

COMPUTER INTEGRATED MANUFACTURING SYSTEMS

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Manual and computer assisted part programming(As per CAM lab)

APT Programming

APT stands for Automatically Programmed Tool. It is a language that defines the tool path with respect to the part geometry, and often forms the basis for post-processor generated NC files.

The APT language consists of four types of statements. **Geometry** statements will be used to specify the elemental features defining the part shape. **Motion** statements are used to specify the path taken by the tool. **Post-processor** statements control the machinery, controlling coolants as well as the feeds and speeds. **Auxiliary** statements complete the picture, specifying the part, required tools, etc. The following sections describe each of the APT statements.

Geometry Statements

All geometric elements must be defined before tool motion may be programmed. Geometry statements associate a symbol with a description of the geometric element and its parameters. The general form for a geometry statement is:

symbol = geometric type/parametric description

The symbol consists of up to six alpha-numeric characters, containing at least one alpha character, and avoiding APT reserved words. The symbols provide a means to name the geometric features. The equals sign separates the symbol from the geometric type.

The geometric type describes these features. **POINT**, **LINE**, **PLANE**, and **CIRCLE** are valid APT geometric types. The forward slash character separates the geometric type from the parametric description of the feature.

The parametric description specifies the location and size of the feature. It may include dimensional data, positional data, and other APT words relating the feature to previously defined APT symbols. The APT language provides a rich means to specify the geometry, as is evidenced by the following examples.

To specify a point:

P0 = **POINT**/1.0,1.2,1.3 *specifies a point at XYZ coordinates 1.0, 1.2, and 1.3, respectively.*

P1 = **POINT**/INTOFL1, L2 *specifies a point at the intersection of lines L1 and L2, which*

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must have been defined prior to the statement.

P2 = POINT/YLARGE, INTOF,L3,C1 specifies a point at the intersection of line L3 and circle C1 at

a Y position above the center point of the circle.

To specify a line:

L1 = LINE/P0,P1 specifies a line by two points, previously defined.

L1 = LINE/1.0, 1.2, 1.3, 2.0,2.1,2.3 specifies a line by two points, given as explicit coordinates.

L2 = LINE/P2,PARLEL, L1 specifies a line through point P2 and parallel to line L1.

L3 = LINE/P1, RIGHT,TANTO,C1 specifies a line through point P1 and tangent to circle C1 on the right side of the center point.

L4 = LINE/P1, ATANGL,45,L1 specifies a line through point P1 at an angle of 45° to line L1.

To specify a plane:

PL0 = PLANE/P0,P1,P2 specifies a plane through three, non-colinear, previously defined points.

PL1 = PLANE/P3,PARLEL, PL0 specifies a plane through a point P3 parallel to a plane PL0.

To specify a circle:

C0 = CIRCLE/CENTER, P0, RADIUS, 1.0 specifies a circle of radius 1 from a center point of P0.

Lines and planes extend infinitely. Circles are always complete. The same geometry may be defined only once, and may not have more than one symbol.

Motion Statements

The format for motion commands follows the pattern:

motion/description

The initial motion starts from a home position, and takes the form:

FROM/P0 or **FROM/ 0.0, 1.0, 2.0**

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The **FROM** motion statement occurs only once for each set of a motion type, at the start of the set of motions.

Contouring motion – is the most common motion used in APT programming, and these statements specify the tool path continuously throughout the motion. They make use of three surfaces: (a) **drive**; (b) **check**; and (c) **part** surfaces.

Drive surfaces represent the surface along which the vertical edges of the tool will follow. Part surfaces specify the surfaces the tip of the tool will follow. And check surfaces describe where the tool will come to rest after it has completed the motion of the current step. There are four locations for the tool to stop with respect to a check surface. These four possibilities each have their own modifier words.

The **TO** modifier stops the tool when the *first surface* of the tool would come into contact with the check surface. The **ON** modifier stops the tool where the *center point* of the tool would come into contact with the check surface. The **PAST** modifier stops the tool where the *last surface* of the tool would contact the check surface. And the **TANTO** modifier stops the tool at the point of circular tangency with the *edge* of the tool.

The initial contouring motion statement is the **GO/TO**, which defines the initial drive, part and check surfaces. It takes the form:

GO/TO, drive surface, **TO**, part surface, **TO**,

check surface An example would be:

GO/TO, L1, **TO**, PL1,**TO**,L2 specifying that the tool should use line L1 as the drive surface, planeP1

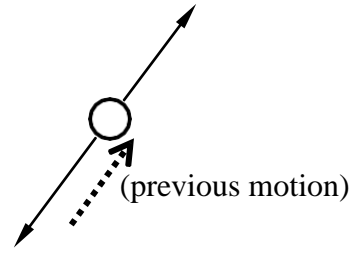
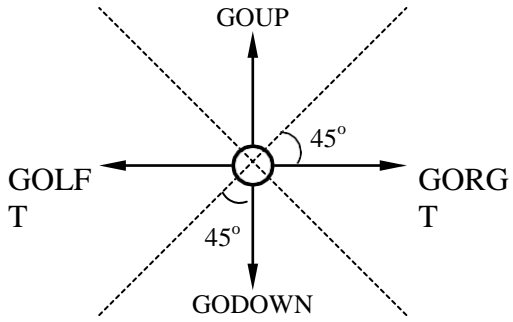
as the part surface, and line L2 as the check surface.

Note: the **GOTO** and the **GO/TO** statements *are not the same*. The former specifies **point to point** motion (see below), and the latter initiates **contouring** motion.

Continuing contouring motion statements are given from the vantage point of a person sitting on the top of the tool. The motion words are: (a) **GOLFT**; (b) **GORGT**; (c) **GOFWD**; (d) **GOBACK**; (e) **GOUP**; and (f) **GODOWN**. The sense of these words depends on the direction the tool has been coming from, and is depicted in Figure 2:

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GOFWD



GOBACK

(a)

(b)

Figure 1. Motion Continuation Statements

Point to point motion – may be specified as absolute, or as incremental (relative to the last point visited). An example of absolute, point to point motion is:

GOTO/P0

An example of incremental, point to point motion is:

GODLTA/1.0, 2.0, 3.0

Point to point motion is useful in peck drilling or similar operations, since the motion path in-between the points is unimportant.

Post-Processor Statements

These statements provide processing parameters to the post-processor program. Typical programs will require parameters for feeds, speed, and other tool/spindle/machine controls. Examples:

SPINDL/600 specifies the spindle to be 600 rpm.

FEDRAT/6.0 specifies a feed rate of 6 inches per minute.

TURRET/T2 specifies loading tool # 2 in the turret.

A final post-processor statement must specify to the post-processor program what type of machine is intended for the final NC code, and the specific controller to generate the code for. An example is:

MACHIN/MILL,2 specifies a mill machine type, and controller
type2

Auxiliary Statements

These statements complete the APT programming language, and include the FINI statement to mark the end of the program as well as statements to define the width of the tool. An example of the latter is:

CUTTER/0.25 specifies a quarter-inch cutter diameter.

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The computer would then know to calculate a 0.125 inch offset to accommodate the cutter diameter in computing the center of the tool.

Example APT Problem:

An APT program for the profiling of the part in Figure 2 is to be generated. The processing parameters are: (a) feed rate is 5.39 inches per minute; (b) spindle speed is 573 revolutions per minute; (c) a coolant is to be used to flush the chips; (d) the cutter diameter is to be 0.5 inches, and (e) the tool home position is (0, -1, 0). (Adapted from Groover, M. P. (1980). *Automation, Production Systems, and Computer-Aided Manufacturing*. Englewood Cliffs, NJ: Prentice-Hall. pp. 253-255.)

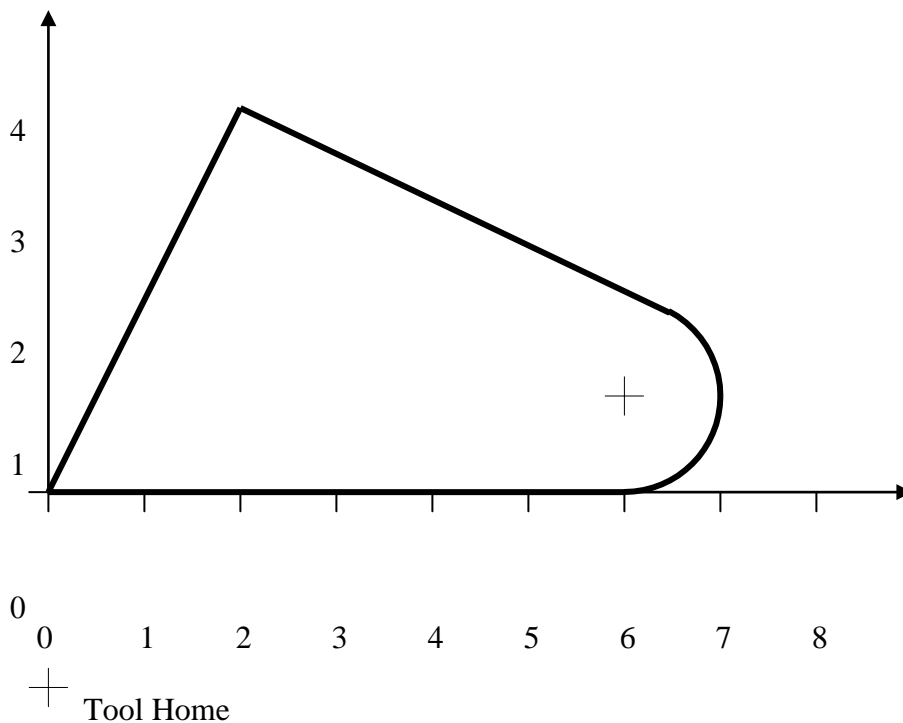


Figure 2. APT Program Workpiece

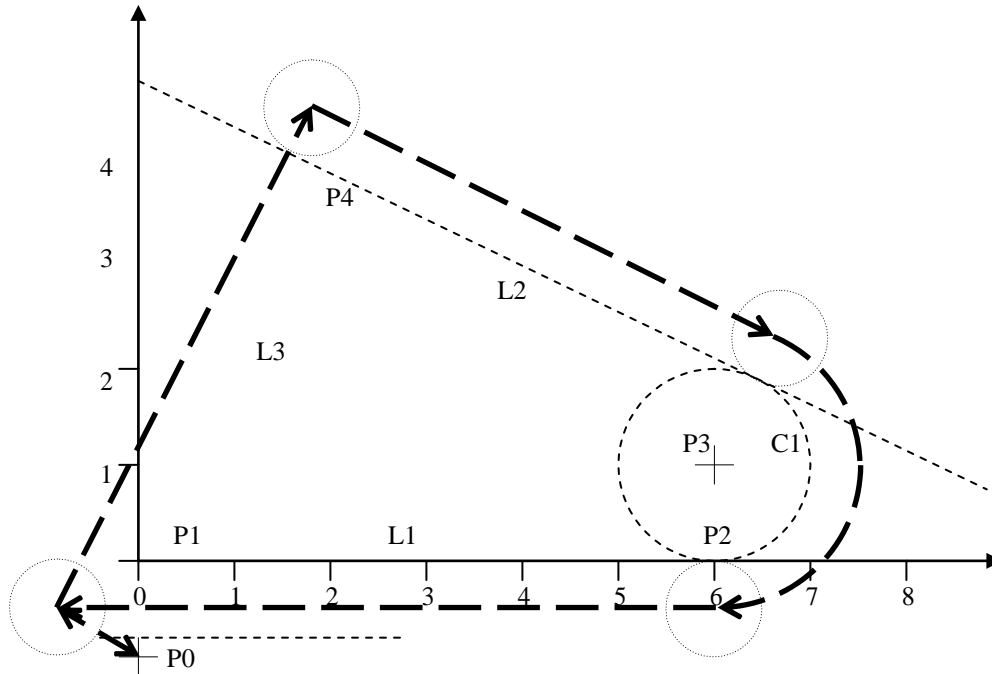


Figure 3. APT Geometry and Tool Path for Workpiece

APT Program Listing

PARTNOEXAMPLE	labels the program "EXAMPLE"
MACHIN/MILL,1	selects the target machine and controller type
CUTTER/0.5000	specifies the cutter
diameter P0 = POINT/0, -1.0, 0	} geometry statements to specify the pertinent surfaces of
P1 = POINT/0, 0, 0	
P2 = POINT/6.0, 0, 0	
P3 = POINT/6.0, 1.0, 0	
P4 = POINT/2.0, 4.0, 0	
L1 = LINE/P1, P2	} motion statements to contour the part in a
the part C1 = CIRCLE/CENTER, P3, RADIUS, 1.0	
L2 = LINE/P4, LEFT, TANTO, C1	} motion statements to contour the part in a
L3 = LINE/P1, P4	
PL1 = PLANE/P1, P2, P3	} motion statements to contour the part in a
SPINDL/573	
FEDRAT/5.39	sets the spindle speed to 573rpm
COOLNT/ON	sets the feed rate to 5.39ipm
FROM/P0	turns the coolant on
GO/PAST, L3, TO, PL1, TO, L1	gives the starting position for the tool
checks surfaces GOUP/L3, PAST, L2	initializes contouring motion; drive, part, and
GORT/L2, TANTO, C1	} motion statements to contour the part in a
GOFWD/C1, ON, P2	
clockwise direction GOFWD/L1, PAST, L3	} motion statements to contour the part in a
RAPID	
GOTO/P0	move rapidly once cutting is done
	return to the tool home position

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COOLNT/OFF
FINI

turn the coolant off
end program

APT Vocabulary

The APT programming language has over 400 words. The Chapter 6 Appendix in the Groover text (pp. 196 – 209) lists several useful words. It is suggested that the diligent student review this appendix, and note the particularly useful/trickier words in her/his engineering notebook.

NC Part Programming Using CAD/CAM

A *CAD/CAM system* is a computer interactive graphics system equipped with software in accomplish certain tasks in design and manufacturing and to integrate the design and manufacturing functions. One of the important tasks performed on a CAD/CAM system is the 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. Recall that the two main tasks of the part programmer in computer- assisted programming are (1) defining the part geometry and (2) specifying the tool path. Advanced CAD/CAM systems automate portions of both of these tasks.

Geometry Definition Using CAD/CAM: -A fundamental objective of CAD/CAM 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 graphics 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 specification 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 recreate the geometry of the part during the programming procedure. Instead, the programmer has the capability to retrieve the part geometry model from 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, circle 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 monitor. The programmer can then refer to those labeled elements during tool path construction.

If the NC programmer does not have access to the data base, then the geometry of the part 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

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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.