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Ενότητα 9: Two – Axis Programming

Δημήτρης Μούρτζης, Επίκουρος Καθηγητής
Πολυτεχνική Σχολή

Τμήμα Μηχανολόγων & Αεροναυπηγών Μηχανικών



COMPUTER NUMERICAL CONTROL OF MACHINE TOOLS

Laboratory for Manufacturing Systems and Automation
Department of Mechanical Engineering and Aeronautics
University of Patras, Greece



Dr. Dimitris Mourtzis
Assistant Professor

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Objectives of section 6

- Identify the **basic parts** of a CNC program
- Describe the **word address code** format
- Write simple **two-axis** programs in word address format to perform **hole** operations
- Write simple **two-axis milling** programs using the word address format
- Write simple **two-axis** programs that combine **milling and hole operations**



Introduction

- This section is concerned with **manual** programming of CNC machinery
- For purposes of continuity the **same machine** will be used for the next several sections
- No two CNC machines program exactly alike
- However, learning to program the machine used in the examples, only **minimal effort** will be required to program other CNC machines
- Programming is done in a format called **Word Address** which is the most common machine code format used today
- **The machine programmed in this section is a vertical machining center**



Introduction

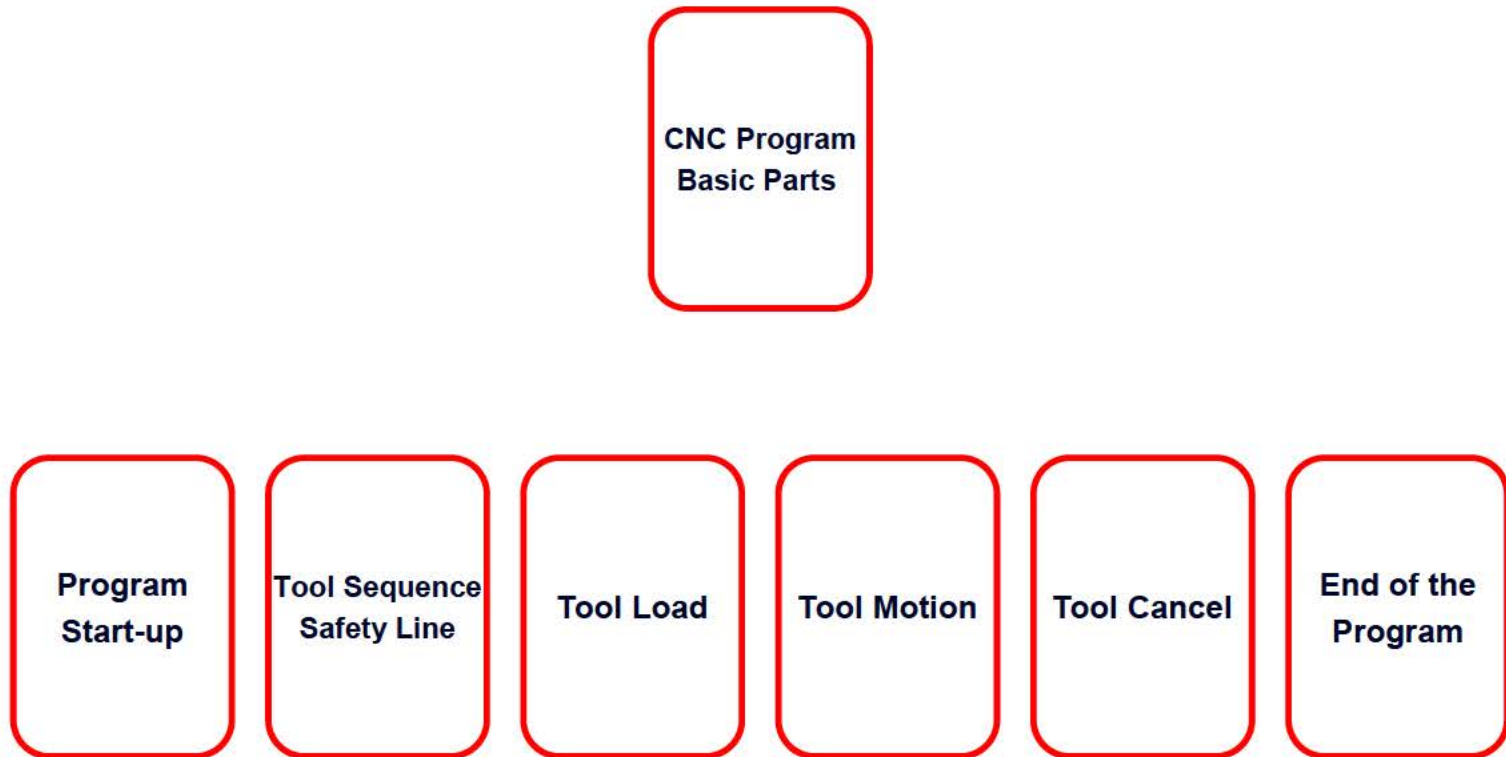
- The machining center is equipped with a **FANUC Machine Control Unit (MCU)**
- It is a **Continuous Path Type Machine**
- The program codes used on FANUC MCU are similar to those used on other MCUs such as **General Numeric and General Electric**
- **Two-Axis mill** programming is not so common in real world application but *in educational level is a prerequisite for easier understanding of Three-Axis programming*



Parts of a CNC Program

Parts of CNC Program

- Regardless the MCU being programmed all CNC programs consist of the same basic parts



Parts of a CNC Program

Program Startup

- The program **startup section** serves to **issue any commands required at the start** of the tape only
- For instance, setting the program to **inch mode** would only be required at the **beginning of the program**

Tool Safety Block

- The **tool sequence safety block(s)** serves to issue commands to **cancel for any machine modes** that could have been left active if the machine operator interrupted the tool cycle
- By **issuing a safety block**, the programmer and operator **know the state of the machine** at the beginning of the tool cycle



Parts of a CNC Program

Tool Load Blocks

- The tool load section are those blocks **of a tool sequence where the tool is placed in the spindle**, either manually or by the machine's automatic tool changing mechanism
- The **tool length compensation** is turned on

Tool Motion Blocks

- The tool motion section contains the code for the ***actual cutting tool motion***
- It is where all the machining work is actually done



Parts of a CNC Program

Tool Cancel Blocks

- The tool cancel section turns off the tool length compensation and ***returns the tool to the tool change position***
- All active cycle commands should be turned off in this section and the control left in a state ready to load the next tool

End of Tape Blocks

- The end of program blocks ***issue any commands necessary after all tool motion is complete***, but before the program terminates
- Often this section consists simply of the end of program code



Word Address Format

Word Address Characteristics:

- Word Address was developed as a **tape programming** format
- Word Address is also named Variable Block Format because the program **lines (blocks)** may vary in length according to the information contained in them
- Earlier tape formats required an entry for all possible machine registers
- In these earlier formats a zero was programmed as a null input if the register values were to be unaffected
- In Word Address **the blocks need only contain necessary information**
- Although Word Address was developed as a Tape Format is used as the format for **Manual Data Input (MDI)** on many CNC machines

Word Address Format

Addresses:

The block format for word address is as follows:

N...G...X...Y...Z...I...J...K...F...H...S...T...M...

- Only the information needed on a line need be given
- Each of the letters is called an address (or word)



Word Address Format

N - The block sequence number

- An **N** number is used to **number the lines of NC code** for operator and/or programmer reference
- **N** numbers are **ignored by the controller** during program execution
- Most NC controls **allow a block to be searched** for by the sequence number for **editing** or **viewing purposes**.

G - Initiates a preparatory function

- Preparatory functions **change the control mode** of the machine
- Examples of preparatory functions are **rapid / feedrate mode**, **drill mode**, **tapping mode**, **boring mode**, and **circular interpolation**
- Preparatory functions are called **prep functions** or more commonly **G Codes**

Word Address Format

X: Designates an **X-axis coordinate**.

X also is used to enter a time interval on FANUC and FANUC style controllers

Y: Designates a **Y-axis coordinate**

Z: Designates a **Z-axis coordinate**

I: Identifies the **X-axis arc vector** (the X-axis center point of an arc)

J: Identifies the **Y-axis arc vector** (the Y-axis center point of an arc)

K: Identifies the **Z-axis arc vector** (the Z-axis center point of an arc)

S: Sets the **spindle rpm**

H: Specifies the **tool length compensation** register

F: Assigns a **feedrate**

T: Specifies the **standby tool** (to be used in the next tool change)

M: Initiates **miscellaneous functions (M functions)**

● **M functions** control **auxiliary** functions such as :

- the turning on and off of the spindle and coolant,
- initiating tool changes, and
- signaling the end of a program

PREPARATORY FUNCTIONS (G CODES) USED IN MILLING

- Following is a list of preparatory functions used in CNC milling examples in this text. Other codes commonly used on General Numeric controllers are also listed.

G00-Rapid traverse positioning.

G01-Linear interpolation (feed rate movement).

G02-Circular interpolation clockwise.

G03-Circular interpolation counterclockwise.

G04-Dwell.

G10-Toollength offset value.

G17-Specifies X/Y plane.

G18-Specifies X/Z plane.

G19-Specifies Y/Z plane.

G20-Inch data input (on some systems).

G21-Metric data input (on some systems).

G22-Safety zone programming.

G23-Cross through safety zone.

G27-Reference point return check.

G28-Return to reference point.

G29-Return from reference point.

G30-Return to second reference point.

G40-Cutter diameter compensation cancel.

G41-Cutter diameter compensation left.

G42-Cutter diameter compensation right.

G43-Toollength compensation positive direction.

G44-Toollength compensation negative direction.

G45-Tool offset increase.

G46-Tool offset decrease.



PREPARATORY FUNCTIONS (G CODES) USED IN MILLING

G47-Tool offset double increase.

G48-Tool offset double decrease.

G49-Tool length compensation cancel.

G50-Scaling off.

G51-Scaling on.

G73-Peck drilling cycle.

G74-Counter tapping cycle.

G76-Fine boring cycle.

G80-Canned cycle cancel.

G81-Drilling cycle.

G82-Counter boring cycle.

G83-Peck drilling cycle.

G84-Tapping cycle.

G85-Boring cycle (feed return to reference level).

G86-Boring cycle (rapid return to reference level).

G87-Back boring cycle.

G88-Boring cycle (manual return).

G89-Boring cycle (dwell before feed return).

G90-Specifies absolute positioning.

G91-Specifies incremental positioning.

G92-Program absolute zero point.

G98-Return to initial level.

G99-Return to reference (R) level.



PREPARATORY FUNCTIONS (G CODES) USED IN TURNING

- Following is a list of preparatory functions used in CNC milling examples in this text. Other codes commonly used on FANUC controllers are also listed.

G00-Rapid traverse positioning.

G01-Linear interpolation (feedrate movement).

G02-Circular interpolation clockwise.

G03-Circular interpolation counterclockwise.

G04-Dwell.

G10-Tool length offset value setting.

G17-Specifies X/Y plane.

G18-Specifies X/Z plane.

G19-Specifies Y/Z plane.

G20-Inch data input (on some systems).

G21-Metric data input (on some systems).

G22-Stored stroke limit on.

G23-Stored stroke limit off.

G27-Reference point return check.

G28-Return to reference point.

G29-Return from reference point.

G30-Return to second reference point.

G40-Tool nose radius compensation cancel.

G41-Tool nose radius compensation left.

G42-Tool nose radius compensation right.

G50-Programming of work coordinate system.

G68-Mirror image for double turrets on.

G69-Mirror image for double turrets off.

G70-Inch programming (some systems) or finish cycle.

G71-Metric programming (some systems) or stock removal in turning code.

G72-Stock removal in facing code.

G73-Pattern repeat.

PREPARATORY FUNCTIONS (G CODES) USED IN TURNING

G74-Z axis peck drilling.

G75-Groove cutting cycle, X axis.

G76-Multipass thread cutting.

G90-Absolute positioning.

G91-Incremental positioning.

G94-Per minute feed (some systems).

G95-Per revolution feed (some systems).

G98-Per minute feed (some systems).

G99-Per revolution feed (some systems).



MISCELLANEOUS (M) FUNCTIONS USED IN MILLING AND TURNING

- Following is a list of miscellaneous functions used in the milling and turning examples in this text. Other M functions common to General Numeric and FANUC controllers are also listed.

M00-Program stop.

M01-Optional stop.

M02-End of program (rewind tape).

M03-Spindle start clockwise.

M04-Spindle start counterclockwise.

M05-Spindle stop.

M06-Tool change.

M08-Coolant on.

M09-Coolant off.

M13-Spindle on clockwise, coolant on (on some systems).

M14-Spindle on counterclockwise, coolant on.

M17-Spindle and coolant off (on some systems).

M19-Spindle orient and stop.

M21-Mirror image X axis.

M22-Mirror image Y axis.

M23-Mirror image off.

M30-End of program, memory reset.

M41-Low range.

M42-High range.

M48-Override cancel off.

M49-Override cancel on.

M98-Jump to subroutine.

M99-Return from subroutine.



Summary 1/3

The important concepts presented in this section are:

- An NC or CNC program consists of six basic parts
 - I. Program startup section
 - II. Tool sequence safety line
 - III. Tool load (or tool change) section
 - IV. Tool motion sequence
 - V. Tool cancel section
 - VI. End of program section
- In word address format, each CNC command is called a *word*. Each word begins with an alpha address which identifies the command's function
- The address is followed by a numeric value. Some values are used to set machine modes.
- Others are used to specify positioning coordinates



Summary 2/3

- The spindle must be positioned safely out of the way at the end of the program, to allow safe loading and unloading of the workpiece
- This is accomplished in both the milling and drilling examples by sending the spindle back to its tool change location at the end of the program
- Incremental programs differ from absolute programs only in the coordinates used
- Programs in absolute and incremental positioning use the same programming logic
- In incremental positioning, it is imperative that the machine start and stop in the same location
- Failure to program for this will result in incorrect positioning for the second cycle



Summary 3/3

- To perform hole operations, it is necessary to position the spindle over the centerline of the hole
- A program stop command is used at hole locations to halt the program and enable the operator to drill the hole
- When programming coordinates for milling, an allowance must be made for the size of the cutter



Vocabulary Introduced in this section

- Addresses
- End of tape blocks
- Leading zero
- Program startup blocks
- Tool cancel blocks
- Tool load blocks
- Tool motion blocks
- Tool safety blocks
- Trailing zero
- Two-axis programming



End of Section



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Reference Note

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