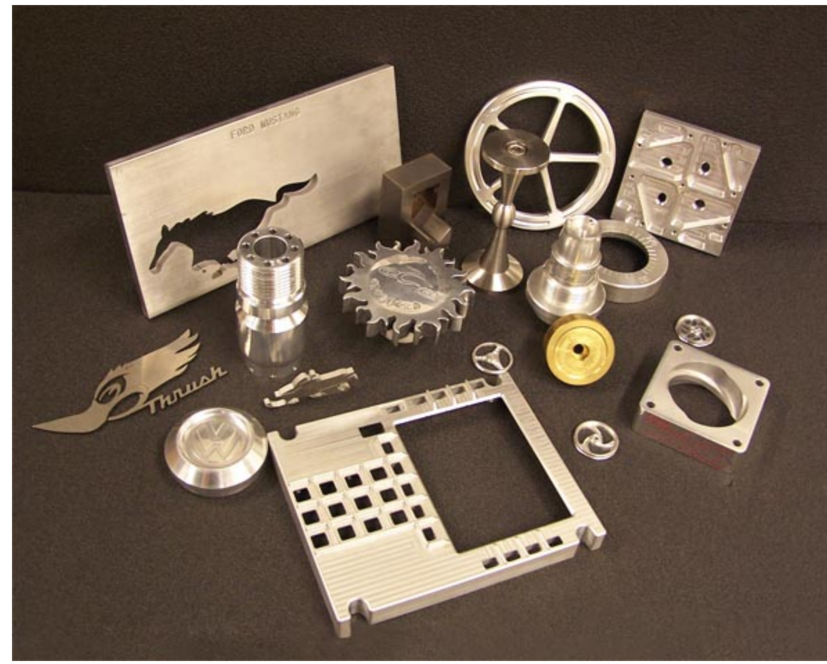
CNC Basics

Introduction

- Computerized numerical control (CNC) machines
  - Perform complex operations faster, more accurately and consistently



Examples of some workpieces produced by CNC machines.

A CNC lathe.

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HAAS
Tools are changed manually
Photo courtesy of Haas Automation, Inc

CNC turning center.

A CNC milling machine.

Photo courtesy of Haas Automation, Inc

A CNC machining center.

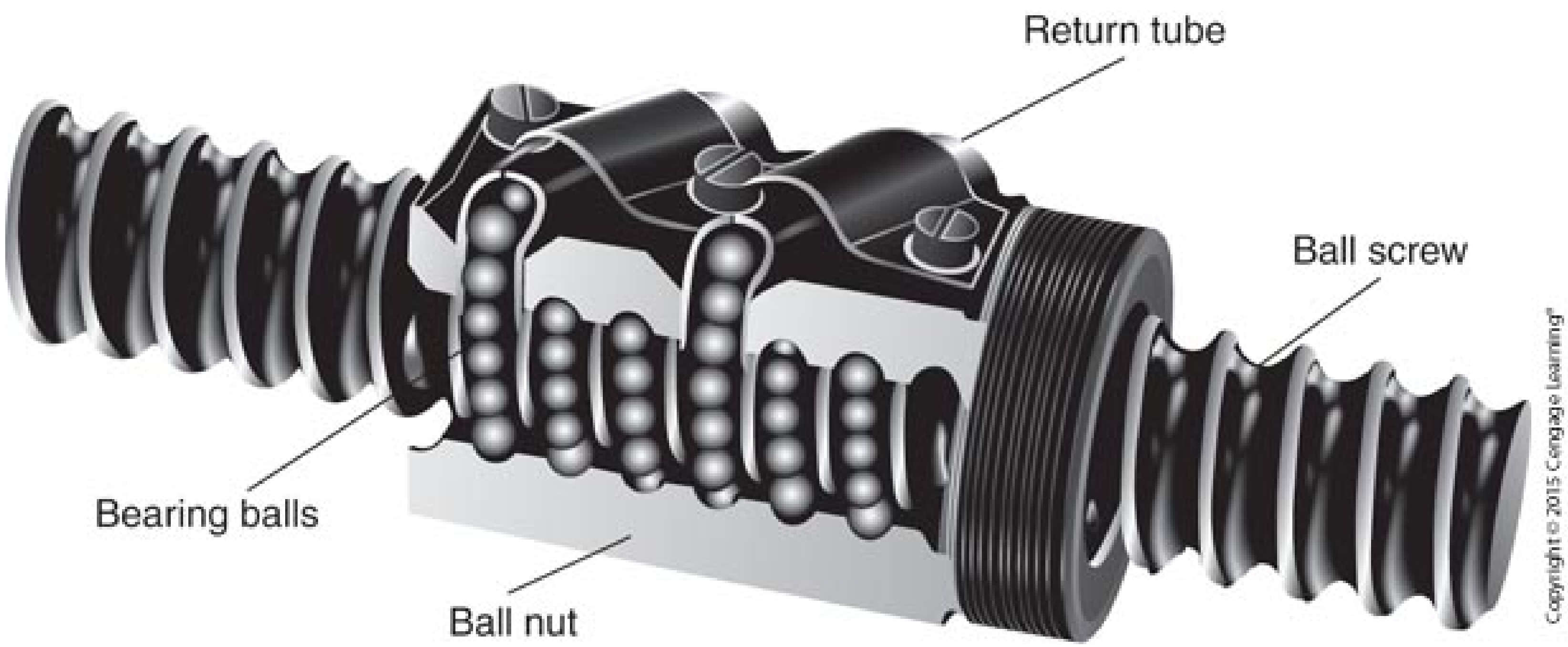
The CNC Machine Control Unit

- CNC program created & stored in MCU (machine control unit)

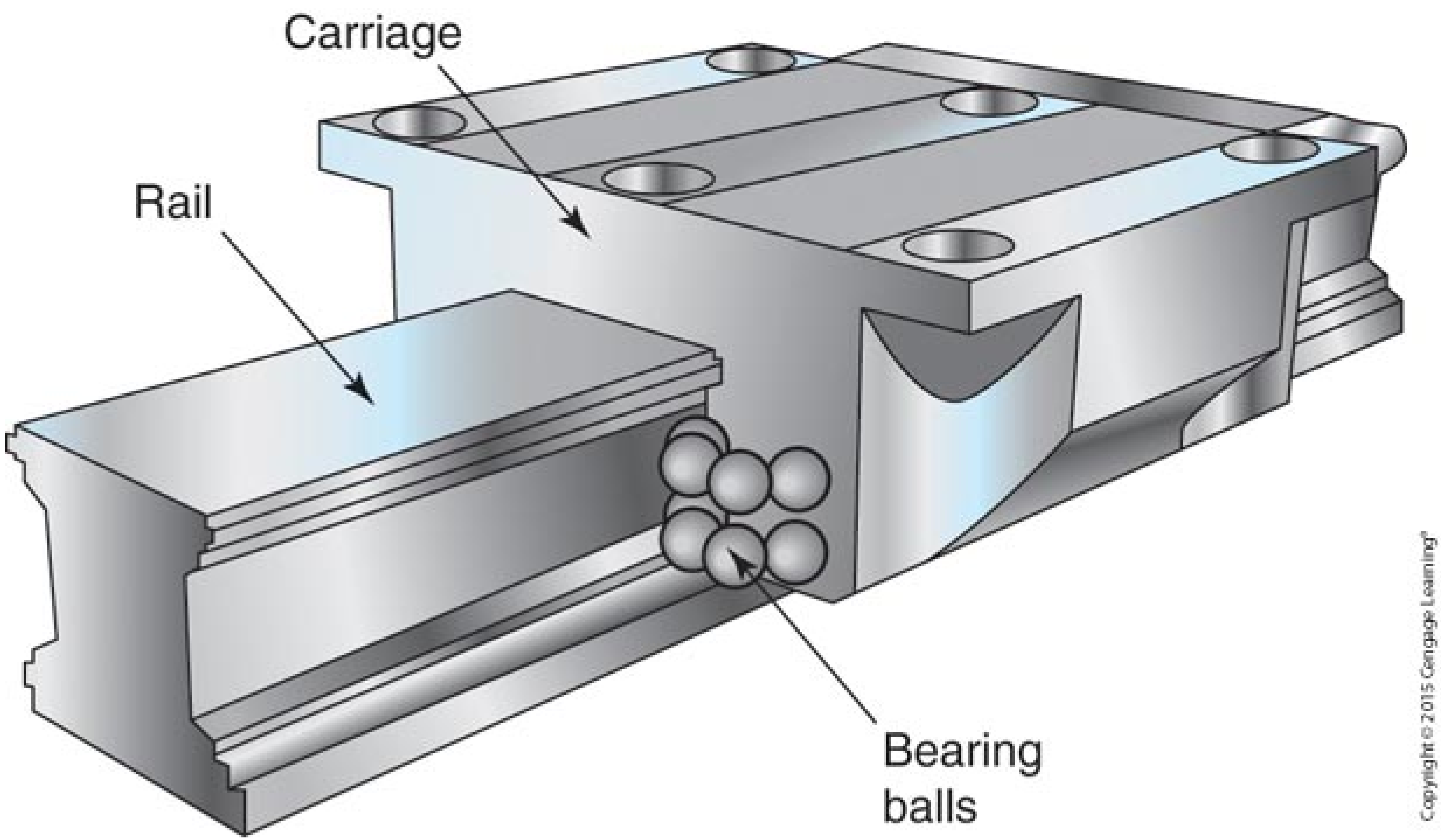
An operator control panel mounted on the exterior of the machine control unit.

CNC Motion Control

- Machine locates axes from programmed commands
- Components: drive screws, CNC guideways, servo motors



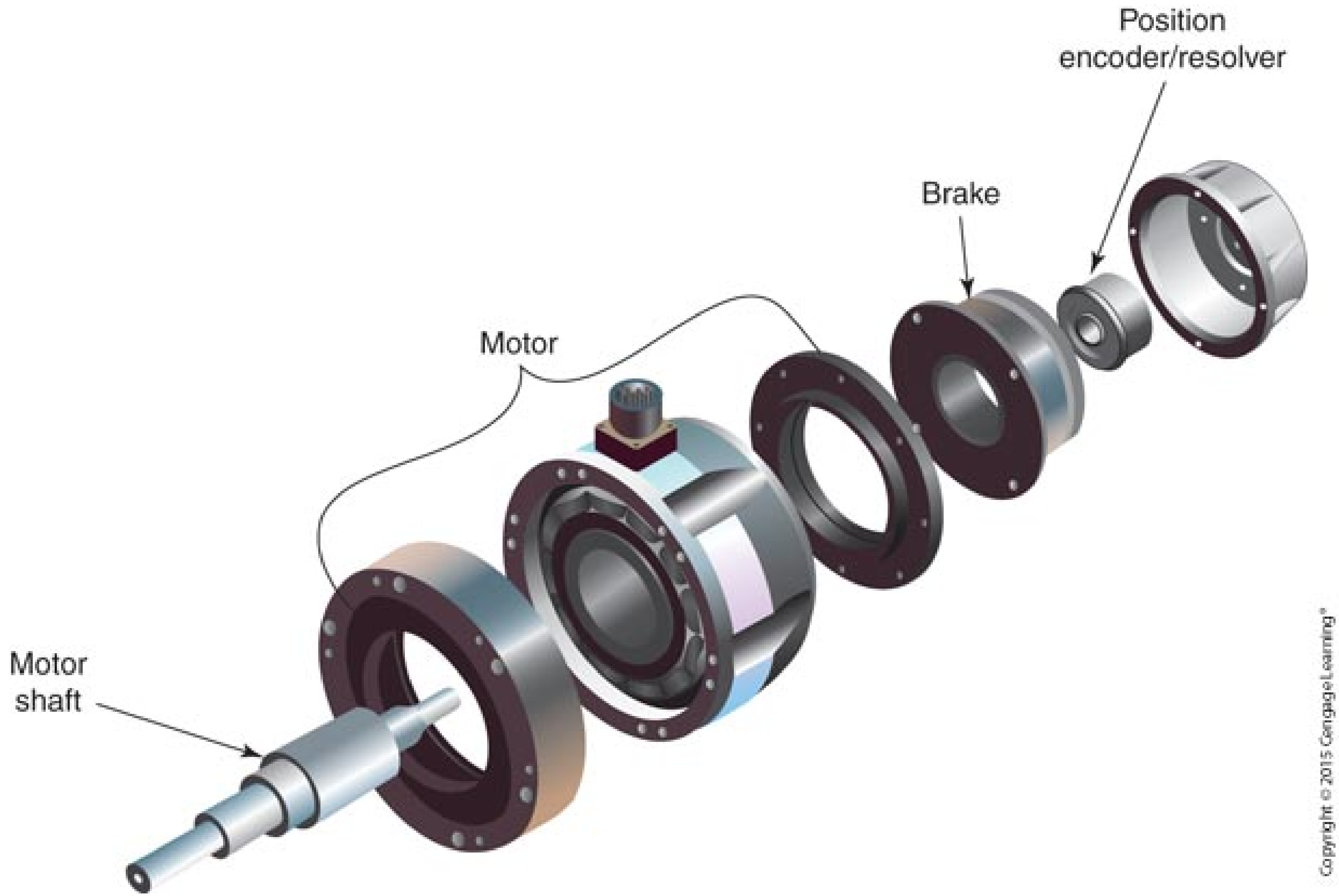
A ballscrew assembly.



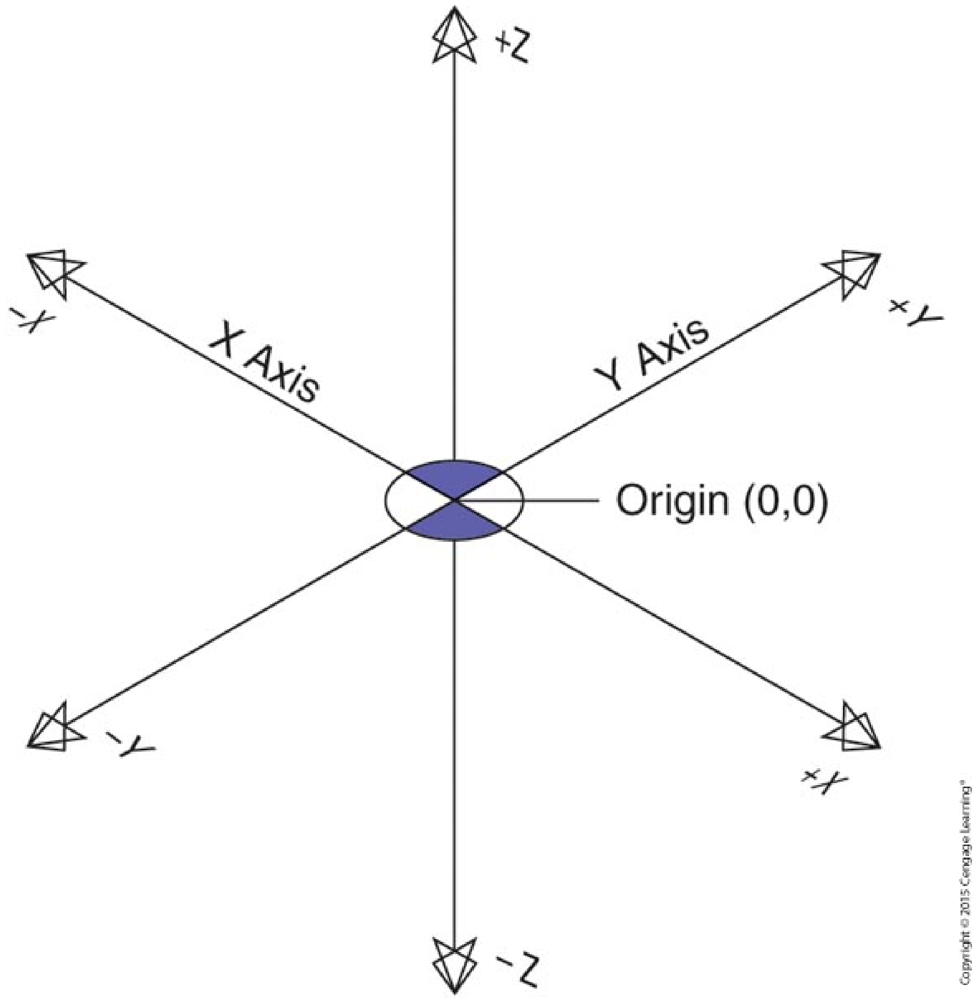
A linear guide assembly and its parts.

Coordinate Systems

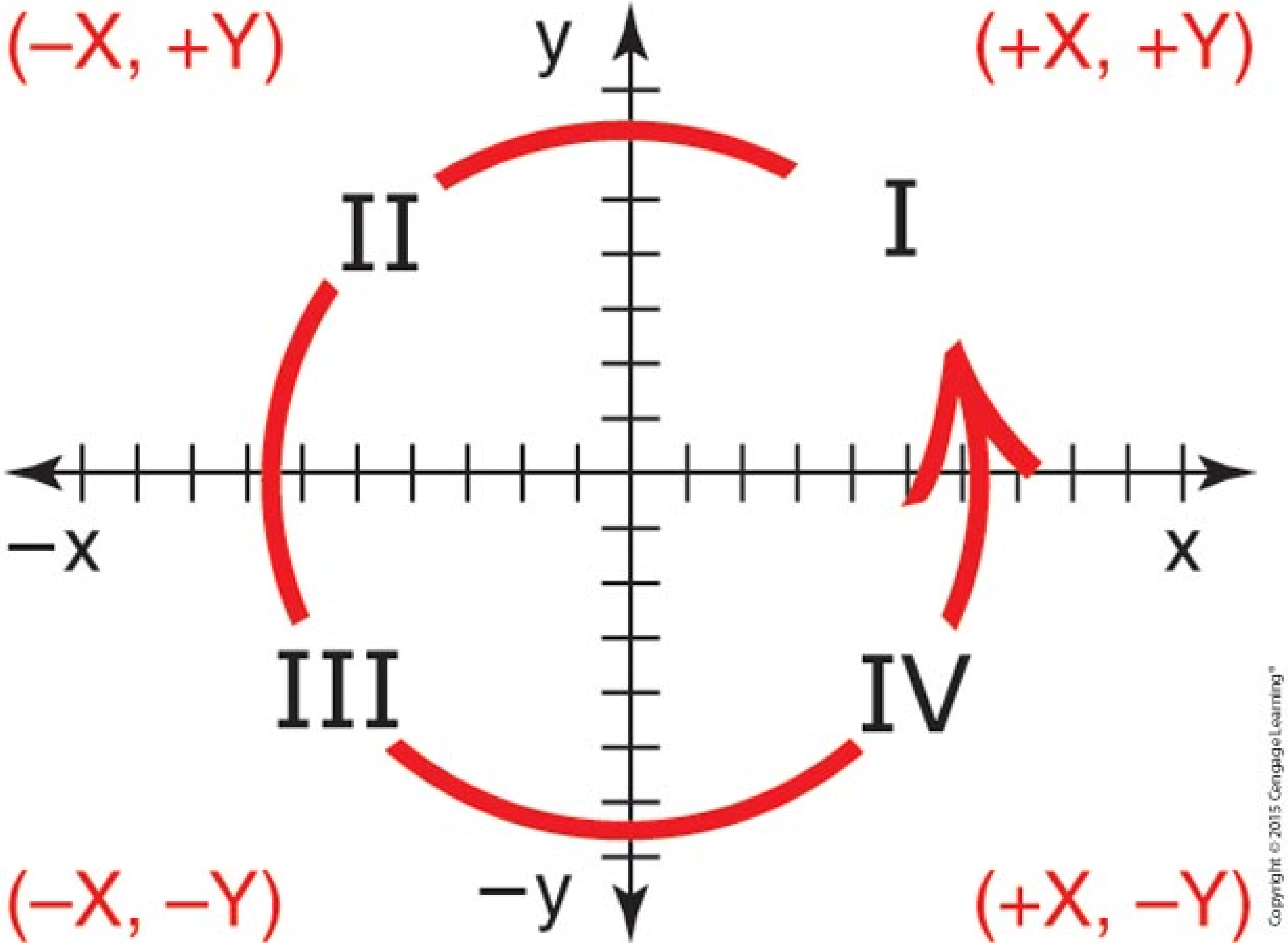
- Programs tell machine function and where to perform it
- Coordinate system maps locations
  - Cartesian/rectangular system maps positive/negative values on X- and Y- axes relative to origin
  - Polar system locates points by angle and distance from origin



The parts of a servo motor.

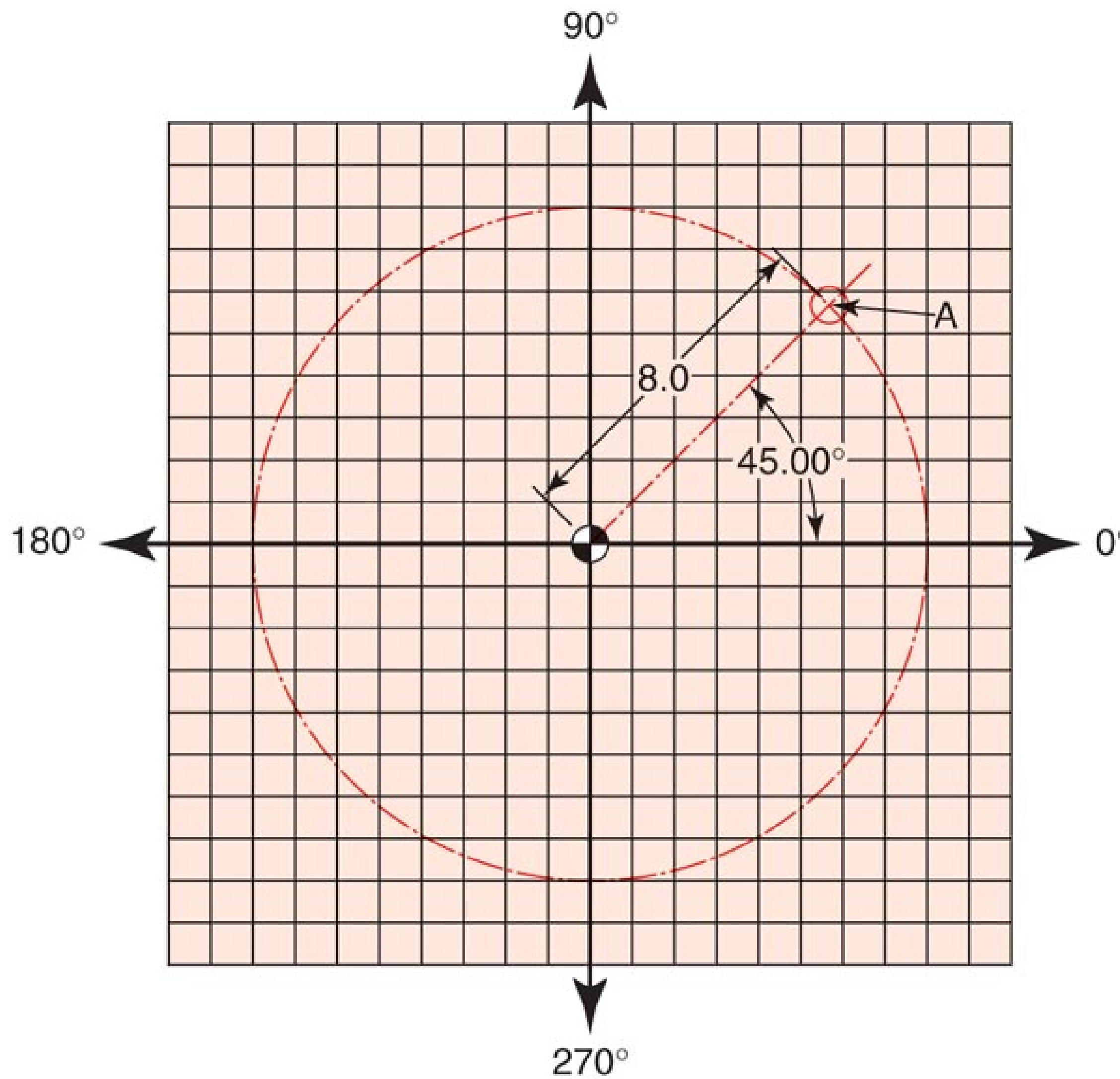


The parts of the Cartesian coordinate system.

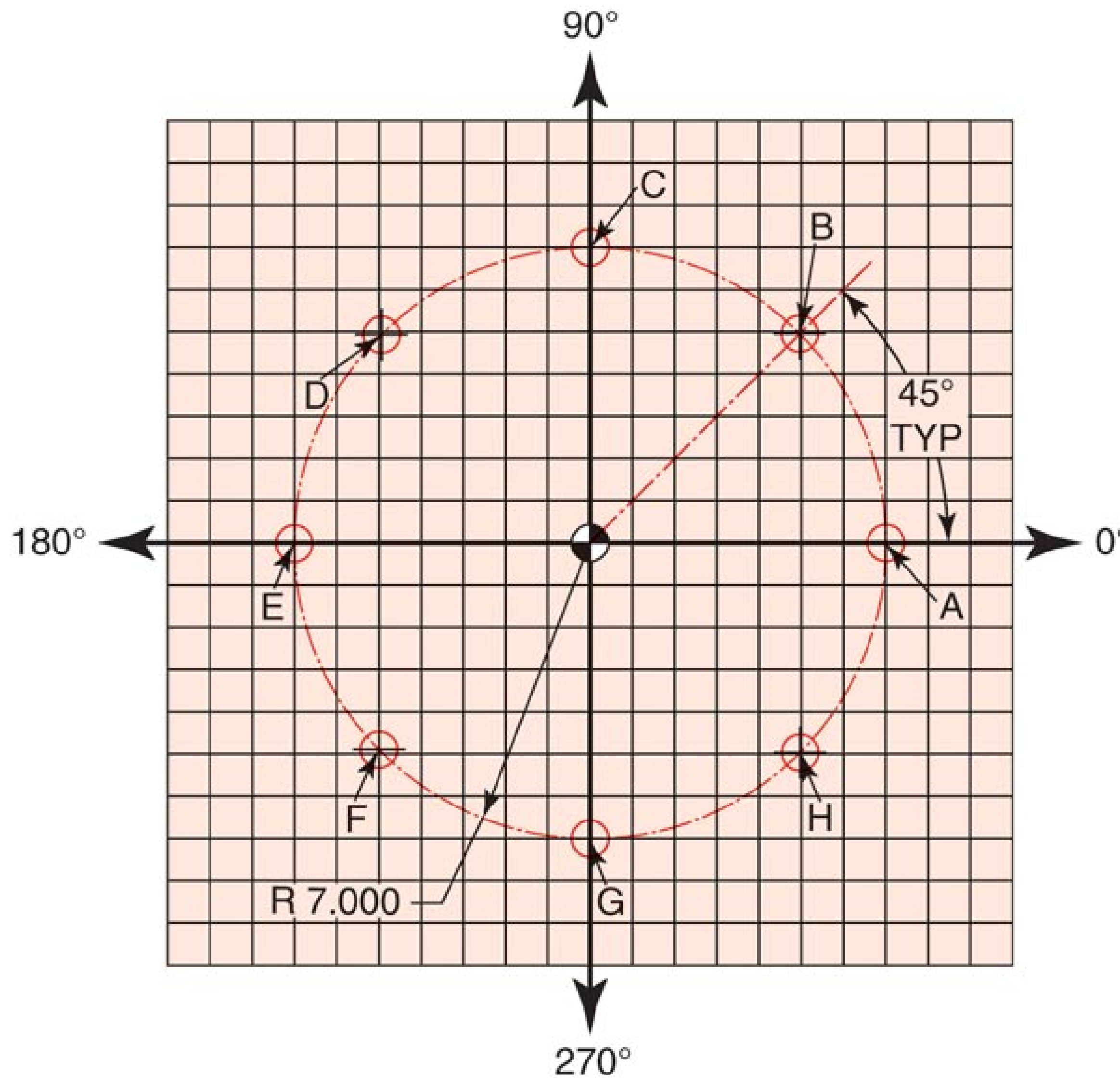


Quadrants separate a coordinate plane into four regions.

A diagram showing the polar coordinate system. When using this system, the X-value specifies the distance from the origin, and the Y-value specifies the angle relative to the zero degree mark. The position “A” shown is located at an angle of 45° and a distance of 8.0" from the origin; when using the polar coordinate system this is written as X8.0 Y45.0



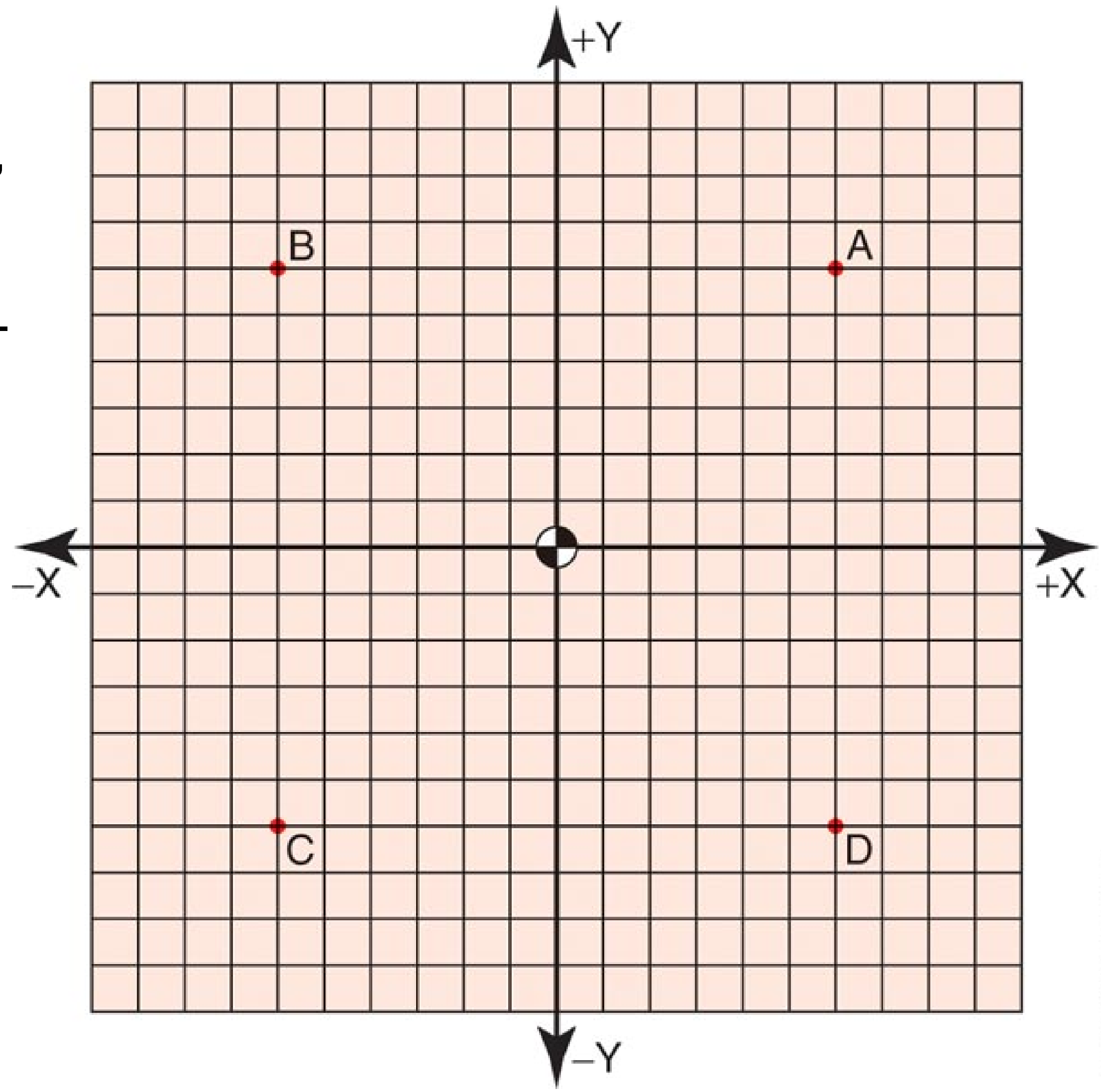
An example of how each position in an eight-hole workpiece can be identified using polar coordinates. The positions for each location are programmed as: (A) X7.0 Y0; (B) X7.0 Y45.0; (C) X7.0 Y 90.0; (D) X7.0 Y135.0; (E) X7.0 Y180.0; (F) X7.0 Y225.0; (G) X7.0 Y270.0; (H) X7.0 Y315.0



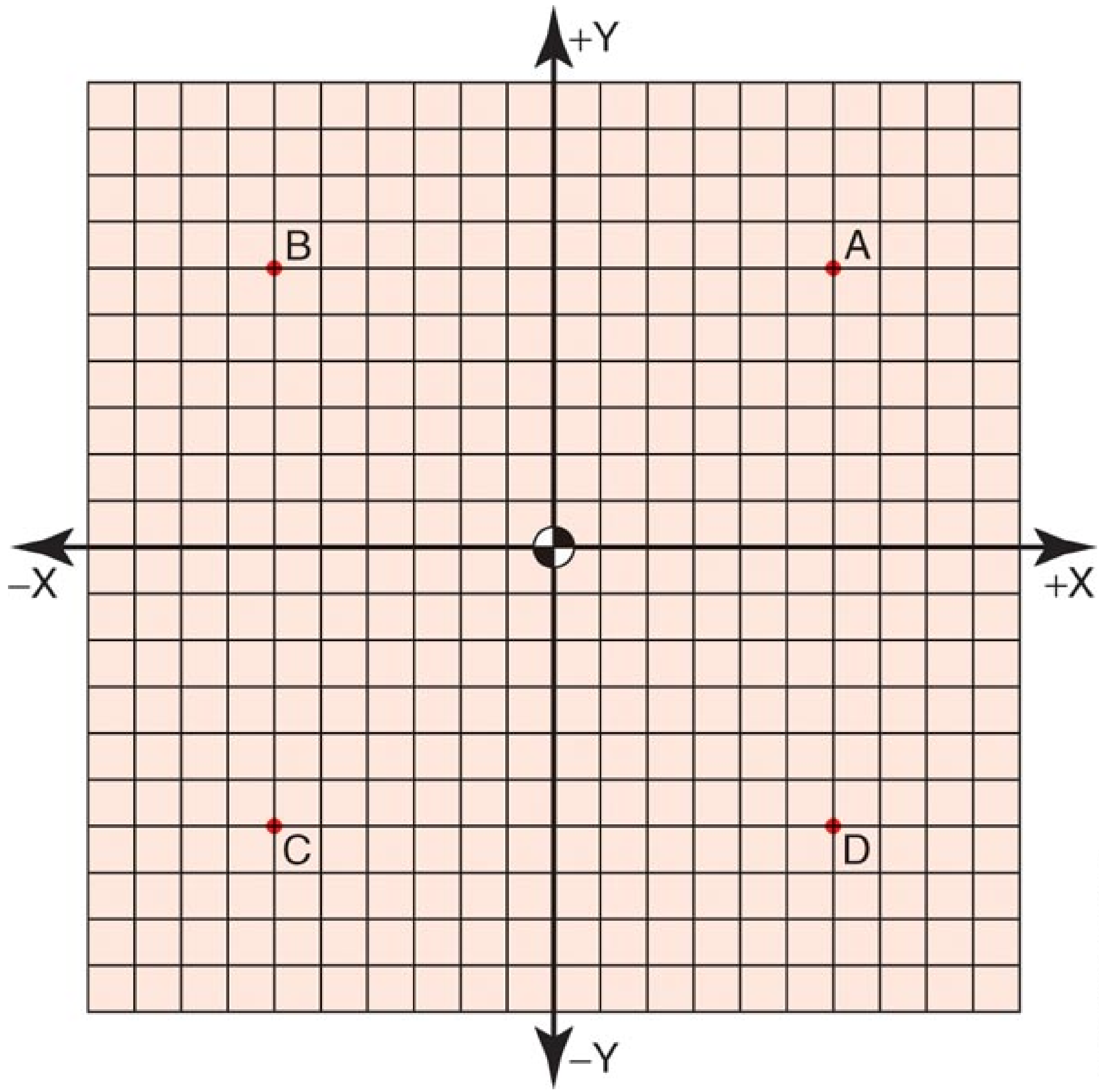
Positioning Systems

- Absolute positioning system references all positions relative to origin
- Incremental positioning system specifies distance from current position to next

Assume that each block on the grid equals 1". Using the absolute programming method, the coordinates for each identified location are: (A) X6.0 Y6.0; (B) X-6.0 Y6; (C) X-6.0 Y-6; (D) X6.0 Y-6.0.



Assume that each block on the grid equals 1". Using the incremental programming method, assuming the cutting tool is already at position A, the coordinates for each following location are: (B) X-12.0 Y0; (C) X0.0 Y-12; (D) X12.0 Y0.0



Codes

- Codes tell machine what to do at position
  - G-codes: preparatory commands (set mode)
  - M-codes: miscellaneous functions (on/off)
  - Other word address commands
  - Binary

Parameter Number	Bit Number							
	#7	#6	#5	#4	#3	#2	#1	#0
0401	1	1	0	1	0	0	0	1

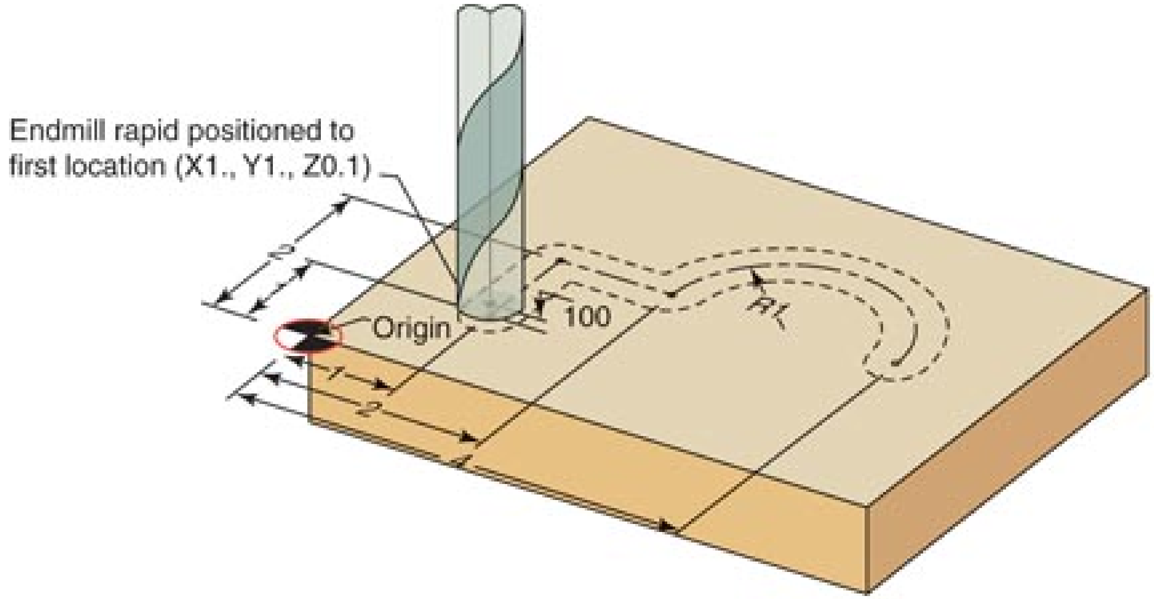
An example of the parameter numbering format. Notice the parameter number is 0401 and the bits are read in sequence from right to left. Each bit can be either a ‘0’ or a ‘1’.

Conversational-Type Programming

- Operator selects function and machine prompts for more information

Parts of a CNC Program

- Safe-start: clears machine for new operation
- Material removal: performs operations
- Program ending: safely positions tool & axes out of the way



O0001 (SAMPLE PROGRAM); — Program number and (operator label). Since this label is within parentheses, it is not read by the machine, only by the operator.

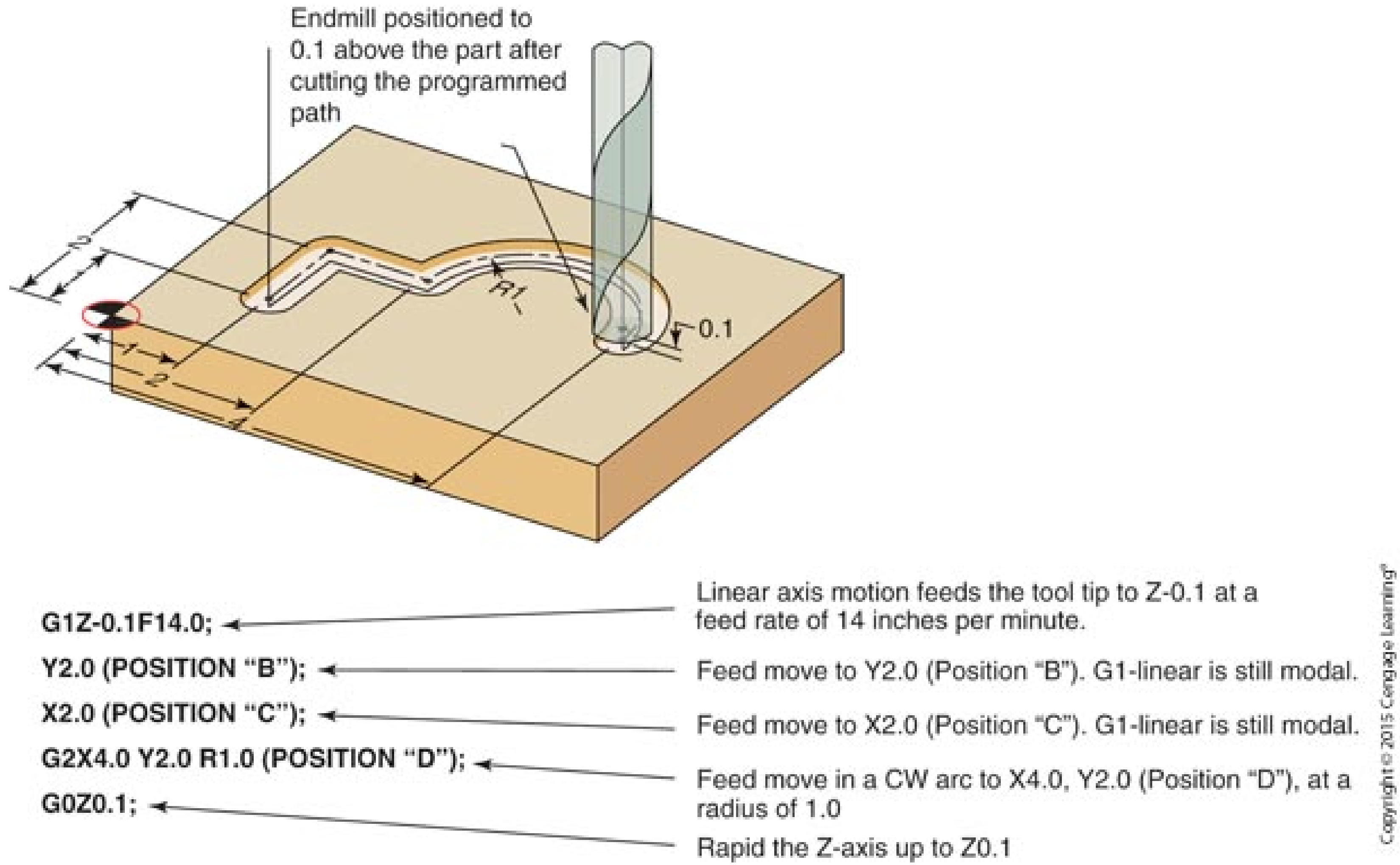
G0G90G20; — Safe start block initiating the modal codes for rapid traverse (G0), absolute programming (G90), and inch units (G20)

M6T1; — Tool change to tool #1

X1.Y1.(POSITION "A"); — Rapid to X1. Y1. (Position "A"). Rapid and absolute modes are still modal from above so they do not need to be programmed again here.

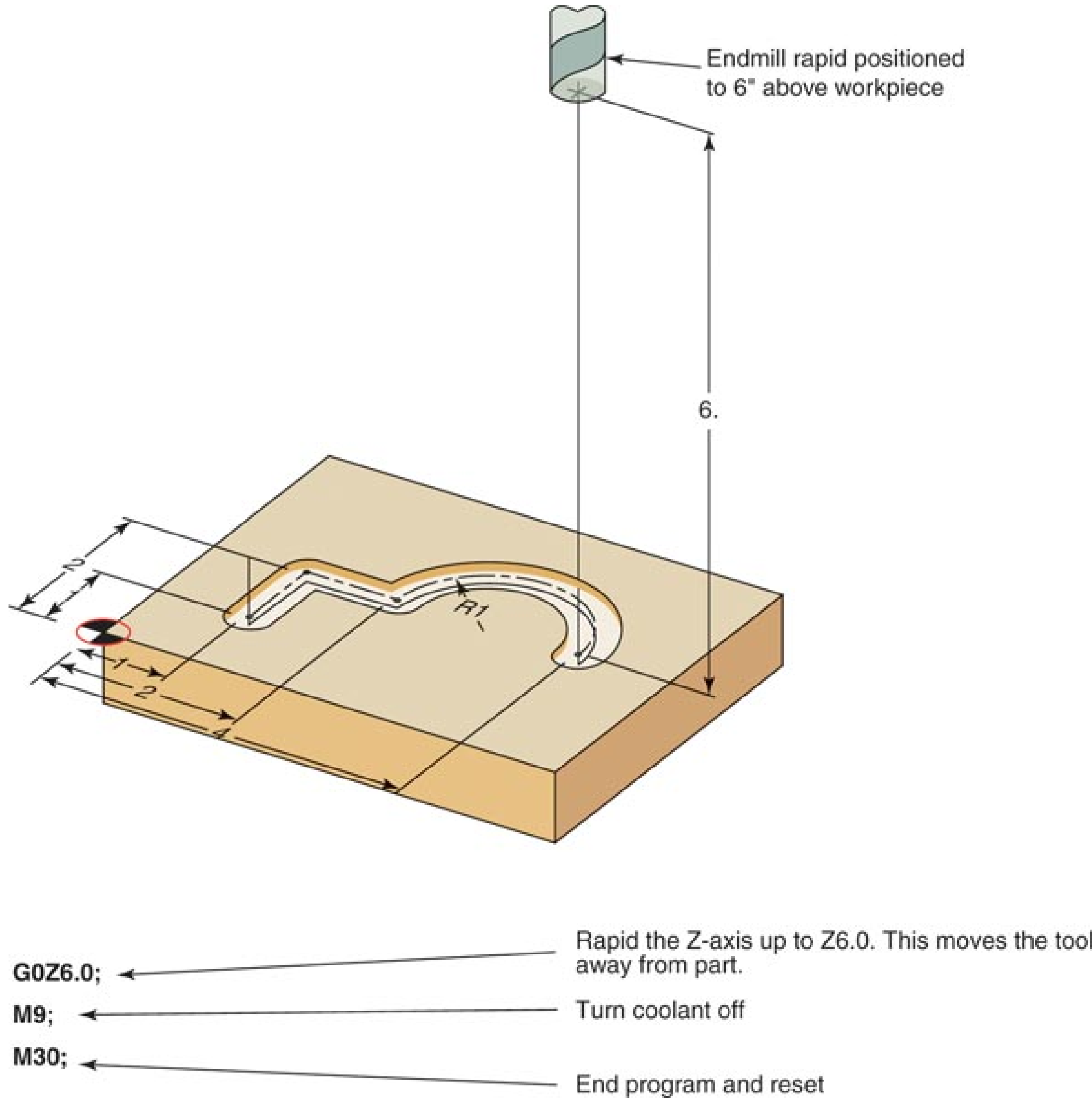
Z0.1S4500M3; — Move the Z-axis to 0.1, start spindle in forward direction to 4500 RPM. The Z-axis move is a rapid move because the G0 is still active.

The program begins by the tool being loaded, the spindle being started, and the tool being rapid positioned to the first location.



The tool is fed to depth and then fed to each location. Once machining is complete, the tool is then retracted to a clearance point above the workpiece.

The tool is rapid positioned to a location far above the workpiece. The coolant is turned off and the program is ended.



Introduction to CNC Milling

Introduction

- CNC milling machines perform same functions as manual, and creates arcs, contours and 3D surfaces

CNC milling machines can produce complex part surfaces that would be virtually impossible to produce with manual milling machines.

Types of CNC Milling Machines

- Two classes of machining centers:
  - Vertical spindle and horizontal spindle
- Types of milling machines: vertical and horizontal machining centers (VMC and HMC)
- ATC types: carousel-type and swing-arm-type

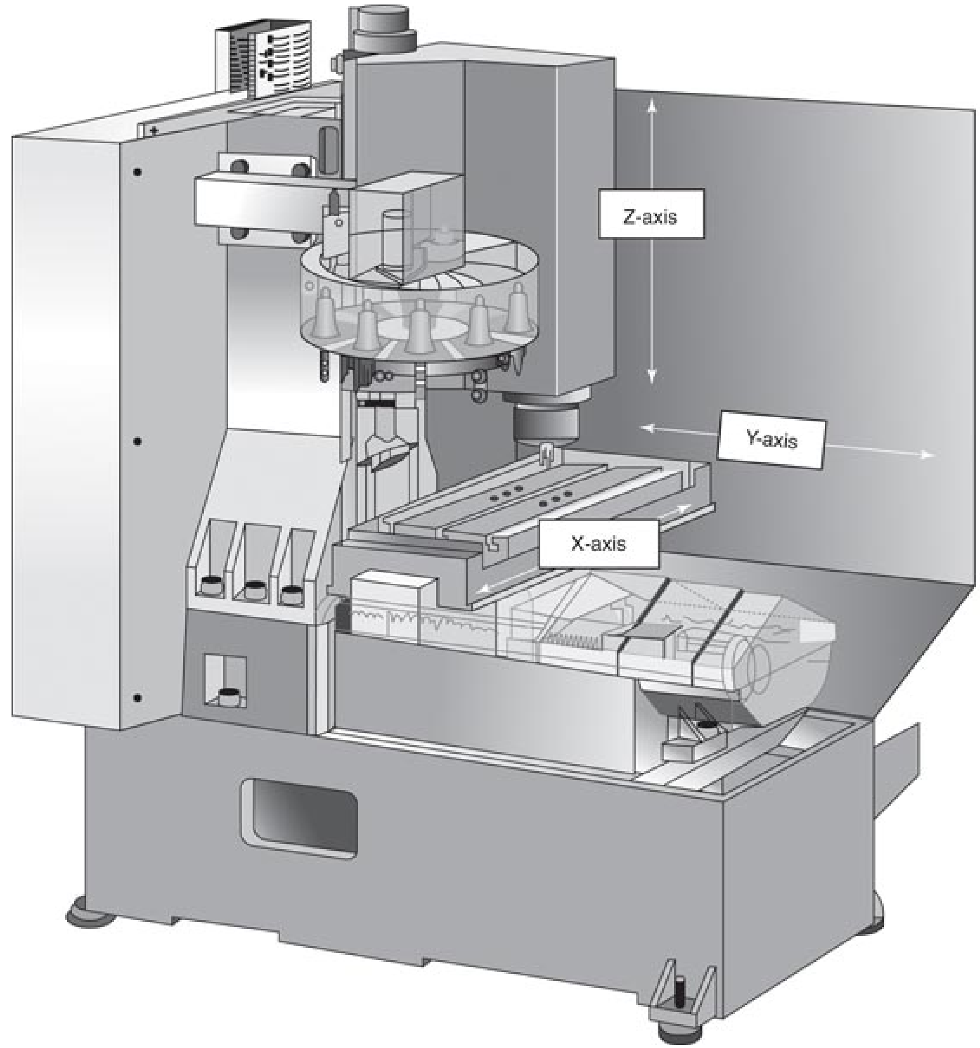
A vertical CNC milling machine

Courtesy of Bridgeport Milling

A vertical machining center

Photo courtesy of Haas Automation, Inc

A vertical machining center (VMC). Notice the similarities to a manual vertical milling machine.



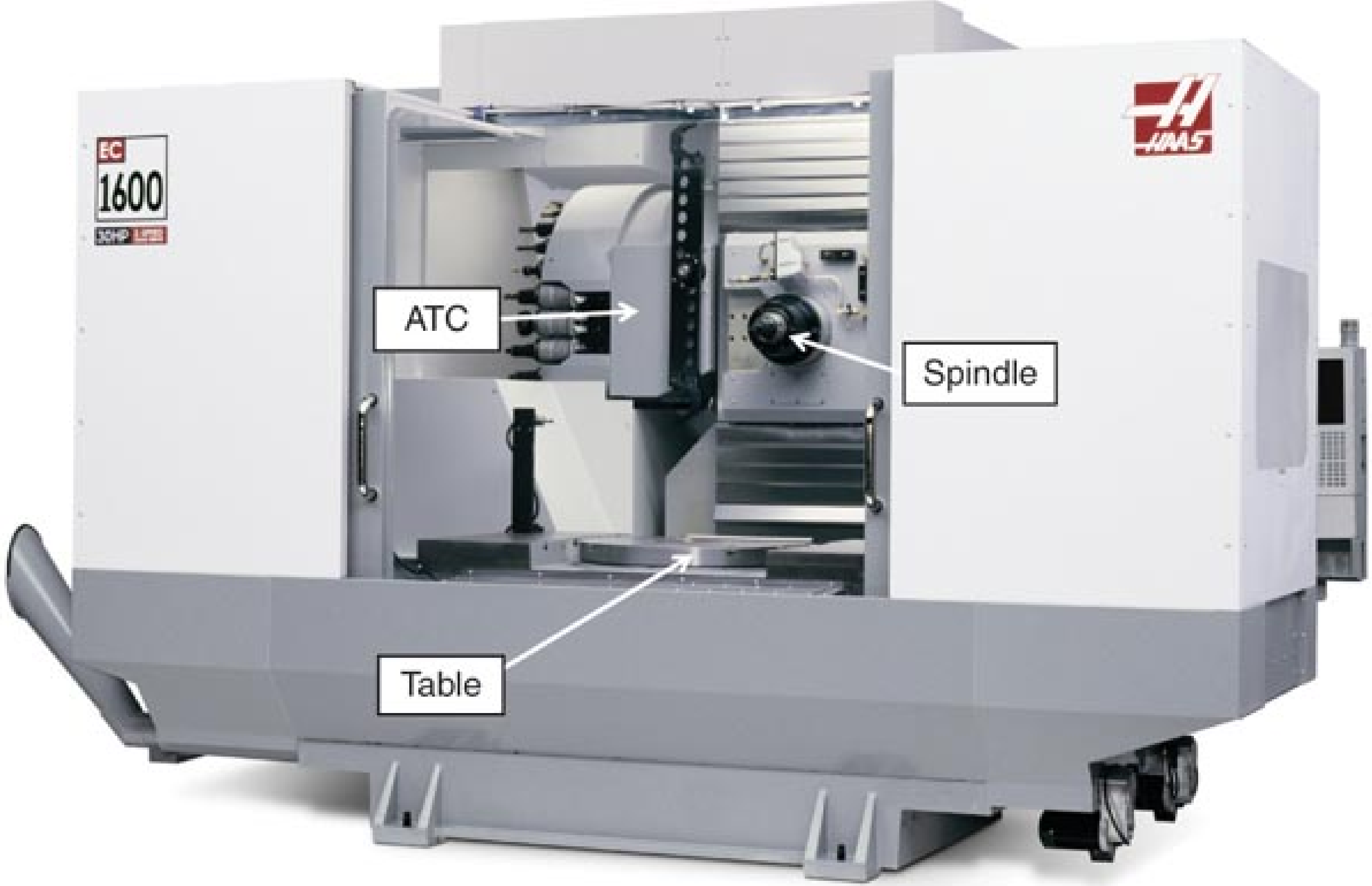


Photo courtesy of Haas Automation, Inc

A horizontal machining center (HMC). Notice the orientation of the spindle, table, and ATC.

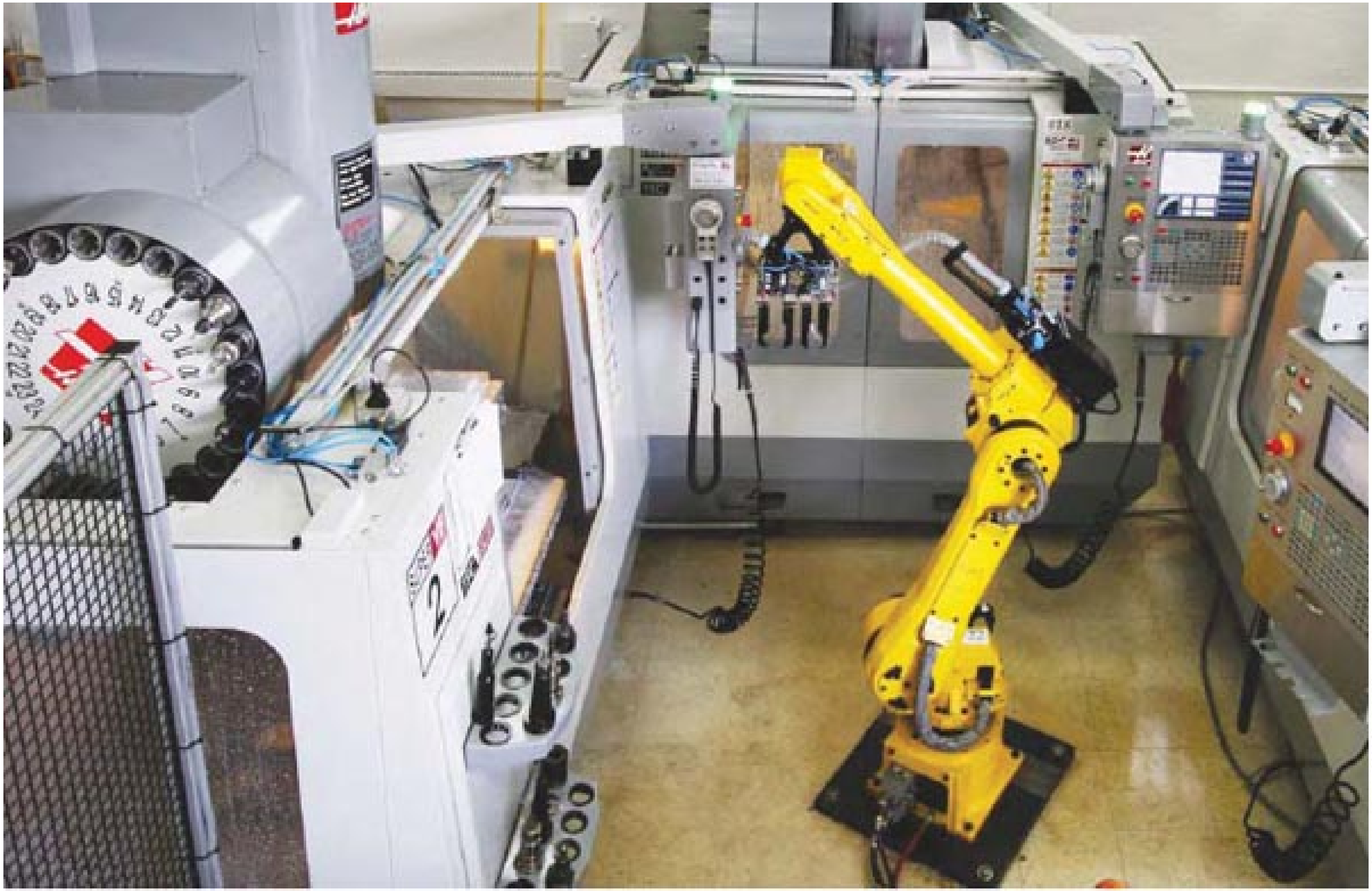


Photo courtesy of Haas Automation, Inc

A manufacturing cell with multiple CNC machining centers and automated part handling.

Courtesy of Mag Americas

A carousel-type ATC.

Courtesy of Mag Americas

The swing-arm-type ATC changes tools much faster than the carousel-type ATC.

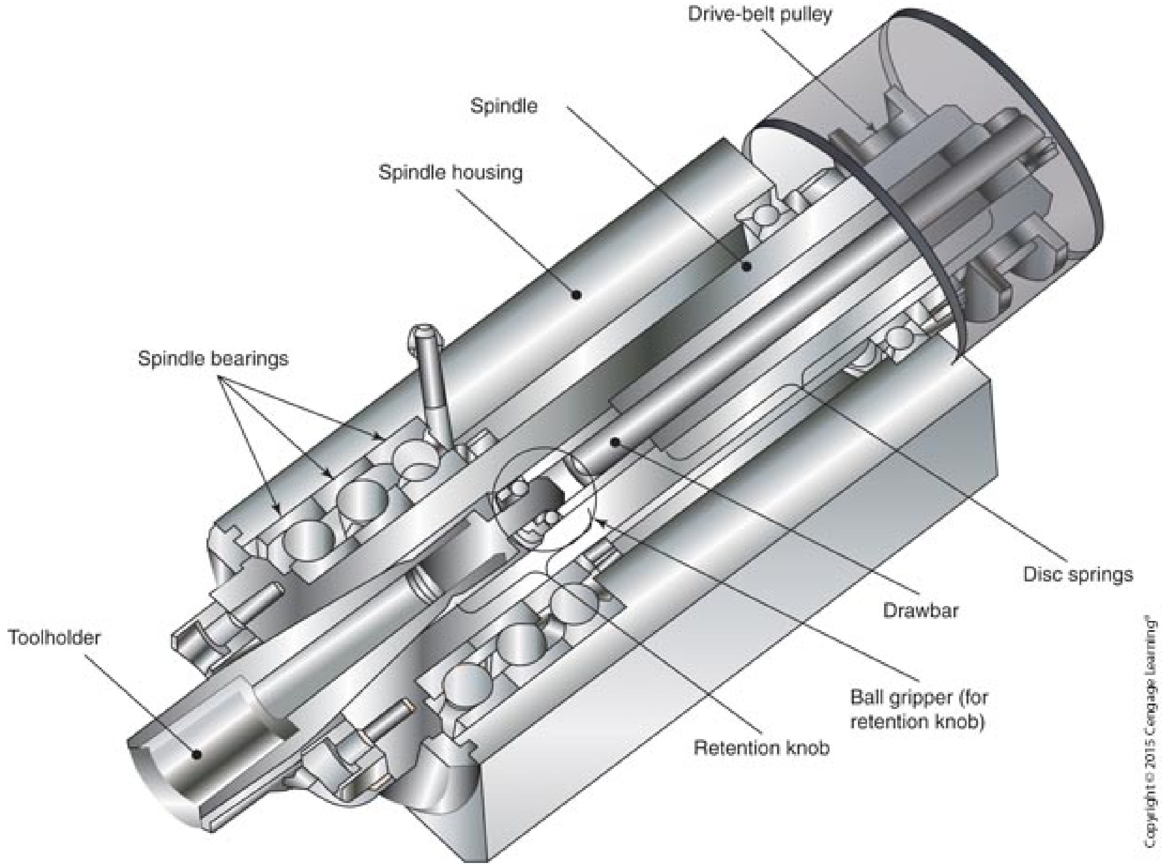
Toolholding

- Toolholding
  - CNC spindle types and tool attachment styles
  - Workholding: many devices available

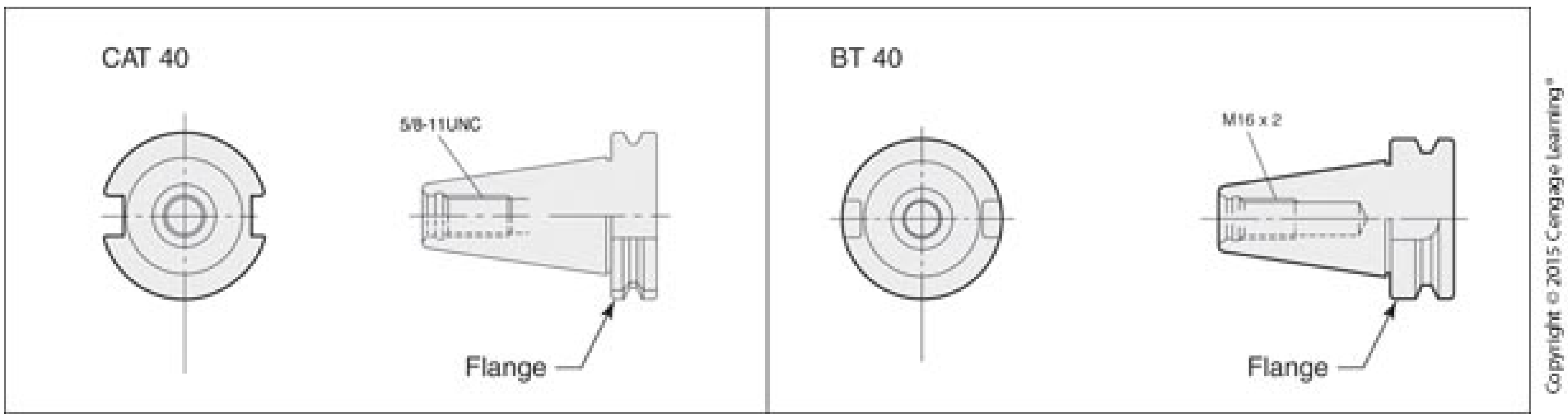
National Machine Tool Builder (NMTB) toolholders in 30, 35, 40, 45, and 50 size tapers.

Retention knobs thread into tapered toolholders to secure the holder in the machine spindle.

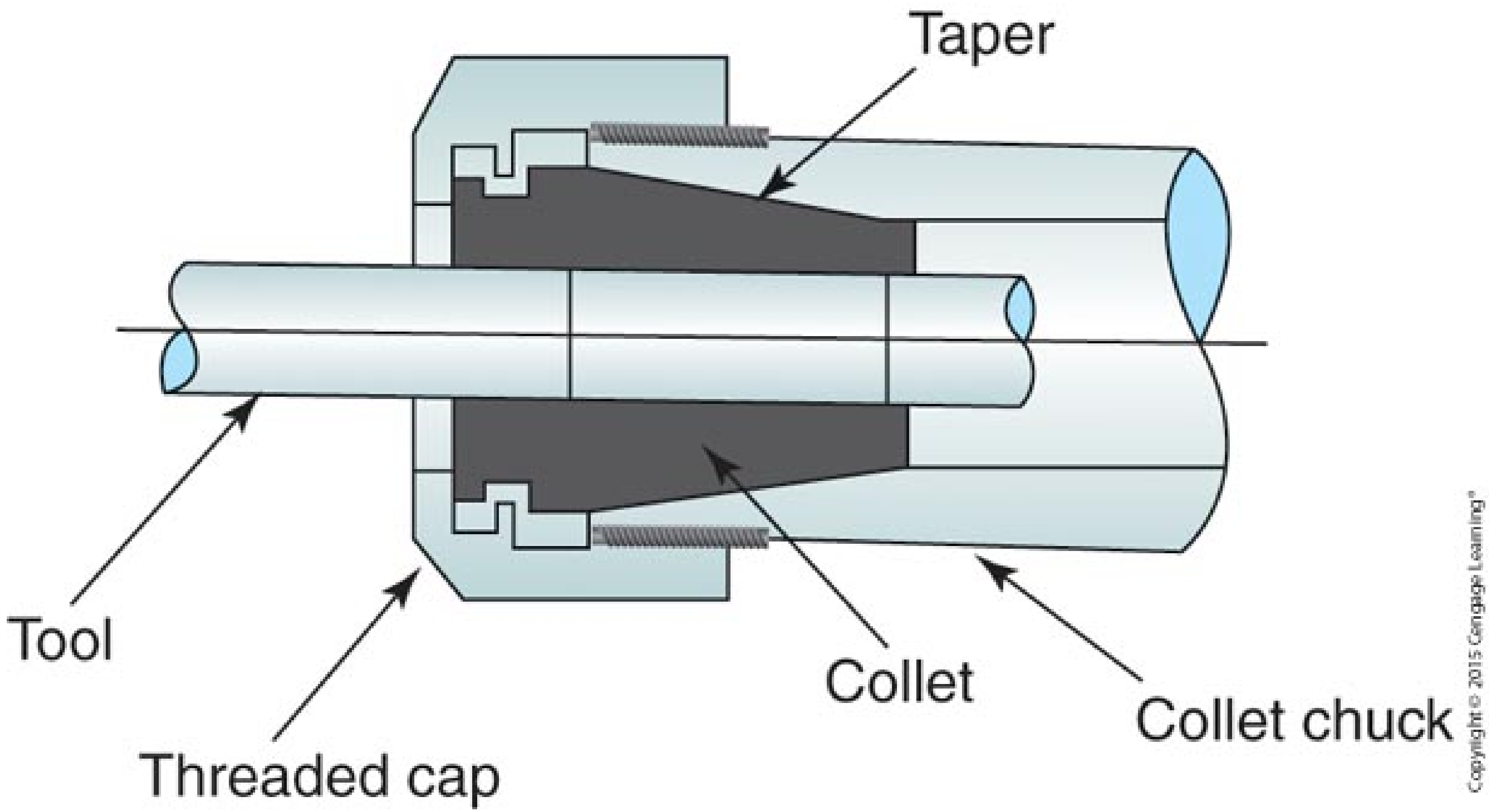
Courtesy of Lyndex-Nikken, Inc



A cutaway view showing the many parts of a milling spindle. Notice how the ball gripper mechanism at the end of the drawbar grasps the retention knob. Spring tension from a series of disc springs pulls on the drawbar to secure the toolholder taper.



A CAT holder and a BT holder. Notice the difference in the size of the flanges and the location of the grooves.



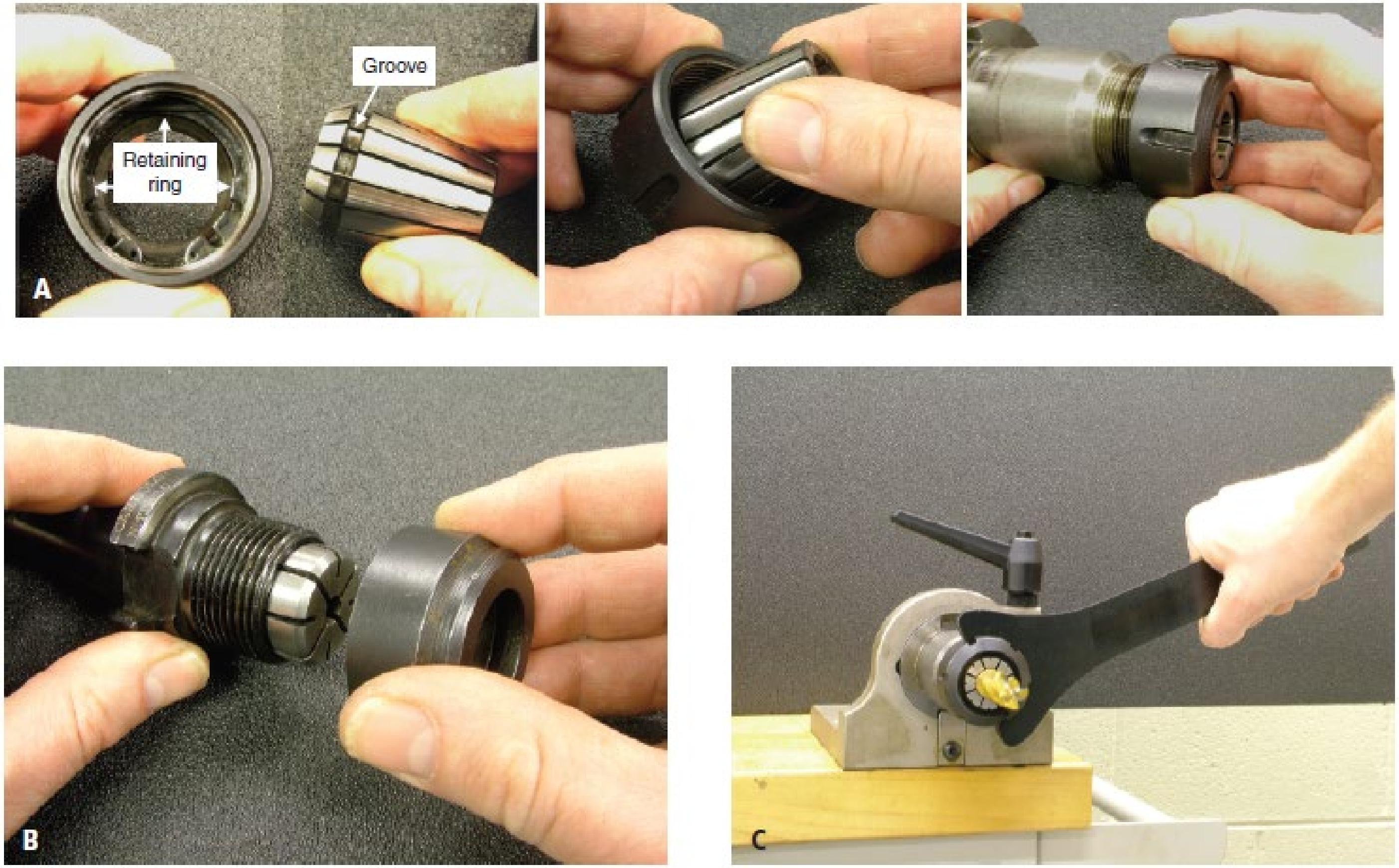
A collet chuck grips a tool shank by tightening the threaded cap.

Courtesy of Lyndex-Nikken, Inc

Courtesy of Lyndex-Nikken, Inc

Courtesy of Lyndex-Nikken, Inc

(A) ER-, (B) TG-, and (C) DA-style collets.



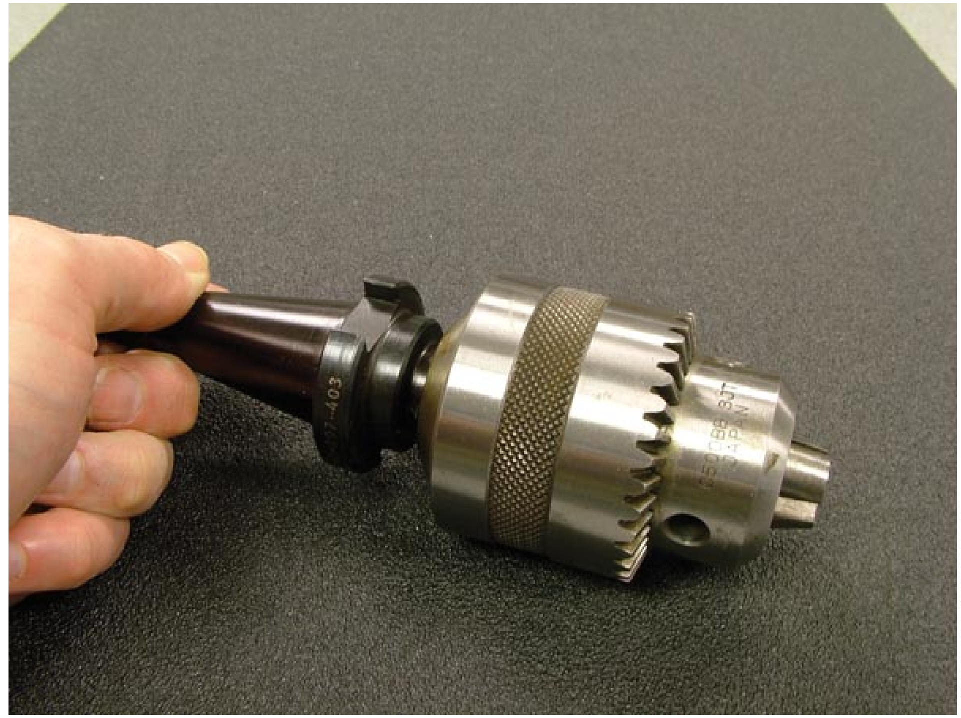
(A) The groove on an ER collet snaps into a retaining ring in the threaded cap and the cap is then threaded into the collet chuck. (B) DA collets slip into the chuck and then the cap is threaded onto the chuck. (C) The toolholder is then mounted in a bench-top clamping device, the tool is inserted in the collet, and the cap is tightened.

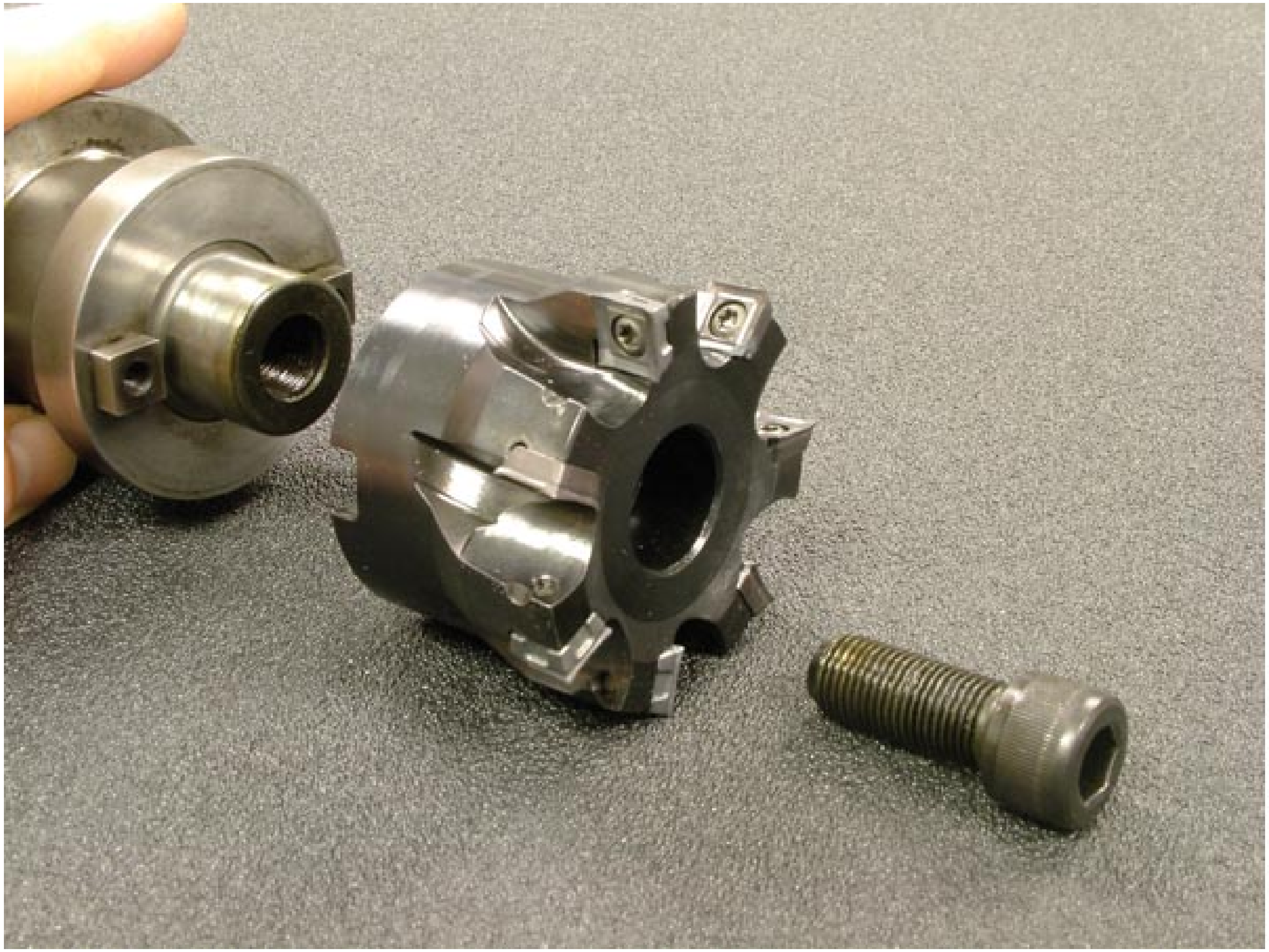
Photo courtesy of Haas Automation, Inc

(A) A shrink-fit toolholder.
(B) The machine that assembles and disassembles shrink-fit tooling.

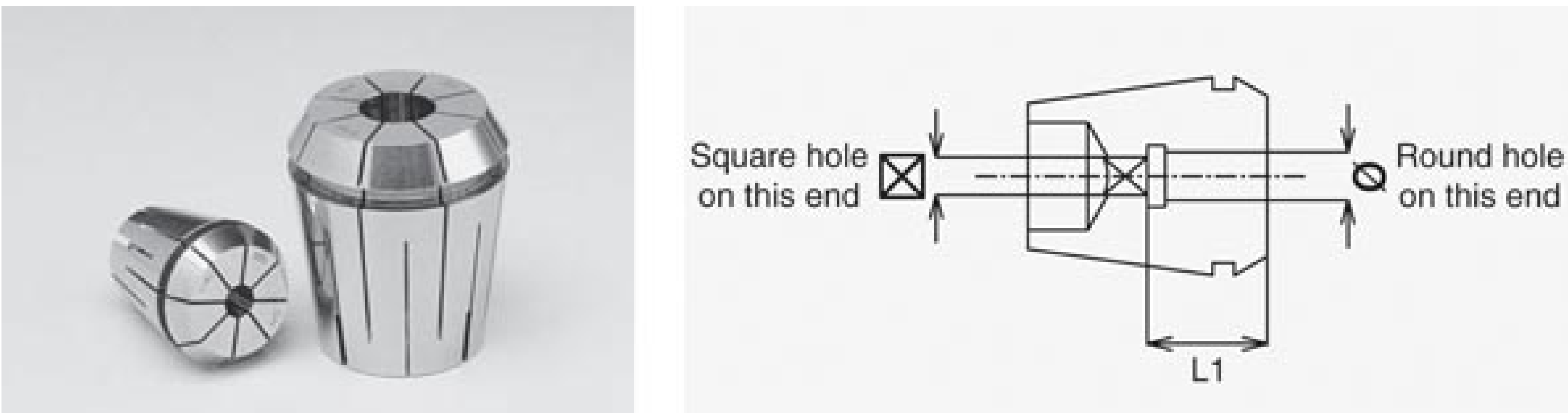
ourtesy of Bilz Tool Co

FIGURE 8.5.16
(A) A key-type chuck with a quick change size 30 NMTB taper and (B) a keyless chuck with a CAT type flange..



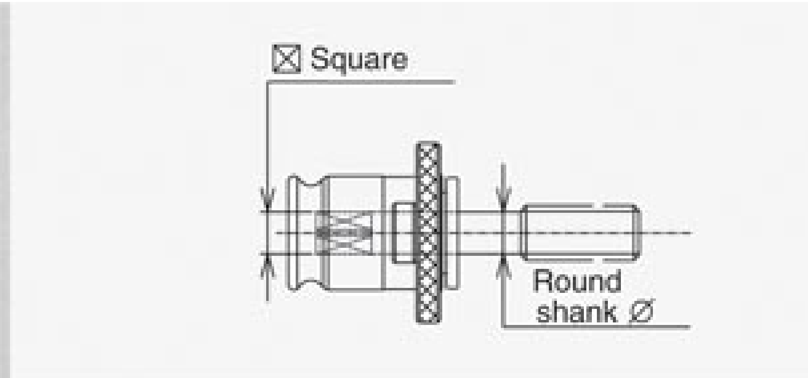


A face mill and toolholder.



Courtesy of Lyndex-Nikken, Inc

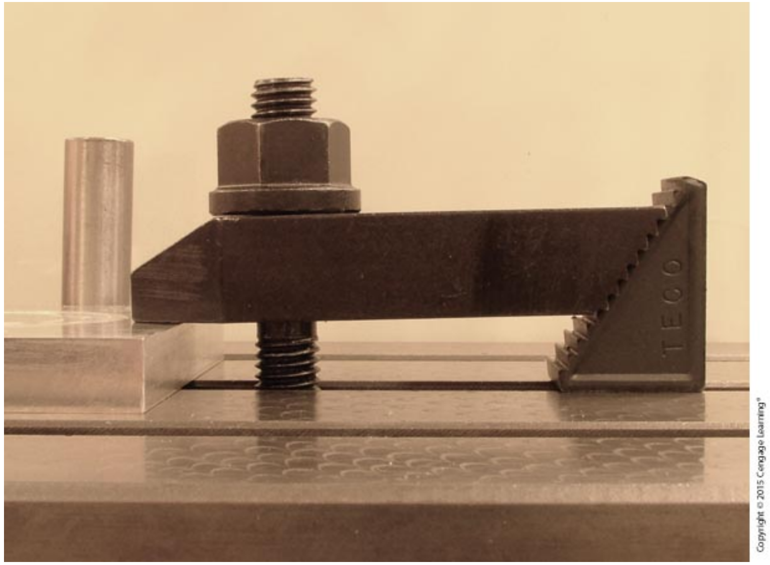
An ER collet with an internal square for holding taps rigidly.



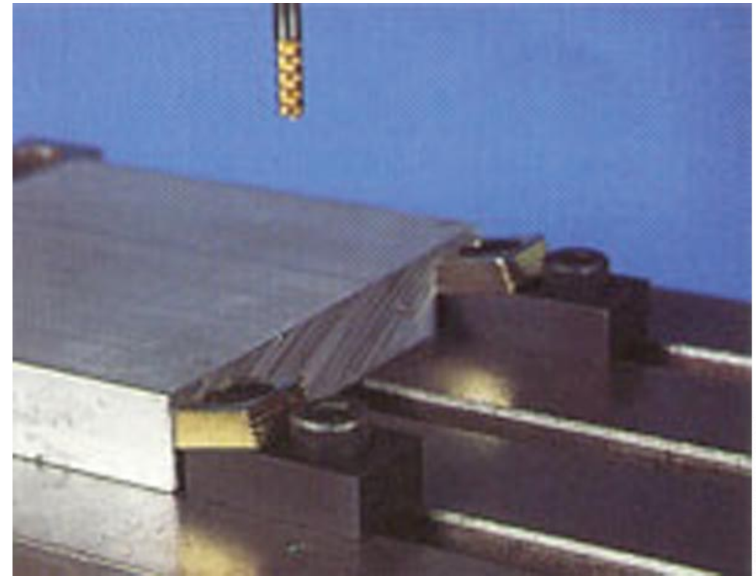
Courtesy of Lyndex-Nikken, Inc

Courtesy of Lyndex-Nikken, Inc

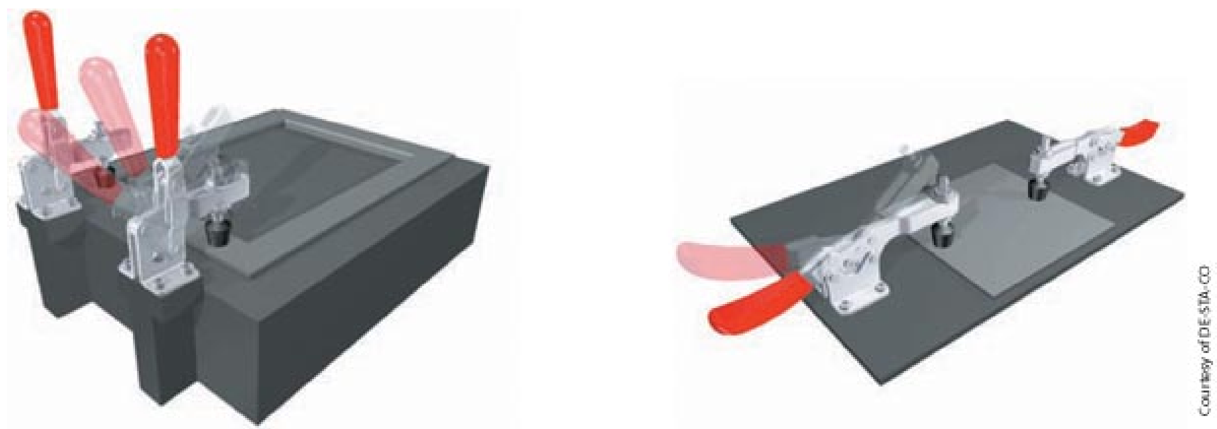
(A) A quick-change tap adapter designed to quickly mount taps into a
(B) floating holder.



Step clamps



Toe clamps

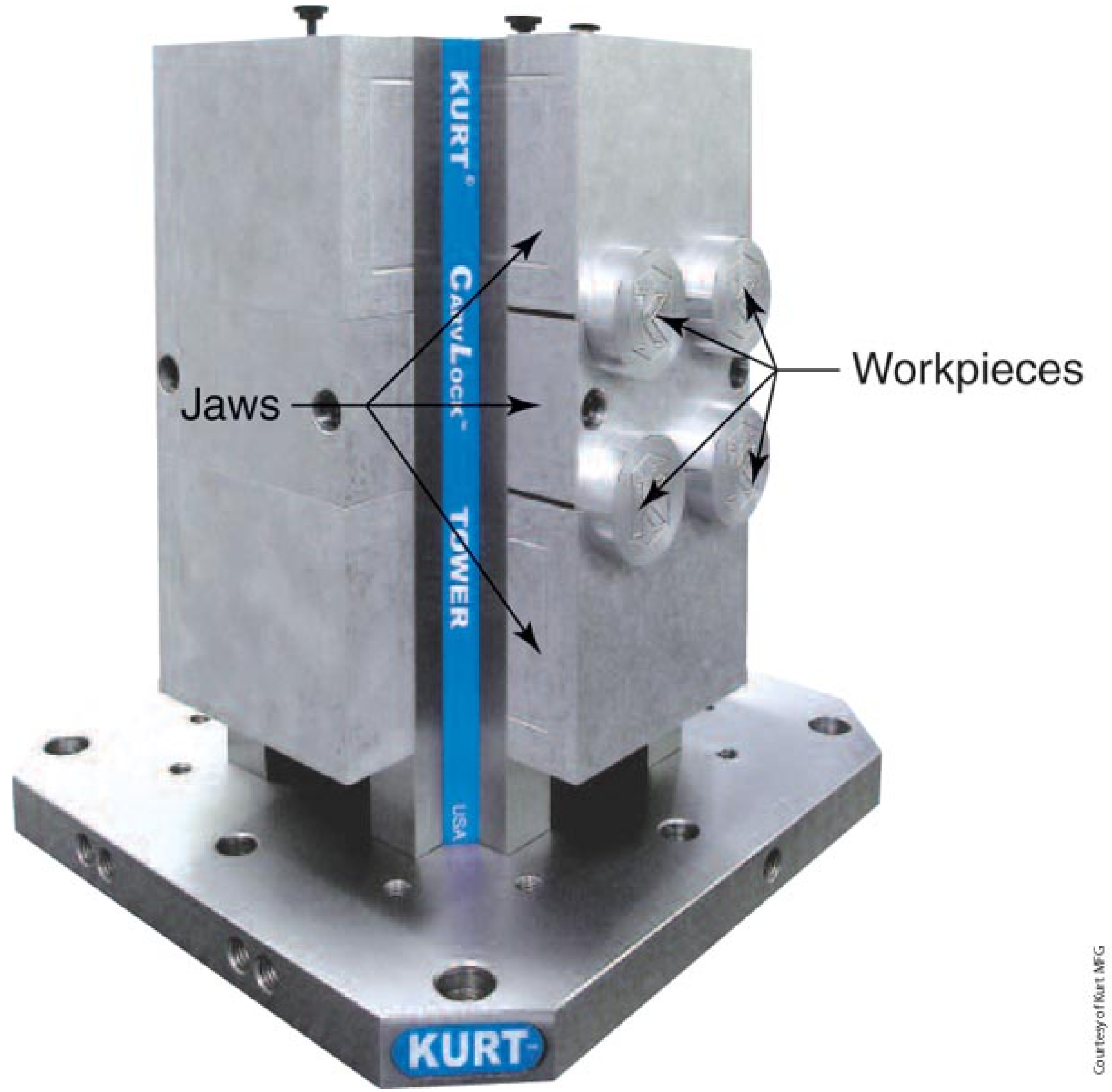


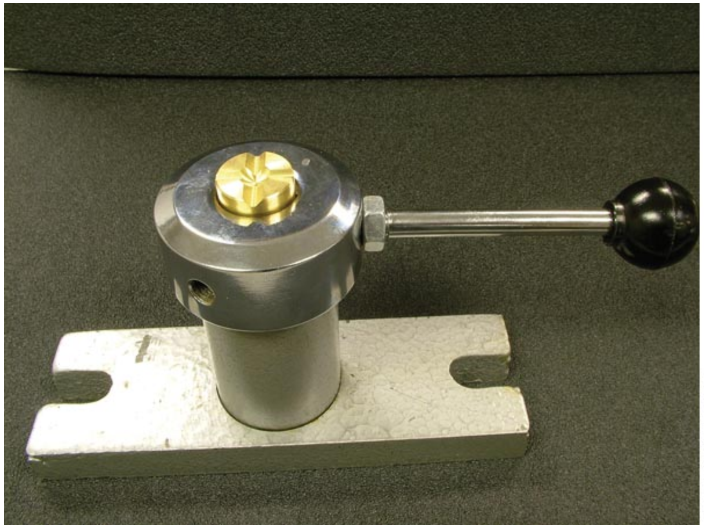
Toggle clamps

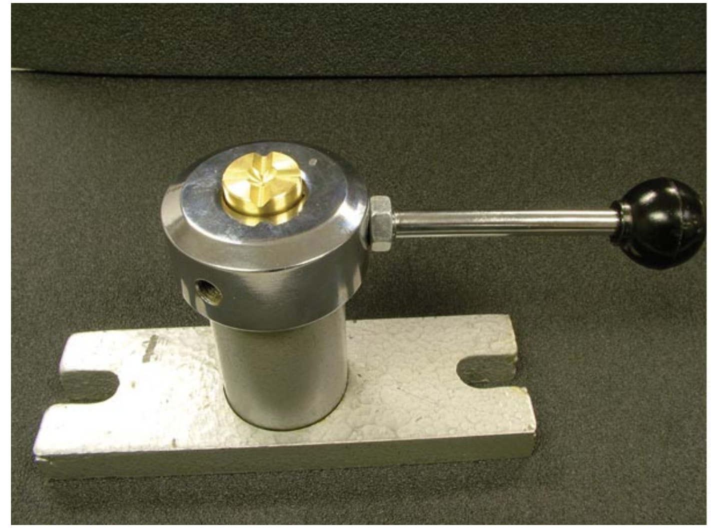
A large workpiece clamped to the table of a VMC using step clamps.

A vise with two moveable jaws can hold two parts in one setup.

This multi-sided vertical double vise has machinable aluminum jaws, or soft jaws, that can be machined to match the shape of the workpiece. Soft jaws can also be made of soft steel or cast iron.





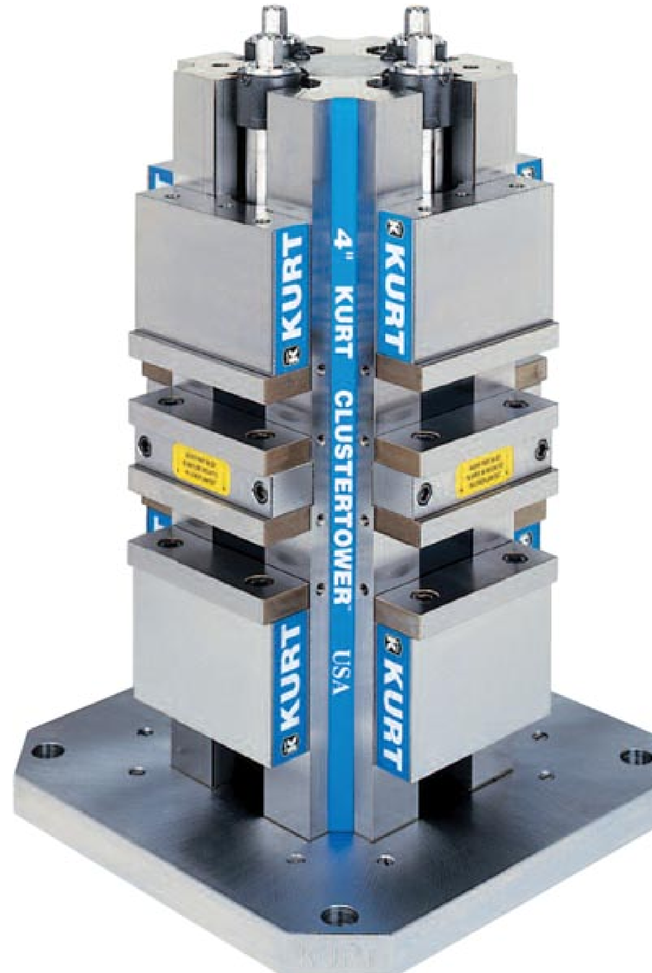


Manual collet fixtures

A programmable CNC rotary axis

This machining center has an APC that uses six pallets. The machine can be programmed to load any of the pallets automatically. Work is loaded on each pallet at the station on the right side of the APC.

Courtesy of Kurt Manufacturing, Inc



Courtesy of Kurt Manufacturing, Inc

The tombstone tower in (A) can be machined as needed for mounting work or other workholding devices. The tombstone tower in (B) has four integrated vises, one on each of the four sides of the tower.

Photo courtesy of Haas Automation, Inc

A custom fixture designed and built to hold an oddly shaped pump housing.

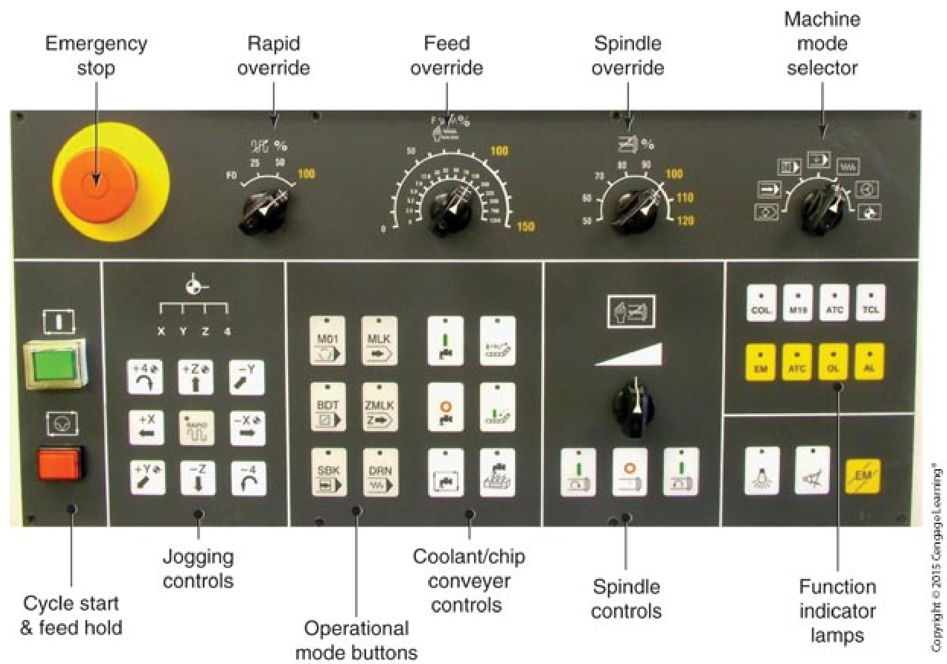
Process Planning

- Manufacturing process: all operations required to machine a part
- Process plan describes all steps in detail
  - Includes a description of each operation, the tools required, speed and feed data, workholding information, other notes and comments, and often a sketch depicting the part orientation

CNC Milling: Setup and Operation

Machine Control Panel

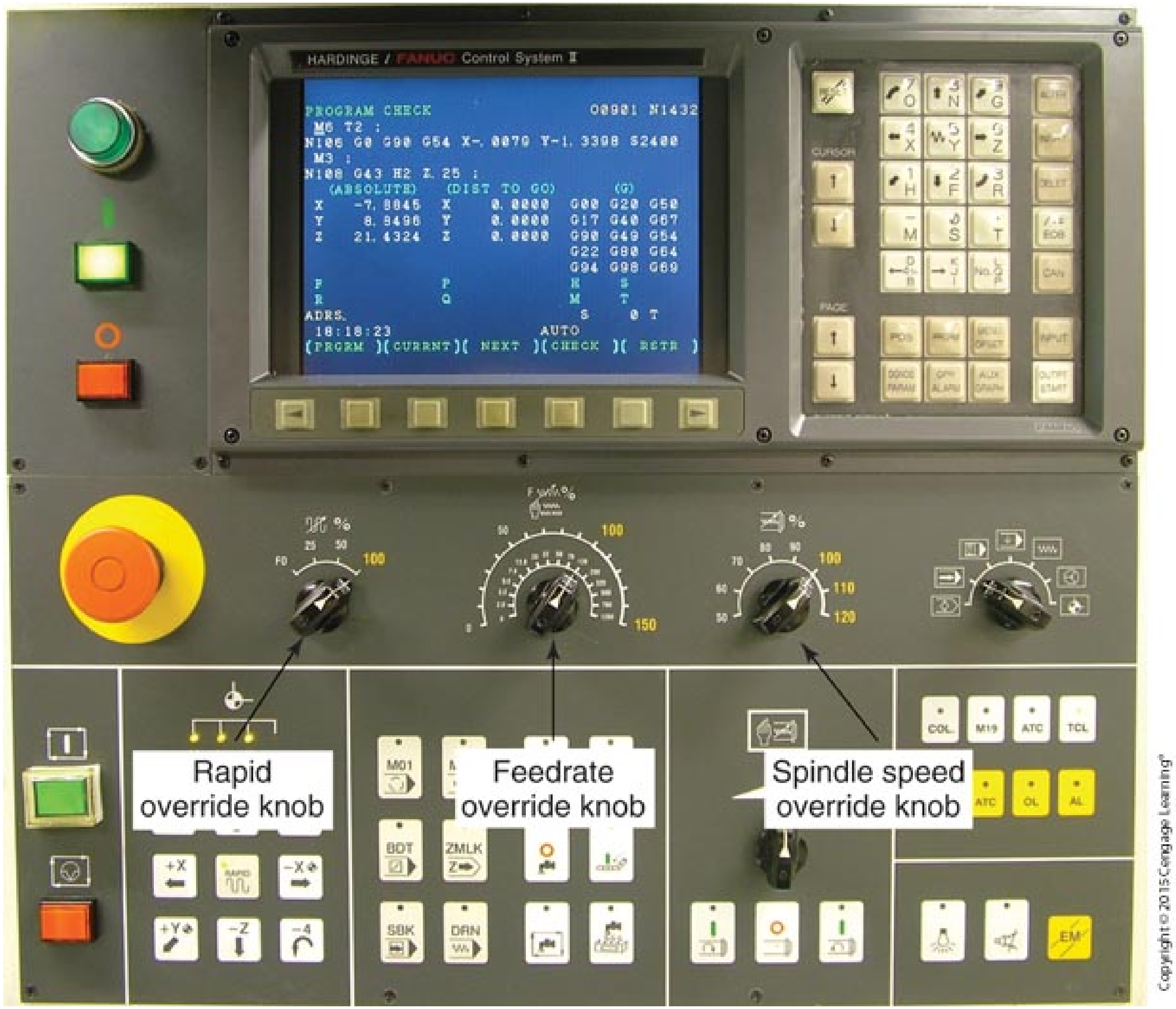
- Attached to MCU, contains displays and inputs
- Allows operator to program, set up and operate machine



The parts of a machining center control panel.

Soft keys are used on some machines. These keys are universal and can be used for different functions according to their on-screen label.

Arrow keys used for constant jogging of each axis.



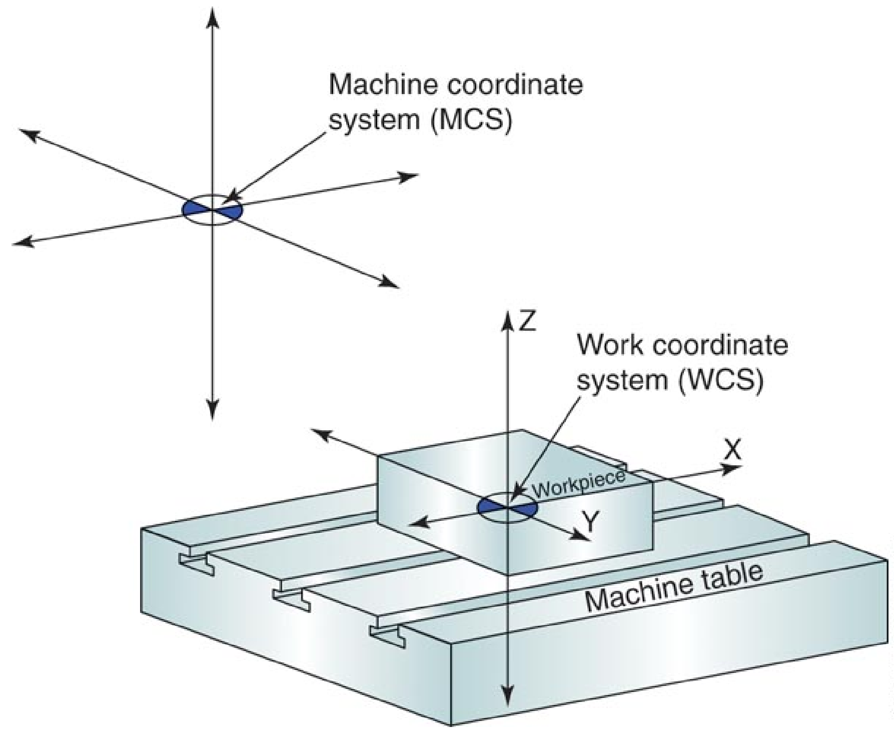
A spindle speed, feed rate, and rapid override control.

Workholding Setup

- Inspect/clean vises and fixtures
  - Allow proper height in the vise jaws
- Set clamps to avoid collisions
  - Special attention to overall height
- Use the same torque on clamp fasteners and vise screws
  - Prevent distortion

Machine and Work Coordinate Systems

- Cartesian coordinate system
  - WCS sets flexible origin, MCS has set origin



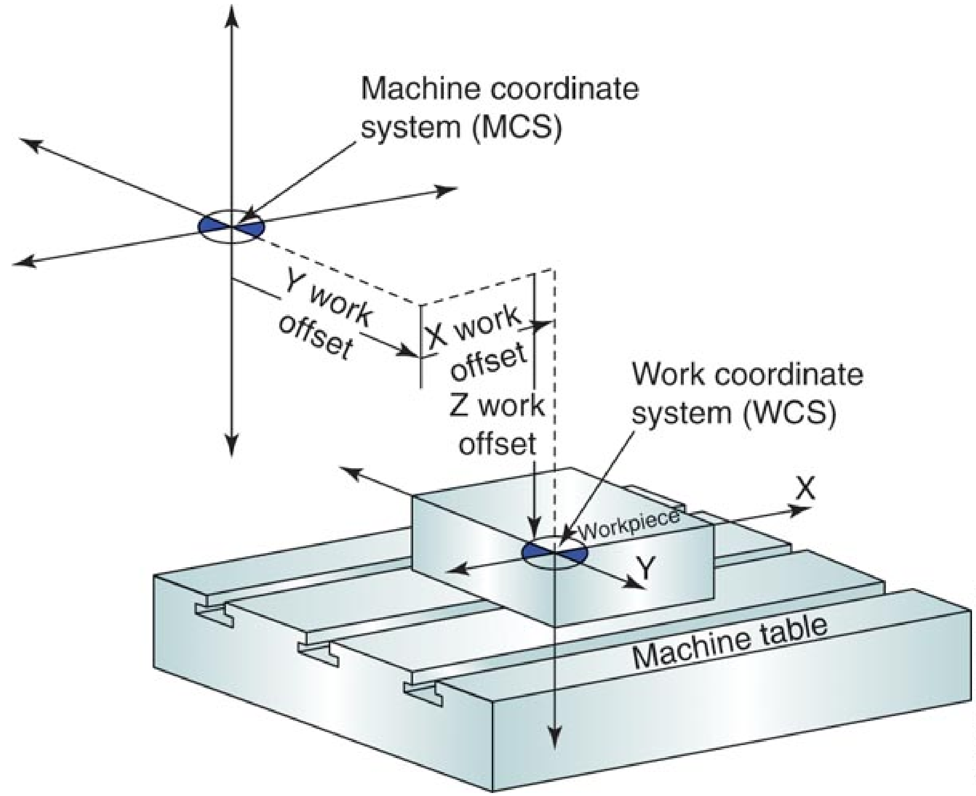
The relationship of the machine coordinate system (MCS) to the work coordinate system (WCS).

Power-up and Homing

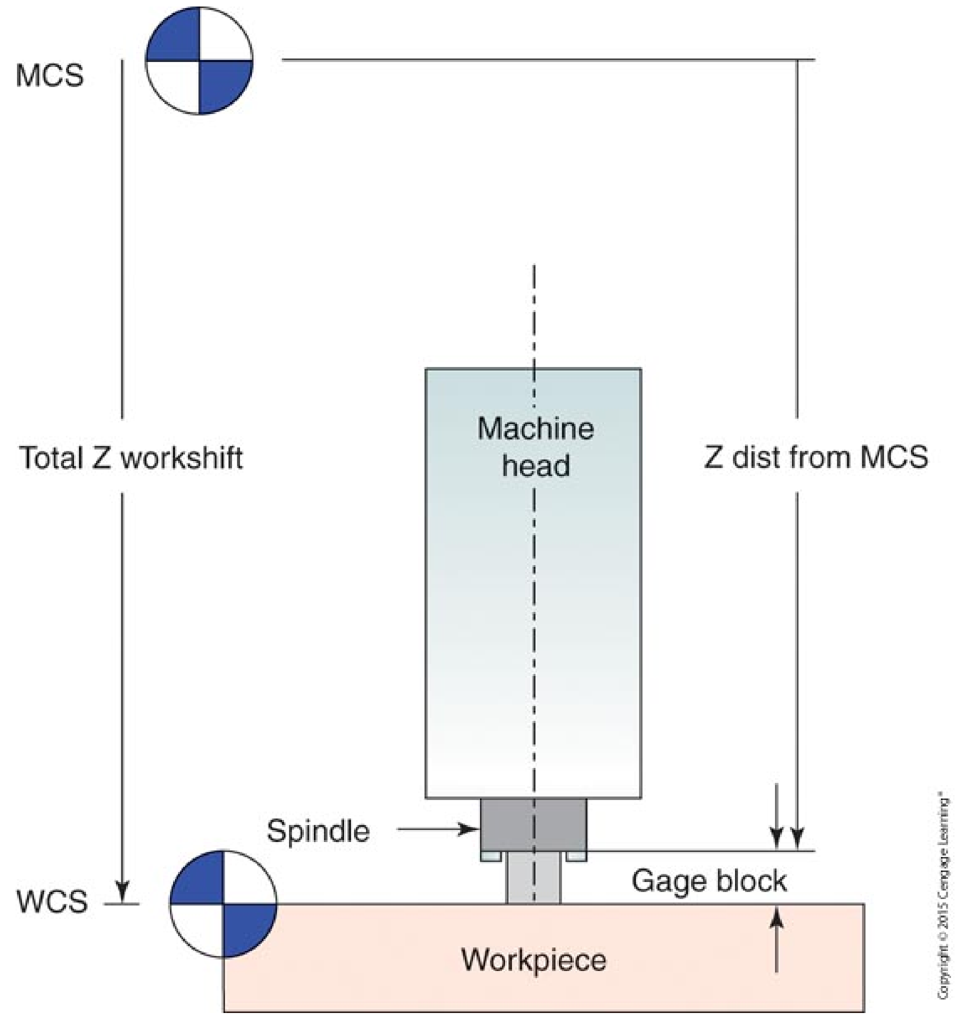
- Power up machine properly
- Machine home position of the MCS
  - Select “zero-return” or “home” mode on control panel
  - Jog each axis towards home position
  - Most machines will automatically complete the procedure
  - Machine will zero the machine coordinate system

Work Offset Setting

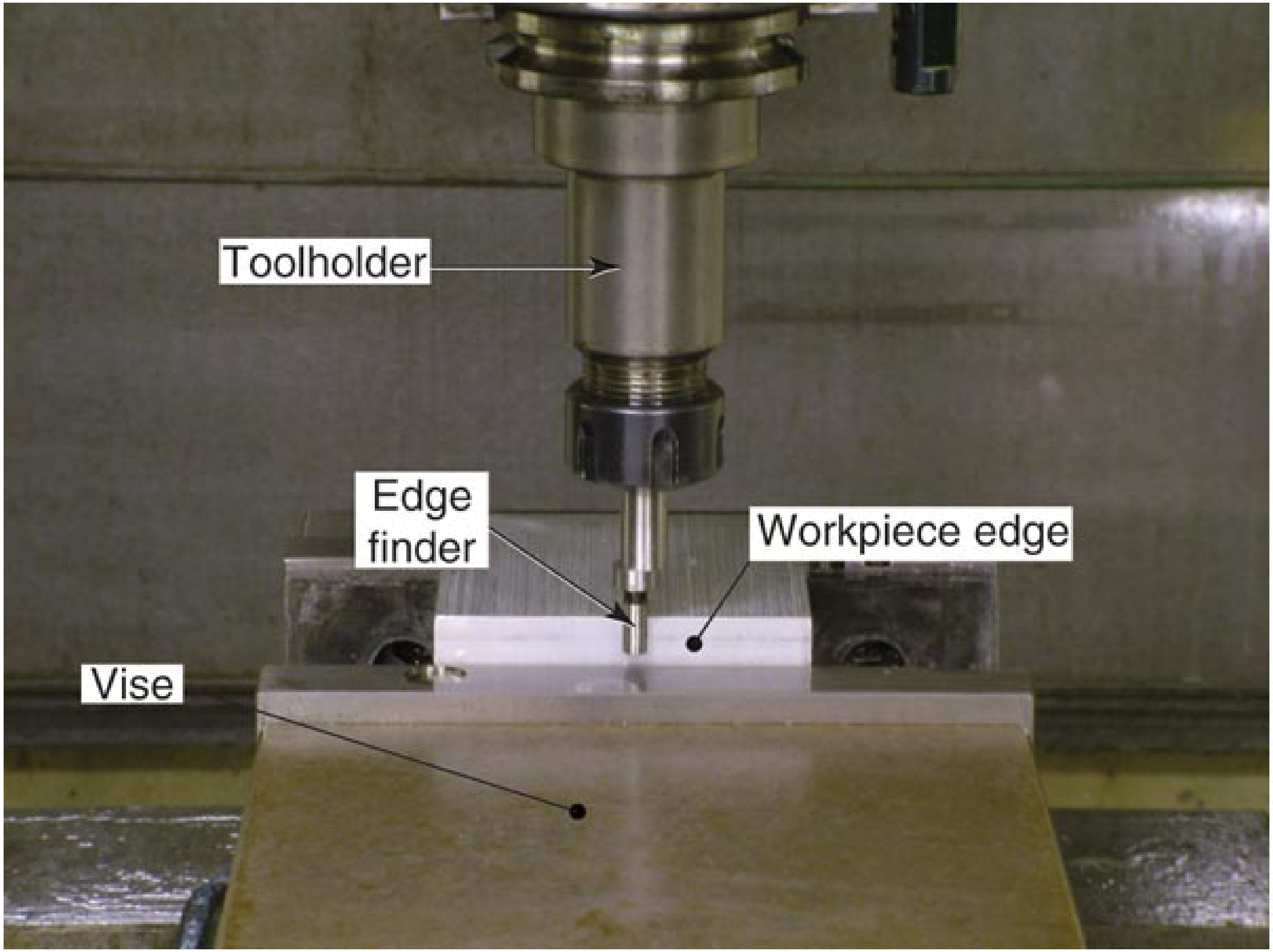
- Difference between MCS and WCS on X-, Y- and Z-axes



Workpiece offset, or workshift, is the distance from the MCS origin to the desired location of the WCS origin.

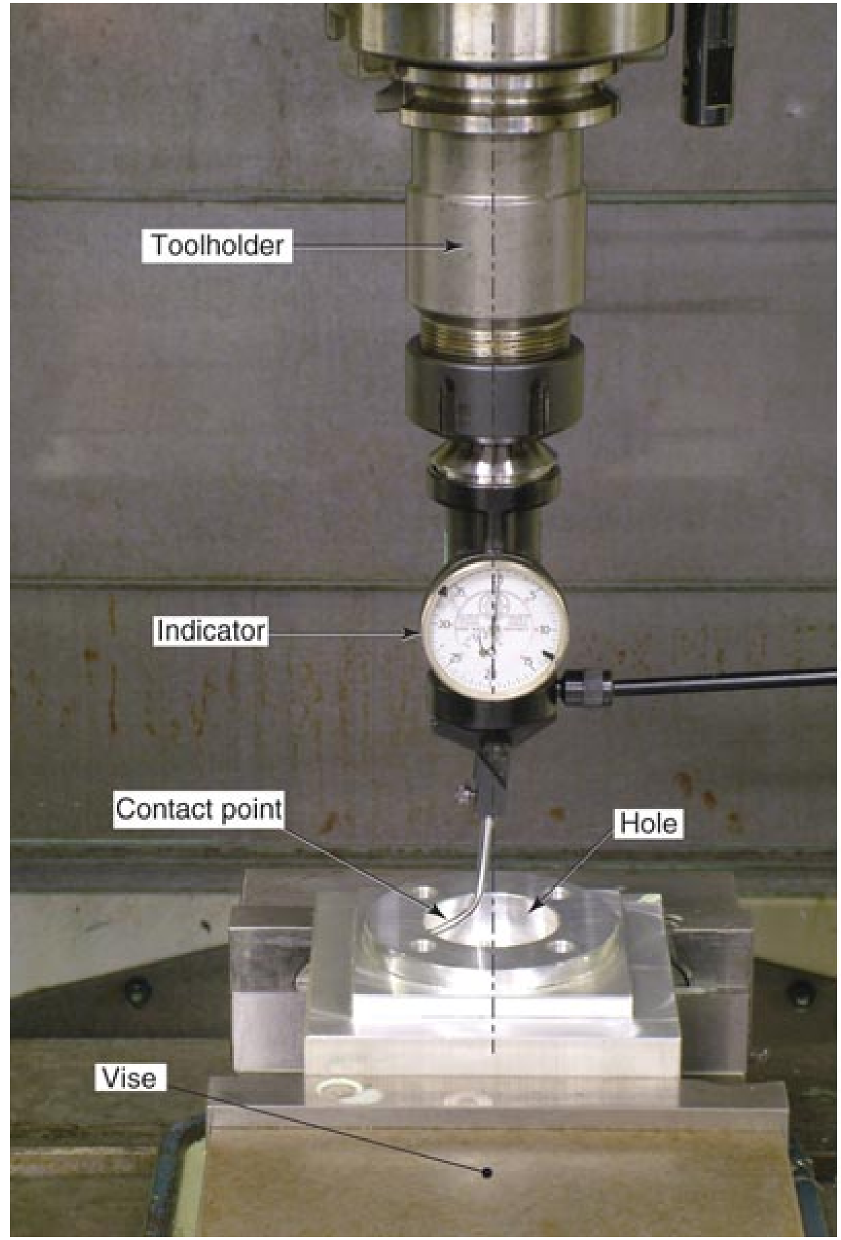


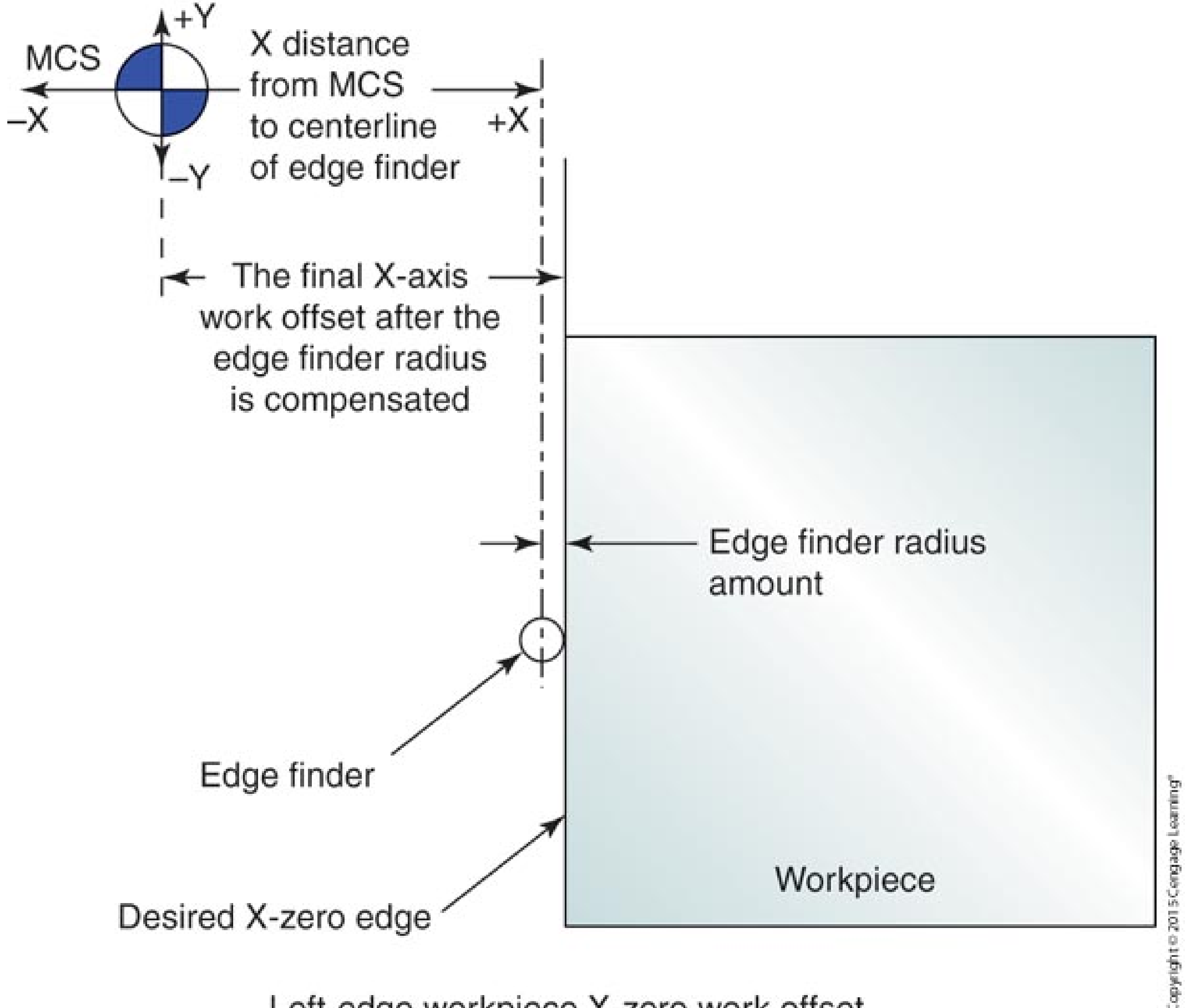
This front view shows a VMC spindle face and a gage block being used to determine the Z-axis work offset. Note the relationship of the MCS to the WCS.



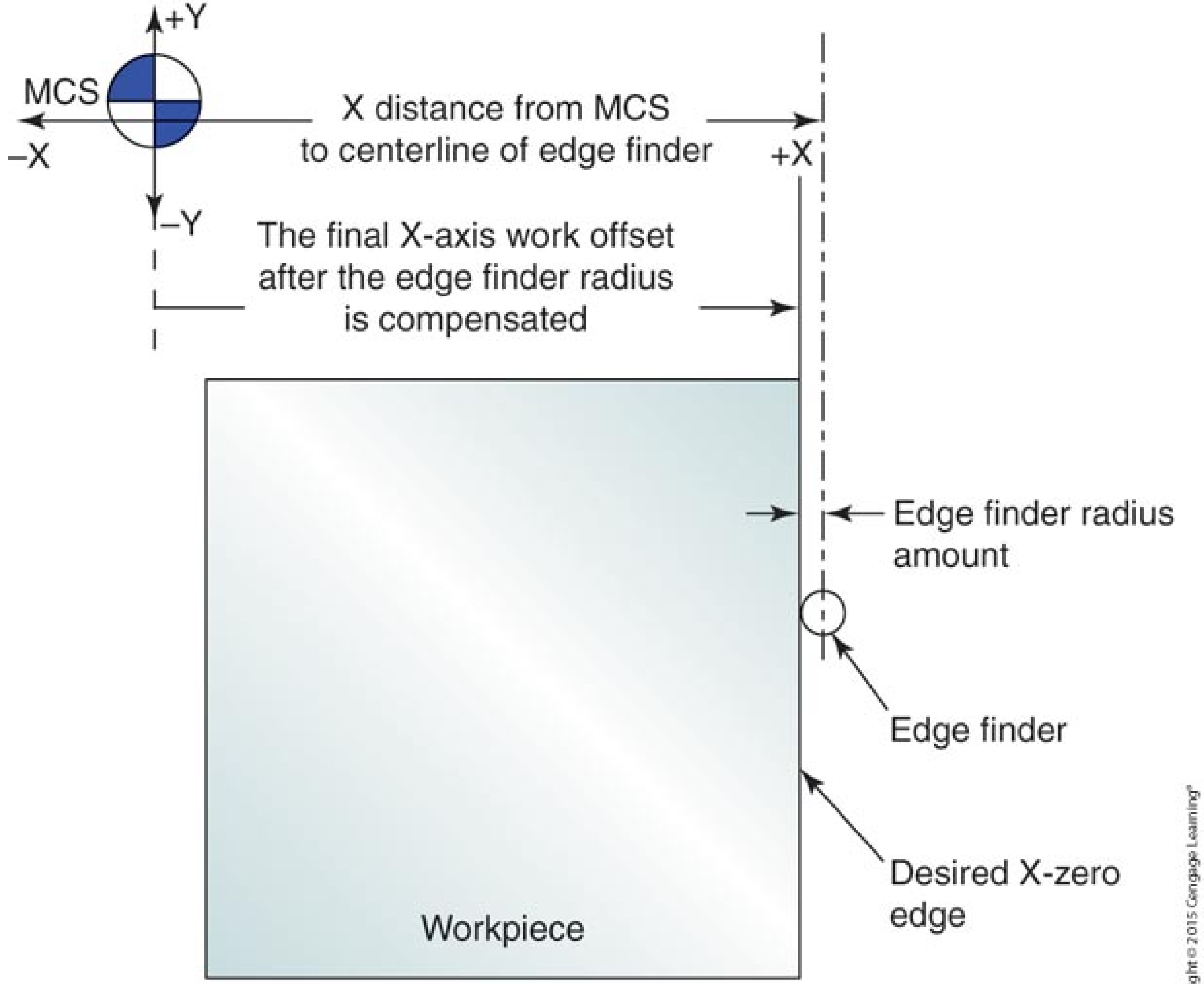
An edge is located with an edge finder.

Finding the center of a hole by sweeping with a dial indicator.

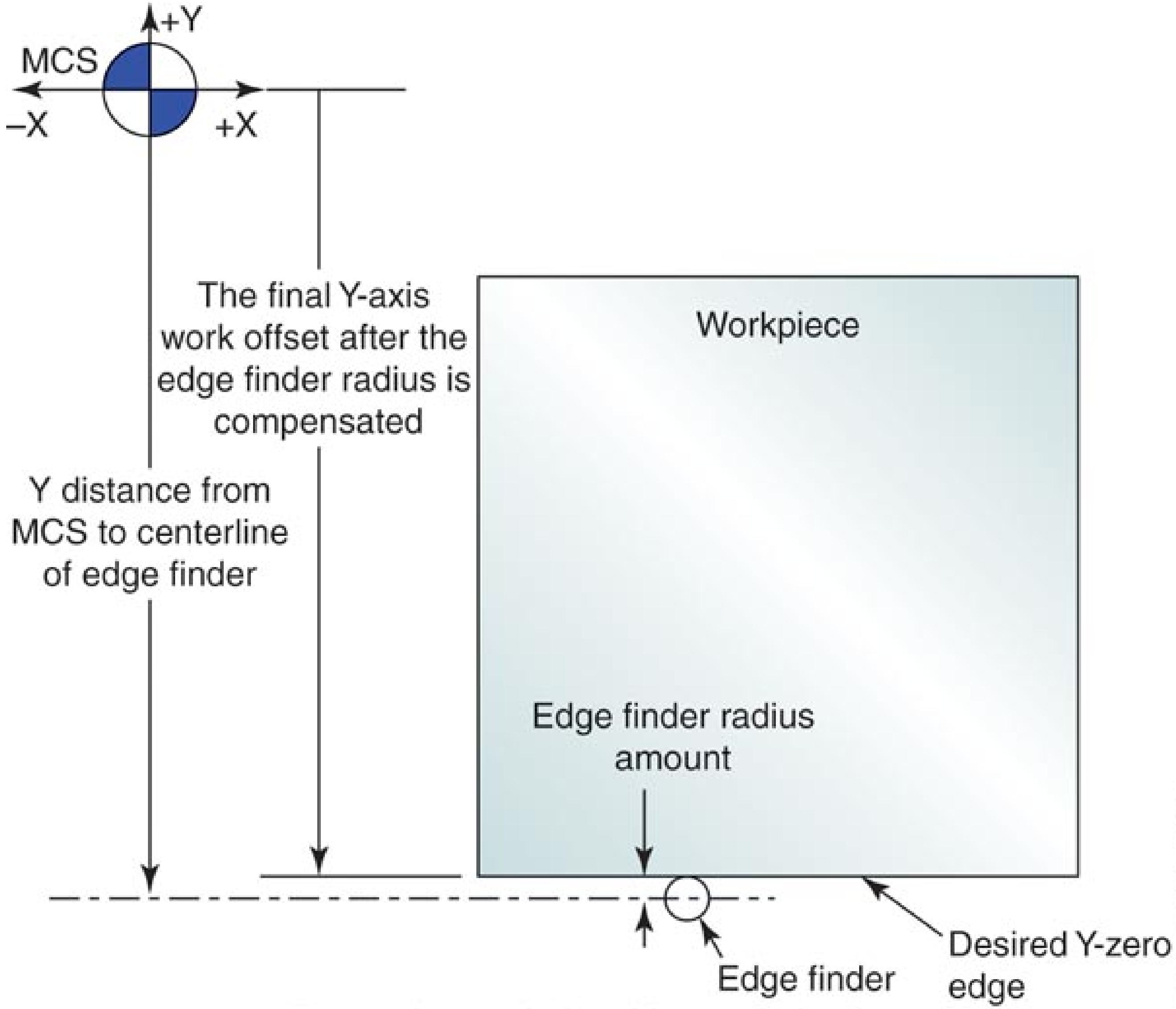




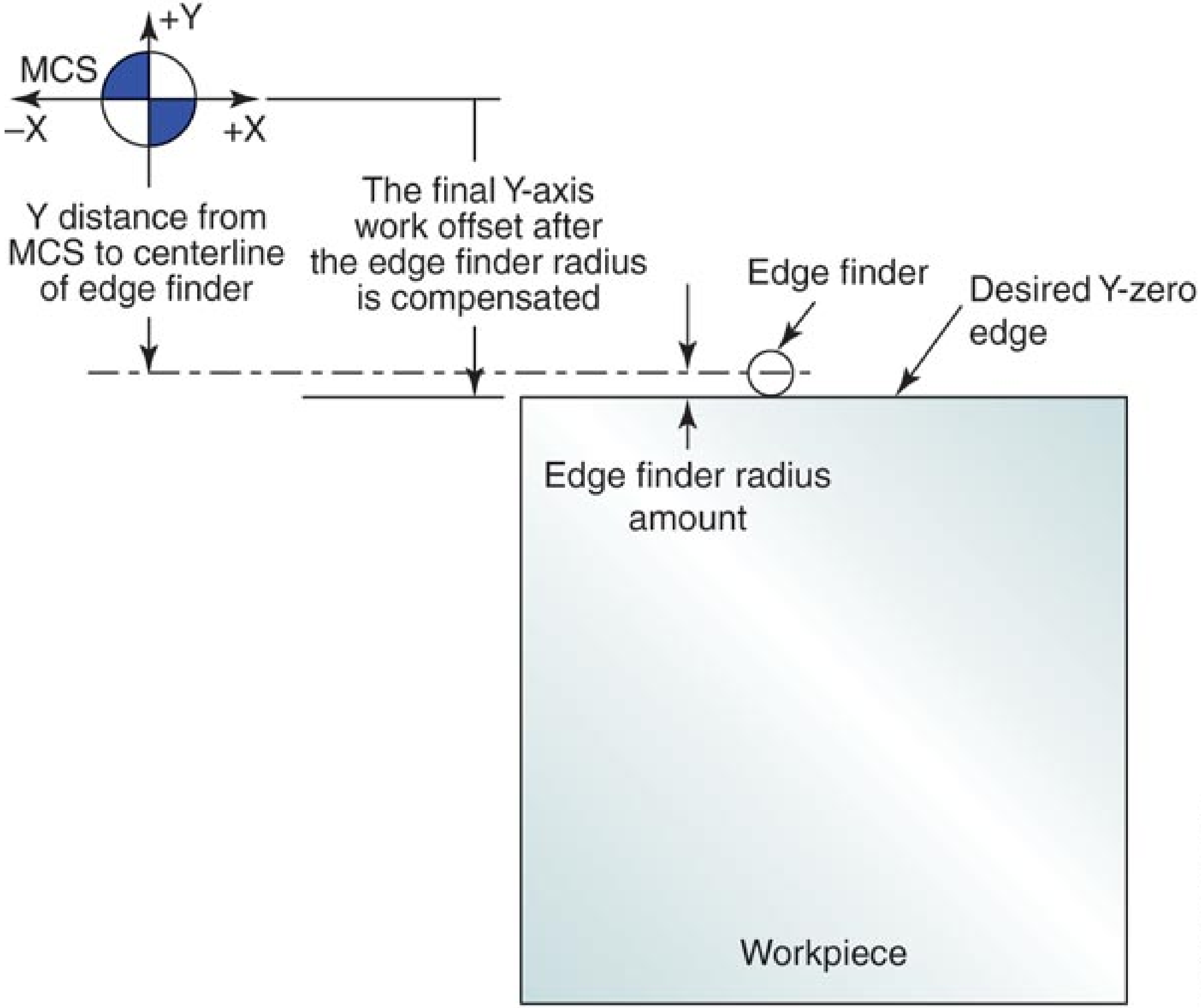
Left-edge workpiece X-zero work offset



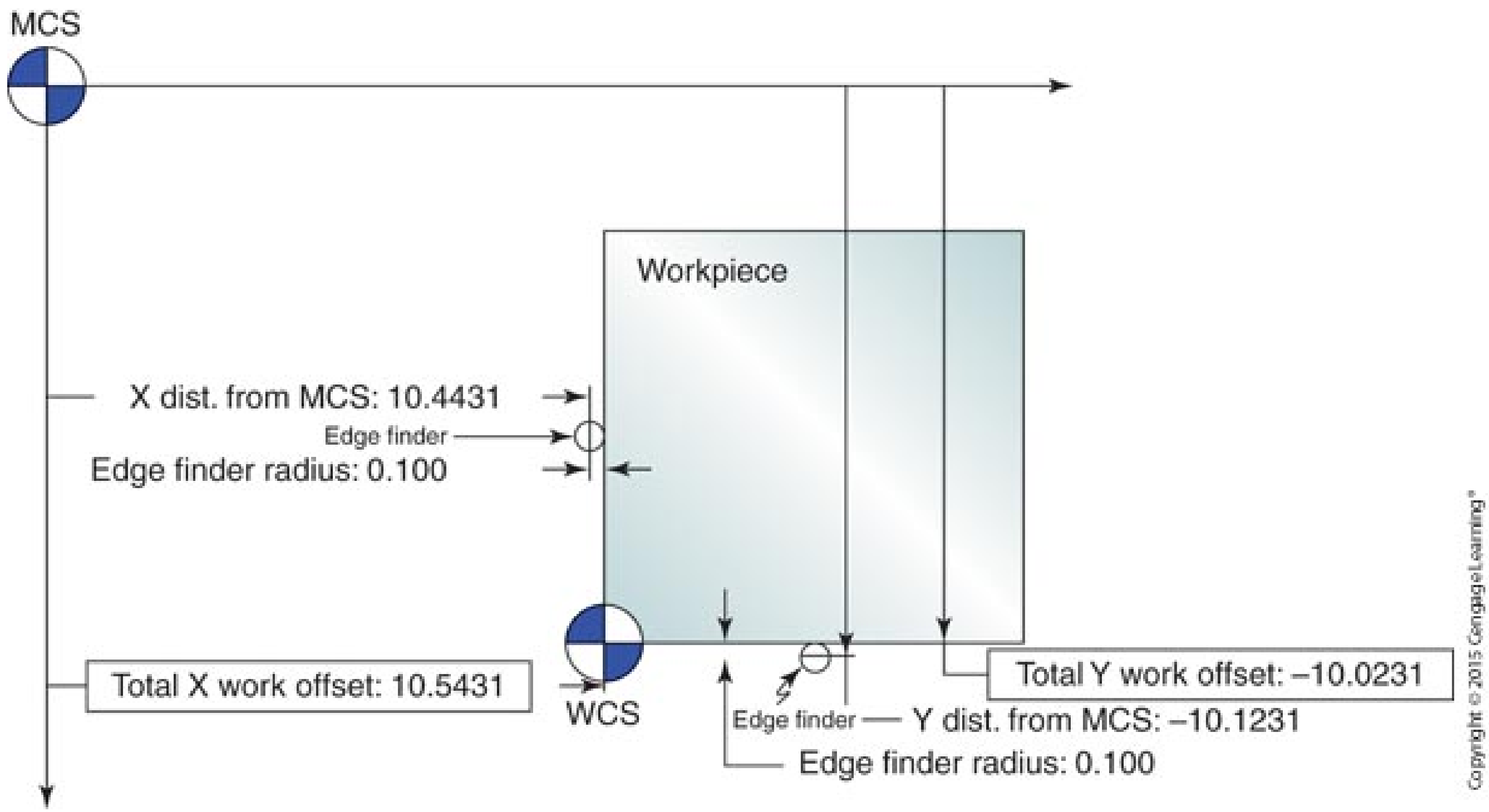
Right-edge workpiece X-zero work offset



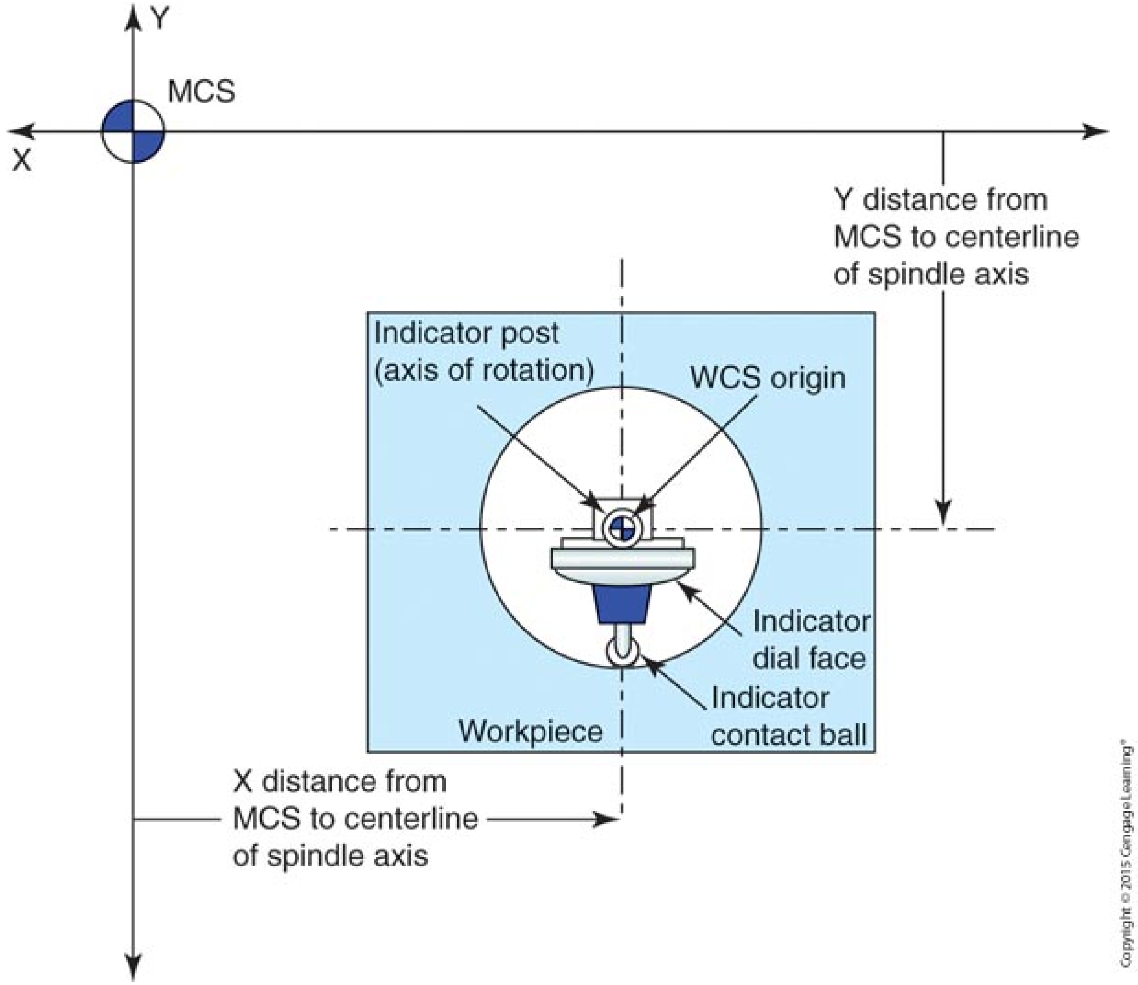
Front-edge workpiece Y-zero work offset



Rear-edge workpiece Y-zero work offset



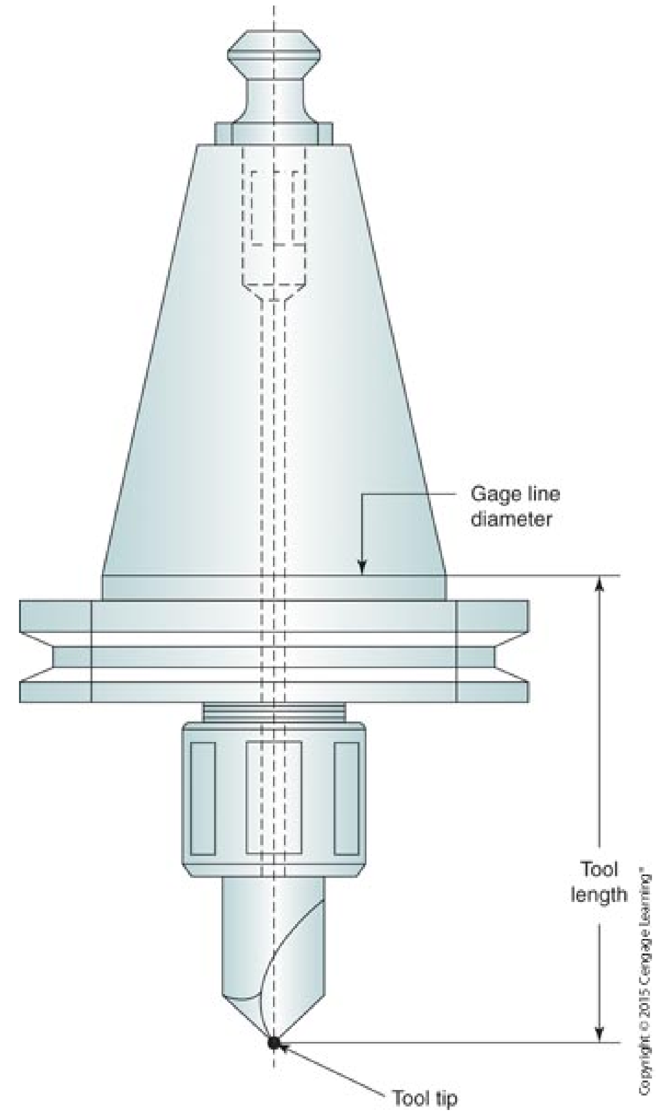
A dimensioned example of how a work offset is derived for a workpiece having the origin in the front left corner.



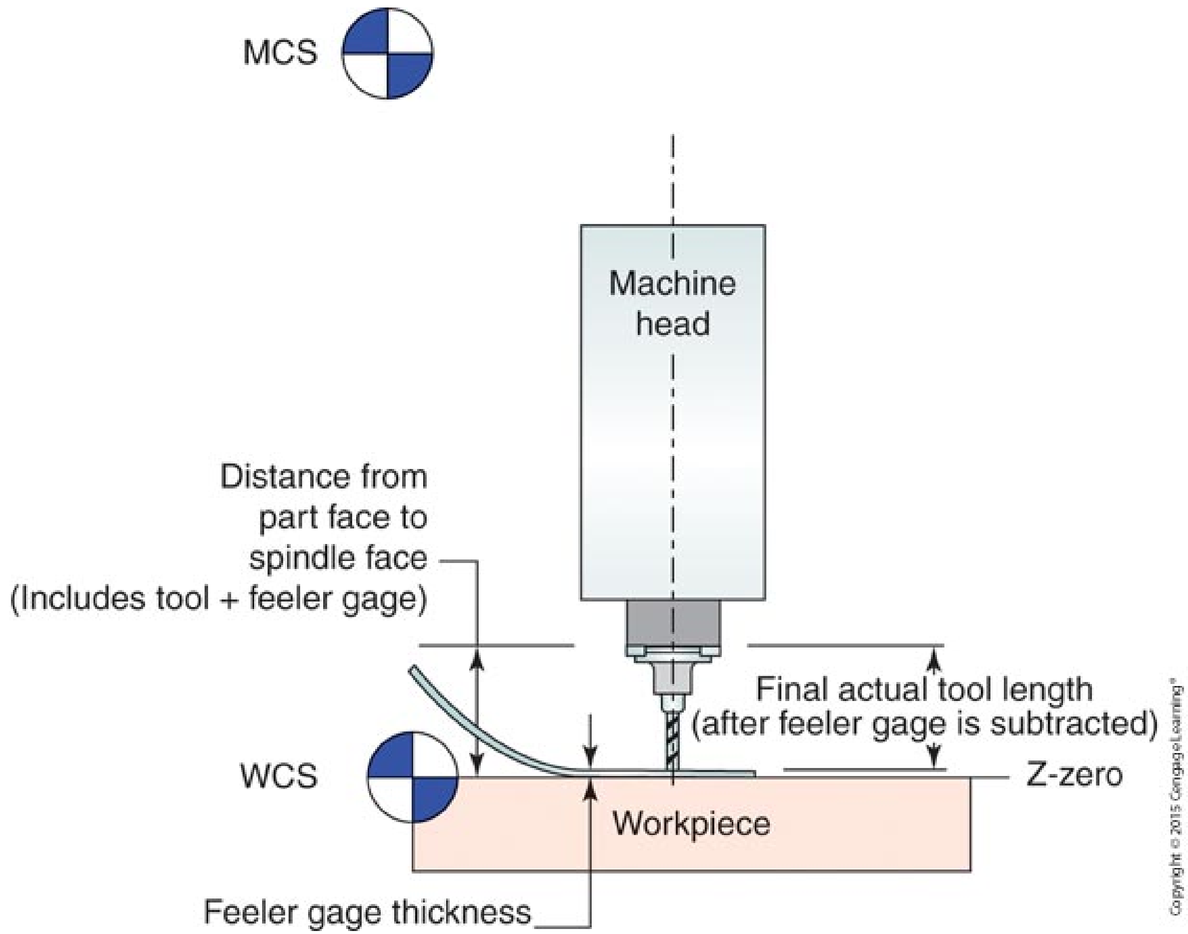
This top view shows that when a hole center is to be used as the X/Y location of the work origin, the hole center can be found by sweeping with a dial indicator. This aligns the spindle centerline with the hole centerline.

Cutting Tools

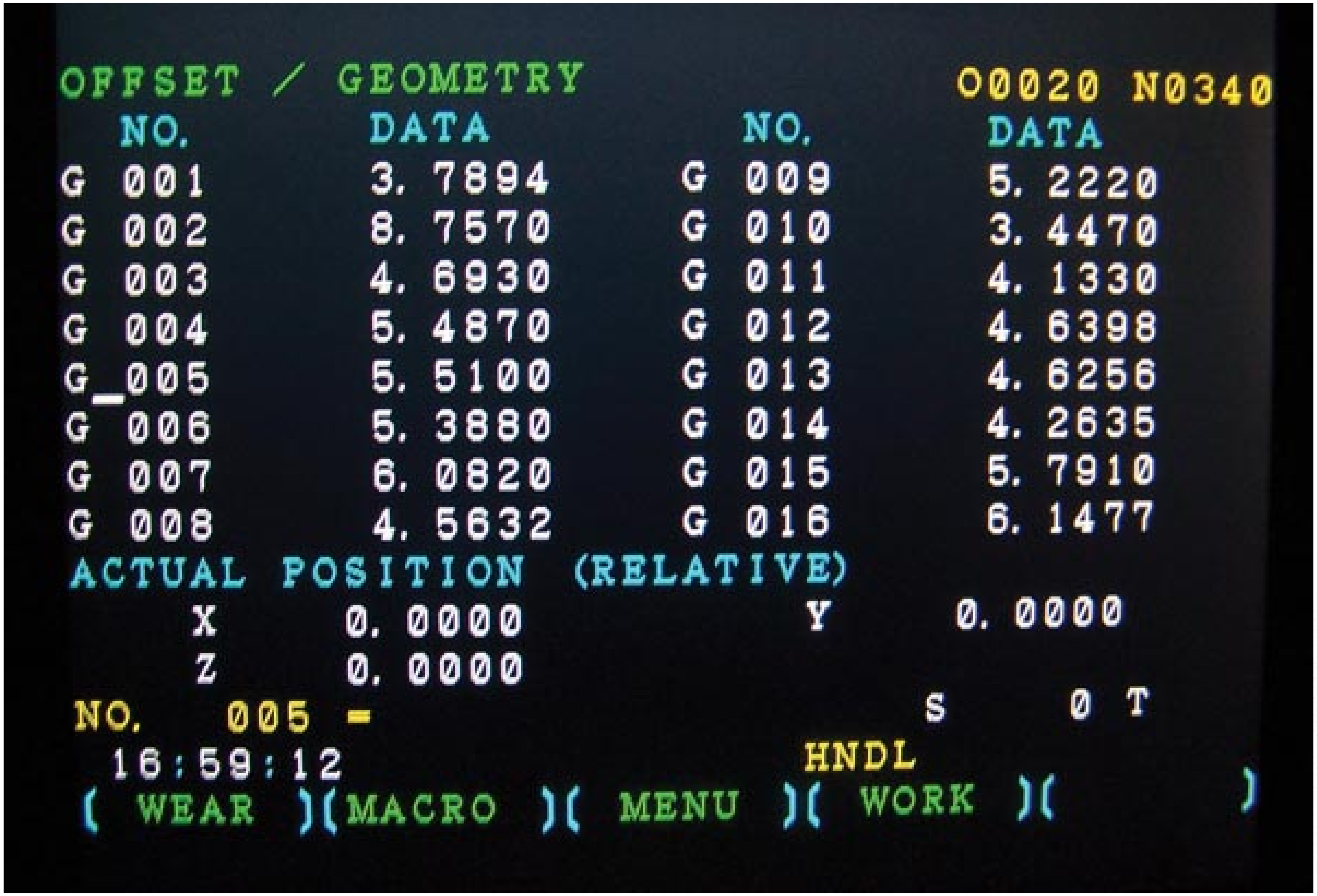
- Installation: see Section 8.5
- Offset types:
  - Tool height, geometry, wear



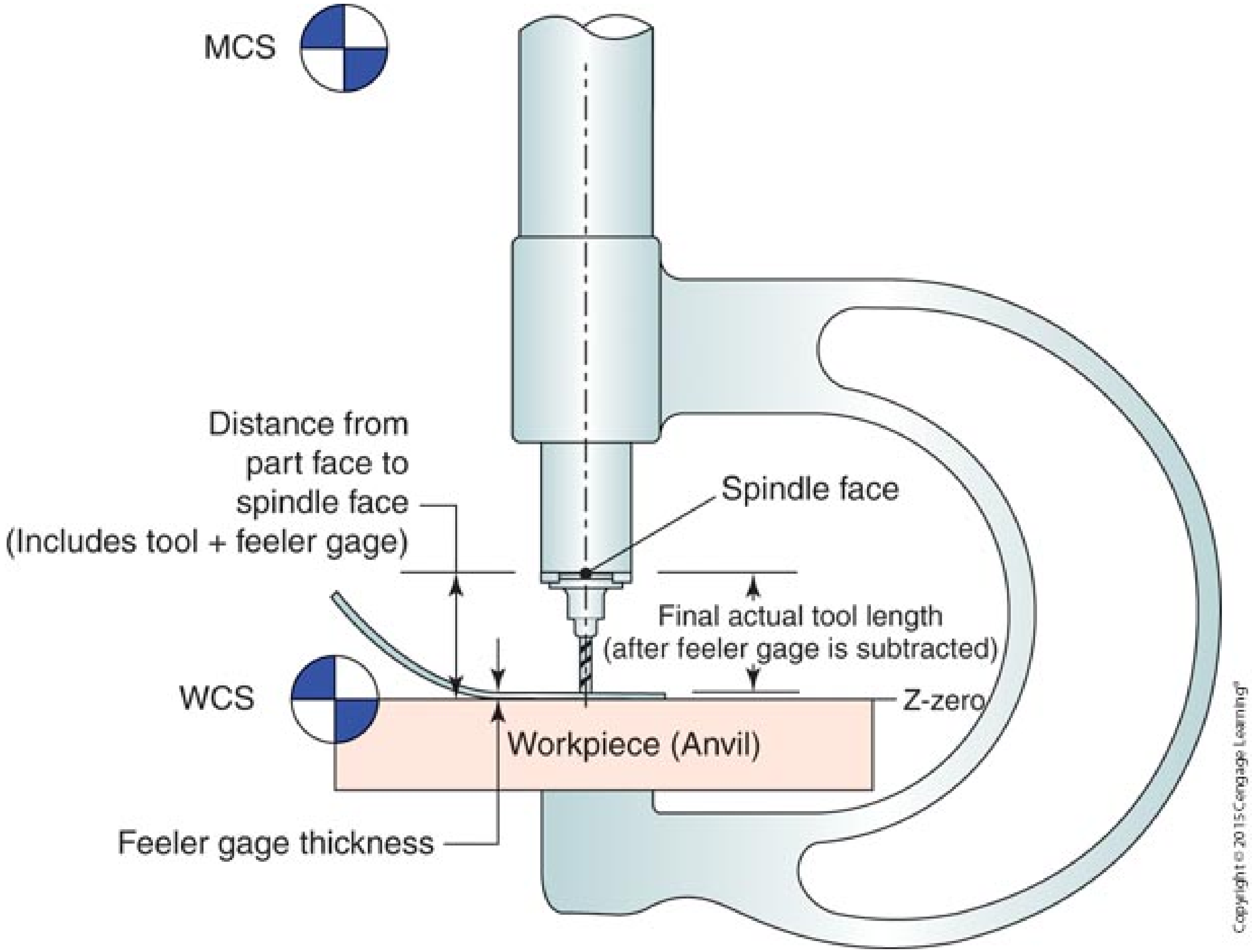
Tool length is measured from the gage line on the tool holder’s taper to the tool tip.



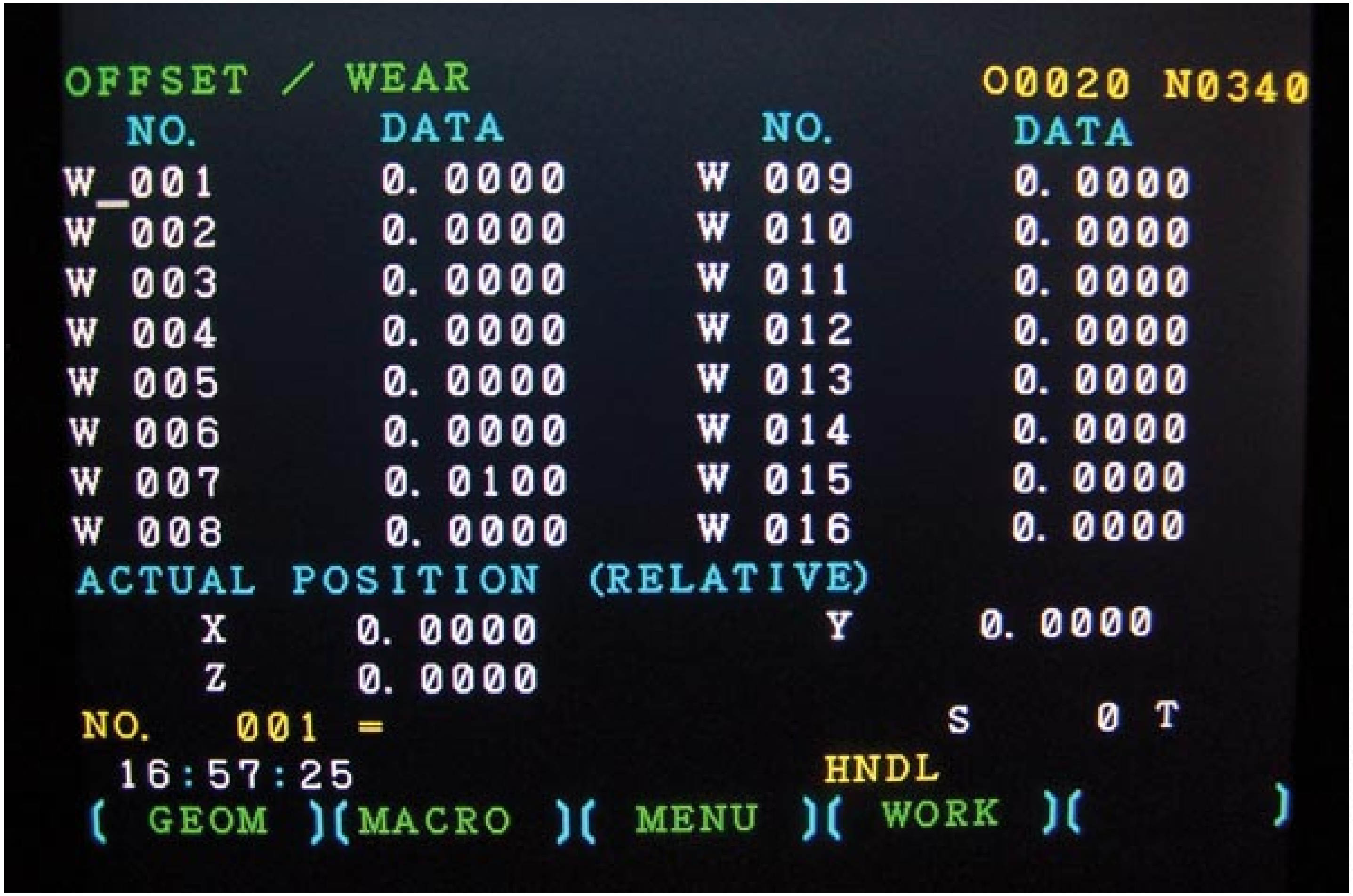
A VMC Z-axis can be used to measure tool length. The length offset is found by touching the tool tip off of the work Z-zero surface with a feeler gage and then subtracting the feeler gage thickness. The objective is to determine the dimension labeled “Final actual tool length.”



A typical milling geometry offset page on the machine display screen. These numbers reflect the tool length from gage line to the tool tip in its original and unworn state.



The way a VMC Z-axis can be used to measure tool length can be compared to the way a micrometer measures.



A typical milling wear offset page on the machine display screen. The number that will be entered into the wear offset will be an incremental adjustment from a baseline of zero tool length wear.

Program Entry

- Three methods for input:
  - Typing into control
  - Uploading from storage
  - Sending from PC
- Direct numerical control (DNC)
  - Sometimes called drip feeding
  - Program is fed from a PC to the control line by line

Machine Operation

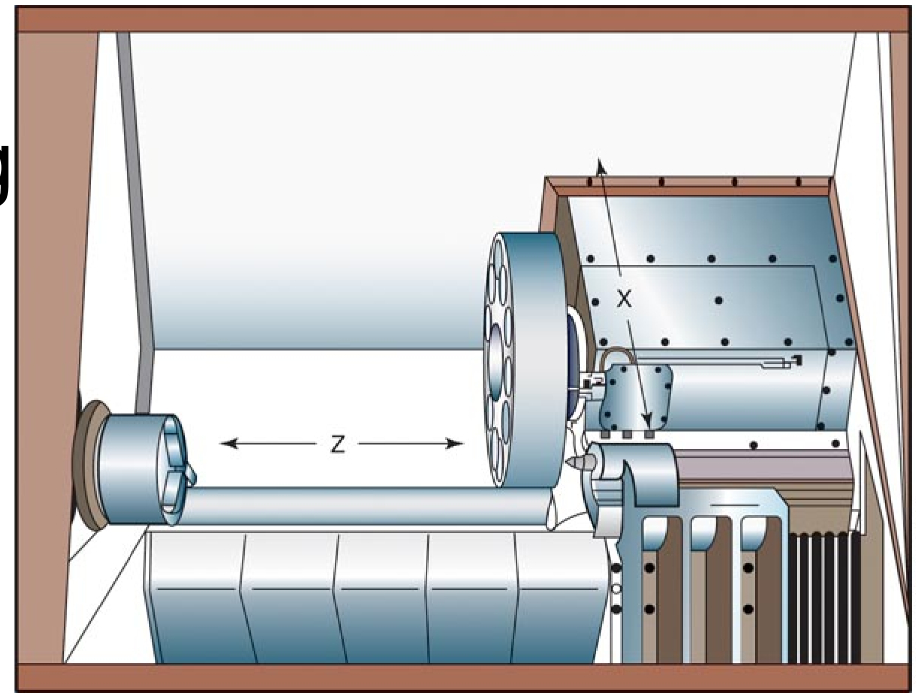
- Prove-out before operation
  - Run auto mode once program is proven

A graphic part simulation on a display screen.

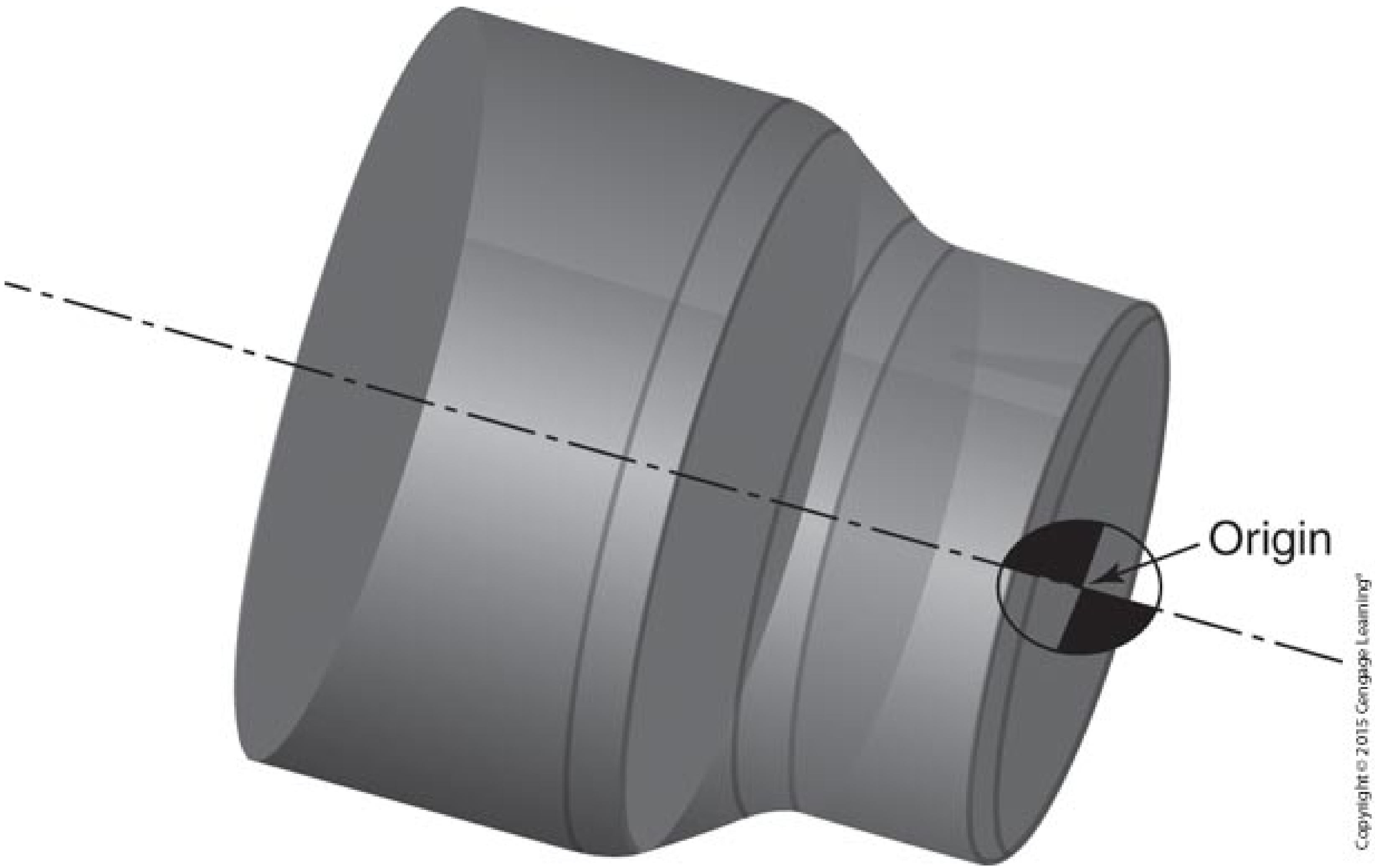
Introduction to CNC Turning

Introduction

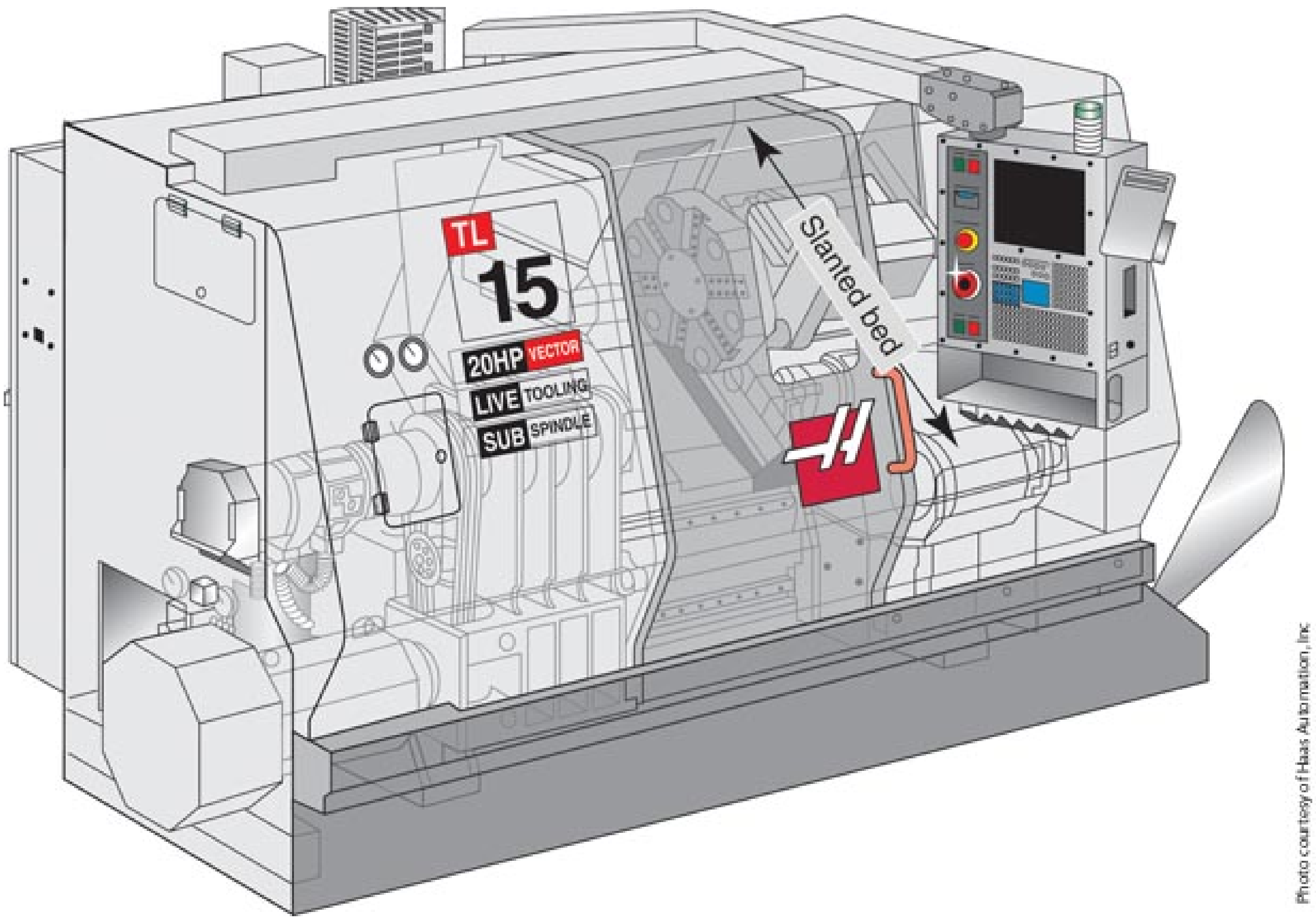
- CNC turning like manual lathe or milling machine
- Z-axis = motion along slide, X-axis = perpendicular



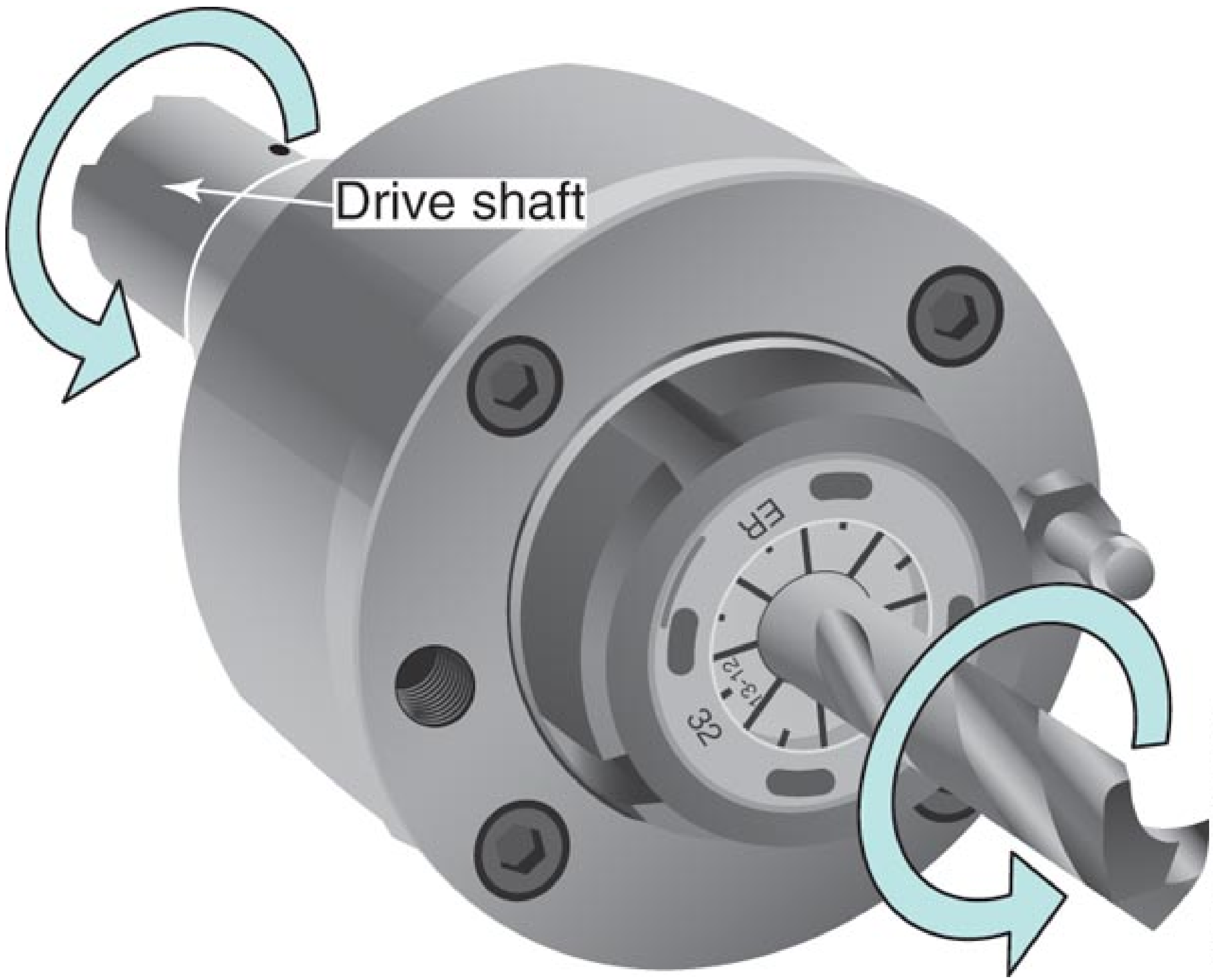
The coordinate system for CNC turning and the relationship of the axes.



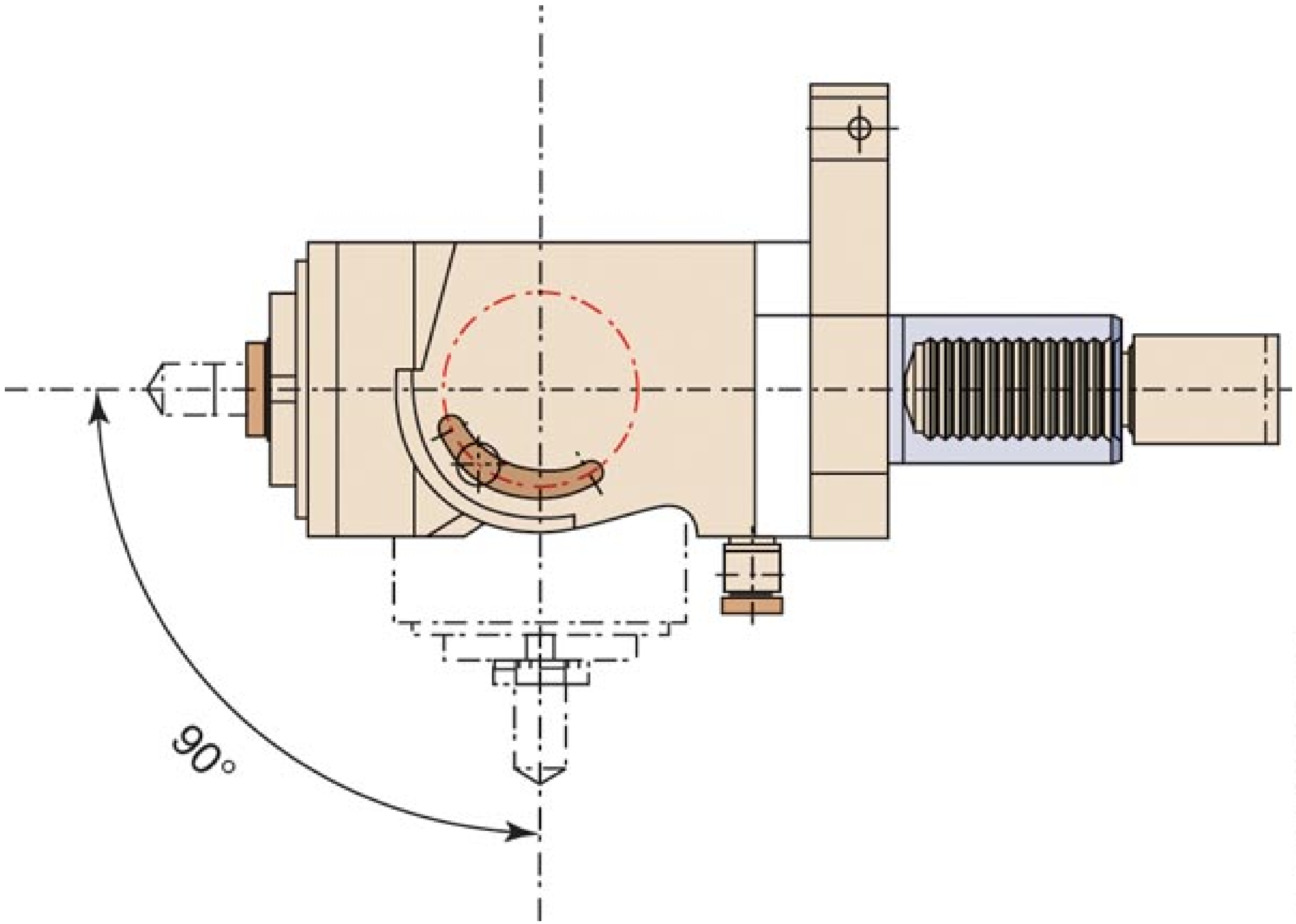
The origin for turning is usually located on the workpiece face on the part center line.



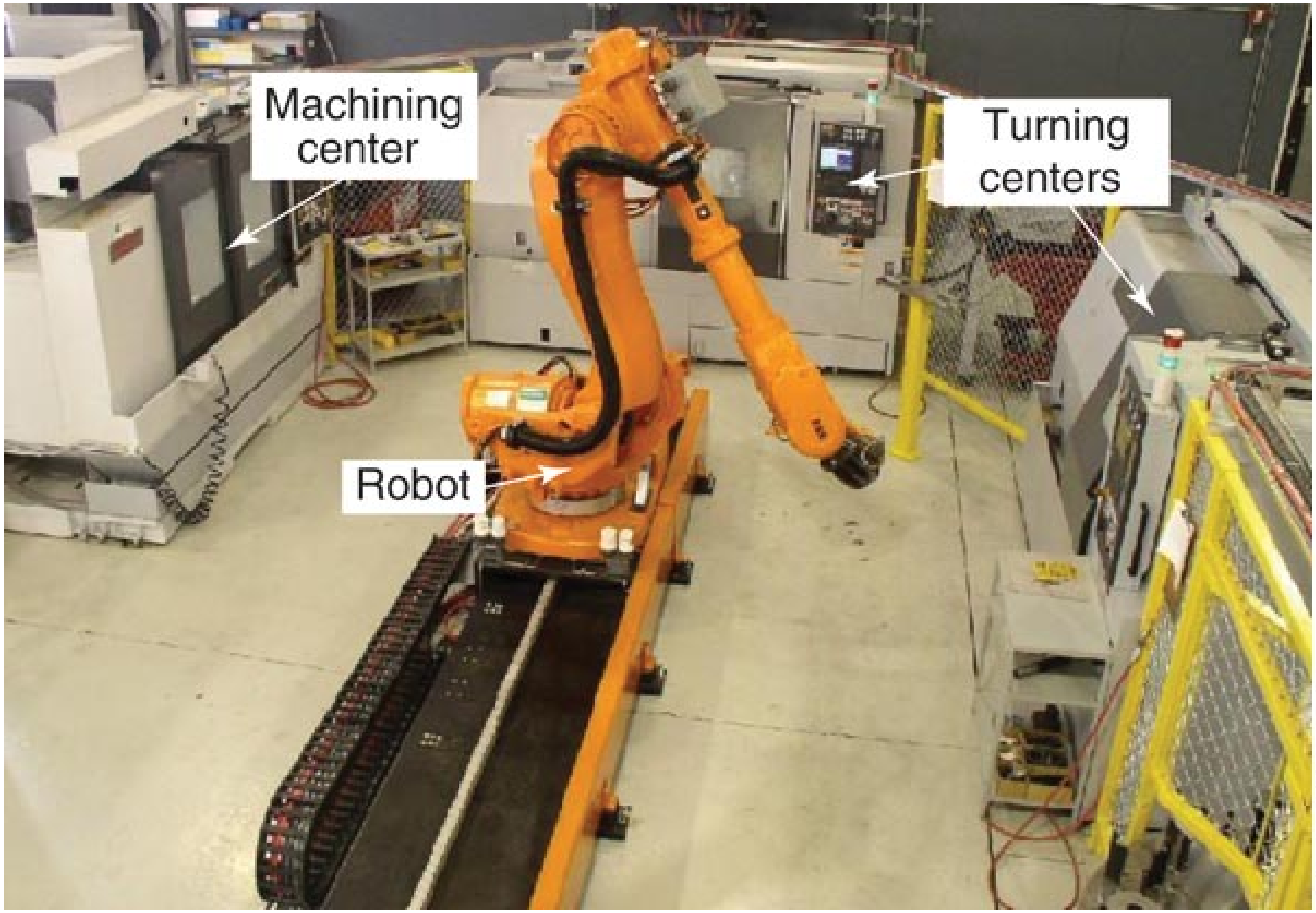
A slant-bed turning center has an inclined bed.



An end-working live tooling attachment for milling and performing holemaking operations on the face of a part.



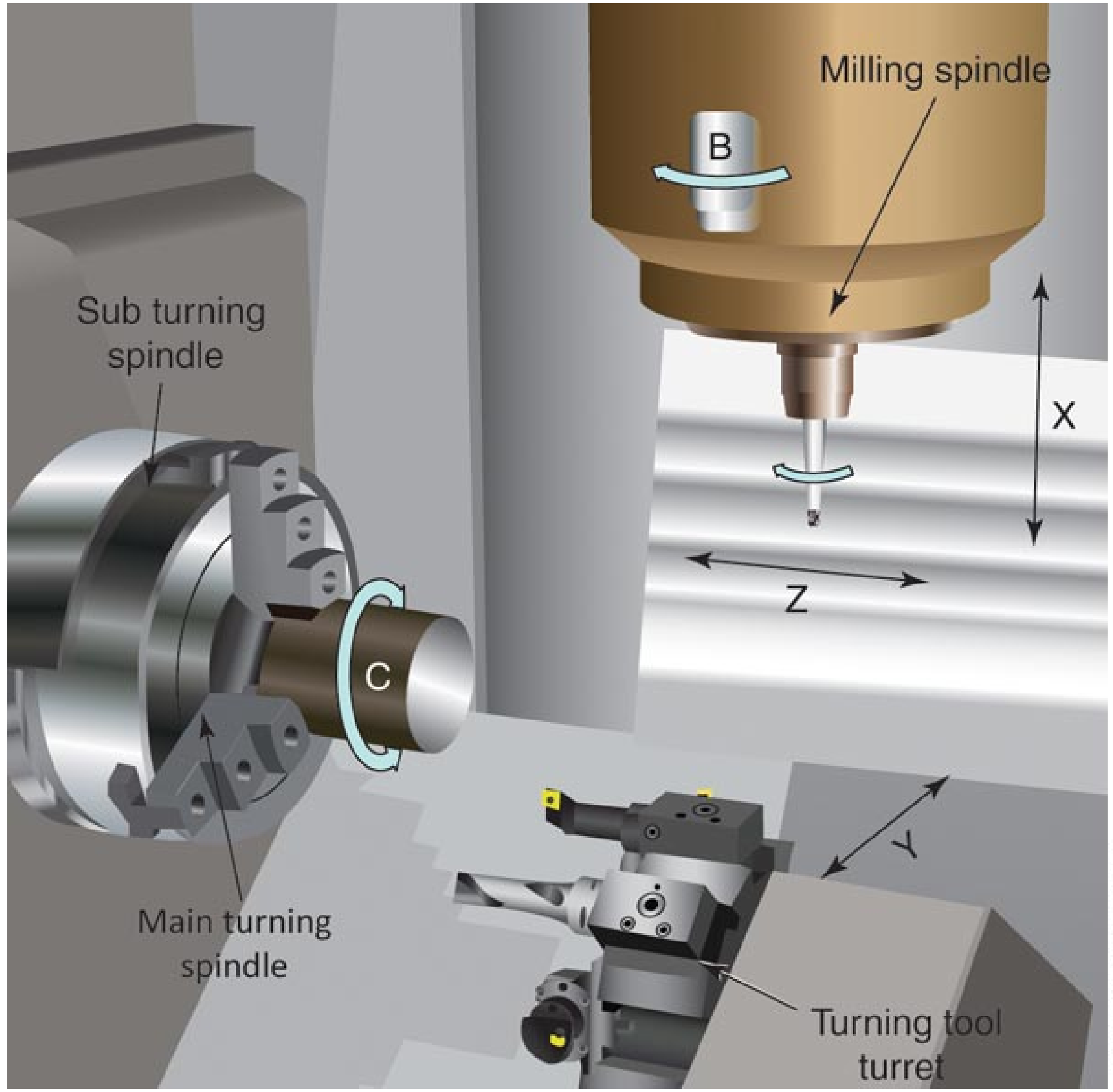
An adjustable angle-head live tooling attachment allows angular milling to be performed on the turning center.

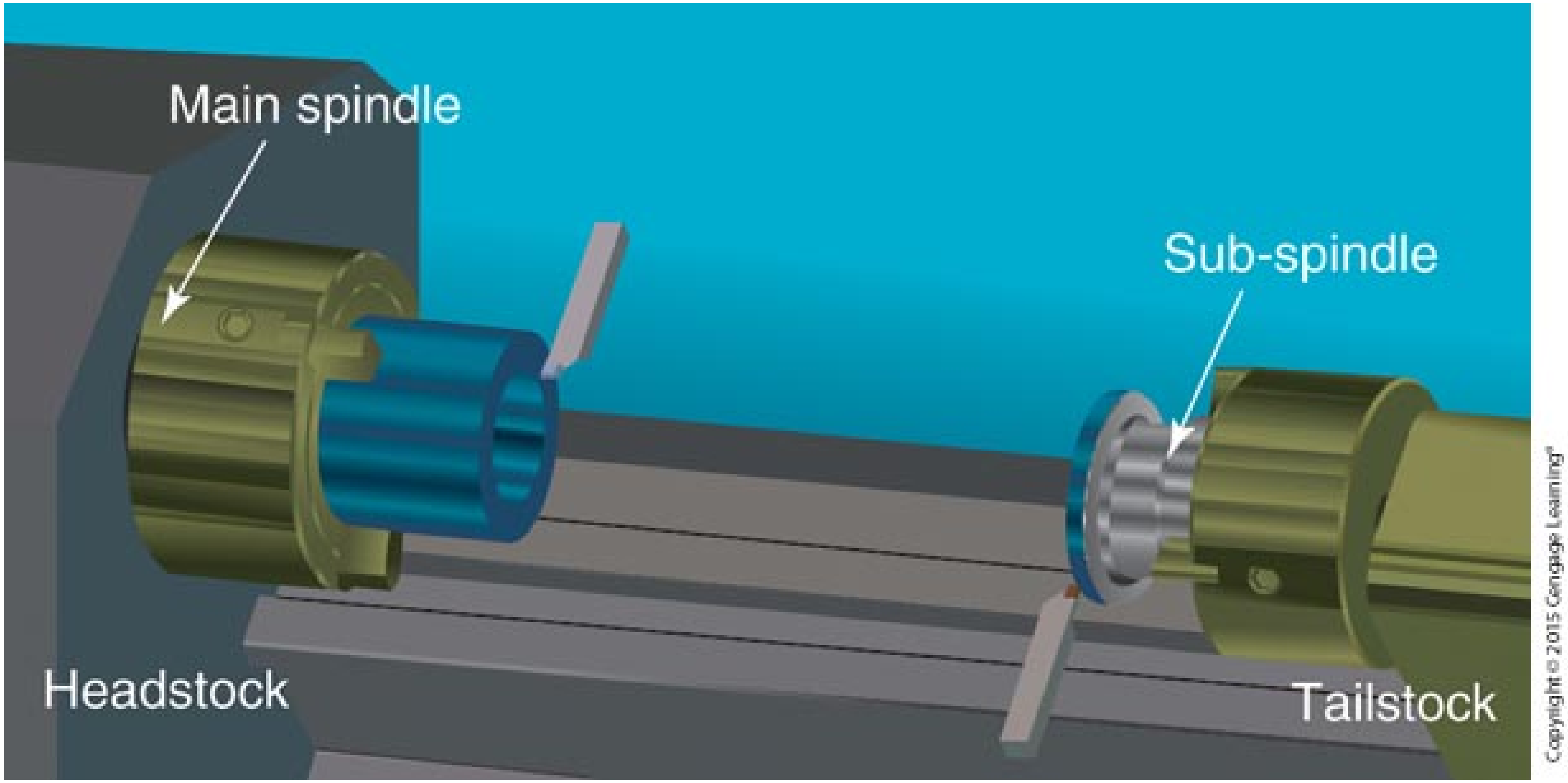


Courtesy Mariluk Industries, Inc

A robotic manufacturing cell can enhance productivity by minimizing operator intervention. The workpiece is transferred between machines by the robot.

A specialized mill/turn machine that can perform heavy milling and turning operations.



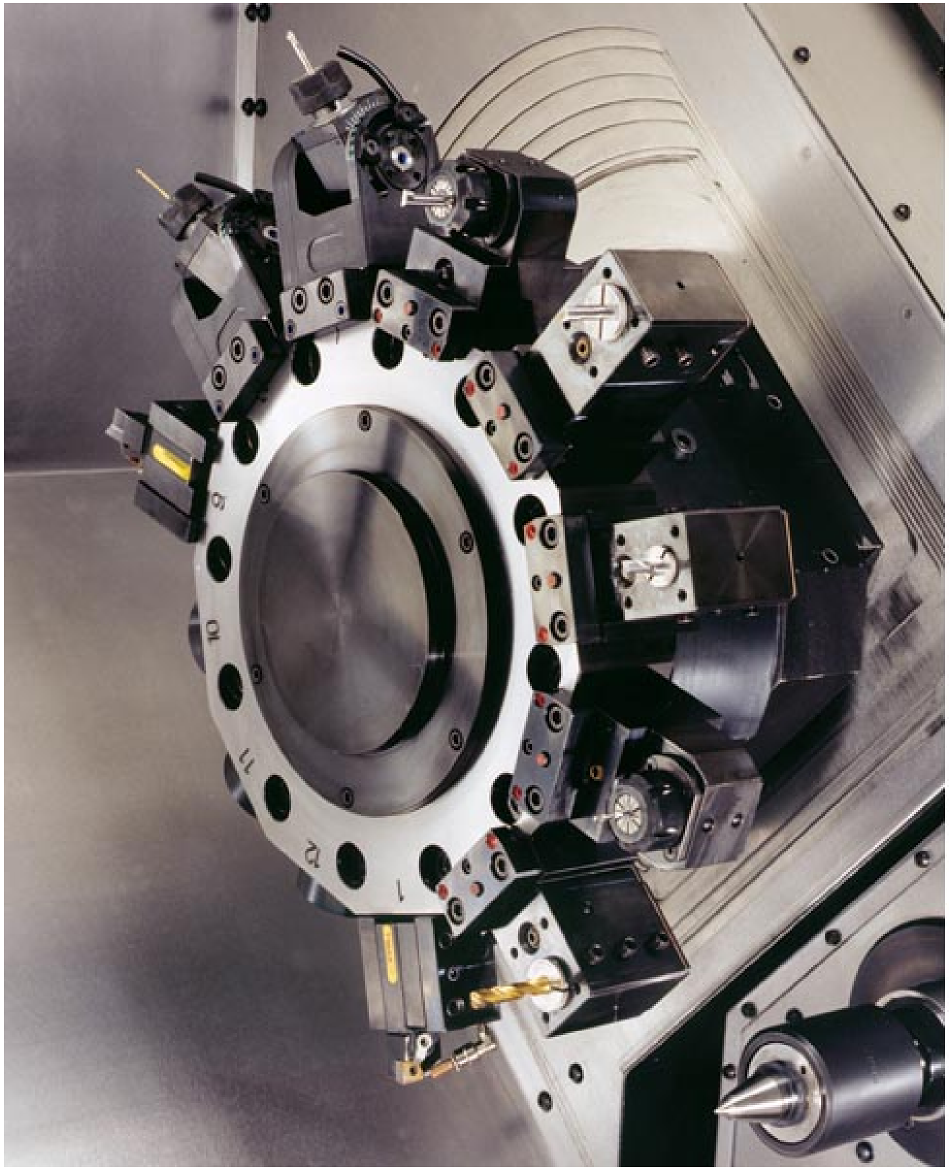


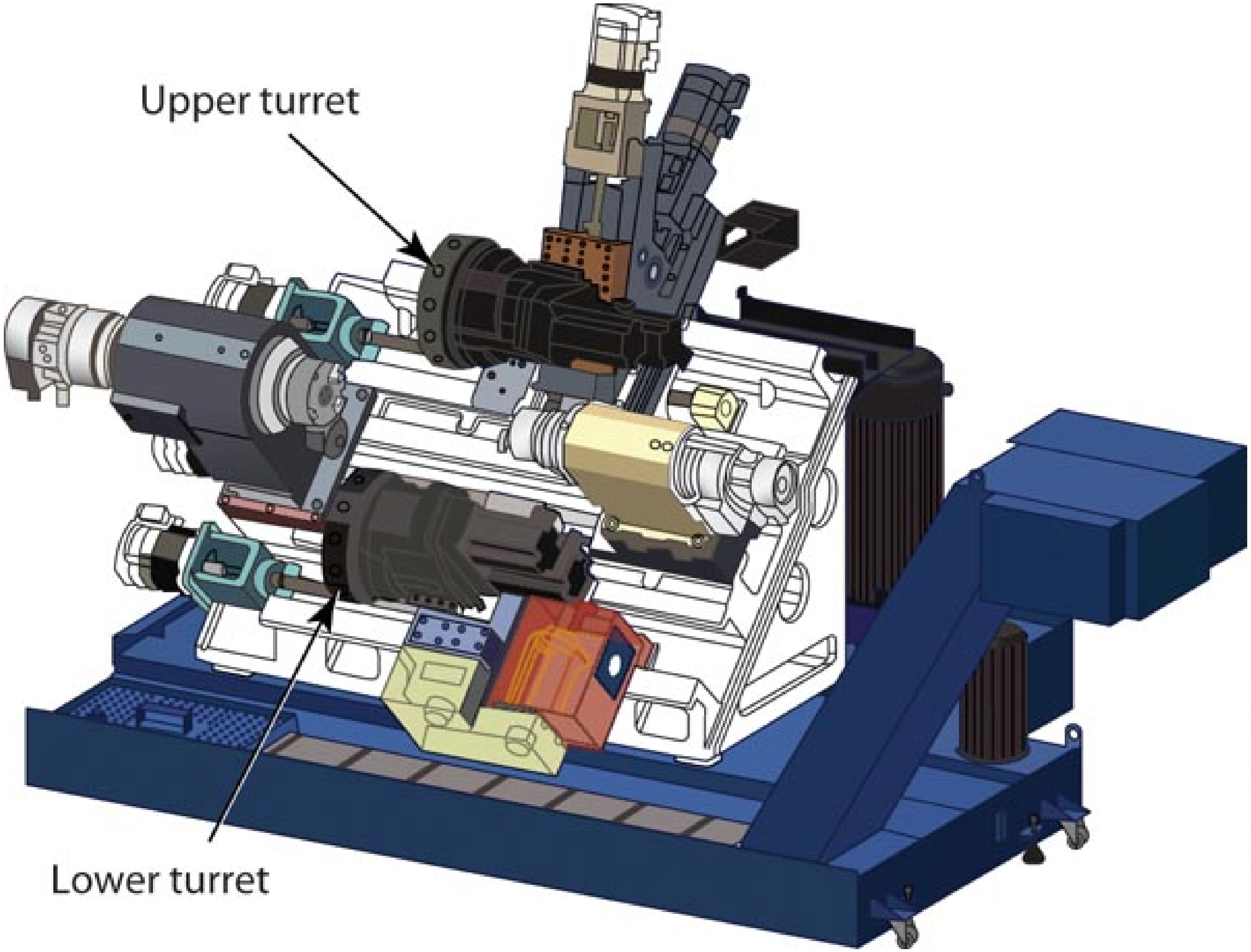
A sub-spindle opposes the machine's main spindle. The workpiece can be transferred from the main spindle to the sub-spindle so that the backside of the workpiece can be machined.

Types of Turning Machines

- Turret-type machines, gang-tool-type machines, CNC lathes, Swiss-type turning centers

A circular turret holds multiple tools and can index to any one of them with a program command.





A twin turret machine can move both turrets independently for machining.

A gang tool machine top plate with the tools arranged in a row.

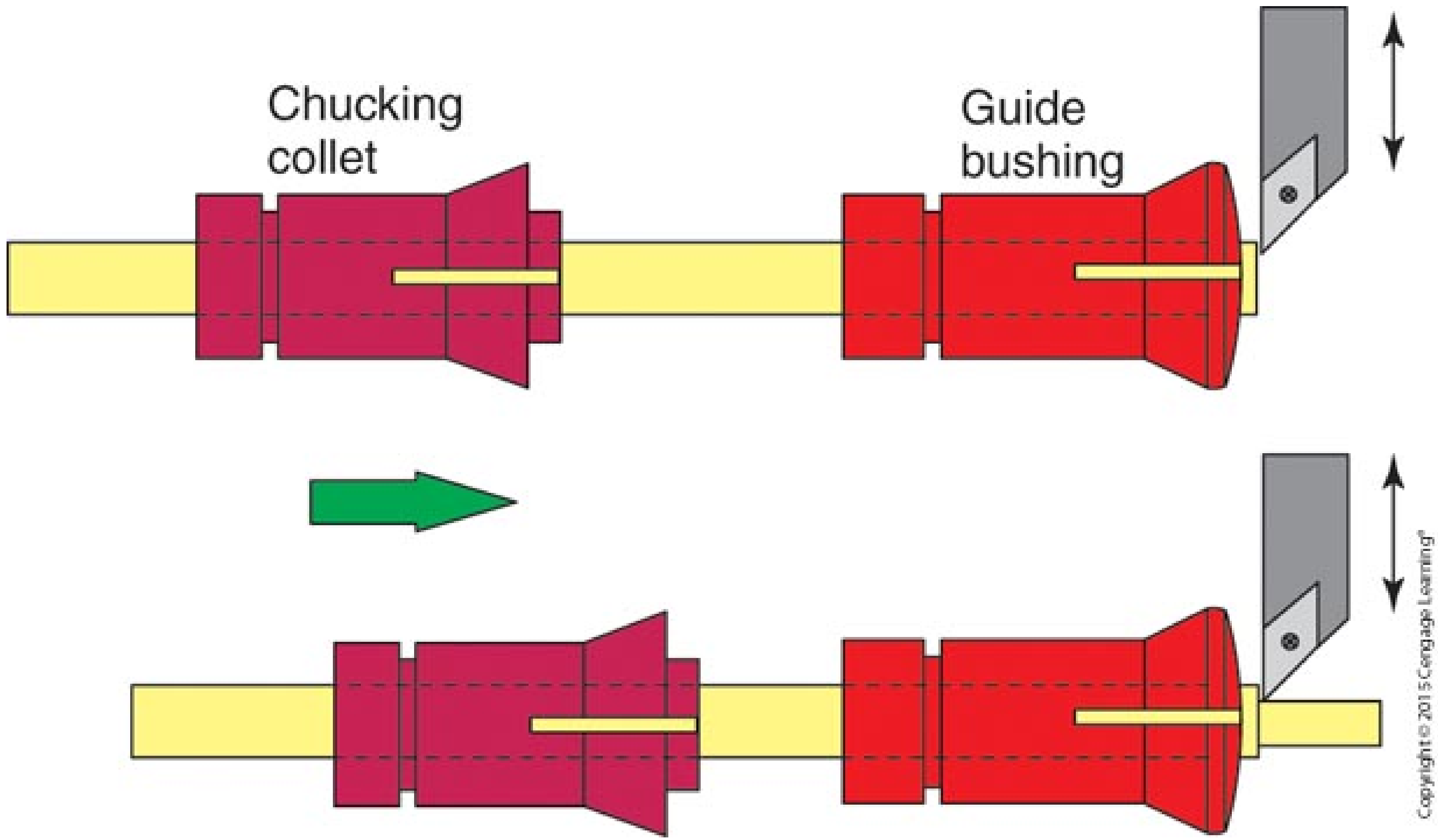
Courtesy of Hardinge, Inc

Courtesy of Hardinge, Inc

A gang tool turning center.

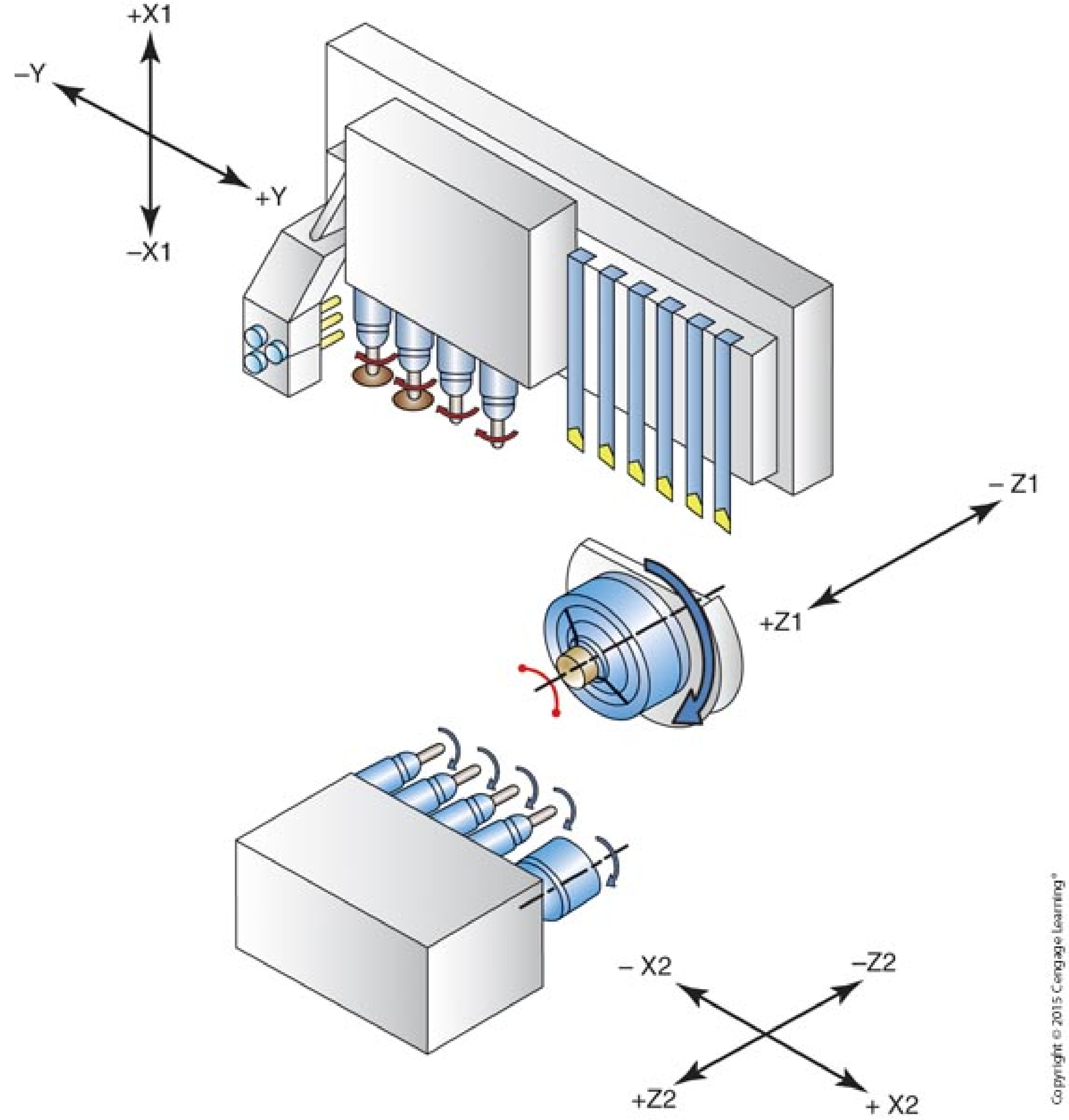
A CNC lathe holds cutting tools with a tool post similar to that used on a manual lathe.

Photo courtesy of Haas Automation, Inc



A Swiss turning machine moves the entire workpiece in the Z-axis instead of moving the cutting tool.

A typical tool arrangement on a Swiss turning machine.



Tool-Mounting Adapters

- Styles of tool-mounting adapters for different machines
  - Each accepts tools differently
  - CNC machines use same types of cutting tools as non-CNC, but different holding methods

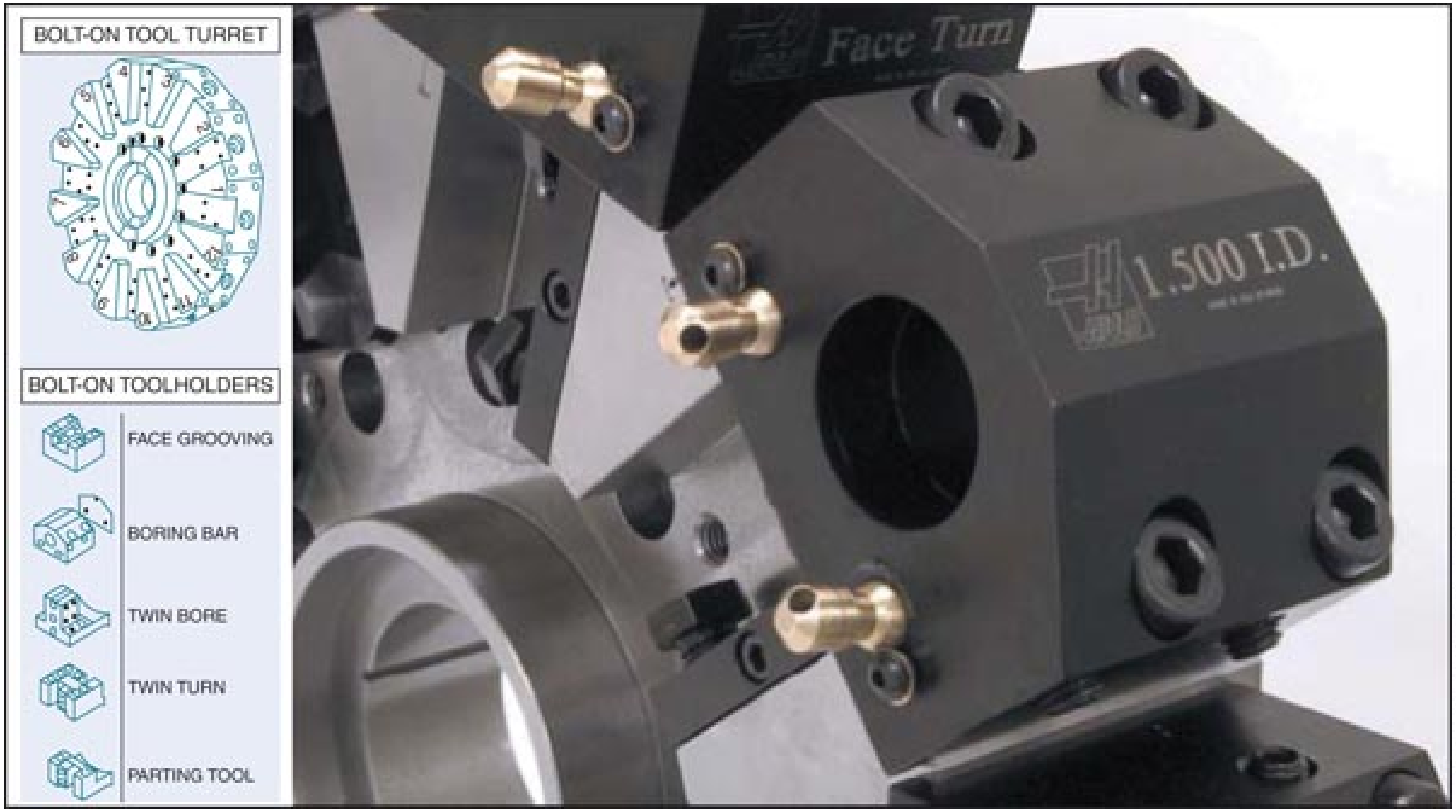
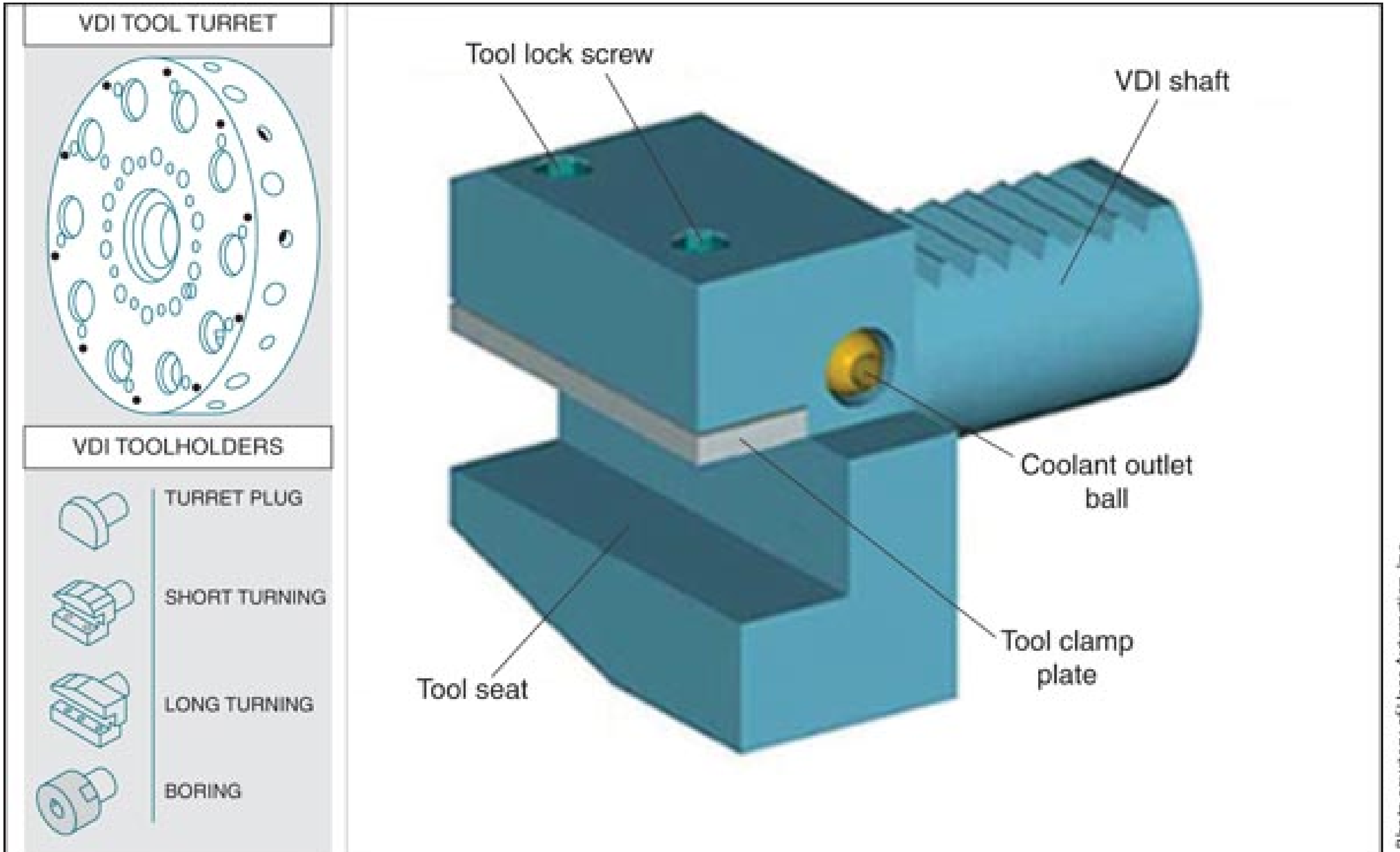
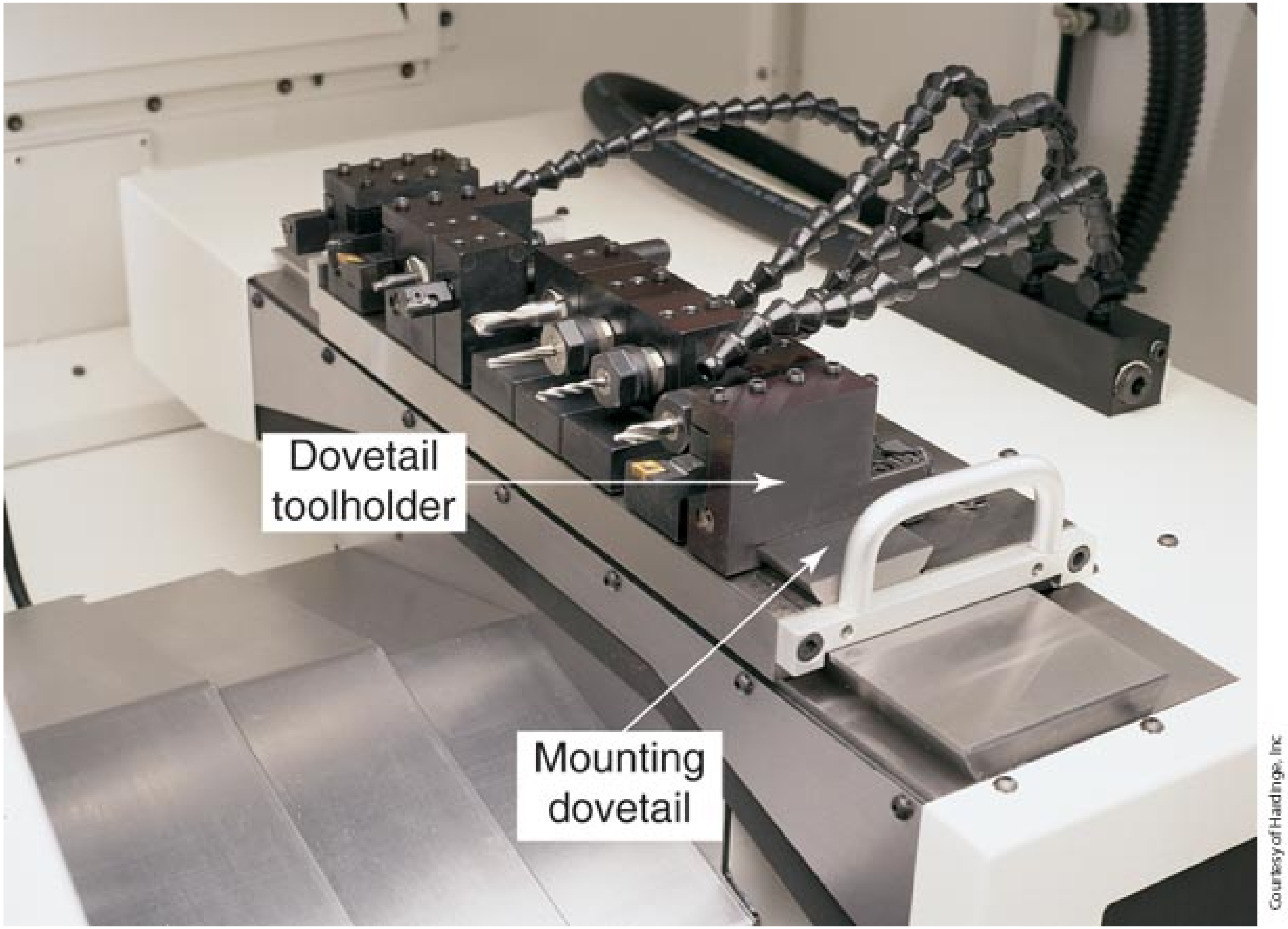


Photo courtesy of Haas Automation, Inc

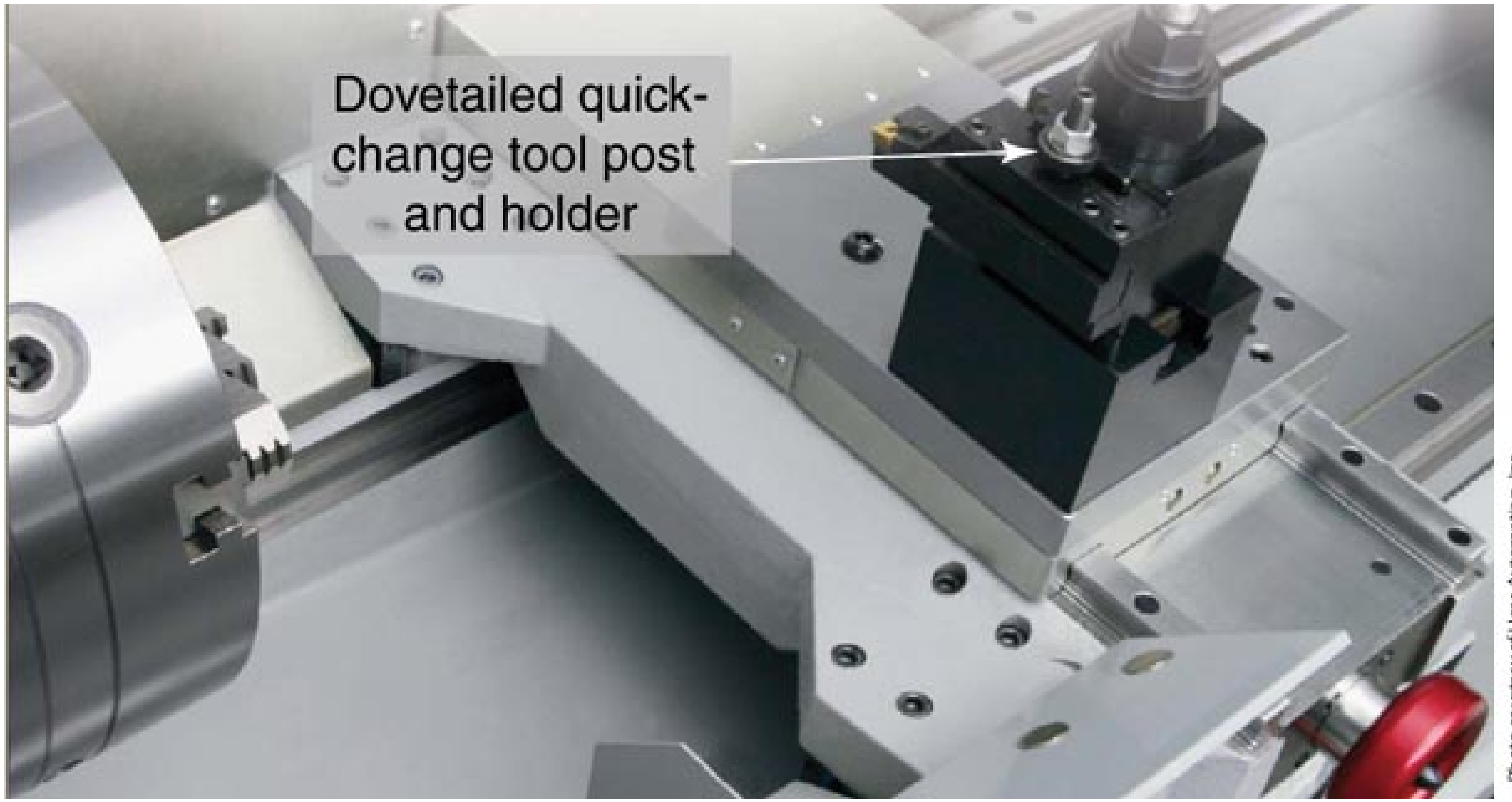
This type of toolholding adapter bolts directly to the turret with cap screws..



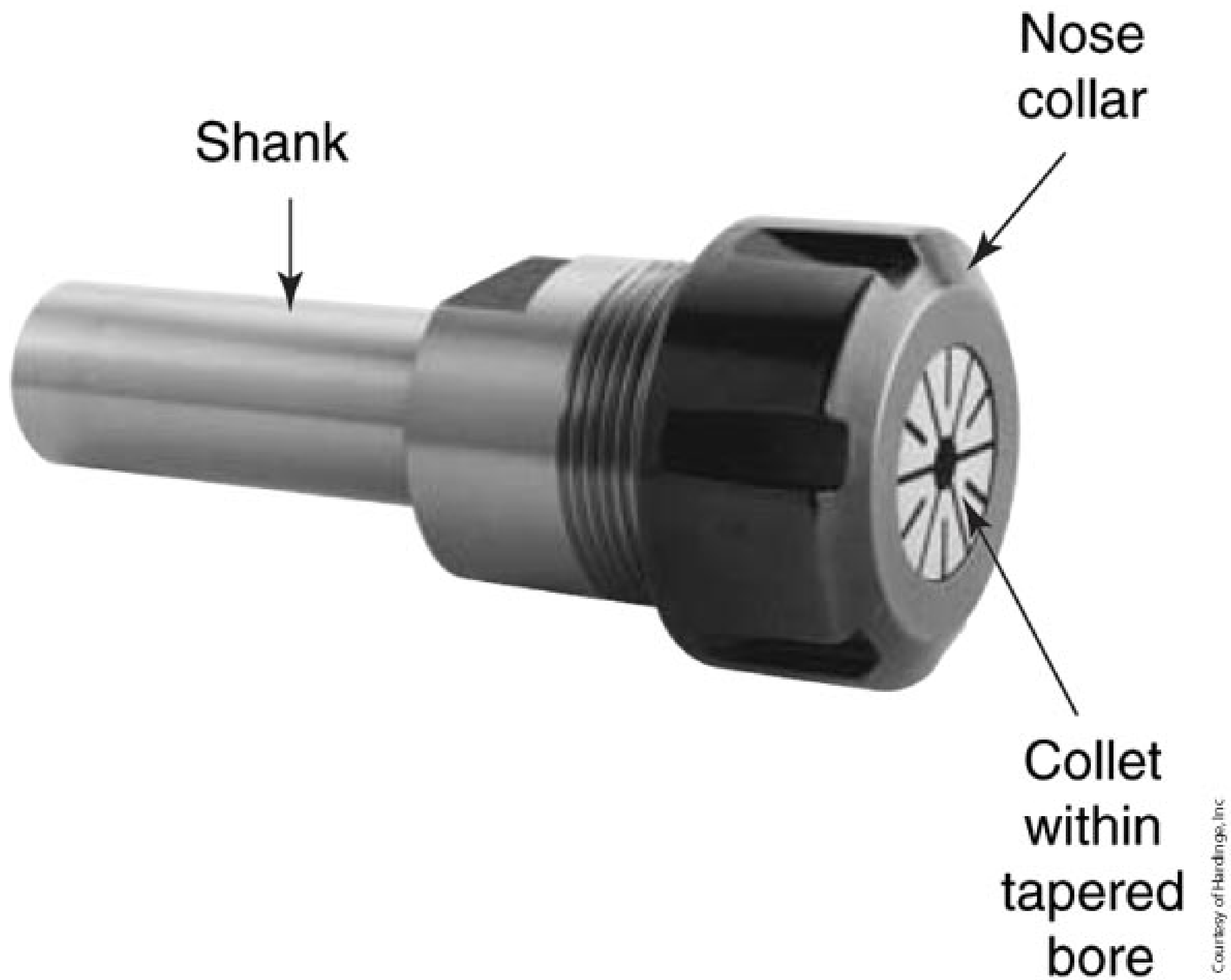
A VDI toolholding adapter mounts to the turret with a VDI shank. The adapter is drawn tight to the turret with the serrated teeth.



A dovetail mounting system used on a gang tool machine.

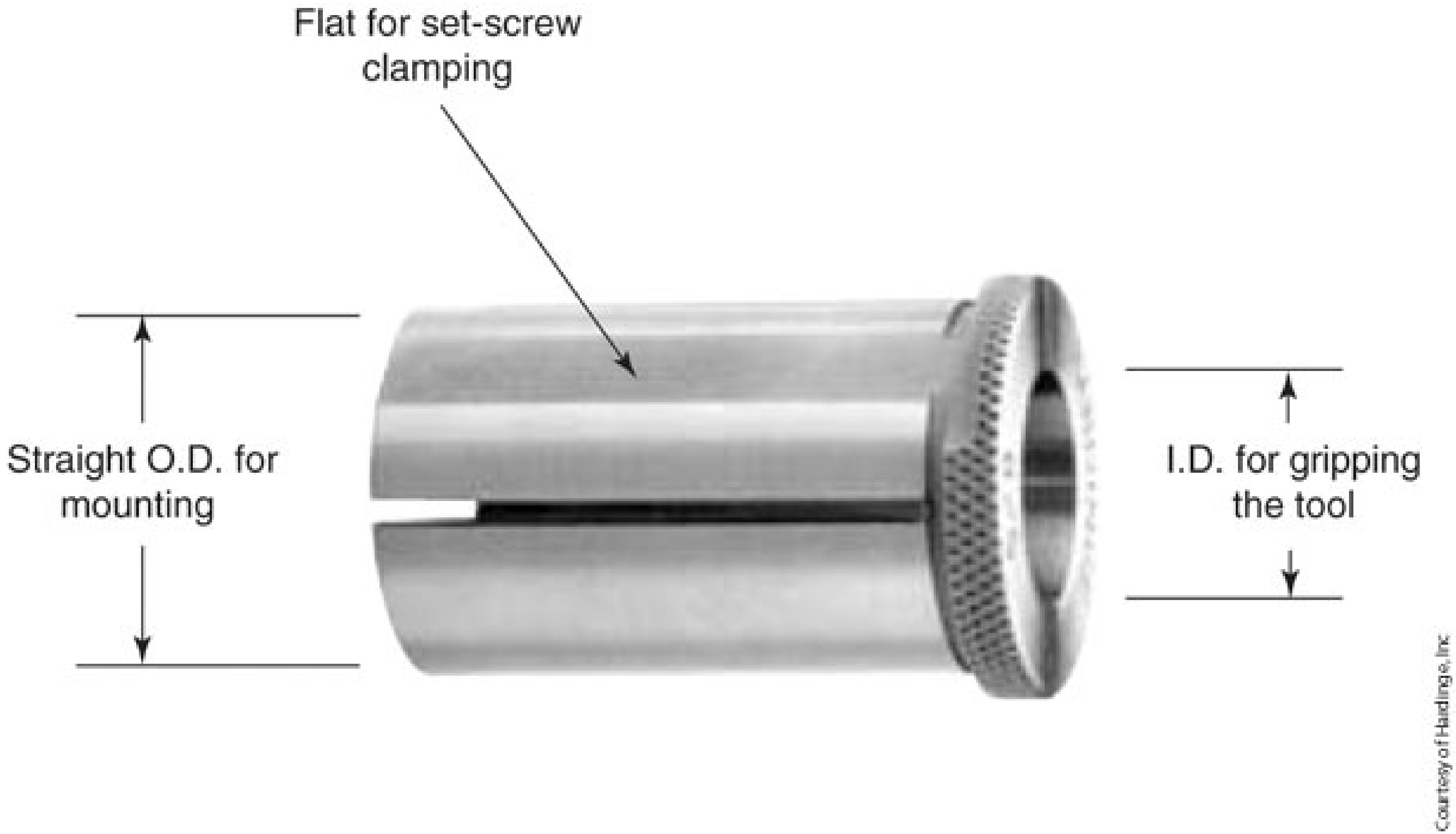


Quick-change toolholders used on a CNC lathe.

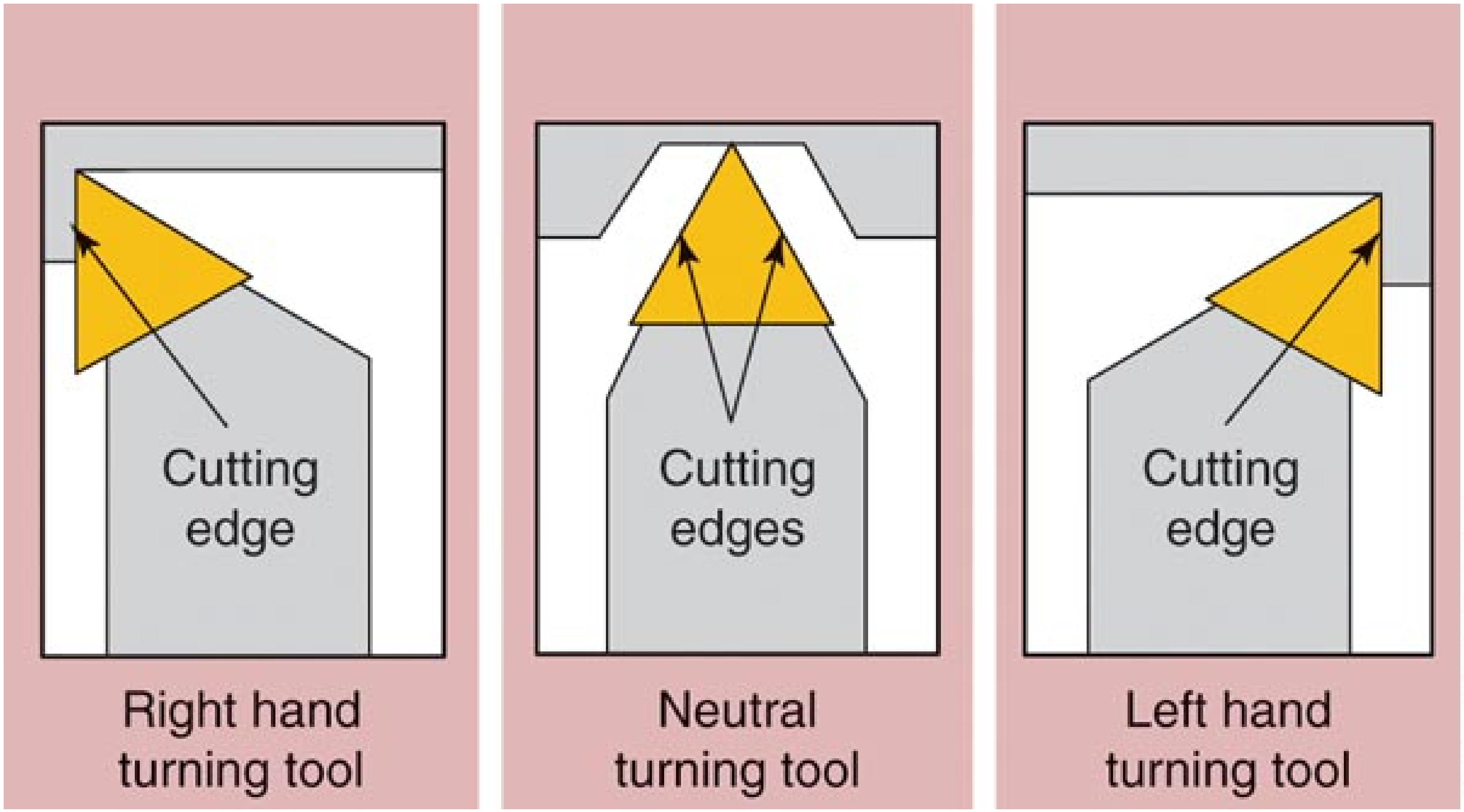


A CNC collet chuck for holding holemaking tools.

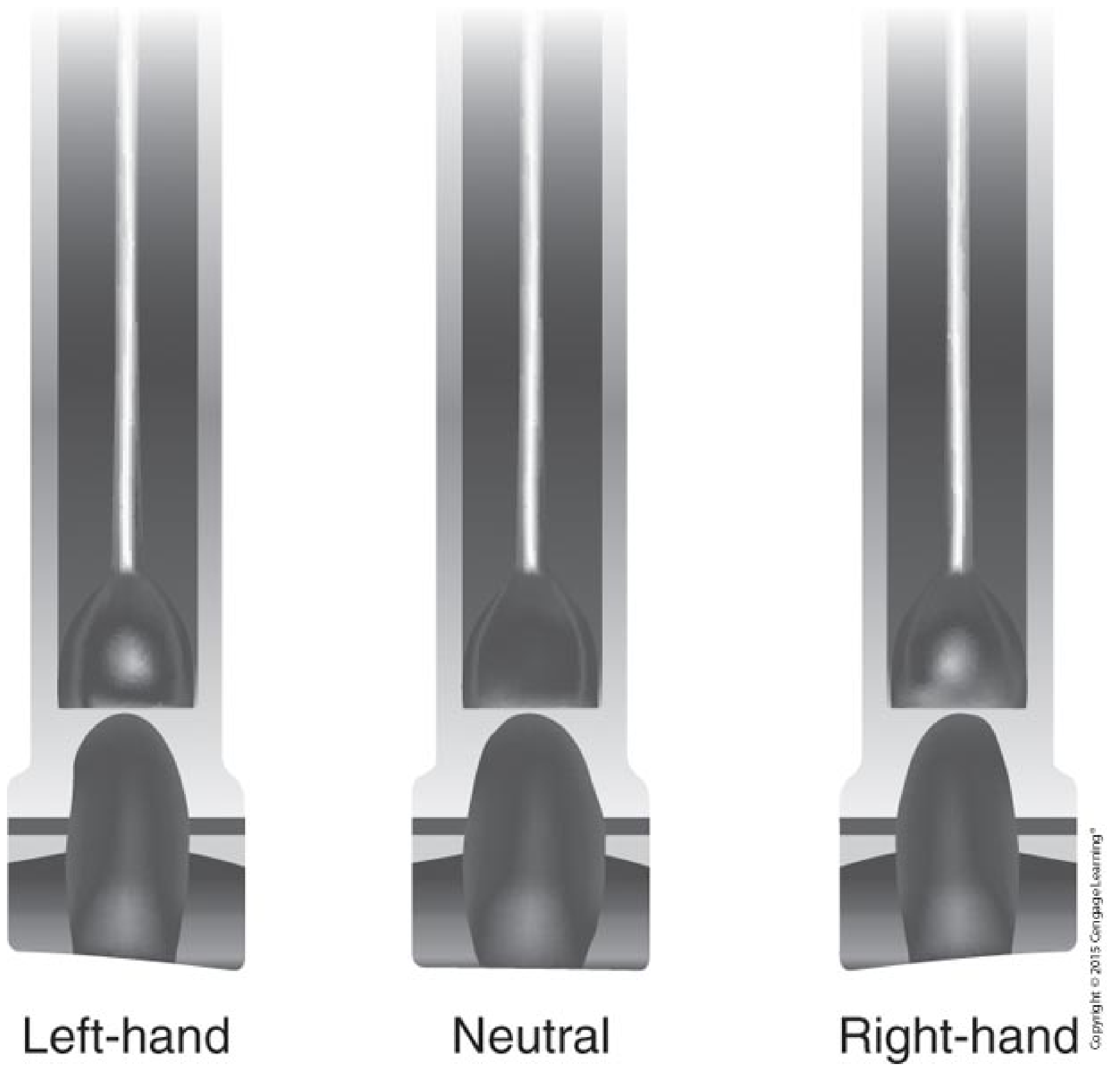
The collet types shown from left to right are the ER series, DA series, and TG series.



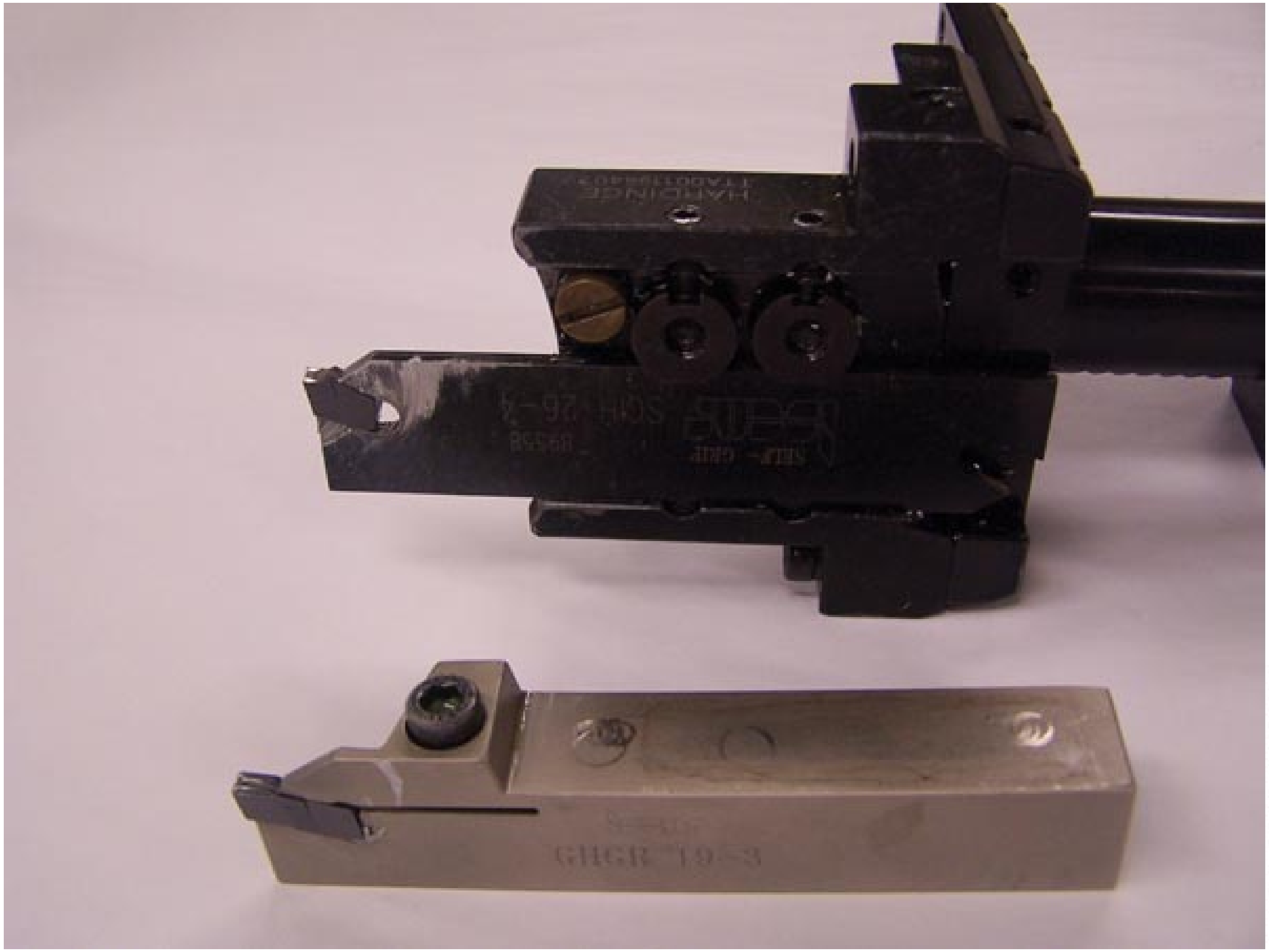
A Hardinge HDB drill bushing used to hold holemaking tools.



The turning tool orientations shown are right hand, neutral, and left hand.

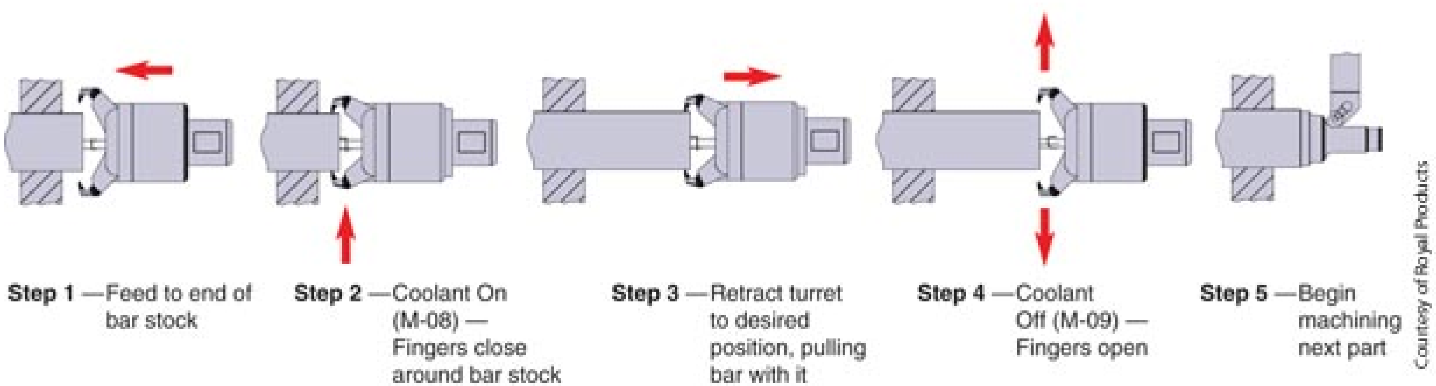


Cutoff inserts are available with a biased cutting edge to minimize burrs on the part being cut off.



A grooving tool is in the foreground and a cutoff tool is in the background.

A gripping-ring-type bar puller grips the bar end by sliding a ring of spring-steel teeth over the perimeter of the bar.

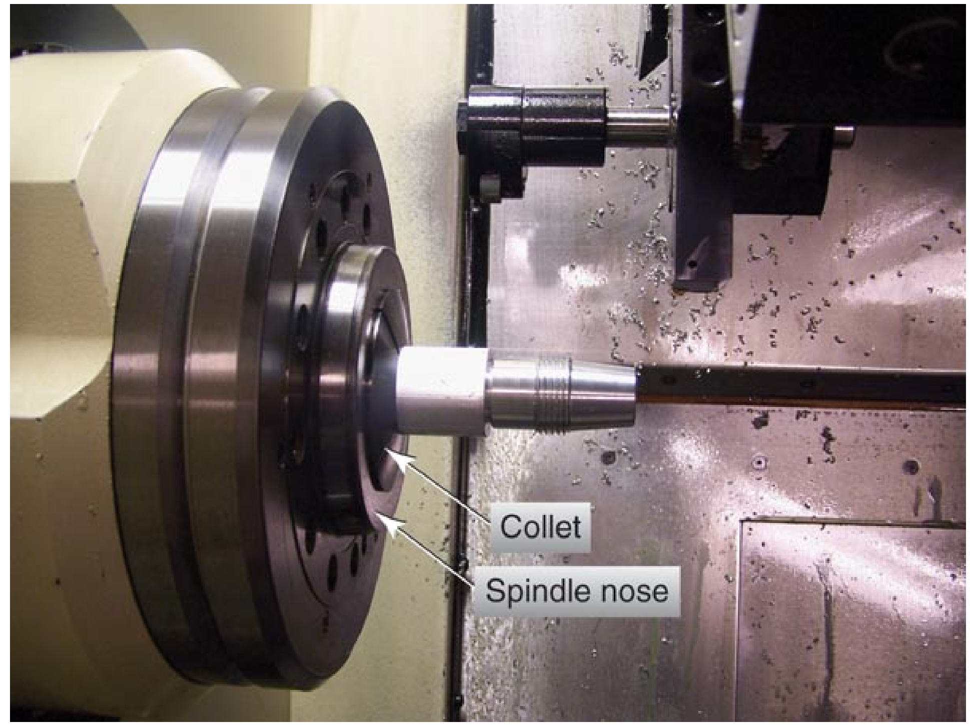


This coolant-actuated bar puller's jaws grip the stock using the hydraulic pressure of the machine’s coolant system.

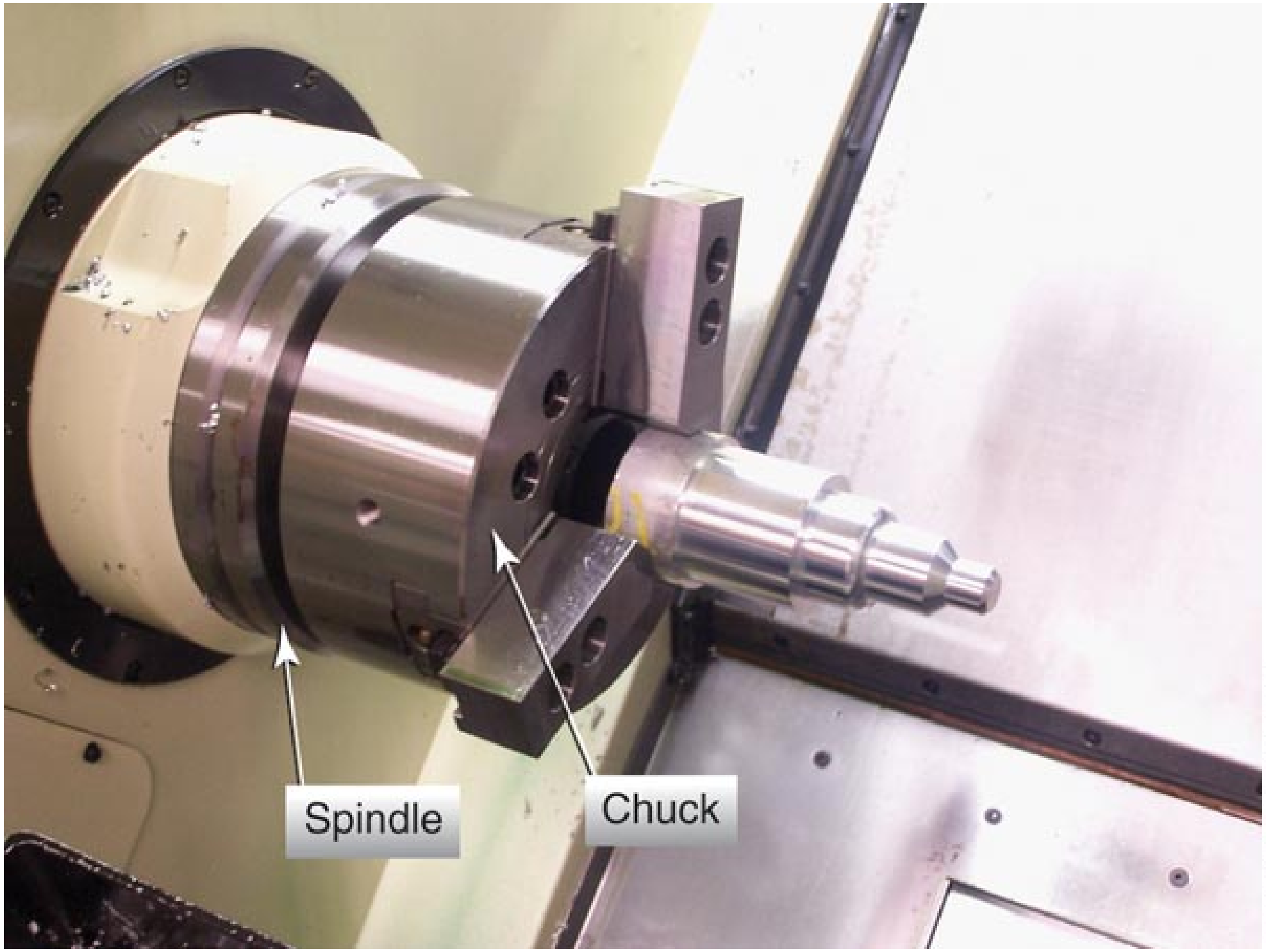
A CNC turning center equipped with an automatic bar feeder.

Workholding

- Workholding devices for CNC like those for manual lathes
  - Types: workholding collets, workholding chucks



A CNC turning center using a collet for workholding.



A three-jaw power-actuated chuck in a CNC turning center. This setup is using soft jaws that were machined to match the outside diameter of the workpiece.

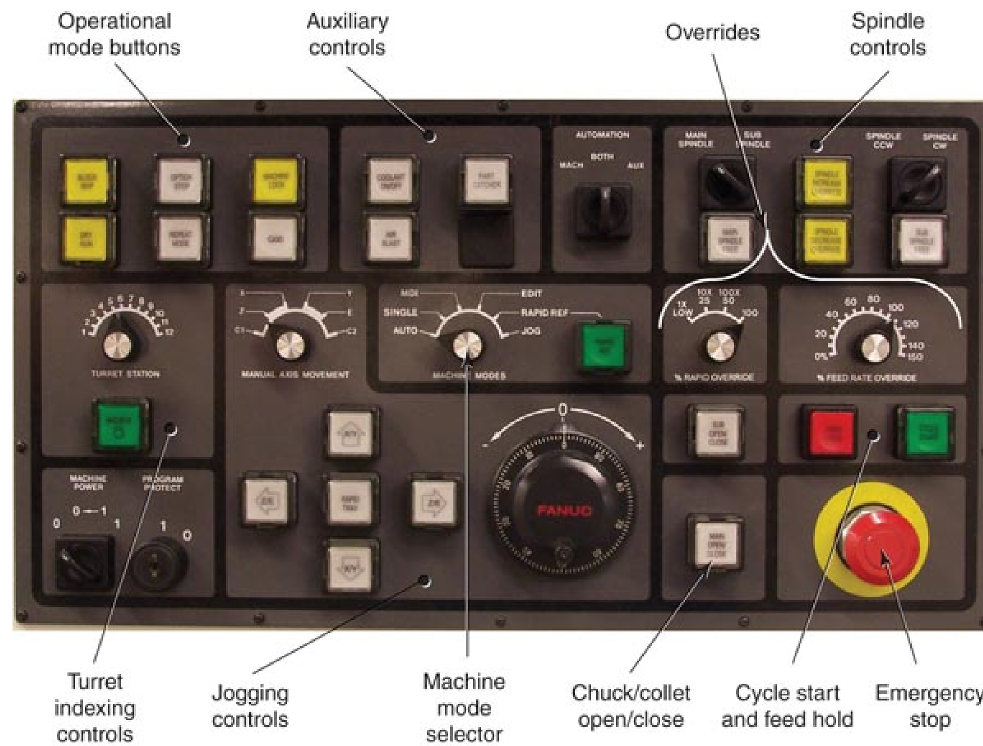
Process Planning

- Manufacturing process: all operations required to machine a part
- Process plan describes all steps in detail
  - Includes a description of each operation, the tools required, speed and feed data, workholding information, other notes and comments, and often a sketch depicting the part orientation

CNC Turning: Setup and Operation

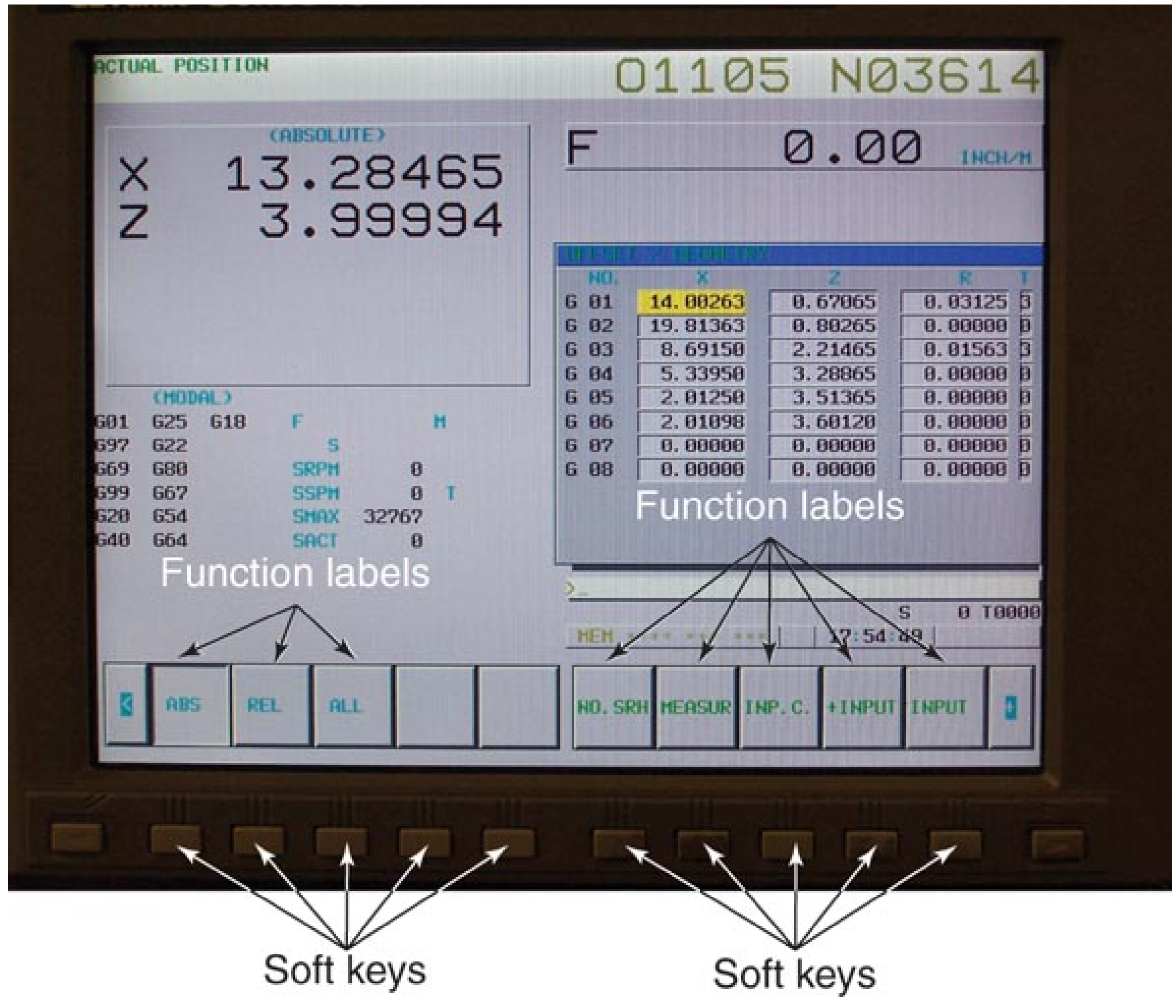
Machine Control Panel

- Attached to MCU, contains displays and inputs
- Allows operator to program, set up and operate machine



The parts of a turning center control panel.

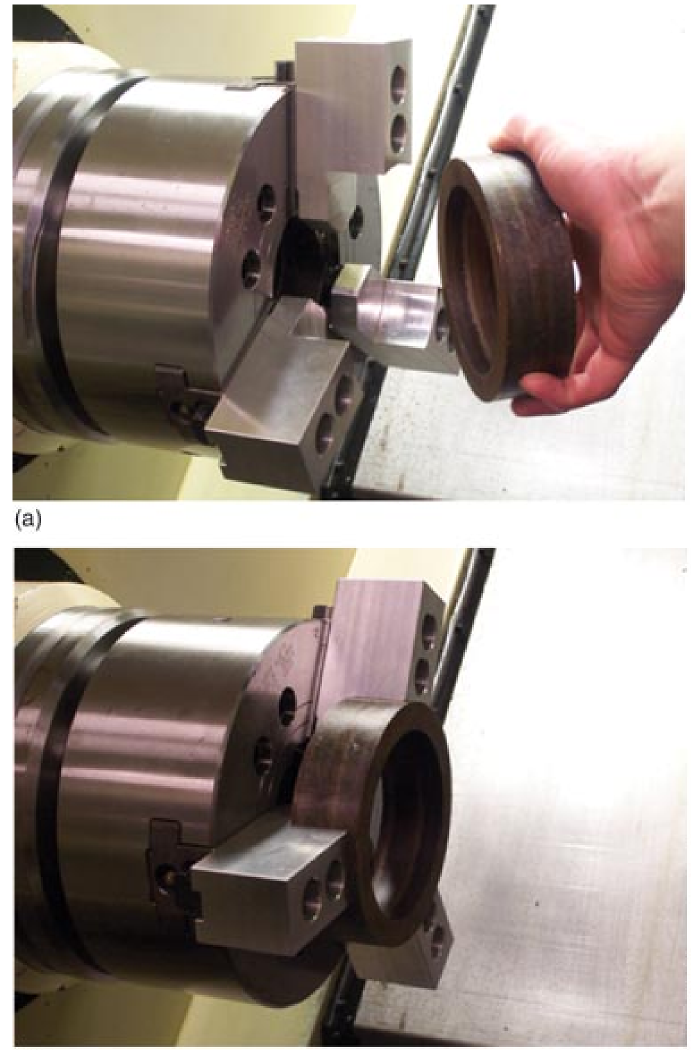
Soft keys are used on some machines. These keys are universal and can be used for different functions according to their on-screen label.



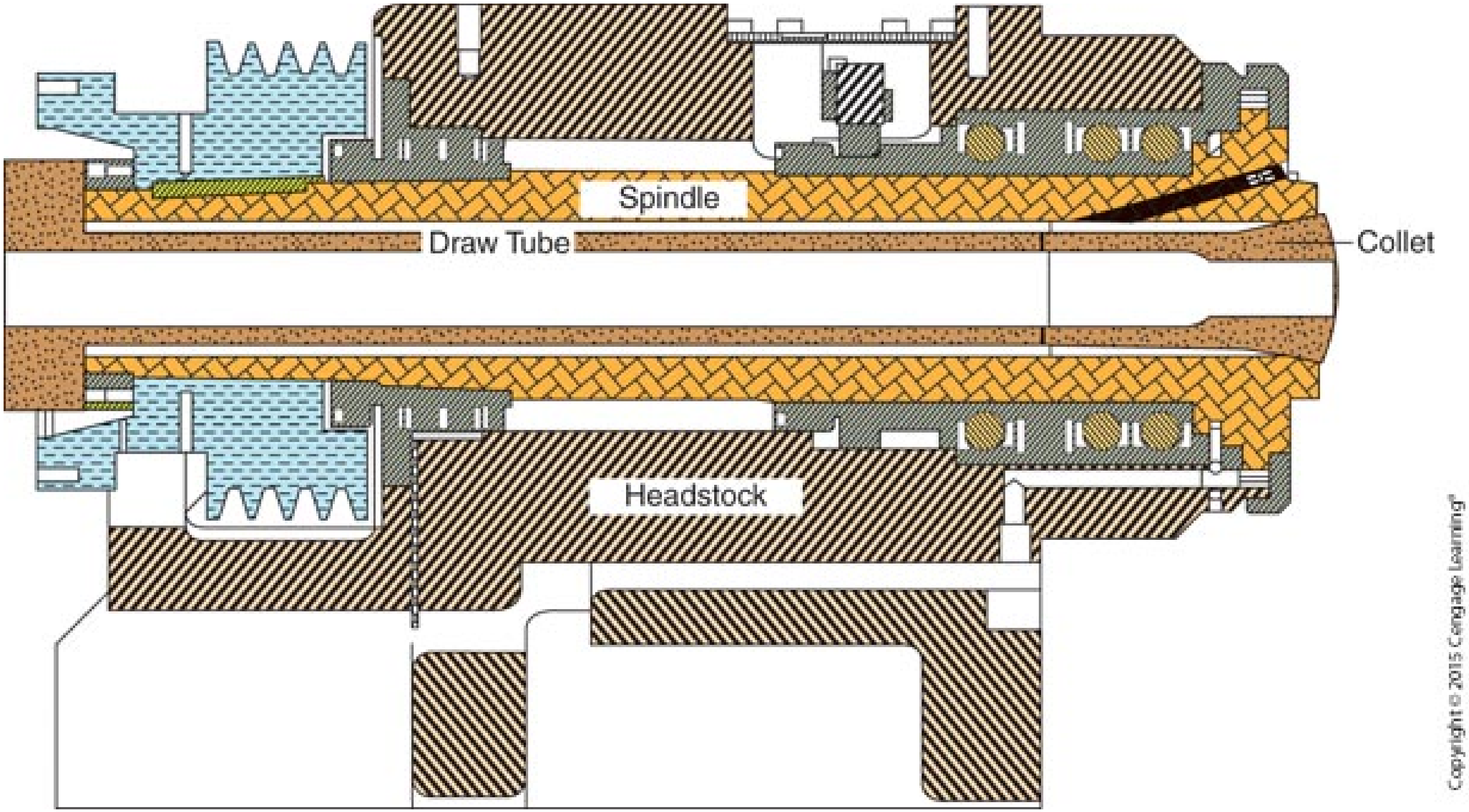
Arrow keys used for constant jogging of each axis.

Workholding Setup

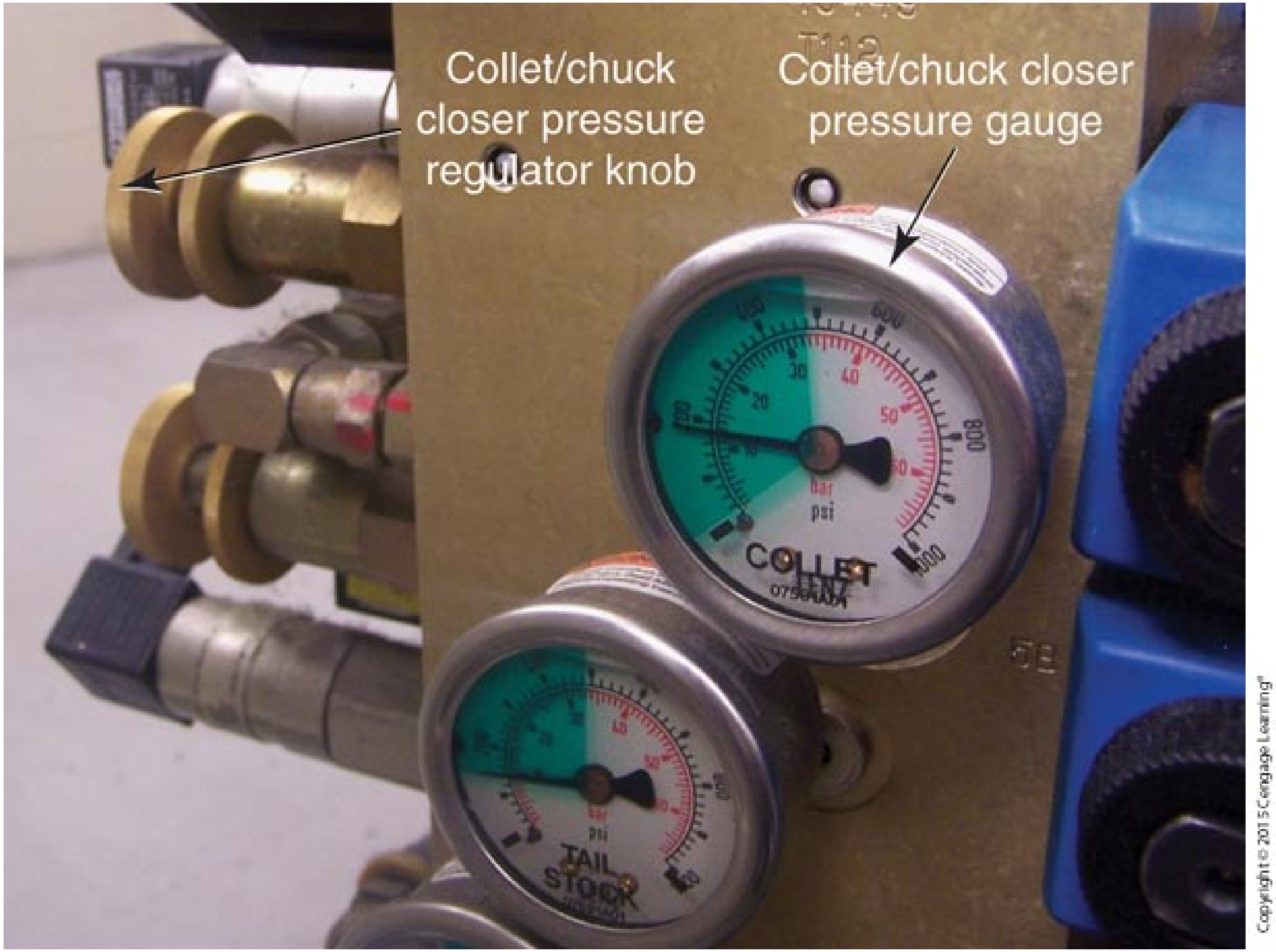
- Text advises how to prepare chuck or collet
  - Use appropriate clamping pressure


(a) (b)

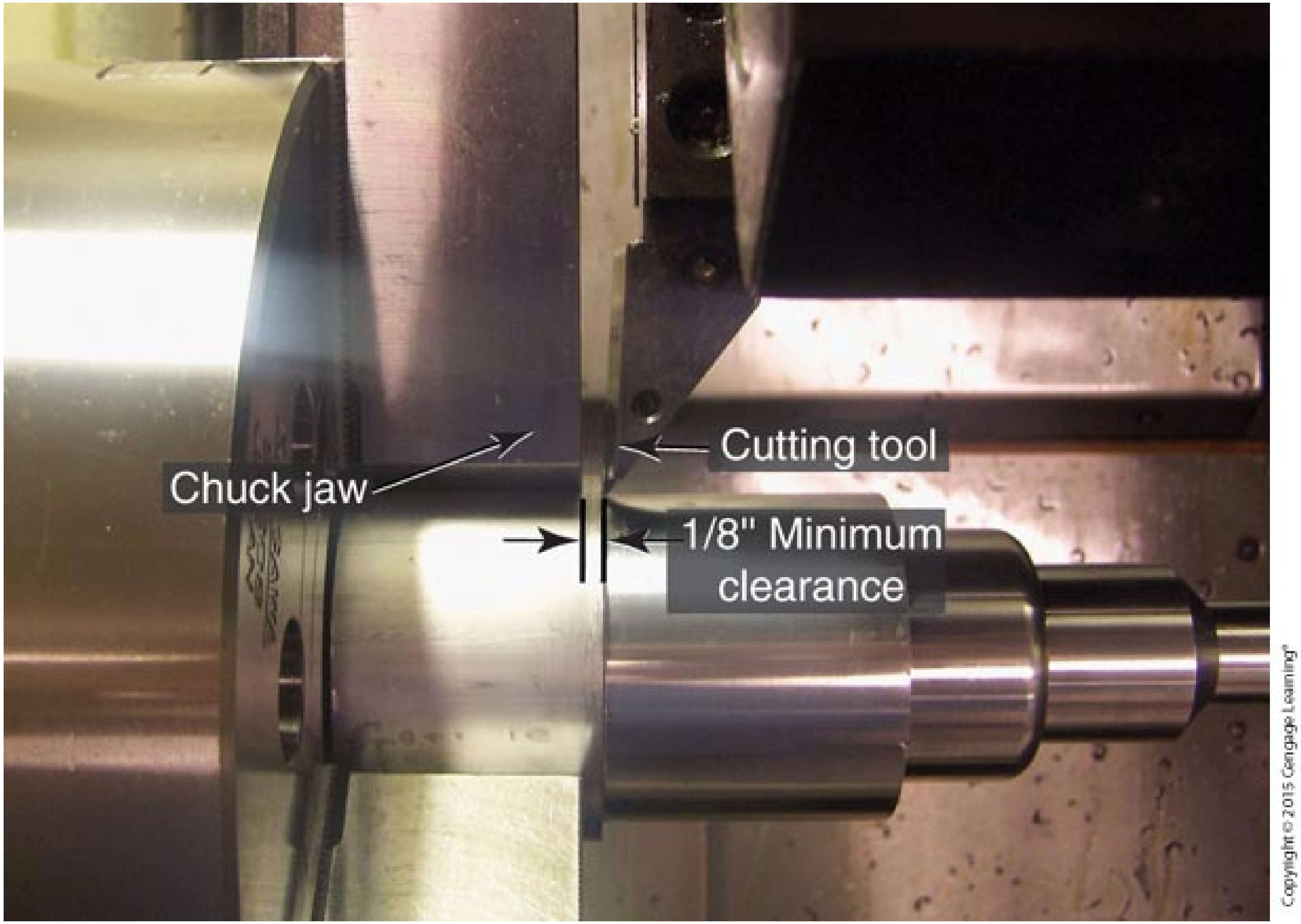
Appropriately bored soft-chuck jaws and a mating workpiece.



A turning center drawtube and collet assembly within a machine spindle.



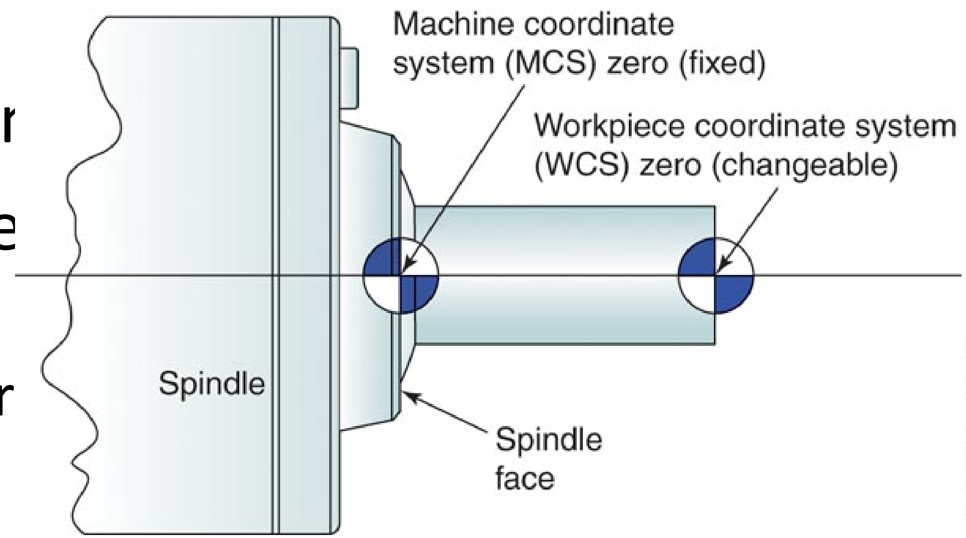
A picture of a turning center hydraulic regulator and gauge for adjusting collet or chuck clamping pressure.



A minimum of 1/8" clearance should be maintained between the cutting tool and the workholding device.

Machine and Work Coordinate Systems

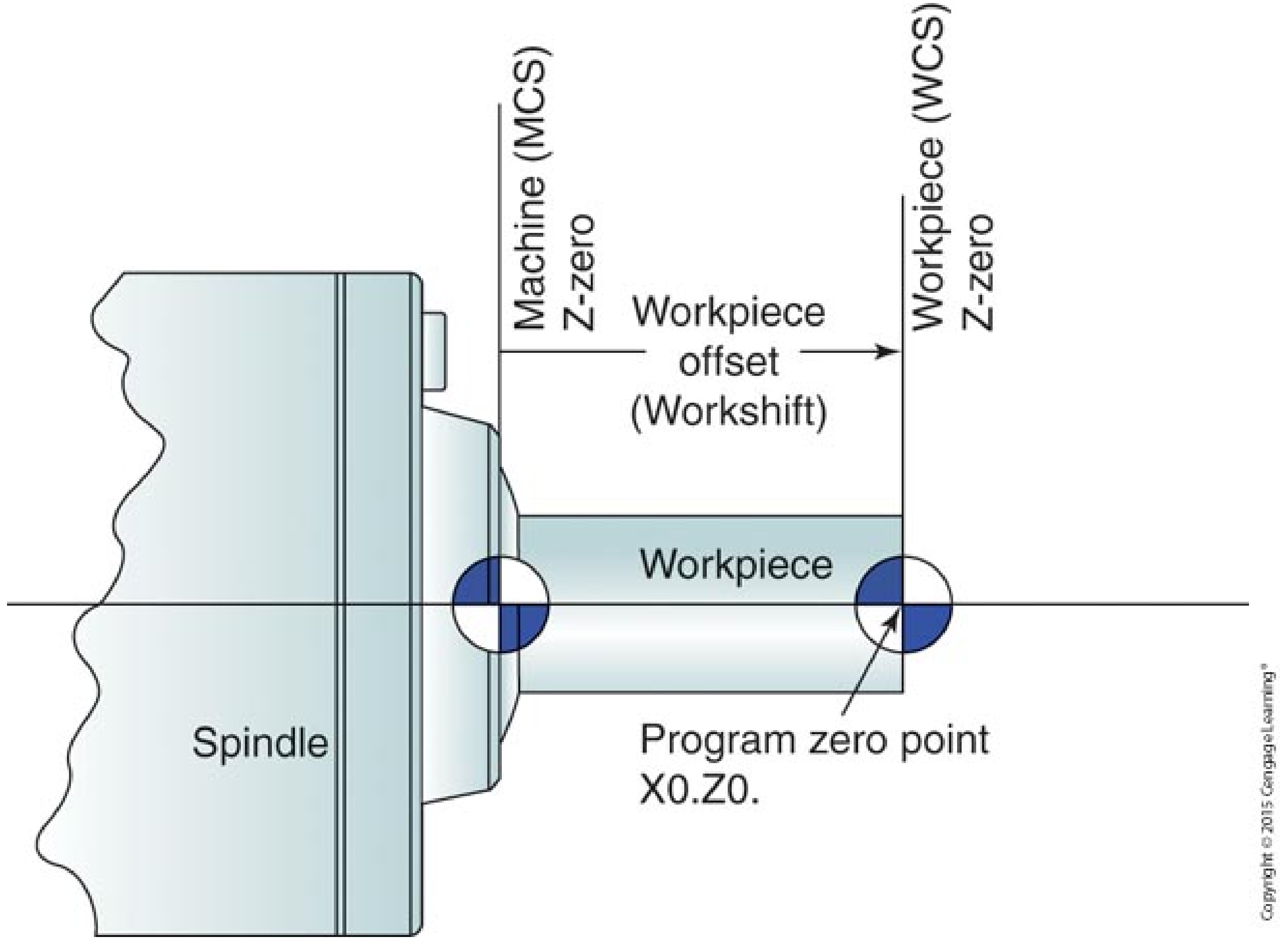
- WCS (work coordinate system) sets flexible origi
- MCS (machine coordinate system) has set origin
  - Power up and home befor working



The relationship of the machine coordinate system (MCS) to the established work coordinate system (WCS).

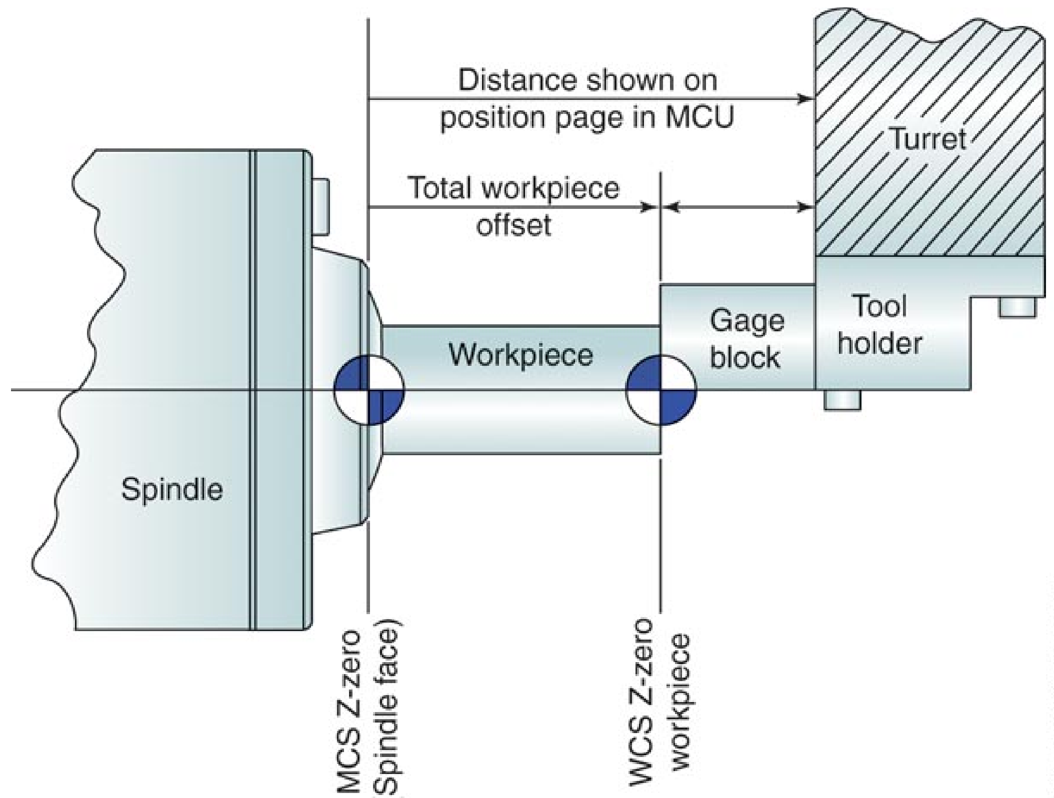
Work Offset Setting

- Difference between MCS (set) and WCS (flexible)
  - Program coordinates reference WCS; WCS references MCS
  - Some controls call this offset a workshift
  - Basic steps for setting a work offset in text



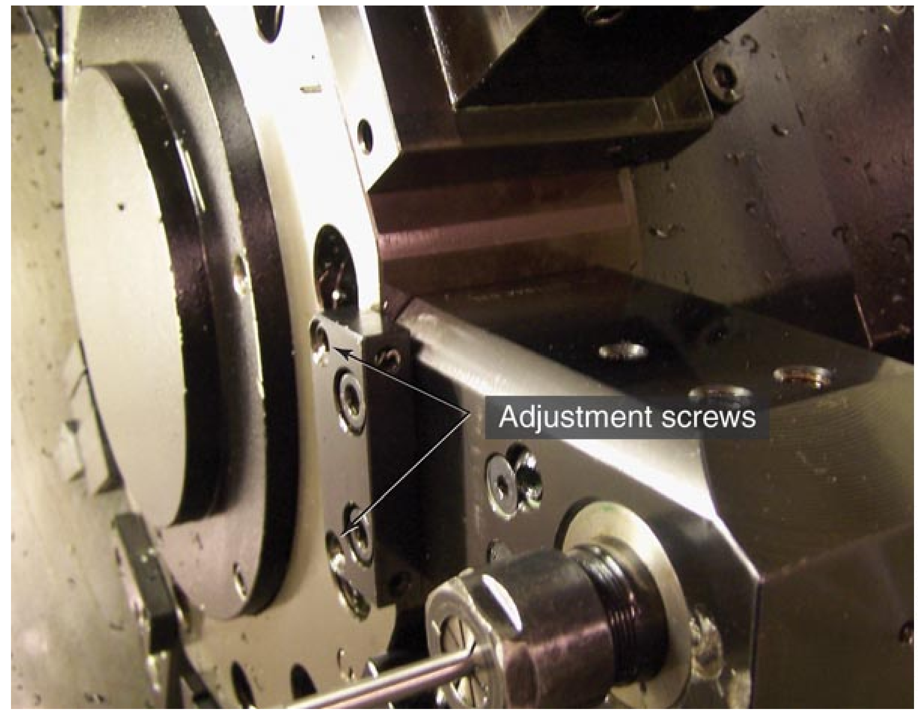
Workpiece offset is the Z-axis distance from the MCS zero to the WCS zero. The X-axis offset should remain zero since the spindle and workpiece share the same center line.

A gage block can be used to determine the workpiece offset by touching a turret reference surface on the desired part Z-zero. The turret's position will be displayed on the machine position page. With the turret touching the spindle face, the position would read Z-zero. With the turret touching the gage block as shown, the position would display the length of the workpiece to its face, plus the gage block length. Subtracting the gage block length from this dimension reveals the workpiece length from the spindle face (work offset).

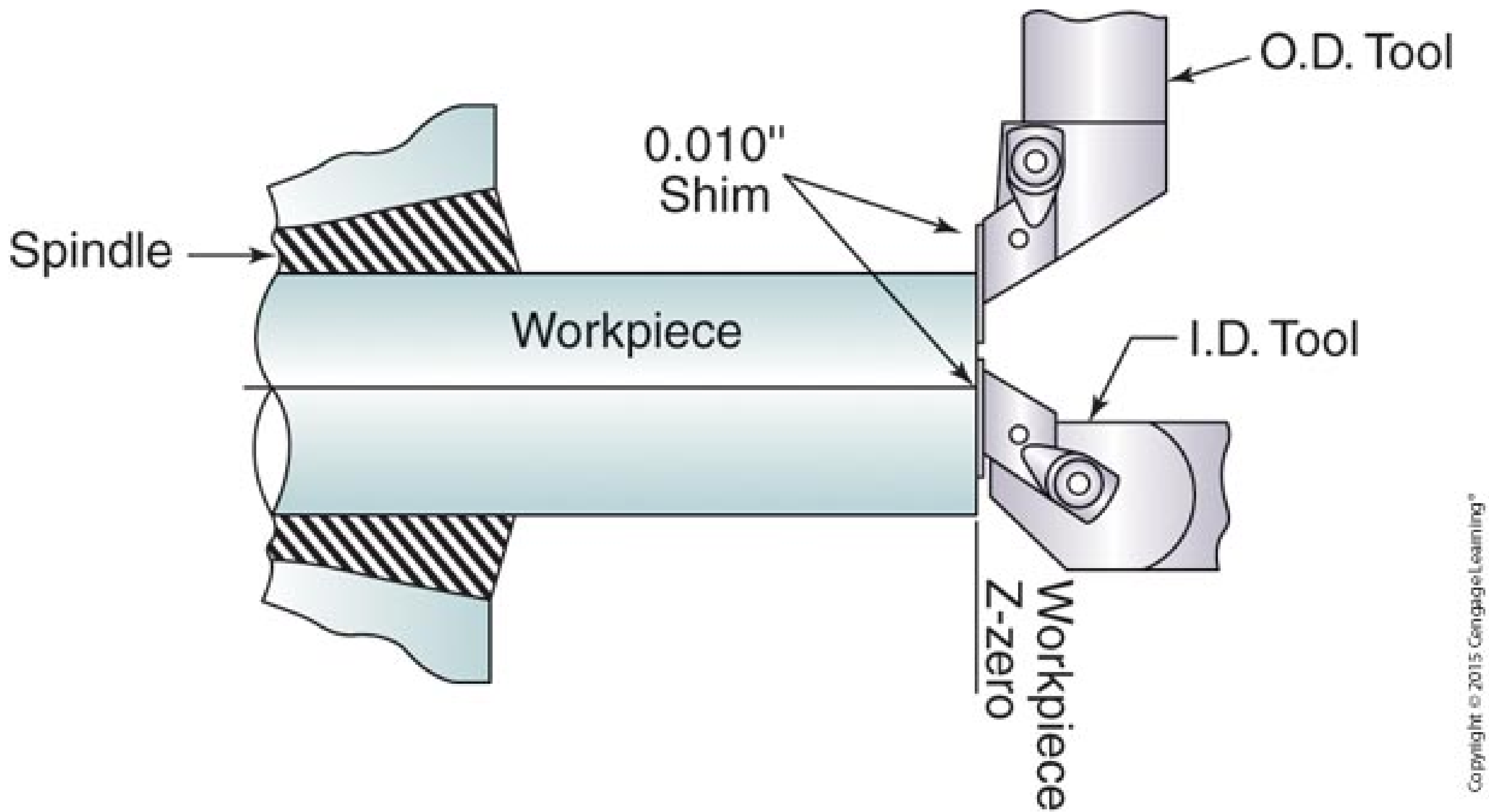


Cutting Tools for Turning

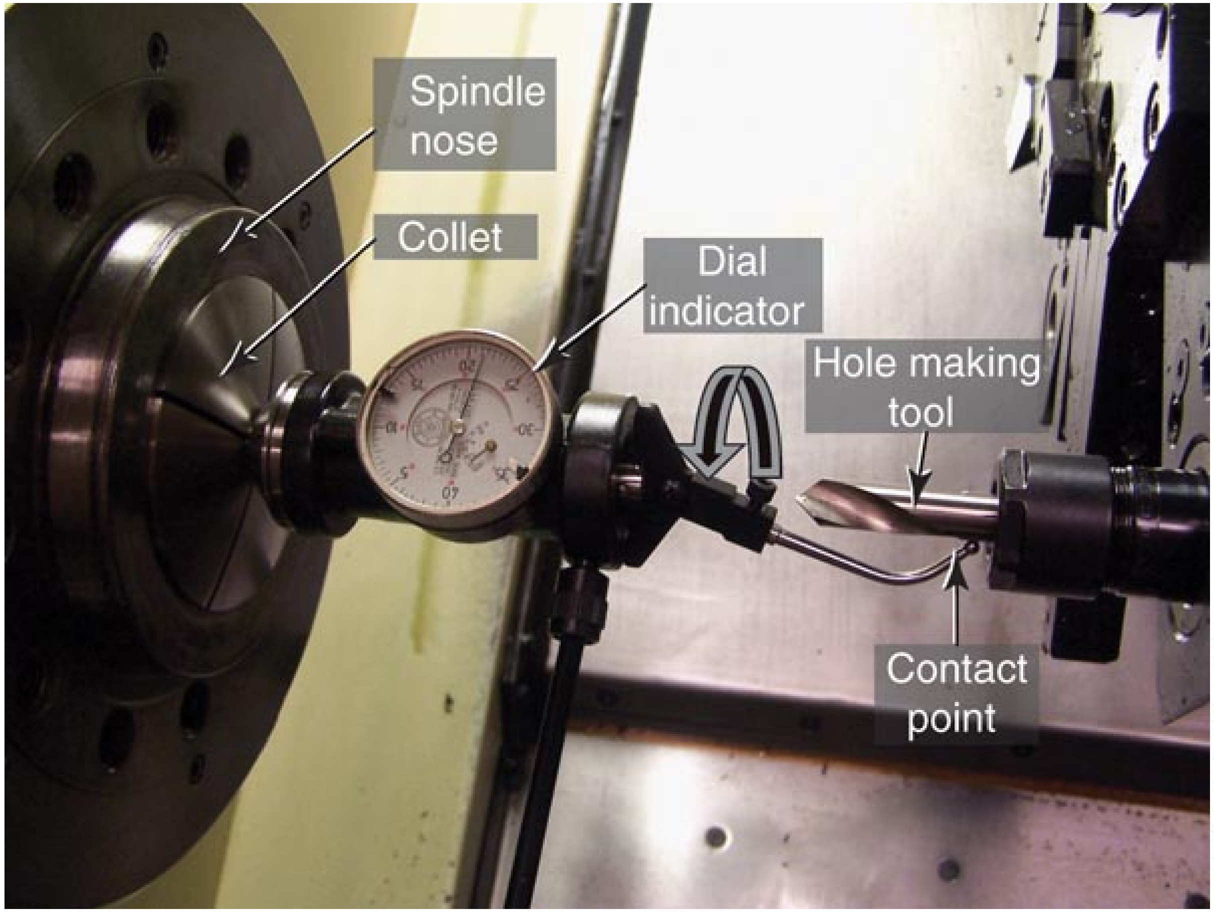
- Installation: mount tools correctly for rotation direction, check alignment
- Offsets: distance reference to tool tip
    - Geometry offsets and wear offsets



Adjustment screws for squaring a holemaking tool holder.

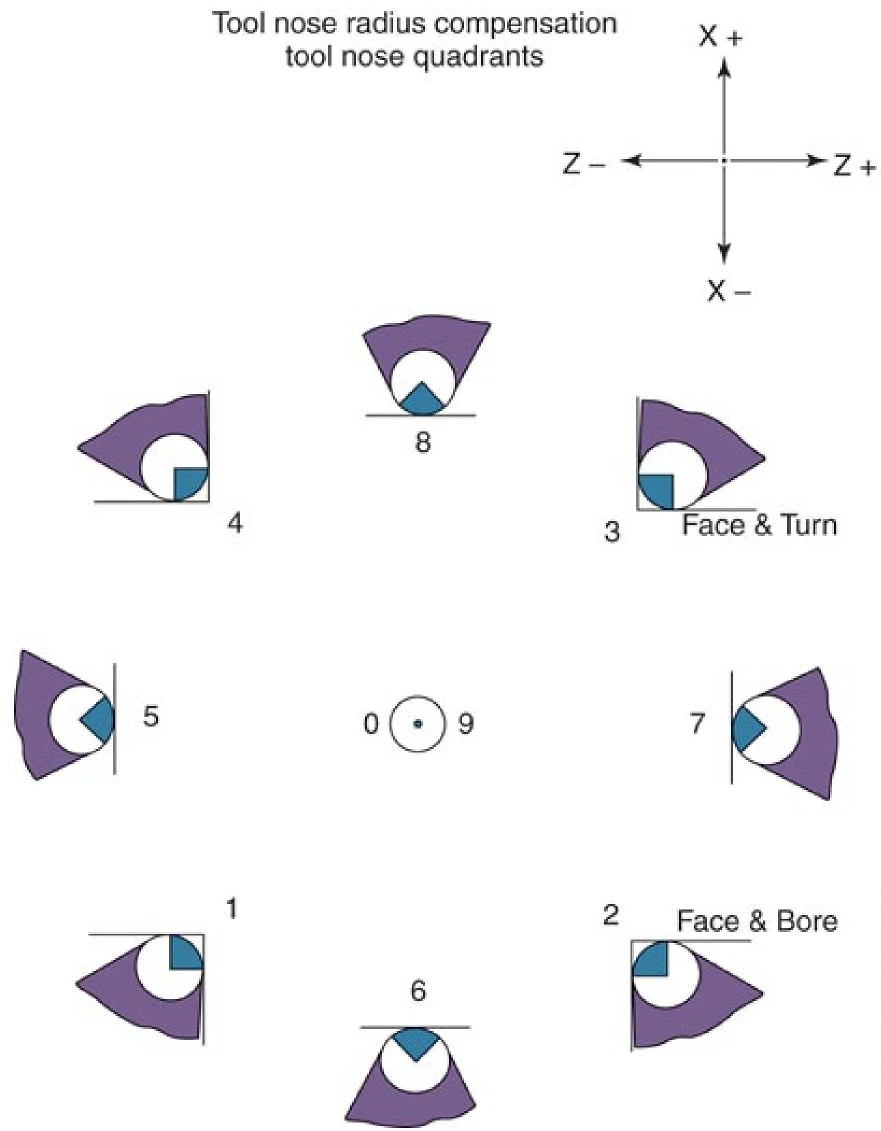


Method for setting tools off the part face of Z-zero with a 0.010"-thick feeler gage. While in this position the tool's position can be set as positive 0.010" in the Z-axis.



A holeworking tool being swept with a spindle-mounted indicator to find alignment with the spindle axis.

In order for TNRC to be successful, the control must know the cutting zone (shaded in blue) on the tool nose where compensation must occur. The available quadrants are shown relative to the tool tips on various styles of cutting tools.

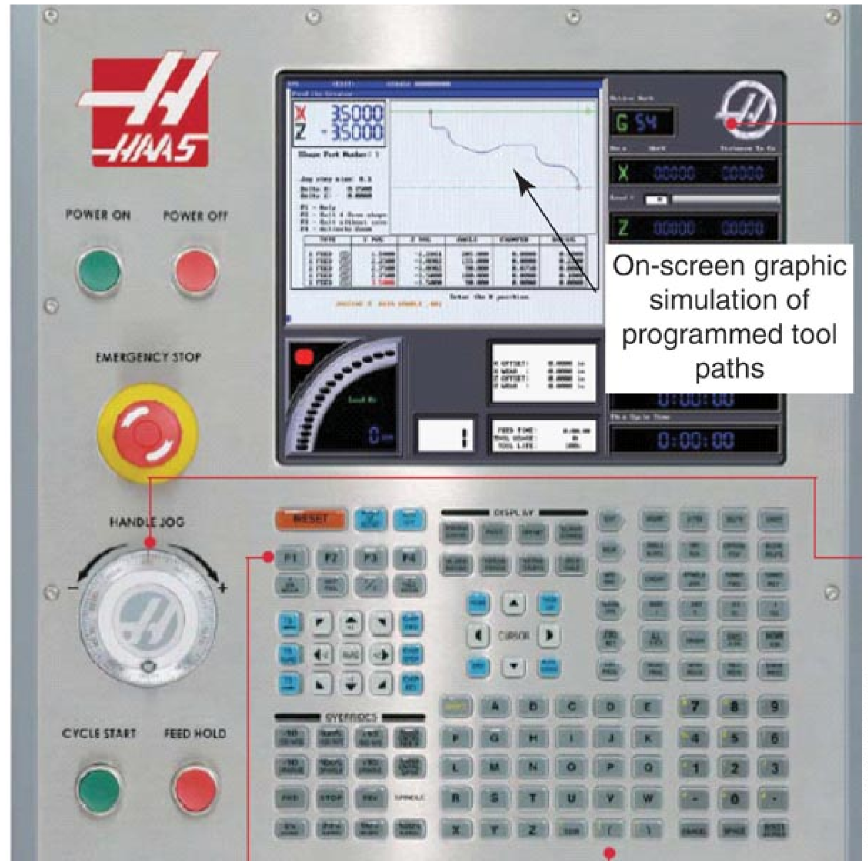


Program Entry for Turning

- Programs can be entered three ways:
  - Manually typing on shop floor
  - Uploaded to memory from PC or storage
  - Sent direct from PC as program runs
- Direct numerical control (DNC)
    - A/K/A drip feeding
  - Program fed from a PC to the control line by line

Turning Machine Operation

- Run program prove-out to identify mistakes
    - Graphic simulation, dry run, safe offset
  - Auto mode: running proven program without supervision



A graphic part simulation on a display screen.