UNIT – V

PART PROGRAMMING

SPRX1008 – PRODUCTION TECHNOLOGY - II

Methods of NC Part Programming

The tape can be prepared for submission to the MCU using any of several different methods of NC part programming. NC programming represents one of the elements in the broader procedure called process planning. We defined process planning as a function of manufacturing engineering in which the sequence of individual production operations for making the part are planned. We assume here that a portion of the processing is to be done on one or more NC machines. For those machines, the program must be prepared.

The part programming methods include a variety of procedures ranging from highly manual to highly automated:

1. Manual part programming
2. Computer assisted part programming
3. Manual data input
4. NC programming using CAD/CAM
5. Computer automated part programming

In manual part programming, the processing instructions are documented on a form called a part program manuscript. The manuscript is a listing of the positions of the tool relative to the work piece that the machine must follow in order to perform the processing. The listing may also include other commands such as speeds, feeds, tooling, and so on. A punched tape is then prepared directly from the manuscript.

In computer-assisted part programming, much of the tedious computational work required in manual programming is performed by the computer. For complex work part geometries or jobs with many processing steps, use of the computer results in significant savings in the part programmer's time. When computer assisted part programming is used, the programmer prepares the set of processing instructions in a high-level computer language. For complex jobs, this computer language is much easier to use than the lower-level coding required in manual part programming. The high-level language commands are interpreted by the computer, and the required calculations and data processing are accomplished to prepare the NC program for the tape reader (or other input device).

Manual data input (MDI) is a procedure in which the NC program is entered directly into the MCU at the site of the processing machine. Consequently, the use of the punched tape is avoided, and the programming procedure is simplified to permit machine operators rather than part programmers to do the programming.

NC part programming using CAD/CAM is an advanced form of computer-assisted part programming in which an interactive graphics system equipped with NC programming software is used to facilitate the part programming task. The term CAD/CAM means computer-aided design and computer-aided manufacturing. In this method the programmer works on a CAD/CAM workstation to enter the machining commands. The actions indicated by the commands are displayed on the graphics monitor, which provides visual feedback to the programmer. Also, certain portions of the programming cycle are automated by the NC programming software to reduce the total programming time required.

Computer-automated part programming extends the notion of automating certain portions of the. NC part programming procedure to its logical conclusion. It automates the complete part programming task using software that is capable of making logical and even quasi intelligent decisions about how the part should be machined.

Manual Part Programming

In manual programming, the part programmer specifies the machining instructions on a form called a manuscript. Manuscripts come in various forms, depending on the machine tool and tape format to be used. For example, the manuscript form for a two-axis point-to-point drilling machine would be different than one for a three-axis contouring machine.

As mentioned, the manuscript is a listing of the relative tool and workpiece locations. It also includes other data, such as preparatory commands, miscellaneous instructions, and speed/feed specifications, all of which are needed to operate the machine under tape control. The manuscript is designed so that the NC tape can be typed directly from it on a Flexowriter or similar tape-punch device.
We shall divide manual programming jobs into two categories : point-to-point jobs and contouring jobs. Except for complex work parts with many holes to be drilled, manual programming is ideally suited for point-to-point applications. On the other hand, except for the simplest milling and turning jobs, manual programming can become quite time-consuming for applications requiring continuous-path control of the tool. Accordingly, we shall only concern ourselves with manual part programming for point-to-point operations in this chapter. Manual contour programming requires such tedious and detailed calculations that the space needed for the topic would be more than is warranted by the basic purpose of this book, which is to survey the field of automated manufacturing systems.

COMPUTER ASSISTED PART PROGRAMMING

Computer Assisted Part Programming was relatively simple, it was a suitable application for manual programming. Most parts machined on NC systems are considerably more complex. In the more complicated point-to-point jobs and in contouring applications, manual part programming becomes an extremely tedious task and subject to error. In these instances it is much more appropriate to employ the high-speed digital computer to assist in the part programming process. Many part programming language systems have been developed to automatically perform most of the calculations which the programmer would otherwise be forced to do. This saves time and results in a more accurate and more efficient part program.

The part programmer's job

The difference in the part programmer's job between manual programming and computer-assisted programming is this. With manual programming, a manuscript is used which is formatted so that the NC tape can be typed directly from it. With computer-assisted part programming, the machining instructions are written in English-like statements of the NC programming language, which are then processed by the computer to prepare the tape. The computer automatically punches the tape in the proper tape format for the particular NC machine.

When utilizing one of the NC programming languages, part programming can be summarized as consisting basically of two tasks :

1. Defining the geometry of the work part
2. Specifying the tool path and/or operation sequence

Let us now consider these two tasks in computer-assisted part programming. Our frame of reference will be for a contouring application, but the concepts apply for a positioning application as well.

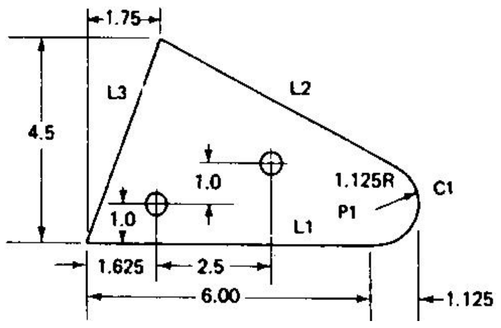

Fig: 1 Basic Geomentry Element

WORK PART GEOMETRY DEFINITION:

No matter how complicated the work part may appear, it is composed of basic geometric elements. Using a relatively simple work part to illustrate, consider the component shown in Figure 1. Although somewhat irregular in overall appearance, the outline of the part consists of intersecting straight lines and a partial circle. The holes in the part can be expressed in terms of the center location and radius of the hole. Nearly any component that can be conceived by a designer can be described by points, straight lines, planes, circles, cylinders, and other mathematically defined surfaces. It is the part programmer's task to enumerate the component elements out of which the work part is formed. Each geometric element must be identified and the dimensions and location of the element explicitly defined. Using the APT programming language as an example, the following statement might be used to define a point :

P1 – POINT/6.0, 1.125,0
The point is identified by the symbol P1 and is located at $x = 6.0$, $y = 1.125$, and $z = 0$.
Similarly, a circle in the *x–y* plane might be defined by the APT statement
C1 = CIRCLE/CENTER, P1 , RADIUS, 1.12
The center of circle C1 is Pi (previously defined) and the radius is 1.125.
The various geometric elements in the drawing of Figure 9.7 would be identified in a similar fashion by the part programmer.

TOOL PATH CONSTRUCTION

After defining the work part geometry, the programmer must next construct the path that the cutter will follow to machine the part. This tool path specification involves a detailed step-by-step sequence of cutter moves. The moves are made along the geometry elements which have previously been defined. To illustrate, using Figure 1 and the APT language, the following statement could be used to command the tool to make a left turn from line L2 onto line L3 :
GOLFT/L3, PAST, L1

This assumes the tool was previously located at the intersection of lines L2 and L3 and had just finished a cut along L2. The statement directs the tool to cut along L3 until it just passes line L1. By using statements similar to the above, the tool can be directed to machine along the work part surfaces, to go to point locations, to drill holes at those point locations, and so on. In addition to geometry definition and tool path specification, the part programmer also provides other commands to the NC system. However, let us await Section 9.5, where we will consider a wide range of possible APT statements.

The computer's job

The computer's job in computer-assisted part programming consists of the following steps:

1. Input translation
2. Arithmetic calculations
3. Cutter offset computation
4. Post processor

The sequence of these steps and their relationships to the part programmer and the machine tool are illustrated in Figure 2

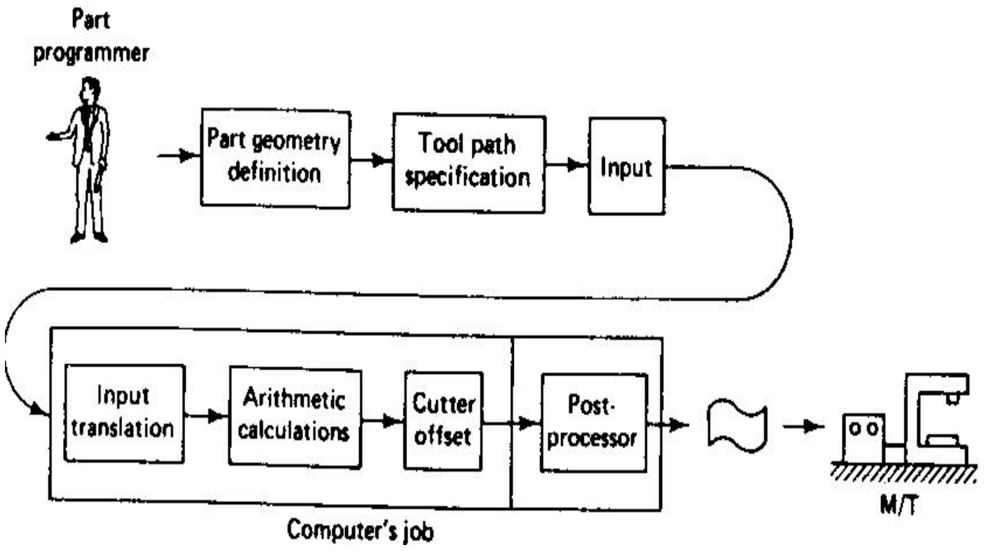

Fig.2 Steps in Computer Assisted Part Programming

INPUT TRANSLATION: The part programmer enters the program using the APT or other language. The input translation component converts the coded instructions contained in the program into computer-usable form, preparatory to further processing.

ARITHMETIC CALCULATIONS: The arithmetic calculations unit of the system consists of a comprehensive set of subroutines for solving the mathematics required to generate the part surface. These subroutines are called by the various part programming language statements. The arithmetic unit is really the fundamental element in the part programming package. This unit frees the programmer from the time-consuming geometry and trigonometry calculations to concentrate on the work part processing.

CUTTER OFFSET COMPUTATION: When we described the second task of the part programmer as that of constructing the tool path, we ignored one basic factor the size of the cutting tool. The actual tool path is different from the part outline. I is is because the tool path is the path taken by the center of the cutter. It is at the periphery of the cutter that machining takes place.

The purpose of the cutter offset computation is to offset the tool path from the desired part surface by the radius of the cutter. This means that the part programmer can define the exact part outline in his geometry statements. Thanks to the cutter offset calculation provided by the programming system, he need not concern himself with this task. The cutter offset problem is illustrated in Figure 3

POST PROCESSOR. As we have noted previously, NC machine tool systems are different. They have different features and capabilities. They use different NC tape formats. Nearly all of the part programming languages, including APT, are designed to be general-purpose languages, not limited to one or two machine tool types. Therefore, the final task of the computer in computer-assisted part programming is to take the general instructions and make them specific to a particular machine tool system. The unit that performs this task is called a post processor.

The post processor is really a separate computer program that has been written to prepare the punched tape for a specific machine tool. The input to the post processor is the output from the other three components: a series of cutter locations and other instructions. This is referred to as the CLFILE or CLDATA (CL stands for cutter location). The output of the post processor is the NC tape written in the correct format for the machine on which it is to be used.

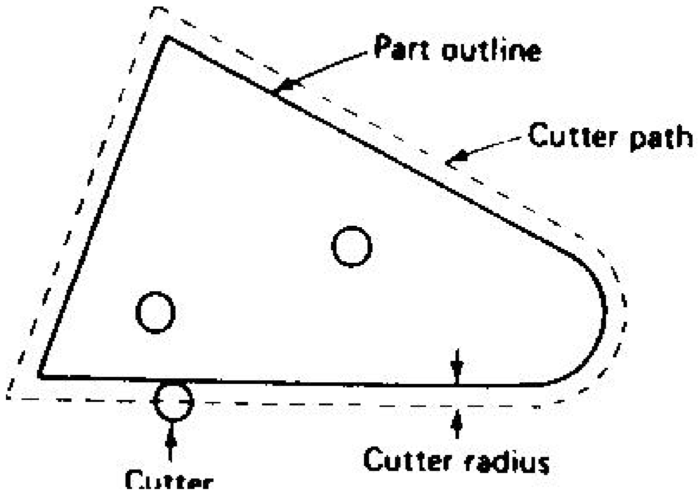

Fig.3 Cutter Offset Problem in computer-assisted part programming

Structure of Part Program

A *part program* is simply an NC program used to manufacture a part. *Part programming* for NC maybe performed manually (*manual part programming*) or by the aid of a computer (*Computer-aided partprogramming*).

Many *programming languages* have been developed for part programming. The first that used Englishlikestatements and one of the most popular languages is called APT (for *Automatically*

ProgrammedTools). Many variations of APT have been developed, including ADAPT (ADaptation of APT), EXAPT(a European flavor of APT), UNIAPT (APT controller for smaller computer systems), etc.

NC programming for complex parts are generated using advanced computer programs (CAD/CAMprograms), which create automatically the machine code (so called *G-code*) in a graphic environment.Machine code is also largely used for manual part programming of simple shapes and is covered inthe present section.

Machine code

The structure of a NC program written in machine code is standardized and for a two-axis NC systemhas the following format:

NC program block consists of a number of program words. The NC program is executed block by block:each next block is entered in the system and executed only after entirely completing the current block.

Each *program word* is an ordered set of characteristics, letters and numbers, to specify a single action ofthe machine tool. Program words fall into two categories,

Œ *modal*, which are active in the block in which they are specified and remain active in the subsequent blocks until another program word overrides them;

• *non-modal*, which are only active in the block in which they are specified.

Some of the most important program words are as follows

- *sequence numbers* (N****)

Sequence numbers are a means of identifying program blocks. In some systems they are not required although sequence numbers are needed in most *canned cycles* (covered later in this section);

- *preparatory functions (*also *G-codes)* (G**)

Preparatory functions are used to set up the mode in which the rest of the operation is to be executed.

Some of examples of G-codes are given in the table:

G00	Positioning (not cutting)
G01	Linear interpolation
G02	Clockwise circular interpolation
G03	Counterclockwise circular interpolation
G20	Inch data input
G21	Metric data input
G54	Workpart coordinate preset
G80	Canned cycle cancel
G81-89	Canned cycles

G90 Absolute programming
G91 Incremental programming

- *Dimension words* (D****.***), where D stands for X, Z, U, or WDimension words specify the coordinate positions of the programmed path. X andZ specify the *absolute coordinates*, and U and W specify the *incremental coordinates*(absolute and incremental programming are explained later in this section);
- *Arc center coordinates* (D****.***), where D stands for I, or KArc center coordinates specify the incremental coordinate position of the arc center (I inthe direction of X-axis, and K in the direction of Z-axis), measured from the arc startingpoint;

- *Feed function* (F**.**)

Specifies the velocity of feed motion;

- *Spindle control function* (S****)

Specifies spindle rotational speed in revolutions per minute, or cutting velocity in meterper minute depending on the type of NC system and machine tool;

- *Tool calls* (F**.**)

The tool call word is used to access the required tool. It also gives the information for theradial compensation of tool corner wear for each new run of the program (and eachnew part);

- *Miscellaneous functions* (M**)

The M-function performs miscellaneous machine actions such as these listed in thetable:

M00	Program stop
M02	Program end
M03	Start spindle CW
M04	Start spindle CCW
M05	Stop spindle
M06	Execute tool change
M07	Turn coolant on
M25	Open chuck
M26	Close chuck

Program points

The NC system must know where the part is positioned in the work space. The procedure for defining the *work coordinate system* (WPC) is called *work piece coordinate setting*. Two important factors deal with work piece coordinate setting,

Œ where the *part datum* (the origin of the WPC) is situated with respect to the work piece;

- Where the part datum is situated with respect to the machine tool.
-

The WPC origin may be located at any part of the work piece, but to avoid dimensional recalculations and respectively errors, the good programmers will chose the WPC origin at the point, from where the part features are dimensioned:

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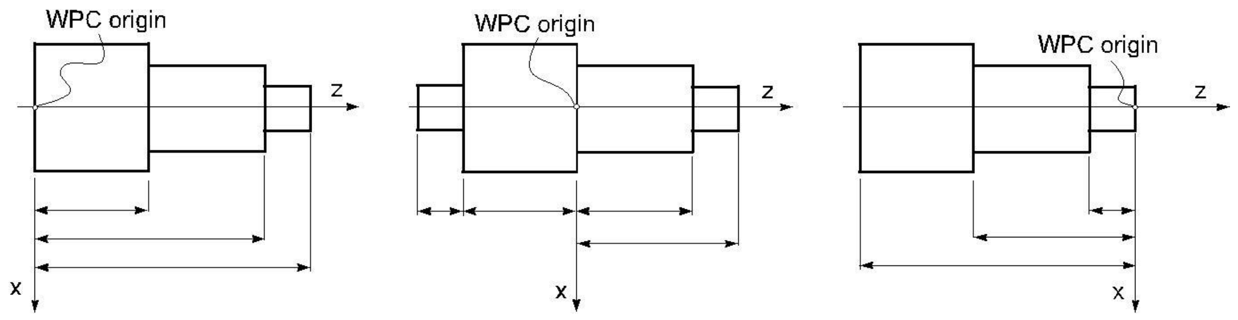


Fig:4 Selection of Work Piece Coordinate origin

The methods for locating the positions of the WPC origin with respect to the machine tool varies for each machine tool. Some systems use a *zero-set button* to set the WPC origin. On other types of NC systems, the WPC is set with a G54 or a G92 code followed by X, and Z dimensions.

The G54 code tells the machine where the position of the WPC measured from the machine zero point is. *Machine zero point* (*machine datum*) is a fixed point on the machine tool and cannot be programmed or altered.

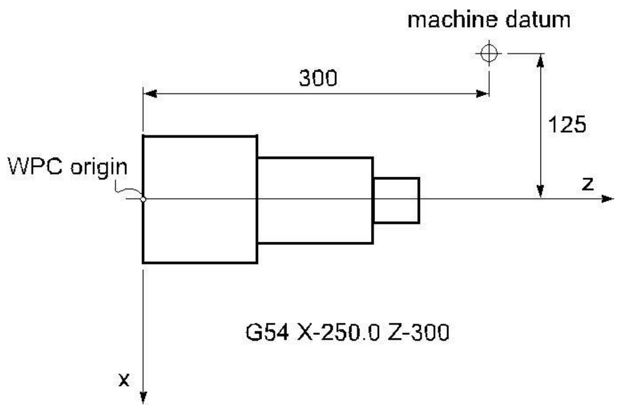


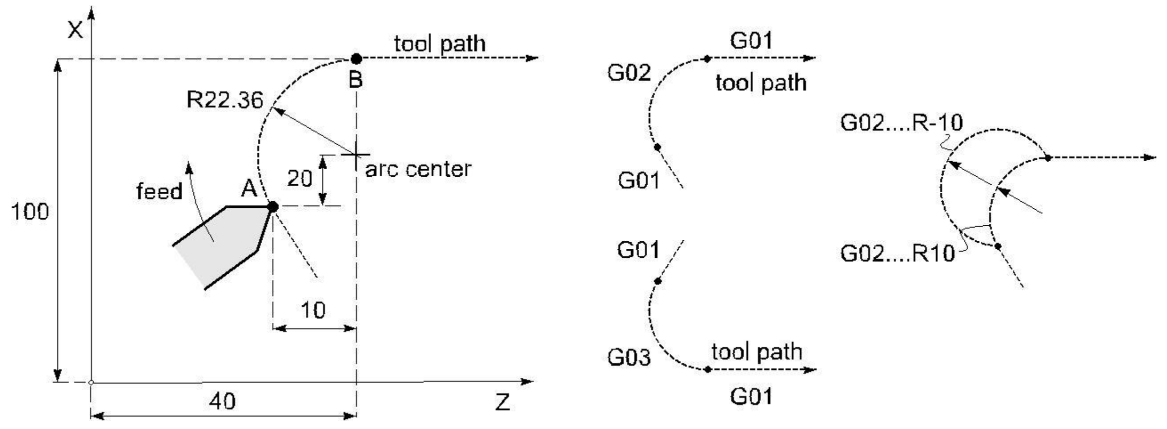
Fig:5 Setting of WPC

Another important point is the *program start point* (also *tool home position*). This point is selected by the programmer at some distance from the work piece, not too far to save some time when the tool returns home, and not too close to allow for safe indexing of the tool turret when the cutting tool is changed. The program, therefore the new part machining, starts and ends with the tool at home position, but the tool needs also to be returned to home whenever a tool change take place during the program execution.

Linear and circular interpolation

A G01 *linear interpolation* code moves the tool to a position with coordinates defined with program words in a straight, including angular line at the specified with F-code feed rate. The command is modal and is active until either a G00, or G02, or G03 overrides it.

NC system are capable of commanding a circular motion. Arc movement is known as *circular interpola-tion* and is carried out with a G02 (*clockwise circular interpolation*) or G03 (*counter clockwise circular interpolation*) codes. The arc radius is specified either by the incremental dimensional words I and K, which defines the position of arc centerpoint with respect to the arc start point, or directly by the radius R-code. In both methods, the program block, which starts with a G02 or G03 codes must also include the coordinates of the arc end point. If R-code is used, arcs less than 180^o are given a positive radius and arcs more than 180^o are given a negative radius value:



```
N0010 G02 X100.0 Z40.0 I20.0 W10

                or

N0010 G02 X100.0 Z40.0 R22.36
```

Fig:6 Linear and circular interpolation.

TOOL LENGTH COMPENSATION

Tool length compensation is instated with a G43 word. Included within the G43 command is an H-word that specifies the **offset** number in which the **tool length compensation** value is stored. You must also include a Z-word in the G43 command, telling the machine where you want the **tool** tip to be positioned.

Cutting tools used on machining centers differ from one another. For one thing, there are a variety of cutting tool types that are used on machining centers, including center drills, spot drills, drills, taps, reamers, boring bars, end mills, and face mills (among many others). Each type of tool requires a different way of gripping the actual cutting tool in its holder. Some tools (like some straight shank tools) use a collet system. Others (like end mills) use a set- screw to hold the cutting tool in place. Yet others (like face mills and taps) require a very special style of tool Holder–designed especially for the cutting tool.

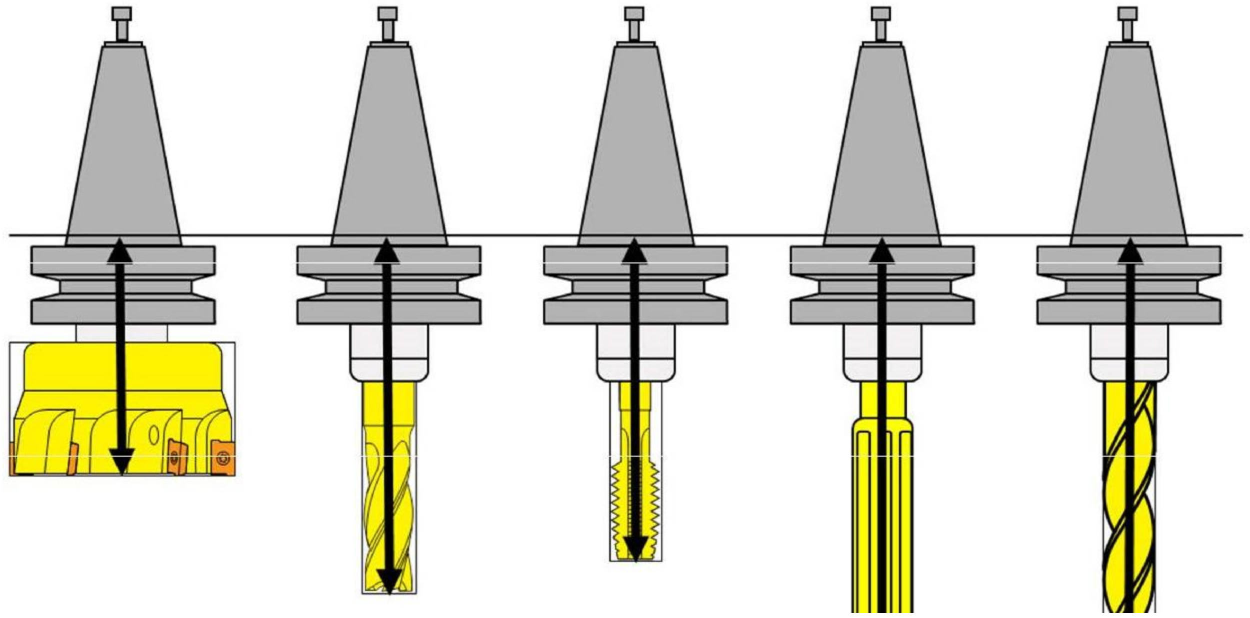


Fig:7 Tool Length compensation

Tool length compensation will allow you to write programs even though you don't know how long the cutting tools will be at production time.

Tool's Length Will Vary from Each Time it is Assembled

When a cutting tool is assembled more than once (even with the same components), its length will usually vary. Consider, for examples, straight shank tools that are placed in collet holders. Each time you assemble the tool, it will be of a different length. Tool length compensation will allow you to use the same program over and over again, even though each tool's length changes from one time the job is run to the next.

Tool Data is Entered Separately from the Program

The same program will work regardless of how long each cutting tool is. The program tells the control where to look for the length of each tool. During setup, the setup person (or someone) assembles and measures each cutting tool. The length of each tool is then placed in the appropriate location (a tool offset register).

Sizing and Trial Machining Must Often be Done

The importance of being able to trial machine in order to machine the first work piece correctly. And during a given tool's life a tool will wear and cause the surface being machined to change. Tool length compensation allows the setup person and operator to easily hold size for Z-axis related dimensions (pocket depths, hole-depths, etc.). The program need not be changed when work piece dimensions must be adjusted.

CUTTER RADIUS COMPENSATION

Cutter Radius Compensation also known as CRC, is a function of the CNC controller to automatically shift the tool from the **cutter** center line to the **cutter** edge along the programmed **cutter** path. If it were not for CRC the **cutter** path locations would have to be calculated to the **cutter** center line. Cutter Radius Compensation (CRC) can be used to program continuous path milling operations.

There are a few special rules that must be applied to the programming method when using CRC.

1) The point before the CRC approach and exit from the contour cut must be equal to or greater than the cutter radius.

2) CRC can only be started and stopped along linear motion.

3) CRC can only be applied to 2 axis of motion at a time.

4) The use of more than one non motion block in a row is not allowed.

Three main advantages to using Cutter Radius Compensation (CRC) programming

1)The programmer can use point values that are directly along the cutter path rather than having to calculate the tool center.

2)During production runs, cutters of different sizes can be used such as undersize tools when the original size tool is no longer available. It is a simple radius offset value change in the machine control to achieve this. The programming will remain the same.

3)A program section or operation can be used over and over with different tools to create roughing passes and finish passes. This is done by changing the radius offset value and using multiple offsets.

TOOL NOSE RADIUS COMPENSATION

During processing of the work piece contour, due to the tool radius, tip and a half Diameter of the existence of the tool tip and work piece center or imaginary contours do not coincide. If the digital system does not have automatic tool radius compensation function can only be converted into contour programming tool center path, and then processed. When the tool wear, heavy wear, tool change, to re-calculate the tool center path, modify the program. However, when the numerical control system with automatic tool radius compensation function, you can just press the work piece contour programming,

CNC system will automatically calculate the tool center path, deviate from the contour of the tool with a radius value, even if the tool wear, heavy wear, tool change, also need to modify the radius of the tool deviate from the contour value that offsets, tool radius compensation automatically, without modifying the program.

CNC lathe programming is based on imaginary tip movement; the actual tip location is a small circular, conical surface and in the turning arc will produce processing errors. If the use of nose radius compensation, pre-tip to tip radius and arc parameters such as input to the tool position within the database, according to work piece contour programming, numerical control system automatically calculates the tool center trajectory, the control center path for cutting knives processing, eliminating the tip of the arc caused by processing errors. You can also modify the value to eliminate abrasion tool wear or tool failure caused by processing errors.

Similarly, in CNC milling, the tool radius offset pre-register in the specified register, the use of the tool radius compensation commands, by adjusting the tool radius compensation value to compensate for tool wear, in order to eliminate the tool wear caused by processing errors . At the same time even if a replacement tool or tool re-grinding, as long as the contour is the same, processing the same coordinate system, you can use the original program. At the same time as the application can also adjust the tool radius compensation amount to the same profile using the same procedures under the same conditions, rough and finish.

Cycles

The repetitive program (and machining) sequence is called a cycle. Cycles are classified into two principlegroups,

Œ canned cycles (also fixed cycles), and user-defined cycles (sub-routines).

Canned cycles are an inbuilt feature of the NC system. The usage of canned cycles makes easier programmingfor threading, drilling holes and other repetitive machining tasks. The next figure illustrates athread cutting canned cycle:

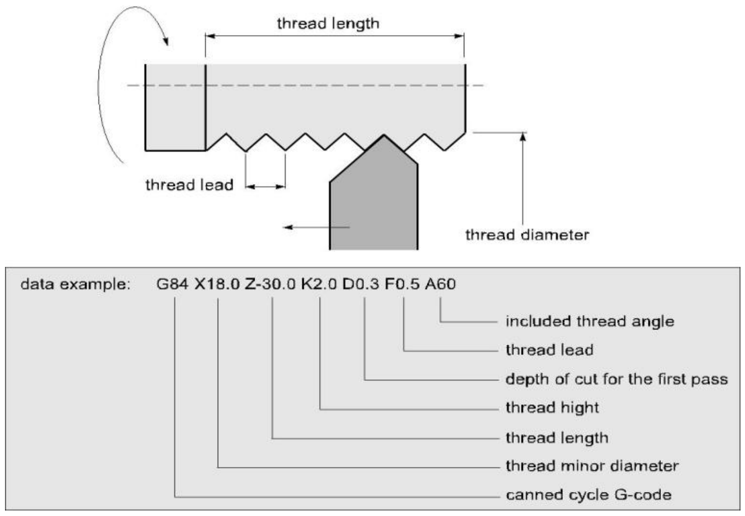


Fig:7 Threaded canned cycle

User sub-routines are useful, when the necessary canned cycle is not available. The user sub-routine is a NC program, which describes a sequence of operations, which is often repeated when machining particular part. The sub-routine is called from the main NC program with a M98 command.

A special type of user-defined cycles is so-called *macros*, which are generic cycles with parametric variables. The macro is called from the main program with a set of numerical values for these variables. This allow to use one and the same macro to machine different in size, but similar in shape components. Programming with macros is often referred to as a parametric programming.

Mirror Image

The mirroring command is used when features of components shares symmetry about one or more axes and are also dimensionally identical. By using this code components can be machined using a single set of data and length of programs can be reduced.

G10 cancellation of mirroring image
G11 Mirror image on X axis
G12 Mirror image on Y axis
G13 Mirror image on Z axis

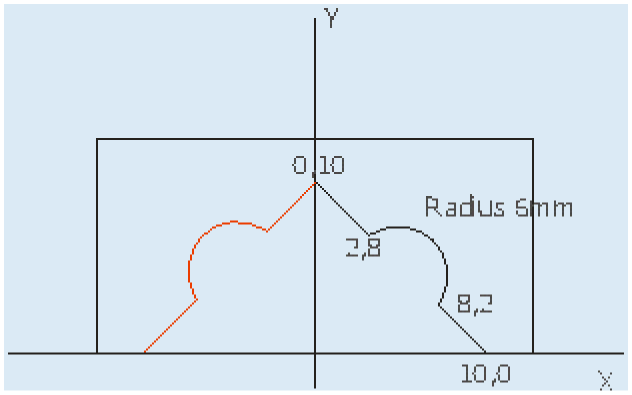
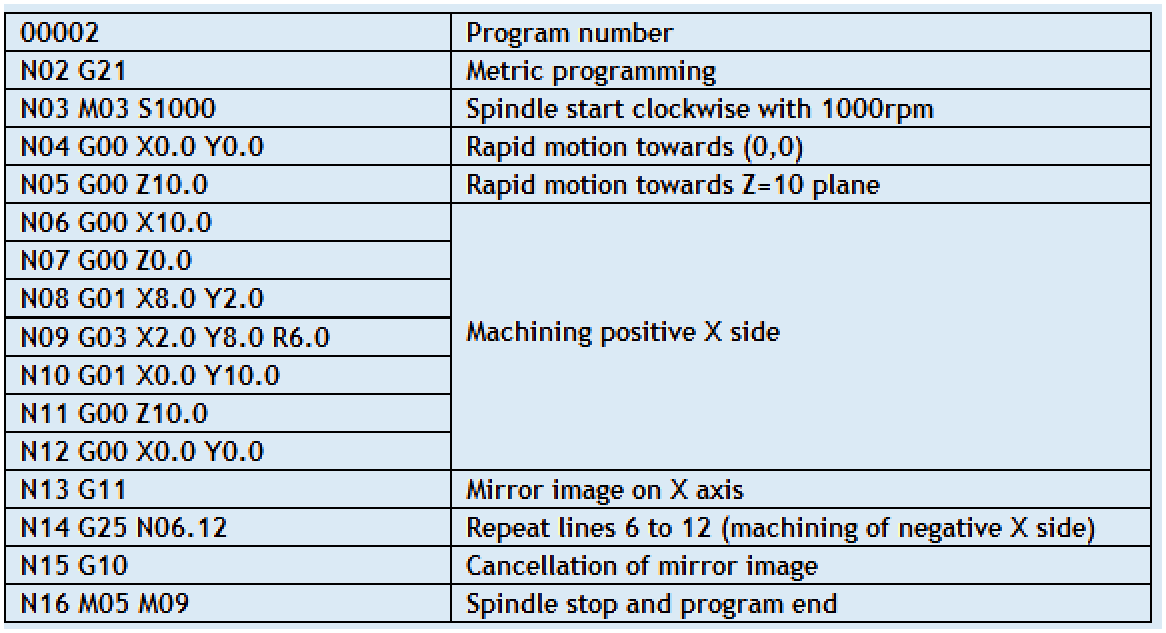


Fig. 8 Illustrative Example for mirroring



00002	Program number
N02 G21	Metric programming
N03 M03 S1000	Spindle start clockwise with 1000rpm
N04 G00 X0.0 Y0.0	Rapid motion towards (0,0)
N05 G00 Z10.0	Rapid motion towards Z=10 plane
N06 G00 X10.0	Machining positive X side
N07 G00 Z0.0	
N08 G01 X8.0 Y2.0	
N09 G03 X2.0 Y8.0 R6.0	
N10 G01 X0.0 Y10.0	
N11 G00 Z10.0	
N12 G00 X0.0 Y0.0	
N13 G11	Mirror image on X axis
N14 G25 N06.12	Repeat lines 6 to 12 (machining of negative X side)
N15 G10	Cancellation of mirror image
N16 M05 M09	Spindle stop and program end

Parametric Programming

Parametric programming can be compared to any computer programming language like BASIC, C Language, and PASCAL. However, this programming language resides right in the CNC control and can be accessed at G code level, meaning you can combine manual programming techniques with parametric programming techniques. Computer-related features like variables, arithmetic, logic statements, and looping are available. Like computer programming languages, parametric programming comes in several versions. The most popular is Custom Macro B (used by Fanuc and Fanuc-compatible controls). Others include User Task (from Okuma), Q Routine (from Sodick), and Advanced Programming Language [APL] (from G& L)

In addition to having many computer-related features, most versions of parametric programming have extensive CNC-related features. Custom macro, for example, allows the CNC user to access many things about the CNC control (tool offsets, axis position, alarms, generate G codes, and program protection) right from within a CNC program. These things are impossible with only normal G code programming techniques.

Applications:
Many companies have excellent applications for custom macro and don't even know it. Of course, if you don't even know you have an application for something, it's impossible to even consider using it. While these applications are covered in much greater detail during our video course and CD-rom course, applications for custom macro fall into five basic categories.

Example:
To stress what can be done with parametric programming, we show a simple example written in custom macro B for a machining center application. It will machine a mill a hole of any size at any location. Notice how similar this program is to a program written in BASIC.

Program

```
        O0001 (Program number)
        #100=1. (Diameter of end mill)
        #101=3.0 (X position of hole)
        #102=1.5 (Y position of hole)
        #103=.5 (Depth of counter bored hole)
        #104=400 (Speed in RPM)
        #105=3.5 (Feed rate in IPM)
        #106=3. (Tool length offset number)
        #107=2.0 (Diameter of counter bored hole)
        G90 G54 S#104 M03 (Select abs mode, coordinate system, start spindle)
        G00 X#101 Y#102 (Rapid to hole center)
        G43 H#106 Z.1 (Instate tool length compensation, rapid to approach Z position)
        G01 Z-#103 F[#105 / 2]
        Y[#102 + #107 / 2 - #100 / 2] F#105
        G02 J-[#107 / 2 - #100 / 2]
        G01 Y#102
        G00 Z.1
        M30
```

Automatically Programmed Tool (APT)

The API language was the product of the MIT developmental work on NC programming systems. Its development began in June 1956, and it was first used in production around 1959. Today it is the most widely used language in the United States. Although first intended as a contouring language, modern versions of APT can be used for both positioning and continuous-path programming and continuous-path programming in up to five axes.

AUTOSPOT (AUTOMATIC SYSTEM FOR POSITIONNING TOOLS). This was developed by IBM and first introduced in 1962 for PTP programming. Today's version of AUTOSPOT can be used for contouring as well.

SPLIT (SUNDSTRAND PROCESSING LANGUAGE INTERNALLY TRANSLATED). This is a proprietary system intended for Sundstrand's machine tools. It can handle up to five axis positioning and possesses contouring capability as well. One of the unusual features of SPLIT is that the post processor is built into the program. Each machine tool uses its own SPLIT package, thus obviating the need for a special post processor.

COMPACT II. This is a package available from Manufacturing Data Systems, Inc. (MDSI), a firm based in Ann Arbor, Michigan. The NC language is similar to SPLIT in many of its features. MDSI leases the COMPACT II system to its users on a time-sharing basis. The part programmer uses a remote terminal to feed the program into one of the MDSI computers, which in tum produces the NC tape.

ADAPT (ADAPTATION OF APT). Several part programming languages are based directly on the APT program One of these is ADAPT, which was developed by IBM under Air Force contract. It was intended to provide many of the features of AFT but to utilize a significantly smaller computer. ADAPT is not as powerful as APT, but can be used to program for both positioning and contouring jobs.

EXAPT (EXENDED SUBSET OF APT). This was developed in Germany starting around 1964 and is based on the APT language. Itere are three versions: EXAPT I designed for positioning (drilling and also straight-cut milling), EXAPT ll designed for turning, and EXAPT III designed for limited contouring operations. One of the important features of EXAPT is that it attempts to compute optimum feeds and speeds automatically.

PART PROGRAMMING USING CAD/CAM

A CAD/CAM system is a computer interactive graphics system equipped with software to accomplish certain tasks in design and manufacturing functions. One of the important tasks performed on a CAD/CAM system is NC part programming. In this method of part programming, portions of the procedure usually done by the part programmer are instead done by the computer. The two main tasks of a part programmer in a computer assisted programming are (a) defining the part geometry and (b) specifying the tool path. The proposed methodology is used to automate both of these tasks.

Part geometry definition:

The fundamental objective of CAD/CAM system is to integrate the design engineering and manufacturing engineering functions. Certainly one of the important design functions is to design the individual components of the product. If a CAD/CAM system is used, a computer g raphics model of each part is developed by the designer and stored in the CAD/CAM database. That model contains all of the geometric, dimensional and material specifications for the part. When the same CAD/CAM system, or a CAM system that has access to the same CAD database in which the part model resides, is used to perform NC part programming it makes little sense to re create the geometry of the part during the programming procedure. Instead, the programmer has the capability to retrieve the part geometry model from the storage and to use that model to construct the appropriate cutter path. The significant advantage of using CAD/CAM in this way is that it eliminates one of the time consuming steps in computer assisted part programming geometry definition.

After the part geometry has been retrieved, the usual procedure is to label the geometric elements that will be used during part programming. These labels are the variable names (symbols) given to the lines circles and surfaces that comprise the part. Most systems have the capacity to automatically label the geometry elements of the part and to display the labels on the dias.

If the NC programmer does not have access to the data base, then the NC Programming must be defined. This is done by using similar interactive graphics techniques that the product designer would use to design the part. Points are defined in a coordinate system using the computer graphics system, lines and circles are defined from the points, surfaces are defined, and so forth, to construct a geometric model of the part. The advantage of using the interactive graphics system over conventional computer assisted part programming is that the programmer receives immediate visual verification of the definitions being created. This tends to improve the speed and accuracy of the geometry definition process.

Tool path generation using CAD/CAM:

The second task of the NC programmer in computer assisted part programming is tool path Specification. The first step in specifying the tool path is to select the cutting tool for the operation. Most CAD/CAM systems have tool libraries that can be called by the programmer to identify what tools are available in the tool crib. The programmer must decide which of the available tools is most appropriate for the operation under consideration and specify it for the tool path. This permits the tool diameter and other dimensions to be entered automatically for tool offset calculations. If the desired cutting tool is not available in the library, an appropriate tool can be specified by the programmer. It then becomes part of the library for future use.

The next step is tool path definition. There are differences in capabilities of the various CAD/CAM systems, which result in different approaches for generating the tool path. The most basic approach involves the use of the interactive graphics system to enter the motion Commands one by one, similar to computer assisted part programming. Individual statements in APT or other part programming language are entered and the CAD/CAM system provides an immediate graphic display of the action resulting from the command, thereby validating the statement. A more advanced approach for generating tool path commands is to use one of the automatic software modules available on the CAD/CAM system. These modules have been developed to accomplish a number of common machining cycles for milling, drilling and turning. They are subroutines in the NC programming package that can be called and the Required parameters given to execute the machining cycle.

Computer Automated part programming:

In the CAD/CAM approach to NC part programming, several aspects of the procedure are automated. In the future, it should be possible to automate the complete NC part programming procedure. The proposed system is an automated system where the input is a geometric model of a part that has been defined during product design and the output is a NC part program. The system possesses sufficient logic and decision making capability to accomplish NC part programming for the entire part without human assistance.

This can most readily be done for certain NC processes that involve well defined, relatively medium complex part geometries. Special algorithms have been developed to process the design data and generate the NC program.