NcStudio Programming Manual

6th Edition

Weihong Electronic Technology Co., Ltd.

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Preface

About This manual

This manual introduces about CNC programming and the commands involved in programming. You can learn better about NcStudio programming system and prepare for programming after reading this manual.

With four chapters, this manual can be divided into three parts, as follows:

1) Part 1: chapter 1.This chapter gives general description to CNC programming and CNC machine tool.
2) Part 2: chapter 2 and 3. This part gives introduction to programming structure and programming command system.
3) Part 3: chapter 4. This part gives introduction to other info about programming system.

Revision History

You can refer to the following table for the revision records of each edition.

Date	Edition	Revision
2016.03	R6	1) Command index added; 2) Illustrations updated; 3) Chapter 3 updated; 4) Document structure updated.

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Precautions

Precautions can be divided into caution and warning according to the degree of possible loss or injury in case of negligence or omission of precautions stipulated in this manual.

CAUTION: general info, mainly for informing, such as supplementary commands and conditions to enable a function. In case of negligence or omission of this kind of precautions, you may not activate a function. Note that in some circumstances, negligence or omission of this kind of precautions could cause physical injury or machine damage.

WARNING: warning info requiring special attention. In case of negligence or omission of this kind of precautions, you may suffer physical injury, or even death, machine damage or other losses.

Table of Contents

Index of Commands

1 CNC Programming and Machine Tool

1.1 An Overview of CNC Programming

1.1.1 Definition of Machine Program

Composed of a series of commands in CNC programming language, a machine program is translated into motion actions to control the machine tool by CNC device. The most commonly used storage mediums for machine programs are punched tape and disk.

1.1.2 Creation of Machine Program

As shown in Fig. 1-1, a machine program can be created with traditional manual programming or CAD/CAM application, such as the popular MasterCAM application.

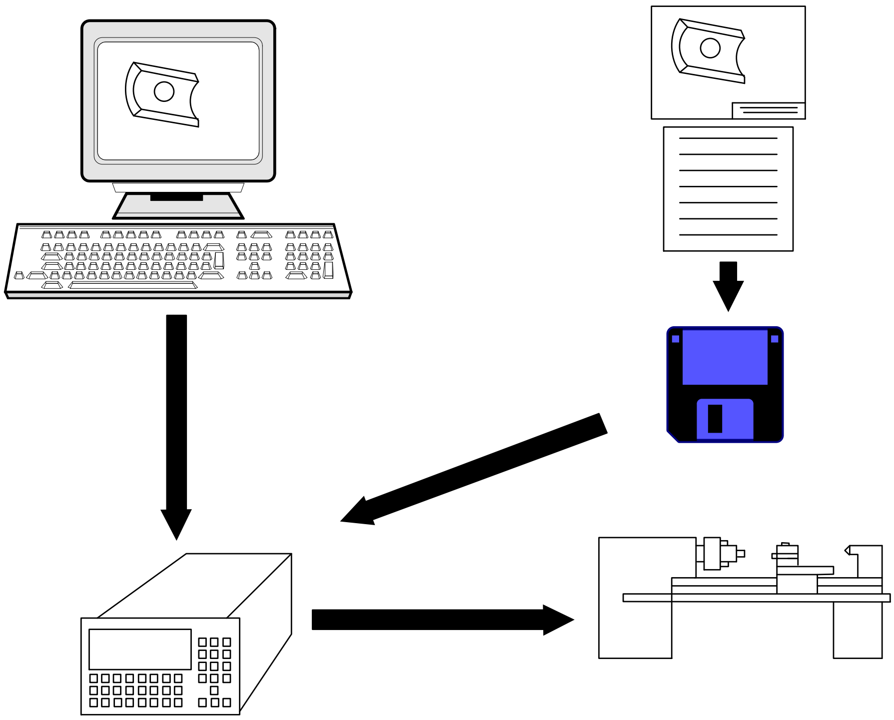


Fig. 1-1 Creation of a Machine Program

1.2 An Overview of CNC Machine Tool

1.2.1 Machine Tool Coordinate Axes

- **Basic Coordinate Axes**

To simplify programming and to 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 to as basic coordinate axes. The correlation of X, Y and Z axes is determined by the Right-hand Rule, as shown in Fig. 1-2. The thumb points in the +X direction, the index finger points in the +Y direction, and the middle finger points in the +Z direction.

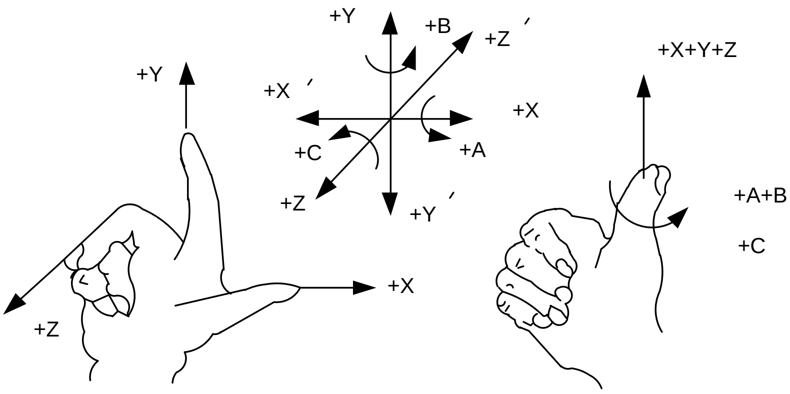


Fig. 1-2 Machine Coordinate Axes

- **Rotary 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 single quote ’. 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 direction of Machine Coordinate Axes**

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 you face 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 the Right-hand Rule.

1.2.2 Machine Origin(OM) and Machine Reference Point(Om) 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 position of machine origin can't be determined when a CNC device is powered on, and the mechanical stroke of each coordinate axis is limited by maximum and minimum limit switch.

To set MCS correct during machining, we normally set a machine reference point (the initial point of measurement) within the stroke range of each coordinate axis. After starting the machine, it is necessary to back to reference point manually or automatically so as to create the MCS. The reference point can coincide with machine origin or not. If not, the distance from machine reference point to machine origin can be set through the relevant parameters. After the machine returns to the reference 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 limits.

The relationship between machine origin (OM), machine reference point (Om), the mechanical stroke and valid stroke of MCS is as shown in Fig. 1-3.

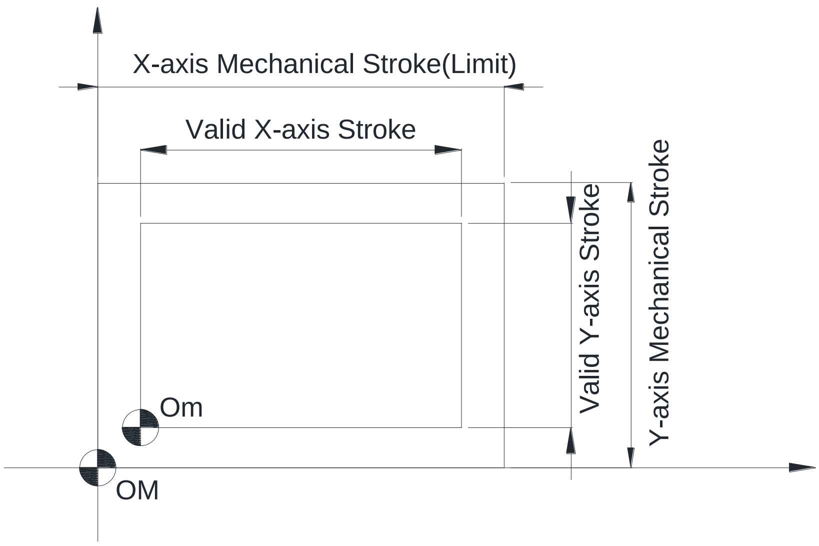


Fig. 1-3 Machine Origin OM and Machine Reference Point Om

2 Structure of Machine Program

A machine program is a group of commands 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. 2-1 for program structure.

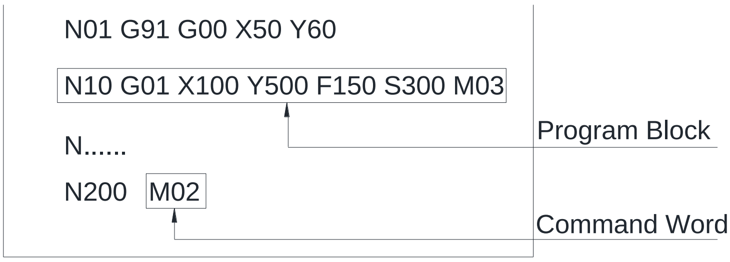


Fig. 2-1 Structure of Machine Program

2.1 Address Symbols

Address symbols and their description are shown as follows.

Address Symbol	Description	B (Basic Function)	O (Optional Function)
D	Tool radius offset	●	●
F	Feedrate	●	
G	Preparatory commands	●	●
H	Tool length offset	●	
I	X-axis coordinate of arc center	●	●
J	Y -xis coordinate of arc center	●	●
K	Z-axis coordinate of arc center	●	
L	Repetition count	●	●
M	Miscellaneous Function	●	
N	Sequence no. or block no.	●	
O	Program no.	●	
P	Dwell time in milliseconds, subprogram No. call, custom macro No. call, block number in main program	●	●
Q	Depth of peck in fixed cycles Shift amount in fixed cycle		●
R	Retract point in fixed cycles Arc radius designation	●	●

Address Symbol	Description	B (Basic Function)	O (Optional Function)
S	Spindle speed	●	
T	Tool function	●	
X	X-axis coordinate	●	
Y	Y-axis coordinate	●	
Z	Z-axis coordinate	●	

2.2 Format of Program Block

A program block defines a command line 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. 2-2.

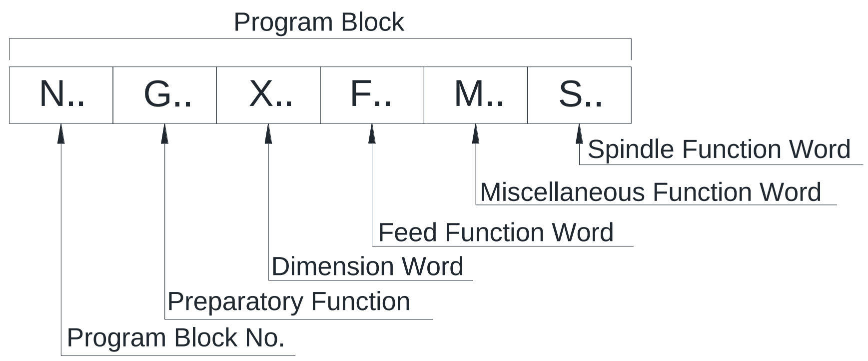


Fig. 2-2 Format of Program Block

2.3 Format of Subprogram

A subprogram is a section of machining command 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. Below is an example of a subprogram.

```
O9999
G91 G1X100
Y50
X-100
Y-50
G90
M17
```

3 Programming Command System

3.1 Spindle Function S

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.

CAUTION

Even though the spindle is off, the value of S remains.

3.2 Feedrate F

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 knob on the operation panel, F can be adjusted between feedrate percent 0% ~ 120%.

Command F functions differently when collocated with different commands:

1) Command G00 specifies the rapid traverse speed, modal for the current machining procedure.
2) Command G01~G03 specify the feed speed, modal for the current machining procedure.

3.3 Tool Function T

Format: T_

Description:

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

When a machining center runs T command, tool magazine will rotate to select the required tool.

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

3.4 Miscellaneous Function M

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

M function has non-modal and modal forms:

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

M commands and meanings are shown in the table below.

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

3.5 Preparatory Function G

Preparatory function G is composed of address word G and 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 non-modal and modal forms:

1) Non-modal G function: only effective in the specified program block, and cancelled at the end of program block.
2) Modal G function: a group of G functions that can be cancelled mutually; a G function remains effective until another G function in the same group appears to cancel it.

3.5.1 Commands Related to Coordinate Systems and Coordinates

- **G90: Absolute Programming**
- **G91: Incremental Programming**

Format: G90/G91

Description:

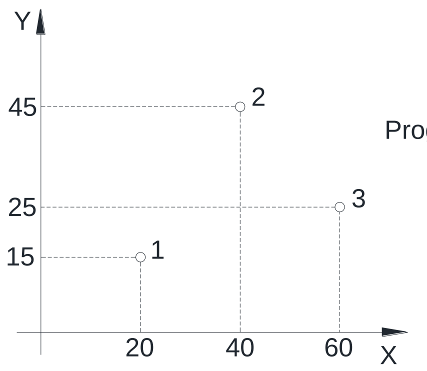
G90: it denotes absolute programming; the programming value on each programming coordinate axis is with respect to the origin of current WCS.

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 they can be mutually cancelled. They cannot be used in the same program block. For example, G90 G91 G0 X10 is not allowed.

Programming Example:

As shown in Fig. 3-1, programming with G90, G91 to make the tool move in sequence from origin to point 1, 2, and 3.



Programming with G90

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

Programming with G91

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

Fig. 3-1 Programming with G90/G91

Selecting the right programming 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 Workpiece Coordinate System**

Format: G92 X_Y_Z_

Description:

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

A program is written based on WCS and begins with the tool initial 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 tool initial point in the MCS.

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

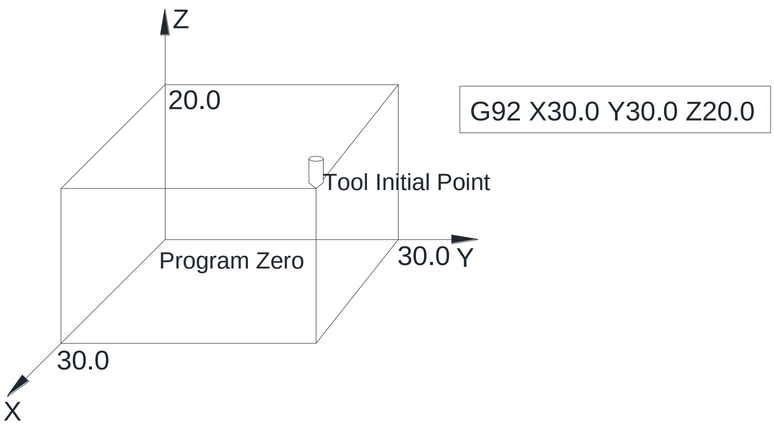


Fig. 3-2 Setup of Workpiece Coordinate System

Programming Example:

Programming with command G92 to create a WCS is as shown in Fig. 3-2.

The execution of the program block only creates a WCS without tool movement.

As a non-modal command, G92 is usually put in the first block of a machine program to create a WCS and synchronously offset origins of other WCSs, which can be used to adjust the length of tool holder.

- **G921: Specify the Worpiece Coordinates of Current Ppoint**

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; the setting is valid only for the current WCS.

Command G921 can be used for measuring the surface, center or boundary of workpiece.

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

Format: G922 X_Y_Z_P_

Description:

X_Y_Z_: offset values

P_: offset type. -4: public 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.

Command G922 can be used for measuring the surface, center or boundary of workpiece.

- **G28: Auto Back to Reference Point**

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. 3-3.

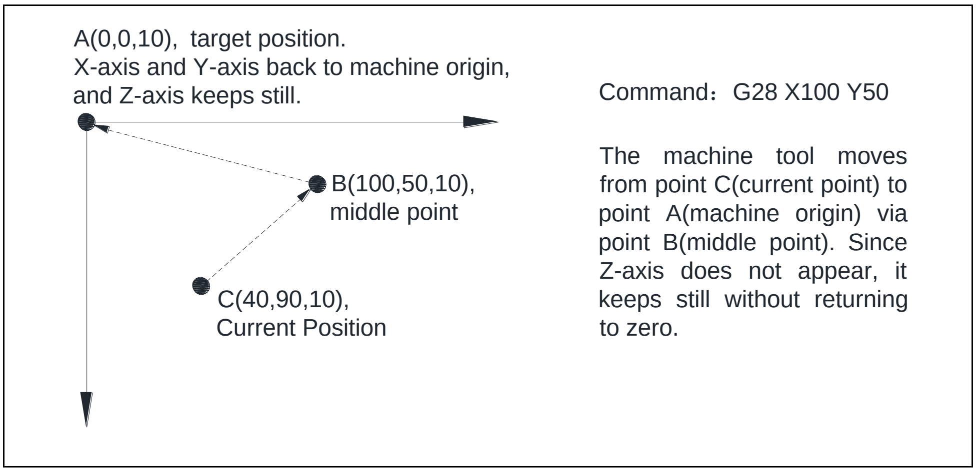


Fig. 3-3 Back to Reference Position

- **G992: Set Temporary WCS**

Format: G992 X_Y_Z_; G992 I_J_K_

Description:

The function of command G992 is similar to that of command G92. The difference between the two is: command G92 alters the WCS permanently and takes the same standard to the whole system, while command G992 alters the WCS temporarily and only influences the coordinate parsing of processing command, which will be restored automatically after machining is completed.

The command can be used for realizing array function. The methods are as follows.

Method one:

```
G992 X_Y_Z_
1. Delete command M30 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 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 command M30 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
```

As shown above, array machining can be realized through programming with command G992. The first 4 parameters, i.e., #1=30, #2=40, #3=30, and #4=30, can be adjusted and customized.

CAUTION

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

- **G54~G59: Selection of WCS**

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

Description:

G54~G59 are 6 default WCSs in the system (as shown in Fig. 3-4). You can select one according to your needs.

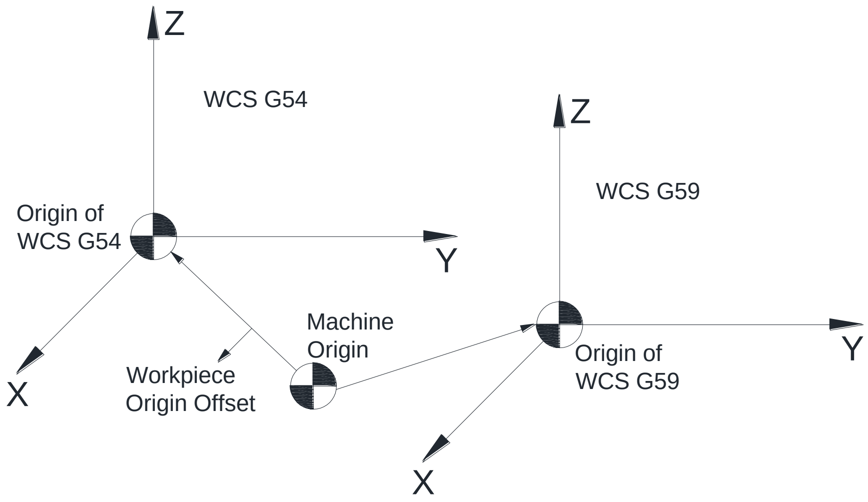


Fig. 3-4 Selection of Workpiece Coordinate System (G54~G59)

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.

CAUTION

1) Once a WCS is confirmed, the following command values in absolute programming are all relative to the origin of WCS.
2) G54~G59 are modal functions, which can be mutually cancelled. G54 is the default.

Programming Example:

As shown in Fig. 3-5, programming based on WCS to make the tool move from current point to point A, and then to point B.

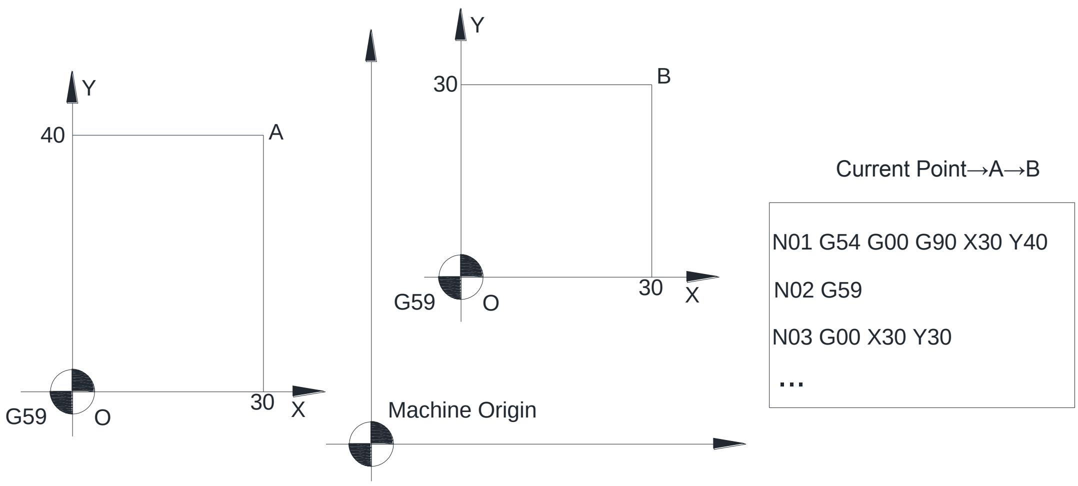


Fig. 3-5 Programming Based on Workpiece Coordinate System

CAUTION

Set the coordinate value of each WCS origin in the MCS before using this group of commands shown in Fig. 3-5.

- **G53: Machine Coordinate System**

Format: G53

Description:

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

- **G17/G18/G19: Selection of Coordinate Plane**

Format: G17/G18/G19

Description:

G17: select XY plane

G18: select ZX plane

G19: select YZ plane

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

G17 (default), G18 and G19 are modal functions (as shown in Fig. 3-6), which can be mutually cancelled.

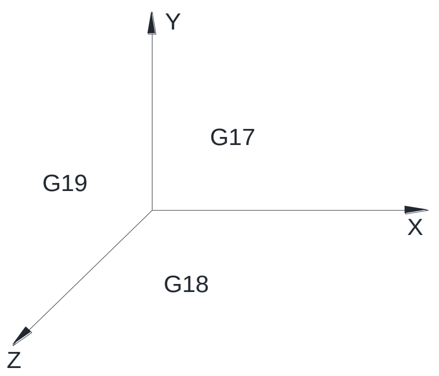


Fig. 3-6 Selection of Coordinate Plane

- **G20/G21 OR G70/G71: Input in Inch/Metric**

Format: G20/G21/G70/G71

Description:

G20/70: input in inch;

G21/71: input in metric.

This group of G commands 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**

Format: G51 X_Y_Z_P_; G51 X_Y_Z_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. Only one of P_ or I_J_K_ can appear in the same program block.

Workpiece contour that is written in the machine program can be reduced or enlarged to scale. G51 is scaling on, while G50 is scaling off. G50 is default.

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.

CAUTION

When using the scaling command, pay attention to the following points.

1) Don't set the scale factor as 0, otherwise an alarm will appear;
2) Scaling function has no effect on compensation value;
3) When executing tool radius compensation C, the scaling command G51 can't be specified;
4) A canned cycle cannot be executed together with the scaling of Z-axis. If so, an alarm will appear;
5) Command G28, G29, G53, and G92 cannot be used in the execution process of scaling function, otherwise the outcome may contain an error;
6) If there is G51 in the program without G50, the scaling function will be automatically closed at the end of the program.

Programming Example:

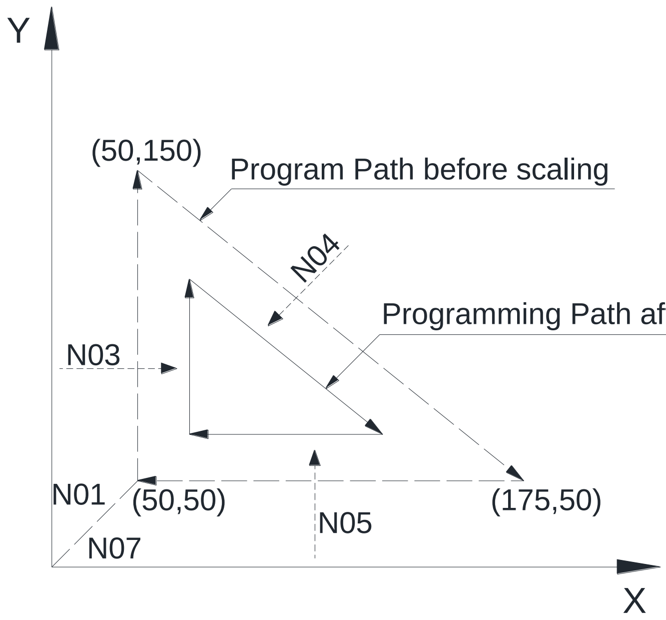


Fig. 3-7 Sketch of Scaling Function

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

- **G68/G69: Rotation Function**

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 command can be used for rotary machining during contour machining. It makes the specified machining contour rotate 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 always constant. When the watch is swiveling in XY plane, the coordinate of Z-axis remains constant; in YZ plane, the coordinate of X-axis remains constant; and in ZX plane, the coordinate of Y-axis remains constant.

Programming example 1:

```
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. 3-8.

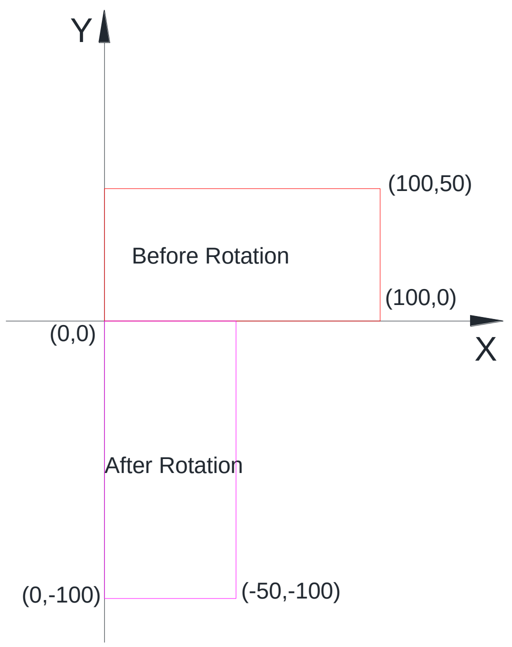


Fig. 3-8 Sketch of Rotation Processing

The command can also be nested as follows.

Programming example 2:

```
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 subsequent rotation command. The subsequent rotation center is not the one in the machine program, but the position after transformation due to the previous rotation.

The function of G69 is to cancel the previous rotation command. In the program mentioned above, line C' cancels G68 of line C, line B' G68 of line B, and line A' G68 of line A. If G69 is 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 actual outcome is as shown in Fig. 3-9.

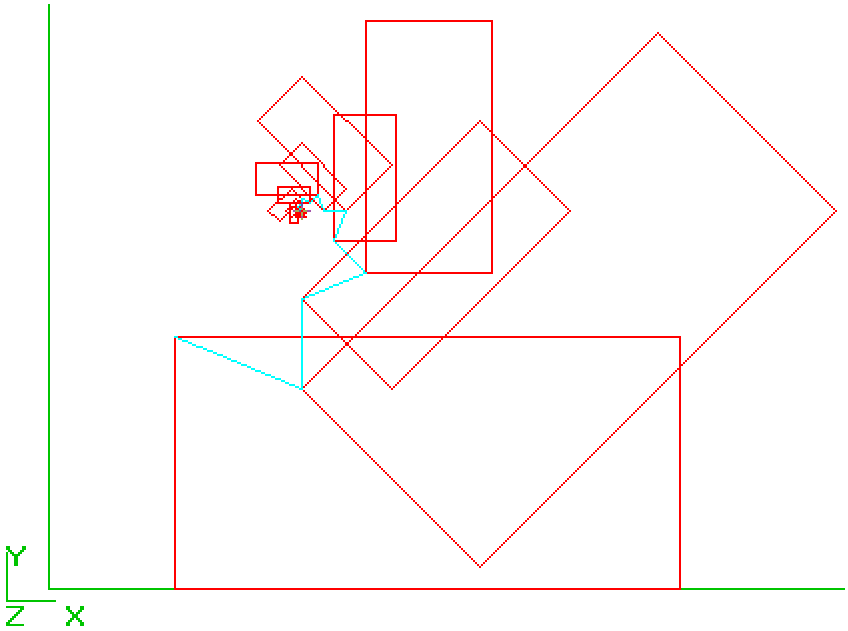


Fig. 3-9 Processing Outcome after Rotation

- **G50.1/G51.1: Mirroring Function**

Format:

G51.1 X_Y_Z_; G50.1 X_Y_Z_

Description:

X_Y_Z_: For G51.1, specifying mirroring center; for G50.1, specifying the axes disabled of mirroring function.

The command indicates machining the mirror image of machining contour. G51.1 denotes mirror image on and G50.1 mirror image 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 axes disabled of mirroring 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.

3.5.2 Feed Control Commands

- **G00: Rapid Positioning**

Format: G0 X_Y_Z_; G00 X_Y_Z_

Description:

G00: rapidly positioning the tool, but not machining the workpiece. It can simultaneously perform rapid movement in several axes to produce a linear track. During analyzing command, if there is any motion in Z-axis, the motion will be resolved into motion in Z-axis and in plane to ensure safe movement. If the motion is Z-axis upward, motion in Z-axis should be before motion in plane, otherwise, motion in plane before motion in Z-axis.

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

G00 is valid until replaced by other G commands (G01, G02, G03…).

Programming Example:

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

- **G01: Linear Interpolation**

Format: G1 X_Y_Z_ ; G01 X_Y_Z_

Description:

G01 provides linear motion from point-to-point at specified 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 valid until replaced by other G commands (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 speed 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**

Format: G02 X_Y_Z_R_F_; G02 X_Y_Z_I_J_K_F_

G03X_Y_Z_R_F_; G03 X_Y_Z_I_J_K_F_

Description:

The commands are used to move a tool along a circular arc to the specified position at specified feed speed. G02 denotes clockwise interpolation, while G03 denotes 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 valid until replaced by other G commands (G00, G01 …).

Circular programming can be radius programming or centre programming. The function word of radius is R. There are two types of arcs with the same start point, end point, radius and rotary direction. When R is negative, an arc is larger than a semicircle (i.e. a major arc); when positive, an arc is smaller than or equal to a semicircle (i.e. a semicircle or a minor arc). 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 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.

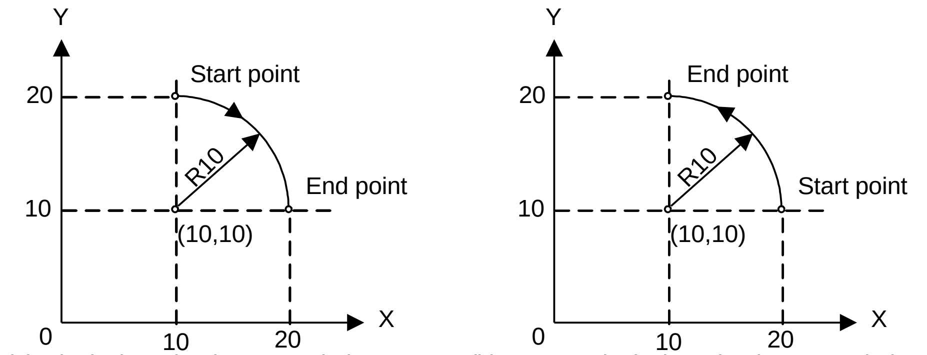
Helical interpolation is available by specifying another axis in a linear command at the same time to move synchronously with circular interpolation.

CAUTION

1) When R>0, the radius angle is smaller than 180° ; When R<0, the radius angle is larger than 180° .
2) Radius programming cannot be used for a whole circle programming, and the circle must be divided into two parts in radius programming.

Programming Example 1:

Clockwise and counterclockwise circular interpolation, as shown in Fig. 3-10.



(a) Clockwise Circular Interpolation (b) Counterclockwise Circular Interpolation

Fig. 3-10 Clockwise and Counterclockwise Circular Interpolation

For Fig. 3-10(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. 3-10(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
```

Programming Example 2:

A full circle interpolation is as shown in Fig. 3-11.

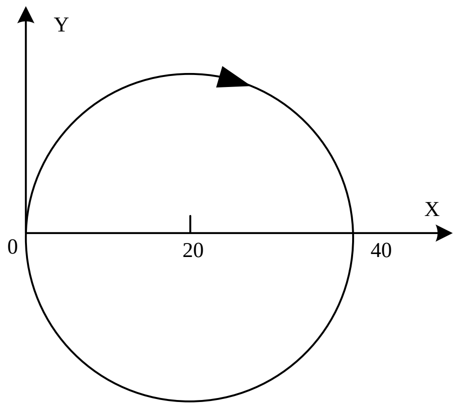


Fig. 3-11 A Full Circle Interpolation

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 3:

Helical programming in G03 is as shown in Fig. 3-12.

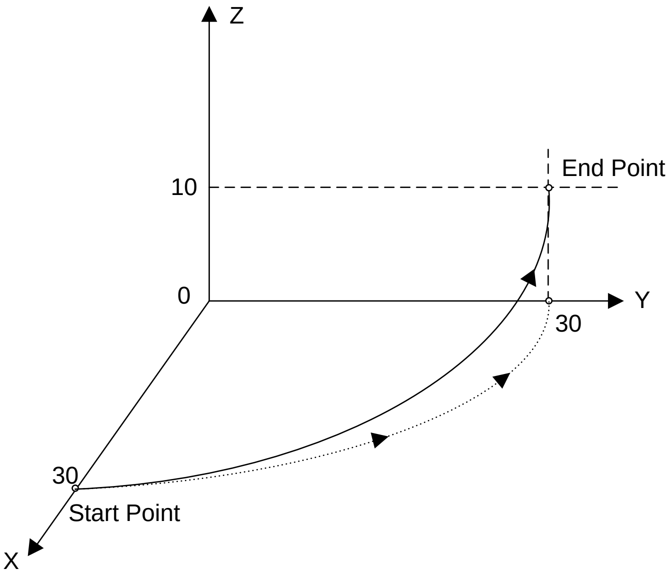


Fig. 3-12 Helical Programming

Programming with command G91,	Programming with command G90,
G00 X30 Y0 G91 G17 F300 G03 X-30 Y30 R30 Z10	G00 X30 Y0 G90 G17 F300 G03 X0 Y30 R30 Z10

- **G04: Dwell**

Format: G04 P_

Description:

P_: the dwell time, with unit “ms”.

G04 can be used in the following situations:

1) In machining a corner, the dwell command can be used to guarantee a sharp corner.
2) In machining a not through hole, when the tool 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 retracting tool to make sure the spindle rotates at least one circle.
5) In 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 takes 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. For example, in free cutting, and dwell time is specified by P function word with unit as “ms”.

Programming Example:

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

3.5.3 Tool Command

- **G40/G41/G42: Tool Radius Compensation**

Format: G41 D_; G42 D_; G40

Description:

G40: cancel tool radius compensation

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

G42: right tool compensation (the tool offsets radius distance on the right side of tool 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 tool radius compensation planes must be executed when compensation is canceled.

Only command G00 or G01, instead of G02 or G03, can be used to establish and cancel tool radius compensation.

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

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

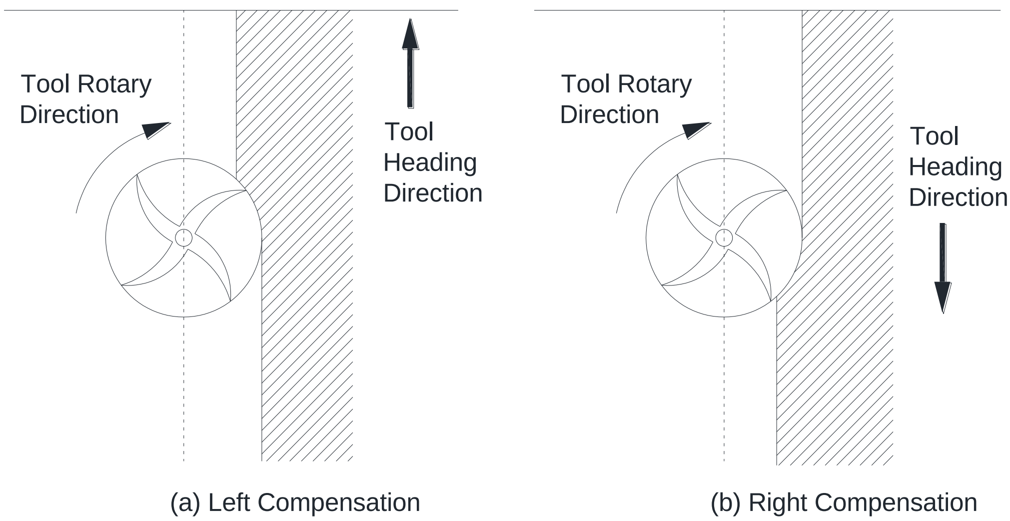


Fig. 3-13 Tool Compensation Direction

Programming Example:

The schematic diagram od tool radius compensation is as shown in Fig. 3-14.

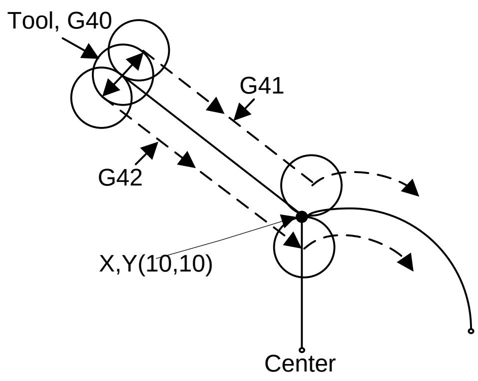


Fig. 3-14 Tool Radius Compensation

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

CAUTION

During compensation or when compensation is canceled, the current tool moving direction cannot be opposite to the previous one.

For example:

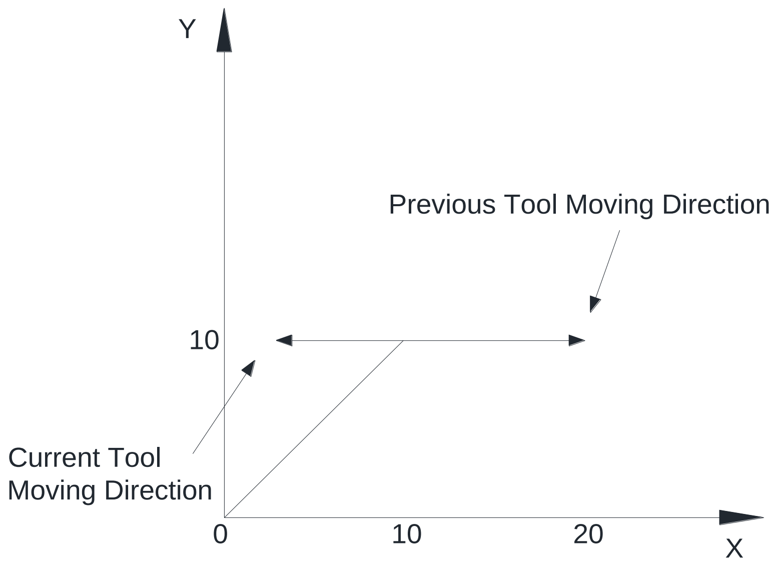


Fig. 3-15 Schematic Diagram of Tool Moving Direction

Program 1

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

Program 2

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

G0 G40 X0 Y10	G0 G40 X0 Y0

Program 1 is wrong because the tool moving direction is opposite to the previous one, while program 2 is correct.

- **G43/G44/G49: Tool Length Compensation**

Format: G43 H_; G44 H_; G49

Description:

G49: cancel tool length compensation

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 in 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 coordinate value of Z-axis.

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

Programming Example:

See Fig. 3-16 for tool length compensation.

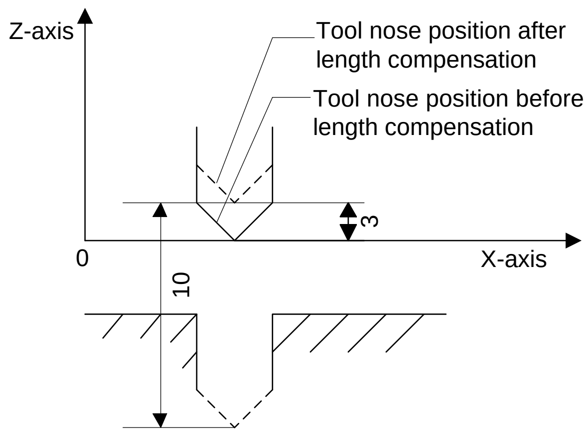


Fig. 3-16 Tool Length Compensation

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

- **G923: Directly Set Tool Offset**

Format: G923 X_Y_Z_ P_

Description:

Set tool offset value for the specified tool; axes unlisted will not be modified.

P_: tool No. For example: “G923 Z 2.392 P1” indicates the tool offset value of tool No.1 is 2.392. If P is omitted, it indicates setting tool offset value for the current tool.

Programming Example: (the tool 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
```

3.6 Canned Cycle

3.6.1 Overview of Canned Cycle

The canned cycles of CNC mills are mainly used in hole machining, including drilling, boring and tapping. With one program block, you can accomplish one or a full set of hole machining operation. In continued 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 canned cycle commands is shown in the following table.

G Command	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 rotates 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 rotates 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

G Command	Drilling operation	Operation at bottom of hole	Retraction operation	Application
*G88	Cutting feed	Dwell, then spindle stop	Manual displacement	Semi-automatic fine boring cycle
G89	Cutting feed	Dwell	Cutting feed	Boring cycle of dwell at bottom of hole

CAUTION

Command G76, G87, and G88 are not supported currently.

3.6.2 Operations in Canned Cycle

Generally speaking, canned cycle of hole machining is composed of six operations, as shown in Fig. 3-17.

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

Operation 2: rapid traverse to point R—the tool 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, tool displacement, and so on.

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

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

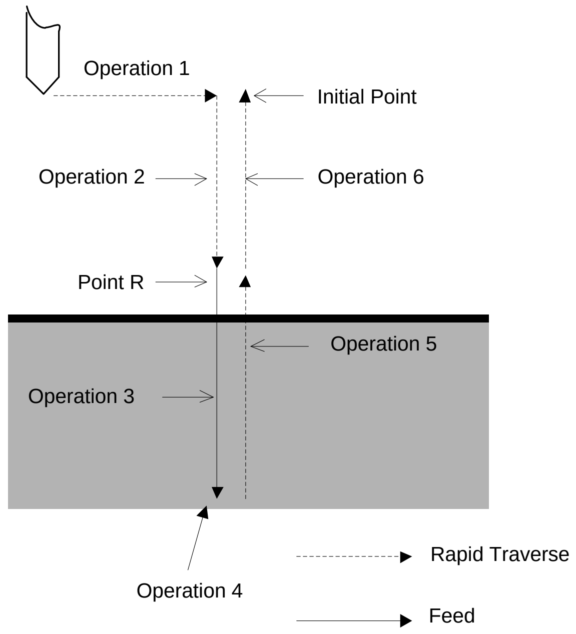


Fig. 3-17 Operation Sequence of Canned Cycle

- **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 tool 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, varies with the dimension of workpiece surface.

- **Hole Bottom Plane**

In machining a blind hole, hole bottom plane is Z-axis height at the bottom of hole. In machining a through hole, the tool usually goes beyond the hole bottom a certain distance to make sure all holes are machined to the specified depth. In 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 commands (G17, G18, and G19). Whichever plane is selected, the tool is positioned in XY plane and drilling in Z-axis direction in hole machining.

3.6.3 Overview of Canned Cycle Commands

- **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. 3-18).

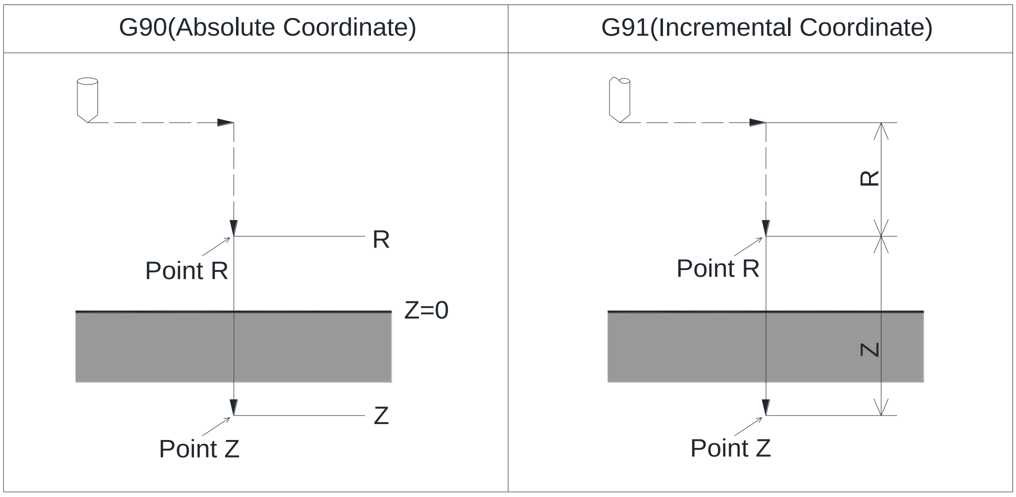


Fig. 3-18 Canned Cycle

- **Gxx: Hole Machining Mode**

The format of hole machining mode command is as shown below:

Gxx X_Y_Z_R_Q_P_F_K_;

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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. In G91 mode, with setting this parameter, one block can implement the machining of several isometric holes distributed in one straight line. In 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 effective 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, such as hole depth, of a certain hole is changed, you only need to modify this data.

Command G80 is used to cancel hole machining mode. If any G command 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 command of Group 01 functions the same.

3.6.4 Detailed Canned Cycle Commands

- **G73: High-speed Peck Drilling Cycle for Deep Holes**

Format: G73 X_Y_Z_R_Q_ F_ K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z at the bottom of hole in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in incremental programming.

Q_: the cutting depth each time (incremental and positive, minus sign 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.

Hole-machining process is as shown in Fig. 3-19. It is easy to break and remove chips by intermittent feeding in Z-axis. Q specifies the cutting depth each time, The "δ" here, specified by parameter "G73_G83 retract amount", refers to the distance between the feed plane where the tool changes from G00 to Gxx and the previous cutting depth.

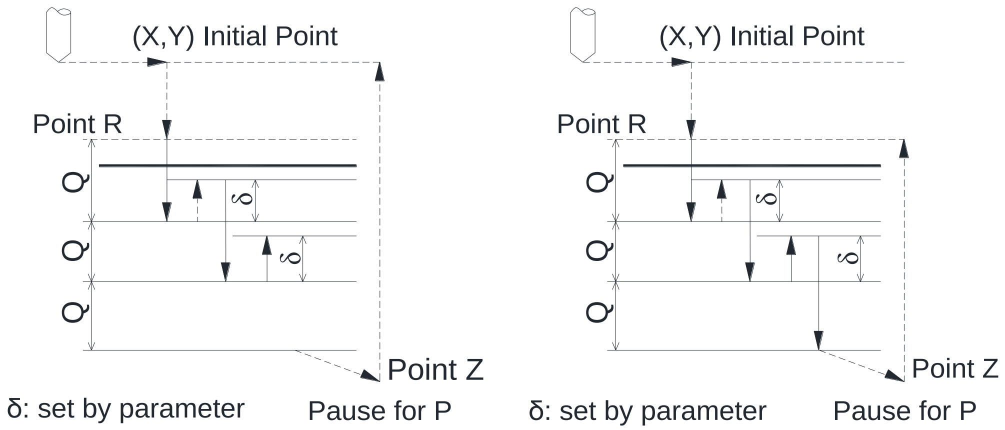


Fig. 3-19 G73 Machining Process

Description of machining process:

1) The tool moves rapidly to the specified hole position (X, Y);
2) The tool moves to point R;
3) The tool moves down cutting depth Q relative to the present drilling depth;
4) The tool moves rapidly upward retract distance δ (specified by parameter "G73_G83 retract amount");
5) The tool repeats the above drilling operations until reaching point Z at the bottom of hole;
6) The tool returns to the initial point (G98) or point R (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 per 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 'spindle stop
M02
```

- **G74: Left Tapping Cycle**

Format: G74 X_Y_Z_R_P_F_K_;

Description:

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

Z_: the position of point Z at the bottom of hole in absolute programming or the distance from point R to point Z at the bottom of hole in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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.

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

Hole-machining process is as shown in Fig. 3-20. In G98, the tool will return to the initial point after hole-machining is finished. But in G99, the tool will return to point R after hole-machining is finished.

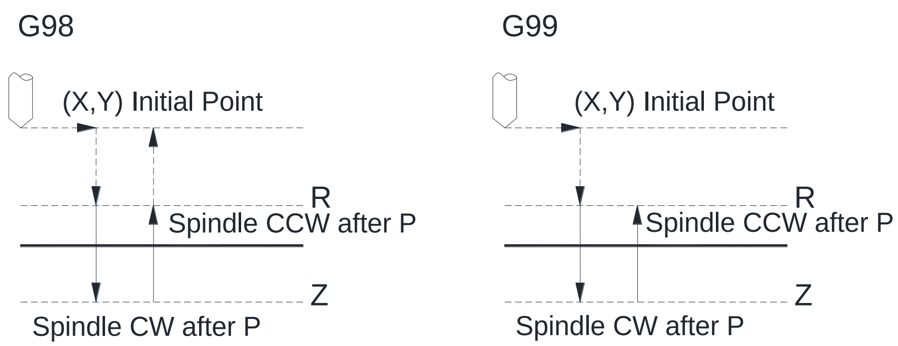


Fig. 3-20 G74 Machining Process

Description of machining process:

1) The tool moves to the specified hole position (X, Y) at G00 speed;
2) The tool goes down to the specified point R at G00 speed;
3) The tool taps down to point Z at the bottom of the hole at G01 speed;
4) The spindle rotates CW after P;
5) The tool returns to point R at G01 speed;
6) The spindle rotates CCW after P;
7) The tool returns to the initial point (G98) or point R (G99) at G00 speed.

Programming Example:

```
F1200 S600
G90
G00 X0 Y0 Z10 'moving to the initial point.
G17
M04 'spindle 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 'spindle stop
M02
```

- **G76: Fine Boring Cycle**

This command is not supported at the moment.

Format: G76 X_Y_Z_R_Q_P_F_K_;

Description:

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

Z_: the position of point Z at the bottom of the hole in absolute programming or the distance from point R to point Z at the bottom of the hole in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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 in G91 incremental mode)

Hole machining process is as shown in Fig. 3-21.

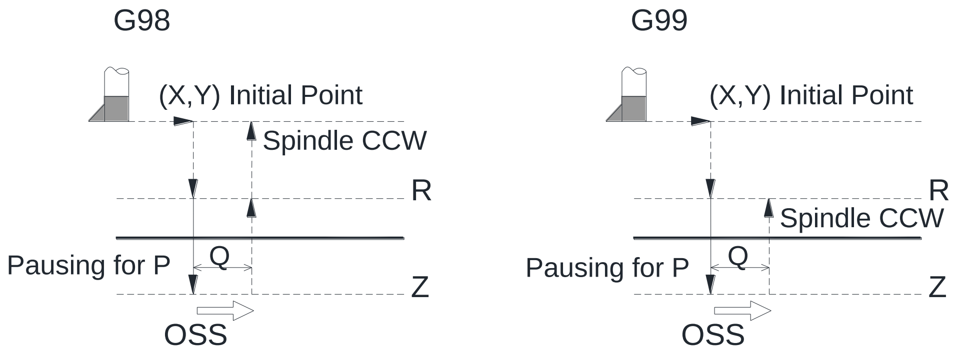
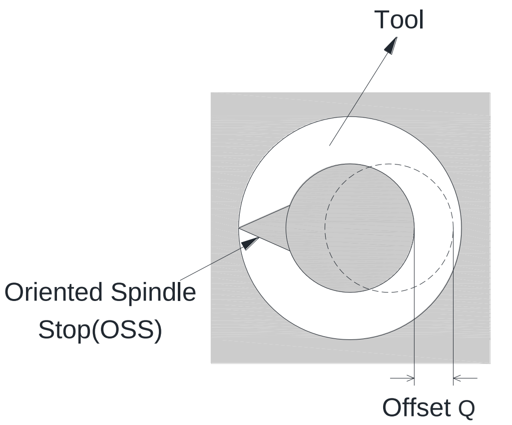


Fig. 3-21 G76 Machining Process



OSS (Oriented Spindle Stop) direction is specified by 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

Fig. 3-22 Oriented Spindle Stop (OSS) Demonstration

Description of machining process:

1) The tool moves to the specified hole position (X, Y) at G00 speed;
2) The tool moves down to the specified point R at G00 speed without spindle orientation;
3) The tool moves down to the point Z at the bottom of the hole at G01 speed, after P, oriented spindle stop executed;
4) The tool shifts cutting depth Q(the offset distance);
5) The tool returns to the initial point (G98) or point R (G99) at G00 speed;
6) The spindle rotates CCW.

WARNING

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

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 'spindle stop
M02
```

- **G81: Drilling Cycle**

Format: G81 X_Y_Z_R_F_ K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z at the bottom of hole in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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 increment mode)

Hole machining process is as shown in Fig. 3-23. G81 is used for general drilling.

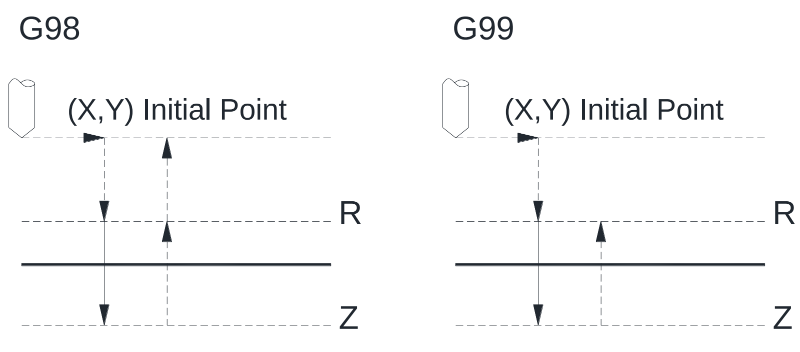


Fig. 3-23 G81 Machining Process

Description of Machining Process:

1) The tool moves to the specified hole position (X, Y) at G00 speed;
2) The tool moves down to the specified point R at G00 speed;
3) The tool moves down to point Z at the bottom of the hole at G01 speed;

4) The tool retracts to the initial point (G98) or point R (G99) at G00 speed.

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 X5Y5 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**

Format: G82 X_Y_Z_R_P_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z at the bottom of hole in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in incremental programming.

P_: the dwell time of the 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 in G91 incremental mode).

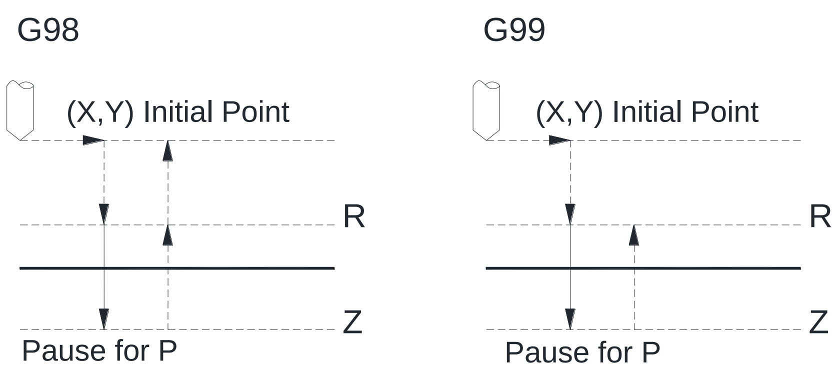


Fig. 3-24 G82 Machining Process

Process Description:

1) The tool moves to the specified hole position (X, Y) at G00 speed;

2) The tool moves down to the specified point R at G00 speed;
3) The tool moves down to point Z at the bottom of the hole at G01 speed;
4) The tool pauses for P;
5) The tool retracts to the initial point (G98) or point R (G99) at G00 speed.

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: Peck Drilling Cycle for Deep Holes**

Format: G83 X_Y_Z_R_Q_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in incremental programming.

Q_: the cutting 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 in G91 incremental mode).

The machining process of hole is as shown in Fig. 3-25. Slightly different from G73, the tool will retract to plane R after each intermittent feed in G83. The "δ" here, specified by parameter "G73_G83 retract amount", refers to the distance between the feed plane where the tool changes from G00 to Gxx and the previous cutting depth. G83 is especially for machining deep holes.

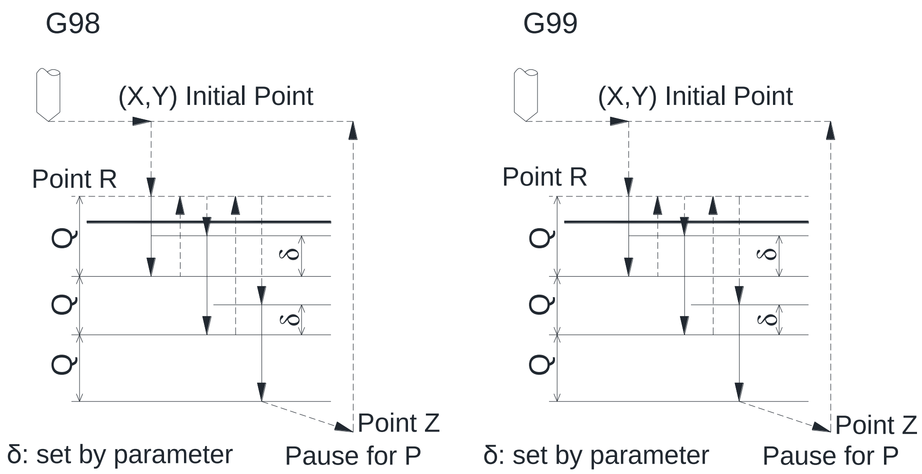


Fig. 3-25 G83 Machining Process

Process Description:

1) The tool moves to the specified hole position (X, Y) at G00 speed;
2) The tool moves to the specified point R at G00 speed;
3) The tool moves down cutting depth Q with respect to current depth at G01 speed;
4) The tool retracts to the R plane at G00 speed;
5) The tool moves down until distance δ (specified by parameter "G73_G83 retract amount") away from current drill depth at G00 speed;
6) The tool goes down downs cutting depth Q with respect to current drill depth;
7) The tool retracts to the R plane at G00 speed;
8) The tool repeats above drilling operations until reaching point Z at the bottom of the hole;
9) The tool retracts to the initial point (G98) or point R (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
'Specifying the coordinates of point R, point Z and hole 1, with cutting 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 'spindle stop
M02
```

- **G84: Tapping Cycle**

Format: G84 X_Y_Z_R_P_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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. (Currently, tapping speed is specified by parameter "Spindle Speed When Tapping", instead of by this F data.)

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

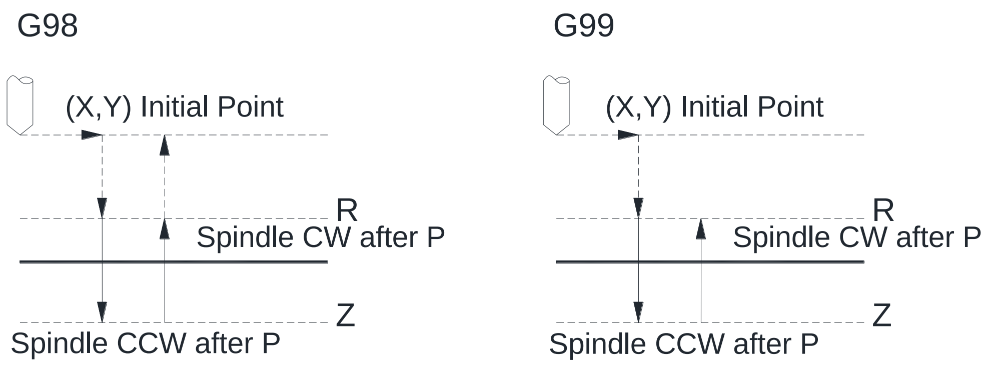


Fig. 3-26 G84 Machining Process

Process Description:

1) The tool moves to the specified hole position (X, Y) at G00 speed;
2) The tool moves down to the specified point R at G00 speed;
3) The tool taps down to point Z at the bottom of the hole at G01 speed;
4) The spindle CCW after P;
5) The tool retracts to point R at G01 speed;
6) The spindle rotates CW after P;
7) The tool retracts to the initial point (G98) or point R (G99) at G00 speed.

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 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 ’spindle stop
M02
```

- **G85: Drilling Cycle**

Format: G85 X_Y_Z_R_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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).

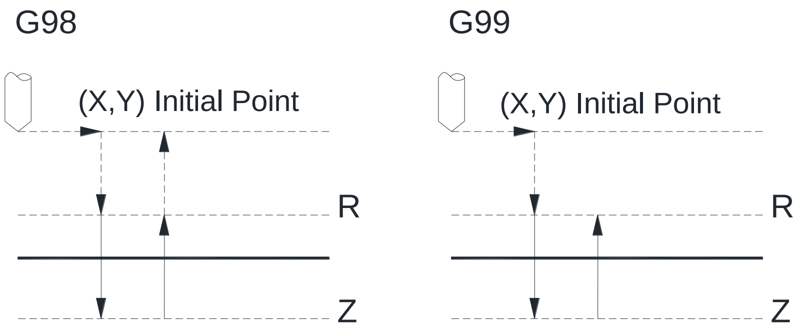


Fig. 3-27 G85 Machining Process

Process Description:

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

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**

Format: G86 X_Y_Z_R_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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).

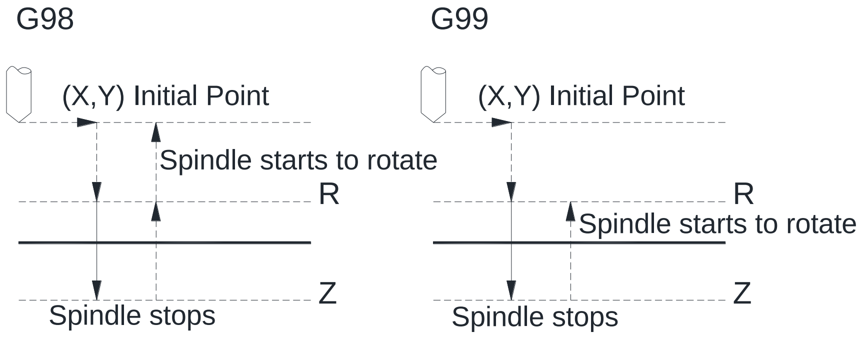


Fig. 3-28 G86 Machining Process

Process Description:

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

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 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 ’spindle stop
M02
```

- **G87: Fine Back Boring Cycle**

This command is not supported at the moment.

Format: G87 X_Y_Z_R_Q_P_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in incremental programming.

Q_: displacement of tool (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 in G91 incremental mode).

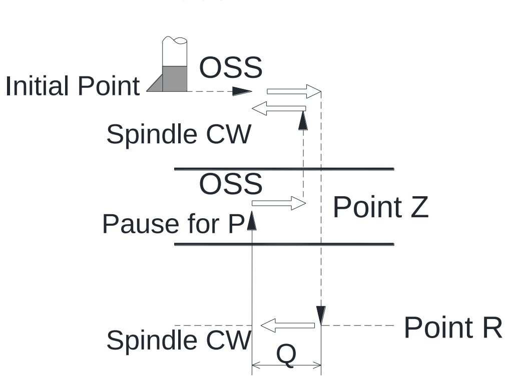


Fig. 3-29 G87 Machining Process

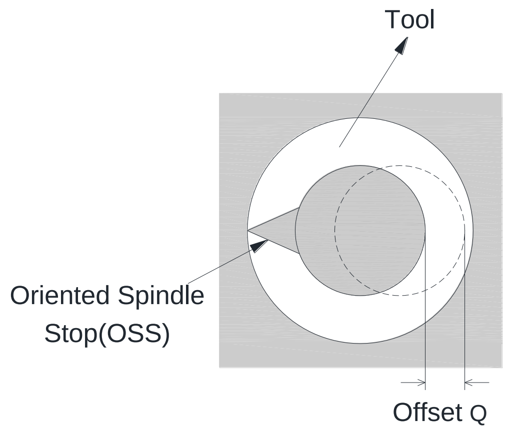


Fig. 3-30 Sketch of Oriented Spindle Stop (OSS)

OSS (Oriented Spindle Stop) direction is specified by 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

Process Description:

1) The tool moves to the hole position (X, Y) at G00 speed;
2) After OSS, offsets cutting depth Q in a direction opposed to the direction of boring tool specified by parameter “Oriented Spindle Stop)”;
3) The tool moves down to the specified point R at G00 speed, and offsets cutting depth Q;
4) The spindle rotates CW;
5) The tool retracts to point Z at G01 speed;
6) After P, offsets cutting depth Q in a direction opposed to previous offset;
7) The tool retracts to the initial point at G00 speed;

8) Offsets cutting depth Q after the spindle rotates CW.

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.

Format: G88 X_Y_Z_R_P_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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 in G91 incremental mode).

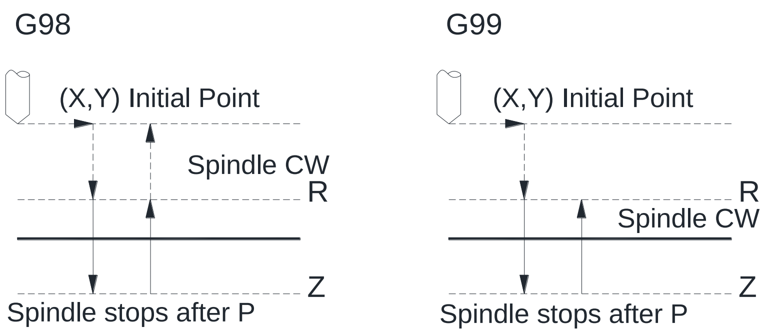


Fig. 3-31 G88 Machining Process

Process Description:

1) The tool moves to the hole position (X, Y) at G00 speed;
2) The tool moves down to the specified point R at G00 speed;
3) The tool moves down to point Z at the bottom of the hole at G01 speed;
4) The spindle stop after P;
5) The tool retracts to point R at G01 speed;
6) The tool retracts to initial point (G98) or point R (G99) at G00 speed;
7) The spindle rotates 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**

Format: G89 X_Y_Z_R_P_F_K_

Description:

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

Z_: the position of point Z in the hole bottom plane in absolute programming or the distance from point R to point Z in the hole bottom plane in incremental programming.

R_: the position of point R in absolute programming or the distance from the initial point to point R in 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 in G91 incremental mode).

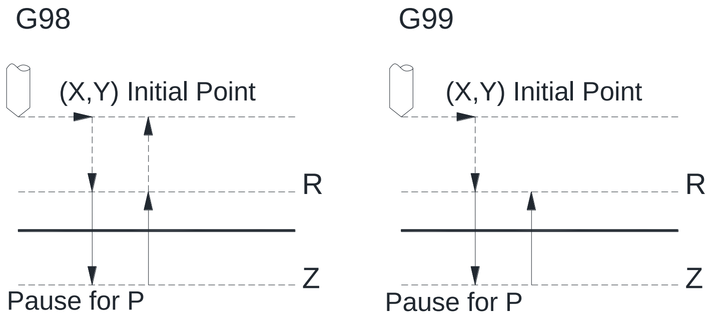


Fig. 3-32 G89 Machining Process

Process Description:

1) The tool moves to the hole position (X, Y) at G00 speed;
2) The tool moves down to the specified point R at G00 speed;
3) The tool moves down to point Z at the bottom of the hole at G01 speed;
4) The tool pauses for P;
5) The tool retracts to point R at G01 speed;
6) The tool retracts to initial point (G98) or point R (G99) at G00 speed.

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
```

3.7 Special Canned Cycle

3.7.1 Overview

1) Unit of length: millimeter (mm). Unit of angle: degree. 1 meter=1000mm, and one full circle= 360 degrees.
2) Special canned cycle commands (G34~37) must be used together with standard canned cycle

commands (G73~89). For Example:

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

3) Standard canned cycle commands must be written before special canned cycle commands; when the execution of a special canned cycle command is finished, the standard canned cycle command 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
```

4) If there is no standard canned cycle command when executing a special canned cycle command, the system will report an error. G0 X0 Y0 Z0

```
G34 X10 Y10 I10 J90 K10
…
```

For example, when the commands above are executed, 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 of the command should be like:

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

3.7.2 Special Canned Cycle Command

- **G34: Circle Drilling Cycle**

Format: G34 Xx Yy Ir Jθ Kn

Description:

Drill a specified number of holes of circular pattern.

X, Y: the center of the cycle. It is influenced by G90/91.

I: circle radius r.

J: θ, the included angle between X-axis and the first drilling point.

K: number of holes, within range -9999~9999. If the number is 0, an error report will be given. If the number is greater than 0, hole drilling direction is CW. If it is less than 0, hole drilling direction 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 the first hole. And the tool moves from one hole to another one at G0 speed.

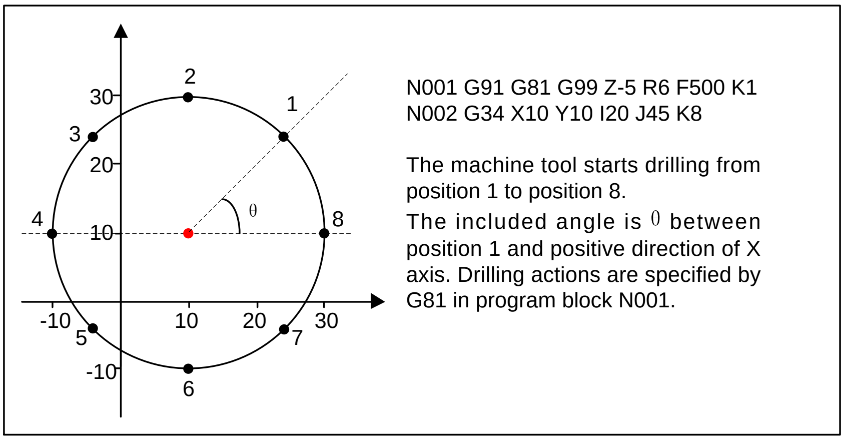


Fig. 3-33 Sketch of Bolt Hole Circle

- **G35: Line Drilling Cycle**

Format: G35 Xx Yy Id Jθ Kn

Description:

Drill 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. And the tool moves from one hole to another one at G0 speed.

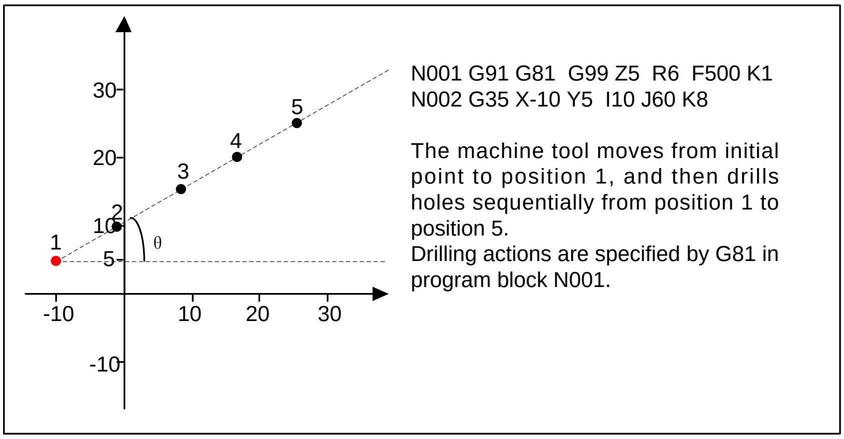


Fig. 3-34 Sketch of Angular Straight Line Drilling Cycle

- **G36: Arc Drilling Cycle**

Format: G36 Xx Yy Ir Jθ PΔθ Kn

Description:

Drill 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. And the tool moves from one hole to another one at G0 speed.

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

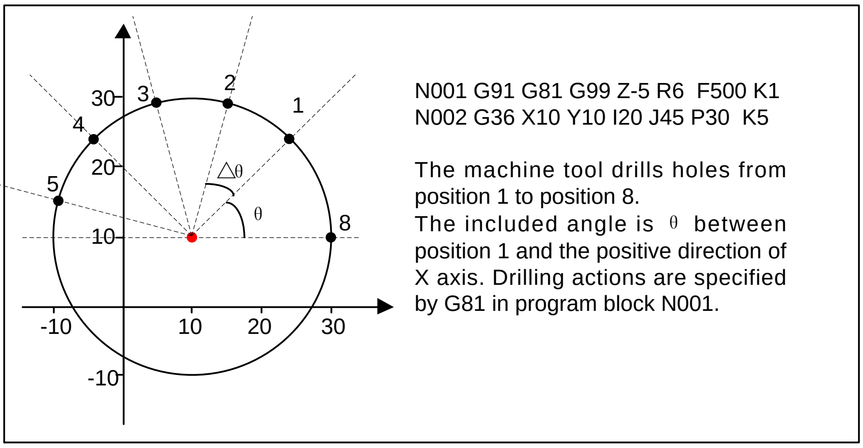


Fig. 3-35 Sketch of Arc Drilling Cycle

- **G37: Chessboard Drilling Cycle**

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 the space in Y-axis is Δy. And the tool moves from one hole to another one at G0 speed.

```
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 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.

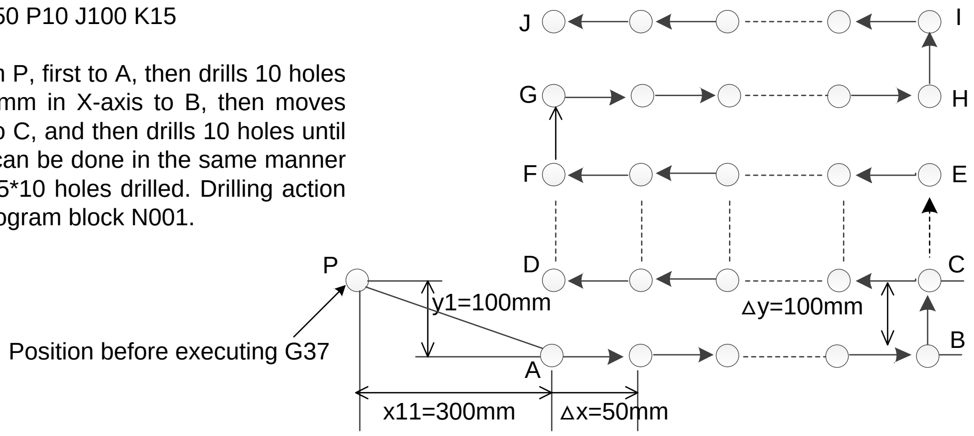


Fig. 3-36 Demonstration for Chess Hole Cycle Drilling

3.8 Customizing Canned Cycle

You can customize G command by programming subprograms in public.dat to customize canned cycle.

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

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

Programming Example:

Take a repeated canned cycle to drill holes as shown in Fig. 3-37.

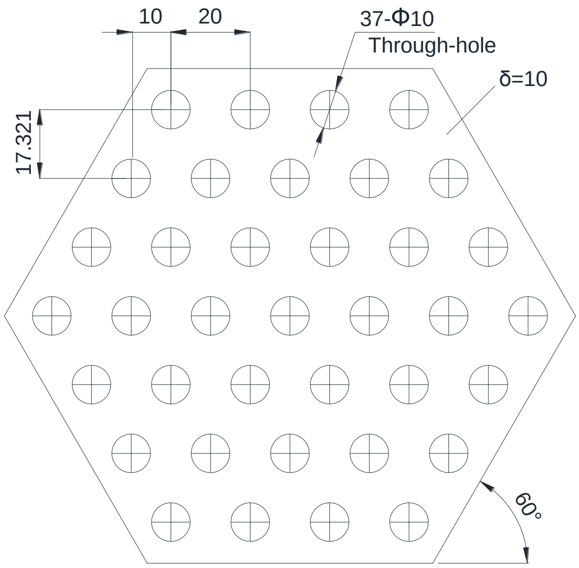


Fig. 3-37 Repeated Canned Cycle Machining

Programming is as follows.

```
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
```

3.9 G Commands 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 command 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) with the deceleration distance from the triggering point of cross-signal calculated.

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 command calculates the distance between triggering point and stop position.

3.10 Advanced Functions

- **G65: Subprogram Call**

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 program some specific programs consisting of a group of commands in Public.dat, and call them for execution with command G65.

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

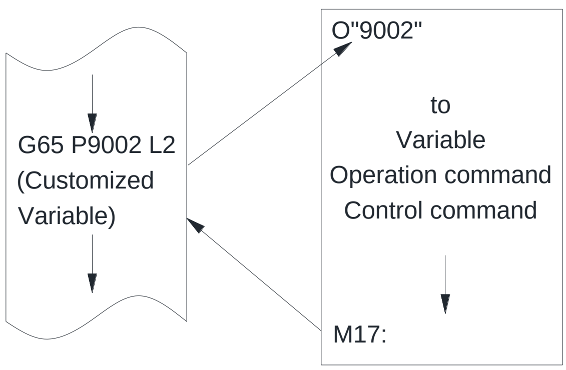


Fig. 3-38 Subprogram Call Command G65

Fig. 3-38 is a process sketch to call and execute the subprogram P9002 twice 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 cannot be Chinese characters.

- **G903: 100% Feedrate Override Command**

Format: G903

Description:

This command sets feedrate override as 100% forcedly, whatever the value you set. 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**

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**

Format: G905

Description:

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

When parameter “Use default speed” is set as valid, this command 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 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 command is used for synchronization. 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 commands concerning modifying system parameters and status, such as G92, M902.

The extended function of G906 is overtime check for a specified port. In the meantime, the synchronization function is also effective. When G906 is only used for synchronization there are no parameters after G906. The format is **G906**. When the extended function overtime check is needed, the programming format will be **G906 PLC [PLCADDRESS] LEVEL_ P_**.

Programming Example:

```
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**

Format: G907

Description:

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

- **G908: Force to Program in Degrees**

Format: G908

Description:

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

- **M801: String Information Command**

Format: M801 MSG_

Description:

This command is used for transferring message between modules.

Programming Example:

```
M801 MSG “Hello”          ’transferring “hello”
```

- **M802: Integer Message Command**

Format: M802 Pxxxx

Description:

This command 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**

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.**

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
```

3.11 Expressions Used in Program Commands

3.11.1 Current 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.

3.11.2 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 according to priority:

Priority	Operation	Symbol
1	OR	||
	AND	&&
2	Equal to	==
	Not equal to	!=
	Greater than	>
	Less than	<
3	Addition	+
	Subtraction	-
4	Multiplication	*
	Division	/
5	Positive	+
	Negative	-
	NOT	!
6	Function	
7	Bracket	()

Following are the mathematical functions currently available:

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

CAUTION

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 Commands:

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

3.11.3 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.

3.12 Demonstration of Machine Programming

- **Example 1**

Programming for sketch 1 as shown in Fig. 3-39:

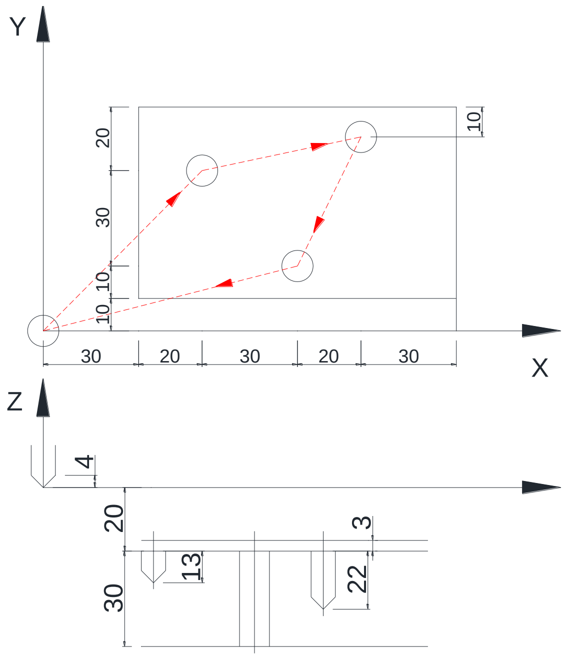


Fig. 3-39 Sketch 1 of Workpiece Machining Process

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 sketch 2 as shown in Fig. 3-40:

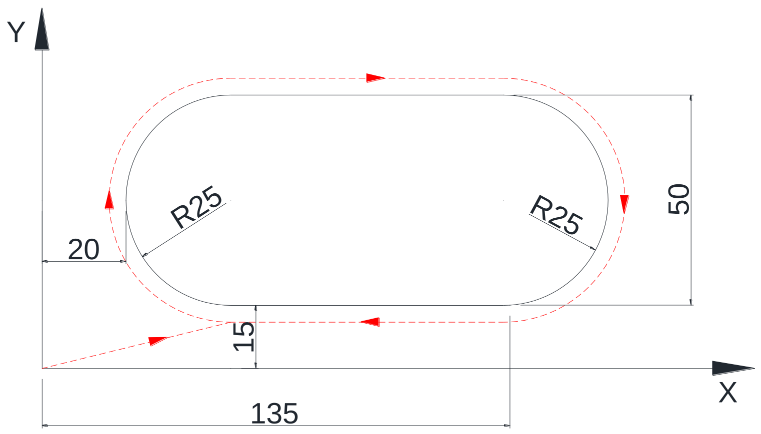


Fig. 3-40 Sketch 2 of Workpiece Machining Process

N01 G92 X0 Y0 Z0 ’workpiece coordinates system setting
N02 G90 G41 G00 X45 Y15 D01 M03 S600 M08 ’absolute programming adopted, tool 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 sketch 3 as shown in Fig. 3-41:

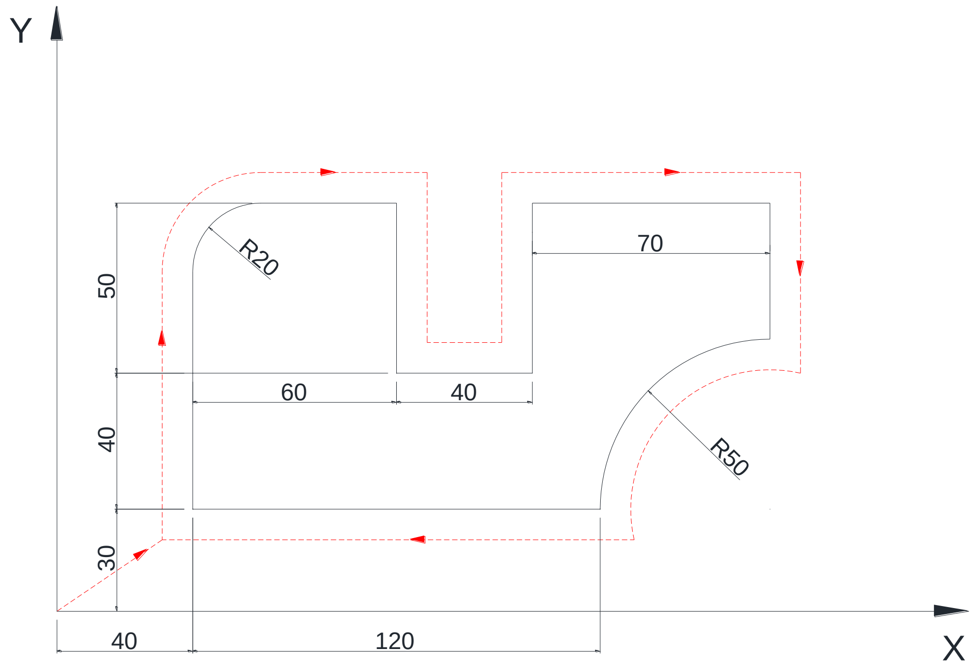


Fig. 3-41 Sketch 3 of Workpiece Machining Process

N01 G92 X0 Y0 Z0 ’workpiece coordinates system establishment
N02 G91 G41 G00 X40 Y30 D01 M03 S600 M08 ’incremental coordinates adopted, tool 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 heade

- **Example 4**

Programming for sketch 4 as shown in Fig. 3-42(CCW tapping):

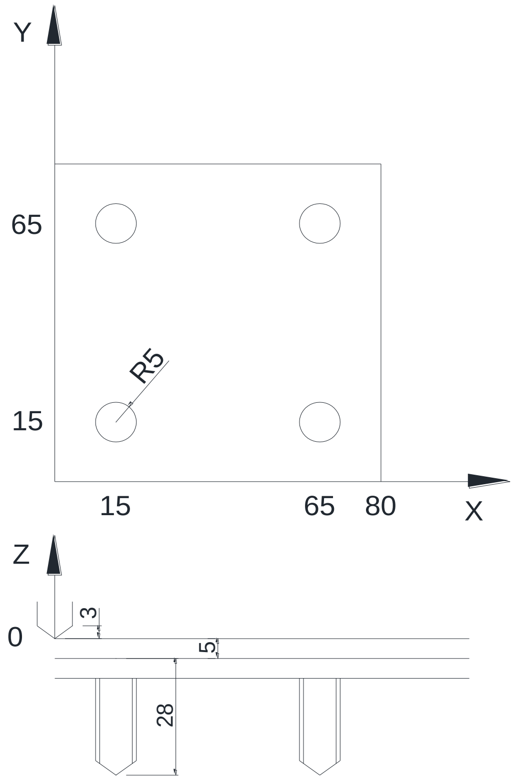


Fig. 3-42 Sketch 4 of Workpiece Machining Process

```
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    ’tool 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 sketch 5 as shown in Fig. 3-43(requirement: amount of feed is 2mm each time in Z-axis):

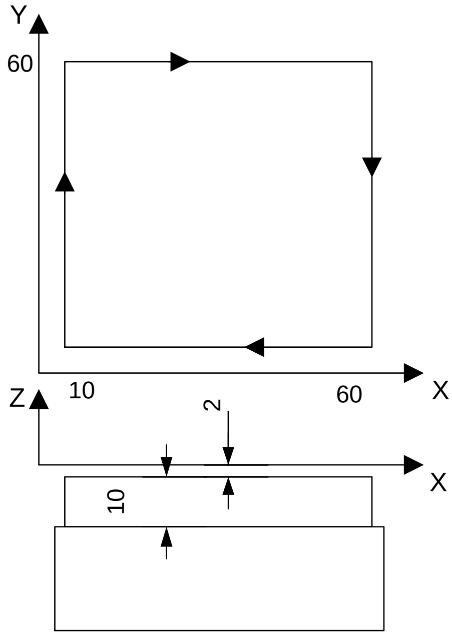


Fig. 3-43 Sketch 5 of Workpiece Machining Process

```
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
```

- **Example 6**

Programming for sketch 6 as shown in Fig. 3-44:

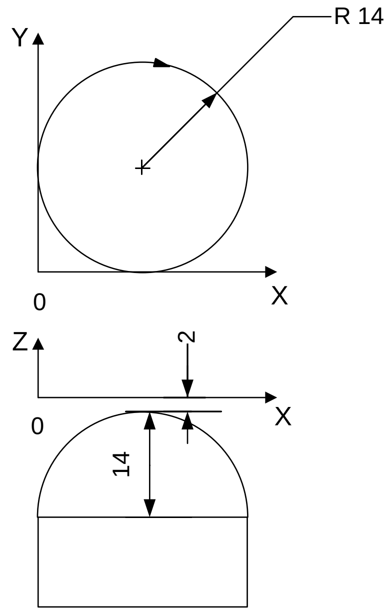


Fig. 3-44 Sketch 6 of Workpiece Machining Process

The programming is as following.

```
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
```

3.13 Appendix of G Commands

G Command	Function	G Command	Function
G00	Rapid positioning	G69	Cancel coordinate system rotation
G01	Linear interpolation	G70	Input in inch
G02	Circular interpolation (clockwise)	G71	Input in mm
G03	Circular interpolation (counterclockwise)	G73	High-speed peck drilling cycle for deep holes
G04	Dwell	G74	Left tapping cycle
G17	XY plane selection	G76	Fine boring cycle
G18	ZX plane selection	G80	Cancel canned cycle
G19	YZ plane selection	G81	Drilling cycle
G20	Input in inch	G82	Drilling cycle of dwell at the bottom of hole
G21	Input in mm	G83	Peck drilling cycle for deep holes
G28	Auto back to reference point	G84	Tapping cycle
G34	Circle drilling cycle	G85	Drilling cycle
G35	Line drilling cycle	G86	High-speed drilling cycle
G36	Arc drilling cycle	G87	Fine back boring cycle
G37	Chessboard drilling cycle	G88	Boring cycle
G40	Cancel tool radius compensation	G89	Boring cycle of dwell at the bottom of hole
G41	Left tool radius compensation	G90	Absolute programming
G42	Right tool radius compensation	G91	Incremental programming
G43	Tool length positive compensation	G92	Set workpiece coordinate system
G44	Tool length negative compensation	G98	Return to initial point
G49	Cancel tool length compensation	G99	Return to point R
G50	Scaling off	G903	100% feedrate override command
G51	Scaling on	G904	Conditional movement command

G Command	Function	G Command	Function
G50.1	Mirroring off	G905	Enable feedrate command
G51.1	Mirroring on	G906	Synchronization command
G53	Machine coordinate system	G907	Move in the shortest path
G54	WCS 1	G908	Force to program in degrees
G55	WCS 2	G916	Writing Axis Configuration Data Command
G56	WCS 3	G918	Clearing Latch Flag Command
G57	WCS 4	G919	Calculating Deceleration Distance of Cross-signal Trigger Point
G58	WCS 5	G921	Specify the workpiece coordinates of current point
G59	WCS 6	G922	Specify the coordinates of WCS origin
G65	Subprogram call	G992	Set temporary WCS
G68	Coordinate system rotation	G923	Directly Set Tool Offset

4 Others

4.1 Named Parameters

4.1.1 Overview

General users can be satisfied with the machining workpiece operations and other basic operations provided by the controller, such as: tool calibration, center calibration, canned cycle, etc.

The controller also provides a group of named parameters for those who need to program some operating details, operating programs and customize canned cycles. With these parameters, you can modify or program operation programs and customize the content of canned cycle in public.dat. In addition, can also program directly in the program edit operation interface.

- **Example 1**

Writing a subprogram of tool coolant and tool change with named parameters is shown 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_POS.Z
'move to the position of tool change
G00 G90 Z10  'or lift the tool directly for tool change
M05
M17
```

- **Example 2**

Modifying the content of G86 canned cycle with named parameters. G86 canned cycle contains retract amount parameter which is not set in the system.

```
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

4.1.2 List of Named Parameters

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
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	DOUBLE	Setting the thickness of tool presetter in mobile tool

No.	Parameter	Parameter Name	Type	Remarks
		tool measurement		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	DOUBLE	The additional moving distance of

No.	Parameter	Parameter Name	Type	Remarks
		Z-axis		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
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

4.2 Customized and Extended M Command

You can customize M command and G command by programming subprograms in public.dat.

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

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

Programming example for customizing and extending M command is as fowllows.

```
'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
```

4.3 PLT Support

At present, the system supports PLT commands as follows.

```
//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-dimension commands.

CAUTION

PLT format is highly expansibe and different products corresponds to different commands. If you are encountered with any unidentifiable command, please contact us as soon as possible, so that we can develop a corresponding interpreter for you.

4.4 DXF Support

- **At present, the system supports Entities as below:**

LINE

LWPOLYLINE

ARC

CIRCLE

ELLIPSE

SPLINE

- **Prompt:**

Save the figure drawn in AutoCAD as .dxf format, and then perform “Open and Load” and “Simulation Mode” in the software. At this time, the figure shown in the track window is what you have drawn in AutoCAD.