# Αριθμητικός Έλεγχος Εργαλειομηχανών

## Ενότητα 13: CNC Lathe

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# COMPUTER NUMERICAL CONTROL OF MACHINE TOOLS

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# Objectives of section 13

- Describe the **difference** between a ***conventional lathe bed arrangement*** and a ***slant bed arrangement***, listing the advantages of the slant bed for NC
- Explain **axis movement** on a CNC lathe
- Describe the **method of toolholding** used on CNC turning machines
- Explain what a **tool offset** number is
- Describe two methods of **tool selection** used on CNC turning machines
- Describe how **spindle speed** is designated on gear head and variable speed lathes
- Explain how **feedrates** are specified on CNC turning equipment
- Define **TNR**

# Objectives of section 13

- Up to this point, the programming features of CNC mills have been discussed, but **numerical control** is used for **turning equipment** as well

- The **coding** will be a version used with **FANUC lathe controllers**, designed to be generic and so to illustrate the basic programming steps involved

- A numerical control lab in a school ***will have equipment that differs*** in one way or another from that presented here

- Students are advised to **familiarize themselves** with the codes used for the machines they will be using.

# Lathe Bed Design

- Older NC lathes, and those that have been converted to numerical control with retrofit units, look like traditional engine lathes. The ***lathe carriage rests on the ways***

- The ways are in the **same plane** and are **parallel** to the floor

- This arrangement allows the machinist to reach all the controls readily. Since the CNC lathe performs its operations **automatically**, this type of arrangement is not necessary.

- In fact, it is quite awkward since the operator will be busy with other responsibilities while the program is running and will ***not necessarily be there to brush the chips off the ways***.

- In a **conventional lathe bed** arrangement, the chips have nowhere to fall except on the ways. To overcome this problem, many CNC lathes make use of the **slant bed design**

# Lathe Bed Design

- On many NC lathes, the **turret tool post** is mounted on the opposite side of the saddle, compared to a conventional lathe, to take advantage of the **slant bed design**.
- The **slant bed** allows the chips to fall into the **chip pan** rather than on tools or bedways.
- Despite its odd appearance, the slant bed NC lathe ***functions just like a conventional lathe***

## Axis Movement

- The ***basic lathe has only two axes, X and Z***. Since the **Z** axis is always parallel to the spindle, **longitudinal** (carriage) travel is designated **Z**.
- The cross slide movement is **designated X**, since it is the primary axis perpendicular to **Z**. If it were possible to move the carriage up and down, that axis would be **Y**. There is, however, a potential **problem** with this arrangement.
- There appear to be **two Z axes**: ***the carriage movement and the tailstock movement.***

# Lathe Bed Design

FIGURE 1 Slant bed design

# Axis Movement

- To eliminate this problem, the ***tailstock is usually called the W axis*** on lathes with **programmable tailstocks**.

- **Programmable tailstocks**, which are **rear turret assemblies** on CNC equipment, are the third and sometimes fourth axes on more complex equipment.

- In such cases, the axes of the second saddle are usually designated **W** and **U**, with **W being saddle travel and U being cross slide travel**.

- There are some imported lathes on which the X-axis direction is **reversed**. The programmer must **determine** if such a situation exists **before** writing the lathe program

# Toolholders and Tool Changing

- Either a **rigid toolholder** or a **tool turret** is used to ***hold the tools*** on an NC lathe.

- When a **tool change is necessary**, the appropriate ***turret is indexed to the next tool*** needed.
- 
- Simple lathes use six-sided turrets; larger turning machines use eight-, ten-, and twelve-sided turrets.

- With the development of **robotics**, new tool changing and work handling schemes are appearing.

- To teach the basics of CNC programming, this text **will focus on nonrobotic tool change**.

# Toolholders and Tool Changing

- The **toolholders** used on NC turning machines are of very **rigid design**

- The tools used for turning are of the **carbide insert type**, made to much more exacting **tolerances** than conventional lathe insert tooling

- A tool change command in a turning program either ***changes the turret position*** or ***causes an automatic tool change***, depending on the type of machine used

# Toolholders and Tool Changing

## Automatic Tool Change

- In a CNC turning program for a machine with a **rigid toolholder**, **M06** is used to initiate an ***automatic tool change***. The **T** address is used (as it is in milling programs) to specify the desired tool. The T address also **calls up the tool offsets**. The format for automatic tool change is:

**M06Tn1 n2**

  - Where **M06** initiates the tool change,
  - **T** is the tool address,
  - **n1** is the tool number, and
  - **n2** is the tool offset number.

- Turret Position **T** is used in a similar manner with ***turret tool selection***. The format is:

**Tn1 n2**

  - Where the **first number** is the turret position and
  - the **second** is the tool offset number.

# Toolholders and Tool Changing

- Since one tool may be used in **several positions**, a turret position is used rather than a tool number. ***The turret position corresponds to the turret station number***.

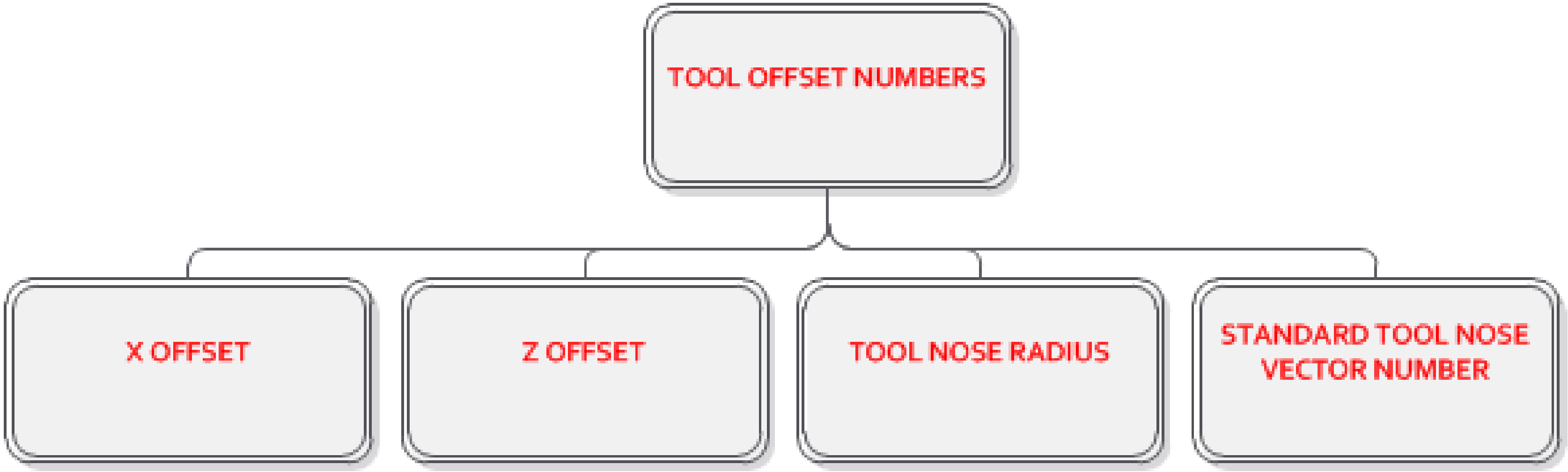
- **T01** will index the tool in **station one** into position.

- Some NC lathes can utilize more than one tool on a single station. It is possible, therefore, for **T0101** to refer to one tool and **T0111** to refer to another. This is referred to as ***piggybacking a tool station.***

- One other point should be kept in mind when changing tools**: the carriage (or tailstock) does not necessarily move to a tool change location**. It is often necessary, therefore, first to move the carriage or tailstock turret **out of the way** before making a tool change.

- It may also be necessary to program a dwell **(G04)** to **halt the program**, giving the tool time to index to ***position safely***

# Toolholders and Tool Changing



# Toolholders and Tool Changing

## Tool Nose Radius And Standard Tool Nose Vector Numbers

- The **tool nose radius** and **tool nose vector** numbers are optional. They are entered if using **cutter comp**
- Cutter diameter **compensation** is called ***tool nose radius compensation (TNR comp)*** on turning machines
- The **tool radius** tells the MCU the **amount of compensation** that is to be used. With NC machining centers this value was entered in a **comp register**
- **TNR comp** is utilized just as **cutter comp** was in section 10. It can be used to **program** the part line or **fine tune** the tool path to **compensate** for tool wear

# Toolholders and Tool Changing

- The **major difference** is that lathe tools are not completely **circular** as is a milling cutter

- To aid in proper **compensation** of the tool path and correctly identify alarm conditions, a **tool nose vector number** is entered in the register.

- **Tool nose vector numbers** tell the MCU the **orientation** of the tool nose.

- These directions are referred to as ***vectors***

- Each vector has a number associated with it that is **used to describe the tool orientation** to the MCU

# Toolholders and Tool Changing

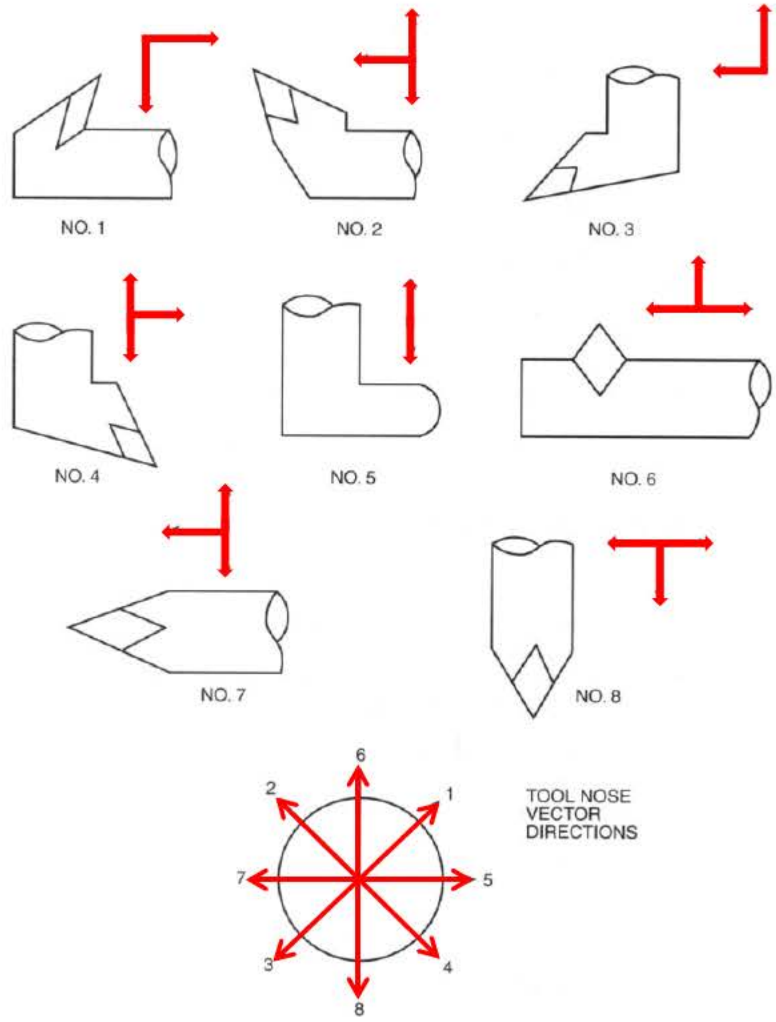



**FIGURE 2 Tool nose vectors**

- The **various directions** in which a tool may be **oriented**.

# Toolholders and Tool Changing

## Tool Edge versus Centerline Programming

- The **tool nose** may be programmed in one of two ways when **TNR comp** is not active:

  - by the **tool edge** or
  - by the **tool nose radius centerline**.

- Tool edge **programming** is adequate for **simple straight line cuts** where the part surfaces intersect each other at right angles.

- **Problems** are encountered, however, when ***angles and especially arcs*** are programmed this way

# Toolholders and Tool Changing

- If the tool edge is programmed, the **I** and **K centerpoints** of the illustrated arc must be **shifted**
- This results in a ***tool path that does not follow the desired arc*** exactly.
- The amount of error that is induced **depends on the size of the cutter** and the **radius of the arc**.
- In any case, tool edge programming **should not be used** when encountering **arcs** and **angles**
- Tool centerline programming is **identical** to the centerline programming done when **milling**

# Spindle Speeds

- **Spindle speed** is specified using an **S address**, just as in milling. On turning machines with a gear head design, the spindle speed is changed by shifting gears in the headstock
- On **gear head machinery**, there are usually **two or more** gear ranges
- An **M** function is used to select the gear range in which the desired speed is located
- **M40** through **M46** generally serve this purpose
- For **gear head** examples in this text:

  - **M40** will be used for low range
  - **M41** for mid range, and
  - **M42** for high range

# Spindle Speeds

- The following chart shows a sample of **speed ranges for gear head machines**. This chart is not for a particular machine but is **representative** of the type of **spindle speed spread** found on a machine

- Some CNC turning machines use a **variable speed drive** with which an **infinite number of speeds** are available between the highest and lowest speeds.

- In these cases, the speed is selected using the **S address** as it is in milling

| LOW RANGE | | | |
|---|---|---|---|
| 10 | 15 | 20 | 25 |
| 30 | 40 | 50 | 65 |
| 75 | 90 | 110 | 125 |

| MEDIUM RANGE | | | |
|---|---|---|---|
| 55 | 70 | 95 | 120 |
| 140 | 155 | 175 | 200 |
| 235 | 260 | 290 | 300 |

| HIGH RANGE | | | |
|---|---|---|---|
| 285 | 335 | 380 | 450 |
| 530 | 660 | 900 | 1200 |
| 1800 | 2100 | 2500 | 3000 |

- **Chart** shows a sample of **speed ranges** for gear head machines

# Feedrates

- With a CNC lathe, assigning **feedrates** is quite simple.

- A **G98** or **G94** code (depending on the controller) tells the MCU that the following feedrate is in inches per minute.

  - For example, **G98 F7** specifies a ***feedrate of 7 inches per minute***. A **G99** or **G95** in a turning program specifies a **feedrate in inches per revolution**.

  - For example, **G99 F.015** specifies a ***feedrate of .015 inch per revolution***

# Machine Origin and Work Coordinate Systems

- An NC lathe generally has a **fixed zero position** assumed by the executive program upon power-up. This position is known as the ***home zero*** or ***machine origin***.

- The physical location of this position **varies** from controller to controller and machine model to machine model.

- It is usually one of two locations: **X0 = centerline of the spindle**, **Z0 = the chuck mounting surface of the spindle**, or **X0 = extreme X + location**, **Z0 = extreme Z + location**.

- It is usually necessary to ***establish a zero point*** on the part different from the machine origin location. This position is called the ***work coordinate system or part zero***.

- There are two methods used to accomplish this.

# Machine Origin and Work Coordinate Systems

- The first method involves the use of an axis preset command—**G50**. The **G50 transfers** the zero point from the **home zero to the coordinates specified** with the command.

- The **format** for a **G50** command is:

G50 Xxx.xxxx  Zzz.zzzz

Where:

**G50** = the axis preset command

**xx.xxxx** = the X-axis distance to the part zero

**zz.zzzz** = the Z-axis distance to the part zero

# Machine Origin and Work Coordinate Systems

- A **G50** command is issued at the **start of each tool**. Since the programmer will not know the axis preset distances in advance, **zeros** should be used or some other prearranged value in the **G50** line.
  - The actual values will be ***determined by the setup person*** and edited in the control when the job is set up.

- The second method uses registers called ***work coordinates.*** These are registers in the MCU that tell the MCU the **distance** from **home zero to the part zero**.

- If a machine has more than one available work coordinate, **multiple zero points** may be used for complex programming.

- Another advantage to multiple work coordinates is the ***ability to have more than one program loaded*** in the MCU, each with its **own work coordinate**.

- This is a decided advantage when running several repeating jobs through a turning center.

# Machine Origin and Work Coordinate Systems

- Each **work coordinate** is called by a **G code**. If a program were to use four work coordinates, they would be selected by the codes **G54**, **G55**, **G56**, and **G57**.
- The first work coordinate (**G54** in this case) is the default work coordinate.
- This work coordinate is **automatically activated** upon power-up.
- If using only the default work coordinate, the **G code** may be omitted.
- The work coordinate values are **entered by the setup person** when the job is prepared.
- The programmer must **instruct** the setup personnel the position on the part of the ***part zero location***.

# Quicksetters

- A fairly recent development has been the use of ***quicksetters*—arms with tool sensors** on them.

- During job setup, the arm is lowered into position, the operator **jogs a tool** to the presetting position, and **touches it off on the sensor**.

- The **quicksetter** automatically ***sets the values of the work coordinate and the tool offset registers***

- ***Quicksetters*** can also measure the size of tools **before** cutting starts, and

- ***Check for tool damage or breakage*** during the machining operation.

# Summary

- CNC turning machines often use a **slant bed arrangement** to protect the machine ways from chips. Although different in appearance, the ***functioning of a slant bed and conventional bed machine is identical***
- There are ***two basic axes, X and Z***, on a CNC lathe. If the lathe has additional axes, they are generally designated **U** and **W**
- **TNR** stands for **tool nose radius** compensation. **TNR** is the **equivalent** in CNC turning to cutter diameter **compensation** in milling
- A **tool turret** or a rigid toolholder is used to **hold the tools** on an NC lathe
- **Tool offset** are entered into the MCU **prior** to running the program to **compensate** for minor setup adjustments
- A standard **tool nose vector number** is used to ***identify the orientation*** of a particular tool when using **TNR**

# Summary

- A **tool change command** in turning programs will either **change the turret position** or cause an automatic tool change, depending on the type of machine used

- The tool change format for turret changing is: **T n1 n2**

  Where **T** is the tool change command, **n1** is the turret position and **n2** is the tool offset

- The format for automatic tool change is : **M06 T n1 n2**

  Where **M06** initiates the tool change, **T** is the tool address, **n1** is the tool number, and **n2** is the tool **offset** number

- **Spindle speeds** are specified directly using the **S address**. On gear head machines, it is necessary ***to specify the gear range*** when selecting a range **outside** the active one.

- **Feedrates** on CNC lathes can be specified either in **inches per minute** (using **G94** or **G98**), or in **inches per revolution** (using **G95** or **G99**).

- To set a part at **X0/Z0** point, it is necessary to **transfer the machine origin** to the workpiece using a G code

# Vocabulary Introduced in this section

- Centerline programming
- Lathe bed
- Quicksetter
- Slant bed
- Tool edge programming
- Tool nose radius
- Tool nose vector number
- Tool offset numbers
- Tool turret
- Turret position

# End of Section

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