Introduction to CNC

Dr. J. M. Zhou

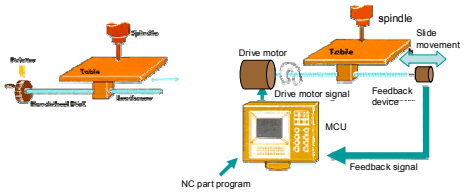
Avdelningen för mekanisk teknologi och verktygsmaskiner
Lund Tekniska Högskola

What is CNC?

- CNC means Computer Numerical Control.
- A form of programmable automation.
- Typical program containing coded alphanumeric data, such as

  G01 X120 Y200

The data represent relative positions between a cutting tool and a workpiece

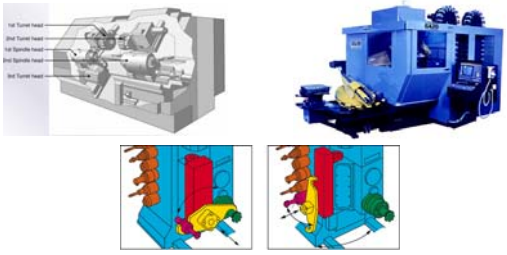


Why CNC machining?

- Improved automation
- Improve the quality and accuracy of manufactured parts
- Flexibility to manufacture complex or otherwise impossible jobs
- 2D and 3D contours
- Stabilize manufacturing costs

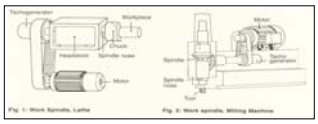
Typical CNC machine

Major component:
- Drivers unit
- Sliding system
- Machine control unit (MCU)

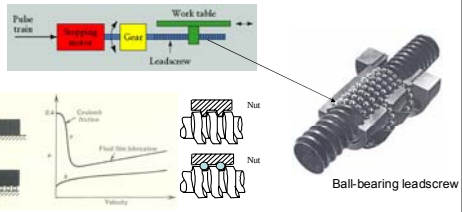


Drives of CNC machine tool

- Hydraulic actuator
  - high power machine tool
- Stepping motor
  - small machine due to limited power and torque
- DC motor
  - excellent speed regulation, high torque, most widely used



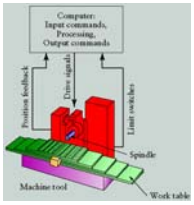
Ball-bearing leadscrew



Friction behavior versus velocity
(a) Sliding friction, conventional screw
(b) Rolling friction, ball-bearing screw

Control of CNC Machine Tool

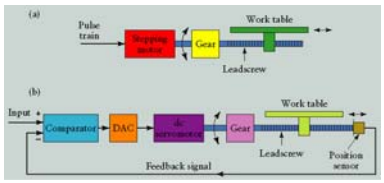
- Interpret a CNC program
- Produce coordinated pulses for multiple axes of motion
- Activate the series of commands in sequential order



Schematic illustration of the major components of a numerical control machine tool.

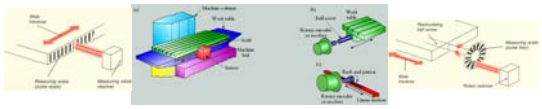
Two Basic Types of Control in CNC

- *Open loop system*
  - Operates without verifying that the actual position is equal to the specified position
  - Usually a stepping motor
- *Closed loop control system*
  - Uses feedback measurement to verify that the actual position is equal to the specified location
  - Servo motor with a feedback loop



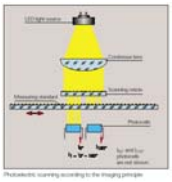
Measurement of linear displacement

- Direct measurement
  A measuring scale secured to the slide or machining table and measuring value resolver (encoder) pick up information optically from measuring scale and converts this into electrical signal.
- Indirect measurement
  The slide traverse is represented by rotation and a resolver records the rotational movement of a pulse disc. The control system calculates the slide traverse movement from rotation pulse.

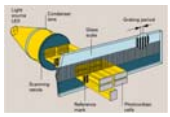


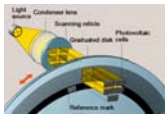
(a) Direct measurement of the linear displacement of a machine-tool worktable. (b) and (c) Indirect measurement methods.

Encoder operating principles



- LED light passes through a moving disc to produce an electronic output from a photodiode cell
- Encoders
  - Incremental encoder
  - Absolute encoder

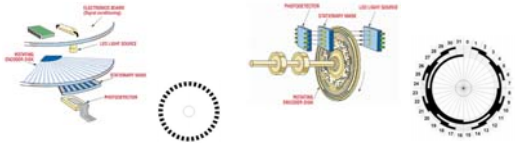




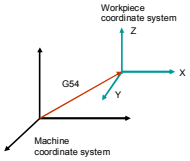
Incremental vs. absolute encoders

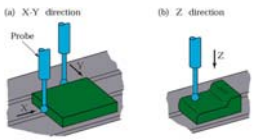
Incremental encoders
• The most common incremental provide a digital pulse for each resolvable position to be counted and referenced to a home position. These digital pulses are then fed into a high-speed counter module located in a drive or controller interface.

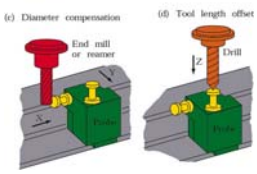
Absolute encoders
• Every position of an absolute device is unique, and these devices do not lose position when power is removed.



Touch Probes

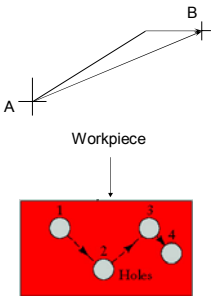






Touch probes used in machining centers for determining workpiece and tool positions and surfaces relative to the machine table or column. (a) Touch probe determining the X-Y (horizontal) position of a workpiece, (b) determining the height of a horizontal surface, (c) determining the planar position of the surface of a cutter (for instance, for cutter-diameter compensation), and (d) determining the length of a tool for tool-length offset. *Source:* Hitachi Seiki Co., Ltd.

Motion control - point to point control

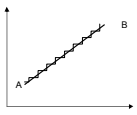


- Workpiece is moved to a programmed location with no regard for path taken to get to that location
- Once the move is completed, some processing action is accomplished by the cutting tool
  – Examples: drilling or punching a hole
- Moving at maximum rate from point to point.
- Accuracy of the destination is important but not the path

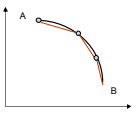
Motion control - continuous path (CP)

Continuous simultaneous control of more than one axis, thus controlling path followed by tool relative to part

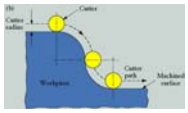
- Controls both the displacement and the velocity.
- Use linear and circular interpolators.
- Interpolator: Digital differential analyzers (DDA).



Linear interpolation

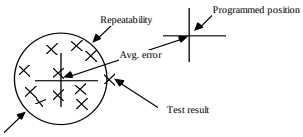


Circular interpolation



NC machine rating

- Accuracy
- Repeatability
- Spindle and axis motor horsepower
- Number of controlled axes
- Dimension of workspace
- Features of the machine and the controller.



NC Part Programming Techniques

1. Manual part programming
2. Computer-assisted part programming
3. CAD/CAM- assisted part programming

Common features:

– Points, lines, and surfaces of the workpart must be defined relative to NC axis system
– Movement of the cutting tool must be defined relative to these part features

NC Words

A G-code program consists the following words:

N, G, X, Y, Z, I, J, K, F, H, D, S, T, R, M

N - Sequence number (Used for line identification)
G - Preparatory function
X - X axis designation
Y - Y axis designation
Z - Z axis designation
R - Radius designation
F - Feedrate designation
S - Spindle speed designation
H - Tool length offset designation
D - Tool radius offset designation
T - Tool Designation
M - Miscellaneous function (See below)

NC Words – G codes

Preparatory functions: preparing MCU to perform a specific mode of operation
– Use G codes followed by two digits
– Interpolation is used, linear and circular
– Canned cycles

TABLE 6.2 **Some Common G Codes**

Code	*Function*
G00	Point-to-point positioning, high rate
G01	Linear interpolation, controlled feed rate
G02	Circular interpolation, clockwise
G03	Circular interpolation, counterclockwise
G04	Dwell for programmed duration
G17	Select $x-y$ plane
G18	Select $x-z$ plane
G19	Select $y-z$ plane
G70	Inch units
G71	Metric units
G90	Absolute dimensions
G91	Incremental dimensions

Example
N10 MSG("This is my first NC program")
N20 F200 S900 T1 D2 M3
N30 **G0** X100 Y100
N40 **G1** X150
N50 **G2** X150 Y120 I=AC(45) J=AC(35)
N60 X100
N70 Y100
N80 G0 X0 Y0
N90 M30

NC Words

Spindle control words

- ”S” word is used to specify the spindle speed
- M03: turn spindle on in clockwise
- M04 turns spindle on in counter clockwise
- M05 turn spindle off

Dimensional words

- X, Y, Z for primary motion direction in X, Y, Z

Feed words

- F Code. feed speed. mm/min (mmpm), or mmpr.

Automatic tool change

- ”T” word is used to tell the machine which tool station is to placed in the spindle.

NC Words – M Codes

M Code. miscellaneous word.

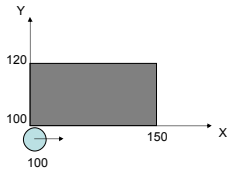
M0	Program stop
M01	Optional stop
M02	End of main program
M03	Spindle CW
M04	Spindle CCW
M05	Spindle stop
M06	Tool change
M07	Flood coolant on
M08	Mist coolant on
M09	Coolant off
M17	End of subprogram
M30	End of program

Example
N10 MSG(“This is my first NC program”)
N20 T1 D2 **M06**
N25 F200 S900 **M3 M07**
N30 G0 X100 Y100
N40 G1 X150
N50 Y120
N60 X100
N70 Y100
N80 G0 X0 Y0 **M05**
N90 **M30**

Manual Part Programming: Example

- Example block command for milling operation:

```
N10 MSG(“This is my first NC program”)
N15 G54
N20 F200 S900 T1 D2 M3
N30 G41 G0 X100 Y100
N40 G1 X150
N50 Y120
N60 X100
N70 Y100
N80 G40 G0 X0 Y0
N90 M30
```



- Complete part program consists of a sequence of such block commands

Summary

- Concept of CNC machine
- Basic components of CNC machine
- CNC control
- CNC programming