Introduction to CNC

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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 workplace

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

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 valve 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.

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),
  - (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).

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 - 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>
<thead>
<tr>
<th>Code</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>G00</td>
<td>Point-to-point positioning, high rate</td>
</tr>
<tr>
<td>G01</td>
<td>Linear interpolation, controlled feed rate</td>
</tr>
<tr>
<td>G02</td>
<td>Circular interpolation, clockwise</td>
</tr>
<tr>
<td>G03</td>
<td>Circular interpolation, counterclockwise</td>
</tr>
<tr>
<td>G04</td>
<td>Dwel for programmed duration</td>
</tr>
<tr>
<td>G17</td>
<td>Select 7 – 1 phase</td>
</tr>
<tr>
<td>G18</td>
<td>Select 7 – 2 phase</td>
</tr>
<tr>
<td>G19</td>
<td>Select 7 – 3 phase</td>
</tr>
<tr>
<td>G20</td>
<td>Inch units</td>
</tr>
<tr>
<td>G71</td>
<td>Metric units</td>
</tr>
<tr>
<td>G90</td>
<td>Absolute dimensions</td>
</tr>
<tr>
<td>G91</td>
<td>Incremental dimensions</td>
</tr>
</tbody>
</table>

NC Words Example:

N10 M05 (This is my first NC program)
N20 F20 M500 T1 D500 G80 X100 Y100
N30 G91 Q100 Z500 T2
N40 G01 X120 Y120 F500
N50 G02 X100 Y120 R20
N60 G03 X100 Y80 R20
N70 G01 X50 Y100
N80 G00 X100
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

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
  N25 G41 G0 X100 Y100
  N30 G1 X150 Y120
  N40 X100 Y100
  N45 G40 G0 X0 Y0
  N50 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