Ncstudio

PC-BASED NUMERIC CONTROLLER

PROGRAMMING MANUAL

Where there is motion control

there is WEIHONG

Thank you for choosing our products!

This manual will help you acquaint with our products and learn the information about programming command system.

This manual makes a detailed introduction to the thought of system software programming and the command system of programming, as well as to system software support of PLT, CAM, and DXF. Before using the products and relative machine equipment, carefully read this manual to have a better use of them.

Because of continuous update in hardware and software, it is possible that the software and the hardware you have received differ from the statement in this manual.

Company address, phone number and our website are listed here for your convenience. Any questions, please feel free to contact us. We will always be here and welcome you.

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1 New Functions

1) New command M802 P458752 is used for clearing the external offset. For detailed information please refer to chapter 4.4.

2) New command G921 is used for specifying the workpiece coordinates of current point in the current coordinate system. For detailed introduction please turn to chapter 4.3 “commands related to coordinate system and coordinates”.

3) New command G922 is used for setting the machine coordinate of the origin of the specified workpiece coordinate system. For detailed introduction please refer to chapter 4.3 “commands related to coordinate system and coordinates”.

4) New support for circle, bias and chessboard drilling cycle command (G34, G35, G36, and G37). For detailed introduction please refer to chapter 4.3 “special canned cycle”.

5) New rotation function commands G68/G69, for detailed introduction please refer to chapter 4.3 “G68/ G69 coordinate system rotation function commands”.

6) New mirror image function commands G50.1/G51.1, for detailed introduction please refer to chapter 4.3 “G50.1/ G51.1 mirror image function commands”.

7) New command G923 is used for direct tool offset setting, for detailed introduction please refer to chapter 4.3 “G923 directly set tool offset”.

8) Strengthened function for command G906 to test if the specified port is timeout. For detailed introduction please refer to chapter 4.4.

9) New command M903 is used for modifying the current tool number. For detailed introduction please refer to command M list in chapter 4.4.

10) Command G92 is taken as invalid command in the array machining, and should be deleted manually. For detailed introduction please refer to chapter 4.3, “commands related to coordinate system and coordinates”.

11) Refer to chapter 4.4 for new function of naming a subprogram.

12) Improvement of command G904: the usage of PLC address; keywords of PX, PY, PZ are compatible with PLC address and equal mark expression.

13) Improvement of M901 and G906: the usage of PLC address; new keywords “PLC” and “LEVEL”; and PLC keywords are compatible with [PLC address] and equal mark expression.

14) New command G992 allows the translation of coordinate system. For detailed introduction please refer to “G992 temporarily set WCS according to tool position” in chapter 4.3.

15) New command G28 is used for backing to the reference point. For detailed introduction please refer to chapter 4.3, “G28 auto back to reference position”.

16) New commands related with encoder. For details, refer to “G codes related with encoder” in chapter 4.3.

2 Summarization of CNC Programming

2.1 Summarization of CNC Programming

Definition of Machining File

Composed of a series of instructions written in a programming language which is specially used for CNC device, a machining file will be translated into motion actions to control the machine tool by CNC device. The most commonly used storage mediums are punched tape and disk.

Creation of Machining File

As shown in Fig. 2-1 below, a machining file can be created by traditional manual programming or CAD/CAM application (Such as the popular MasterCAM application).

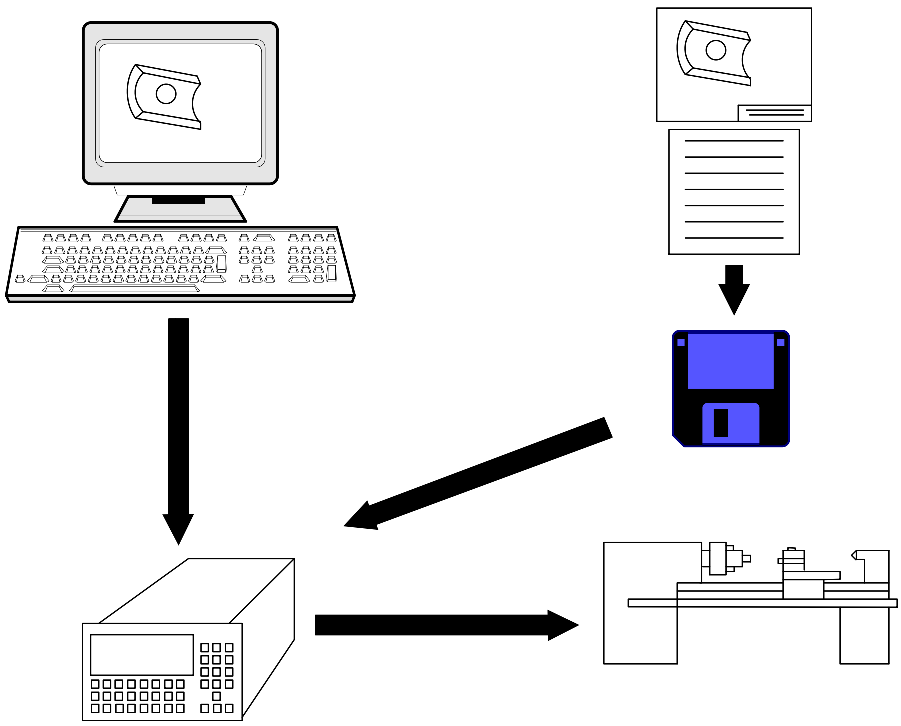


Fig. 2-1 Creation of a Machining File

2.2 Summarization of CNC Machine Tool

Machine Tool Coordinate Axes

To simplify programming and guarantee the generality of program, this manual has standardized the naming of coordinate axes and the direction of CNC machine tool. Linear feeding coordinate axes are denoted by X, Y and Z, which are normally referred as basic coordinate axes. The correlation of X, Y and Z axes follows “the Right Hand Rule”, as shown in Fig. 2-2. The thumb points in the +X direction, the index finger points in the +Y direction, and the middle finger points in the +Z direction.

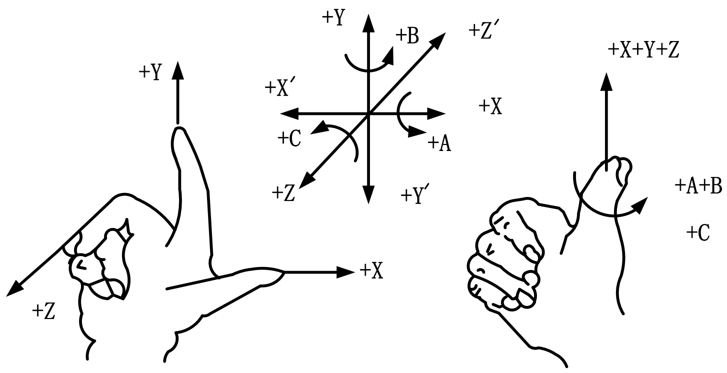


Fig. 2-2 Machine Tool Coordinate Axes

Circle feed coordinate axes swiveling around X, Y and Z are respectively denoted by A, B, and C. According to the Right Hand Screw Rule, the thumb points in +X, +Y and +Z direction, while the index and middle finger points in +A, +B, and +C direction of circle feed motion. The feed motion of CNC machine can be realized by spindle driving the tool or the worktable driving the workpiece. The positive directions of coordinate axes mentioned above are directions of tool feeding relative to the supposedly stationary workpiece. If the workpiece is kinetic, the coordinate axes are marked with “”. According to relative motion, the positive direction of workpiece movement is opposite to that of tool movement, that is:

+X =-X’, +Y =-Y’, +Z =-Z’

+A =-A’, +B =-B’, +C =-C’

Likewise, their negative directions are contrary to each other.

The directions of machine coordinate axes depend on the type of machine tool and the layout of each component. For a milling machine:

Z: Z-axis coincides with the main spindle axis, and the direction of tool moving away from workpiece is the positive direction (+Z);

X: X-axis is perpendicular to Z-axis and parallel to the clamped surface of workpiece. For a single column vertical mill, if the user faces the spindle and looks in the column direction, right moving direction is the positive direction of X-axis (+X);

Y: Y-axis, X-axis and Z-axis together constitute a coordinate system abiding by right hand rule.

Machine Origin (MO) and Machine Reference Point (REFER) of Machine Coordinate System (MCS)

MCS is the intrinsic coordinate system of machine tool. Known as machine origin or machine zero point, or home position, the origin of MCS is confirmed and fixed after designing, manufacturing and tuning of machine. The CNC device doesn't know where machine origin is when power on, and the mechanical stroke of each coordinate axis is limited by maximum and minimum limit switch. To correctly set MCS at machining, we normally set a machine REFER point (the initial point of measurement) within the stroke range of each coordinate axis. After starting the machine, it is necessary to back to REFER point manually or automatically so as to create the MCS. The REFER point can coincide with MO or not. If not, the distance from machine REFER point to MO can be set by parameter setting. After the machine returns to the REFER point, the machine origin, which is the reference point of all coordinate axes, is confirmed, so the MCS is established. The stroke of MCS is defined by the machine tool manufacturer, while the valid stroke of MCS is defined by software limit. The relationship between machine origin (OM), machine REFER point (Om), the mechanical stroke and valid stroke of MCS is as shown in Fig. 2-3.

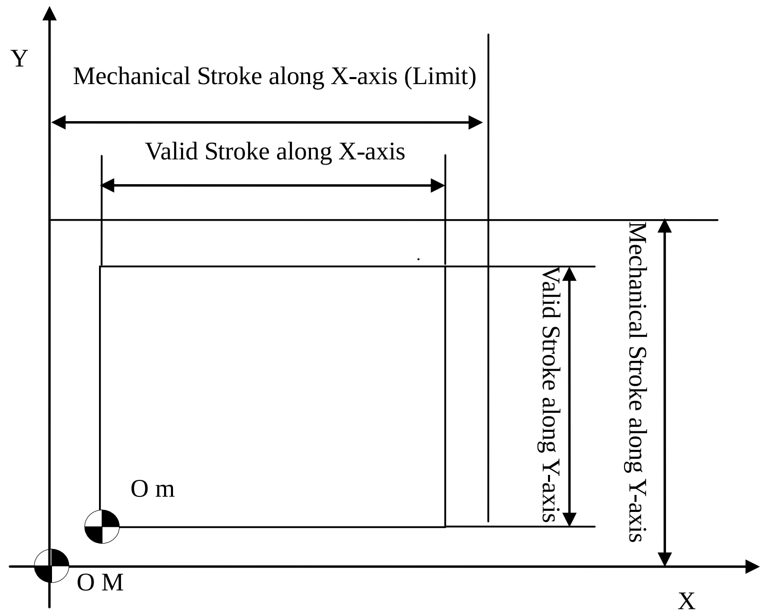


Fig. 2-3 Machine Origin OM and Machine REFER Om

3 Structure of Machining File

A machining file is a group of instructions and data transmitted to the CNC device, and it is composed of program blocks which follow a certain structure, syntax and format rule, while each program block is composed of command words. See Fig. 3-1.

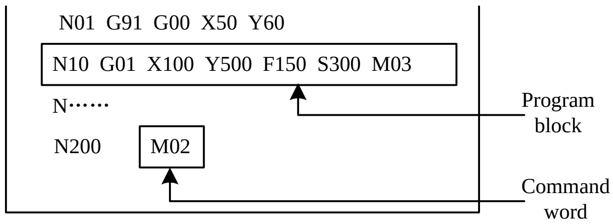


Fig. 3-1 Program Structure

3.1 Address Symbols and Functions

Address symbols and definitions are as shown in Form 3-1.

Form 3-1 Address Symbols

Address Symbol	Description	B: Basic Function O: Optional Function
D	Cutter radius offset number	B, O
F	Feedrate function	B
G	Preparatory commands	B, O
H	Tool length offset	B
I	Arc center modifier for X axis	B, O
J	Arc center modifier for Y axis	B, O
K	Arc center modifier for Z axis	B
L	Repetition count	B, O
M	Miscellaneous function	B
N	Sequence no. or block no.	B
O	Program no.	B
P	Dwell time in milliseconds, subprogram no. call, custom macro no. call, block number in main program when used with M99	O, B
Q	Depth of peck in fixed cycles G73 and G83 Shift amount in fixed cycle G76 and G87	O
R	Retract point in fixed cycles	O, B

Address Symbol	Description	B: Basic Function O: Optional Function
	Arc radius designation	
S	Spindle speed in r/min	B
T	Tool function	B
X	X axis coordinate value designation	B
Y	Y axis coordinate value designation	B
Z	Z axis coordinate value designation	B

3.2 Format of Program Block

A program block defines a line of instructions to be executed by CNC device. The format of program block defines the syntax of function word in each program block, as shown in Fig. 3-2.

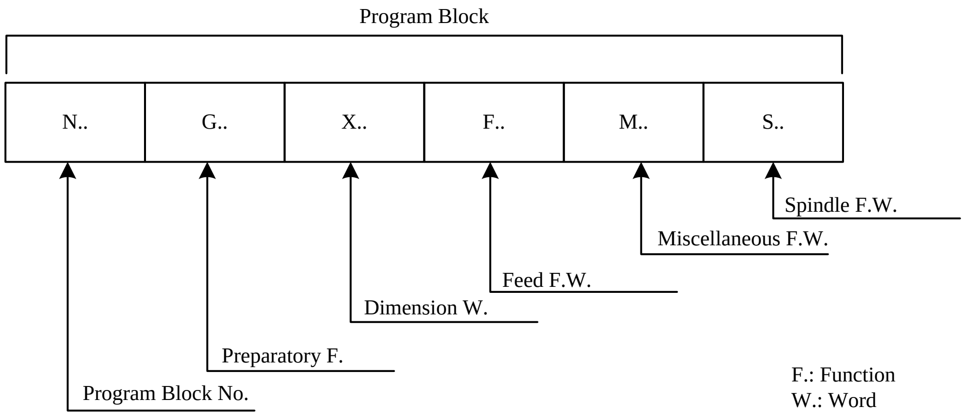


Fig. 3-2 Format of Program Block

3.3 Format of Subprogram

A subprogram is a section of machining codes which can be called repeatedly. It must begin with the address word O and subprogram no. as the first line and end with M17 as the last line. On principle, commands like M30 and M17 are not allowed to appear among the subprogram, but nested subprogram is acceptable.

4 Programming Instruction System

4.1 Spindle Function (S), Feed Function (F) &Tool Function (T)

Spindle Function S

Command Format: S_

Description:

S command is used to control the spindle speed. Its subsequent numerical value denotes the rotate speed of spindle in rpm.

S is a modal command, and S function is valid only when the spindle speed is adjustable. When one S command is specified, it will be valid until the next S command is specified.

Note: even though the spindle is off, the value of S remains.

Feed Speed (Feedrate) F

Command Format: F_

Description:

Command F indicates the synthetic feed speed of tool relative to the workpiece being machined. Its unit is mm/min.

With the help of feedrate override switch on the operation panel, F can be adjusted between feedrate percent 0% -120%.

F functions differently with different commands:

- G00 command, specifying the rapid traverse speed, modal for the current machining procedure.
- G01~G03 command, specifying the feed speed, modal for the current machining procedure.

Tool Function (T Feature)

Command Format: T_

Description:

T is used for selecting a tool; the subsequent value denotes the tool no. selected, and the relationship between T code and a tool is stipulated by machine tool manufacturer.

When a machining center runs T code, tool magazine will rotate to select the required tool, and wait until command M06 comes into effect to finish automatic tool change.

T command calls in tool compensation value (including length and radius) from the tool compensation register. Although T command is a non-modal instruction, the value of tool compensation invoked is effective until a new value is invoked for the next tool change.

4.2 Miscellaneous Function M Code

Miscellaneous function is composed of address word M and its subsequent number of one to three digits. It is mainly used to control the running of machining file and on/off of machine miscellaneous functions.

M function has non-modal and modal forms:

- Non-modal M function: it is effective only in the program block containing it.
- Modal M function: a group of M functions that can be mutually cancelled; an M function remains in effect until another M function in the same group appears to cancel it.

Form 4-1 Miscellaneous Function M Code

M Code	Meaning	M Code	Meaning
M00	Compulsory program stop	M11	Spindle unclamp
M01	Optional program stop	M17	Subprogram return
M02	End of the program	M30	End of program, and return to program top
M03	Spindle on (CW rotation)	M98	Subprogram call
M04	Spindle on (CCW rotation)	M99	End of subprogram, and return to the beginning of main program for continuous execution
M05	Spindle stop	M801	String info transmission between modules
M06	Automatic tool change (ATC)	M802	Integer info transmission between modules
M08	Coolant on	M901	Directly control output port
M09	Coolant off	M902	Directly set REF.
M10	Spindle clamp	M903	Change current tool no.

4.3 Preparatory Function G Code

Preparatory function G code is composed of address word G and its subsequent 1-3 digits. It is used to specify machining operations, such as the moving track of tool relative to workpiece, machine coordinate system, coordinate plane, tool compensation, coordinate offset, subprogram call, dwell, and so on.

G function has two forms, which are non-modal and modal G function:

- Non-modal G function: only effective in the specified program block, and cancelled at the end of program block.

- Modal G function: a group of G functions that can be cancelled mutually; a G function remains in effect until another G function in the same group appears to cancel it.

Commands Related to Coordinate System and Coordinates

G90 Absolute Programming and G91 Incremental Programming

Command Format: G90/G91

Description:

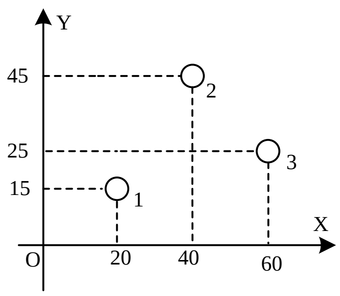
G90: it denotes absolute programming; the programming value on each programming coordinate axis is with respect to the origin of current WCS.

G91: it denotes incremental programming; the programming value on each programming coordinate axis is with respect to the previous position, and the value equals the distance that the tool moves in each axis.

G90, as the default, and G91 are modal functions and can be mutually cancelled. They cannot be used in the same program block. For example, G90 G91 G0 X10 is unallowable.

Programming Example:

As shown in Fig. 4-1 below, programming with G90, G91: the tool moves in sequence from origin to point 1, 2, and 3.



G90 programming

N	X	Y
N01	X20	Y15
N02	X40	Y45
N03	X60	Y25

G91 programming

N	X	Y
N01	X20	Y15
N02	X20	Y30
N03	X20	Y-20

Fig. 4-1 G90/G91 Programming

Selecting the right mode can simplify the programming. If the drawing dimension is given based on a fixed datum, it is better to adopt absolute programming mode; if the drawing dimension is given on the basis of space distance between contour apexes, it is better to adopt incremental programming mode.

G92 Set WCS according to Tool Position

Command Format: G92 X_Y_Z_

Description:

X_Y_Z_: the directed distance between origin of WCS and the beginning point of tool, i.e. the workpiece coordinates of the beginning point of current tool

A program is compiled based on WCS and begins with the cutter beginning point; before machining, the WCS should be learnt by the CNC system so as to link up the WCS with the MCS by setting the coordinates of cutter beginning point in the MCS.

G92 command can set the REFER point; it can also create a WCS by setting the relative position of tool beginning point (tool measurement point) to origin of WCS to be created. Once the WCS is established, the value of the command in absolute programming is the coordinate value in the WCS.

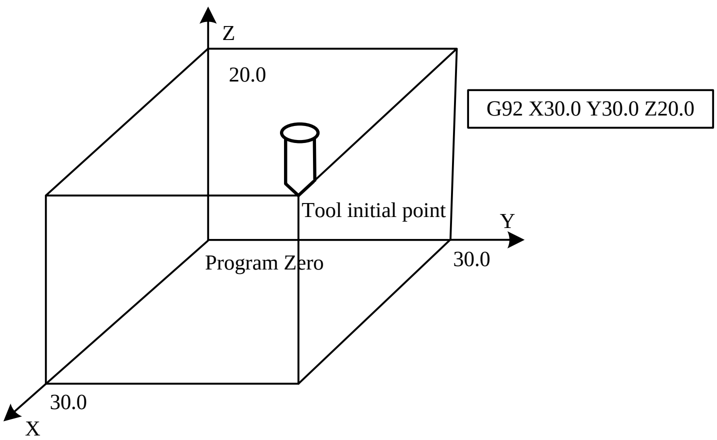


Fig. 4-2 Creation of Workpiece Coordinate System

Programming Example:

Programming with G92 command to create a WCS is as shown in Fig. 4-2.

The execution of the program block only creates a WCS without cutter movement. As a non-modal command, G92 is usually put in the first block of machining file to create a WCS and synchronously offset origins of other WCSs, which can be used to adjust the length of cutter holder.

- **G921 Specify Work Coordinate Value of Current Point**

Command Format: G921 X_Y_Z_

Description:

X_Y_Z_: workpiece coordinates of the current point

G921 is used to set workpiece coordinates of current point in the current WCS; unlisted axes will not be modified; this setting has effect only on the current WCS.

G921 command can be used for measuring workpiece surface, center or boundary.

- **G922 Specify the Machine Coordinates of WCS Origin**

Command Format: G922 X_Y_Z_P_

Description:

X_Y_Z_: offset values

P_: specifying offset type. -4: external offset; -1: current WCS (default); 0~5: corresponding to G54~G59

G922 sets the coordinate value of the specified offset, without changing unlisted axes' offset.

G922 command can be used for measuring workpiece surface, center or boundary.

G28 Auto Back to Reference Position

Command Format: G28 X_Y_Z_

Description:

X_Y_Z_: coordinates of the middle position (Workpiece Coordinates)

A machine tool returns to REFER point (machine origin) through the middle point, as shown in Fig. 4-3.

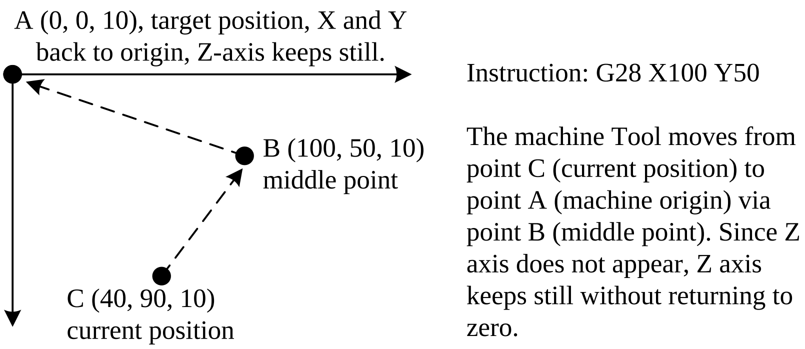


Fig. 4-3 Back to Reference Position

G992 Temporarily Set WCS according to Tool Position

Command Format: G992 X_Y_Z_ /I_J_K_

Description:

The function of this command is similar to G92 command. Their difference is: G92 command alters the WCS permanently and takes the same standard to the whole system, while G992 command alters the WCS temporarily and only influences the coordinate parsing of processing instruction, which will be restored automatically at the end of machining.

The command can be used for implementing array function. The steps are as shown below.

Method one:

```
G992 X_Y_Z_
1. Delete M30 command in the processing file.
2. Adding the following contents at the beginning of the processing file:
        #1=30       ’X offset value
        #2=40       ’Y offset value
        #3=30   ’machining quantity along X axis
        #4=30   ’machining quantity along Y axis
        G65 P3455 L=#4
        G00 G90 X=-#1*#3 Y=-#2*#4
        G992 X0 Y0
        M30
        O3455
        G65 P3456 L=#3
        G00 G90 X=-#1*#3 Y=#2
        G906
```

```
        G992 X0 Y0
        M17
        O3456
3. Add the following contents at the end of the processing file:
        G00 G90 X=#1
        G906
        G992 X0
        M17
```

Method two:

```
G992 I_J_K
1. Delete M30 command in the processing file.
2. Add the following contents at the beginning of the processing file:
        #1=30       'X offset value
        #2=40       'Y offset value
        #3=30   'machining quantity along X axis
        #4=30   'machining quantity along Y axis
        G65 P3455 L=#4
        G00 G90 X=-#1*#3 Y=-#2*#4
        G992 I=-#1*#3 J=-#2*#4
        M30
        O3455
        G65 P3456 L=#3
        G00 G90 X=-#1*#3 Y=#2
        G906
        G992 I=-#1*#3 J=#2
        M17
        O3456
3. Add the following contents at the end of the processing file:
        G00 G90 X=#1
        G906
        G992 I=#1
        M17
```

Both the above two programs can realize the related array machining. The first 4 parameters can be adjusted and customized.

Note:

G992 X_Y_Z_ sets the current point as a specified point in the new coordinate system.

G992 I_J_K_ translates the original coordinate system a specified distance to form into a new coordinate system. Comparatively speaking, G992 I_J_K_ is more efficient because it avoids the redundant rapid traverse instruction produced by origin offset, while G992 X_Y_Z_ sets an origin after backing to the original origin. During array machining, G92 command should be deleted manually because it is not supported by the system.

- **G54~G59 WCS Selection**

  Command Format: G54/G55/G56/G57/G58/G59

  Description:

G54~G59 are 6 WCSs prepared by the system (as shown in Fig. 4-4). Any one of them can be selected.

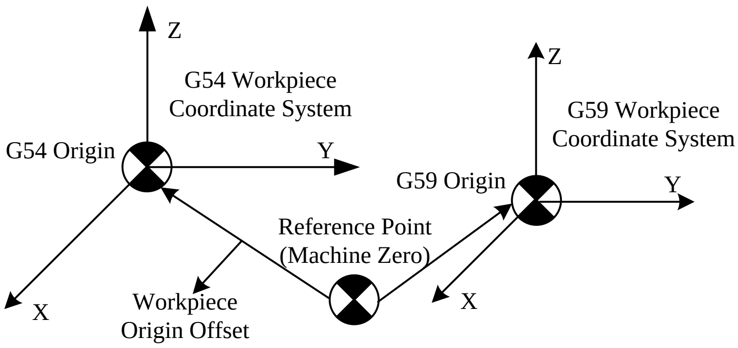


Fig. 4-4 Workpiece Coordinate System Selection (G54~G59)

The origin value of these 6 WCSs in the MCS (offset value of workpiece origin) can be set in the [Param] setting interface. The setting value will be saved automatically by the controller.

Note:

Once a WCS is confirmed, the following instruction values in absolute programming are all relative to the origin of WCS.

G54~G59 are modal functions, which can be mutually cancelled. G54 is the default.

Programming Example:

As shown in Fig. 4-5, programming based on WCS to make the tool move from current point to point A, and then to point B.

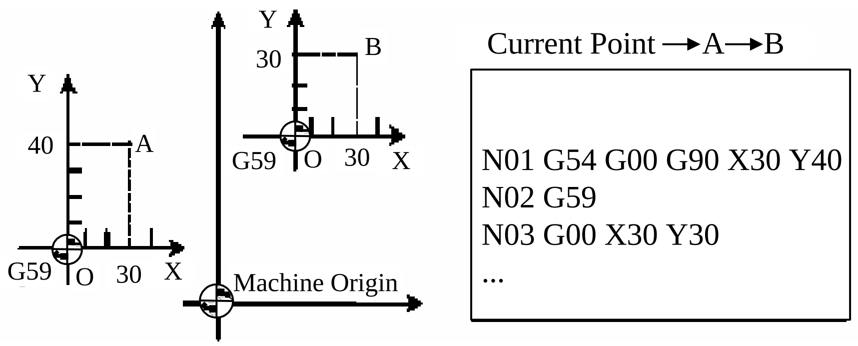


Fig. 4-5 Programming Based on Workpiece Coordinate System

Set the coordinate value of each WCS origin in the MCS before using this group of instructions.

- **G53 Machine Coordinate System**

  Command Format: G53

  Description:

G53: using MCS and disabling zero offset of WCS. It is a non-modal instruction which is only valid in the current program block.

- **G17, G18, G19 Coordinate Plane Selection**

Command format: G17/G18/G19

Description:

G17: XY plane selection

G18: ZX plane selection

G19: YZ plane selection

This group of instructions is used to select the plane to perform circular interpolation and cutter radius compensation.

G17 (default), G18 and G19 are modal functions (as shown in Fig. 4-6), which can be mutually cancelled.

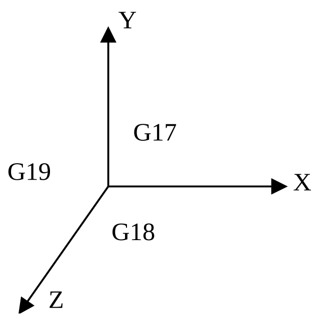


Fig. 4-6 Coordinate Plane Selection

- **G20/G21 OR G70/G71 Inch/Metric Command**

Command format: G20/G21/G70/G71

Description:

G20/70: inch

G21/71: metric

This group of G codes is defined at the beginning of the program block. If one of them is specified, the units of all subsequent operations will be changed. If not specified, the default unit is metric.

- **G50/G51 Scaling Function**

Command Format: G51 X_Y_Z_P_ (I_J_K_)

Description:

X_Y_Z_: the center of scaling. The omitted coordinate axes will inherit the original scaling and remain the same.

I_J_K_: the scaling of X, Y and Z axes

P_: the scaling of all listed axes. Either P_ or I_J_K_ can appear in a program block.

Workpiece contour that is compiled in the machining file can be reduced or enlarged to scale.

G51 is scaling on, while G50 is scaling off (Default: G50).

The range of scaling: 0.000001-99.999999

For example:

I0.666666 denotes that X is scaled down to 0.666666 times of the original dimension, while J3 denotes that Y is scaled up to 3 times of the original dimension.

When using the scaling command, pay attention to the followings:

- Don't set the scale factor as 0, or else an alarm will appear.
- Scaling function has no effect on compensation value.
- When executing cutter radius compensation C, the scaling instruction (G51) can't be specified.
- A canned cycle cannot be executed together with the scaling of Z-axis. If so, an alarm will appear.
- These G codes cannot be used in the execution process of scaling function: G28, G29, G53, and G92, or else the outcome may contain an error.
- If there is G51 in the program without G50, the scaling function will be automatically closed at the end of the program.

Programming Example:

```
N01 G00 X50.0 Y50.0 ’rapid positioning
N02 G51 X100.0 Y80.0 P0.5 ’specifying X100, Y80 as the scaling center, and 0.5 as scale value
N03 G01 Y150.0 F1000 ’linear cutting with feed rate as 1000mm/min
N04 X175.0 Y50.0
N05 G90 X50.0
N06 G50 ’scaling function off
N07 G00 X0.0 Y0.0 ’returning rapidly
N08 M30 ’end of the program
```

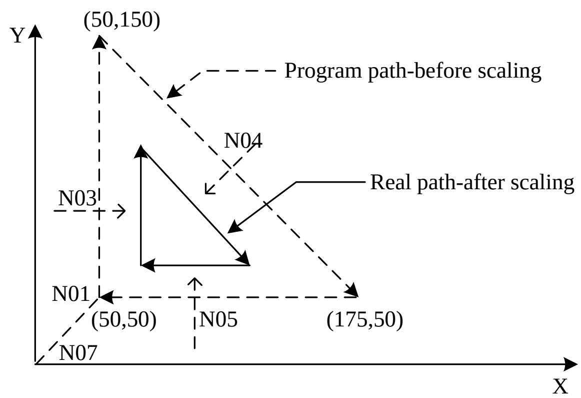


Fig. 4-7 Sketch Map of Scaling Function

G68/G69 Coordinate System Rotation Function

Command Format:

G68 X_Y_Z_R_

G69

Description:

X_Y_Z_: the center of rotation

R_: rotation angle in degree. Negative value is clockwise while positive value counterclockwise.

The instruction can be used for rotary contour machining by making the selected machining contour rotates degrees specified by R around the center in the specified plane. G68 is rotation on, while G69 rotation off.

Meaning of R: put a watch on the current plane, and let the watch surface towards the positive direction of the third axis; positive means counterclockwise rotation, while negative clockwise rotation.

In the process of rotation, coordinate of the third axis perpendicular to the current plane is constant. Respectively, swiveling in XY plane, the coordinate of Z-axis keeps still; swiveling in YZ plane, the coordinate of X-axis keeps still; and swiveling in ZX plane, the coordinate of Y-axis keeps still.

For example:

```
G17G90 X0Y0Z0
G65P9999L1
G68 X0Y0R-90 'rotating 90 degrees clockwise around the center of (0, 0)
G65P9999L1
G69 'rotation off
M30

O9999 'machining a rectangle
G91 G1X100
Y50
X-100
Y-50
G90
M17
```

The actual outcome is as shown in Fig. 4-8:

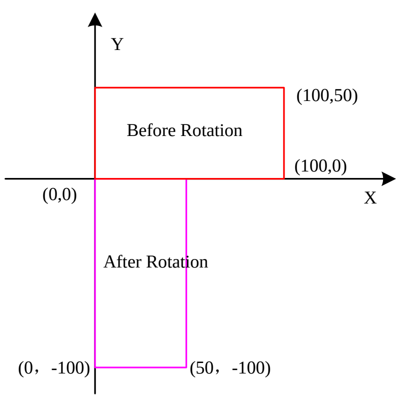


Fig. 4-8 Sketch Map of Rotation Processing

The instruction can be nested:

```
G68 X_Y_Z_R_          ’………A
…
G68 X_Y_Z_R_          ’………B
…
G68 X_Y_Z_R_          ’………C
…
G69          ’………C’
G69          ’………B’
G69          ’………A’
```

Rotation that appears earlier will influence the following rotation instruction. The subsequent rotation center is not the one in the machining file, but the position after transformation due to the previous rotation.

The function of G69 is to cancel the previous rotation command. In the above-mentioned program, line C’ cancels the G68 of line C, line B’ the G68 of line B, and line A’ the G68 of line A. If G69 not used, all rotation commands will be automatically cancelled at the end of current machining.

The following example contains the nesting of rotation command and scaling command.

```
G90 G0 x0 y0 z0
G91G65 P9999 L1
G65 P9998 L10
M30

O9999
G1 x200
y-100
x-200
y100
M17

O9998
G68 x50 y50 R45
G65 P9999 L1
G51 x50 y50 p0.5
G65 P9999 L1
M17
```

The outcome is as shown in Fig. 4-9.

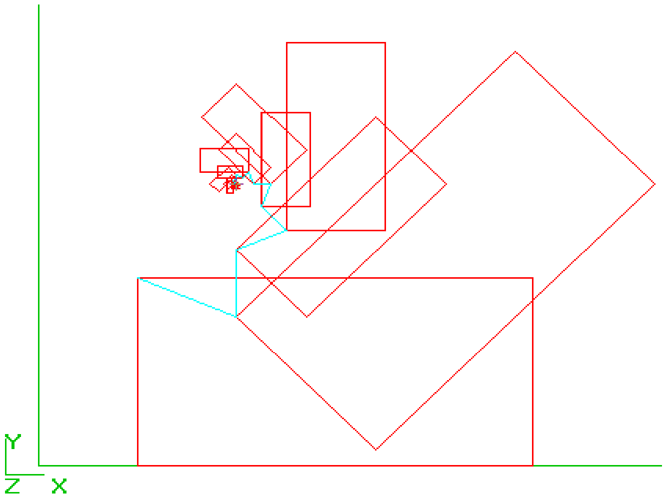


Fig. 4-9 Processing Outcome after Rotation

- **G50.1/G51.1 Mirror Image Function**

Command Format:

G51.1 X_Y_Z_

G50.1 X_Y_Z_

Description:

X_Y_Z_: For G51.1, specifying mirror image center; for G50.1, specifying the invalid axes of mirror image function.

The instruction indicates machining the mirror image of machining contour. G51.1 denotes mirror image on and G50.1 off.

For G51.1, the center of mirror image can be a line, or a point. For example, G51.1 X10 specifies the mirror image of the contour relative to the line X=10, while G51.1 X10 Y10 Z10 specifies the mirror image of the contour relative to the point (10, 10, 10).

For G50.1, X_Y_Z_ is used to specify the invalid axes of mirror image function. For example, G50.1 X0 closes the mirror image function of X-axis, and G50.1 Y0 Z0 closes the mirror image functions of Y-axis and Z-axis. If X, Y and Z axes are all specified or no one is specified, it denotes the mirror image functions of all the axes are closed.

Feed Control Commands

- **G00 Rapid Positioning**

Command Format: G0 X_Y_Z_

Description:

G00: rapidly positioning the tool, but not causing any machining to the workpiece. It can simultaneously perform rapid movement in several axes to produce a linear track. In the process of instruction analysis, if there is motion in Z-axis, the motion can be resolved into Z-axis motion and plane motion to ensure safe movement. For Z-axis upward motion, Z axis motion is before plane motion, otherwise, plane motion first.

The machine data specifies the maximum rapid moving speed of each coordinate axis; a coordinate axis will run at this speed in rapid traverse. If rapid movement simultaneously performs on two axes, the speed will be the maximum possible speed of two axes.

The rapid moving speed in G00 command for each axis is set by the machine parameter “rapid feed speed”, or specified by F_, which is modal in a job program.

G00 is available until replaced by other commands in the group of G function (G01, G02, G03…).

Programming Example:

```
N10 G90 G00 X30 Y30 Z40
```

- **G01 Linear Interpolation**

Command Format: G1 X_Y_Z_

Description:

G01 provides linear motion from point-to-point at appointed speed, i.e. the tool moves along a line from the beginning point to the target point; all coordinate axes can move simultaneously. G01 is available until replaced by other command in the group of G function (G00, G02, G03…).

Programming Example:

```
N05 G00 G90 X40 Y48 Z2 S500 M03
’tool rapidly moves to X40, Y48, Z2, and the spindle rotates CW at 500 rpm
N10 G01 Z-12 F100    ’tool goes to Z-12, with feed rate as 100 mm/min
N15 X20 Y18 Z-10     ’tool moves to P2 along a line
N20 G00 Z100     ’rapid movement
N25 X-20 Y80
N30 M02      ’end of the program
```

- **G02, G03 Circular Interpolation**

Command Format: G02/G03 X_Y_Z_R_ (I_J_K_) F_

Description:

The commands are used to move a tool along a circular arc to the specified position at appointed feed speed. G02 specifies clockwise interpolation, while G03 counterclockwise interpolation.

In a program block, a circular arc path can pass across over two quadrants, or be programmed into a complete circle.

G02 and G03 are available until replaced by other commands in the group of G function (G00, G01 …).

Circular arc programming can be radius programming or centre programming. The function word of radius is R. There are two types of arcs under the same start point, end point, radius and rotary direction. When R is negative, a circular arc is larger than a semicircle (i.e. a major arc); when positive, a circular arc is smaller than or equal to a semicircle (i.e. a semicircle or a minor arc). When the value of R is smaller than half of the distance between start point and end point of arc, a half circle (or a 180-degree arc) will be formed, with half of the distance between the start point and end point as the radius. Circle center is specified by the function words I, J, K in center programming. When I, J, K incremental mode is true, the coordinates of circle center is relative to the start point of the circular arc, otherwise, relative to the coordinates of workpiece origin. (If the coordinates of circle center is marked on a drawing, begin programming directly without calculation). X-Y plane is the default plane in circular programming, or you can specify a circular interpolation plane via G17, G18 or G19.

Helical interpolation is available by specifying another axis in a linear command at the same time to move synchronously with circular interpolation. K can be used to specify the pitch in helical interpolation so as to realize multi-circle helical line.

Radius programming can not be used for a whole circle programming, so a whole circle must be divided into two parts.

Note:

When $R>0$, the radius angle is smaller than 180^0;

When $R<0$, the radius angle is larger than 180^0.

Programming Example:

Clockwise and counterclockwise circular interpolation, as shown in Fig. 4-10.

For Fig. 4-10(a)

Solution 1:

```
G17 G90 X10 Y20
G02 X20 Y10 I0 J-10 F300
```

Solution 2:

```
G17 G90 X10 Y20
G02 X20 Y10 R10 F300
```

For Fig. 4-10 (b)

Solution 1:

```
G17 G90 X20 Y10
G03 X10 Y20 I-10 J0 F300
```

Solution 2:

```
G17 G90 X20 Y10
G03 X10 Y20 R10 F300
```

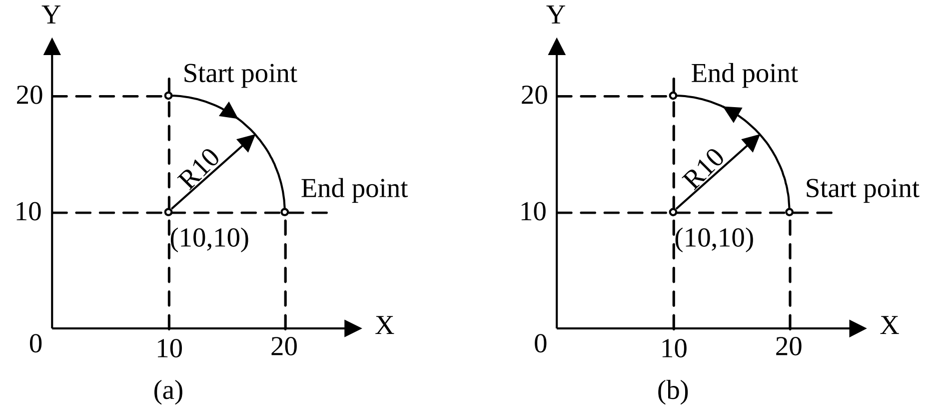


Fig. 4-10 G02/ G03 Programming

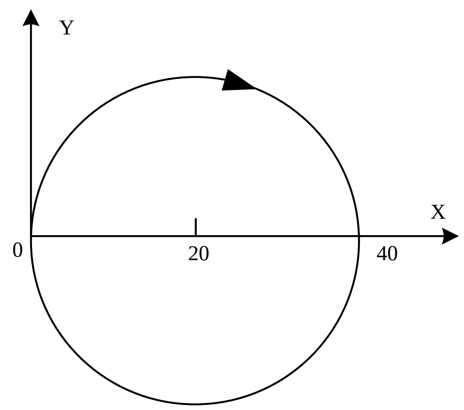


Fig. 4-11 A Full Circle Interpolation

Programming Example:

A full circle interpolation, see Fig. 4-11.

Solution 1:

```
G00 X0 Y0
G02 X0 Y0 I20 J0 F300
```

Solution 2:

```
G00 X0 Y0
G02 X20 Y-20 R-20 F300
G02 X0 Y0   R20 F300
```

Programming Example:

Helical programming in G03, as shown in Fig. 4-12.

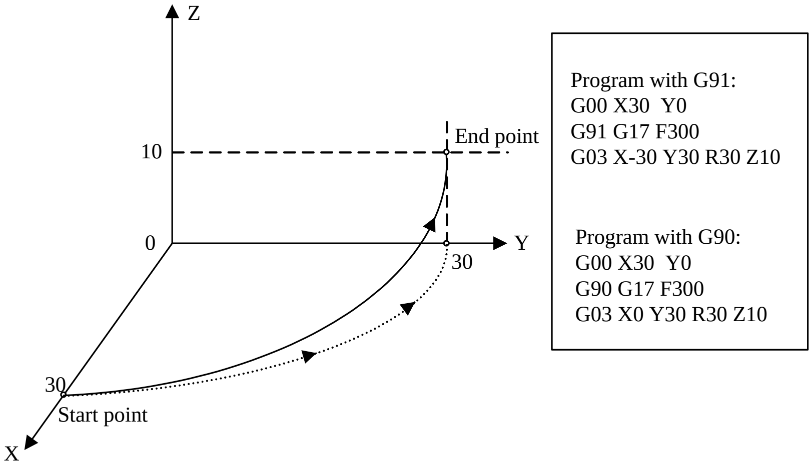


Fig. 4-12 Helical Programming

K can also be used to specify the pitch in Fig. 4-12.

```
G00 X30 Y0
G90 G17 G03 X0 Y30 R30 Z10 K10 F300
```

G04 Dwell

Command Format: G04 P_

Description:

P_: the dwell time in ms

G04 can be used in the following situations:

1. When cutting a corner, the dwell command can be used to guarantee a sharp corner.

2. In machining a not through hole, when the cutter reaches the appointed depth, G04 can be used to stop tool feed. After the spindle rotates more than one circle, execute tool retract to get a smooth hole bottom.

3. After boring a hole, the spindle should be stopped and dwell for 1~3s until totally stopped before tool retract in order to avoid thread scratches and ensure the smoothness of workpiece.

4. In transverse turning, G04 can be used before tool retract to make sure the spindle rotates at least one circle.

5. When chamfering or centering on a lathe, the dwell command, spindle on and tool change, etc. can be used to make sure the smoothness of chamfer surface and conical surface of center hole.

The dwell command comes into effect after the motion of last program block ends (the speed is 0). G04 dwells for the specified time, only effective in the program block containing it.

Inserting G04 between two program blocks can interrupt machining for the specified time, such as in free cutting, and the time is determined by P function word, in ms.

Programming Example:

```
G04 P1000        'dwell for 1000ms
```

Tool Commands

G40, G41, G42 Cutter Radius Compensation

Command Format:

G41 D_

G42 D_

G40

Description:

G40: cutter radius compensation cancel

G41: left cutter compensation (the cutter offsets radius distance on the left side of cutter moving direction)

G42: right cutter compensation (the cutter offsets radius distance on the right side of cutter moving direction)

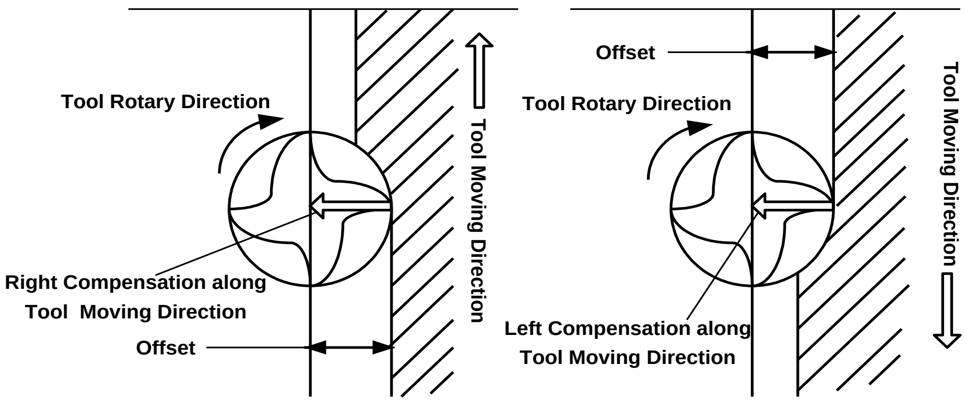
D_: parameter of G41/G42, i.e. tool compensation no. (D00~D07), denotes the radius compensation value corresponding to the tool compensation list

The switch among cutter radius compensation planes must be executed when compensation is off.

The establishment and cancel of cutter radius compensation can only use G00 or G01 command instead of G02 or G03.

When using cutter radius compensation, the radius value must be measured accurately and then saved into the memory as the cutter path offset (cutter radius value). D code is used in programming to make cutter offset no. correspond to cutter radius value.

When G41 (G42) is used, the cutter will move a radius distance to the offset position. After the execution of G41 (G42), the tool is immediately located to the perpendicular position of start position of program block, and the value of movement depends on the offset.



(a) Left Compensation (b) Right Compensation

Fig. 4-13Cutter Compensation Direction

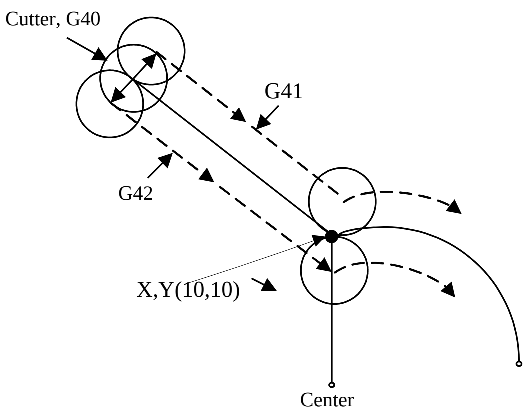


Fig. 4-14 Cutter Radius Compensation

Programming Example:

See Fig. 4-14 Cutter Radius Compensation.

```
G17 G01 G41 (G42) X_ Y_ F_ D_ 'executes linear interpolation and cutter radius compensation
G02 X_ Y_ I_ J_    'circular interpolation
```

> Note:
>
> In the process of compensation or when compensation off, current moving direction of cutter cannot be opposite to last direction.

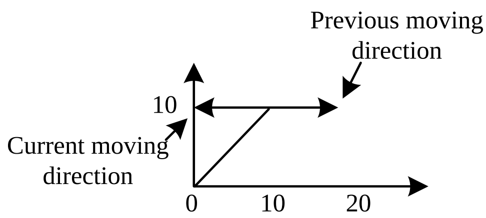


Fig. 4-15 Schematic Diagram of Cutter Moving Direction

For example:

```
G92 G0 X0 Y0
G0 G41 X10 Y10 D01 F1000
G1 X20 Y10
```

If G1 X5 Y10 is added here, an error will appear, because the direction is opposite to that of above-mentioned instruction. Change it to G1 X10 Y50, or other instruction not opposite to the last direction.

G0 G40 X0 Y10 'this instruction is also wrong, because the moving direction of cutter is opposite to the last direction. It will be right if it is changed to G0 G40 X0 Y0.

- **G43, G44, G49 Tool Length Compensation**

Command Format:

G43 H_

G44 H_

G49

Description:

G49: tool length compensation off

G43: compensation along positive direction (end point value of compensation axis adds offset value)

G44: compensation along negative direction (end point value of compensation axis subtracts offset value)

H_: parameter of G43/G44, i.e. tool length compensation offset no. (H00~H07), denotes length compensation value relative to the tool compensation list.

Tool length compensation is used to compensate the deviation of tool length, which subtracts or adds the saved tool offset value from or to the command value of Z-axis.

G43 and G44 are modal commands. When G43 or G44 is programmed, they will be always effective until G49 command appears to cancel them.

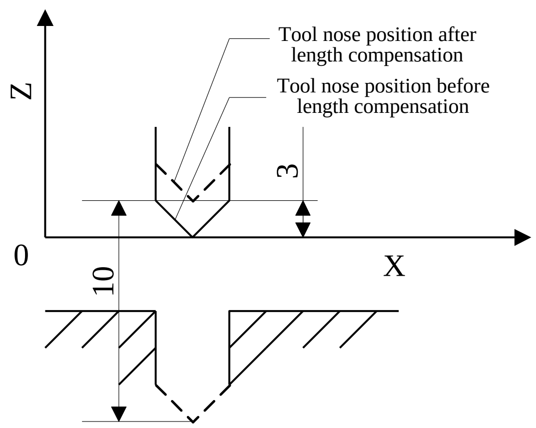


Fig. 4-16 Tool Length Compensation

Programming Example:

See Fig. 4-16 for tool length compensation.

```
G90 G00 X5 Z0 F300
G43 G0 Z10 H1       'length compensation to the cutter
G01 Z-10 F1000
```

- **G923 Directly Set Tool Offset**

Command Format: G923 X_Y_Z_ P_

Description:

Sets tool offset value for the specified tool; axes not listed out will not be modified.

P_: to specify cutter no.

For example:

```
G923 Z 2.392 P1
```

It indicates the tool offset value of cutter no.1 is 2.392.

If P is omitted, it indicates setting tool offset value for the current tool.

Programming Example (the cutter lifting program in Public.dat)

```
M802 P196609
M801 MSG"|D| wait for tool calibration signal"
G904 FZ-60 PZ=#CALIBRATION_SW LZ1
M801 MSG""
M802 P196608
G903 G00 G91 Z5
G923 z0
G906
G923 Z = #CURWORKPOS.Z-#MOBICALI_THICKNESS–5
```

Canned Cycle Function

The canned cycles of CNC mills are mainly used for machining holes, including drilling, boring and tapping. With one program block, you can accomplish one or a full set of hole machining operation. When continuing hole machining, if there is no need to change hole machining operations, all the modal data in the program needn’t to be written, which can greatly simplify the program.

Description of each command is shown in the following table.

G Code	Drilling operation	Operation at bottom of hole	Retraction operation	Application
G73	Intermittent feed	----	Rapid motion	High speed peck drilling cycle
G74	Cutting feed	Dwell, then spindle CW	Cutting feed	Left tapping cycle
*G76	Cutting feed	Oriented spindle stop with one displacement	Rapid motion	Fine boring cycle
G80	----	----	----	Cycle off
G81	Cutting feed	----	Rapid motion	Drilling cycle
G82	Cutting feed	Dwell	Rapid motion	Drilling cycle of dwell at bottom of hole
G83	Intermittent feed	----	Rapid motion	Peck drilling cycle
G84	Cutting feed	Dwell, then spindle CCW	Cutting feed	Taping cycle
G85	Cutting feed	----	Cutting feed	Drilling cycle
G86	Cutting feed	Spindle stop	Rapid motion	Drilling cycle
*G87	Cutting feed	Spindle CW	Rapid motion	Fine back boring cycle
*G88	Cutting feed	Dwell, then spindle stop	Manual displacement	Semi-automatic fine boring cycle

G Code	Drilling operation	Operation at bottom of hole	Retraction operation	Application
G89	Cutting feed	Dwell	Cutting feed	Boring cycle of dwell at bottom of hole

Notes: G76, G87, and G88 commands are not supported for the time being.

Canned Cycle Operations

Generally speaking, canned cycle of hole machining is comprised of the following six operations, see Fig. 4-17.

Operation 1: positioning of X axis and Y axis---the cutter is rapidly located to the position of hole machining.

Operation 2: rapid traverse to point R---the cutter rapidly feeds from initial point to point R.

Operation 3: hole machining----executing hole machining at the mode of cutting feed.

Operation 4: operations at bottom of hole----including dwell, exact stop of spindle, cutter displacement, and so on.

Operation 5: return to point R----for continuing hole machining and safely moving the cutter.

Operation 6: return to initial point at rapid traverse rate----generally, initial point is selected after hole machining completed.

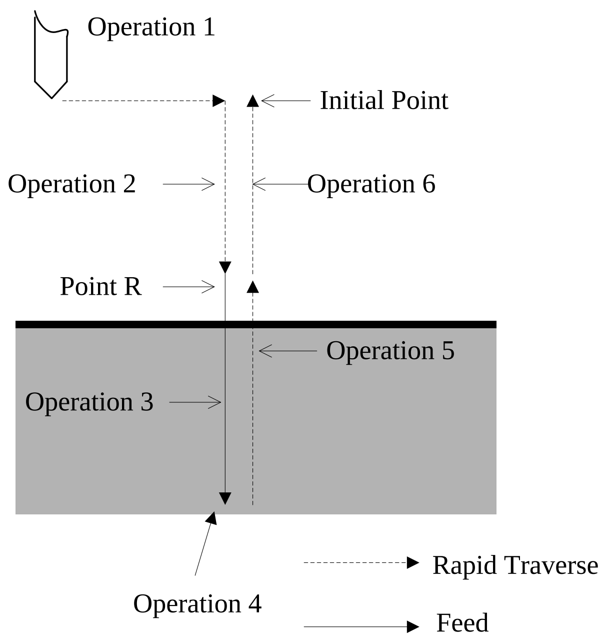


Fig. 4-17 Operation Sequence of Canned Cycle

Initial Plane

Initial plane is a plane specified for a safe plunge. The distance between initial plane and workpiece surface can be set within the safe limit.

Point R Plane

Point R plane is also named R REFER plane; it is a plane where the cutter moves at a speed from rapid traverse rate (G00) to cutting workpiece speed (GXX). The distance between workpiece surface and point R, generally within 2~5mm, mainly varies with the dimension of workpiece surface.

Hole Bottom Plane

When machining a blind hole, hole bottom plane is Z-axis height at the bottom of hole. When machining a through hole, the cutter usually goes beyond the hole bottom a certain distance to make sure all holes are machined to the specified depth. When drilling a hole, the impact of drill on hole depth should also be taken into consideration.

Hole machining cycle is not related to plane selection command (G17, G18, and G19). Whichever plane is selected, hole machining is positioning in XY plane and drilling in Z-axis.

Canned Cycle Codes

Data Form

Data of Address R and Address Z in canned cycle commands are specified in incremental mode (G91); R indicates the distance from initial point to point R, and Z indicates the distance from point R to point Z in the hole bottom plane (refer to Fig. 4-18).

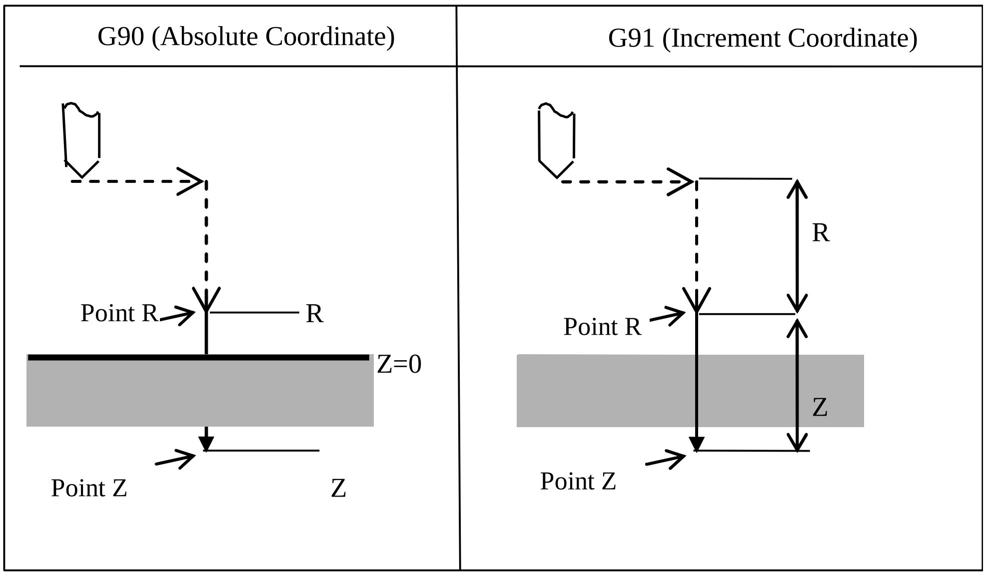


Fig. 4-18 Canned Cycle

Gxx Hole Machining Mode

The command format of hole machining is as shown below:

Gxx X_Y_Z_R_Q_P_F_K_;

X_Y_: position of the hole to be machined (absolute/incremental coordinate)

Z_: the position of point Z in the hole bottom plane (absolute programming); the distance from point R to point Z in the hole bottom plane (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

Q_: the cutting depth each time (incremental and positive)

P_: the dwell time at bottom of hole, in ms, with no decimal point

F_: feed speed; even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats, with default as K1. K (a non-modal command) is only effective in the block containing it. Under G91 mode, with setting this parameter, one block can implement the machining of several isometric holes distributed in one straight line. Under G90 mode, this parameter can specify the repeated machining times on the same position.

Command of hole machining mode, and Z, R, Q, and P, are all modal. They will remain in effect until hole machining mode is cancelled. Therefore, these commands can be specified at the beginning of the program, and then it is unnecessary to specify them again in the following consecutive machining; if the data of a certain hole is changed (such as: hole depth), you only need to modify this data.

G80 command is used to cancel hole machining mode; if any G code of Group 01 (G00/G01/G02/G03…) appears in the program block, the hole machining mode will also be automatically cancelled. In other words, as for canceling a canned cycle, G80 and G code of Group 01 function the same.

Canned Cycle Commands

Followings are the detailed description of various hole-machining modes.

- **G73 High Speed Chipbreaking Drilling Cycle**

  Command Format: G73 X_Y_Z_R_Q_ F_ K_;

  Description:

  X_Y_: hole position data (absolute/incremental coordinate)

  Z_: the position of point Z in the hole bottom plane (absolute programming); the distance from point R to point Z at the bottom of hole (incremental programming)

  R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

  Q_: the cutting depth each time (incremental and positive, minus sign will be ignored)

  F_: feed rate, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats

Hole-machining process is as shown in Fig. 4-19. It is easy to break and remove chips by intermittent feeding in Z-axis. Q specifies each time cutting depth, and "δ" is set by the parameter (G73_G83 retract amount).

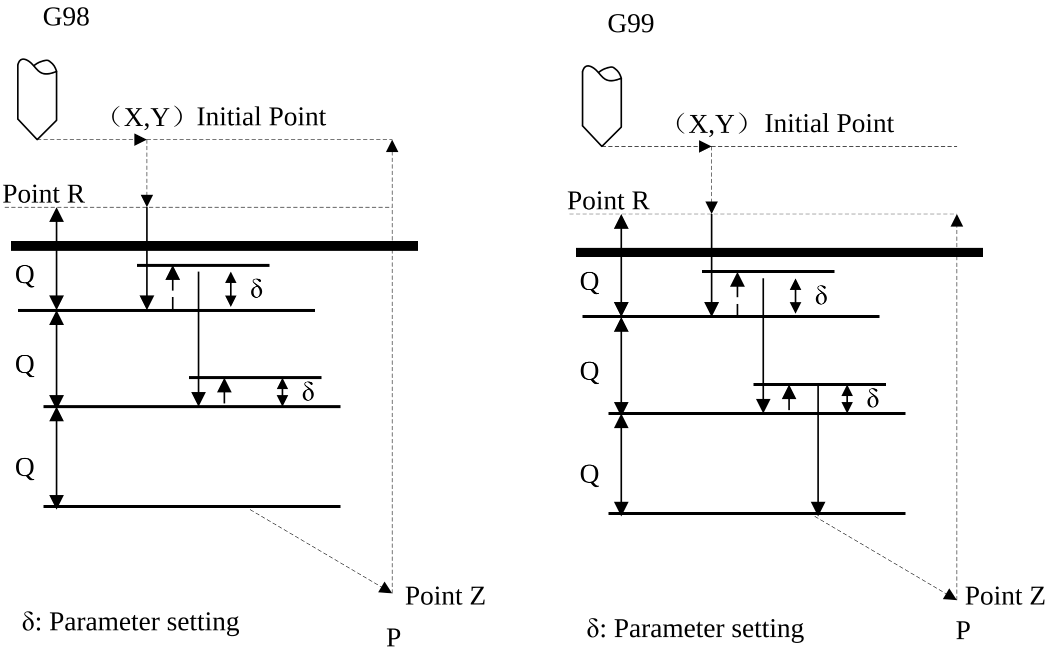


Fig. 4-19 G73 Machining Process

Process Description:

1. The cutter rapidly moves to the specified hole position (X, Y);
2. Moves to the appointed point R;
3. Moves down Q relative to the present drilling depth;
4. Rapidly moves upward retract distance δ (set by the parameter "retract amount");
5. Repeats the above drilling operations until reaching point Z at the bottom of hole;
6. Returns to the initial point (G98) or R point (G99) at G00 speed;

Programming Example:

```
F1200. S600
M03    'spindle CW on
G90
G00 X0. Y0. Z10. 'moving to the initial point.
G17
G90 G99
'Setting coordinates of point R, point Z and hole 1, with cutting depth each time as 2.0, and drilling speed as 800
G73 X5. Y5. Z-10. R-5. Q2. F800
X25. 'hole 2
```

```
Y25. 'hole 3
G98 X5. 'hole 4, and setting to return to the initial point
X10. Y10. Z-20. 'hole 5, and setting a new point Z as -20
G80
M05 'drill stop
M02
```

G74 Left Tapping Cycle

Command Format: G74 X_Y_Z_R_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of hole (absolute programming); the distance from point R to point Z at the bottom of hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

P_: the dwell time at the bottom of hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining. (Currently, tapping speed is specified by the parameter "spindle speed when tapping", instead of by this F data.)

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

Hole-machining process is as shown in Fig. 4-20. In G98, the cutter will return to the initial point after hole-machining is finished. But in G99, the cutter will return to point R after hole-machining is finished.

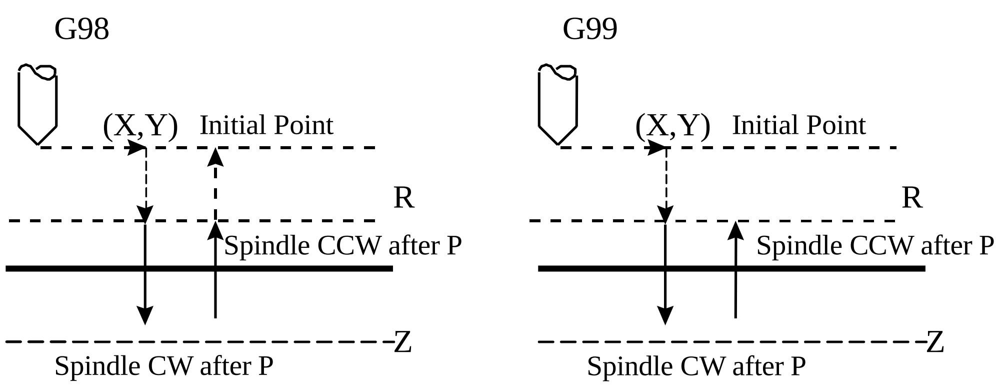


Fig. 4-20 G74 Machining Process

Process Description:

1. The cutter moves to the specified hole position (X, Y) at G00 speed;
2. Goes down to the specified point R at G00 speed;

3. Taps down to point Z at the bottom of the hole in G01;
4. Drill CW after P;
5. Retracts to point R in G01;
6. Drill CCW after P;
7. Retracts to the initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. 'moving to the initial point.
G17
M04 'drill CCW on
G90 G99
'Setting the coordinates of point R, point Z and hole 1, with dwell as 2s and drilling speed as 800
G74 X5. Y5. Z-10. R-5. P2000. F800
X25. 'hole 2
Y25. 'hole 3
G98 X5. 'hole 4, and setting to return to the initial point.
X10. Y10. Z-20. 'hole 5, and setting a new point Z as -20
G80
M05 'drill stop
M02
```

- **G76 Fine Boring Cycle**

This command is not supported at the moment.

Command Format: G76 X_Y_Z_R_Q_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

Q_: displacement of the tool at the bottom of the hole (incremental and positive, and minus sign will be ignored)

P_: the dwell time of tool at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

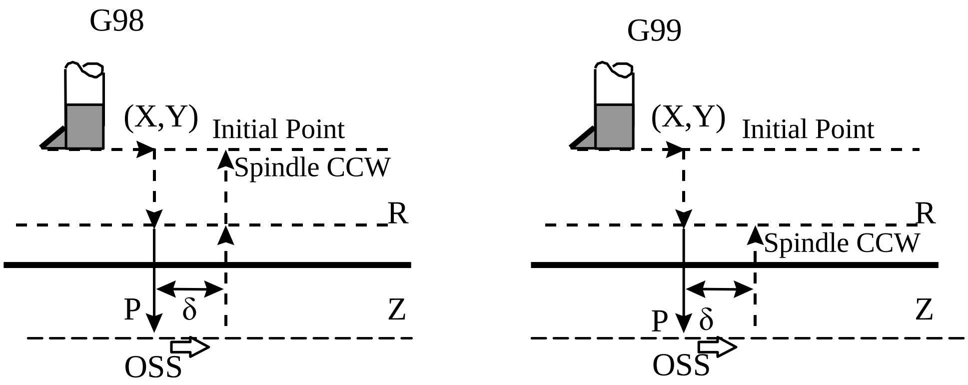


Fig. 4-21 G76 Machining Process

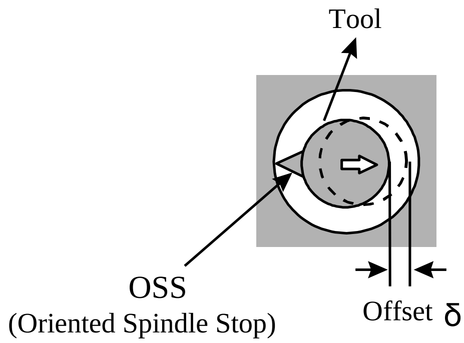


Fig. 4-22 Oriented Spindle Stop (OSS) Demonstration

Process Description:

1. The cutter moves to the specified hole position (X, Y) in G00;

2. Moves down to the specified point R in G00 (without spindle orientation);

3. Moves down to the point Z at the bottom of the hole in G01, after P, oriented spindle stop executed;

4. Shifts δ distance (the offset distance);

5. Retracts to the initial point (G98) or point R (G99) in G00;

6. Spindle CCW on.

※ Alarm:

As a Modal Value requested in G76 cycle, the value of Q must be specified carefully, because it is also used in G73/G83.

OSS (Oriented Spindle Stop) direction is decided by the parameter “Oriented Spindle Stop”:

Oriented Spindle Stop (OSS)	G17	G18	G19
0	+X	+Z	+Y
1	-X	-Z	-Y
2	+Y	+X	+Z
3	-Y	-X	-Z

Programming Example:

```
F1200 S600
M03 'spindle CW on
G90
G00 X0 Y0 Z10 'moving to the initial point
G17
G90 G99
'Specifying the coordinates of point R, point Z and hole 1, with the displacement at the bottom of hole as 2.0, dwell time as 5s, and machining speed as 800
G76 X5. Y5. Z-10. R-5. Q2. P5000. F800
X25. 'hole 2
Y25. 'hole 3
G98 X5. 'hole 4, and setting to return to initial point
X10. Y10. Z-20. 'hole 5, and specifying the new point Z as -20.0
G80
M05 'drill stop
M02
```

- **G81 Drilling Cycle**

Command Format: G81 X_Y_Z_R_F_ K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 increment mode)

Hole machining operation is as shown in Fig. 4-23. G81 is used for general drilling.

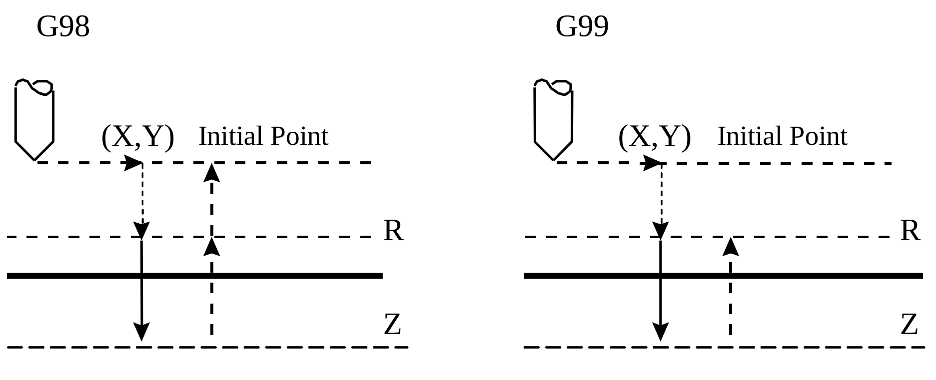


Fig. 4-23 G81 Machining Process

Description of Machining Process:

1. The cutter moves to the specified hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to point Z at the bottom of the hole in G01;
4. Retracts to the initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. 'moving to the initial point
G17
G90 G99
'Setting the coordinates of point R, point Z and hole 1, with machining speed as 800
G81 X5. Y5. Z-10. R-5. F800
X25. 'hole 2
Y25. 'hole 3
G98 X5. 'hole 4, and return to initial point
X10. Y10. Z-20. 'hole 5, and setting the new point Z as -20
G80
M02
```

G82 Drilling Cycle of Dwell at the Bottom of Hole

Command Format: G82 X_Y_Z_R_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

P_: the dwell time of the cutter at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

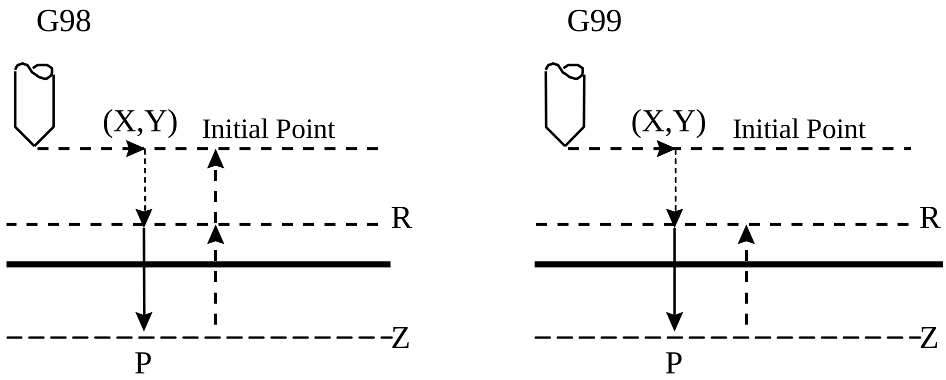


Fig. 4-24 G82 Machining Process

Process Description:

1. The cutter moves to the specified hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to point Z at the bottom of the hole in G01;
4. Pauses for P;
5. Retracts to the initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’spindle CW on
G90 G99
’Setting the coordinates of point R, point Z and hole 1, with dwell time as 2s, drilling speed as 800
G82 X5. Y5. Z-10. R-5. P2000. F800
X25. ’hole 2
Y25. ’hole 3
G98 X5. ’hole 4, and setting to return to the initial point
G80
M05 ’spindle stop
M02
```

- **G83 Deep Hole Peck Drilling Cycle**

Command Format: G83 X_Y_Z_R_Q_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R

(incremental programming)

Q_: the peck depth each time（positive and incremental, minus mark will be ignored）

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

The machining process of hole is as shown in Fig. 4-25. Slightly different from G73, the tool will retract to plane R after each intermittent feed in G83. The "δ" here, set by the parameter "G73_G83 retract amount", refers to the distance between the feed plane where the cutter changes from G00 to Gxx and the previous peck depth. G83 is especially for machining deep holes.

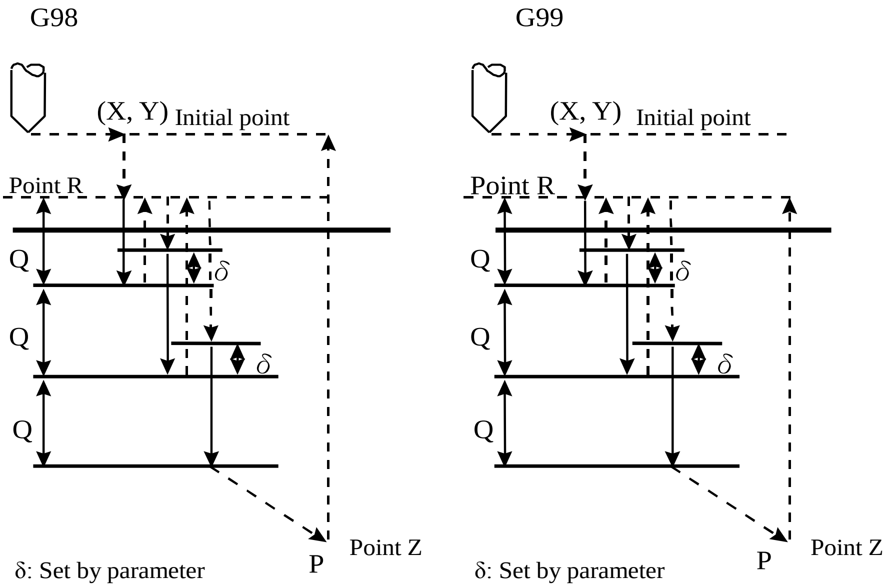


Fig. 4-25 G83 Machining Process

Process Description:

1. The cutter moves to the specified hole position (X, Y) in G00;
2. Moves to the specified point R in G00;
3. Drills down Q distance with respect to current depth in G01;
4. Retracts to the R plane in G00;
5. Moves down until δ distance (decided by the parameter "Retract Amount") away from current drill depth in G00;
6. Drill downs Q distance with respect to current drill depth;
7. Retracts to the R plane in G00;
8. Repeats above drilling operations until reaching point Z at the bottom of the hole;
9. Retracts to the initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
M03 'spindle CW on
G90
G00 X0. Y0. Z10. 'moving to the initial point
G17
G90 G99
'Specifying the coordinates of point R, point Z and hole 1, with peck depth as 3.0, cutting speed as 800
G83 X5. Y5. Z-10. R-5. Q3. F800
X25. 'hole 2
Y25. 'hole 3
G98 X5. 'hole 4, and setting to return to the initial point
G80
M05 'drill stop
M02
```

- **G84 Tapping Cycle**

Command Format: G84 X_Y_Z_R_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

P_: the dwell time at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data still effective in the subsequent machining. (Currently, tapping speed is set by the parameter “Spindle Speed When Tapping”, instead of by this F data.)

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

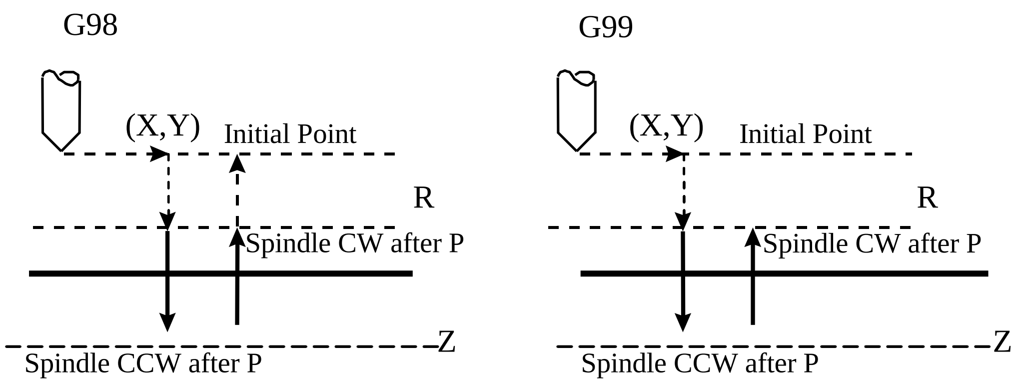


Fig. 4-26 G84 Machining Process

Process Description:

1. The cutter moves to the specified hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Taps down to point Z at the bottom of the hole in G01;
4. Spindle CCW after P;
5. Retracts to point R in G01;
6. Spindle CW after P;
7. Retracts to the initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’drill CW on
G90 G99
’Specifying the coordinates of point R, point Z and hole 1, with dwell as 2s, tapping speed as 800
G84 X5. Y5. Z-10. R-5. P2000 F800
X25. ’hole 2
Y25. ’hole 3
G98 X5. ’hole 4, and setting to return to the initial point
G80
M05 ’drill stop
M02
```

- **G85 Drilling Cycle**

Command Format: G85 X_Y_Z_R_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

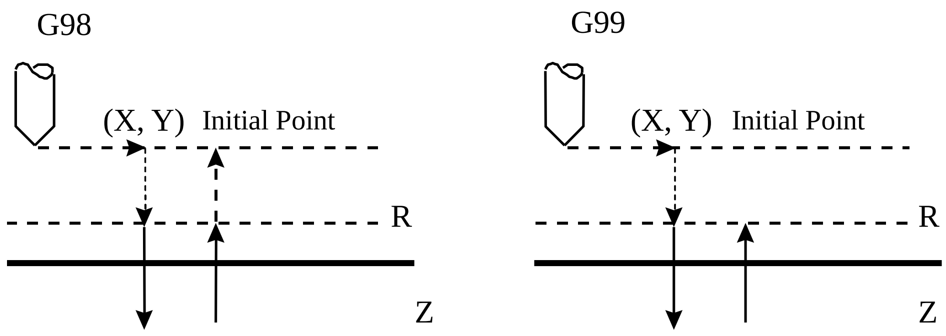


Fig. 4-27 G85 Machining Process

Process Description:

1. The cutter moves to the specified hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to the point Z at the bottom of the hole in G01;
4. Retracts to point R in G01;
5. Retracts to initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’spindle CW on
G90 G99
’Specifying the coordinates of point R, point Z and hole 1, with machining speed as 800
G85 X5. Y5. Z-10. R-5. F800
X25. ’hole 2
Y25. ’hole 3
G98 X5. ’hole 4, and setting to return to the initial point
G80
M05 ’spindle stop
M02
```

- **G86 High Speed Drilling Cycle**

Command Format: G86 X_Y_Z_R_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective in G91 incremental mode)

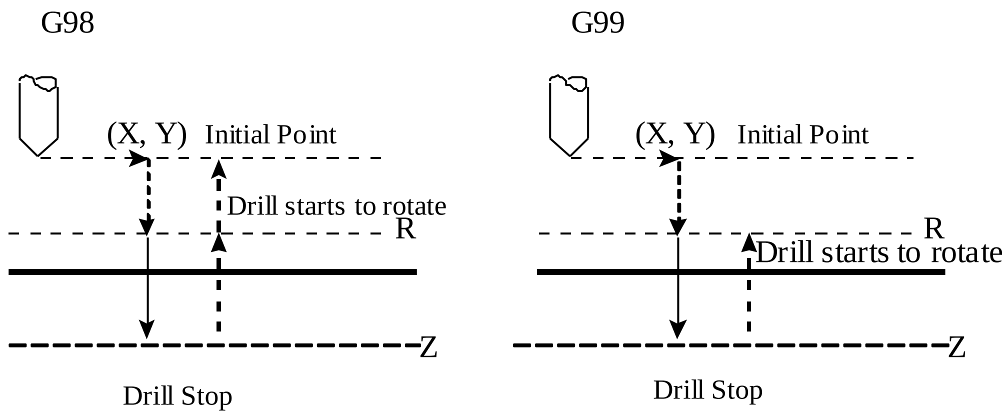


Fig. 4-28 G86 Machining Process

Process Description:

1. The cutter moves to the hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to point Z at the bottom of the hole in G01;
4. Drill stops rotating;
5. Retracts to initial point (G98) or point R (G99) in G00;
6. Drill starts to rotate.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’drill CW on
G90 G99
’Specifying the coordinates of point R, point Z and hole 1, with drilling speed as 800
G86 X5. Y5. Z-10. R-5. F800
X25. ’hole 2
Y25. ’hole 3
G98 X5. ’hole 4, and setting to return to initial point
G80
M05 ’drill stop
M02
```

G87 Fine Back Boring Cycle

This command is not supported at the moment.

Command Format: G87 X_Y_Z_R_Q_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

Q_: displacement of cutter (positive and incremental, minus mark will be ignored)

P_: the dwell time at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

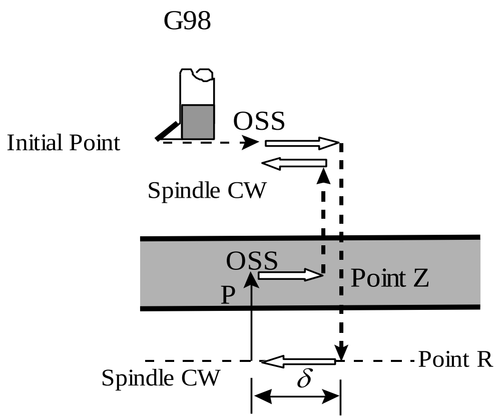


Fig. 4-29 G87 Machining Process

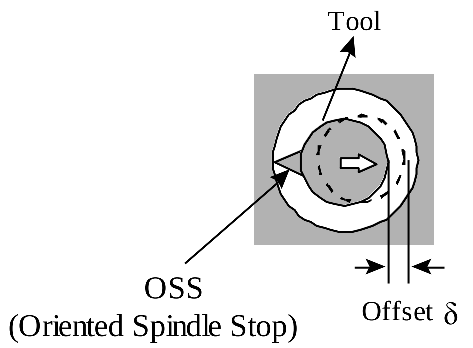


Fig. 4-30 Oriented Spindle Stop (OSS) Sketch Map

Process Description:

1. The cutter moves to the hole position (X, Y) in G00;

2. After OSS, offsets Q distance in a direction opposed to the direction of boring cutter specified by the parameter “Oriented Spindle Stop (OSS)”;

3. Moves down to the specified point R in G00, and offsets Q distance;

4. Spindle CW;

5. Retracts to point Z in G01;
6. After P, offsets Q distance in a direction opposed to previous offset;
7. Retracts to the initial point in G00;
8. Offsets Q distance after spindle CW.

※ Alarm:

As a Modal Value requested in G76 cycle, the value of Q must be set carefully, because it is also used in G73/G83.

OSS (Oriented Spindle Stop) direction is decided by the parameter “Oriented Spindle Stop”.

Oriented spindle stop （OSS）	G17	G18	G19
0	+X	+Z	+Y
1	-X	-Z	-Y
2	+Y	+X	+Z
3	-Y	-X	-Z

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03   ’spindle CW on
G90 G98
’Specifying the coordinates of point R, point Z and hole 1, with offset as 5, dwell time as 4s, and boring speed as 800
G87 X5. Y5. Z-10. R-5. Q5. P4000 F800
X25. ’hole 2
Y25. ’hole 3
X5. ’hole 4, and setting to return to the initial point
G80
M05 ’spindle stop
M02
```

G88 Boring Cycle

This command is not supported at the moment.

Command Format: G88 X_Y_Z_R_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

P_: the dwell time at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

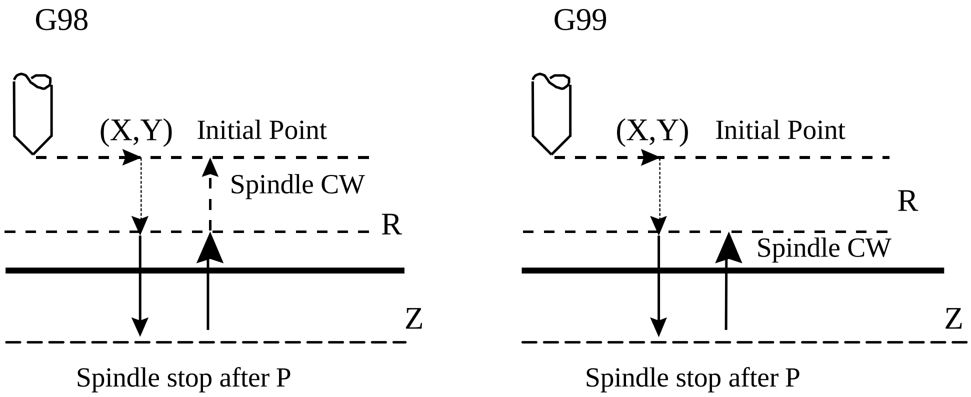


Fig. 4-31 G88 Machining Process

Process Description:

1. The cutter moves to the hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to point Z at the bottom of the hole in G01;
4. Spindle stop after P;
5. Retracts to point R in G01;
6. Retracts to initial point (G98) or point R (G99) in G00;
7. Spindle CW.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’spindle CW on
G90 G99
’Specifying the coordinates of point R, point Z and hole 1, with dwell as 2(s), boring speed as 800
G88 X5. Y5. Z-10. R-5. P2000 F800
X25. ’hole 2
Y25. ’hole 3
G98 X5. ’hole 4, and setting to return to the initial point
G80
M05 ’spindle stop
M02
```

G89 Boring Cycle of Dwell at the Bottom of Hole

Command Format: G89 X_Y_Z_R_P_F_K_;

Description:

X_Y_: hole position data (absolute/incremental coordinate)

Z_: the position of point Z at the bottom of the hole (absolute programming); the distance from point R to point Z at the bottom of the hole (incremental programming)

R_: the position of point R (absolute programming); the distance from the initial point to point R (incremental programming)

P_: the dwell time at the bottom of the hole, in ms, with no decimal point

F_: feed speed, even if the canned cycle is cancelled, this modal data is still effective in the subsequent machining.

K_: number of repeats (repeated movement and drilling, effective under G91 incremental mode)

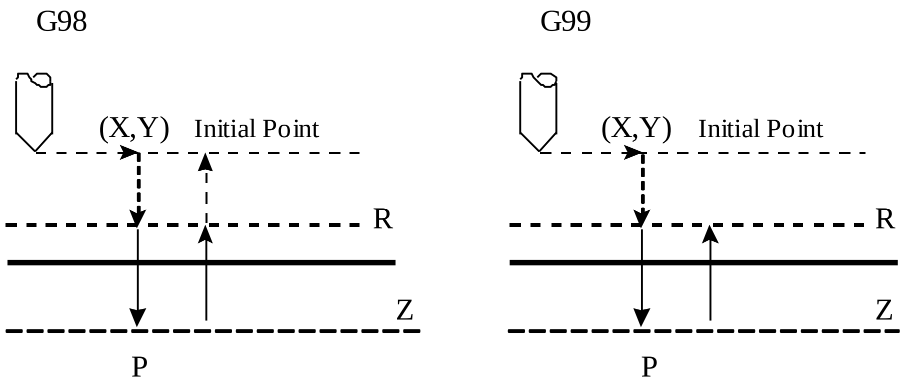


Fig. 4-32 G89 Machining Process

Process Description:

1. The cutter moves to the hole position (X, Y) in G00;
2. Moves down to the specified point R in G00;
3. Moves down to point Z at the bottom of the hole in G01;
4. Pauses for P;
5. Retracts to point R in G01;
6. Retracts to initial point (G98) or point R (G99) in G00.

Programming Example:

```
F1200. S600
G90
G00 X0. Y0. Z10. ’moving to the initial point
G17
M03 ’spindle CW on
G90 G99
’Setting coordinates of point R, point Z and hole 1, with dwell as 2.5s, machining speed as 800
G89 X5. Y5. Z-10. R-5. P2500 F800
```

```
X25. 'hole 2
Y25. 'hole 3
G98 X5. 'hole 4, and setting to return to the initial point
G80
M05 'spindle stop
M02
```

Special Canned Cycle

Description:

Unit of length: millimeter (mm)

Unit of angle: degree

1 meter=1000mm, one full circle= 360 degrees

Special canned cycle instructions (G34-37) must be used together with standard canned cycle instructions (G73-89).

For Example:

```
G81 Z-20 R-5 F100 K0
G34 X10 Y10 I10 J90 K10
```

Standard canned cycle instructions must be written before special canned cycle instructions; when the execution of a special canned cycle instruction is finished, the standard canned cycle instruction remains effective until canceled.

For Example:

```
G81 Z-20 R-5 F100 K0 'specifying the cycle action
G34 X10 Y10 I10 J90 K10 'drilling10 holes around a circle
X100      'drilling another hole, not influenced by the previous G34
```

If there is no standard canned cycle instruction when executing a special canned cycle instruction, the system will report an error.

If the following instructions are executed:

```
G0 X0 Y0 Z0
G34 X10 Y10 I10 J90 K10
…
```

An error prompt as following will pop up:

G34/35/36/37 instruction error: special canned cycle instructions do not match, with no designation.

A correct form should be like:

```
G0 X0 Y0 Z0
G81 Z-20 R-5 F100 K0
G34 X10 Y10 I10 J90 K10
…
```

G34 Bolt Hole Circle

Command Format: G34 Xx Yy Ir Jθ Kn

Description:

Drills a circular pattern of a specified number of holes.

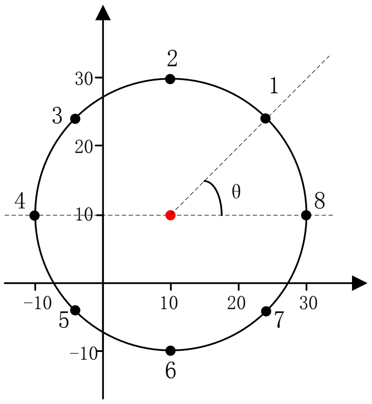
X, Y: the center position of this cycle (G90/91 is influential)

I: circle radius r

J: θ, the included angle between X-axis and the point to be drilled first

K: number of holes, within -9999~9999. If the number is 0, an error report will be given. If the number is greater than 0, hole drilling is CW, but if smaller than 0, hole drilling is CCW.

G34 drills n evenly-spaced holes on one circle with X & Y as center and r as radius, with included angle as θ between X axis and first hole position, G0 speed employed from one hole to another one.



N001 G91 G81 G99 Z-5 R6 F500 K1
N002 G34 X10 Y10 I20 J45 K8
The machine tool starts drilling from position 1 until to position 8.
The included angle is θ between position 1 and positive direction of X axis. Drilling actions are specified by G81 in program block N001.

Fig. 4-33 Sketch Map of Bolt Hole Circle

G35 Holes on Line at Angle Cycle

Command Format: G35 Xx Yy Id Jθ Kn

Description:

Drills holes on a line at an angle with respect to X-axis.

X, Y: the initial position to be drilled (G90/91 is influential)

I: distance (d) between adjacent holes. If the value is minus, drilling holes in symmetry direction.

J: angle θ, specifying the angle of the line holes to be drilled on.

K: number of holes, within 0~9999. If the number is 0, an error report will be given.

G35 drills n evenly-spaced holes on a line at an angle with respect to X axis, with X and Y as initial position, d as spacing distance between adjacent holes, G0 speed adopted when moving from one hole to another one.

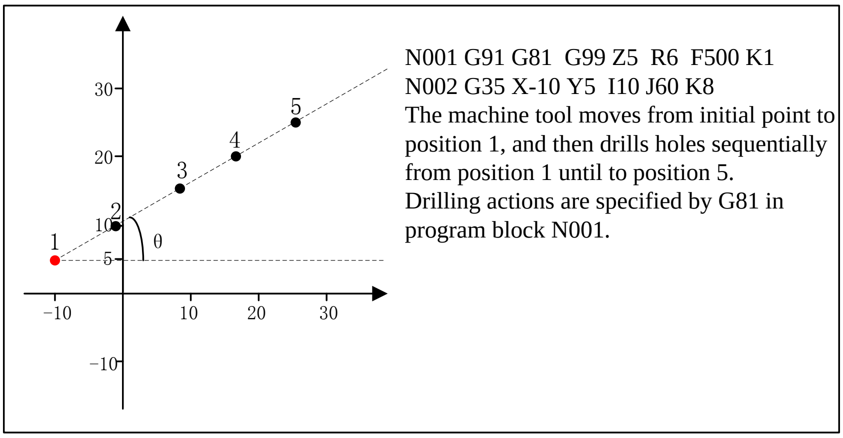


Fig. 4-34 Sketch Map of Angular Straight Line Drilling Cycle

G36 Arc Drilling Cycle

Command Format: G36 Xx Yy Ir Jθ PΔθ Kn

Description:

Drilling evenly-spaced holes on a circle with specified angle between adjacent holes.

X, Y: center position of this cycle (G90/91 is influential)

I: circle radius r

J: θ, the included angle between the first point to be drilled and X-axis

K: number of holes, within -9999~9999. If the number is 0, an error report will be given. If the number is greater than 0, hole drilling will be clock-wise, but if smaller than 0, hole drilling will be counter-clockwise.

G36 drills n evenly-spaced holes on a circle with X, Y as center and r as radius, at the same time, the included angle is θ between the first drilling point and X-axis, and the angle between adjacent holes is Δθ, G0 speed used when moving one hole to another one.

The only difference between G36 and G34 is that the former one specifies the included angle between two holes.

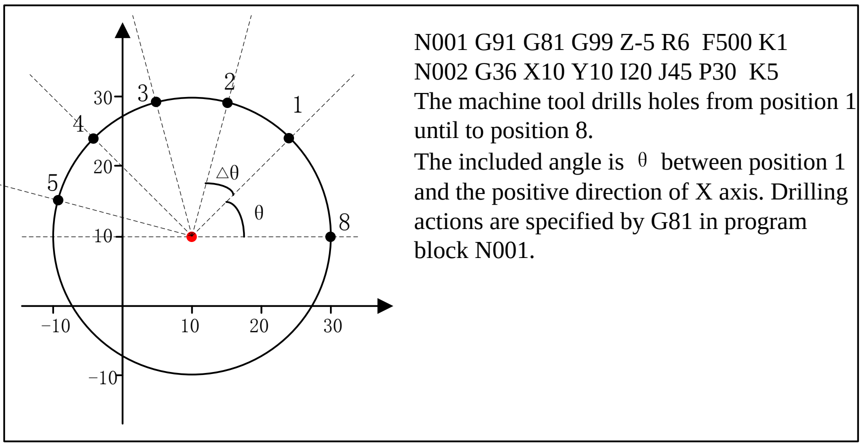


Fig. 4-35 Sketch Map of Arc Drilling Cycle

- **G37 Chessboard Hole Cycle**

Command Format: G37 Xx Yy IΔx Pnx JΔy Kny

Description:

Chessboard hole cycle.

X, Y: the first position to be drilled (G90/91 is influential)

I: hole interval in X axis

P: number of holes in X axis

J: hole interval in Y axis

K: number of holes in Y axis

G37 drills P*K holes in XY plane with XY as start position. The space between adjacent holes is Δx in X axis, while in Y axis, the space is Δy, G0 speed used when moving from one hole to another one.

N001 G91 G81 G99 Z-5 R6 F500 K1

N002 G37 X300 Y-100 I50 P10 J100 K15

Machine tool moves from P, first to A, then drills 10 holes with hole interval as 50mm in X-axis until to B, then moves 100mm in Y+ direction to C, and then drills 10 holes until to D in X axis. The rest can be done in the same manner until J is reached with 15*10 holes drilled. Drilling action is specified by G81 of program block N001.

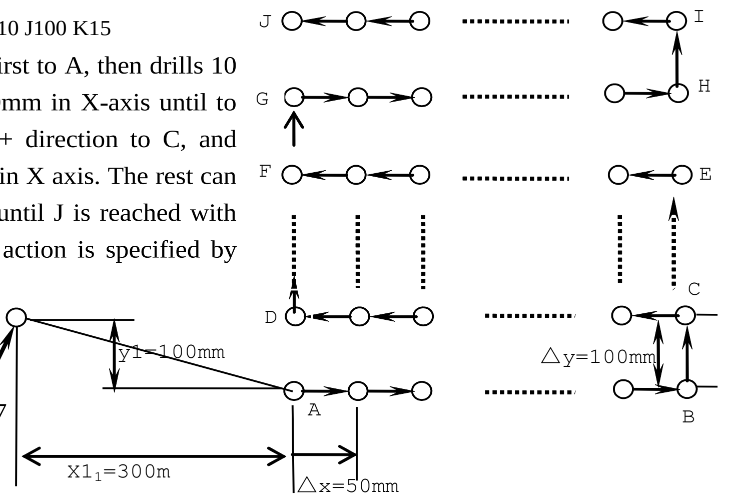


Fig. 4-36 Demonstration for Chess Hole Cycle Drilling

Customized Canned Cycle

The user can customize G coeds by writing a subprogram in public.dat.

Subprogram no. 200~999 is used by internal parse engine. The code range of M command is 200~599, while that of G code is 600~999.

Therefore, G code (0~99) plus 600 is regarded as the corresponding subprogram.

Programming Example:

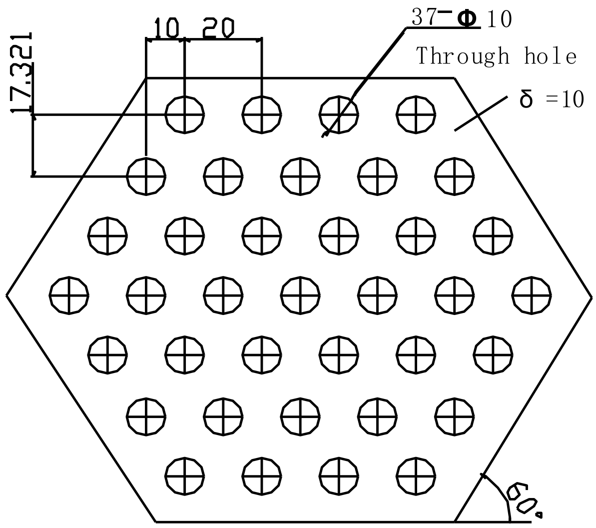


Fig. 4-37 Repeated Canned Cycle Machining

Take a repeated canned cycle to drill holes as shown in Fig. 4-37.

Programming is as following:

```
N01 G90 X0. Y0. Z100.
N02 G00 X-50. Y51.963 M03 S800
N03 Z20. M08 F4000
N04 G91 G81 X20. Z-18. F4000 R-17. K4
N05 X10. Y-17.321
N06 X-20. K4
N07 X-10. Y-17.321
N08 X20. K5
N09 X10. Y-17.321
N10 X-20. K6
N11 X10. Y-17.321
N12 X20. K5
N13 X-10. Y-17.321
N14 X-20 K4
N15 X10 Y-17.321
N16 X20. K3
N17 G80 M09
N18 G90 G00 Z100.
N19 X0. Y0. M05
N20 M30
```

G Codes Related with Encoder

- **G916 Writing Axis Configuration Data Command**

  Format: G916 PX[_]LX_PY[_]LY_PZ[_]LZ_

  Description:

PX[_], PY[_], PZ[_]: PLC address of to-be triggered latch signals of X, Y and Z axes

LX_, LY_, LZ_: Signal status to trigger latch of X, Y and Z axes

Programming Example:

```
G916 PX[00000]LX0;
'In the process of homing, encoder zero is used to trigger the latched encoder data. This instruction informs the drive to write the configuration data of X axis and trigger latch when level is low.
```

G918 Clearing Latch Flag Command

Format: G918

Description:

Clears the flag bit of encoder latch of each axis.

Programming Example:

```
G918;
'Clear the latch flag of encoder of each axis before the encoder latches data. After latch is done, the flag will be set as 1.
```

G919 Calculating Deceleration Distance of Cross-signal Trigger Point

Format: G919 H_

Description:

H_: axis No. (0: X axis; 1: Y axis; 2: Z axis) that needs to calculate the deceleration distance from the triggering point of cross-signal

Programming Example:

```
G919 H0;
'Calculate the cross-signal deceleration distance of X axis, i.e. the X axis will stop with deceleration after passing through a waiting signal. This instruction calculates the distance between triggering point and stop position.
```

4.4 Advanced Functions

G65 Subroutine Call Command

Command Format: G65 P_ L_

Description:

P: to specify the sequence number or the name of a subprogram to be called

L: times of executing the subprogram

P is used to specify the sequence number or the name of a subprogram to be called in a macro program. The subprogram will be executed L times. The default value of L is 1.

An argument can be defined in a user macro program if necessary.

The machine tool designer or the user can write some specific programs consisting of a group of commands in Public.dat, and call them for execution with instruction G65.

These specific programs are defined as public subprograms which have the same format as a subprogram.

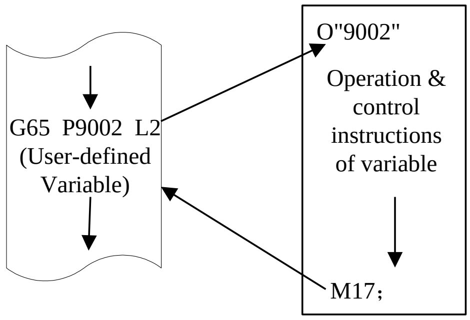


Fig. 4-38 Subprogram Call Instruction G65

Fig. 4-38 is a process sketch map to call and execute the subprogram P9002 two times and then continue executing the following commands.

New function of naming the subprogram is available. The format is O"subprogram name" and G65 P"subprogram name" L numerical digit (1,2,3…) for writing and calling a subprogram, which is convenient to remember. Note that a program name can not be Chinese characters.

- **G903 100% feedrate override command**

Command Format: G903

Description:

This instruction sets feedrate override as 100% forcedly, whatever the value the user sets. It is often used in functions of backing to machine origin and tool measurement to ensure accuracy.

This non-modal command should be used together with G00, G01, G02, or G03.

Programming Example:

```
G905 G903 G01 X10 Y20 Z0 F600; 'F (feedrate) is set as 600 mm/min forcedly
```

- **G904 Conditional Movement Command**

Command Format: G904 FX_PX_ LX_ FY_PY_LY_ FZ_PZ_LZ_ X_Y_Z_

Description:

FX_, FY_, FZ_: the moving speed and direction of X, Y and Z axes

PX_, PY_, PZ_: the to-be-detected signal port no. of X, Y and Z axes

LX_, LY_, LZ_: the signal status that is waited to stop movement of X, Y and Z axes (1: on; 0: off)

X_, Y_, Z_: the longest moving distance

Unnecessary axes can be omitted. However, once an axis appears, except X_Y_Z_, the other data must be complete.

- **G905 Enable feedrate command**

Command Format: G905

Description:

G905 enables feed speed specified by F command temporarily, instead of the default speed.

When the parameter “Use default speed” is set as valid, this instruction disables the default speed and forces to use the programmed speed temporarily, commonly used in functions of backing to reference point and tool measurement, and so on.

This non-modal command is used together with G00, G01, G02 or G03.

Programming Example:

```
G905 G903 G01 X10 Y20 Z0 F600; 'F (feed speed) is set as 600 mm/min forcedly
```

- **G906 Synchronization /Overtime Check**

When only used as synchronization function, Command Format: G906

When used as overtime check function, Command Format: G906 PLC [PLCADDRESS] LEVEL_ P_

Description:

PLC [PLCADDRESS]: PLC address of port; PLC [PLCADDRESS] or PLC=Integer Expression indicating PLC internal address

LEVEL_: port value (0/1)

P_: wait time, in milliseconds

This instruction is used for synchronization. That is to say, the following operation will go on only after various parameters are synchronized.

G906 should be executed for synchronization before using the internal system parameters or instructions concerning modifying system parameters and status, such as G92, M902.

The extended function of G906 is overtime check for a specified port. In the mean time, the synchronization function is also effective. When G906 is only used for synchronization there are no parameters after G906. When the extended function is needed, see the following example for the programming format:

```
G906 PLC [04] LEVEL1 P1000; 'wait until PLC port 04 is in state 1 and exit after timeout (1000 milliseconds)
```

- **G907 Move in the Shortest Path**

Command Format: G907

Description:

G907 is used to move in the shortest track under rotary axis mode. This instruction is only available under rotary axis mode.

- **G908 Force to Program in Degrees**

Command Format: G908

Description:

G908 forces to program in degrees under rotary axis mode. This instruction is only available under rotary axis mode.

- **M801 String Information Command**

Command Format: M801_

Description:

This instruction is used for transferring message between modules.

Programming Example:

```
M801 "Hello"        'transferring "hello"
```

- **M802 Integer Message Command**

Command Format: M802 Pxxxx

Description:

This instruction is used to transfer integer message.

xxxx: integer message to be transferred

For Example:

M802 P196609	close the buffer zone
M802 P196608	open the buffer zone
M802 P131072	limit off
M802 P131073	limit on
M802 P458752	clear external offset. After modifying G codes of fixed tool measurement, use this command to clear external offset after measurement.

- **M901 Directly Control Output Port**

Command Format: PLC [PLCADDRESS] LEVEL_

Description:

PLC [PLCADDRESS]: PLC address of port; PLC [PLCADDRESS] or PLC = Integer Expression indicating PLC internal address

LEVEL_: port value (0/1)

Programming Example:

```
M901 PLC [04] LEVEL1; 'assign 1 to the port 04 (PLC address)
```

- **M902 Directly Set REF.**

Command Format: M902 Ha

Description:

a: axis address; 0-3 are respectively corresponding to X, Y, Z, and A axes.

Programming Example:

```
M902 H0; 'end of X-axis returning to reference point, i.e. the machine coordinate of current point is 0 (machine origin) in X-axis
```

4.5 Expressions Used in Program Instructions

Current Definition for Expression:

All positions behind the address characters that are taken up by numbers can be replaced by assignment expressions.

No characters of space type are allowed to exist in the expression, including Space, Tab and Enter, etc. What's more, an expression must be ended with a valid separator.

Definition for Assignment Expression:

An assignment expression begins with an equal mark, followed by an arithmetic expression which is constituted by various operators, functions, variables, brackets, etc.

The operators available now are divided into the following seven classes in order of priority:

1. Bracket
2. Function
3. Plus sign +, Minus sign -, NOT !
4. Multiplication *, Division /
5. Addition +, Subtraction –
6. Equal ==, Not equal !=, Greater than >, Less than <
7. OR ||, AND &&

Following are the mathematical functions available now:

Function	Meaning
Sin	sine
Cos	cosine
exp	exponent
sqrt	square root
log	natural logarithm
tg	tangent
ctg	cotangent
asin	arcsine
acos	arc cosine
atg	arc tangent
int	round-down
abs	absolute value

Note:

Radian is the unit for the numbers in the brackets which are behind sin, cos, tg, ctg, asin, acos, atg.

For example: sin (5), 5 represents 5 radians.

Application of Expression in Program Instructions:

```
Instance one: B=1+2; ’i.e. B=3
Instance two: G00 X3 Y5 Z=5+sin (5+abs (-8)); ’Assign 5+sin (5+abs (-8)) to Z
Instance three: #1=4+log6
                G01 X2 Y=#; ’Assign 4+log6 to Y
```

4.6 Comments in Program

A comment in a program is started with a single quotation mark:

’—— end-of-line pattern, content behind the single quotation mark does not work until the end of line.

For Example:

```
G00 X3 Y5        ’rapid traverse to X3, Y5
```

The content behind the single quotation mark can only act as a comment and will not be executed when the program is run.

4.7 Demonstration of Machining File Programming

Example 1 Programming for the Workpiece Shown in Fig. 4-39

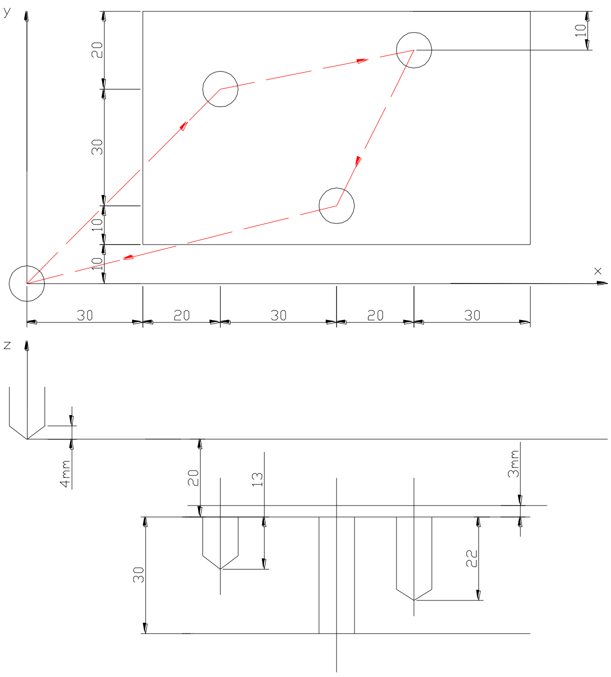


Fig. 4-39 Workpiece Machining Sketch

```
N01 G92 X0 Y0 Z0      ’workpiece coordinates system setting
```

N02 G91 G00 X50 Y50 M03 S600 M08
’incremental mode selected, the tool moves X50 Y50 at rapid traverse rate, spindle CW at 600 rpm, and coolant on
N03 G43 Z-17 H01 ’rapid traverse 17mm downward in Z axis, length compensation on
N04 G01 Z-16 F400 ’linear interpolation 16mm downward at 400mm/min in Z-axis
N05 G04 P2000 ’dwell for 2s
N06 G00 Z16 ’16mm upward in Z axis at rapid traverse rate
N07 X50 Y10 ’50mm and 10mm towards the positive direction of X axis and Y-axis respectively at rapid traverse rate
N08 G01 Z-25 ’linear interpolation 25mm downward in Z-axis
N09 G04 P2000 ’dwell for 2s
N10 G00 Z25 ’upward 25mm in Z axis at rapid traverse rate
N11 X-20 Y-40 ’20mm and 40mm in the reverse direction of X axis and Y axis respectively
N12 G01 Z-40 ’linear interpolation 40mm downward in Z-axis
N13 G00 Z57 ’upward 57mm in Z axis at rapid traverse rate
N14 G49 X-80 Y-20 M05 M09 M30
’length compensation cancel, 80mm and 20mm in the reverse direction of X axis and Y axis respectively, spindle stop, coolant off, end of program and return to the program header

Example 2 Programming for the Workpiece Shown in Fig. 4-40

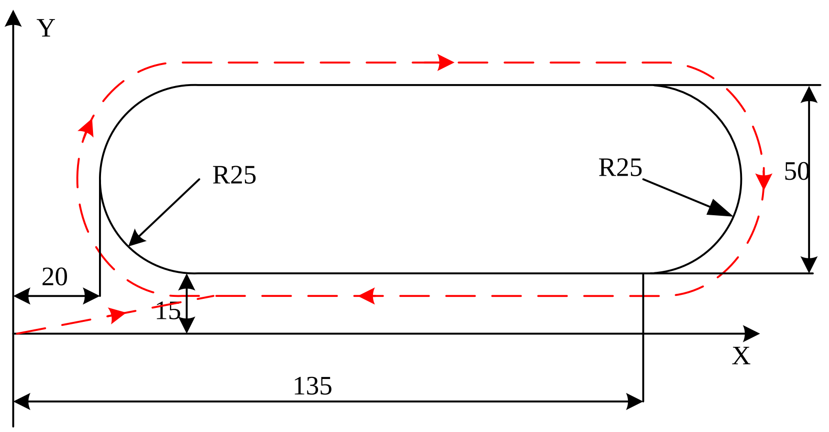


Fig. 4-40 Workpiece Machining Sketch

N01 G92 X0 Y0 Z0 ’workpiece coordinates system setting
N02 G90 G41 G00 X45 Y15 D01 M03 S600 M08 ’absolute programming adopted, cutter radius compensation on, rapid traverse to X45, Y15, spindle CW at 600 rpm, and coolant on
N03 G17 G02 X45 Y65 I0 J25 F700
’Clockwise circular interpolation to X45, Y65, radius 25mm, feed speed 700mm/min
N04 G01 X135 Y65 ’linear interpolation until X135, Y65
N05 G17 G02 X135 Y15 I0 J-25 ’CW circular interpolation to X135, Y15, radius 25mm
N06 G01 X45 Y15 ’linear interpolation to X45, Y15
N07 G00 G40 X0 Y0 M05 M09 M30
’Cutter radius compensation cancel, rapid traverse to X0, Y0, spindle stop, coolant off, end of program and return to the program header

Example 3 Programming for the Workpiece Shown in Fig. 4-41

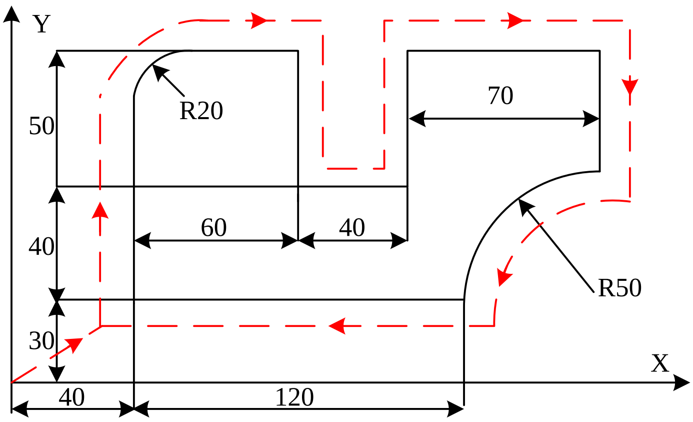


Fig. 4-41 Workpiece Machining Sketch

N01 G92 X0 Y0 Z0 ’workpiece coordinates system establishment

N02 G91 G41 G00 X40 Y30 D01 M03 S600 M08 ’incremental coordinates adopted, cutter radius compensation on, rapid traverse to X40, Y30, spindle CW at 600 rpm, and coolant on

N03 G17 G01 X0 Y70 F800 ’linear interpolation to X40, Y100, feed speed 800mm/min

N04 G02 X20 Y20 I20 J0 ’clockwise circular interpolation to X60, Y120, radius 20mm

N05 G01 X40 ’linear interpolation 40mm in the positive direction of X-axis

N06 Y-50 ’linear interpolation 50mm in the reverse direction of Y-axis

N07 X40 ’linear interpolation 40mm in the positive direction of X-axis

N08 Y50 ’linear interpolation 50mm in the positive direction of Y-axis

N09 X70 ’linear interpolation 70mm in the positive direction of X-axis

N10 Y-40 ’linear interpolation 40mm in the reverse direction of Y-axis

N11 G03 X-50 Y-50 I0 J-50 ’counterclockwise circular interpolation to X160, Y30, radius 50mm

N12 G01 X-120 ’linear interpolation 120mm in the reverse direction of X-axis

N13 G00 G40 X-40 Y-30 M05 M09 M30

’Cutter radius compensation cancel, rapid traverse to X0, Y0, spindle stop, coolant off, end of program and return to the program header

Example 4 Programming for the Workpiece Shown in Fig. 4-42 (CCW tapping)

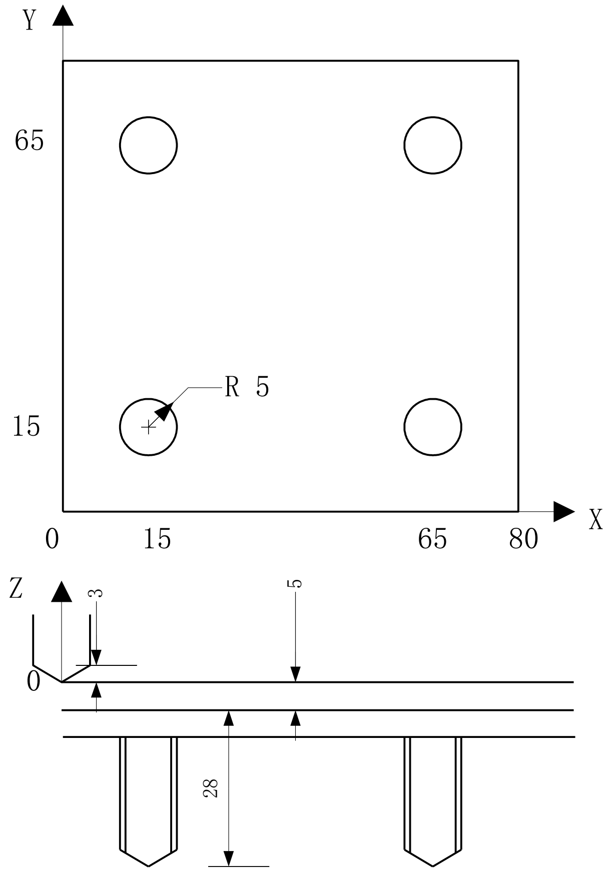


Fig. 4-42 Workpiece Machining Sketch

N01 G92 X0 Y0 Z0 ’workpiece coordinates system establishment
N02 G91 G00 X-35 Y15 M04 S600 M08
’Incremental coordinates adopted, rapid traverse to X-35, Y15, spindle CCW at 600 rpm, and coolant on
N03 G43 G00 Z0 H01 ’cutter length compensation on
N04 G74 X50 Y0 Z-28 R-5 P1000 F1000 L2
’CCW tapping at 1000mm/min, tapping depth 28mm, dwell for 1s at the bottom of the hole, executed twice
N05 G00 X-50 Y50 ’rapid traverse to X15, Y65, and start tapping
N06 G00 X50 ’rapid traverse to X65, Y65, and start tapping
N07 G80 ’hole machining cancel
N08 G00 X-65 Y-65 ’rapid traverse to X0, Y0
N09 G49 M05 M09 M30 ’length compensation cancel, spindle stop, coolant off, end of program and return to the program header

Example 5 Programming for the Workpiece Shown in Fig. 4-43 (requirement: amount of feed is 2mm each time in Z-axis)

N01 G92 X0 Y0 Z0 ’workpiece coordinates system establishment

N02 G91 M03 S800 M08 ’incremental coordinates adopted, spindle CW at 800 rpm, coolant on
N03 G65 P9001 L6 ’subprogram 9001 call, executed six times
N04 G00 Z12 M05 M09 M30 ’rapid traverse to X0, Y0, Z0, spindle stop, coolant off, end of program and return to the program header
O9001 ’subprogram 9001
N100 G00 X10 Y0 Z-2 ’rapid traverse to X10, Y0, Z-2
N110 G01 Y60 F1000 ’linear interpolation to X10, Y60, feed speed 1000mm/min
N120 X50 ’linear interpolation to X60, Y60
N130 Y-50 ’linear interpolation to X60, Y10
N140 X-60 ’linear interpolation to X0, Y10
N150 G00 Y-10 ’rapid traverse to X0, Y0
N160 M17 ’subprogram return

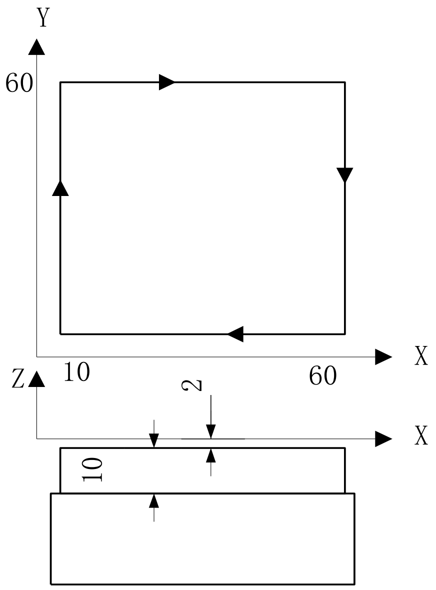


Fig. 4-43 Workpiece Machining Sketch

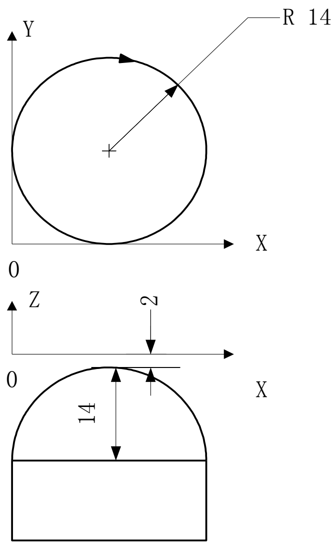


Fig. 4-44 Workpiece Machining Sketch

Example 6 Programming for the Workpiece shown in Fig. 4-44.

N01 G92 X10 Y0 Z0 ’workpiece coordinates system establishment
N02 G91 G00 X-10 M03 S1000 M08
’Incremental coordinates adopted, spindle CW at 1000 rpm, and coolant on
N03 G00 Y14 Z-16 ’rapid traverse to X0 Y14 Z-16
N04 G02 X0 Y0 I14 J0 F600 ’clockwise circular interpolation, feed speed 600mm/min
N05 G01 X1 Z1 F600 ’linear interpolation, advance 1mm along both X-axis and Z-axis
N06 G02 X0 Y0 I13 J0 F600
N07 G01 X1 Z1 F600
N08 G02 X0 Y0 I12 J0 F600
N09 G01 X1 Z1 F600
N10 G02 X0 Y0 I11 J0 F600
N11 G01 X1 Z1 F600
N12 G02 X0 Y0 I10 J0 F600

```
N13 G01 X1 Z1 F600
N14 G02 X0 Y0 I9 J0 F600
N15 G01 X1 Z1 F600
N16 G02 X0 Y0 I8 J0 F600
N17 G01 X1 Z1 F600
N18 G02 X0 Y0 I7 J0 F600
N19 G01 X1 Z1 F600
N20 G02 X0 Y0 I6 J0 F600
N21 G01 X1 Z1 F600
N22 G02 X0 Y0 I5 J0 F600
N23 G01 X1 Z1 F600
N24 G02 X0 Y0 I4 J0 F600
N25 G01 X1 Z1 F600
N26 G02 X0 Y0 I3 J0 F600
N27 G01 X1 Z1 F600
N28 G02 X0 Y0 I2 J0 F600
N29 G01 X1 Z1 F600
N30 G02 X0 Y0 I1 J0 F600
N31 G90 G00 X0 Y0 Z0 M05 M09 M30
'Rapid traverse to X0, Y0, Z0, spindle stop, coolant off, end of program and return to the program header
```

4.8 G Command Appendix

The appendix of G codes is as shown below:

G code	Function	G code	Function
G00	Rapid positioning	G65	Subprogram call
G01	Linear interpolation	G68	Coordinate system rotation
G02	Circular interpolation (clockwise)	G69	Cancel coordinate system rotation
G03	Circular interpolation (counterclockwise)	G70	Input in inch
G04	Dwell	G71	Input in mm
G17	XY plane selection	G73	High speed peck drill cycle
G18	ZX plane selection	G74	Left tapping cycle
G19	YZ plane selection	G76	Fine boring cycle
G20	Input in inch	G80	Cancel canned cycle
G21	Input in mm	G81	Drilling cycle
G28	Return to reference position	G82	Drilling cycle of dwell at the bottom of hole
G34	Bolt hole circle	G83	Peck drilling cycle (for deep holes)

G code	Function	G code	Function
G35	Line at angle drilling cycle	G84	Tapping cycle
G36	Arc drilling cycle	G85	Drilling cycle
G37	Chessboard hole cycle	G86	High speed drilling cycle
G40	Cancel cutter radius compensation	G87	Fine Back boring cycle
G41	Left cutter radius compensation	G88	Boring cycle
G42	Right cutter radius compensation	G89	Boring cycle of dwell at the bottom of hole
G43	Tool length positive compensation	G90	Absolute coordinate programming
G44	Tool length negative compensation	G91	Incremental coordinate programming
G49	Cancel tool length compensation	G92	Set WCS according to tool position
G50	Scaling off	G98	Return to initial point
G51	Scaling on	G99	Return to point R
G50.1	Mirror image off	G903	100% feedrate override command
G51.1	Mirror image on	G904	Conditional movement command
G53	Machine coordinate system	G905	Enable feedrate command
G54	WCS 1	G906	Synchronization command
G55	WCS 2	G907	Move in the shortest path
G56	WCS 3	G908	Force to program in degrees
G57	WCS 4	G921	Specify work coordinate value of current point
G58	WCS 5	G922	Specify WCS origin (including external offset)
G59	WCS 6	G992	Temporarily set WCS according to tool position

5 Named Parameters

For a common user, the machining workpiece operations and other basic operations provided by the controller can meet his demands, such as: tool calibration, center calibration, canned cycle, etc.

While for an advanced user who needs to modify some operating details, write operating programs and customize canned cycles, the controller provides a group of fast and convenient named parameters. With these parameters, it is not only convenient for the user to modify or write operation programs and customize the content of canned cycle in public.dat to meet the machining demand, but also convenient to write programs directly in the program edit operation interface.

Example 1, Use named parameters to compile a subprogram of tool coolant and tool change, as follows:

```
O1000 ’subprogram of tool coolant and tool change
M901 H=#COOLANT_START_PORT P1
G04 P10
IF(#ENABLE_CTP) G53 G00 G90 X=#CTP_POS．X Y=#CTP_POS．Y Z=#CTP_POSZ ’move to the position of tool change
G00 G90 Z10       ’or lift the cutter directly for tool change
M05
M17
```

Example 2, Use named parameters to modify the content of G86 canned cycle from without retract amount parameter in the system to with retract amount parameter, as follows:

```
O686
#FC50=#CANNEDCYCLE_BACK
IF (! #FC13) G90 G65 P786
IF (#FC13) G91 G65 P786 L=#FC11
M17
O786
G00 X=#FC1 Y=#FC2
G90 G00 Z=#FC4
G90 G01 Z=#FC4-ABS (#FC5) F=#FC7
G65 P886 L=INT(ABS(#FC4-#FC3）/ABS（#FC5））-1
G90 G01 Z=#FC3 F=#FC7
M05
G90 G00 Z=#FC4
IF (!#FC12)G90 G00 Z=#FC14
M03
IF (#FC13) G91
M17
O886
```

```
G91 G00 Z=#FC50
G91 G00 Z=-#FC50
G91 G01 Z=-ABS (#FC5) F=#FC7
M17
```

The variables defined in the canned cycle and their meanings:

X--#FC1---- X-coordinate of the hole center

Y--#FC2---- Y-coordinate of the hole center

Z--#FC3---- workpiece coordinate of Z plane (hole depth, negative)

R--#FC4---- workpiece coordinate of R plane (changing from the rapid traverse speed to the cutting speed in R plane, >0)

Q--#FC5---- cutting depth each time (incremental and positive); offset value in G76/G87

G99/G98--#FC12---G99->1; G98->0

G90/G91--#FC13---G91->1; G90->0

Z0--#FC14---Initial point height

The list of named parameters is as shown blow:

No.	Parameter	Parameter Name	Type	Remarks
01	CURMACHPOS.X	Mechanical coordinate of current point (X axis)	DOUBLE	Mechanical coordinate of current point (X axis)
02	CURMACHPOS.Y	Mechanical coordinate of current point (Y axis)	DOUBLE	Mechanical coordinate of current point (Y axis)
03	CURMACHPOS.Z	Mechanical coordinate of current point (Z axis)	DOUBLE	Mechanical coordinate of current point (Z axis)
04	CURWORKPOS.X	Workpiece coordinate of current point (X axis)	DOUBLE	Workpiece coordinate of current point (X axis)
05	CURWORKPOS.Y	Workpiece coordinate of current point (Y axis)	DOUBLE	Workpiece coordinate of current point (Y axis)
06	CURWORKPOS.Z	Workpiece coordinate of current point (Z axis)	DOUBLE	Workpiece coordinate of current point (Z axis)
07	INPORTMAP	Mapping of port input	INT	Status of port input
08	OUTPORTMAP	Mapping of port output	INT	Status of port output
09	SAFEHEIGHT	Safe height	DOUBLE	This height is relative to the workpiece origin, and only valid during backing to workpiece origin and resuming breakpoint.
10	ISYREVAXIS	Y axis as the rotary axis	BOOL	Whether to set Y as rotary axis
11	WPREVDIAM	Diameter of rotary workpiece	DOUBLE	Diameter of rotary workpiece being currently machined

No.	Parameter	Parameter Name	Type	Remarks
12	UNIT.YR	Programming unit of rotary axis	INT	0:angle (unit: radian) 1: surface distance of rotary workpiece (unit: millimeter)
13	AUTOSTOPSPINDLE	Spindle stop when stop	BOOL	Whether to stop spindle automatically after machining finishes
14	SPINDLE_DELAY	Delay when spindle On/ Off	DOUBLE	Setting the delay time when spindle starts/ stops automatically
15	MOBICALI_THICKNESS	The thickness of tool presetter in mobile tool measurement	DOUBLE	Setting the thickness of tool presetter in mobile tool measurement
16	FIXEDCALI_POS.X	The position of tool presetter in fixed tool measurement (X-axis)	DOUBLE	The mechanical coordinate of the position where tool presetter stands (X-axis) in fixed tool measurement
17	FIXEDCALI_POS.Y	The position of tool presetter in fixed tool measurement (Y-axis)	DOUBLE	The mechanical coordinate of the position where tool presetter stands (Y-axis) in fixed tool measurement
18	FIXEDCALI_POS.Z	The position of tool presetter in fixed tool measurement (Z-axis)	DOUBLE	The mechanical coordinate of the position where tool presetter stands (Z-axis) in fixed tool measurement
19	ENABLE_CTP	Back to fixed point valid	BOOL	Back to fixed point after the program ends normally.
20	CTP_POS.X	The position of fixed point (X axis)	DOUBLE	Mechanical coordinate of fixed point（X axis）
21	CTP_POS.Y	The position of fixed point (Y axis)	DOUBLE	Mechanical coordinate of fixed point（Y axis）
22	CTP_POS.Z	The position of fixed point (Z axis)	DOUBLE	Mechanical coordinate of fixed point（Z axis）
23	BKREF_SW1.X	Port no. input of X-axis coarse positioning switch	INT	The signal port input of X-axis coarse positioning switch
24	BKREF_SW1.Y	Port no. input of Y-axis coarse positioning switch	INT	The signal port input of Y-axis coarse positioning switch
25	BKREF_SW1.Z	Port no. input of Z-axis coarse positioning switch	INT	The signal port input of Z-axis coarse positioning switch
26	BKREF_SW2.X	Port no. input of X-axis fine positioning switch	INT	The signal port input of X-axis fine positioning switch
27	BKREF_SW2.Y	Port no. input of Y-axis fine positioning switch	INT	The signal port input of Y-axis fine positioning switch
28	BKREF_SW2.Z	Port no. input of Z-axis fine positioning switch	INT	The signal port input of Z-axis fine positioning switch
29	BKREF_F1.X	The speed at the coarse positioning stage (X-axis)	DOUBLE	The feed speed of X-axis in coarse positioning stage when backing to the reference point

No.	Parameter	Parameter Name	Type	Remarks
30	BKREF_F1.Y	The speed at the coarse positioning stage (Y-axis)	DOUBLE	The feed speed of Y-axis in coarse positioning stage when backing to the reference point
31	BKREF_F1.Z	The speed at the coarse positioning stage (Z-axis)	DOUBLE	The feed speed of Z-axis in coarse positioning stage when backing to the reference point
32	BKREF_F1_DIR.X	The direction in coarse positioning stage (X-axis)	INT	The moving direction of X-axis in coarse positioning stage when backing to the reference point
33	BKREF_F1_DIR.Y	The direction in coarse positioning stage (Y-axis)	INT	The moving direction of Y-axis in coarse positioning stage when backing to the reference point
34	BKREF_F1_DIR.Z	The direction in coarse positioning stage (Z-axis)	INT	The moving direction of Z-axis in coarse positioning stage when backing to the reference point
35	BKREF_F2.X	The speed of X-axis in fine positioning stage	DOUBLE	The feed speed of X-axis in fine positioning stage when backing to the reference point
36	BKREF_F2.Y	The speed of Y-axis in fine positioning stage	DOUBLE	The feed speed of Y-axis in fine positioning stage when backing to the reference point
37	BKREF_F2.Z	The speed of Z-axis in fine positioning stage	DOUBLE	The feed speed of Z-axis in fine positioning stage when backing to the reference point
38	BKREF_F2_DIR.X	The direction of X-axis at the fine positioning stage	INT	The moving direction of X-axis in fine positioning stage when backing to the reference point
39	BKREF_F2_DIR.Y	The direction of Y-axis at the fine positioning stage	INT	The moving direction of Y-axis in fine positioning stage when backing to the reference point
40	BKREF_F2_DIR.Z	The direction of Z-axis at the fine positioning stage	INT	The moving direction of Z-axis in fine positioning stage when backing to the reference point
41	BKREF_BACK.X	The retract distance of X-axis	DOUBLE	The additional moving distance of X-axis after fine positioning stage during backing to the reference point
42	BKREF_BACK.Y	The retract distance of Y-axis	DOUBLE	The additional moving distance of Y-axis after fine positioning stage during backing to the reference point
43	BKREF_BACK.Z	The retract distance of Z-axis	DOUBLE	The additional moving distance of Z-axis after fine positioning stage during backing to the reference point
44	CALIBRATION_SW	Port no. input of tool calibration signal	INT	Specifying port no. input of tool calibration signal
45	SPINDLE_START_PORT	Port no. output of spindle	INT	Specifying port no. output of signal for spindle on/off
46	COOLANT_START_PORT	Output port no. for coolant liquid pump	INT	Specifying the output port no. of signal for coolant on/off

No.	Parameter	Parameter Name	Type	Remarks
47	DD_BKREF_DELTA	MO difference between double-driving shaft (MO: Machine Origin)	DOUBLE	The difference between the double-driving shafts when they arrive the machine origin after the adjustment of the transom (Y-axis), (only used in the double-drive configuration)
48	FIXEDCYCLE_BACK	G73_G83 retract amount	DOUBLE	The retract amount after each peck in high speed deep hole chip breaking drilling cycle
49	FIXEDCYCLE_OSS	The direction of G76_G87 oriented spindle stop	INT	Orientation is only effective within X-Y plane (G17) 0/1:(G17:+X/-X)
50	FIXEDCALI_REC	Z-axis workpiece coordinate in fixed tool measurement	DOUBLE	Recording the Z-axis workpiece coordinate of tool nose when it touches the tool presetter in fixed tool measurement

6 Customize and Extend Command M

The user can customize command M and G code by writing subprograms in public.dat.

Subprogram no. 200~999 is used by internal interpreter engine. The code range of command M is 200~599, while that of G code is 600~999.

As a result, command M 0~99 plus 200 is regarded as the corresponding subprogram, while G code 0~99 plus 600 is regarded as the corresponding subprogram.

Program Example for Custom and Extended M Command:

```
’Conditional statement “if” can be used to set the actions (like gear shift) during spindle rotating
O202
M17
’spindle CW (only one direction supported)
O203
M901 H2 P1
G04 P5
M17
’spindle CCW (only one direction supported)
O204
M901 H2 P1
G04 P5
M17
’spindle stop
O205
M901 H2 P0
G04 P5
M17
’coolant on
O208
M901 H24 P1
G04 P5
M17
’coolant off
O209
M901 H24 P0
G04 P5
M17
```

7 PLT Support

At present, the system supports PLT instructions as below:

```
//PU    Pen Up
//      PU [ X,Y [,...]] [;]

//PD    Pen Down
//      PD [ X, Y [,...]] [;]

//PA    Plot Absolute
//      PA [X, Y [,...]] [;]

//PR    Relative Coordinate Pen Move
//      PR [X, Y [,...]] [;]

//AA    Absolute Arc Plot
//      AA X, Y, qc [, qd] [;]

//AR    Relative Arc Plot
//      AR X, Y, qc [, qd] [;]

//CI    Circle
//      CI r [, qd] [;]

//EA    Edge Absolute Rectangle
//      EA X, Y [;]

//ER    Edge Relative Rectangle
//      ER X, Y [;]

//EW    Edge Wedge
//      EW r, q1, qc (, qd) [;]
```

Besides, PA, PR, PU, PD also support three-dimensional instructions.

Notes:

PLT format has strong expansibility and different products have different instructions. If you meet unidentifiable instructions, please contact us as soon as possible, so that we can develop a corresponding interpreter for you.

8 DXF Support

At present, the system supports Entities as below:

LINE
LWPOLYLINE
ARC
CIRCLE
ELLIPSE
SPLINE

Prompt:

Save the figure drawn with Auto CAD as DXF format, and then perform “Open and Load” and “Simulation Mode” in our system. At this time, the figure shown in the track window is what you have drawn with Auto CAD.

RMB: 21.00