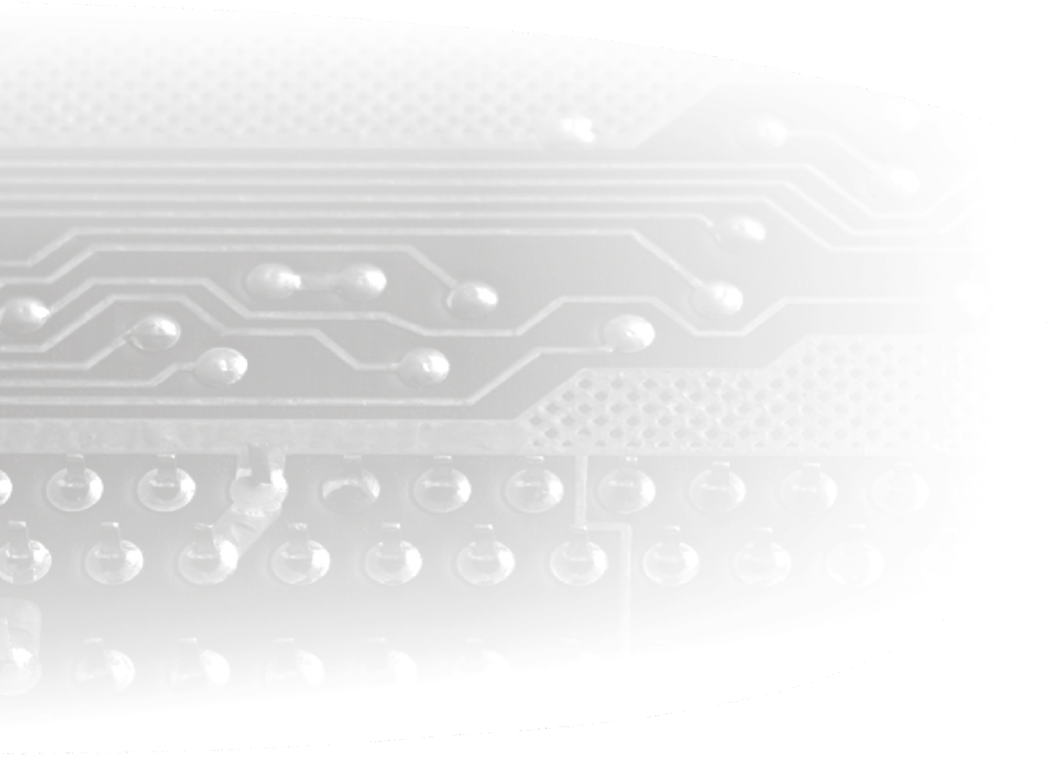
ADT-CNC4620

CNC4620 Lathe Control System

Programming Manual



ADTECH众为兴

Adtech (Shenzhen) Technology Co., Ltd.

Add: F/5, Bldg/27-29, Tianxia IC Industrial Park, Yiyuan Rd, Nanshan District, Shenzhen
Postal code: 518052
Tel: 0755-26722719 Fax: 0755-26722718
Email:export@machine-controller.com http://www.machine-controller.com

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Version History

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Revision

Date	Version/Page	Result	Confirmed by

Remark: above table is only for the version update of the Manual.

1. We have collated and checked this Manual strictly, but we can’t ensure that there are no error and omission in this Manual.
2. Due to constant improvement of product functions and service quality, any products and software described in this manual and the content of the manual are subject to changes without prior notice.

Precautions

※Transportation and storage

The packaging boxes shouldn’t be stacked more than six layers
Do not climb onto, stand on or put heavy objects on the packaging box
Do not drag or convey the product with a cable connected to the product
Do not impact or scratch the panel and display
Keep the packaging box away from moisture, insulation and rain

※Unpacking and checking

Unpack and check whether the product is the one you ordered
Check whether the product is damaged during transporting
Check whether the parts are complete and intact according to the packing list
If the model doesn’t match, any accessories are missing or damaged, please contact us immediately

※Wire connection

The personnel for wire connection and checking should be qualified
The product must be grounded reliably (resistance < 4Ω) and do not use neutral wire to replace the earth wire
The wires must be connected properly and firmly to avoid failures and accidents
The surge absorption diode must be connected to the product properly, or else it will damage the product
Please cut off the power supply before inserting/removing the plug or opening the enclosure

※Checking and repairing

Please cut off the power supply before repairing or replacing the components
Check the failure if short circuit or overload occurs, and restart after eliminating all failures
Do not connect/cut off the power supply frequently; wait for at least one minute before restarting

※Others

Do not open the enclosure without permission
Please cut off the power supply if it won’t be used for a long time
Prevent dust and iron powder from entering the controller
If non-solid state relay is used for output, please connect freewheeling diode to relay coil in parallel. Check whether the connected power supply is qualified to avoid burning out the controller
The lifetime of the controller depends on the environment temperature. If the temperature of processing field is too high, please install cooling fan. The allowable temperature range of the controller is 0℃-60℃
Avoid using in the environment with high temperature, moisture, dust or corrosive gas
Install rubber cushion if the vibration is severe

※Maintenance

Under normal condition (environment: daily average 30℃, load rate 80%, running rate 12 hours every day), please perform daily and periodic checking according to the items below.

Daily checking	Daily	Confirm environment temperature, humidity and dust Whether there is abnormal vibration or sound Whether the vent hole is blocked by yarn
Periodic checking	1 year	Whether the fixed parts are loose Whether the terminal block is damaged

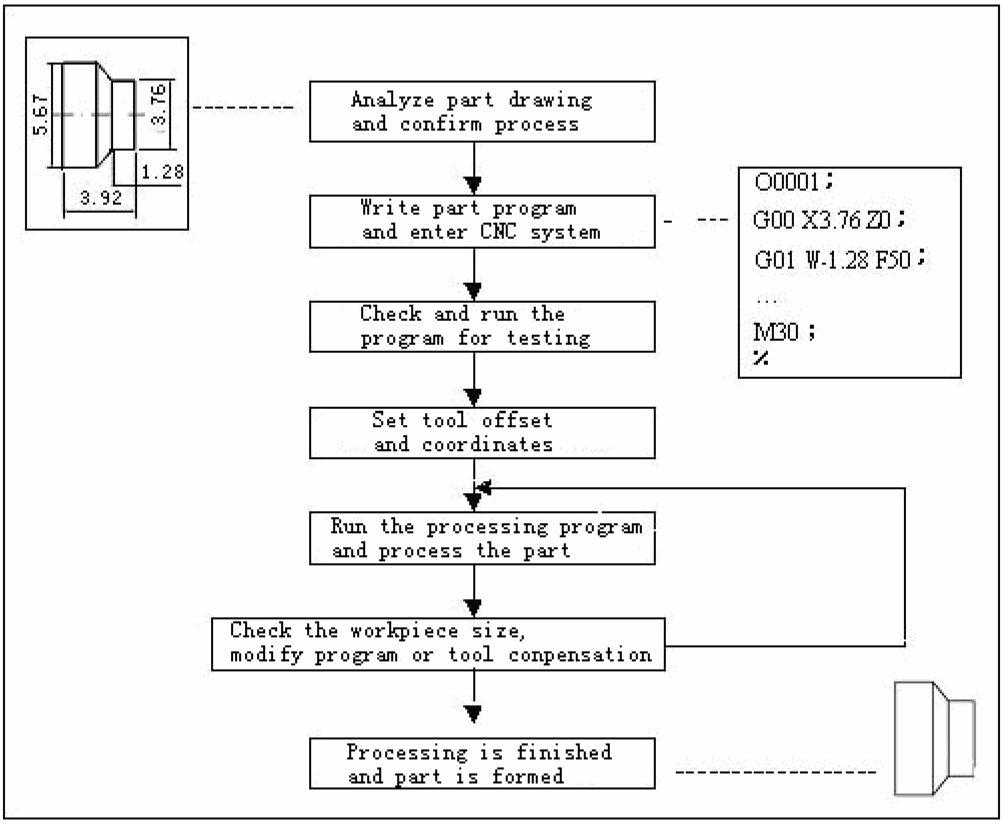
Contents

1. Programming Basics

1.1. Introduction of CNC machine tool

CNC (Computer Numerical Controler) machine tool consists of CNC system, servo motor (or step motor) drive, machine tool (including headstock, feed drive mechanism, worktable, tool holder, electric control cabinet), etc. After CNC processing, the part program edited by the user will send motion instructions and control instructions, while motion instructions drive the feeding of machine tool through motor drive, and control instructions include principal axis start/stop, tool selection, cooling, lubrication, etc. It achieves parts cutting through relative motion of tool and workpiece.

CNC programming is to write part processing program according to the dedicated programming instructions of CNC system with the information such as part size, processing process, process parameters, tool parameters, etc. CNC processing is that the CNC system controls the machine tool to finish part processing according to the requirement of part processing program. The working principle of CNC machine tool and the flow of CNC processing are shown in the figure below.


5.67
3.76
1.28
3.92
Analyze part drawing and confirm process
Write part program and enter CNC system
Check and run the program for testing
Set tool offset and coordinates
Run the processing program and process the part
Check the workpiece size, modify program or tool conpensation
Processing is finished and part is formed

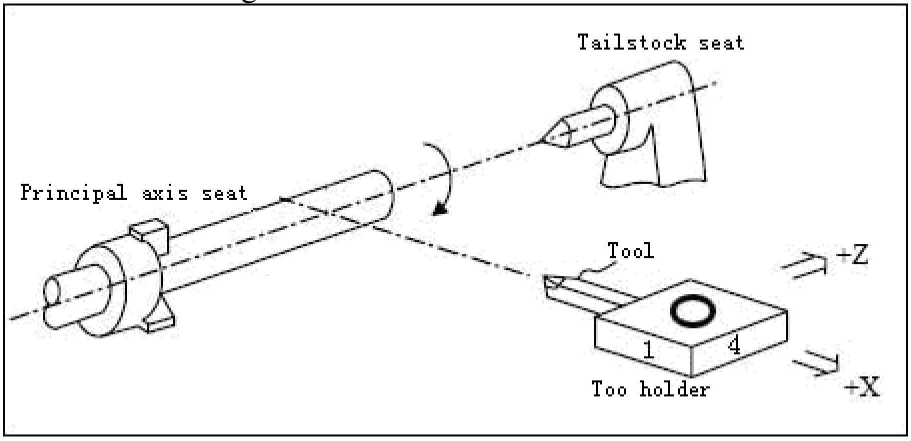
```
O0001；
G00 X3.76 Z0；
G01 W-1.28 F50；
……
M30；
%
```

Analyze part drawing and confirm process
Write part program and enter CNC system
Check and run the program for testing
Set tool offset and coordinates
Run the processing program and process the part
Check the workpiece size, modify program or tool conpensation
Processing is finished and part is formed

Fig. 1-1 CNC Processing Flow Chart

1.2. Definition of coordinate axis

CNC machine tool is shown in Fig. 1-2-1

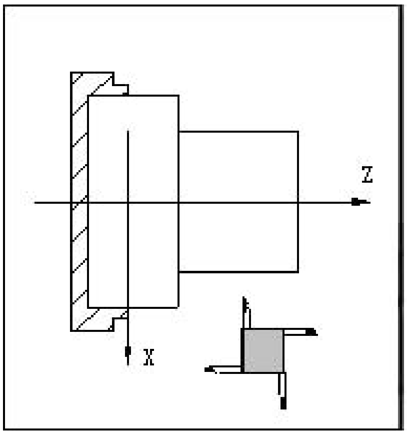


Tailstock seat Principal axis seat Tool Too holder

Fig. 1-2-1

The system uses the right angle coordinate system constituted with X axis and Z axis. X axis is vertical to the principal axis, and Z axis is parallel to the principal axis. The direction to the workpiece is negative, and the direction from the workpiece is positive.

According to the relative position of the tool holder and principal axis of the machine tool, CNC lathe has front tool holder and rear tool holder. Same programming instruction has different motion tracks in front tool holder and rear tool holder. This system can be used in the front tool holder and rear tool holder of the CNC lathe. Seen from the figures below, the X directions of front and rear tool holder coordinate systems are different, while the Z direction is same. The figures and examples in this manual use front tool holder coordinate system to describe the application of programming.



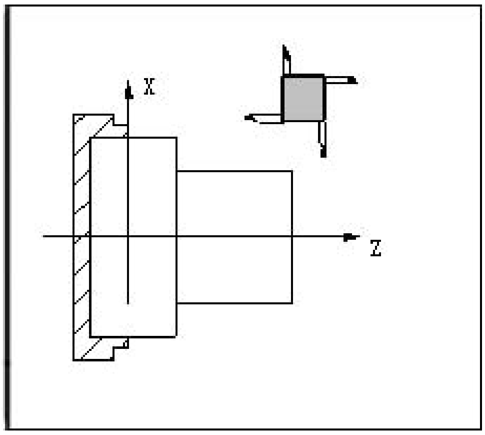


Fig. 1-2-2 Front tool holder coordinate system Fig. 1-2-3 Rear tool holder coordinate system

1.3. Machine tool coordinate system and mechanical home

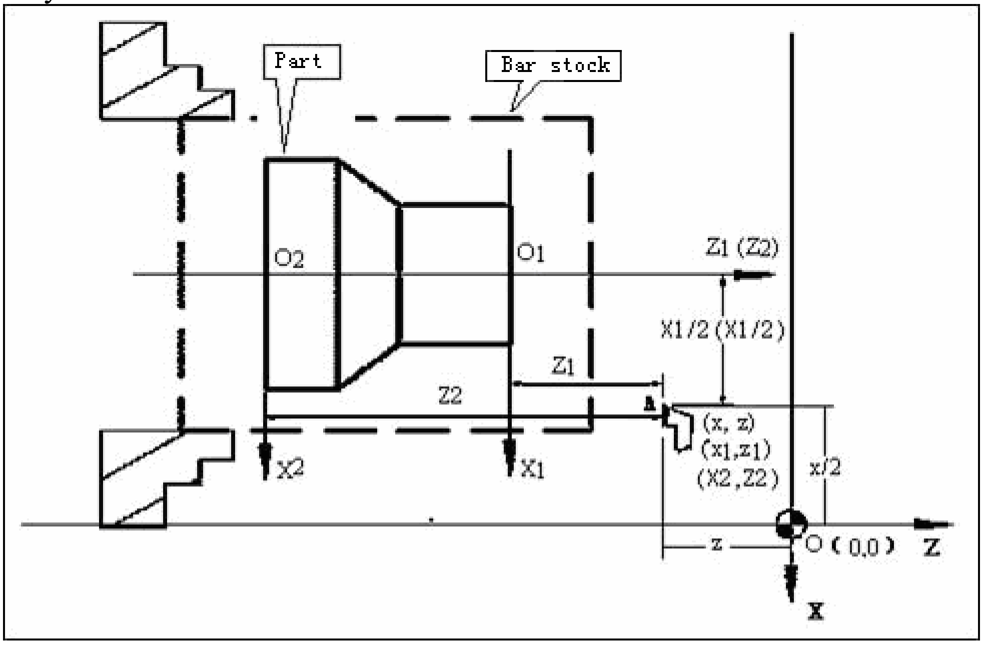
Machine tool coordinate system is the reference of CNC for coordinate calculation, and is the intrinsic coordinate system of the machine tool. The origin of the machine tool coordinate system is mechanical reference or mechanical home.

Mechanical home is determined by the zero switch or home switch on the machine tool, which are usually installed at the maximum travel in positive direction of X axis and Z axis. For mechanical home operation, the system will set current machine tool coordinates to 0 after returned to mechanical home, and create a machine tool coordinate system with current position as the coordinate origin.

Note: If the zero switch isn't installed on the lathe, it isn't possible to perform home operation.

1.4. Workpiece coordinate system and program home

Workpiece coordinate system is the right angle coordinate system set on the part drawing for programming, which is also called floating coordinate system. When the part is installed on the machine tool, set the absolue coordinates of the current position of the tool with G50 instruction according to the relative position of tool and workpiece, and thus create workpiece coordinate system in the system. The current position of the tool is the program home. Generally, Z axis and principal axis of the workpiece coordinate system coincide, and X axis is in the head or end of the part. The workpiece coordinate is always valid once created until replaced by new workpiece coordinate system.



Part Bar stock

Fig. 1-4

In the figure above, XOZ is machine tool coordinate system, X1O1Z1 is the workpiece coordinate system of X axis in the head of the workpiece, X2O2Z2 is the workpiece coordinate system of X axis in the end of the workpiece, O is the mechanical home, A is tool tip, and the coordinates of A in above three coordinate systems are as follows:

The coordinates of point A in machine tool coordinate system (X, Z);

The coordinates of point A in X1O1Z1 coordinate system (X1, Z1);

The coordinates of point A in X2O2Z2 coordinate system (X2, Z2);

Interpolation function

Interpolation is to control two or several axes to move simultaneously. The motion track complies with fixed mathematical relationship, constitutes two-dimensional (plane) or three-dimensional (space) profile, and interpolation is also called profile control. During interpolating, the motion axis is called joint axis, the movement amount, direction and speed of which are controlled simultaneously in the entire motion process, to form desired synthetic motion track.

Only control the motion end of one axis or multi-axis, do not control the track in the motion process, and the motion control mode is called point-position control.

The X axis and Z axis of this system are linked, which is two axes linked CNC system. This system has linear, arc and thread interpolation function.

Linear interpolation: the synthetic motion track of X axis and Z axis is the straight line from the start point to the end point.

Arc interpolation: the synthetic motion track of X axis and Z axis is arc from the start point to the end point, the radius is specified by R, or the circle center is specified by I, K.

Thread interpolation: X axis, Z axis or two axes motion and principal axis rotation interpolation; F specifies the pitch of threads, which is the movement (unsigned) of the axis (X or Z) that moves longer when the principal axis rotates for a circle in the process of thread cutting. This system can process metric straight thread, taper thread and end thread, and the machine tool must be installed with principal axis encoder to process threads. If the encoder isn't installed and it is threading, the system can't receive signals from the encoder and can't perform other operations. (1000 wires encoder or above is recommended for this system)

1.5. Absolute/relative coordinate programming

Two methods are available for specify the end position of the track during programming:

1: The end position of the track is expressed in absolute coordinates and it is called absolute coordinate programming (instruction address uses X, Z).

2: The end position of the track is expressed with the coordinate difference of end point relative to start point and it is called relative coordinate programming (instruction address uses U, W). The negative value of relative coordinates represents running in negative direction of the axis, while the positive value of relative coordinates represents running in positive direction of the axis.

This system allows expressing one axis of the end position with absolute coordinates and expressing the other axis with relative coordinates in the same block. This method is called mixed programming.

For example: A→B linear interpolation (as in Fig. 1-5)

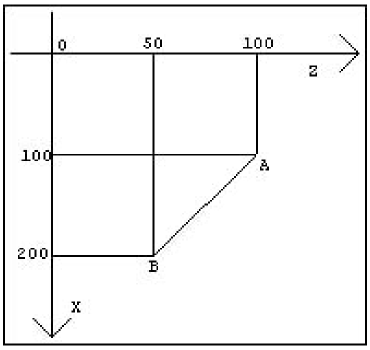


Fig. 1-2-5

Absolute coordinates programming: G01 X200 Z50;

Relative coordinates programming: G01 U100 W-50;

Mixed coordinates programming: G01 X200 W-50; or G01 U100 Z50;

1.6. Conversion between imperial and metric system*

Set the unit to imperial or metric with G code (G20, G21).

System	G code	Minimum unit
Imperial	G20	0.0001 inch
Metric	G21	0.0001mm

The G code for imperial and metric switch should be placed in front of the program. Use separate block instruction before setting the coordinate system. The unit system of the following values changes according to the G code for imperial and metric switch.

(1) Feeding speed instruction value expressed with F.

(2) Instruction value related to position

(3) Compensation

(4) The value of one scale of the Handwheel pulse generator

(5) Movement of single step

(6) Part value of the parameter

Note:

1. When the system is electrified, the G code for imperial and metric switch is same as before the power supply is cut off
2. In the program, do not change G20, G21
3. If the mechanical unit system is different from the input unit system, the maximum error would be 0.5 of minimum movement unit, and the error won't be accumulated.
4. When imperial input (G20) and metric input (21) are switched, the offset should comply with the new setting of the input unit.

1.7. Program constitution

To complete automatic processing of the part, you need to write the part program (the program) according to the instruction format of the CNC system, which will execute the program and complete the controls such as machine tool feeding, principal axis start/stop, tool selection, cooling and lubrication, and thus finish the part processing.

For example:

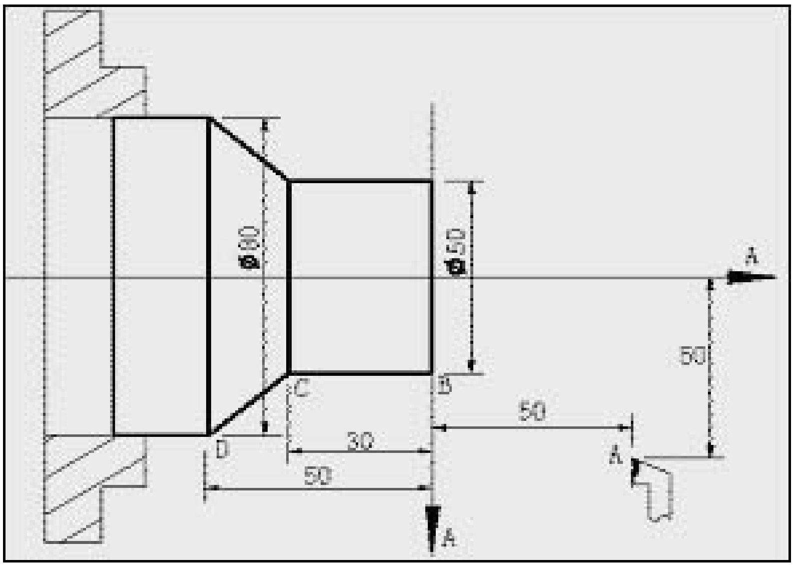


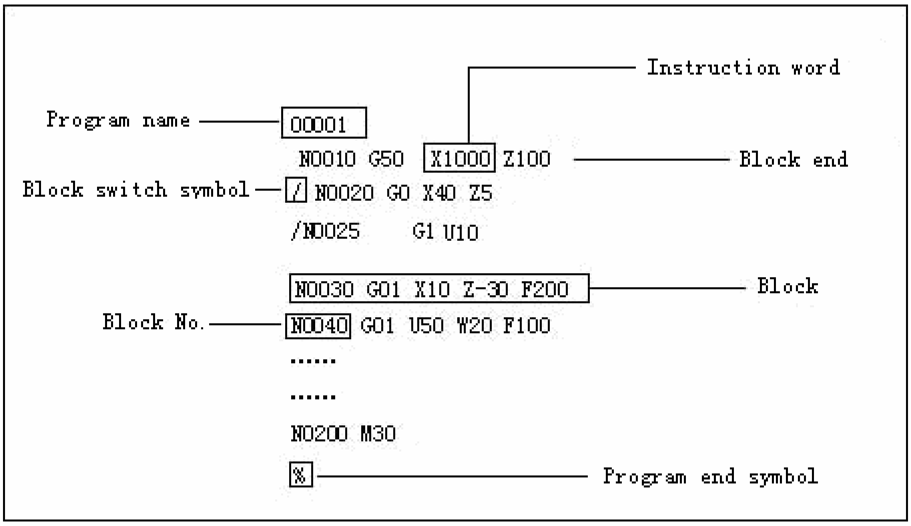
Fig. 1-7

```
O0001;   (program name)
G0 X100 Z50;     (quickly locate point A)
M12;       (clamp the workpiece)
T0101;   (replace tool #1 and execute tool #1 offset)
M3 S600;          (start the principal axis, and set the principal axis rotation to 600rpm)
M8   (coolant on)
G1 X50 Z0 F600;      (approach point B at the speed of 600mm/min)
W-30 F200;               (cut from point B to point C)
X80 W-20 F150;           (cut from point C to point D)
G0 X100 Z50;                 (quickly back to point A)
T0100;                   (cancel tool offset)
M5 S0;                   (stop principal axis)
M9;                       (coolant off)
M13;                            (release workpiece)
M30;                            (program ends, principal axis/coolant off)
%
```

After above program, the tool will have a track of A→B→C→D→A.

1.8. General structure of program

The program consists of several block started with "OXXXX" (program name) and ended with "%", while block consists of several instruction words started with block number (can be omitted), changed line with "CR" and ended with "LF". The general structure of a program is shown in Fig. 1-3-2 below:



```
O0001
N0010 G50 X1000 Z100
/ N0020 G0 X40 Z5
/N0025      G1 U10

N0030 G01 X10 Z-30 F200
N0040 G01 U50 W20 F100
......
......
N0200 M30
%
```

Instruction word
Block end
Block No.
Program end symbol

Program name
Block switch symbol
Block

Fig. 1-8 General Program Structure

1) Program name

To identify the programs, every program has a name consists of instruction address O and four digits later in the start of the program. This system can save up to 9999 programs, and the program names can't repeat.

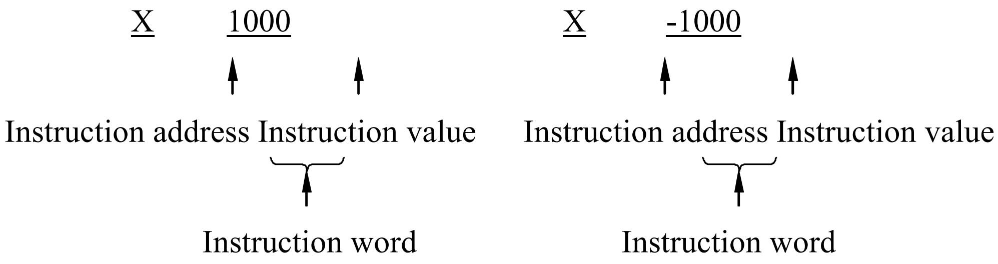
O □□□□

Program No. (0000~9999, leading zero can't be omitted)

Instruction address O

2) Instruction word

Instruction word is the basic instruction unit for CNC system to complete the control function. Instruction word consists of one English letter (instruction address) and later digits (instruction value, signed or unsigned). Instruction address regulates the meaning of following instruction value. In different combinations of instruction word, same instruction address may have different meanings.

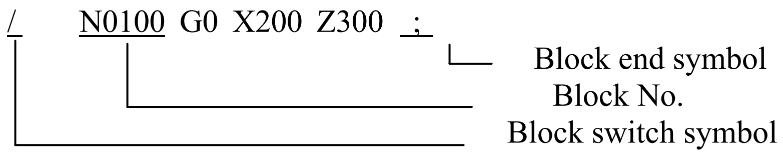

X 1000
X -1000
Instruction address Instruction value
Instruction address Instruction value
Instruction word
Instruction word

3) Block switch symbol, block No. and block

A program consists of several blocks and is executed in blocks. Generally, a block is executed only the previous block has been executed. Blocks are separated with ";" or "*", and ";" is used in this manual. A block consists of several instruction words, and is started with block No. and ended with ";" or "*".

For example: block may have "/" symbol in the front, which is called block switch symbol

4) When the program is run automatically, if the switch function is enabled, the program will execute next block automatically when running to this block. If the switch function isn't enabled, this block will be executed. The option of switch function is in the auxiliary interface of main menu. This function won't be saved after power off, and it is disabled by default after initialization.



5) Block No.

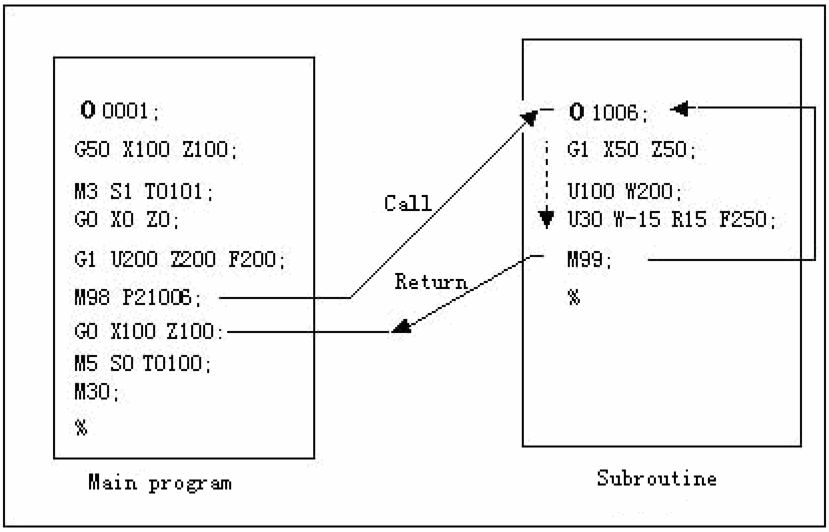
N0000~N9999; the leading zero can be omitted. Block No. can be omitted, but the target block for program call and switch must exist. The sequence of block No. may be random, and the block No. in latter part doesn't need to be larger than previous number. For the convenience of reference, the line No. is usually arranged according to certain increment. During manual editing, it is possible to determine whether insert line No. increment automatically through No. 47 comprehensive parameter. The initialized value is 0, i.e. do not insert line No. automatically.

6) Program end symbol

The program is started from program name and ended with "%", which is the end symbol of the program file. During communicating, "%" is the end symbol and start symbol.

1.9. Main program and subroutine

To simplify the programming, if same or similar processing track and control process need to be used for several times, the program instructions of this part can be edited to independent program for calling. The program that calls other programs is called as main program, and the program being called (ended with M99) is called as subroutine. Both subroutine and main program occupy system capacity and storage space. Subroutine also must have independent program name, and can be called by any other main proram or run independently. When subroutine ends, it returns to the main program and continues the execution. The system supports nine layers nesting, i.e. a subroutine can call other subroutines, as shown in Fig. 1-9 below.



```
O0001;
G50 X100 Z100;
M3 S1 T0101;
G0 X0 Z0;
G1 U200 Z200 F200;
M98 P21006;
G0 X100 Z100:
M5 S0 T0100;
M30;
%
```

```
O1006;
G1 X50 Z50;
U100 W200;
U30 W-15 R15 F250;
M99;
%
```

Call
Main program

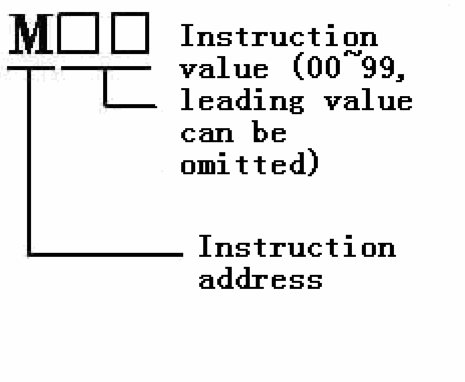
Return
Subroutine

Fig. 1-9

2. M S F T Instruction

2.1. Auxiliary function (M code)

M instruction consists of instruction address M and later 1~2 digits, and is used to control the flow of executing program or output signals to machine tool.



Instruction value (00~99, leading value can be omitted)
Instruction address

One block only contains one valid M instruction. If a block has two or more M instructions, the last M instruction is valid.

If M instruction and the instruction word that executes moving function are in the same block, the sequence follows:

① If M instruction is M00, M30, M98 and M99, execute M instruction after moving;

② When M instruction outputs signal to the machine tool, execute M instruction while moving.

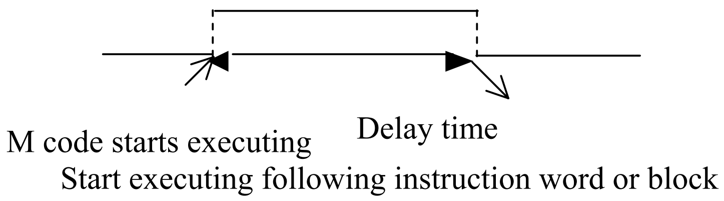
M Instructions List

Instruction	Function	Remark
M00	Program pauses	State isn't retained
M30	Program ends	
M98	Subroutine calling	
M99	Return from subroutine	
M03	Principal axis forward rotation	Functions are interlocked, and state is maintained
M04	Principal axis reverse rotation	
*M05	Principal axis stop	
M08	Coolant on	Functions are interlocked, and state is maintained
*M09	Coolant off	
M10	Tailstock forward	Functions are interlocked, and state is maintained
M11	Tailstock backward	
M12	Chuck clamped	Functions are interlocked, and state is maintained
M13	Chuck released	
M32	Lubricant on	Functions are interlocked, and state is maintained
*M33	Lubricant off	

M40	Gear position speed setting output off	
M41	First gear speed output	
M42	Second gear speed output	
M43	Third gear speed output	
M44	Fourth gear speed output	
M88	Check the signa of specified input pin	Allow specifying effective input voltage level
M89	Control the switch of specified output pin	Allow specifying output voltage level

Note: the instructions marked with "*" are valid after electrified.

After the system executed the M instruction that output signal to machine tool, delay for a period and then execute following instruction word or block. The delay time is set by the system parameter M code waiting time.



2.1.1. Subroutine call M98

Instruction format:

M98 P○○○　□□□□

Subroutine No. (0000~9999) being called. If the calling time isn't entered, the leading 0 of the subroutine No. can't be omitted; if the calling time is entered, the subroutine No. must contain four digits.

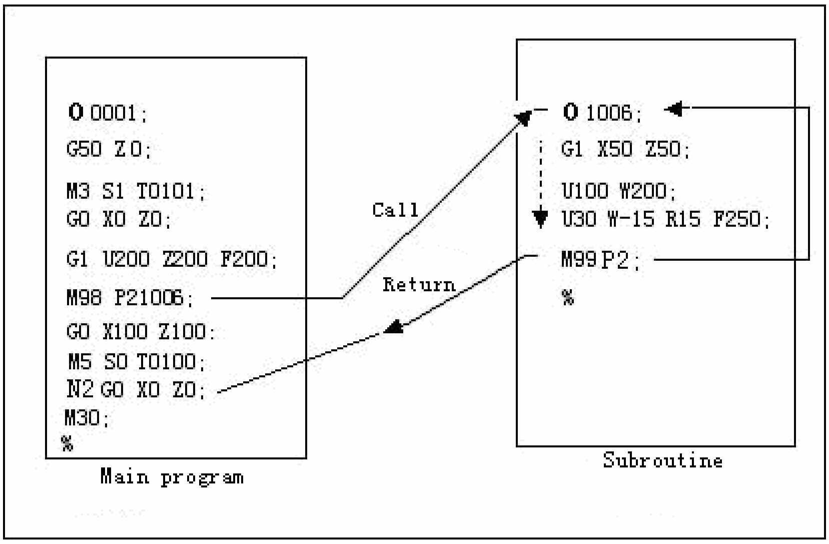
If the calling time (1-999) is 1, it isn't required to enter

Instruction function: after other iinstructions of current block are executed, the system won't execute next block, but to execute the subroutine specified by P. The subroutine can be executed for 999 times at most. In MDI mode, the subroutine can't be called.

2.1.2. Return from subroutine and return to main program M99

Instruction format: M99 P○○○ (return from subroutine)

Instruction function: when the called subroutine is finished, return to the block specified by P in the main program and continue to execution; if P isn't entered, return to the next block of M98 instruction that calls current subroutine in the main program. If M99 is used in the end of the main program (i.e. current program isn't called and executed by other programs), current program will execute repeatedly. M99 iinstruction is invalid in MDI mode.



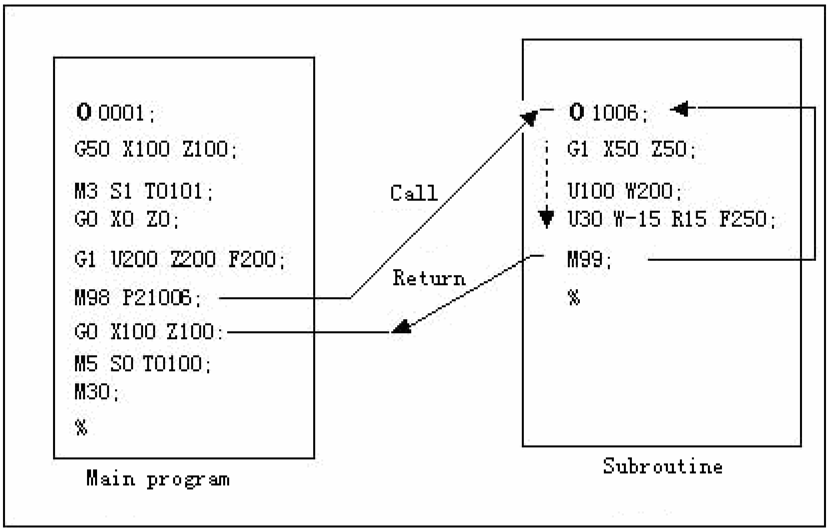
```
O 0001;
G50 Z0;
M3 S1 T0101;
G0 X0 Z0;
G1 U200 Z200 F200;
M98 P21006;
G0 X100 Z100:
M5 S0 T0100;
N2 G0 X0 Z0;
M30;
%
```

```
O 1006;
G1 X50 Z50;
U100 W200;
U30 W-15 R15 F250;
M99 P2;
%
```

Call Return

Main program Subroutine

Fig. 2-1-1 Returning from Subroutine



```
O 0001;
G50 X100 Z100;
M3 S1 T0101;
G0 X0 Z0;
G1 U200 Z200 F200;
M98 P21006;
G0 X100 Z100:
M5 S0 T0100;
M30;
%
```

```
O 1006;
G1 X50 Z50;
U100 W200;
U30 W-15 R15 F250;
M99;
%
```

Call Return

Main program Subroutine

Fig. 2-1-2 Returning to Main Program

The system can call nine layers subroutine, i.e. a subroutine can call other subroutines (as shown in the figure below)

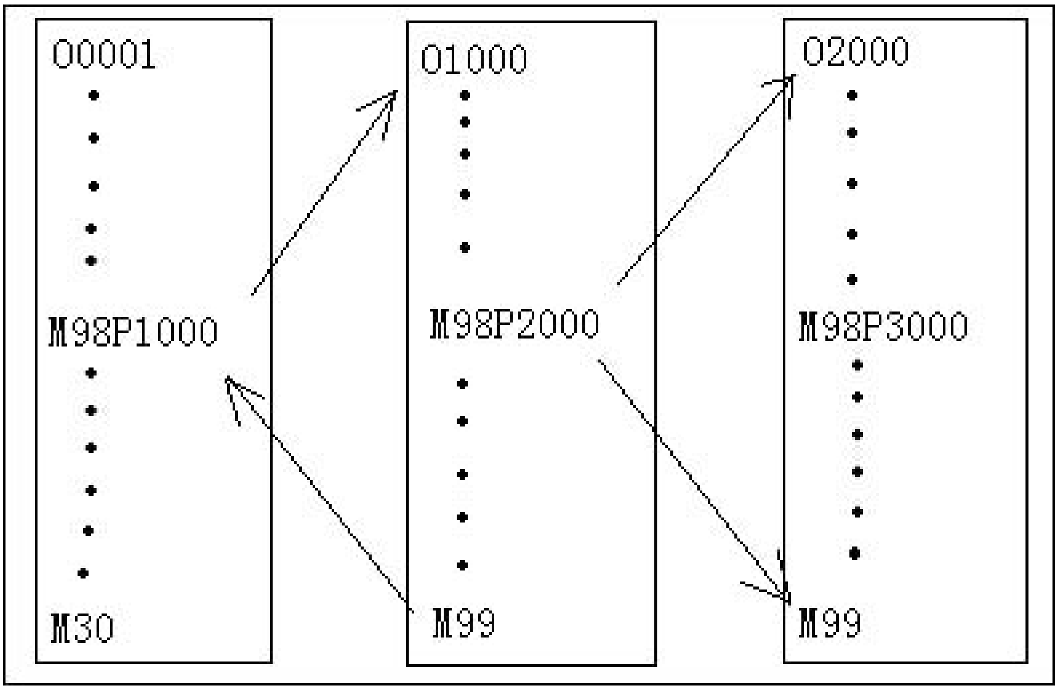


Fig. 2-1-3 Program Nesting Calling

2.1.3. Principal axis control M03, M04, M05

Instruction function: M03 or M3: Principal axis forward rotation;
M04 or M4: Principal axis reverse rotation;
M05 orM5: Principal axis stop

M05 output is valid when the system is electrified, and executes M03 or M04 at this moment. M03 or M04 output is valid and maintains, and cancels M05 output at the same time (output is invalid); when M03 or M04 output is valid, execute M05, cancel M03 or M04 output, M05 output is valid and maintains. The interlocking of principal axis and chuck can be selected through #022 management parameter. The default setting is MFUNC(L)1, i.e. not interlocked. MFUNC(L)2 is interlocked, User-Def is user-defined M code. The parameter setting requires restarting the system.

Note: when the system is stopped in emergency, cancel M03 and M04 output, and M05 output is valid.

2.1.4. Coolant control M08, M09

Instruction function: M08 or M8: cooling pump open;
M09 or M9: cooling pump closed

After the system is electrified, M09 is valid, i.e. M08 output is invalid. Execute M08, and M08 output is valid, cooling pump opens; execute M09, and cancel M08 output, cooling pump closes. Coolant control port is determined by #075 port parameter, and the initialized value is OUT4.

Note1: when the system is stopped in emergency, cancel M08 output.

Note 2: M09 doesn't have corresponding output signal, and M08 output is canceled when M09 is executed.

2.1.5. Tailstock control M10, M11

Instruction function: M10: tailstock forward.
M11: tailstock backward

After the system is electrified, both M11 and M10 do not have output; execute M10, M10 output is valid, cancel M11 output, and tailstock forwards; execute M11, M11 output is valid, cancel M10 output and tailstock retreats.

M10 and M11 can't be valid at the same time.

Note1: when the system is reset or stopped in emergency, the output states of M10 and M11 won't change.

2.1.6. Chuck control M12, M13

Instruction function: M12: chuck clamped;
M13: chuck released.

After the system is electrified, both M12 and M13 have no output; execute M12, M12 output is valid, and cancel M13 output; execute M13, M13 output is valid, and cancel M12 output. M12 and M13 can't be valid simultaneously. Chuck locking port is OUT8 by default, and chuck release is OUT9. When chuck is locked, OUT8 output is valid; when chuck is released, OUT9 output is valid. External input control port is IN12. The interlocking of chuck and principal axis is selected through #022 management parameter. MFUN(L)1 is not interlocked, and MFUNC(L)2 is interlocked. M12 and M13 are released through macro program. The user can customize. After parameter #022 is changed to User-Def, it is realized by writing the macro program of M code.

Note 1: When the system is reset or stopped in emergency, the output states of M12 and M13 won't change.

Note 2: chuck can be controlled with external input signal.

2.1.7. Lubricant control M32, M33

Instruction function: M32: lubricant pump open;

M33: lubricant pump closed

After the system is electrified, M33 is valid, i.e. M32 output is invalid. Execute M32, M32 output is valid, and lubricant pump opens; execute M33, cancel M32 output, and lubricant pump clodes; lubricant output port is specified by #075 port parameter; the default option is OUT5.

Note 1: when the system is stopped in emergency, M32 output is invalid;

Note 2: M33 doesn't have corresponding output signal; cancel M32 output when M33 is executed;

2.1.8. Program pause M00

Instruction format: M00 or M0

Instruction function: after other instructions of current block are executed, the program pauses. Press the cycle start key to run next block.

2.1.9. Program running ends and return to program beginning M30

Instruction format: M30

Instruction function: after other instructions of current block are executed, the program stops automatically, executes M05, M09, and the processing pieces increase by 1. The cursor returns to the beginning of the program.

2.2. Programmable I/O instructions

2.2.1. Programmable input instruction M88

Instruction function: the user defines the function of standby input point.

Instruction format:M88 Pxx Lx Qxxxx

P is used to specify the value range of output port number 0-23.

L is used to specify the valid input level, “1” is high voltage level and “0” is low voltage level.

Q is used to specify the testing time in the unit of ms.

Note 1: if specified voltage level isn’t detected in the time specified by Q instruction, the alarm prompts “abnormal program termination error”.

Note 2: if Q instruction isn’t specified, the system will always wait for input signal by default, and won’t execute next instruction until the signal is valid.

Note 3: if the specified port isn’t in the range 0-23, the alarm prompts “specified port number error”.

Note 4: if P instruction isn’t written, the alarm prompts “specified port number error”.

2.2.2. Programmable output instruction M89

Instruction function: the user defines the function of standby output point.

Instruction format: M89 Pxx Lx

P is used to specify the value range of output port number 0-23.

L is used to specify the valid output level, “1” is high voltage level and “0” is low voltage level.

Note 1: if the specified port isn’t in the range 0-23, the alarm prompts “specified port number error”.

Note 2: if P instruction isn’t written, the alarm prompts “specified port number error”.

2.3. Principal axis function (S instruction)

S instruction consists of instruction address S and later digits, and is used to control the rotation of principal axis.

Gear position control: S _1~16 principal axis rotation is controlled by switching 16-gear BCD code. In gear position control mode, #061 comprehensive parameter must be 1, and port parameters #070~073 specify the output port of gear position.

Analog control: S _0~maximum rotation; in analog control mode, #061 comprehensive parameter must be 0, and it is required to set the maximum principal axis rotation of parameter #20. The controller will output 0~10V analog voltage on principal axis port XS8 according to this parameter. If S instruction and the instruction word that executes moving function are in the same block, motion instruction and S instruction are executed at the same time.

2.3.1. Principal axis rotation switching control

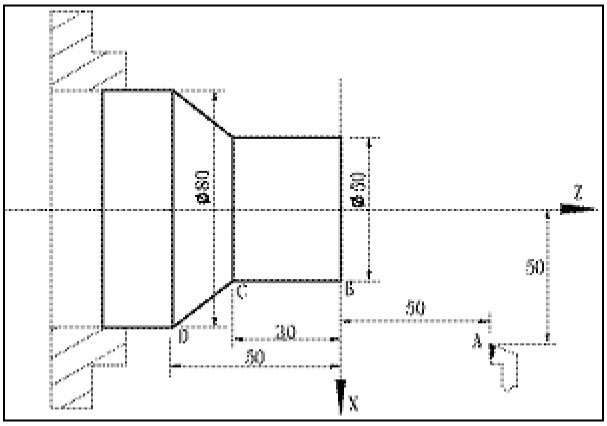
Instruction format: S_1~16.
Instruction function: 16 gear BCD coding position control.

2.3.2. Principal axis rotation analog voltage control

Instruction format: M03 (M04) S____

Instruction function: set principal axis rotation, the system outputs 0~10V analog voltage to control principal axis servo or inverter, achieve stepless speed change, and the value of S instruction is saved after power off.

For example:



Program:

```
O0001;              (program name)
M3 S300;            (principal axis forward rotation)
G0 X100 Z50;        (quickly move to point A)
G0 X50 Z0;          (quickly move to point B)
G1 W-30 F200;       (cut from point B to point C)
X80 W-20 F150;      (cut from point C to point D)
G0 X100 Z50;        (quickly back to point A)
M30;                (program ends, principal axis/coolant off)
%
```

2.3.3. Principal axis rate

If principal axis rotation analog voltage control mode is valid, the actual rotation of the principal axis can be adjusted in 10%~150% instruction rotation range by 15 levels (change 10% every level) with

the principal axis ratio adjustment key. In the main menu of the controller, you can press the left/right key to modify the ratio, or use the principal axis ratio knob on the additional panel to modify principal axis ration; to modify with the left/right key, the principal axis should be started first.
The actual rotation after the principal axis ratio is adjusted is limited by the maximum rotation of the current gear position of the principal axis. The principal axis ratio isn't saved after power off, and the initial ratio after electrified is 100%.

2.3.4. Constant line speed control G96, constantrotation speed control G97*

Instruction format: G96 S___; (S0000-S9999, leading 0 can't be omitted).
Instruction function: constant line speed control is valid, specify cutting line speed (m/min), and cancel constant rotation control. G96 is mode G instruction. If current mode is G96, it is not necessary to enter G96.
Instruction format: G97 S__; (S0000-S9999, leading 0 can't be omitted).
Instruction function: cancel constant line speed control and constant rotation control is valid, specify principal axis rotation (r/m); G97 is mode G instruction. If current mode is G97, it is not necessary to enter G97.

When the lathe is shaping workpiece, the workpiece usually rotates around the principal axis. The cutting point of the tool may be considered as circle motion around the principal axis, and the instant speed in circumferential tangent direction is called as cutting line speed (line speed for short).

Constant line speed control function is valid only when principal axis rotation analog voltage control function is valid. In constant line speed control, the principal axis rotation reduces along with the change of X axis absolute coordinates of the programming track (neglecting tool length compensation) and increase of X axis absolute coordinates, and the principal axis rotation increases along with the decrease of X axis absolute coordinates, making cutting line speed maintain at S instruction value.
Line speed = principal axis rotation *|X|*л/1000 (m/min)
In constant line speed control, Z coordinate axis of the workpiece coordinate system must coincide with the principal axis, or else the actual line speed isn't consistent with the specified line speed.

2.3.5. Principal axis maximum rotation limit*

Use the value following G50S to specify the maximum principal axis rotation (r/m) of constant line speed control
G50 S__;
In constant line speed control, the principal axis rotation is limited to the maximum if it is higher than the value specified in above program.

2.4. Fast moving and feeding function (G98/G99, F instruction)

This system has three axis control modes, i.e. fast moving, cut feeding and manual feeding.

2.4.1. Fast moving

Fast moving: for lathe, X axis direction and Z axis direction move at independent speed, set through #105 and #107 parameters, and the motion of the two directions doesn't constitute fixed linear or arc track. This system allows G instruction and manual fast moving; X axis direction and Z axis direction can't move simultaneously in manual fast moving.

The fast moving speeds of X axis and Z axis are set by X axis fast moving speed and Z axis fast moving speed respectively. You can adjust the actual fast moving speed with the ratio adjustment key, and the actual fast moving speed is 25%, 50% or 100% of the set fast moving speed.

The ratio isn't saved after power off, and the initial value is 100 after electrified.

2.4.2. Cutting feeding instruction F

Cutting feeding: the system controls the motion of X axis and Z axis simultaneously, making the motion track of the tool consistent with the track (linear, arc) defined by the instruction, and the instantaneous speed of the motion track in tangential direction is consistent with F instruction value, and the process of this motion control is called cutting feeding or interpolation. The speed of cutting feeding is specified by F instruction word. When the system is executing interpolation instruction (cutting feeding), it desomposes the cutting feeding speed specified by F instruction to X axis and Z axis according to the programming track, the system controls the instantaneous speed of X axis and Z axis simultaneously, making the vector synthesis speed of the two direction equal to F instruction value.

Remark: use the feeding ratio key on the panel of the machine tool or external ratio switch to adjust the cutting feeding speed in real time, and the actual cutting feeding speed can be adjusted in the range of 0~150% of the instruction speed by 16 levels (10% every level). The adjustment of feeding ratio is invalid for thread cutting.

$$F=\sqrt{f_X^2+f_Z^2}$$

$$f_X=\frac{dx}{dt}$$

$$f_Z=\frac{dz}{dt}$$

F is the vector synthesis speed of the instantaneous speed of X axis and Z axis;

dx is the instantaneous (dt period) increment of X axis, and fx is the instantaneous speed of X axis;

dz is the instantaneous (dt period) increment of Z axis, and fz is the instantaneous speed of Z axis;

For example: as in Fig. 2-4-1, the values in the brackets are coordinates of the points (diameter value in X direction).

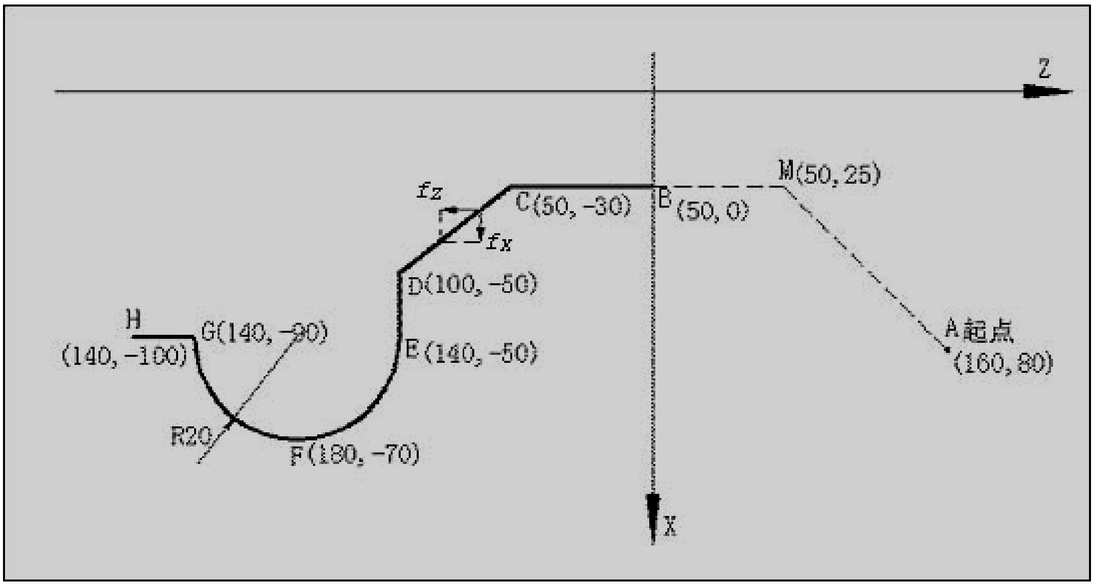


Fig. 2-4-1

The program follows:

```
O0010;
G00 X160 Z80; (move the machine tool to safe position first)
G98;
G0 X50 Z0;      (move to point B quickly from point A through point M)
G1 W-30 F250; (B→C)
X100 W-20;      (C→D)
X140;           (D→E)
G2 W-40 R20; (EFG arc interpolation)
W-10;           (G→H)
M30;
%
```

2.4.3. G98, G99

Instruction format: G98 Fxxxx; (F0001~F8000, the leadin 0 can be omitted, specify the feeding speed every minute, mm/min)

Instruction function: specify the cutting feeding speed in the unit mm/min, G98 is mode G instruction. If current mode is G98, it isn't required to enter G98.

Instruction format: G99 Fxxxx; (F0.0001~F500, the leadin 0 can be omitted)

Instruction function: specify the cutting feeding speed in the unit mm/r, G99 is mode G instruction. If current mode is G99, it isn't required to enter G99. When the system executes G99 Fxxxx, the product of of F instruction value (mm/r) and current principal axis rotation (r/m) is used as the instruction feeding speed to control the actual cutting feeding speed. When the principal axis rotation is changed, the actual cutting feeding speed also changes. Use G99 Fxxxx to specify the cutting feeding every rotation of the principal axis, and form even cutting grain on the surface of the workpiece. In G99 mode, the machine tool must be installed with principal axis encoder, and set principal axis encoder wires.

G98 and G99 are in the same group of mode G instruction, and only one is valid at the same time. G98 is initial G instruction, and G98 is valid by default when the system is electrified.

2.4.4. Manual feeding

Manual feeding: this system allows X axis or Z axis positive/negative motion at current manual feeding speed in the manual mode, X axis and Z axis can’t move simultaneously. The actual manual speeds in X axis direction and Z axis direction are adjusted with the manual ratio adjustment key in the range 10%~150%. The manual speed of each level is the product of the fixed value set by the system parameter and manual ratio, and the manual speed of every axis is set by the parameter independently. When manual fast moving key is valid, manual speed uses the fast moving speed of every axis, and manual ratio is invalid.

Manual feeding ratio isn’t saved after power off, and the initial ratio is 100% after electrified.

2.5. Tool compensation function (T instruction)

The system allows automatic tool change, and can control the automatic tool holder of position 4~8 to change tools during the processing, achieving the part processing of multi-process and multi-tool.

The system also allows tool length compensation, which doesn’t need to consider the actual position of the tool while programming, and only needs to get the position offset data of every tool (tool offset) through tool setting operation before processing. Before processing with tool, execute tool length compensation first, i.e. offset the system coordinates according to tool offset to make the motion track of the tool tip consistent with the programming track. After tool is changed, the user only needs to reset the tool and modify tool offset, and doesn’t need to modify processing program. If the processing size has error due to tool abrasion, modify tool offset according to tool offset directly to eliminate processing size error.

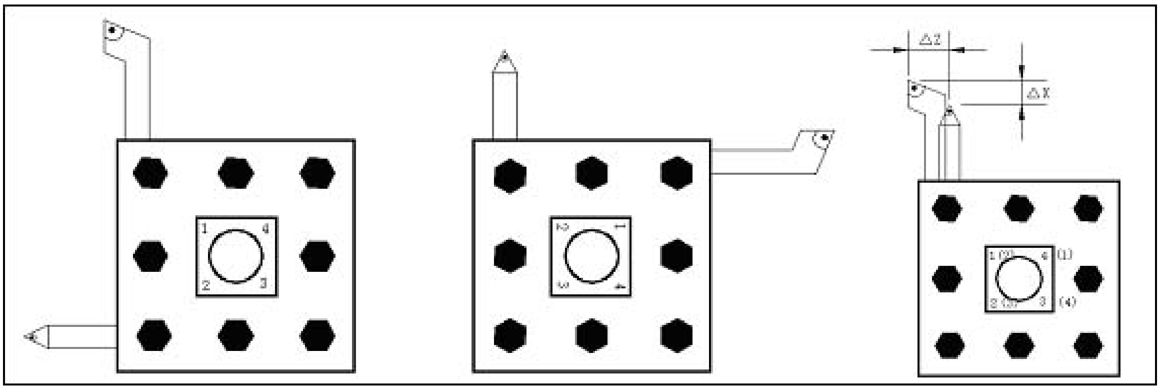


Fig. 2-5-1

Instruction format:

T ○○ ○○

Tool offset No. (00-16, leading 0 can’t be omitted)

Target tool No. (00-08, leading 0 can’t be omitted)

Instruction function: automatic tool holder changes tool to target tool No., and executes tool length compensation according to the tool offset corresponding to the tool offset No. of the instruction. Tool offset No. may be same to or different from tool No., i.e. one tool can correspond to several offset No. The tool offset corresponding to tool offset No. 00 is X=0, Z=0, and the system doesn't have tool compensation state, i.e. coordinate offset of the system is 0 (without coordinate offset). After tool length compensation, execute T□□00, the system will offset the system coordinates reversely according to current tool offset, the state is changed from tool length compensated to not compensated, the displayed tool offset No. is 00, and this process is to cancel tool length compensation.

For example: T0101 is to select #1 tool and execute #1 tool offset;

T0102 is to select #1 tool and execute #2 tool offset;

T0301 is to select #3 tool and execute #1 tool offset

After electrified, the tool No. and offset No. displayed by T instruction are the state before power off.

Only one T instruction is valid in one block; if two or more T instructions are in the block, the last the valid.

If T instruction and the instruction executing moving function are in the same block, the tool change instruction is executed before the moving instruction.

This system is suitable for automatic tool holder with 4—8 tool positions; by modifying the parameters of #2 tool magazine and modifying parameters #17, #18, #19 and #20, tool position signals (independent) input directly, tool holder forward to change the tool, and reverse to lock after in position. The control of tool holder is realized through embedded T code macro program; #023 management parameter is TFUNC(L) by default, and you can customize T code if this parameter is changed to User-Def.

In manual mode, press the tool change key on the panel of the machine tool to change the tool manually.

In coordinate menu of the system, tool setting includes setting and compensation. For tool setting, it is necessary to cut current workpiece for test first, enter actually measured X axis diameter and Z axis length, and the system will calculate the offset automatically and save in the parameter. For example, if cut with #1 tool, press the record mode in tool setting interface, enter X cutting diameter and Z cutting length to #1 parameter and call T0101. Compensation is to offset current compensation No.

3. G Instruction

3.1. Introduction

G instruction consists of instruction address G and later 1~2 instruction values. It is used to regulate the interpolation mode, pause function and coordinate setting of the tool relative to the workpiece.

G □□

Instruction value (00~99, first 0 can be omitted)

Instruction address G

G instruction word is divided into group 00, 01, 02, 03, and 04. In the same block, you can enter G instruction words of different groups. If two or more G instruction words of same group are entered in the same block, only the last G instruction word is valid. The G instruction words of different groups without common parameter (instruction word) may be in the same block, and the functions are valid simultaneously and are unrelated with the sequence. The system doesn't support the G instruction words not in this table, and will alarm if there is.

3.1.1. Modal, non-modal and initial state

The modal function is that a code is always valid once it is specified in current block, until another code of the same group appears in the block, and it isn't required to specify if this instruction is used in next block.

The non-modal function is that a code is only valid in its block, and it should be specified again if it is used in next block.

After the system is electrified, the mode G instruction word that is valid before the function or state is executed is called initial G instruction word. If the initial G instruction word is executed after electrified, it isn't required to enter this G instruction word. The initialized instruction word of the system is G01.

3.1.2. Relative definition

This manual has the following description:

Start point: the position when current block is running;

End point: the position after current block ends;

X: absolute coordinates of the end point in X direction;

U: difference between start point and end point in X absolute coordinates;

Z: absolute coordinates of the end point in Z direction;

W: difference between start point and end point in Z absolute coordinates;

F: cutting feeding speed

G instruction word list

Instruction word	Group	Function	Remakr
G00	01	Fast moving	Initial G instruction
G01		Linear interpolation	Modal G instruction
G02		Arc interpolation (CW)	

G03		Arc interpolation (CCW)	
G32		Thread cutting	
G90		Axial cutting cycle	
G33		Z axis taping cycle	
G92		Thread cutting cycle	
G94		Radial cutting cycle	
G04	00	Pause, quasi stop	Non-modal G instruction
G31		Jump instruction	
G27		Reference point returns checking instruction	
G28		Return to mechanical home	
G29		Return instruction from the reference point	
G30		Return to second reference point instruction	
G50		Coordimate system setting	
G70		Finishing cycle	
G71		Axis roughing cycle	
G72		Radial roughing cycle	
G73		Closed cutting cycle	
G74		Axial grooving multi-cycle	
G75		Radial grooving multi-cycle	
G96	02	Constant line speed on	Modal G instruction
G97		Constant line speed off	Initial G instruction
G98	03	Feeding every minute	Initial G instruction
G99		Feeding every revolution	Modal G instruction

3.2. Interpolation function

3.2.1. Fast moving G00

Instruction format: G00 X(U)Z(W);

Instruction function: X axis and Z axis move to the end point simultaneously from the start point at the fast moving speed respectively. G00 is initial G instruction.

The two axes move at independent speed respectively. Set the fast moving speed of X axis and Z axis through comprehensive parameter 009 and 011. The synthetic track isn’t straight line necessarily, and it should be noted that the two axes may not reach the end point at the same time.

Either or both instruction addresses X(U) and Z(W) can be omitted. If one is omitted, the coordinates of the start point and end point of the axis are consistent; if both are omitted, the start point and end point are in the same position.

The fast moving speed of X axis and Z axis are set by X axis fast moving speed and Z axis fast moving speed respectively, and the actual moving speed can be adjusted with the fast ratio key on the panel of the machine tool.

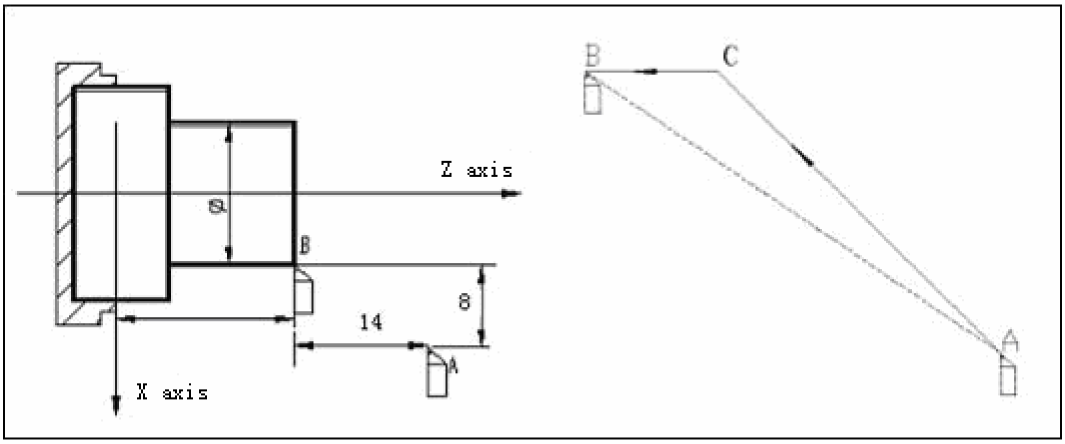
The maximum speed that the machine tool actually can reach depends on the actual condition of the machine tool and the motor. For detailed parameters, please refer to the manual of the machine tool.

G00 is modal instruction, and can be omitted if next block is same.

G00 can be abbreviated to G0, which is equivalent to G00.

If X axis and Z axis are moved at the same time, note whether the tool is in safe area to avoid bump.

For example: the tool moves from point A to point B quickly.



Z axis X axis

G0 X20 Z25; (A coordinates)

G0 U-8 W-14; (A→B)

3.2.2. Linear interpolation G01

Instruction format: G01 X(U)_ Z(W)_F_;

X(U)/Z(W): absolute or relative coordinates of the end point.

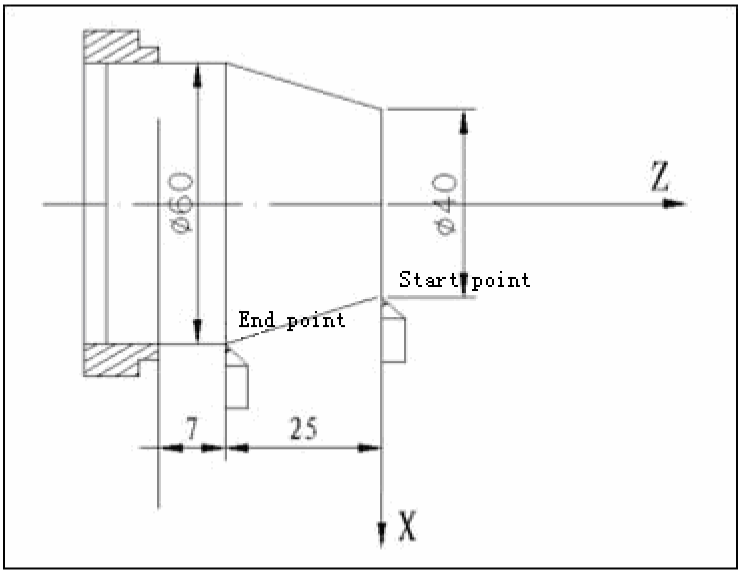
F : cutting feeding speed

Instruction function: G01 instruction makes the tool arrive at the position of specified point along the connection line from current point to the point specified by X(U), Z(W) at specified speed. The motion track is a straight line from the start point to the end point. F instruction value is the vector synthetic speed of instantaneous speed of X axis and Z axis, and the actual cutting feeding speed is the product of feeding ratio and F instruction value. Once executed, F instruction value is maintained until new F instruction value is executed.

For example:

G01 X60.0 Z-25 F200; (absolute value programming)

G01 U20.0 W-25.0; (relative value programming)



End point Start point

3.2.3. Arc interpolation G03, G02

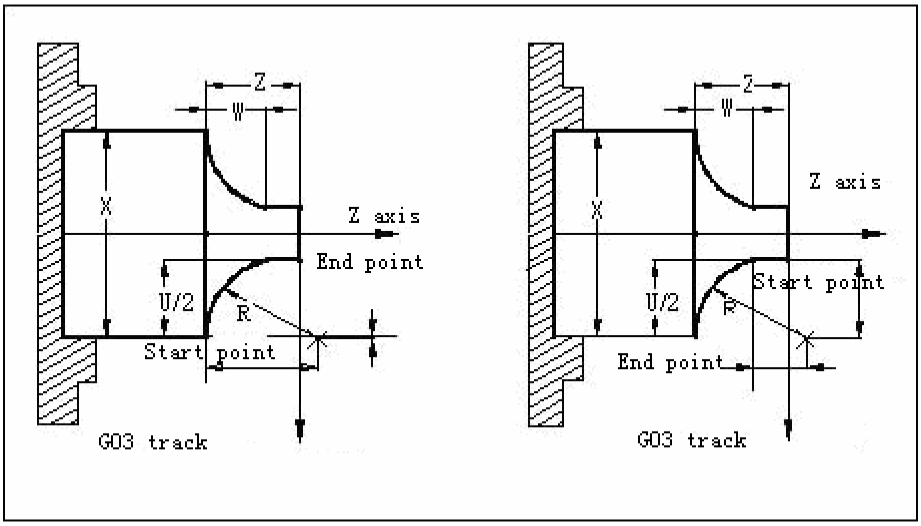
Instruction format: G03/ G02 X(U)_ Z(W)_ R_ (I_ K_) F_;

Instruction function: the motion track is the CW arc/CCW arc from the start point to the end point, and the track is shown in the figure below.

R: arc radius (0~9999.999mm);

I: the difference between X coordinates of the circle center and arc start (-9999.999~9999.999mm);

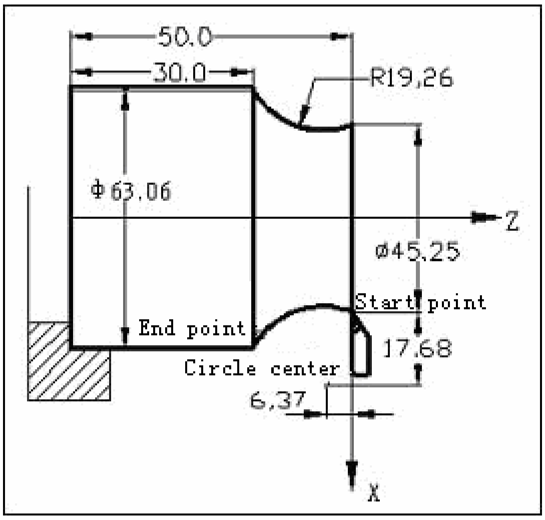
K: the difference between Z coordinates of the circle center and arc start (-9999.999~9999.999mm);



Z axis	Z axis	End point	Start point
Start point	End point	X axis	end point
G03 track	G02 track		

Fig. 3-2-3-1

For example: as shown in Fig. 3-2-3-2 below



Start point End point Circle center

Fig. 3-2-3-2

Program:

G02 X63.06 Z-20.0 R19.26 F300;

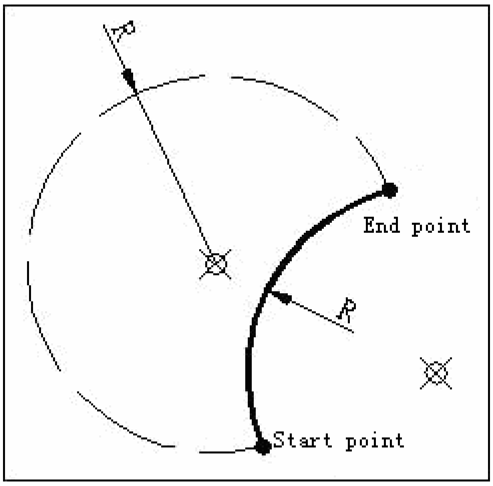
Or G02 U17.81 W-20.0 R19.26 F300;

Or G02 X63.06 Z-20.0 I35.36 K-6.37 F300;

Or G02 U17.81 W-20.0 I35.36 K-6.37 F300;

Notice:

- In G02/G03 block, it is required to enter at least one of the instruction addresses of I, K and R, or else the system will alarm; if I, K and R are entered at the same time, R is valid, while I and K are invalid; if R isn't entered or R equals to 0, the system alarms;
- If X(U) and Z(W) aren't entered, and R is used to specify the radius, X axis and Z axis won't move when G02/G03 instruction is executed; if R isn't entered and use I, K instruction word, the track of executing G02/G03 instruction is a full circle (360°);
- When R instruction is used, it is two arcs larger and smaller than 180° in theory. In this system, the arc smaller than 180° is valid (as in Fig. 3-4-3 below). If the end point ins't on the arc defined with R, the system will alarm;

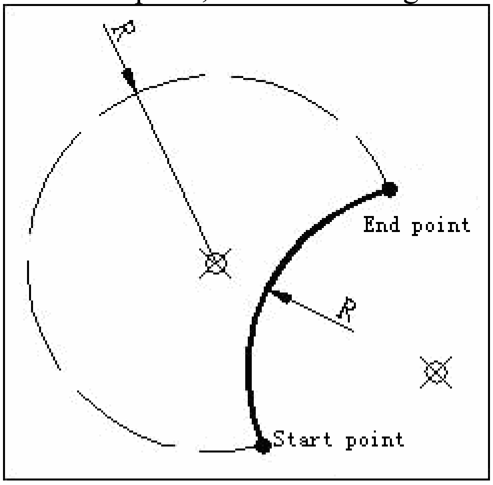


End point Start point

Fig. 3-4-3

- In G02/G03 block, if I and K instruction words are used to define the circle center, the system won't alarm even if the end point isn't on the arc. The track of the instruction is:

in the circle center and arc direction defined by the instruction, X axis and Z axis move along the arc from the start point at the same time; if the coordinates of X axis or Z axis are same to the end point, X axis or Z axis stops motion, and the axis (Z axis or X axis) continues to move to the end point, as shown in Fig. 3-4-4 below



End point Start point

Fig. 3-4-4

3.2.4. Pause instruction G04

Instruction format: G04 P__;

Or G04 X__ ;

Instruction function: every axis stops motion, do not change current G instruction mode and maintained data and state, delay for specified time, and then execute next block. The delay time is specified with instruction word P__(unit: ms), X__(unit: sec). G04 is non-modal G instruction.

G04 P1000 delay 1000ms = 1sec

G04 X1 delay 1sec

3.2.5. Return to mechanical home G28

Instruction format: G28 X(U)_ Z(W)_;

Instruction function: from the start point, arrive at the center point specified by X(U), Z(W) at the fast moving speed and then return to the mechanical home at the same time. G28 is non-modal G instruction.

One or both instruction addresses X(U) and Z(W) can be omitted; see the table below for details

Instruction	Function
G28 X(U)_	X axis returns to mechanical home, Z axis stays at the original position
G28 Z(W)_	Z axis returns to mechanical home, X axis stays at the original position
G28	Two axes stay at original position, and continue to execute next block
G28 X(U) Z(W)	X and Z axis return to mechanical home

	simultaneously

X: absolute coordinates of center point in X direction; U: the difference of the absolute coordinates of the center point and start point in X direction;

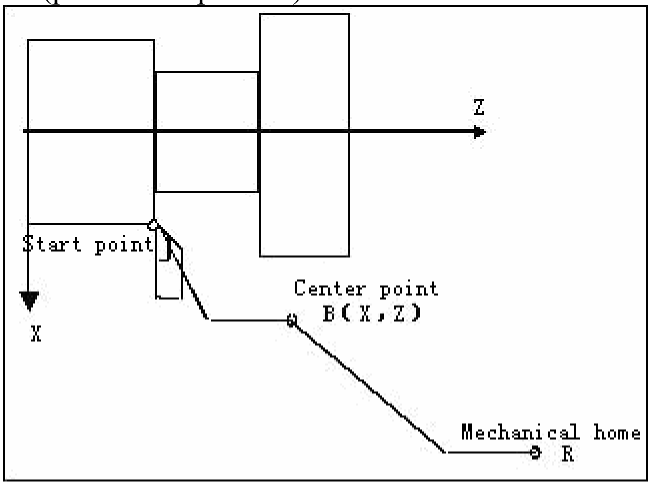
Z: absolute coordinates of center point in Z direction; W: the difference of the absolute coordinates of the center point and start point in Z direction.

Process of instruction action (see the figure below):

(1) Move to center point from the start point simultaneously at independent fast moving speed (point A → point B).

(2) When the two axes reach the center point, move to the mechanical home from the center point simultaneously at independent fast moving speed (point B →point R).

(3) If U and W are 0, return to the machine tool home directly, e.g. G28 U0 W0, the system returns to the reference point directly, and doesn't pass through the center point (point A → point R).



Start point Center point Mechanical home

3.3. Thread cutting

3.3.1. Thread cutting instruction G32

Instruction format: G32 X(U)__Z(W)__ F__P__D__V__;

X(U): thread X axis end point coordinates or increment value

Z(W): thread Z axis end point coordinates or increment value

F: metric thread pitch (0.001~500 mm), it is the movement of the long axis when the principal axis rotates a circle, maintain valid after F instruction value is executed, until the F instruction word of specified thread pitch is executed again.

P: thread cutting acceleration pitch, the unit is mm, unsigned, the acceleration length of the long axis during thread cutting; if the program doesn't specify the P value, the system calls parameter #109 automatically for calculation; if X is long axis, P is the radius.

D: thread cutting deceleration pitch, the unit is mm, unsigned, the deceleration length of the long axis during thread cutting; if the program doesn't specify the D value, the system calls parameter #110 automatically for calculation; if X is long axis, D is the radius.

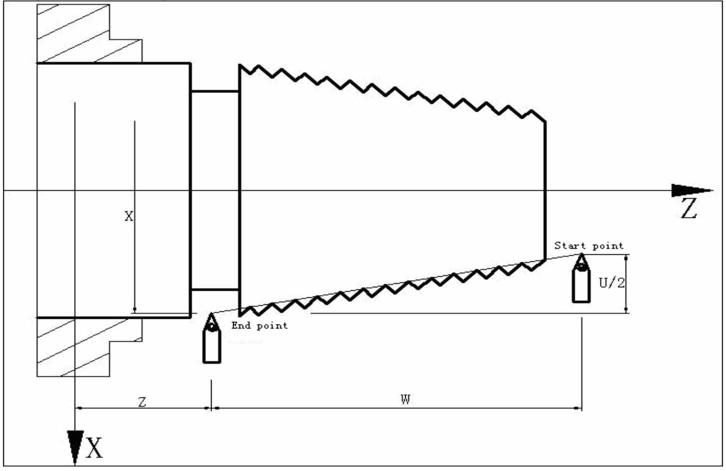
V: pitch cutting back amount, the unit is mm, signed; the sign relates to the back direction; it is the back length of the short axis during thread cutting; if the program doesn't specify the V value, the system calls parameter #111 automatically for calculation; if X is short axis, V is the radius.

Instruction function: the motion track of the tool is a straight line from the start point to the end point; the coordinate axis with larger displacement from the start point to the end point (X axis depends on the radius value) is the long axis, and the other is the short axis. During motion, the long axis moves a pitch when the long axis rotates a circle, short axis and long axis make linear interpolation; when the tool cuts the workpiece, a spiral grooving with equal pitch is formed on the surface of the workpiece, achieving thread processing of equal pitch. F instruction word can be used to specify the pitch of metric thread, and execute G32 instruction to process straight thread, taper thread and end thread of metric equal pitch:

If the X coordinates of start point and end point are same (do not enter X or U), it is straight thread cutting;

If the Z coordinates of start point and end point are same (do not enter Z or W), it is end thread cutting;

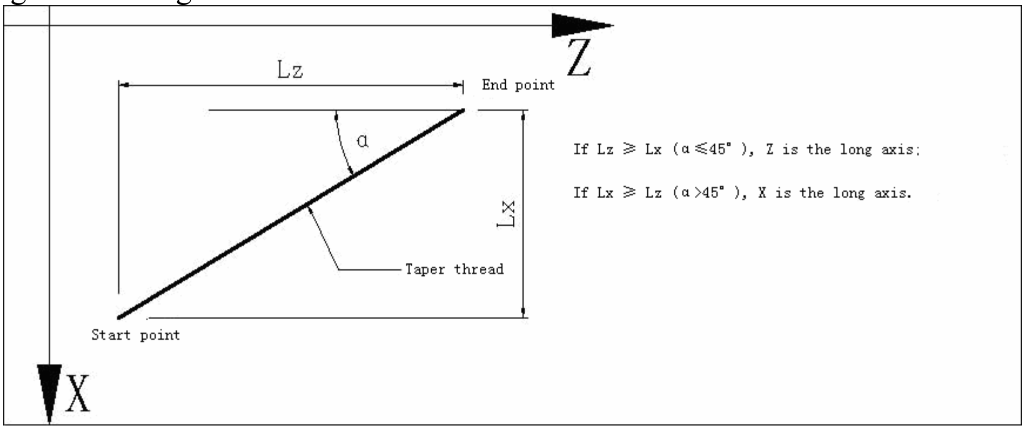
If the X coordinates and Z coordinates of start point and end point are different, it is taper thread cutting, as in Fig. 3-7-1 below



Start point
End point

Fig. 3-7-1

The thread pitch is the displacement of the long axis when the principal axis rotates one circle (X axis displacement depends on the radius); see Fig. 3-7-2 below for the method to distinguish the long axis and short axis:


Z
Lz
End point
α
Lx
Taper thread
Start point
X
If Lz ≥ Lx (α≤45°), Z is the long axis;
If Lx ≥ Lz (α>45°), X is the long axis.

Start point

If Lz ≥ Lx (α≤45°), Z is the long axis;

If Lx ≥ Lz (α>45°), X is the long axis.

Taper thread End point

Fig. 3-7-2

Thread cutting notice:

- The machine tool must be installed with principal axis encoder for thread cutting; the transmission ration of principal axis encoder and the principal axis is 1:1, modify #013 principal axis encoder wires, and the system is initialized to 0. When the system receives the signals from principal axis encoder Z (origin), it moves X axis or Z axis and starts thread processing, therefore, the processing of same thread can be finished through roughing and finishing as long as the principal axis rotation isn't changed.

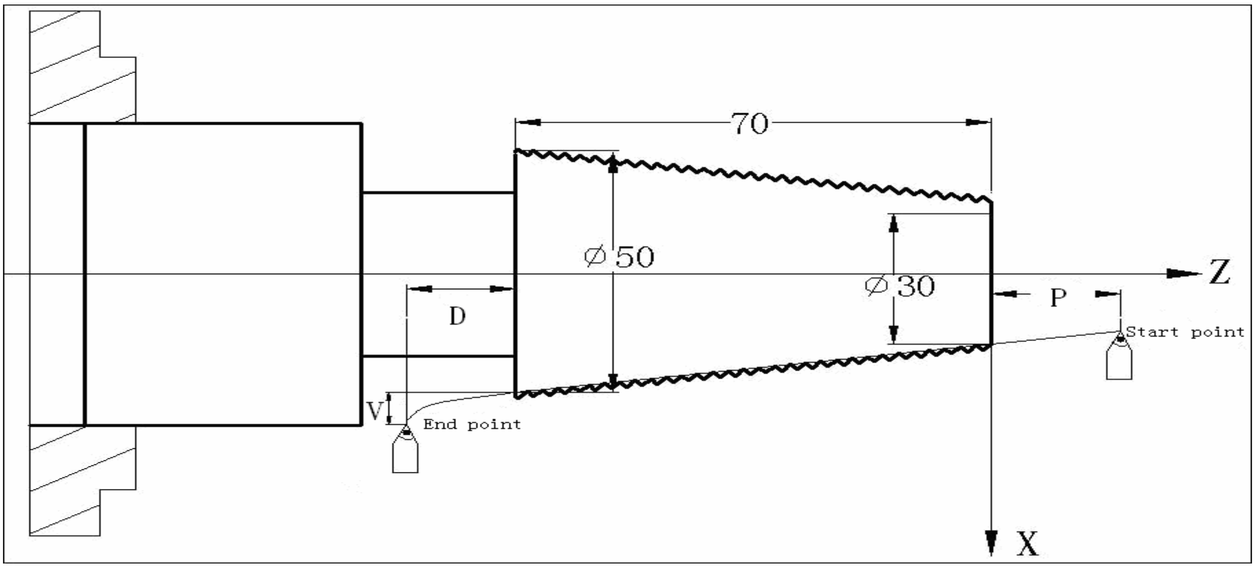
- Since X axis and Z axis have acceleration and deceleration process in the beginning and at the end of thread cutting, the pitch error is large at this moment, and therefore acceleration pitch P must exist before the long axis start point and deceleration pitch D (usually called as retreating groove) must exist after the end point of the long axis during actual thread cutting, i.e. programmed thread length is longer than actual thread length. Thread cutting length includes P, D; similarly, the end position of the short axis must have back amount V, i.e. at the end position of thread cutting, the short axis exits thread cutting in V back amount, as shown in the figure below.

For example:

Thread pitch: 4mm. P = 3.5mm, D = 3.5mm, V=1, total cutting depth 1mm (single side), cut in two times

```
G00 X28 Z3;                (cut 0.5mm in the first time)
G32 X51 W-77 F4.0 P3.5 D3.5 V1; (taper thread first cutting)
G00 X55;                   (tool exits)
W77;                       (Z returns to the start point)
X27;                       (cut another 0.5mm in the second time)
G32 X50 W-77 F4.0; (taper thread second cutting)
G00 X55;                   (tool exits)
 W77;                      (Z returns to the start point)
```

As in Fig. 3-7-3:



Start point End point

Fig. 3-7-3

- Under the condition that the start point, end point and thread pitch of G32 are fixed, the moving speed of X axis and Z axis during thread cutting depends on the principal axis rotation, and doesn't relate to cutting feeding ration. During thread cutting, principal axis ratio control is valid; when principal axis rotation is changed, the pitch error increases due to acceleration/deceleration of X axis and Z axis, therefore, do not adjust the principal axis rotation during thread cutting or stop the principal axis (or else the tool and workpiece will be damaged).
- During thread cutting, the long axis increment should be larger than the value of (P+D), and the actual thread length of the long axis should be larger than pitch F.
- When the system is reset, stopped in emergency or alarms, thread cutting stops

immediately.

3.3.2. Z axis taping cycle G33

Instruction format: G33 Z(W)__ F__;

Instruction function: the motion track of the tool is from the start point to the end point, and then returns to the start point. During the motion, Z axis moves a pitch when principal axis rotates one circle, always keeps consistent with the pitch of the thread, forms a spiral grooving in the internal hole of the workpiece, and completes the thread processing of the internal hole after once cutting.

Instruction description: G33 is modal G instruction;

Z(W): do not enter Z or W, the Z coordinates of the start point and end point are same, and do not execute thread cutting;

F: metric thread pitch, range: 0.001~500 mm;

Cycle process:

① Z axis feeding and taping (principal axis must be specified to ON before G33 instruction);

② M05 signal outputs after reaching the Z axis coordinate end specified by the program;

③ Principal axis stops completely;

④ Principal axis reverse signal output (opposite to original rotation of the principal axis);

⑤ Z axis back to the start point;

⑥ Principal axis resumes the turning before G33.

Program:

```
O0011;
G00 Z90 X0Z0 M03; start the principal axis
G33 -Z50 F1.5; taping cycle
G00 X60 Z10; continue processing
M30
```

Note 1: before taping, determine the principal axis according to the rotation of the thread, and the principal axis will resume original rotation after taping.

Note 2: this instruction is rigid taping; when principal axis stop signal is valid, the principal axis stops rotation after a period of deceleration, and Z axis will feed following the rotation of the principal axis at this moment, until the principal stops completely, and therefore, the bottom hole position of the thread is deeper than actual required position during actual processing; the specific exceeded length depends on the principal axis rotation and principal axis brake device during taping.

Note 3: during taping cutting, the moving speed of Z axis depends on the principal axis rotation and pitch, and isn’t related to cutting feeding speed ratio.

Note 4: during single block running or feeding maintenance operation, the system displays “Pause”, taping cycle doesn’t stop, until taping completes and returns to the start point.

Note 5: when the system is reset, stopped in emergency or alarms, taping cutting decelerates to stop.

3.4. Workpiece coordinate system setting G50

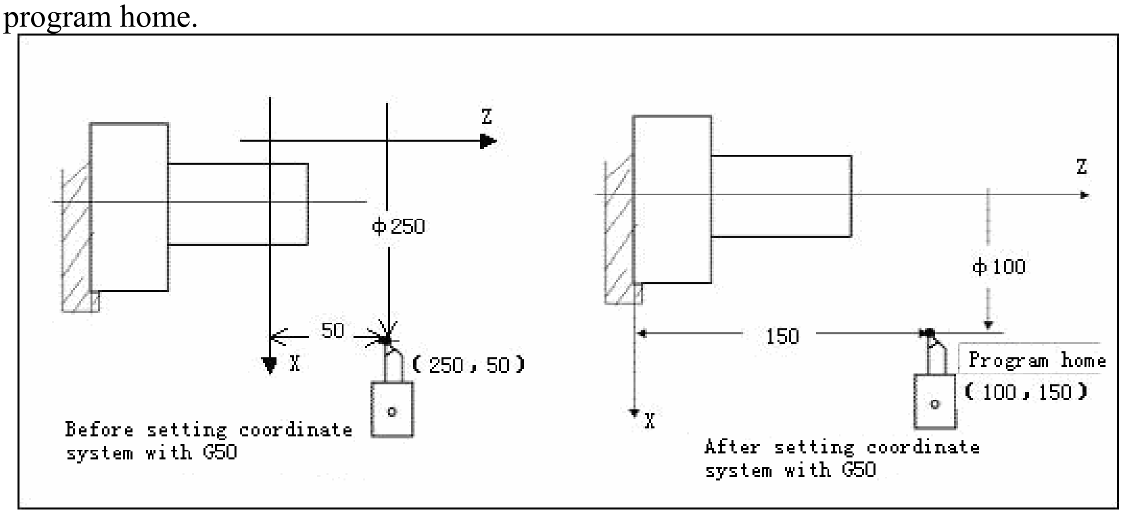
Instruction format: G50 X _ Z _ ;

X: new X axis absolute coordinates of current position;

Z: new Z axis absolute coordinates of current position;

Instruction function: set the absolute coordinates of current position, and thus create workpiece coordinate system (also floating coordinate system). After executing this instruction, the system sets current position as the program home. When workpiece coordinate system is created, absolute coordinate programming enters the coordinates according to this coordinate system, until G50 is executed again to create new workpiece coordinate system. G50 is non-modal G instruction.

X or Z isn't entered in G50 instruction, the coordinate axis isn't entered sets the coordinates according to current absolute coordinates; if both X and Z aren't entered, current coordinates won't be changed. Aslong as G50 is executed, current position will be set as the program home.


Z
Φ250
50
X
(250，50)
Before setting coordinate system with G50
Z
Φ100
150
Program home
(100，150)
X
After setting coordinate system with G50

Program home
Before setting coordinate system with G50
After setting coordinate system with G50

As shown in the figure above, after instruction "G50 X100 Z150" is executed, the workpiece coordinate system as shown in the figure is created, and point (X100, Z150) is set to program home.

Note: If G50 is executed to set coordinate system in tool length compensation state, the absolute coordinates displayed by the system are the coordinate value after current tool offset is modified; program home is the position defined by G50 coordinate value in workpiece coordinate system. Return to program home in tool length compensation state, the position of home end is the program home position after tool length compensation is canceled.

For example:

Current tool compensation state	Coordinates after G50 X20 Z20 is executed		#01 tool compensation
T0100	X:20	Z:20	X:12
T0101	X:32	Z:43	Z:23

3.5. Fixed cycle

To simplfy the programming, the system provides a G instruction of single processing cycle that only uses one block to complete fast moving positioning, linear/thread cutting, and finally returns to start point:

G90: axial cutting cycle
G94: radial cutting cycle
G92: thread cutting cycle

3.5.1. Axial cutting cycle G90

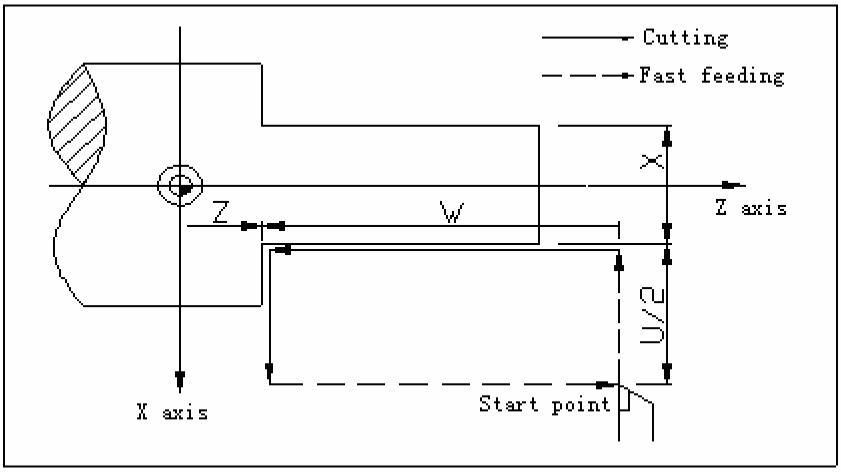
Format: G90 X/U__ Z/W__ R__ F_;

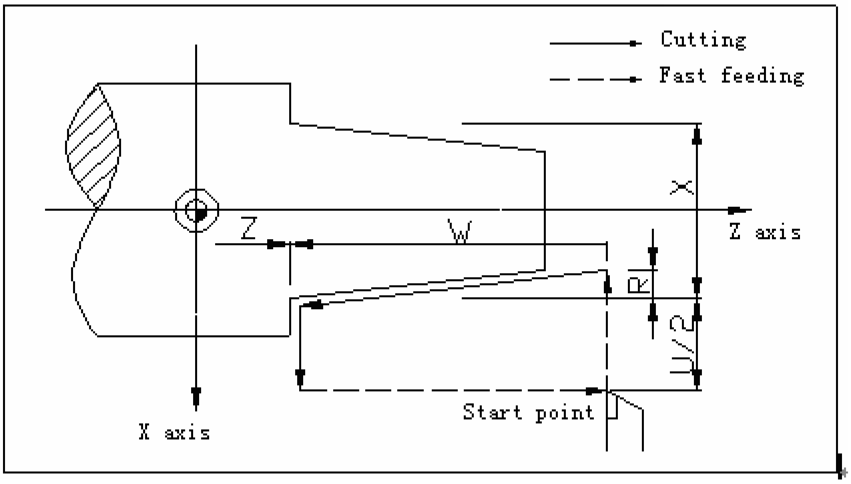
X/U: cutting end X axis coordinates;

Z/W: cutting end Z axis coordinates;

F: cutting speed

R: cone slope; radial coordinate difference (radius) between cutting start and cutting end; if R and U do not have same sign, |R| ≤ |U/2| (diameter programming) or |R| ≤ |U/2|(radius programming) is required. If R isn't specified, the cylinder processing is shown in the figure below:





Cutting Fast feeding
Z axis X axis Start point

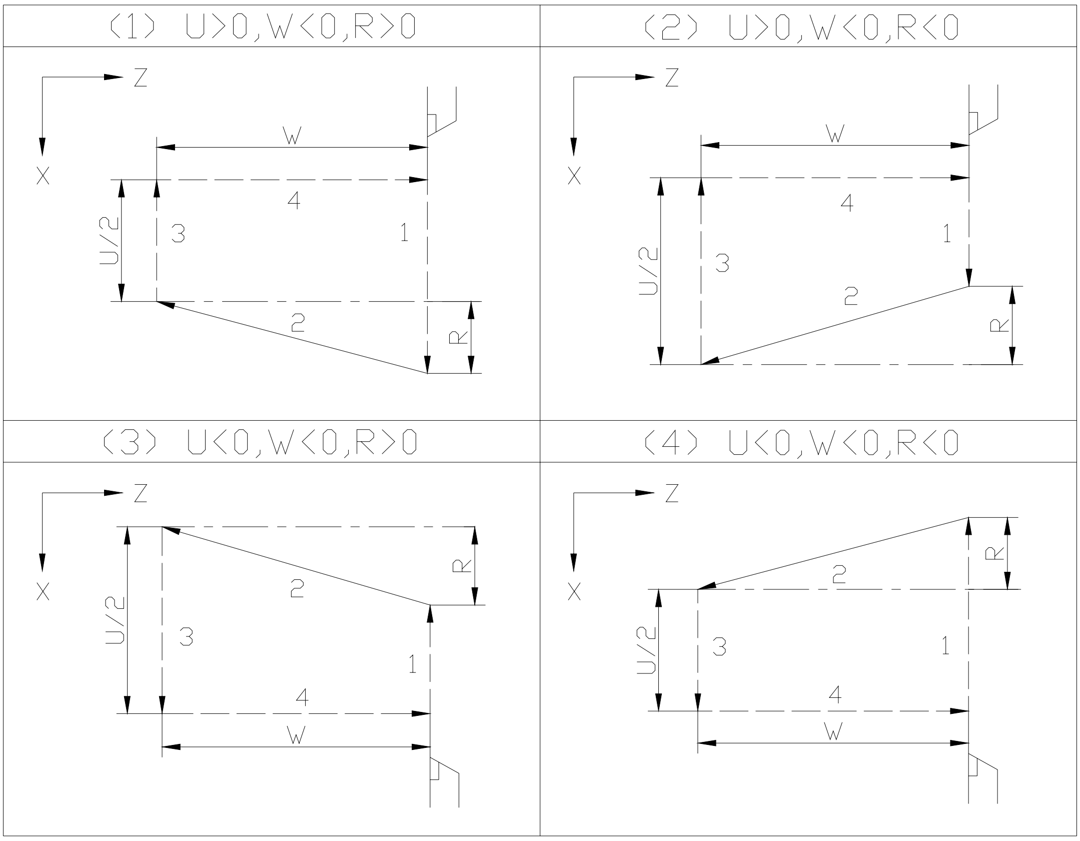
Execution process:

1) X axis locates (G0) to cutting start quickly from cycle start;
2) Interpolate (G1) to cutting end from cutting start in linear;
3) X axis radially back to radial coordinate position of cycle start in line interpolation (G1) mode;
4) Z axis quickly locates (G0) and returns to the start point, and cycle ends.

Note:

1) G90 is modal instruction.
2) In single block operation, the system stops at the end position of every block, and pause and resetting operation are valid in the motion process.

3) U, W and R reflect the relative position of cutting end and start. G90 has four track combinations depending on the sign.



During diameter programming, if R and U do not have same sign and |R| > |U/2|, 0792-G90, G92, G94 program error alarms, and the value of R exceeds allowed range

4) During first tool cutting, if U is 0, current value is the end coordinates by default; W can't be 0, or else the system alarms

5) Before executing G90, specify the position of start point, or else the system takes current point as the start

6) G90 is valid in MDI mode, and modal function is also available.

As in Fig. 3-5-1:

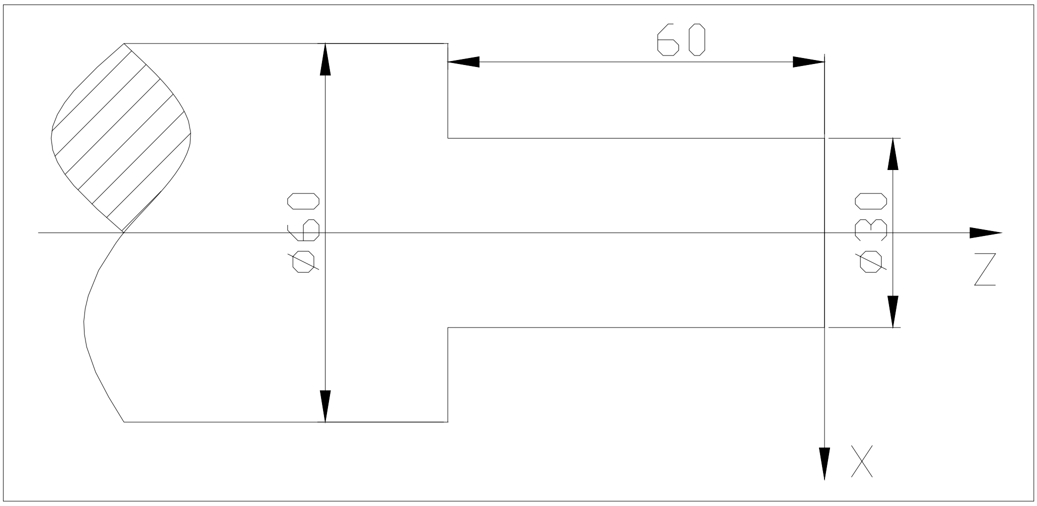


Fig. 3-5-1

```
O9001
M03 S500T0101
G00 X70 Z2
G90X56Z-60F500
X52
X48
X44
X40
X36
X32
X30
M30
 %
```

3.5.2. Thread cutting cycle G92

Instruction format: G92   X/U__ Z/W__ R__ F__ P__ D__ V__;

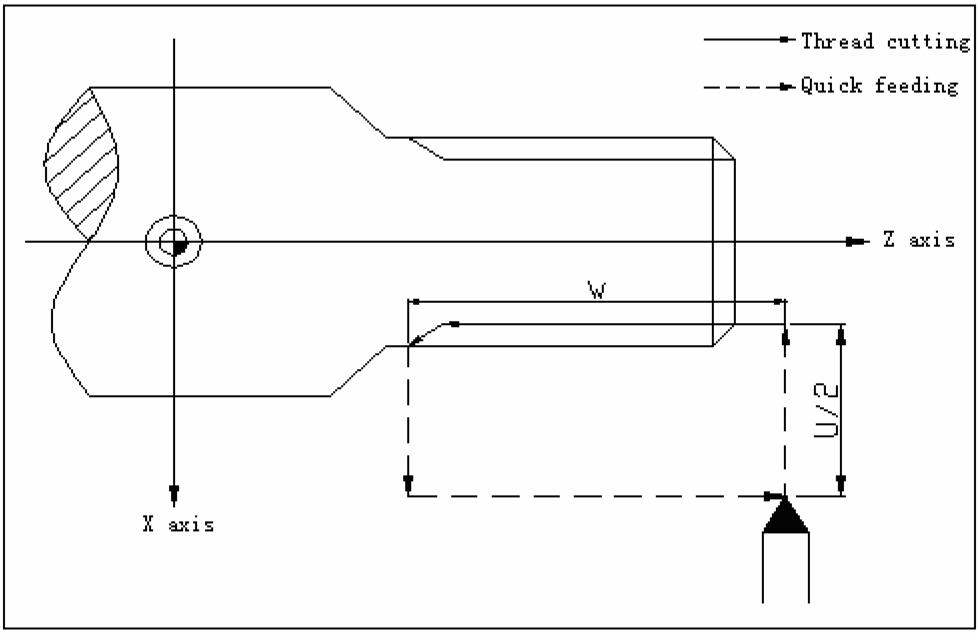
X/U: thread end X axis coordinates;

Z/W: thread end Z axis coordinates;

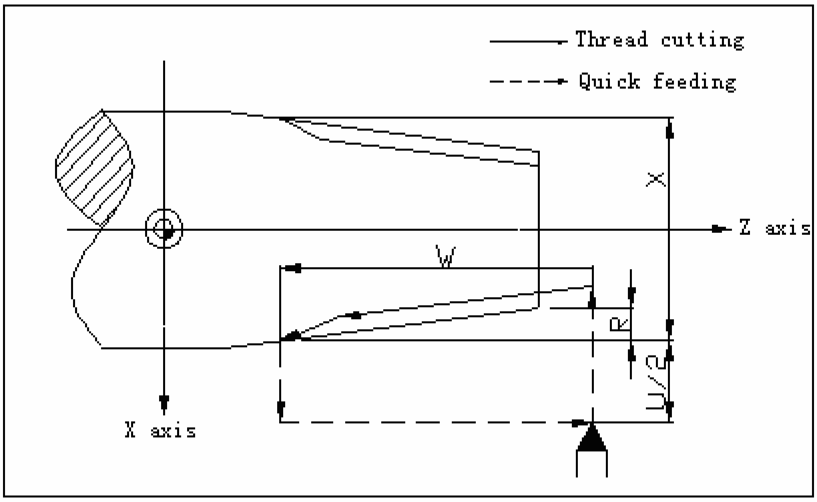
F: thread pitch

R: thread slope; radial coordinate difference (radius) between cutting start and cutting end; if R and U do not have same sign, |R| ≤ |U/2| (diameter programming) or |R| ≤ |U|(radius programming) is required. If R isn't specified, it is straight thread

P, D, V: same to G32 instruction function, but the value of V in G92 is unsigned; the system retreats the tool according to the direction of the start point automatically, and G32 needs to check the retreating direction of the specified V sign



Thread cutting
Quick feeding
Z axis
X axis



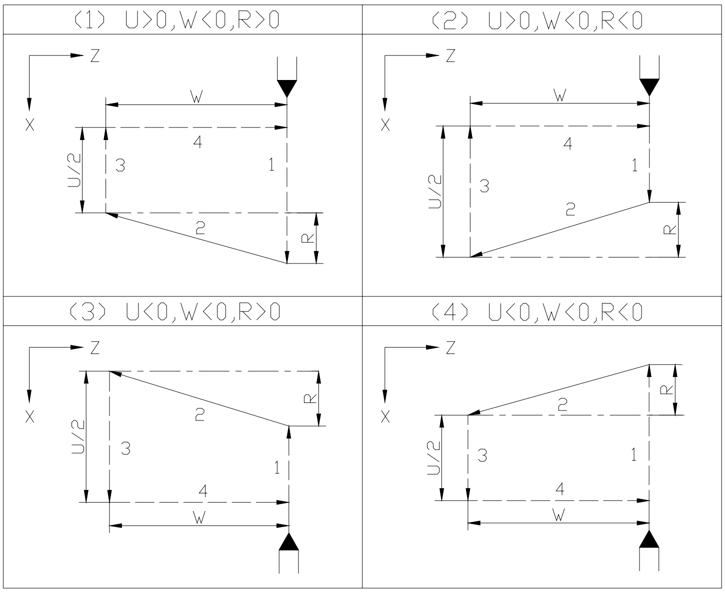
Thread cutting Quick feeding Z axis X axis

Execution process:

1) X axis locates (G0) to cutting start quickly from cycle start;
2) Interpolate to thread end from cutting start;
3) X axis radially back to radial coordinate position of cycle start in quick positioning (G0) mode;
4) Z axis quickly locates (G0) and returns to the start point, and cycle ends.

Function description:

1) G92 instruction function is similar to G32 function, and only cycle cutting function is increased.
2) U, W, and R reflect the relative position of cutting end and start. G92 has four track combinations depending on the sign.

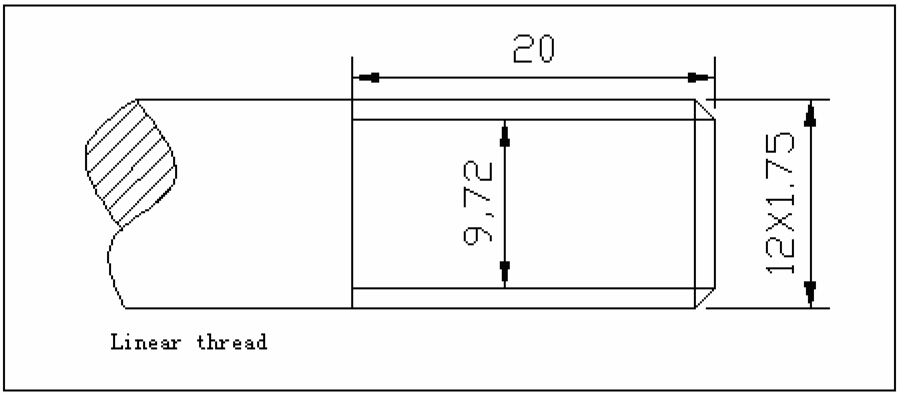


3) During first tool cutting, if U is 0, current value is the end coordinates by default; W can't be 0, or else the system alarms
4) Principal axis ratio control is invalid during thread cutting
5) If the converted feeding speed every minute exceeds the maximum feeding speed, the system alarms
6) G92 instruction can process one thread in several times of feeding, but the processing of two continuous threads can't be realized, nor process endd thread. G92 instruction thread pitch has the same definition as G32, and the pitch is the displacement of the long axis that the principal axis rotates one circle (X axis displacement depends on the radius).

G92 thread cutting notice:

- The machine tool must be installed with principal axis encoder for thread cutting; the transmission ration of principal axis encoder and the principal axis is 1:1; the principal axis encoder outputs A/B differential signal and Z signal (conversion signal) with 90° phase difference. When cutting thread, the system starts thread processing after receiving principal axis encoder Z signal. Therefore, the processing of same thread can be finished through roughing and finishing of several connected G92 blocks as long as the principal axis rotation isn’t changed.
- Since X axis and Z axis have acceleration and deceleration process in the beginning and at the end of thread cutting, the pitch error is large at this moment. The thread back function of G92 function can be used to process the thread without retreating groove.
- Under the condition that the start point, end point and thread pitch of G92 are fixed, the moving speed of X axis and Z axis during thread cutting depends on the principal axis rotation, and doesn’t relate to cutting feeding ration. During thread cutting, principal axis ratio control is valid; when principal axis rotation is changed, the pitch error increases due to acceleration/deceleration of X axis and Z axis, therefore, do not adjust the principal axis rotation during thread cutting or stop the principal axis (or else the tool and workpiece will be damaged).
- During thread cutting, and after feeding maintenance operation is executed, thread cutting doesn’t stop.
- Thread cutting is invalid when single block is running, and the running pauses after the first non-thread cutting in the thread cutting cycle is executed. When the system is reset, stopped in emergency or alarms, thread cutting stops immediately.

As in Fig. 3-10-7:



Linear thread

Fig. 3-10-7

Program: O3201

```
M03S500
G00X9.72Z2;
G32W-20 F1.75
G00X20
Z20
M30
```

3.5.3. Radial cutting cycle G94

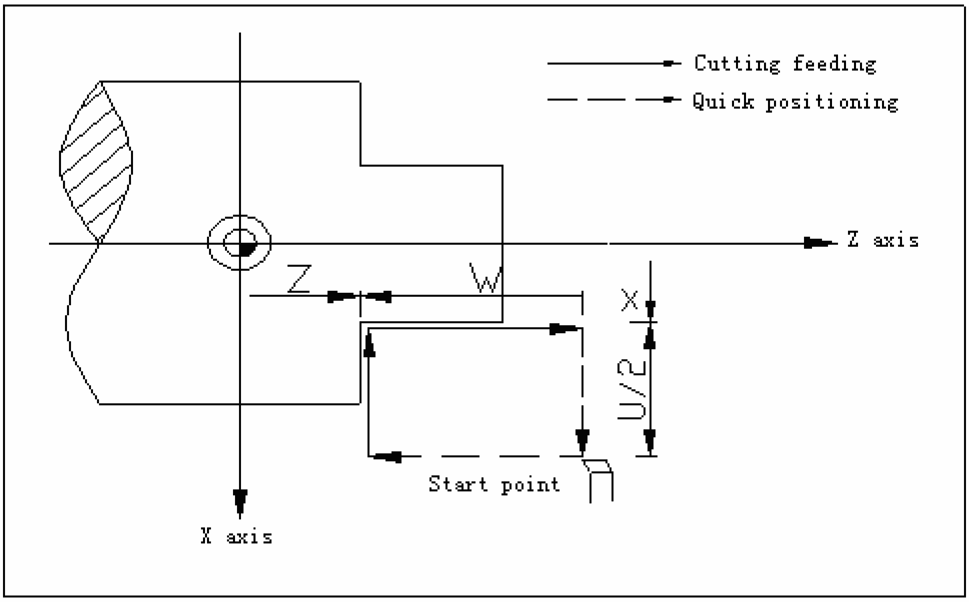
Instruction format: G94 X/U Z/W R_ F_ ;

X/U: cutting end X axis coordinates;

Z/W: cutting end Z axis coordinates;

F: cutting speed

R: cone slope; axial coordinate difference between cutting start and cutting end; if R and W do not have same sign, |R| ≤ |W| is required. If R isn't specified, it is straight end processing



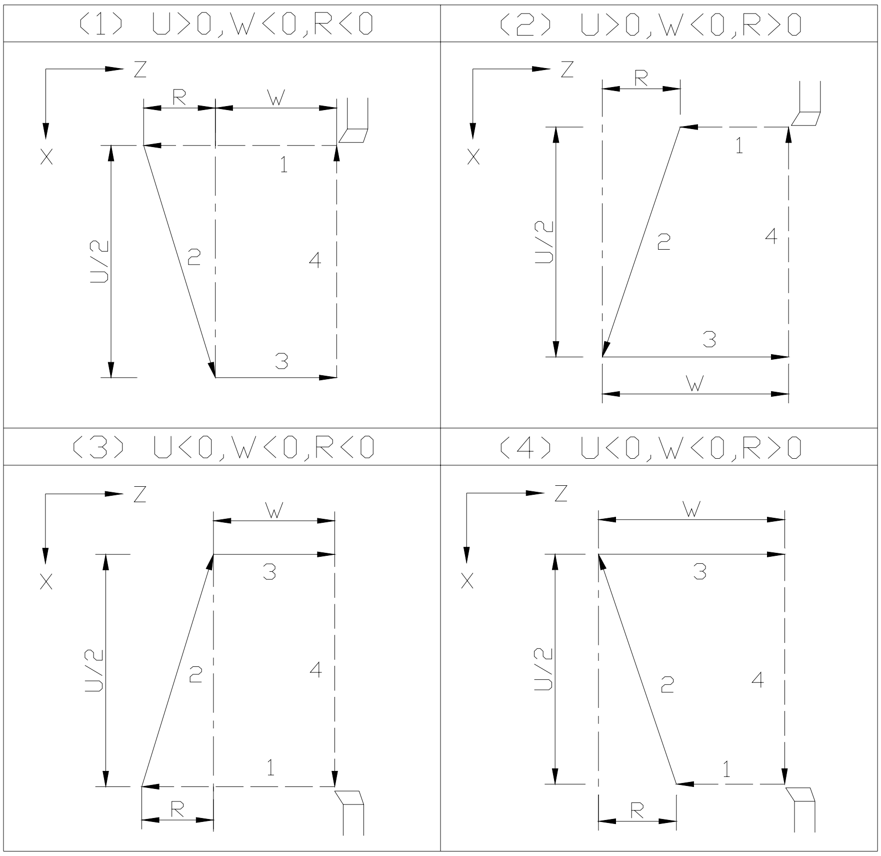
Cutting feeding Quick positioning
Z axis Start point X axis

Execution process:

1) X axis locates (G0) to cutting start quickly from cycle start;
2) Interpolate (G1) to cutting end from cutting start in linear;
3) Z axis axially back to axial coordinate position of cycle start in linear interpolation (G1) mode;
4) Z axis quickly locates (G0) and returns to the start point, and cycle ends.

Instruction description:

1) G94 is modal instruction.
2) In single block operation, the system stops at the end position of every block, and pause and resetting operation are valid in the motion process.
3) U, W and R reflect the relative position of cutting end and start. G94 has four track combinations depending on the sign.



If R and W do not have same sign and |R| > |W|, 0792-G90, G92, G94 program error alarms, and the value of R exceeds allowed range

4) During first tool cutting, if W is 0, current value is the end coordinates by default; U can't be 0, or else the system alarms
5) Before executing G94, specify the position of start point, or else the system takes current point as the start
6) G94 is valid in MDI mode, and modal function is also available.

3.5.4. Notice for fixed cycle instructions

1) In the fixed cycle instruction, once X(U), Z(W) and R are executed, the instruction values of X(U), Z(W) and R are always valid before new fixed cycle instruction to re-specify X(U), Z(W) and R. If G00, G01, G02, G03 and G32 are executed, the values of X(U), Z(W) and R will be cleared;
2) If the next block of G90, G92 or G94 is instruction word without motion, the action of G90, G92 or G94 block will be executed again when the block without motion is executed. To avoid this instance, it is required to cancel the cycle action with other G instructions after the fixed cycle instruction;

(For example)

```
M3; (turn on the principal axis)
  …
G90 X200.0 Z10.0 F2000;
X205.0 (repeat G90 once)
```

```
X206.0 Z20.0 (repeat G90 once)
 …
```

3) If the fixed cycle instruction is in the same block as M, S and T instructions, the cycle instruction can be executed at the same time with M, S and T instructions. However, if the fixed cycle is canceled (due to instruction G00, G01) after instruction M, S, T as in the example below, the fixed cycle instruction must be re-specified.

(For example)

```
  N003 T0101;
  …
N010 G90 X20.0 Z10.0 F2000;
N011 G00 T0202;
N012 G90 X20.5 Z10.0;
```

3.6. Multi-cycle instructions

G code	Function	Format
G70	Finishing cycle G70	G70 P(ns) Q(nf);
G71	Axial roughing cycle G71	G71 U(Δd) R(e) F__ S__ T__ ; G71 P(ns) Q(nf) U(Δu) W(Δw);
G72	Radial roughing cycle G72	G72 W(Δd) R(e) F__ S __T__ ; G72 P(ns) Q(nf) U(Δu) W(Δw);
G73	Closed cutting cycle G73	G73 U(Δi) W (Δk) R (d) F_ S_ T_ ;G73 P(ns) Q(nf) U(Δu) W(Δw) ;
G74	Axial grooving multi-cycle G74	G74 R(e) ; G74 X(U)_ Z(W)_ P(Δi)Q(Δk) R (Δd) F_ ;
G75	Radial grooving multi-cycle G75	G75 R(e) ; G75 X(U)_ Z(W)_ P(Δi)_ Q(Δk) R(Δd) F_ ;
G76	Multi-thread cutting cycle G76	G76 P(m)(r)(a) Q(△dmin) R(d); G76 X(U)_ Z(W)_ R(i) P(k)_ Q(△d) F(I) ;

3.6.1. Axial roughing cycle G71

Standard instruction format:

Format: G71 U(△d) R(e) F_ S_ T_

G71 P(ns) Q(nf) U(△u) W(△w)

U(△d): the single tool feed (radius) of X axis during roughing, unsigned

R (e): the single tool retreat (radius) of X axis during roughing, unsigned

P (ns): start block line of finishing track

Q(nf): end block line of finishing track

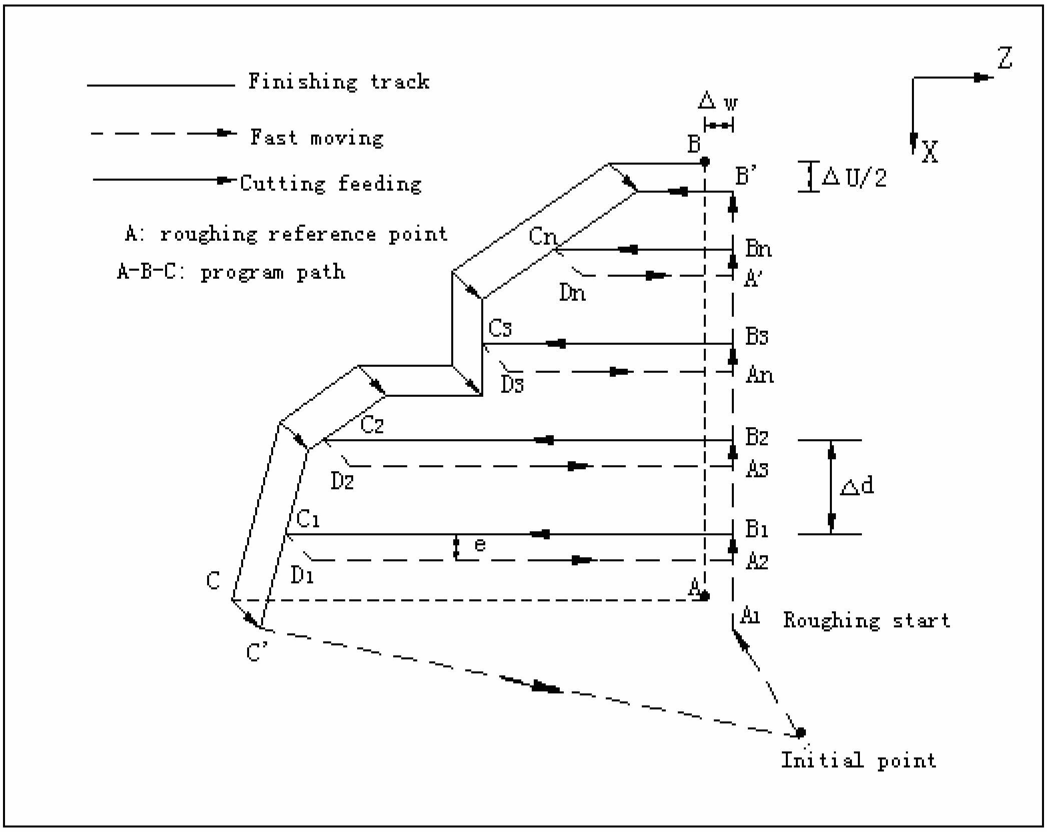
U(△u): reserved finishing amount of X axis, unsigned

W(△w): reserved finishing amount of Z axis, unsigned

F: feeding speed during roughing

S: principal axis rotation during roughing

T: tool No., tool offset No.



Finishing track---FT (finish turning) track　Fast moving　Cutting feeding

A: roughing reference point　A-B-C: program path

Roughing start (rough turning start)　Initial point

Execution process:

① Initial point → A1: fast moving;

② First roughing cycle: A1→B1→C1→D1→A2

A1→B1, C1→D1→A2: fast moving

B1→C1: linear interpolation

③ Second roughing cycle: A2→B2→C2→D2→A3

A2→B2, C2→D2→A3: fast moving

B2→C2: linear interpolation

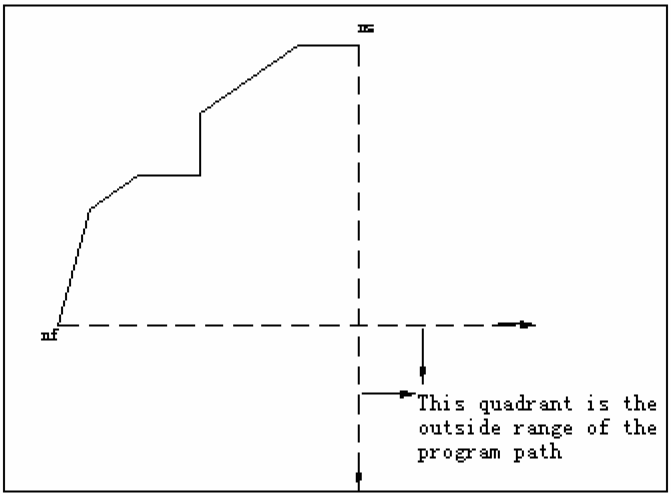
④ The nth roughing cycle: An→Bn→Cn→Dn→A'

An→Bn, Cn→Dn→A’: fast moving
Bn→Cn: linear interpolation

⑤ The last roughing cycle: A’→B’→C’→ initial point
A’→B’: fast moving
B’→C’: interpolation depends on the mode specified by ns→nf block. Interpolation speed specifies F value or the F value in ns→nf block according to G71 block, and uses current default F value if not specified.
C’→ Initial point: fast moving. G71 roughing cycle ends.

Function description:

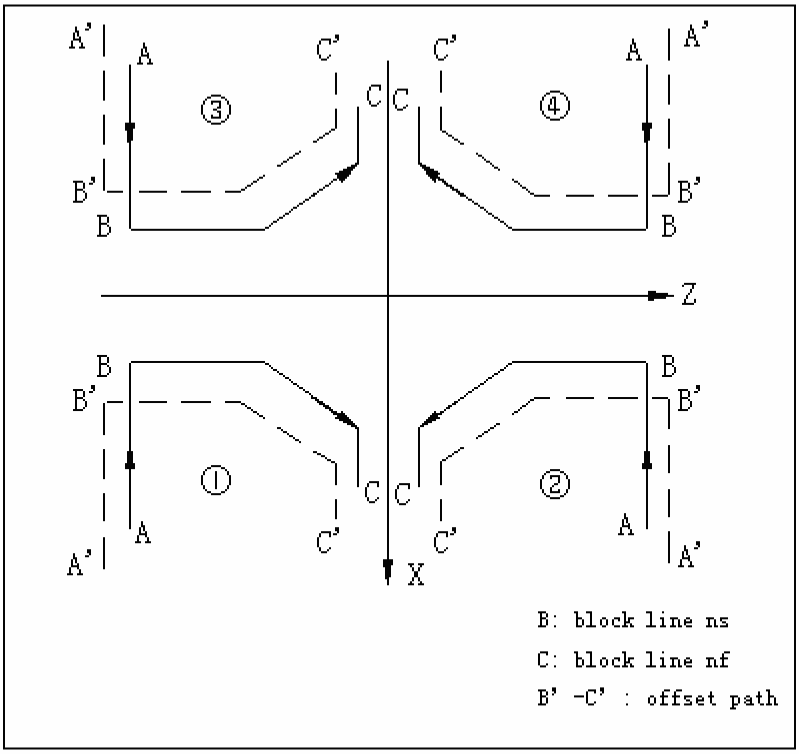
1) ns-nf block must follow G71 block. The system won’t execute the block written between G71 block and ns block
2) The F value in G71 block is valid when executing G71 roughing cycle; if the F value isn’t specified in G71 block, execute in current default value.
3) Pause and reset are valid in the motion process.
4) If the combined cycle instruction should be used several times in the same program, ns~nf can’t have same block No., or else the ns~nf profile may have error when the next combined cycle instruction is executed.
5) If the last tool feed is smaller than U(△d), the system will execute the last roughing cycle directly
6) Tool retreating path: after last roughing, the tool retreats to the initial point from point nf.
7) Before executing G71, the tool must specify the position of the initial point first, which must be out of the program path limit range, or else the system alarms (0769--G71, G72, G73 initial point position error). If the position of the initial point isn’t specified, the current point is the initial point.
8) The outside range of the program path is defined as below



This quadrant is the outside range of the program path

9) The offset direction of roughing depends on program path automatically (as in the figure below, the processing path program is A→B→C)

Condition	Result
X axis of C (nf block) > X axis of B (ns block); Z axis of C > Z axis of B	①
X axis of C (nf block) > X axis of B (ns block); Z axis of C < Z axis of B	②
X axis of C (nf block) < X axis of B (ns block); Z axis of C > Z axis of B	③
X axis of C (nf block) < X axis of B (ns block); Z axis of C < Z axis of B	④
X axis of C (nf block) = X axis of B (ns block) or Z axis of C (nf block) = Z axis of B (ns block)	Generate error alarm 0768



B: block line ns C: block line nf
B'-C': offset path

Related parameters and notice:

1) If Δd is 0 or larger than total cutting amount, the system alarms. The tool retreating angle is 45°, and do not retreat if R (e) is 0.
2) If △u is 0, X axis doesn't reserve for finishing; if △u is larger than △d, the system alarms because it can't calculate the first roughing end.
3) If △w is 0, Z axis doesn't reserve for finishing.
4) In ns-nf block, the size of X axis and Z axis must change one-way (constantly increase or decrease), or else the system alarms.
5) ns-nf block only contains the following instructions: G00, G01, G02, G03, G04; can't include the following M functions: M30, M98, M99, or else the system alarms.
6) ns block only can be G00 or G01 instruction.

G71 program processing example:

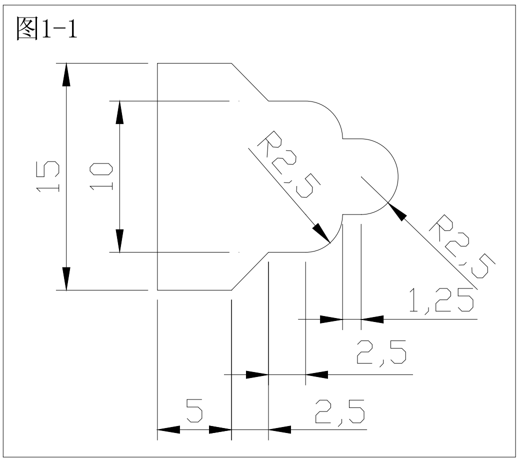


Fig. 1-1

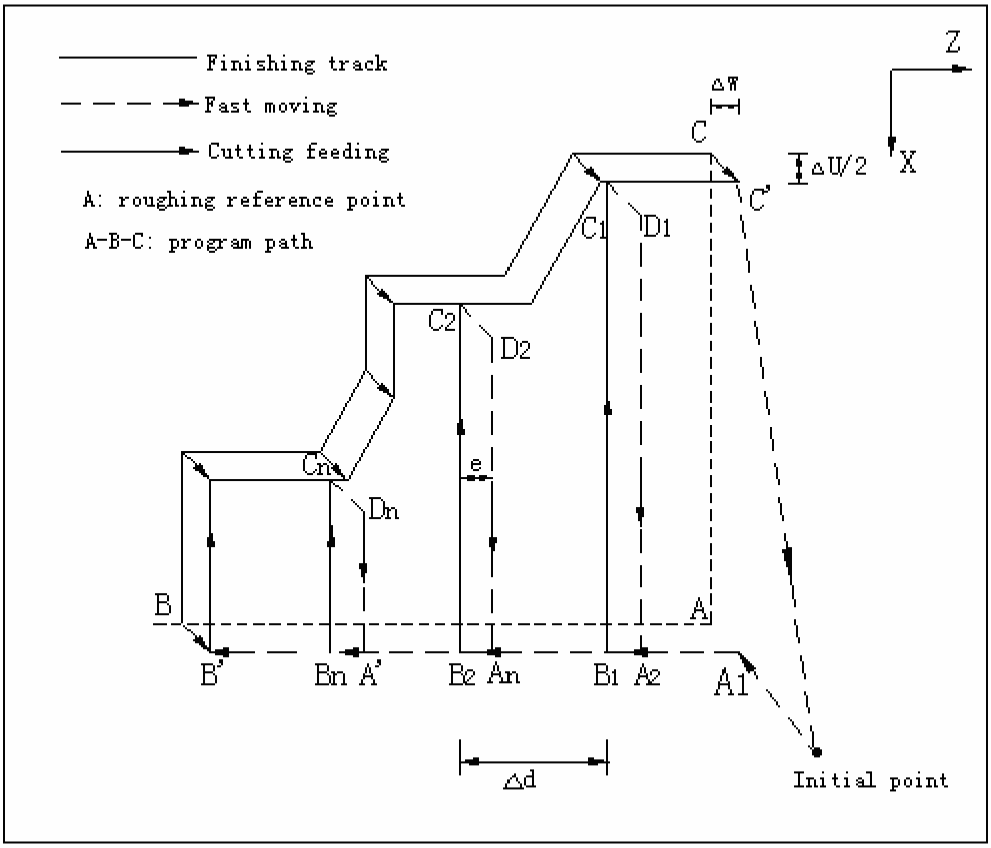
Fig. 3-11-3

O7101

```
M03 S500T0101
G00 X25Z10
M03S550F3000
G71U0.5R0.5
G71P10Q20U0.2W0.2
N10G0X0Z0F300
G2X5Z-2.5R2.5F200
G1W-1.25F300
G2X10W-2.5R2.5F200
G1W-2.5F300
N20X15W-2.5
G70P10Q20
G0X20
Z0
M30
%
```

3.6.2. Radial roughing cycle G72

Instruction format: G72 W(△d)_ R(e)_ F_ S_ T_
G72 P(ns) Q(nf) U(△u) W(△w)
W(△d): the single tool feed of Z axis during roughing (unsigned, unit: mm)
R(e): the single tool retreating of Z axis during roughing (unsigned, unit: mm)
P (ns): start block line of finishing track
Q(nf): end block line of finishing track
U(△u): reserved finishing amount of X axis, unsigned
W(△w): reserved finishing amount of Z axis, unsigned
F: cutting feeding speed during roughing
S: principal axis rotation
T: tool No., tool offset No.



Finishing track
Cutting feeding
A-B-C: program path

Fast moving
A: roughing reference point
Initial point

Execution process:

① Initial point → A1: fast moving;

② First roughing cycle: A1→B1→C1→D1→A2
  A1→B1, C1→D1→A2: fast moving
  B1→C1: linear interpolation

③ Second roughing cycle: A2→B2→C2→D2→An
  A2→B2, C2→D2→An: fast moving
  B2→C2: linear interpolation

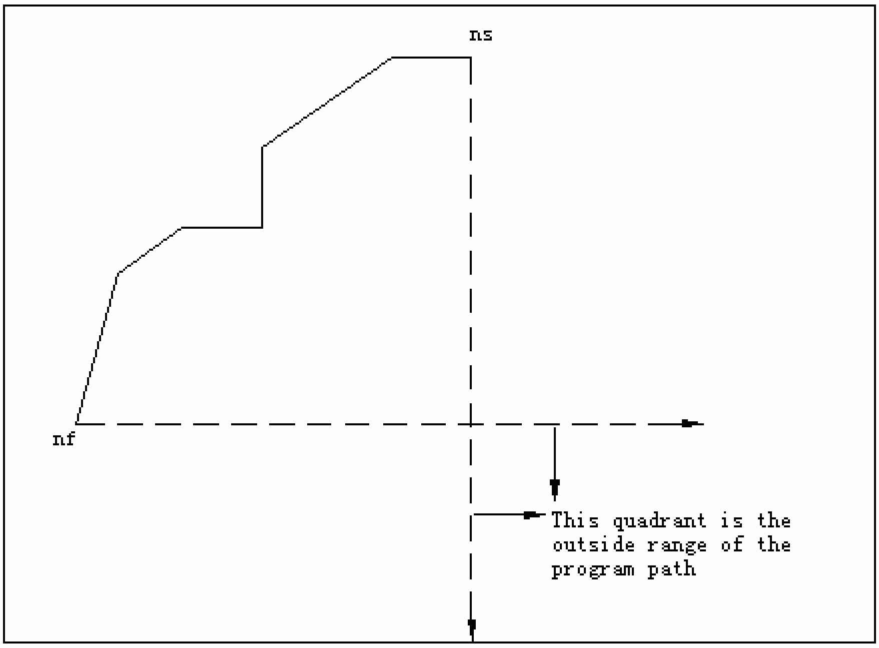
④ The nth roughing cycle: An→Bn→Cn→Dn→A'
  An→Bn, Cn→Dn→A': fast moving
  Bn→Cn: linear interpolation

⑤ The last roughing cycle: A'→B'→C'→ initial point
  A'→B': fast moving
  B'→C': interpolation depends on the mode specified by ns→nf block. Interpolation speed specifies F value or the F value in ns-nf block according to G72 block, and uses current default F value if not specified.
  C'→ Initial point: fast moving. G72 roughing cycle ends.

Function description:

1) ns-nf block must follow G72 block. The system won't execute the block written between G72 block and ns block
2) The F value in G72 block is valid when executing G72 roughing cycle; if the F value isn't specified in G72 block, execute in current default value.
3) Pause and reset are valid in the motion process.

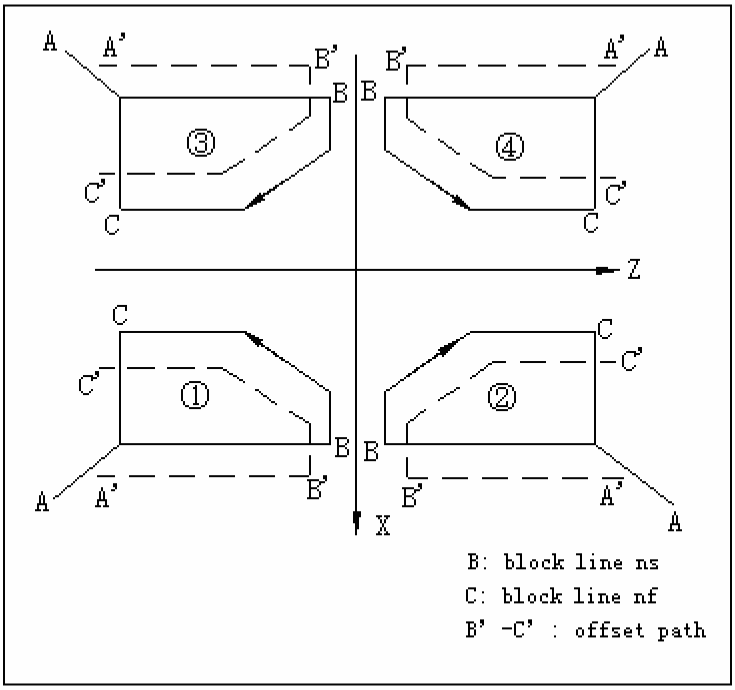
4) If the combined cycle instruction should be used several times in the same program, ns~nf can't have same block No., or else the ns~nf profile may have error when the next combined cycle instruction is executed.
5) If the last tool feed is smaller than U(△d), the system will execute the last roughing cycle directly
6) Tool retreating path: after last roughing, the tool directly retreats to the initial point from point nf.
7) Before executing G72, the tool must specify the position of the initial point first, which must be out of the program path limit range, or else the system alarms. If the position of the initial point isn't specified, the current point is the initial point.
8) The outside range of the program path is defined as below



This quadrant is the outside range of the program path

9) The offset direction of roughing depends on program path automatically (the processing path program is A→B→C)

Condition	Result
X axis of C (nf block) > X axis of B (ns block); Z axis of C > Z axis of B	④
X axis of C (nf block) > X axis of B (ns block); Z axis of C < Z axis of B	③
X axis of C (nf block) < X axis of B (ns block); Z axis of C > Z axis of B	②
X axis of C (nf block) < X axis of B (ns block); Z axis of C < Z axis of B	①
X axis of C (nf block) = X axis of B (ns block) or Z axis of C (nf block) = Z axis of B (ns block)	Generate error alarm



B: block line ns C: block line nf
B'-C': offset path

Related parameters and notice:

1) If Δd is 0 or larger than total cutting amount, the system alarms.
2) The tool retreating angle is 45°, and do not retreat if R (e) is 0.
3) If △u is 0, X axis doesn't reserve for finishing.
4) If △w is 0, Z axis doesn't reserve for finishing; if △w is larger than △d, the system alarms.
5) In ns-nf block, the size of X axis and Z axis must change one-way (constantly increase or decrease), or else the system alarms.
6) ns-nf block only contains the following instructions: G00, G01, G02, G03, G04; can't include the following M functions: M30, M98, M99, or else the system alarms.
7) ns block only can be G00 or G01 instruction.

G72 processing example:

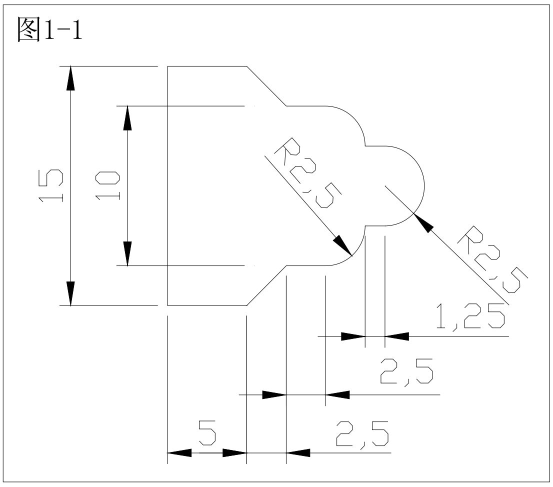


Fig. 1-1

Fig. 3-11-6

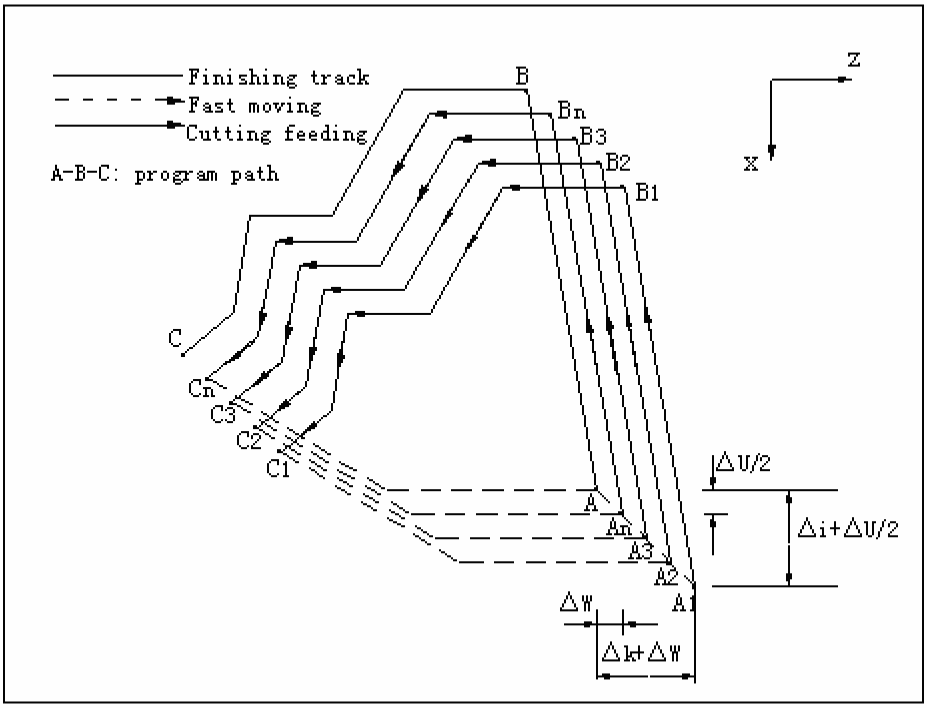
```
O7201
M03S500T0101
G00X20Z5
M03S500F3000
G72W0.5R-0.4
G72Q20U0.2W0.2
N10G1X17Z-11.25F300
X15
W5
G1X10W2.5F200
G1W2.5F300
G02X5W2.5R2.5F200
G1W1.25F300
N20G2X0W2.5R2.5F200
G70P10Q20
G0X20
Z5
M30
%
```

3.6.3. Closed cutting cycle G73

Instruction format:

G73 U(△i) W(△k) R(d) F_ S_ T_
G73 P(ns) Q(nf) U(△u) W(△w)

U(△i): X axis roughing reserve. Unsigned, negative sign is invalid (radius)
W(△k): Z axis roughing reserve. Unsigned, negative sign is invalid
R(d): Roughing cutting times; Unsigned integer, decimal fraction is invalid (unit: time)
P (ns): start block line of finishing track
Q(nf): end block line of finishing track
U(△u): reserved finishing amount of X axis. Unsigned, negative sign is invalid (diameter)
W(△w): reserved finishing amount of Z axis. Unsigned, negative sign is invalid
F: cutting feeding speed during roughing
S: principal axis rotation during roughing
T: tool No., tool offset No. during roughing



Finishing track(program path) Fast moving Cutting feeding A-B-C: program path

Execution process:

① A→A1: fast moving;

② First roughing cycle: A1→B1→C1→A2:

A1→B1→C1: interpolation depends on the mode specified by ns→nf block. The interpolation speed specifies F value according to G73 block, and uses current default F value if not specified.

C1→A2: fast moving

③ Second roughing cycle: A2→B2→C2→A3

A2→B2→C2: interpolation depends on the mode specified by ns→nf block. The interpolation speed specifies F value according to G73 block, and uses current default F value if not specified.

C2→A3: fast moving

④ The nth roughing cycle: An→Bn→Cn→A

An→Bn→Cn: interpolation depends on the mode specified by ns→nf block. The interpolation speed specifies F value according to G73 block, and uses current default F value if not specified.

Cn→A: fast moving. Roughing cycle ends.

Function description:

1) ns-nf block must follow G73 block. The system won't execute the block written between G73 block and ns block

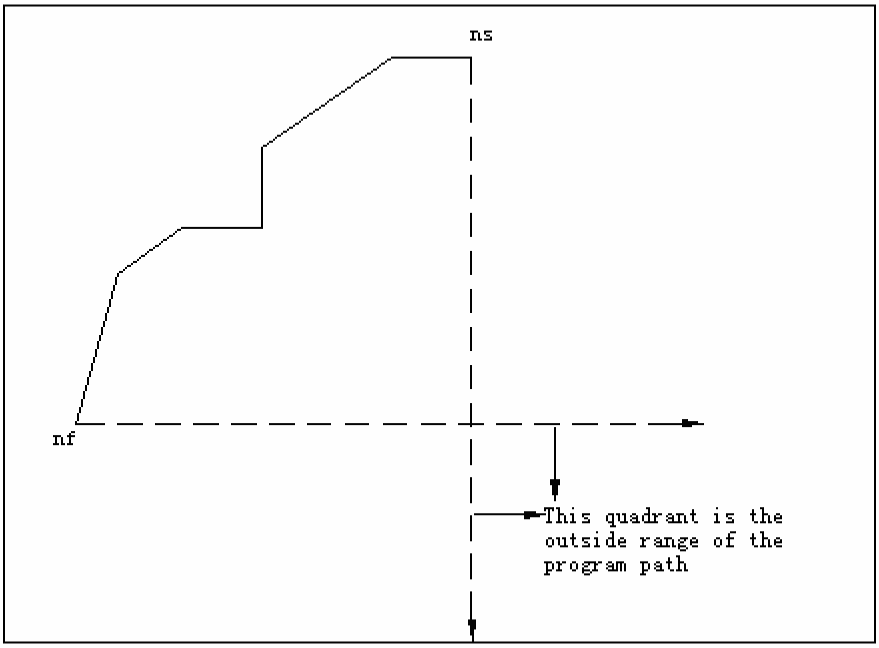
2) The F value in G73 block is valid during G73 roughing cycle. If the F value isn't specified in G73 block, execute according to current default value. The F value in ns-nf block is valid while executing G70.

3) The compensation function is valid when the G73 instruction is executed in tool tip radius compensation, but the tool initial point in G73 cycle is the position where tool tip radius compensation function is canceled temporarily.

4) In single block operation, the system stops at the end position of every block; the pause and resetting operation are valid during the motion.

5) If the combined cycle instruction should be used several times in the same program, ns~nf can't have same block No., or else the ns~nf profile may have error when the next combined cycle instruction is executed.

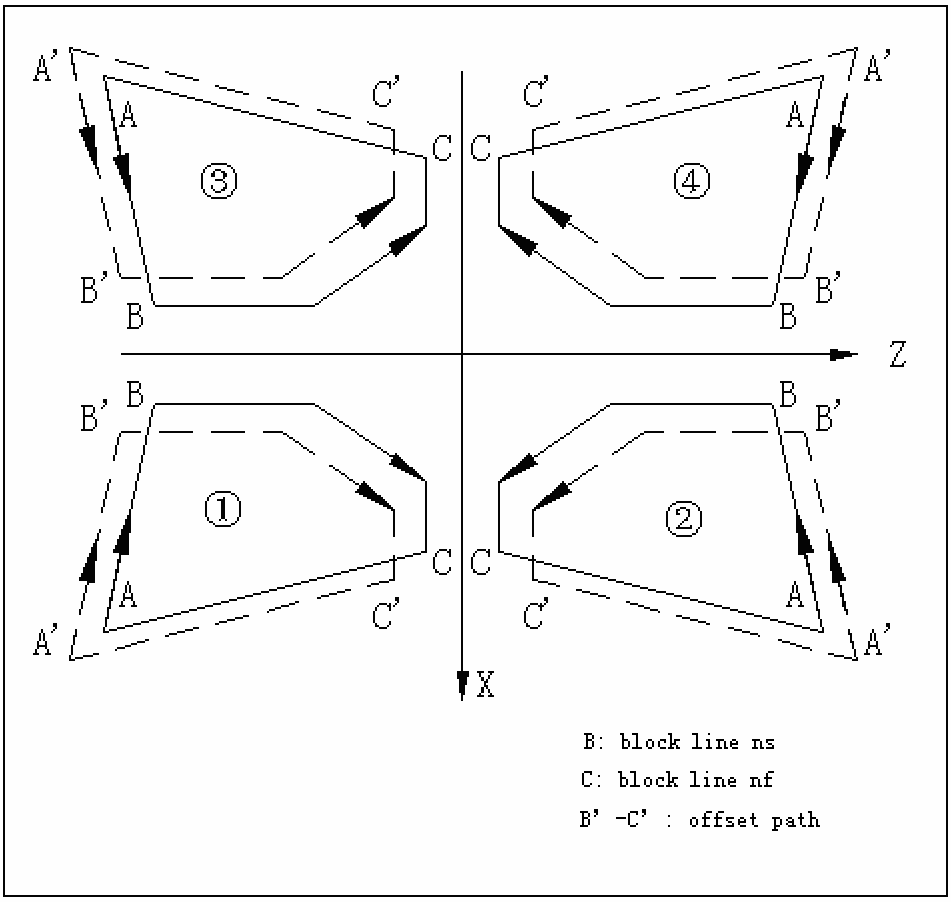
6) Before executing G73, the tool must specify the position of the initial point first, which must be out of the program path limit range, or else the system alarms. If the position of the initial point isn't specified, the current point is the initial point.
7) The outside range of the program path is defined as below



This quadrant is the outside range of the program path

8) The offset direction of roughing depends on ns~nf program path (the processing path program is A→B→C)

Condition	Result
X axis of C (nf block) > X axis of B (ns block); Z axis of C > Z axis of B	①
X axis of C (nf block) > X axis of B (ns block); Z axis of C < Z axis of B	②
X axis of C (nf block) < X axis of B (ns block); Z axis of C > Z axis of B	③
X axis of C (nf block) < X axis of B (ns block); Z axis of C < Z axis of B	④
X axis of C (nf block) = X axis of B (ns block) or Z axis of C (nf block) = Z axis of B (ns block)	Generate error alarm



B: block line ns　　　　C: block line nf
B'-C': offset path

Related parameters and notice:

1) △i can be set with parameter (116-G73 X axis margin), or modify parameter setting with program instruction; if △i is smaller than △u, the system alarms.
2) △k can be set with parameter (117-G73 Z axis margin), or modify parameter setting with program instruction; if △k is smaller than △w, the system alarms.
3) D can be set with parameter (120-G73 cycle times), or modify parameter setting with program instruction; if d is non-integer larger than 1, the system only calculates the integer, if d is smaller than 1, the system calculates as 1.
4) The system alarms if ns and nf aren't specified.
5) △u can be set with parameter (118-G73 X axis finishing margin), or modify parameter setting with program instruction; if △u is 0, X axis doesn't reserve for finishing.
6) △w can be set with parameter (119-G73 Z axis finishing margin), or modify parameter setting with program instruction; if △w is 0, Z axis doesn't reserve for finishing.
7) In ns-nf block, the size of X axis and Z axis must change one-way (constantly increase or decrease), or else the system alarms.
8) ns-nf block only contains the following instructions: G00, G01, G02, G03, G04; can't include the following M functions: M00, M30, M98, M99, or else the system alarms.
9) ns block only can be G00 or G01 instruction, or else the system alarms.
10) G73 instruction can't be executed in MDI mode, or else the system alarms.

G73 processing example programming

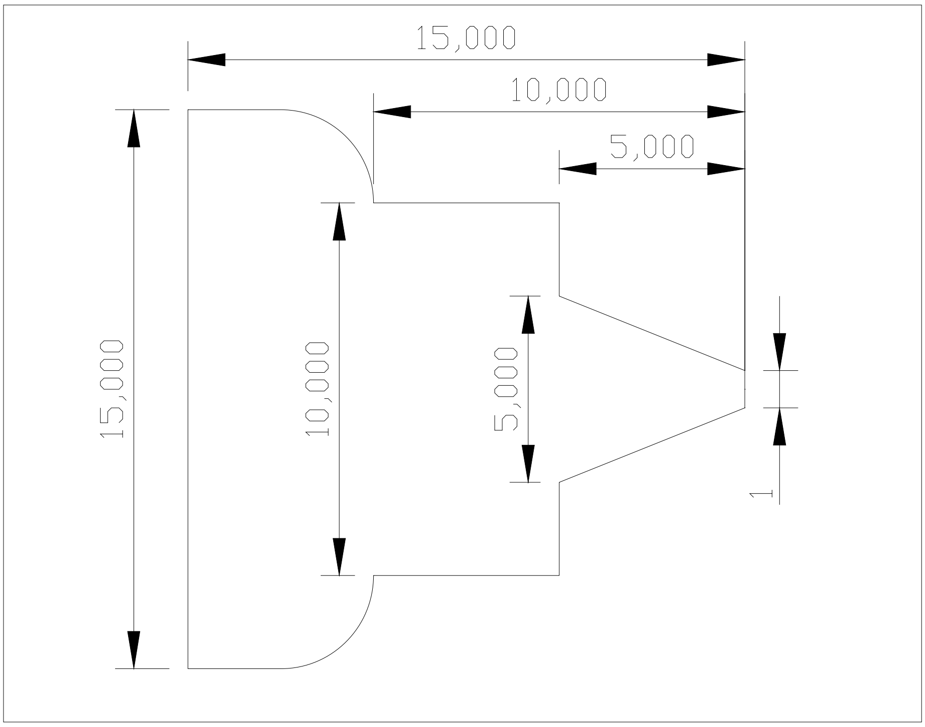


Fig. 3-11-8

```
O7301
M03S500T0101
G00X25Z5
G73U5W5R5F500
G73P10Q20U0.2W0.2
N10G0X1Z-0.5R0.5F300
X5Z-5
X10
Z-10
G03X15W-2.5R2.5
G1Z-15
N20G2X20W-2.5R2.5F200
G70P10Q20
G0X20
Z5
M30
%
```

3.6.4. Finishing cycle G70

Instruction format:G70 P(ns) Q(nf);

P(ns): the number of the first block of the finishing track;

Q(nf): the number of the last block of the finishing track;

Instruction function: the tool starts finishing from the start position along the workpiece finishing track specified by ns~nf block. After G71, G72 or G73 roughing, finish with G70 instruction, and complete the cutting of finishing margin in one time. After G70 cycle, the tool returns to the start point and executes the next block after G70.

G70 instruction track depends on the programming track of ns~nf block. The relationship of ns and nf in G70~g73 block is as follow:

```
, , , , , , , ,
G71/G72/G73 ……;
N(ns) , , , , , ,
, , , , , , , ,
      · F_
      · S_
      · T_                Finishing path block
      ·
      ·
N(nf) … … …
G70 P(ns)   Q(nf) ;
```

Note:

- F, S and T instructions in ns~nf block are valid when executing G70;
- While executing G70 instruction, it is possible to stop automatic running and move manually; however, when G70 cycle is executed again, it is required to return to the position before manual movement. If not, it will continue the execution and following running track will be dislocated.
- ns~nf block can’t have the following instructions:
  Other group oo G instructions except G04 (pause);
  Other group 01 instruction except G00, G01, G02 and G03;
  Subroutine calling instruction (e.g. M98/M99).

3.6.5. Axial grooving multi-cycle G74

Instruction format: G74 R (e);
G74 X/U _   Z/W_ P(Δi) Q(Δk) R(Δd) F_ ;

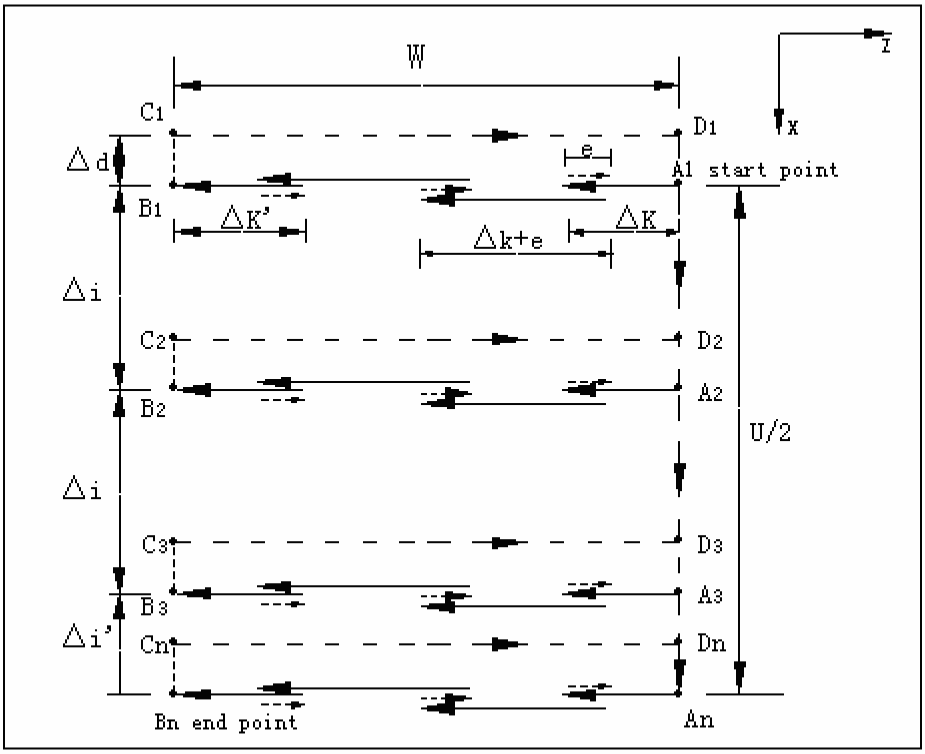
R(e): axial (Z axis) tool retreating, unsigned
X/U: groove end coordinates (X is absolute coordinates, and U is the increment from current coordinates to point coordinates)
Z/W: groove end coordinates (Z is absolute coordinates and W is the increment from current coordinates to point coordinates)

P(Δi): single radial (X axis) offset of the tool, radius, unsigned. Offset direction is same to the radial direction of the end coordinates.

Q(Δk): single axial (Z axis) feeding of the tool, unsigned. Feeding direction is same to the axial direction of the end coordinates.

R(Δd): radial (X axis) tool retreating after cutting to the groove bottom, unsigned. The retreating direction is opposite to the radial offset direction.

F: axial grooving cycle feeding speed



A1 start point Bn end point

Execution process:

① First grooving cycle: A1→B1→C1→D1→A2

A1→B1: axially feed to point B1 in pecking style; B1→C1→D1→A2: fast moving (the cycle B1→C1 doesn't have tool retreating action)

② Second grooving cycle: A2→B2→C2→D2→A3

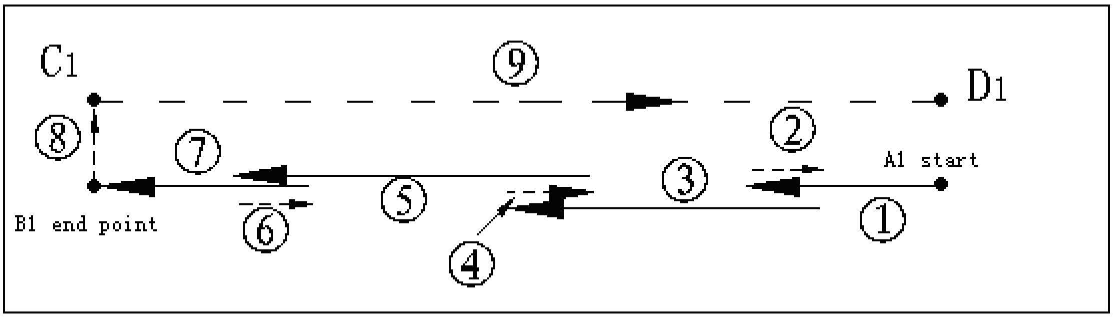
A2→B2: axially feed to point B2 in pecking style; B2→C2→D2→A3: fast moving.

③ The nth grooving cycle: An→Bn→Cn→Dn→A1

An→Bn: axially feed to point Bn in pecking style; Bn→Cn→Dn→A1: fast moving. G74 grooving cycle ends

Function description:

1) The position of thee cutting start (A1) should be specified before grooving cycle, or else the system takes current point as the cutting start.
2) In the first grooving cycle, the tool isn't retreated in radial direction when cut to the groove bottom (B1)
3) If X/U isn't specified or movement is 0, the system considers P(Δi) as 0 no matter whether P(Δi) is specified. In this case, only Z axis acts and cuts to groove end, and the tool isn't retreated in radial direction.
4) Pecking style tool feeding cycle



A1 start B1 end point

Related parameters and notice:

1) If e is 0, the system doesn't have axial tool retreating action.
2) The system alarms if Z/W isn't specified or the movement is 0.
3) The system alarms if X/U is specified but P(Δi) is larger than X axis movement (U/2). If P(Δi) is specified to 0, it can be used for axial cycle drilling.
4) If Δk is 0 or larger than entire groove depth (W), the system reports error.
5) If Δd is 0, the tool isn't retreated in radial direction; if Δd is larger than Δi, the system reports error.

G74 processing example: Fig. 3-11-10

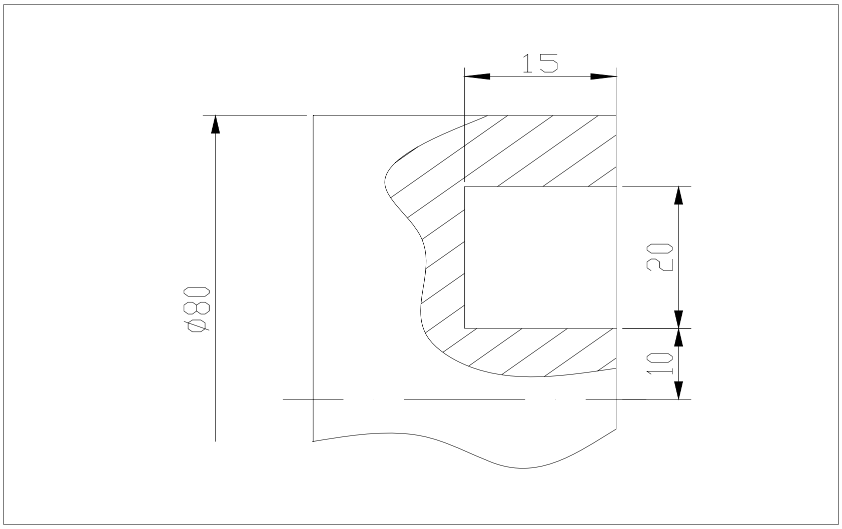


Fig. 3-11-10

```
O7401
G00X100Z20
M03S800T0101
 G01X60Z2
G74R3
G74X20Z-15P2Q5R1F500
G00X100Z20
 M30
 %
```

3.6.6. Radial grooving multi-cycle G75

Instruction format: G75 R(e) ;
G75 X/U _ Z/W_ P(Δi) Q(Δk) R(Δd) F_ ;

R(e): radial (X axis) tool retreating, radius, unsigned

X/U: groove end coordinates (X is absolute coordinates, and U is the increment from current coordinates to point coordinates)

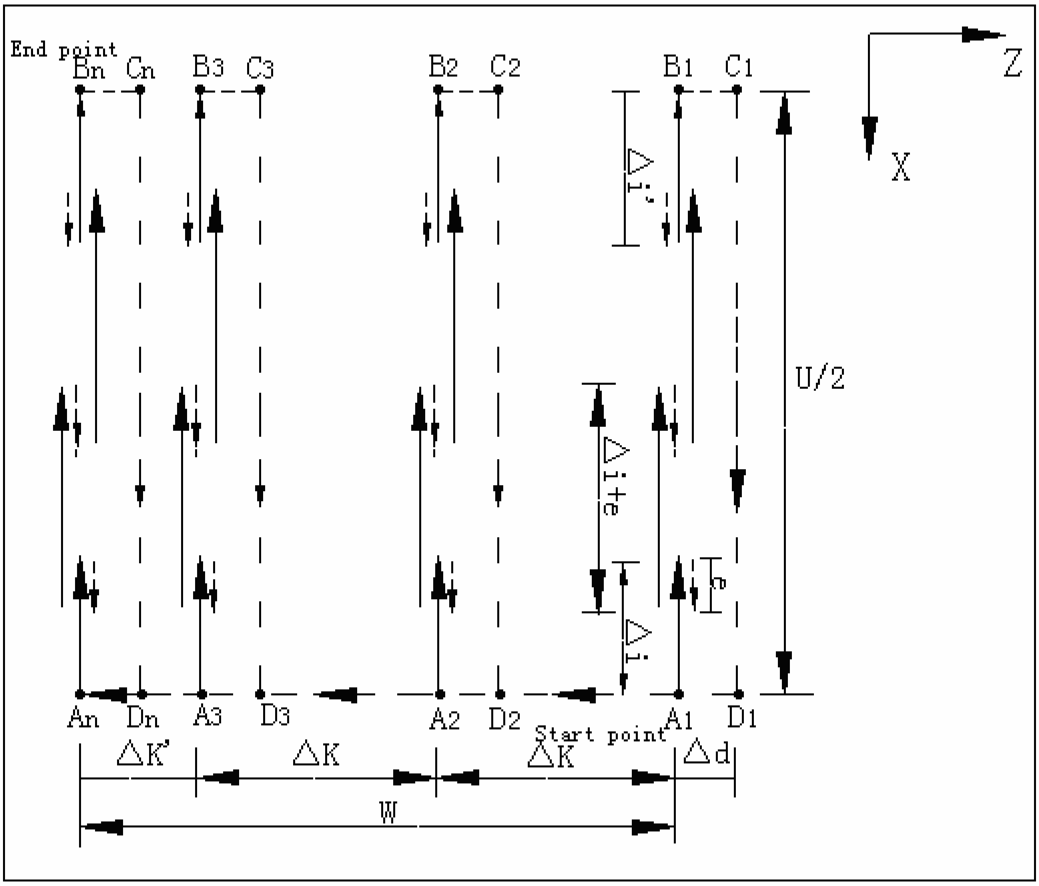
Z/W: groove end coordinates (Z is absolute coordinates and W is the increment from current coordinates to point coordinates)

P(Δi): single radial tool feeding, unsigned, radius. Feeding direction is same to the radial direction of the end coordinates.

Q(Δk): axial offset of the tool, unsigned. Offset direction is same to the axial direction of the end coordinates.

R(Δd): axial (Z) tool retreating after cutting to the groove end, unsigned. The retreating direction is opposite to the axial offset direction of the tool.

F: axial grooving cycle feeding speed



Start point

Execution process:

① First grooving cycle: A1→B1→C1→D1→A2

A1→B1: radially feed to point B1 in pecking style; B1→C1→D1→A2: fast moving (the cycle B1→C1 doesn't have tool retreating action)

② Second grooving cycle: A2→B2→C2→D2→A3

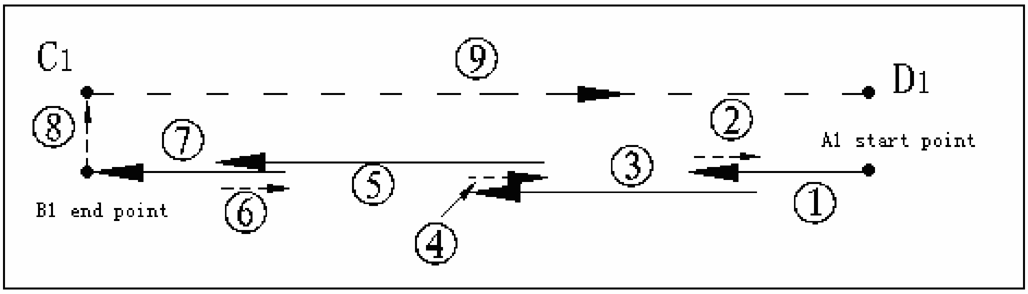
A2→B2: radially feed to point B2 in pecking style; B2→C2→D2→A3: fast moving.

③ The nth grooving cycle: An→Bn→Cn→Dn→A1

An→Bn: radially feed to point Bn in pecking style; Bn→Cn→Dn→A1: fast moving. G75 grooving cycle ends

Function description:

1) The position of thee cutting start (A1) should be specified before grooving cycle, or else the system takes current point as the cutting start.
2) In the first grooving cycle, the tool isn't retreated in axial direction when cut to the groove bottom (B1)
3) If Z/W isn't specified or movement is 0, the system considers Q(Δk) as 0 no matter whether Q(Δk) is specified. In this case, only X axis acts and cuts to groove end, and the tool isn't retreated in axial direction.
4) Pecking style tool feeding cycle



B1 end point A1 start point

Related parameters and notice:

1) If e is 0, the system doesn't have radial tool retreating action.
2) The system reports error if X/U isn't specified or the movement is 0.
3) If Δi is 0 or larger than entire groove depth (U/2), the system reports error.
4) The system reports error if Z/W is specified but Δk is larger than z axis movement (W). If Δk is 0, it can be used for radial cycle drilling
5) If Δd is 0, the tool isn't retreated in axial direction; if Δd is larger than Δk, the system reports error.

G75 processing example: Fig. 3-11-12

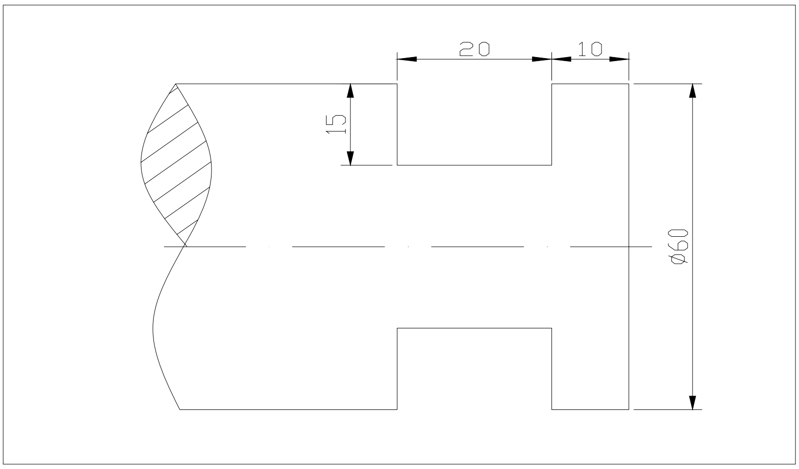


Fig. 3-11-12 G75 Instruction Cutting Diagrma

```
O7501
G00X100Z0
M03S800T0101
G01X80Z-10
G75R3
G75X30Z-30P5Q2R1F500
G00X100Z20
 M30
```

4. CNC Process Knowledge

1. What is the content of CNC programming?
A: Analyze part drawing, determine process and path, calculate the coordinates of tool track, write processing program, enter programs into CNC system, check the program, cut for testing, etc.

2. What is the objective of CNC processing analysis? And the content?
A: To process parts on the CNC machine tool, it is required to analyze and treat the process according to part drawing, create CNC process, and then prepare processing program. The entire process is automatic. The content includes machine tool cutting amount, work step arrangement, feeding path, processing margin, tool size and model, etc.

3. What is tool setting point? What is the influence of tool setting point selection to programming?
A: Tool setting point is the start point of the tool relative to workpiece motion during CNC processing. This start point is also the program start of programming. If the tool setting point is selected properly, it is convenient for mathematic processing and programming; easy to align on the machine tool; convenient for checking and reduce processing error during processing.

4. What are machine tool coordinate system and workpiece coordinate system? And their differences?
A: Machine tool coordinate system is also called mechanical coordinate system, which is the feeding coordinate system of the moving parts of the machine tool, and the coordinate axes and direction are standard. The coordinate origin is set by the manufacturer, and is called machine tool (or part) origin. Workpiece coordinate system is calso called as programming coordinate system, which is used for programming.

5. Please simply describe the tool position, tool change point and workpiece coordinate origin.
A: Tool position point is the reference point to confirm the tool position. If the CNC machine tool with multi-tool processing needs to change tool during processing, it is also required to set a tool change point during programming. Tool change point is the reference point to change tool position. The positions of tool change points shouldn’t interfere with each other. The origin of workpiece coordinate system is also workpiece home or programming home; the position is set by the programmer at the design and process reference position of the workpiece for size calculation.

6. What is the effect of tool compensation and what are compensation instructions?
A: Tool compensation usually includes length compensation and radius compensation. Tool length compensation can be tool length compensation or position compensation. With tool radius compensation: execute roughing and finishing with the tool of same program and same size; program with part profile directly to avoid calculating tool center track; if the diameter is changed due to tool abrasion or change, it doesn’t need to modify the program, and only needs to enter the value of tool radius change in tool parameter setting state; with tool compensation function, use same program to process the internal and external profiles of same nominal size.

7. What is separated roughing and finishing? And the advantages?
A: When determine the part processing flow, the roughing and finishing should be executed separately, execute the finishing after the roughing of every surface, and do not execute both roughing and finishing on the machine tool, which is called separated roughing and finishing. This

processing allows using the machine tool reasonably, making the distortion and error produced in roughing be modified in finishing, to improve processing precision; in addition, it also finding crack, pore and other defects in advance and stop the processing in time.

8. What is the advantage of installing workpiece with clamps?
A: Since the positioning components of the clamp and the relative position of the tool and machine tool motion can be adjusted in advance, using clamp when processing parts is fast and convenient, and has high repeat precision, which can ensure the processing requirement of the workpiece.

9. What is the advantage of selecting refined reference according to the principle of unified reference?
A: The refined reference selected in this principle can be used for the processing of multi-surface and multi-process, reduce the error due to reference change and improve the processing precision. In addition, it also can reduce the types of clamp and the workload in clamp design.

10. What is the principle to confirm the direction of clamping force?
A: (1) The direction of clamping force doesn't destroy the accuracy of workpiece positioning.
(2) The direction of clamping force should minimize the force.
(3) The direction of clamping force should minimize the workpiece distortion.

11. What are the factors that cause principal axis rotation error?
A: Concentricity between over-bearing holes of the bearings, verticality between shell hole positioning face and the axis, bearing clearance, roundness of the bearing raceway, size and shape error of the roller, beating of locking nut end, etc.

12. What are the bad results if the beating of the principal axis shoulder bearing surface exceeds the tolerance?
A: In this case, the holes bored through principal axis feeding and reference surface tilt. In addition, if the cutter wears due to principal axis feeding is uneven and the wear of some blades speeds up, tool use is not economical.

13. How the materials difficult process are measured?
A: The materials difficult to process are measured in quality of processed surfaces, chip formation and difficulty of discharge. If one of above three aspects is poor obviously, the material is difficult to process.

14. What are the cutting characteristics of materials difficult to process?
A: In the following five aspects:

1) Since the materials difficult to process have low thermal conductivity and high thermal strength, the cutting temperature is high;
2) The chip distortion has large factor, and the hardening is serious;
3) The materials usually have high strength and thermal strength, and thus the cutting force is large;
4) Cutter wear soon, and thus the durability is low;
5) Chip rolling, breaking and discharging are difficult.

15. What improvement measures should be taken to cut the materials difficult to process?
A: The following improvement measures should be taken:

1) Select appropriate tool material with good cutting performance;
2) Select reasonable tool geometric parameters;
3) Use proper cutting liquid;
4) Select reasonable cutting amount.
5)

16. What are the advantages of using indexable carbide blade?

A: Have the following advantages:

1) Since the blade isn't welded and doesn't require grinding during usage, it will avoid internal stress and crack due to welding and grinding and improve the tool durability.
2) The tool is used for long time, and it will avoid internal stress and crack due to welding and grinding and improve the tool durability.
3) The tool can be used for long time, therefore it will not only reduce the tool material, but also reduce the labor and equipment required to manufacture and grind the tool.
4) If the tool is blunt, you can just rotate the blade to continue using, and thus shorten the time in tool change, tool setting, etc.
5) It is convenient to recycle when the blade is blunt, reduce tool material consumption and reduce the cost.

17. What is size reference?

A: The start size is the size reference.

18. How to sselect reference while drawing?

A: The design reference, process reference and measurement reference should be unified, so as to reduce error and convenient for measurement and checking.

19. What is metal cutting process?

A: While cutting, under the impact of cutting blade and tool face, the metal being cut slipd and becomes chips.

20. What are the influences of cutting amount on cutting force?

A: (1) When cutting depth ap and feeding amount f increase, cutting force increases; it known from the cutting force calculation formula FZ=150apf0.75 that if the cutting depth increases by one time, main cutting force FZ increases by one time; if the feeding amount increases by one time, the main cutting force FZ increases by 70% (chip thickness increases and chip distortion decreases due to the increase of feeding amount, and therefore the cutting force must be lower).

(2) When cut plastic metal, the cutting force usually decreases along with the increase of cutting speed; when cut brittle metal, cutting speed doesn't have much influence on cutting force.

21. What are the materials of tool cutter?

A: At present, the tool materials include metal and non-metal materials: metal materials include carbon tool steel, alloy tool steel and high-speed carbide. Non-metallic materials include synthetic diamond and cubic boron nitride ceramics, in which the hard red performance of carbon tool steel and alloy tool steel is low (about 200 to 400°C), and are rarely used to make tools.

22. What are the influences of cutting amount on cutting temperature?

A: If cutting speed increases by one time, the cutting temperature increases about 30%-40%; if the feeding amount increases by one time, the cutting temperature only increases 15%-20%; if the cutting depth increases by one time, the cutting temperature only increases 5%-8%.

23. What is process dimension chain?

A: The connected dimensions are arranged into closed dimension drawing, which is the dimension chain; the dimension chain applied in the processing is called process dimension chain.

24. What is positioning error?

A: The position error of the processing surface relative to process reference due to workpiece positioning is called positioning error.

25. What are the errors may be generated in the processing?

A: The errors in the processing might be principle, clamp installation, machine tool, clamp precision, process system distortion, worepiece residual stress, tool and measurement.

26. What is the objective of using clamp in machinery manufacture?

A: In machinery manufacturing, the objective of using clamp is to ensure product quality, improve labor productivity, solve the special difficulty in lathe processing, expand the processing range of the machine tool, and reduce the technical requirement on workers.

27. What spindles are used if the workpiece is positioned with internal hole?

A: Commonly used spindles include cylindrical, small taper, cone, thread, and splined spindles.

28. What are the effects of positioning device and clamping device?

A: The effect of the positioning device is to confirm the position of the workpiece in the clamp, making the workpiece in the proper position relative to tool and cutting motion during processing. The effect of the clamp device is to clamp the workpiece, ensuring that the given position of the workpiece in the clamp won’t change during processing.

29. What is repeat positioning? What is partial positioning?

A: The positioning points are more than the degrees of freedom that should be limited, indicating that certain positioning points limit same degree of freedom, which is called repeat positioning.

30. What are machine tool errors? What are their main influences on the quality of workpiece?

A: Machine tool errors include:

1) The error between machine tool principal axis and bearing due to manufacture and wear; It has bad influences on roundness, flatness and surface roughness of the workpiece.
2) The error due to machine tool rail wear, which will causse error in the straightness of cylinder.
3) Machine tool transmission error: it destroies proper motion relationship and cause pitch error.
4) Machine tool installation position error, e.g. parallel error of guide rail and principal axis installation, which will cause taper error in processed cylinder.

31. What are geometric accuracy and work precision of the lathe?

A: Geometric accuracy of the machine tool refers to the geometric shape accuracy of the basic parts of the machine tool, geometric accuracy of relative position, and geometric accuracy of the relative motion. The work precision of the machine tool is the precision of the machine tool in motion state and under the effect of the cutting force. The precision of the machine tool in work state is reflected on the precision of the processed parts.

32. What are the conditions of ribbon cutting?

A: When process plastic metal materials, the cutting speed is high, cutting thickness is low, cutting angle is large, the slide amount of the chips is low, haven't destroyed the materials, and thus form ribbon chips.

33. What is the important meaning of process analysis?

A: Appropriate process analysis has important meaning to ensure processing quality, improve productivity, reduce production cost, reduce labor strength and make reasonable process regulations.

34. What are design reference and process reference (including assembly reference, positioning reference, measurement reference and procedure reference)?

A: (1) Design reference is the reference on the part drawing to determine the positions of other points, lines and surfaces.

(2) Process reference is the reference of the parts used in processing and assembly. According to the purpose, it is divided into assembly reference, measurement reference, positioning reference and procedure reference.

1) Assembly reference is used to confirm the position of the part in component and product during assembly.

2) The measurement reference is used to measure the size and position of processed surface.

3) The positioning reference is used to make the workpiece occupy the proper position in machine tool or clamp during processing.

4) Procedure reference is used to confirm the size, shape and position precision of the processed surface on the procedure drawing.

35. What is the reason of positioning error? How to calculate?

A: When a batch of workpieces are processed in clamp, the reasons for errors in processing size might be:

1) The maximum displacement of same batch of workpieces along the direction of processing size caused by the size and geometric shape error of the positioning reference and the clearance between the positioning reference and positioning components is called positioning reference displacement error, which is expressed in NY.

2) The displacement of the size of same batch workpieces relative to procedure reference caused by noncoincidence between procedure reference and positioning reference is called reference noncoincidence error, which is expressed in ÑB.

The sum of above errors is positioning error, resulting in the formula ÑD=ÑY +ÑB. The positioning reference displacement error and reference noncoincidence error that cause positioning error also include many elements respectively in calculation. For example, in addition to the clearance in NY, the geometric shape and position error of clamp positioning component (verticality, coincidence degree) also have influence on reference displacement.