UNIT 2 CNC CONTROLS

Structure

2.1 INTRODUCTION

In Unit 1, introduction to numerical control is provided. This unit provides some of the general developments in the NC technology that would be required for understanding and utilizing CNC machine tools.

Objectives

After studying this unit, you should be able to

- understand the various types of control systems available,
- identify the axes of any CNC machine tool,
- explore the various features that will be present in a typical CNC controller, and
- get an idea about some of the developments that are taking place in the controller technology.

2.2 CLASSIFICATION OF CNC SYSTEM

The motion of the tool in a NC machine tool is basically in two modes :

- Point to point, and
- Continuous path

The point to point systems make the tool to move from one point to the other in rapid motion, while performing a certain operation at each of these points as shown in Figure 2.1. This is generally used for drilling and punching operations. The controllers are relatively simple and low cost for such operations. The type of applications can be PCB drilling machines or sheet metal punching presses. The motion path taken between the points is generally at the fastest speed possible, thereby reducing the idle time.

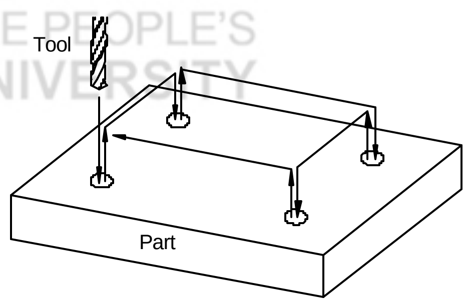

Figure 2.1 : Point to Point Tool Movement

In the case of continuous path movement, the tool will move in any of a number of valid axes simultaneously through a specified path such as a straight line or circular as shown in Figure 2.2. This calls for an interpolation to be worked out by the controller for all the intermediate points so that the tool will be able to trace the path properly. The capability of the contouring machines is such that they may have simultaneous interpolation from 2 to
5 axes depending upon the profile geometry being generated. These controllers are generally expensive because of the larger capability of the computers involv ed.

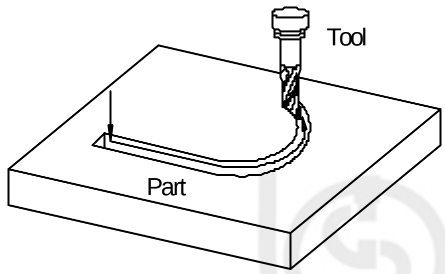

Figure 2.2 : Continuous Path Tool Movement

2.3 AXES DESIGNATION

In order to generate the part shape, the tool needs to move through the contour of the part geometry. As a result, the major part of a NC part program requires the input of co-ordinates of the tool end point. For this purpose, it is necessary to identify an appropriate coordinate system for the NC machine tools. The axes designations have been standardised by EIA (Electronics Industry Association, USA) and ISO.

Co-ordinate System

All the machine tools make use of the right hand Cartesian co-ordinate system. The main axes to be designated are the rectangular axes and the rotary axes. Typical right-handed co-ordinate system is shown in Figure 2.3. One could use his right hand (as shown in Figure 2.4) to arrive at the correct orientation of the system. The positive direction of the rotary axes can also be obtained by the use of right hand as shown in Figure 2.5.

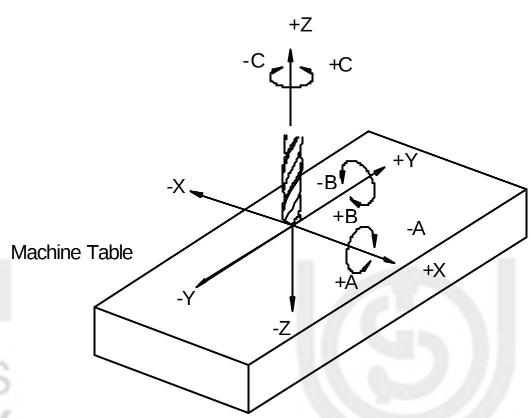

Figure 2.3 : Right Hand Co-ordinate Systems

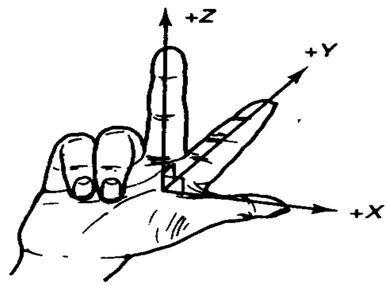

Figure 2.4 : Finding Directions in a Right Hand Co-ordinate System

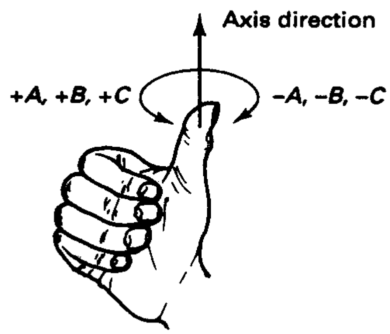

Figure 2.5 : Finding Directions for Rotary Motions

Designating the Axes

As per the standards, the first axis to be identified is the Z-axis, followed by the X- and Y-axes.

Z-Axis

The principal axis is considered as the Z-axis. The Z-axis is considered coincident or parallel to the spindle axis. The positive direction of the Z-axis is the tool moving away from the work holding surface towards the cutting tool. In the case of machine without a spindle such as shapers and planers, it is identified as the one perpendicular to the work-holding surface.

X-Axis

The X-axis is the principal motion direction in a plane perpendicular to the Z-axis. It is perpendicular to the Z-axis and should be horizontal and parallel to the work-holding surface wherever possible. When an operator is standing in front of the machine tool, the positive (+) X is to his right side. For turning machines, it is radial and parallel to the cross slide. X is positive when the tool recedes from the axis of rotation of the workpiece.

Y-Axis

It is perpendicular to both X- and Z-axes and the direction is identified by the right hand Cartesian co-ordinate system.

In the case of several spindles and slide ways, one of the spindles, preferably the one perpendicular to the work-holding surface may be chosen as the principal spindle and associated with the Z-axis. The motions of other spindles or slides, may be treated as secondary and tertiary motions and accordingly designated as U, V, W and P, Q, R respectively.

The designation of Z-axis is demonstrated in Figure 2.6 for a vertical axis milling machine. In Figure 2.7 is shown a turning centre.

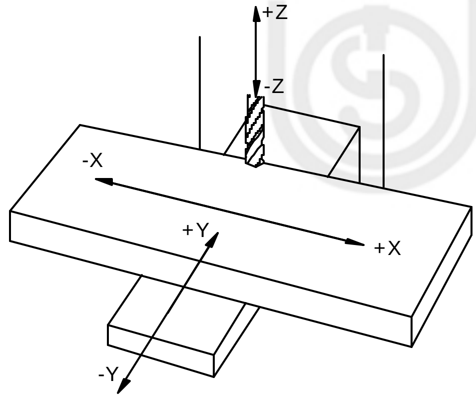

Figure 2.6 : Vertical Axis Milling Machine or Machining Centre

As already discussed, most of the machine tool manufacturers adhere to the standard to a very great extent. However, some deviations may be present in some cases because of the historical reasons or specific convenience in operation or programming of the machine tool.

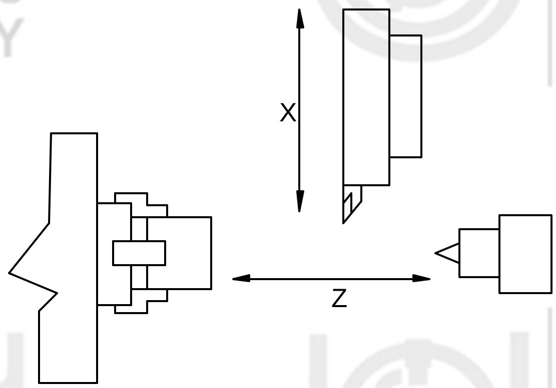

Figure 2.7 : Axes Designation for CNC Turning Centre

Rotary Motions

A, B and C are defined as the primary rotary motions and are assigned about the axis parallel to X, Y and Z respectively. Additional rotary motions if present are designated as D or E regardless of whether they are parallel or not to A, B and C.

2.4 CNC CONTROL SYSTEMS

A typical CNC machine control unit (MCU) has a number of units present inside to do all these functions. An example of sub systems that are present in an MCU are shown in Figure 2.8. A brief description of what these subsystems mean for the performance of the MCU is given below :

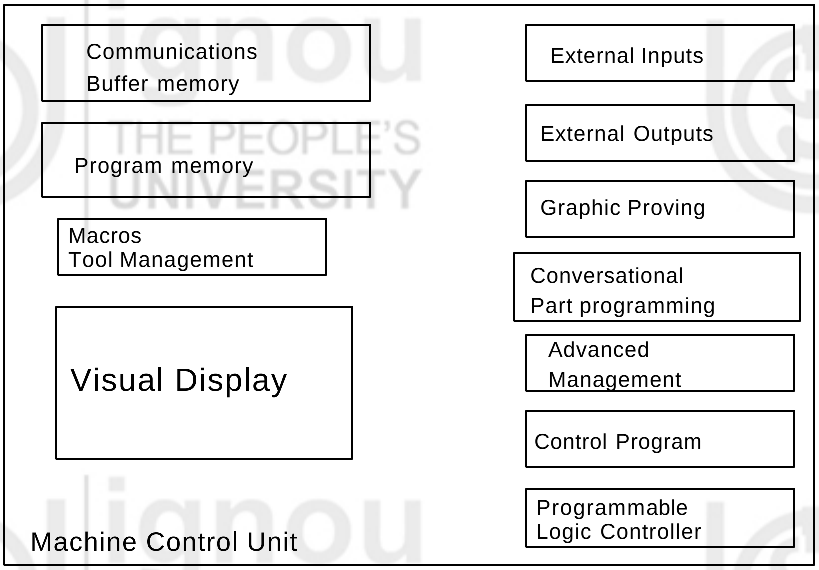

Figure 2.8 : Organisation of the Modern Machine Control Unit Functions

Control Program

The control program is that part which actually controls the various elements of the CNC machine tool. It has to take into account the interactions between the control system components, the machine tool mechanics, tooling, material changes during machining and other interactions that result in the final machine tool performance. It should analyze the part program a few blocks ahead so that the speed of the slides can be adjusted in advance to cater for future difficulties in the path (sharp changes in direction, tight radii). The control program should fully integrate with the servo and feedback systems involved.

External Inputs

This allows for interaction of the CNC with the outside world. For example to link with a PC for DNC functions such as part program downloading, remote datuming and operation so that it could be linked to integrated systems such as robots and automated guided vehicles (AGV), etc.

External Outputs

These are to send output from the CNC to outside world, for such tasks as uploading the generated or corrected programs, sending the controller information such as certain PLC register status, diagnostic information, etc.

Program Memory

It is to store the part programs and macros in the MCU for use. Earlier controls had very little such memory, but the current day controllers have much larger memory. With larger memory it is possible to store more programs as well as longer programs.

Additional Programming Facility

Better programming facilities can be provided in addition to the basic G and M-code programming as standardised by ISO. One such major area is in the provision of newer canned cycles to facilitate major machining of the components using simple programming. Some additional canned cycles as available in Anilam Controls is given below :

- Ellipse
- Spiral

- Helical
- Irregular pocket / area clearance
- Rectangular profile (in/outside)
- Circular profile (in/outside)
- Mold rotation (any axis)
- Rectangular plunge pocket
- Circular plunge pocket
- Draft angle pocket
- Rough turning
- Rough facing
- Grooving (ID/OD)
- Face grooving

Communications (Buffer Memory)

When the part programs become very large it will not be possible to store them completely in the MCU memory. In such cases the part program will reside in the DNC computer and it will be fed into the controller in small drips. The MCU communications would therefore be in a position to support such an activity.

Advanced Management

In addition to the basic functions as described earlier, it is more important for the newer controllers to provide additional facilities. Some typical possibilities are outlined below :

- Axis calibration
- Adaptive control
- Thermal compensation
- Pitch error compensation

Tool Management

Tooling is a very important element in the running of a CNC machine tool not only for the productivity but also the accuracy of the parts machined. Some form of tool life management function needs to be present.

There are various systems available as part of modern CNC controllers, which are termed tool management systems that are able to keep track of the actual time for which each of the tool is in use. When the tools are entering the system (loading in the tool magazine), the expected tool life is entered in the controller memory along with all other tool related information such as offsets. This value is generally a conservative estimate of the tool life expected based on the work materials and the process parameters used. This value can be generally obtained from machinability data banks used on the shop floor or from previous experience.

As machining proceeds with various components, the controller records the actual time for which each tool is used. This time used when subtracted from the expected tool life gives the left-over tool life for each tool. When the left over tool life is less than a certain nominal value, the controller initiates the action for replacing it by a sister tool. Controllers manufactured by Yamazaki, Fanuc, Sinumeric and others have this type of tool management option available with them.

It is also possible to have tool life monitored outside the controllers, for example the tool life of all the tools present in the manufacturing system consisting of more than one machine tool may be monitored in an IBM PC compatible.

Diagnostics

To keep the machine utilisation high, it is necessary to check the health of the machine tool continuously. For this purpose a number of sensors are normally built into the machine tools. The control therefore should have the necessary ability to get the information from these sensors, analyse and then diagnose any faults already present or likely to come in future. Such diagnosis can be immediately communicated as alarms to the operator through the VDU. Alternatively with a built-in modem and a connected telephone line such information can be sent to the manufacturer or service facility for proper attention.

Graphic Proving

The part program before actually doing the machining can be simulated on the screen of the MCU to verify the accuracy of the geometry generated. This verification normally has a number of options such as the actual tool path shown in various 2D-view planes or with 3D such as isometric or axonometric projections. However, this type of simulation though fast will not give the real feel of the actual material removal process. Hence most modern controls provide a solid simulation process in which the blank and the tool are actually shown in 3D shaded image. As the tool moves through the work material, the material is actually removed as a solid subtraction between the work volume and the swept volume of the tool in contact with the workpiece. The layer removed is shown with a different colour to give a realistic feel of the material removal process. This process will be actually able to simulate the uncut material at the corners because of the tool radius, burr formation, etc. more realistically. Some controls can also incorporate the surface finish generation process in terms of the feeds and speeds used, so that the operator can get a feel of the final surface finish to be obtained on the component.

Conversational Part Programming

Many of the controllers are available with some form of conversational part programming facility built in. This can be in many forms. FAPT-TURN was one of the first such system which uses a vector drawing technique for making the turning part contour in 2D on screen. Based on that the system automatically selects the tools, and generates completely the part program. Similar systems have become available in many of the systems.

2.5 DEVELOPMENTS IN CNC SYSTEMS

The machine control unit (MCU) in the early NC machine tools was hardwired with all the control logic to operate the machine tool embedded in the hardware circuitry. This makes the controller really bulky, with a large amount of power consumed that used to generate a large amount of heat. In addition because of a large number of wires running through the controller, the reliability also suffered. The availability of the microprocessors from mid 1970s helped in changing that situation. The microprocessor allowed for the availability of large processing power inside the controller thereby allowing for a large number of innovations.

All the control logic of the machine tool is converted into software, which allowed for a reduction in a large amount of electronic hardware used in the controller. As a result the controller is a small unit unlike the earlier NC controllers. In addition the computer is available in the controller, which can be utilized for other associated functions. Consequently the controller is now called as Computer Numerical Control or CNC to recognize the computer inside the controller. All of the controllers that are being manufactured in the present day are CNC incorporating the latest microprocessors. Consequently the word NC that represented the earlier day controllers is strictly speaking obsolete. However, people tend to use NC now-a-days as synonymous to CNC.

As mentioned earlier, the computing power built into the controller allows for providing a number of advances, which were not possible with the older NC systems. Some of these developments are detailed below :

- It is possible to have large part program storage compared to single blocks in the previous controllers. This would allow a number of part programs to be stored in the controller for easy job changeover. It is also possible to store large part programs, which are generally required for complex 3D surface machining.
- The computer present in the control can allow for part program graphical proving and editing to be carried out on the controller. This would allow for carrying out necessary changes in the part programs at the machine as well as allowing for a graphical proving of tool path directly on the controller.
- It is also possible to generate a part program using computer aided part programming such as workshop oriented conversational part programming methods such as FAPT TURN. This would make the development of part programs on the controller without a separate part programming station and downloading from that to the controller.
- It is also possible to have background part programming to be carried out when the machine tool is actually doing the cutting operation. This is possible since most of the current day microprocessors are more powerful, and as a result, spare processing power is available in addition to the control of the machine tool in real time.
- The computer and a large processing capability of the MCU helps with a range of enhanced part programming facilities which are otherwise not possible in the NC controls.

Some examples are :

- Complex interpolations such as parabolic, elliptical and helical
- Additional canned cycles (other than the drilling series G 80 to 89)
- Circular pocket milling
- Rectangular pocket milling
- Pitch circle diameter hole making
- Rough turning stock removal
- Rough facing stock removal
- Thread cutting stock removal
- Grooving (ID/OD)
- Face grooving
- Reduction of the bulk of part program can be done by using repetitive part programming facilities such as IF and DO loops. This will also help to make the part programs more intelligent.
- Many a times, it is necessary to reuse a part of the program at a number of locations in a part program, because of the symmetry of the geometry. This

will be made easier with the facilities such as subroutines and macros that will be made possible in the CNC.

- Another function that is made possible with the CNC is the use of touch trigger probes discussed later. These probes can be used for dimensional and accuracy measurement.
- It is also possible to use variables or parameters in writing part programs. The use of variables help in customizing the part programs for specific applications to take care of the possible variations in design or manufacturing methods.
- The controller can have the tool life management function that may include a large number of tool offset registers as well as the ability to monitor the life of the individual tools used.
- Better communications with the outside world can be developed, basically for part program downloading and uploading using a CNC.
- A number of diagnostic functions can be built into the controller, which will improve the maintainability of the machine tool. It may also provide the possibility of direct linking with the service centres using modems for reducing the machine downtime.
- Use of standard operating systems such as Windows 2000 is possible now in CNC. This also helps in better integration of these controllers with other factory networks.
- It is possible to provide special machine control functions such as adaptive control, lead screw pitch error compensation, thermal compensation, etc.

SAQ 1

(a) What are the various types of control systems possible in NC machine tools?

(b) Briefly explain the basis of designating the coordinate axes in CNC machine tools.

(c) Describe the basis on which the Z-axis of a CNC machining centre would be identified.

(d) How is a CNC control system organised? Briefly explain the functions of any three elements in the control.

(e) Give the examples of a few enhancements to programming that are available in the modern CNC control systems.

2.6 SUMMARY

The CNC machine tool controls can be broadly classified as point to point and contouring controls. Contouring controls are more versatile and therefore are more widely used in industry. Principal axis of a machine tool is the spindle axis and it is designated as Z-axis. The other axes are identified by using the right hand Cartesian coordinate system. The CNC controllers have a number of functions depending upon the nature of the machine

tool to which it is attached. A variety programming functions and other management functions are being added in the modern control systems.

2.7 KEY WORDS

CNC Control, Classification, Controller, MCU, Axes Designation.