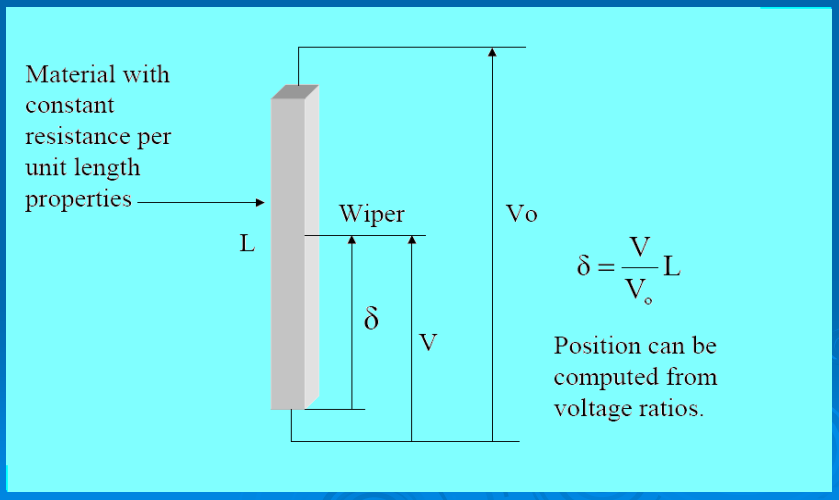
- DC servo motors
- AC servo motors
- Stepper motors
- Hydraulic motors

POSITION FEEDBACK

- Incremental encoder
- Quadrature
- Absolute encoder
- Resolver
- Tachometer
- No feedback (open loop)



POTENTIOMETERS



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POTENTIOMETERS

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VELOCITY FEEDBACK

- **Tachometers:**

  Electrical output is proportional to rate of angular rotation.
- **Encoders, Resolvers, Potentiometers:**

  Number of pulses per time is proportional to rate change of position.

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CNC MACHINES
CUTTING TOOLS (CUTTERS)

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CNC CUTTERS

- Turning center cutters
- Machining center cutters

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TURNING CENTER CUTTERS

Types of cutters used on CNC turning centers

- Carbides (and other hard materials) insert turning and boring tools
- Ceramics
- High Speed Steel (HSS) drills and taps

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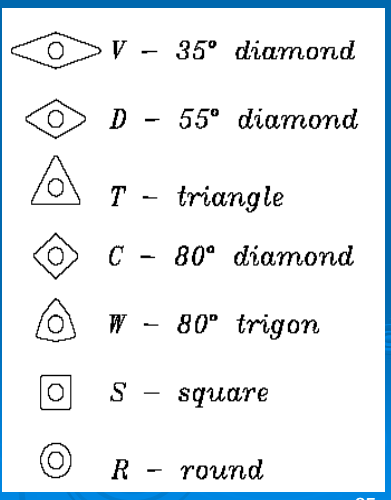
STANDART INSERT SHAPES

- V – used for profiling, weakest insert, 2 edges per side.
- D – somewhat stronger, used for profiling when the angle allows it, 2 edges per side.
- T – commonly used for turning because it has 3 edges per side.
- C – popular insert because the same holder can be used for turning and facing. 2 edges per side.
- W – newest shape. Can turn and face like the C, but 3 edges per side.
- S – Very strong, but mostly used for chamfering because it won't cut a square shoulder. 4 edges per side.
- R – strongest insert but least commonly used.



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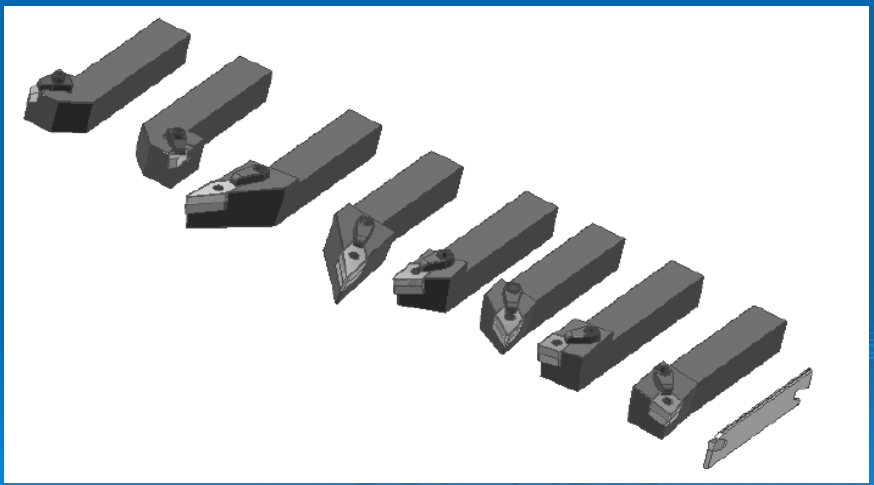
TYPICAL TURNING, THREADING and PARTING TOOLS



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MACHINING CENTER CUTTING TOOLS

- Most machining centers use some form of HSS or carbide insert endmill as the basic cutting tool.
- Insert endmills cut many times faster than HSS, but the
- HSS endmills leave a better finish when side cutting.

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MACHINING CENTER CUTTING TOOLS (cont'd)

- Facemills flatten large surfaces quickly and with an excellent finish. Notice the engine block being finished in one pass with a large cutter.

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MACHINING CENTER CUTTING TOOLS (cont'd)

- Ball endmills (both HSS and insert) are used for a variety of profiling operations such as the mold shown in the picture.
- Slitting and side cutters are used when deep, narrow slots must be cut.

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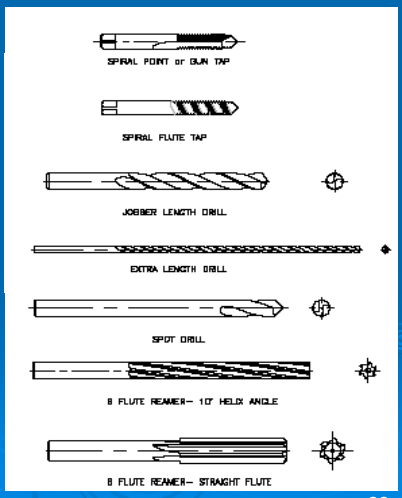
MACHINING CENTER CUTTING TOOLS (cont'd)

Drills, Taps, and Reamers

- Common HSS tools such as drills, taps, and reamers are commonly used on CNC machining centers. Note that a spot drill is used instead of a centerdrill. Also, spiral point or gun taps are used for through holes and spiral flute for blind holes. Rarely are hand taps used on a machining center.



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TOOL HOLDERS

- All cutting tools must be held in a holder that fits in the spindle. These include end mill holders (shown), collet holders, face mill adapters, etc. Most machines in the USA use a CAT taper which is a modified NST 30, 40, or 50 taper that uses a pull stud and a groove in the flange. The machine pulls on the pull stud to hold the holder in the spindle, and the groove in the flange gives the automatic tool changer something to hold onto. HSK tool holders were designed a number of years ago as an improvement to CAT tapers, but they are gaining acceptance slowly.

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