

**A Laboratory manual**

**For**

**CAD / CAM LAB (PR-3)**

**In accordance to syllabus (2022-23)**

**By S.C.T.E & V.T, Odisha**

**Semester – 5<sup>th</sup>**

**DEPARTMENT OF MECHANICAL ENGINEERING**



*Er. SATYA NARAYAN TRIPATHY, LECTURER  
DEPARTMENT OF MECHANICAL ENGINEERING*

## **Vision & Mission**

### **Vision of the Institute:**

To be a leading technical institute that provides excellent education to create human resources of high standard for the society and industry.

### **Mission of the Institute:**

1. To develop state of the art facilities for technical education.
2. To create a well experienced faculty that understands need of the society and industry.
3. To provide resources that make faculty and students keep abreast of industry.

### **Vision of the Department of Mechanical Engineering:**

To produce human resources of high standard in mechanical engineering who can contribute favorably to the technological and socioeconomic development of the nation.

### **Mission of the Department of Mechanical Engineering:**

1. Develop state of the art facilities related to mechanical engineering.
2. Make the students competitive for employment or higher studies in highly esteemed organizations/institutions.
3. Encourage to solve problems of society implementing technical knowledge.

## Pr.3 CAD/CAM LAB

Name of the Course: Diploma in Mechanical Engg.			
Course code:		Semester	5th
Total Period:	60	Examination	3 Hrs
Theory periods:	4 P/W	Sessional:	25
Maximum marks:	75	End Semester Examination:	50

### **OBJECTIVES**

At the end of the course the students will be able to

- 1.To understand the fundamentals and use of CAD.
- 2.To conceptualize drafting and modelling in CAD.
- 3.To interpret the various features in the menu of solid modelling package.
- 4.To synthesize various parts or components in an assembly.
- 5.To prepare CNC programmes for various jobs

### **COURSE CONTENTS**

#### **PART-A.**

##### **INTRODUCTION:**

Part modelling, Datum plane, Datum plane; constraint; dimensioning; extrude; revolve; sweep; protrusion; extrusion; rib; shell; hole; round; chamfer; copy; mirror; assembly; align; orient.

##### **EXERCISES:**

2D Drawings of Rectangle, circle, polygon and its dimensioning

3D Drawings of;

- 1.Gib and cutter joint
- 2.Screw Jack;
- 3.Connecting Rod;
- 4.Bearing Block.

Print the orthographic view from the above assembled 3D drawing

#### **PART-B.**

CNC Programming and Machining

INTRODUCTION;

- 1.Study of CNC lathe, milling;
- 2.Study of international codes; G-Codes and M – Codes
- 3.Format –Dimensioning methods;
- 4.Programme writing –Turning Simulator-Milling simulator IS practice-commands menus
- 5.Editing the programme in the CNC MACHINES;
- 6.Execute the programme in the CNC machines;

##### **Exercise:**

1. Print the programme and make the component in the CNC machine;
- 2.Using canned cycle-create a part programme for thread cutting, grooving and produce component in the CNC Turning Machine
- 3.Using Linear interpolation and Circular Interpolation-Create a part programme for grooving and produce component in the CNC Milling Machine

## **PART-A.**

### **INTRODUCTION TO AUTO-CAD**

- AUTOCAD is a drawing package software developed by the company "AUTODESK" in USA .
- It is one of the widely used software for creating drawing easily.
- Generation of geometric modeling along with the Engineering analyze and evaluate the design and produce drawing for manufacturing with the help of computer.
- The first name of this software is "MICROCAD". Which is evaluated in 1982.
- AutoCad is a command base, non-parametric and low end software. It is the best drawing software.

#### **DEFINITION OF CAD/CAM:**

##### **Computer Aided Design – CAD**

CAD is technology concerned with using computer systems to assist in the creation, modification, analysis, and optimization of a design. Any computer program that embodies computer graphics and an application program facilitating engineering functions in design process can be classified as CAD software.

The most basic role of CAD is to define the geometry of design – a mechanical part, a product assembly, an architectural structure, an electronic circuit, a building layout, etc. The greatest benefits of CAD systems are that they can save considerable time and reduce errors caused by otherwise having to redefine the geometry of the design from scratch every time it is needed.

##### **Computer Aided Manufacturing – CAM**

CAM technology involves computer systems that plan, manage, and control the manufacturing operations through computer interface with the plant's production resources. One of the most important areas of CAM is numerical control (NC). This is the technique of using programmed instructions to control a machine tool, which cuts, mills, grinds, punches or turns raw stock into a finished part. Another significant CAM function is in the programming of robots. Process planning is also a target of computer automation.

#### **THE BASIC AUTO-CAD COMMANDS ARE:**

A-Arc M-Move B-Block diagram

O-Offset C- Circle

R-Redraw D-Dimensioning

S-Sketch E- Erase

T-Text F- Fillet

U-previous command G-Grouping

V-View H-Hatching W-Write block I-insert X-explode J-Join Z-Zoom L-Line

## EXPERIMENT NO -01

### AIM OF THE EXPERIMENT

To create a rectangle by using 2D drafting

### THEORY-

A rectangle in a two dimensional plane has 4 corner points which are specified by coordinates. By knowing all coordinates we can construct/ create rectangles in a two dimensional plane by using Auto CAD.

### APPARATUS/SOFTWARE REQUIRED –

1. Auto-Desk-2010

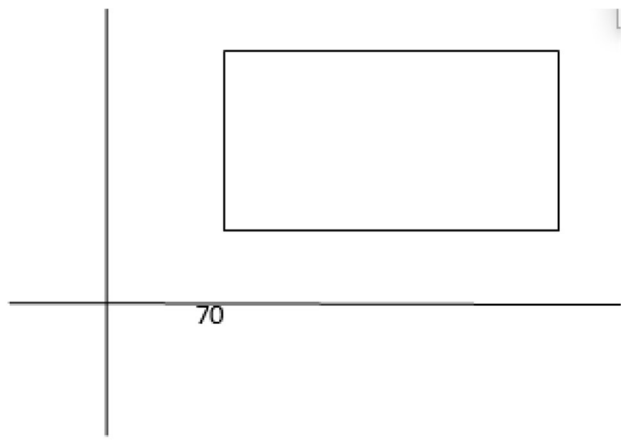
### LIMIT COMMAND :

- 1) Limits ↵
- 2) Specify the lower left corner : 0,0 ↵
- 3) Specify the upper right corner : 297,210 ↵
- 4) Z ↵
- 5) A ↵

### COMMAND FOR LINE :

1. Line/ L ↵
2. Specify the first point : (     ,     ) ↵
3. Specify the next point : (     ,     ) ↵
4. ESC ↵

### PROBLEM -3 (To draw a rectangle of size-30 ' x 40')



## **PROCEDURE**-80

1. Line ↵
2. 30, 50 ↵
3. 70, 50 ↵50
4. 70, 80 ↵
5. 30, 80 ↵30
6. 30, 50 ↵

## **CONCLUSION** -

We successfully draw a rectangle by using 2D drafting where the co-ordinates of the rectangles are (30, 50), (70, 50), (70, 80) and (30, 80). One can take other co-ordinates and draw the rectangle also.

## EXPERIMENT NO -02

### AIM OF THE EXPERIMENT

To draw a Circle by using 2D drafting

### THEORY-

A Circle in a two dimensional plane has a fixed radius/diameter and its centre has specified by coordinates. By knowing its centre coordinates and radius/diameter we can construct/create Circle in a two dimensional plane by using Auto CAD.

### APPARATUS/SOFTWARE REQUIRED –

1. Auto-Desk-2010

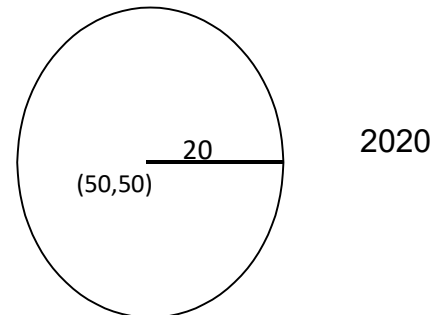
### COMMAND FOR CIRCLE :

- 1) Circle / C ↵
- 2) Specify the center of circle ↵
- 3) Specify the radius or Diameter of the circle ↵
- 4) Specify the value of R / D of the circle ↵

**PROBLEM :** (Create a Circle/draw a circle of  $\phi$  40)

### PROCEDURE –

1. C ↵
2. 50, 50 ↵  
A
3. 20 ↵

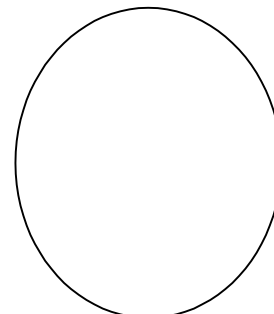


### COMMAND FOR 2P ( P = Point ) CIRCLE :

- 1) Circle / C ↵
- 2) Specify the circle center (2P, 3P, TTR) ↵
- 3) 2P )↵
- 4) Specify the first point ↵
- 5) Specify the second point ↵

**PROBLEM :** To Create/draw 2P Circle of  $\phi$ 60)

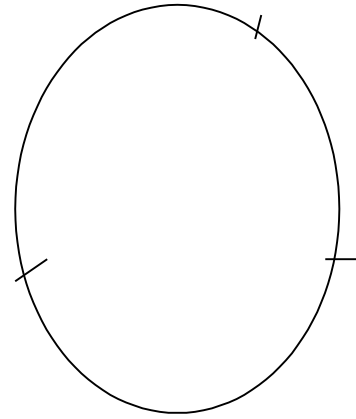
1. C ↵
2. 2P ↵ (20,40) (80,40)
3. (20, 40) ↵
4. (80, 40) ↵



### COMMAND FOR 3P ( P = Point ) CIRCLE :

- 1) Circle / C ↵

- 2) Specify the circle center (2P, 3P, TTR) ↵ (55,75)
- 3) 3P ) ↵
- 4) Specify the first point ↵
- 5) Specify the second point ↵
- 6) Specify the third point ↵



**PROBLEM :** To Create /draw a 3P circle of  $\phi 50$  (30,50)(80,50)

1. C ↵
2. 3P ↵
3. (30, 50) ↵
4. (80, 50) ↵
5. (55, 75) ↵

### **COMMAND FOR TTR (Tangent, Tangent, Radius)**

- 1) Circle/ C ↵
- 2) TTR ↵
- 3) Specify the first tangent on the circle ↵
- 4) Specify the second tangent on circle ↵
- 5) Specify the radius on the circle ↵

**PROBLEM :** Draw a Circle TTR (Tangent, Tangent, Radius)

- 1) C ↵
- 2) TTR ↵
- 3) Select the first tangent on the circle ↵
- 4) Select the second tangent on the circle ↵
- 5) Radius found ↵

### **CONCLUSION –**

We successfully draw a Circle by using 2D drafting where ...

- i. Radius and coordinate of centre are given.
- ii. any arbitrary 2 points on the circumference of the circle are given .
- iii. any arbitrary 3 points on the circumference of the circle are given .

any 2 tangents are given and from it we can found the radius of the circle



## EXPERIMENT NO -03

### AIM OF THE EXPERIMENT

**Draw a Polygon by using 2D drafting.**

### THEORY-

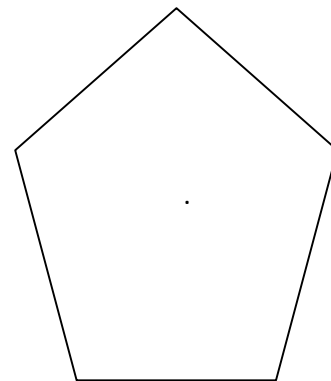
A Polygon of various no. of sides can be created /drawn if the centres of the polygon and no of sides are specified. We can also inscribe or circumscribe a circle in the polygon in a two dimensional plane by using Auto CAD.

### APPARATUS/SOFTWARE REQUIRED –

1. Auto-Desk-2010

### COMMAND FOR POLYGON

1. Polygon ↵
2. Enter no of sides ↵
3. Specify centre of polygon ↵
4. Specify inscribed or circumscribed ↵
5. Specify radius of the circle ↵



### PROBLEM-(To draw a Polygon of any size)

1. Polygon ↵
2. 5 ↵
3. 50,50 ↵
4. I or C ↵
5. 30 ↵

### CONCLUSION –

We have successfully drawn a Polygon using 2D drafting where no. of sides is 5 and its centre coordinates (50, 50), having circle of radius 30 inscribed in the polygon.

## EXPERIMENT NO -04

### AIM OF THE EXPERIMENT

#### Dimensioning a rectangle / Circle/ Polygon

### THEORY-

In this case **corner coordinates of any rectangle, centre coordinates and radius of the circle and no of sides and circle inscribed or circumscribed on a polygon** are given then we can make necessary dimensioning of the side of the rectangle, centre, diameter / radius of a circle and the distance (dimension) of any sides of the polygon in a two dimensional plane by using Auto CAD.

### APPARATUS/SOFTWARE REQUIRED –

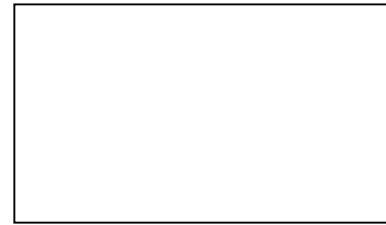
1. Auto-Desk-2010

### COMMAND FOR RECTANGLE

1. Rectangle
2. Specify 1<sup>st</sup> corner of the rectangle : ( , ) ↵
3. Specify the 2<sup>nd</sup> corner corner of the rectangle : ( , ) ↵
4. Select dimension linear : ( , ) ↵(150,125)

### PROBLEM-

1. Rectangle ↵
2. 50, 50 ↵
3. 150, 125 ↵(50,50)
4. Select dimension –Linear ↵
5. Specify 1<sup>st</sup> selection line origin ↵selected
6. Specify 2<sup>nd</sup> extension line origin ↵

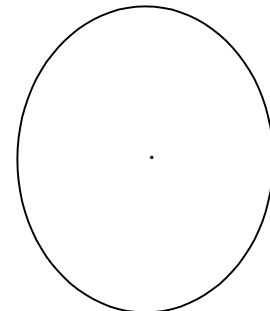


### COMMAND FOR CIRCLE :

- 1) Circle / C ↵
- 2) Specify the center of circle ↵
- 3) Specify the radius or Diameter of the circle ↵
- 4) Specify the value of R / D of the circle ↵

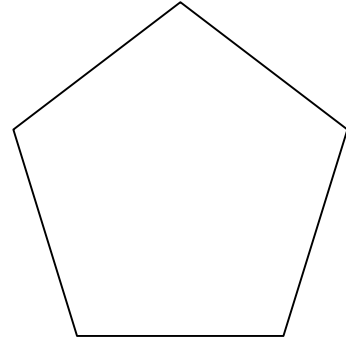
### PROBLEM :(Dimensioning of a circle)

1. C ↵
2. Specify the center and radius ↵
3. Select the dimension–radius ↵
4. Select Arc or circle ↵



## **COMMAND FOR POLYGON**

1. Polygon ↵
2. Enter no of sides ↵
3. Specify centre of polygon ↵
4. Specify inscribed or circumscribed ↵
5. Specify radius of the circle ↵



## **PROBLEM-(To draw a Polygon of any size)**

1. Polygon ↵
2. 5 ↵
3. Specify the centre of the polygon ↵
4. I or C ↵
5. 30 ↵
6. Specify the radius of the circle ↵
7. Select dimension –Linear ↵
8. Specify 1<sup>st</sup> selection line origin ↵
9. Specify 2<sup>nd</sup> extension line origin ↵

## **CONCLUSION –**

We successfully dimensioning a rectangle , Circle and Polygon.

## EXPERIMENT NO -05

### AIM OF THE EXPERIMENT

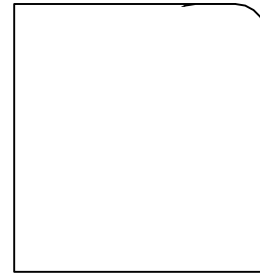
**Commands essential for creating 2D drawing**

### THEORY-

In this case we are required to smoothening out one corner/edge of required radius of curvature by using 2D drawing of a Square/Rectangle. Further we can also draw an exact replica (mirror) of a given figure or an object. Similarly we can make/draw Ellipse and Chamfer of an Object etc. by using Auto CAD Command.

### APPARATUS/SOFTWARE REQUIRED--R-2

1. Auto-Desk-2010



### COMMAND FOR FILLET :

- 1) Fillet / F ↵
- 2) Radius / R ↵
- 3) Specify the radius value ↵
- 4) Specify or select the first line of the first object ↵
- 5) Specify or select the second line of the first object ↵

### PROBLEM:

**Choose / make a rectangular whose one corner is smoothed/Fillet radius 2**

1. F↵
2. R↵
3. 2↵
4. Specify or select the first line of the first object↵
5. Specify or select the second line of the first object↵

### COMMAND FOR MIRROR(rectangle, circle etc) :

- 1) Mirror / MI ↵
- 2) Select the object ↵
- 3) Select the first end point of the mirror line ↵
- 4) Select the second end point of the mirror line ↵

### PROBLEM:(Choose an object)

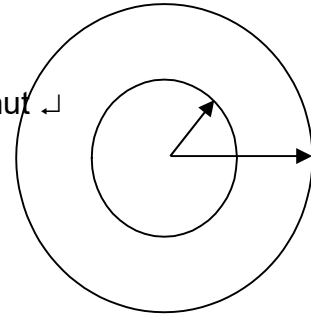
**Make an exact Replica of an Object/Figure.**

1. Mirror↵

2. Select the object ↵
3. Select the first and point of the mirror ↵
4. Select the second and point of the mirror ↵

**COMMAND FOR DONUT :**

- 1) DONUT ↵
- 2) Specify the inside diameter : ( , ) ↵
- 3) Specify the outside diameter : ( , ) ↵
- 4) Select the position for Donut / Specify the center point of donut ↵



**PROBLEM:**

1. Do Nut ↵
2. 40 ↵
3. 60 ↵
4. Select the position for Do nut ↵

**COMMAND FOR RECTANGLE :**

- 1) Rectangle ↵
- 2) Specify the first corner of the rectangle : [ (0,0)/ (x1, y1)] ↵
- 3) Specify the second corner of the rectangle : [ (x2,y2)/ (x3, y3)] ↵
- 4) ESC ↵

B

**PROBLEM:**(150,75)

1. Rectangle ↵
2. (50,50) ↵
3. (150, 75) ↵
4. Esc ↵(50,50)



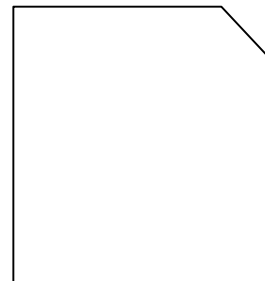
**COMMAND FOR CHAMFER :**

- 1) Chamfer / CHA ↵
- 2) Specify the chamfer distance i.e. D ↵
- 3) Specify the first chamfer distance ( , ) ↵
- 4) Specify the second chamfer distance ( , ) ↵

**PROBLEM:**

Draw a Rectangle

1. CHA ↵
2. 6 ↵
3. 2 ↵



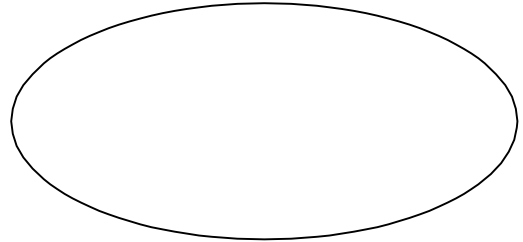
4. 4.↓

### **COMMAND FOR ELLIPSE :**

- 1) Ellipse ↓
- 2) Specify the center point of the ellipse ( , ) ↓
- 3) Specify the major axis of the ellipse ( , ) ↓
- 4) Specify the minor axis of the ellipse ( , ) ↓

OR

1. Toll bar >Ellipse > click over ellipse >
2. Define major axis ( , ) ↓
3. Define minor axis ( , ) ↓



### **PROBLEM:** Draw an Ellipse

1. Ellipse ↓
2. 50,50 ↓
3. 150,75 ↓
4. 100,25 ↓

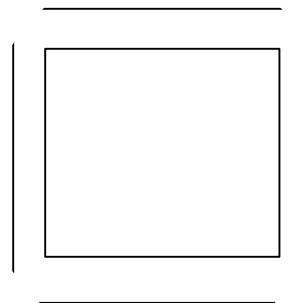
### **COMMAND FOR OFFSET :**

1. O ↓
2. Specify the offset distance : ( , ) ↓
3. Select the line ↓
4. Choose the side for offsetting the line and click here ↓

### **PROBLEM:**

Make an offset for a rectangle

1. O ↓
2. 5 ↓
3. Select the line ↓
4. Choose the side of the offsetting ↓



### **COMMAND FOR HATCHING:**

1. Hatch ↓
2. Click over add : pick a point ↓
3. Hatch type (Predefined) ↓
4. Select pattern of hatch ↓
5. Preview , OK ↓

### **PROBLEM :**



1. Hatch↵
2. Pick a point↵
3. Hatch type (select from table)↵
4. Select pattern of hatch↵
5. Preview OK↵

### **COMMAND FOR TEXT :**

1. Text ↵
2. Specify the starting point of the text ↵
3. Specify the text height ↵
4. Specify the rotation angle of text ↵
5. Writing text ↵

### **PROBLEM:**

1. Text ↵
2. Specify the starting point of ↵
3. Specify the text height ↵
4. Specify the rotation angle of text ↵
5. Writing text ↵

### **COMMAND FOR VERTICAL LINE :**

1. XL ↵
2. V ↵
3. Place the vertical line ↵

### **PROBLEM:**

1. XL ↵
2. V ↵
3. Selected the vertical line ↵

### **COMMAND FOR HORIZONTAL LINE:**

1. XL ↵
2. H↵
3. Place the horizontal line ↵

### **PROBLEM:**

1. XL ↵
2. H ↵
3. Selected the horizontal line↵



## **CONCLUSION –**

We successfully know the various essential commands for creating 2D drawing.



## 3-D DRAWINGS

### EXERCISE-1

**AIM** - To develop the part drawing of Gib & Cotter joint in the orthographic representation using Auto cad.

#### **Description about Gib & Cotter Joint:**

When the rods of square or rectangular cross sections subjected to axial forces have to be connected temporarily, a strap joint is used. In this type of cotter joint, the end of one of the rods is formed into a fork into which the end of the other rod fits. The forked end of the rod is called STRAP. Since the strap is open on one side, if only a cotter is used to connect the two rods as explained earlier and when the rods are subjected to axial forces, the end of the strap opens out. To prevent the opening out of the ends of the strap, a gib is used in conjunction with the cotter. The gib is a wedge shaped piece of steel of rectangular in cross section with one side tapered and the other straight and has two projections, called gib-heads. These gib heads act like hooks prevent and prevent the opening out of the ends of the straps. The use of gib along with the cotter facilitates the cutting of the slots with straight faces.

#### **Procedure:**

1. Model different parts of a gib & cotter joint using Extrude, Revolve etc., features.
2. Select the assembly in solid works main menu.
3. Using Insert component icon of property manager, insert base component & next components to be assemble.
4. Assemble using MATE Feature.
5. Continue the inserting the component & mating until the entire component are assembled.
6. Save the assembly.
7. From the main menu of solid works select the drawing option.
8. Drawing icon in main menu of Solid works
9. Select the drawing sheet format size as – A4 Landscape.
10. Using the model view manager browse the document to be open.
11. Click the view orientation from the model view manager & place the drawing view in the proper place in the sheet.

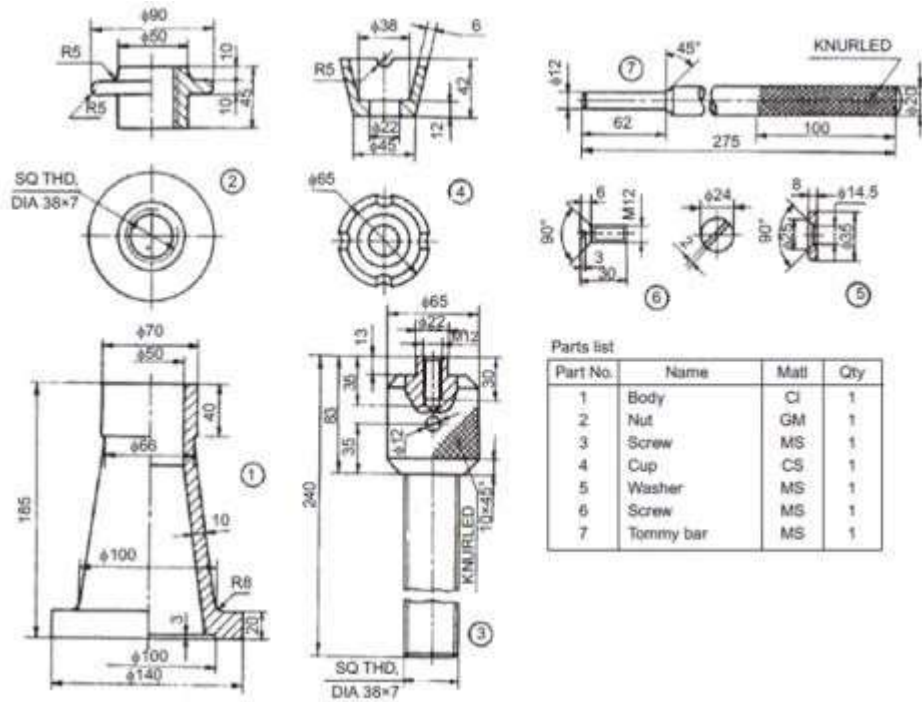
12. Using the placed view as parent view project the other or needed views
13. Move cursor to any one view and right click the mouse button.
14. Select the Table – BOM.
15. Place the BOM in the proper place in the drawing sheet.
16. Save the drawing sheet.

**Result:**

Thus, the part drawing of Gib & Cotter joint is drawn in orthographic view.

## EXERCISE-2

**AIM** - To develop the part drawing of Screw jack in the orthographic representation using Auto cad.



### List of commands:

**Line**-To draw a line of required dimension.

**Circle**- To draw a circle of required radius.

**Polyline**- To draw multiple lines of required dimensions.

**Arc**- To draw arc of required dimensions.

**Trim**- To remove unwanted or excess dimensions of the element.

**Zoom**- To enlarge or reduce the view of component.

**Fillet**- To join sharp corners with a curve.

**Mirror**- To reflect the image on other side of the object.

**Offset**- To draw the image of the object at required distance.

**Erase-** To erase any object.

**Block-** To convert into single entity.

**Hatch-** Used to hatch enclosed area.

**Join-**To join two objects.

**Break-** To cut the object to required dimensions.

**RESULT:** Thus, the part drawing of screw jack is drawn in orthographic view

### EXERCISE -3

**AIM** - To develop the part drawing of connecting rod in the orthographic representation.

**List of commands:**

**Line**-To draw a line of required dimension.

**Circle**- To draw a circle of required radius.

**Poly line**- To draw multiple lines of required dimensions.

**Arc**- To draw arc of required dimensions.

**Trim**- To remove unwanted or excess dimensions of the element.

**Zoom**- To enlarge or reduce the view of component.

**Fillet**- To join sharp corners with a curve.

**Mirror**- To reflect the image on other side of the object.

**Offset**- To draw the image of the object at required distance.

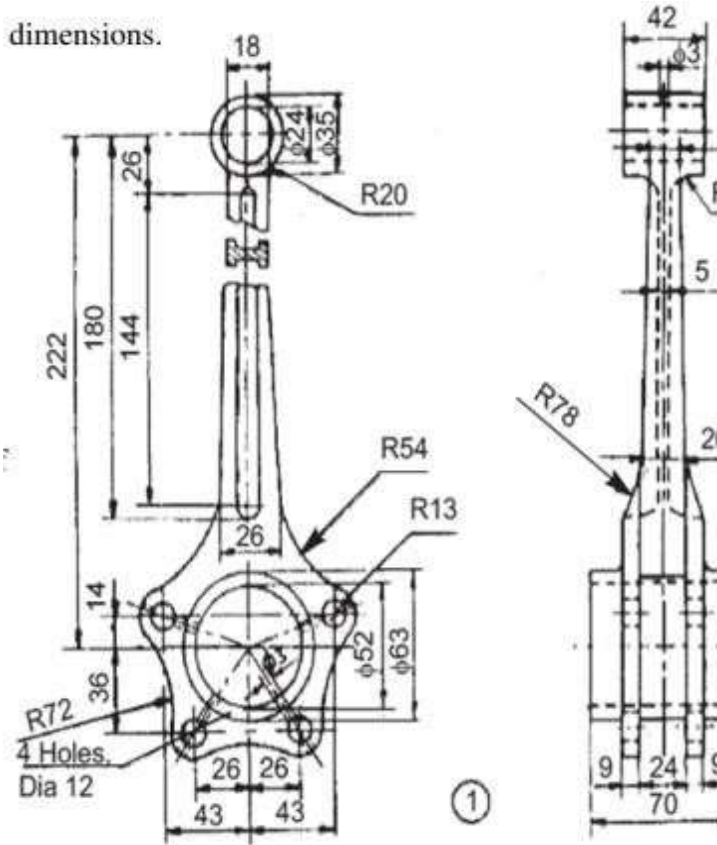
**Erase**- To erase any object. **Block**- To convert into single entity.

**Hatch**- Used to hatch enclosed area.

**Join**-To join two objects.

**Break**- To cut the object to required dimensions.

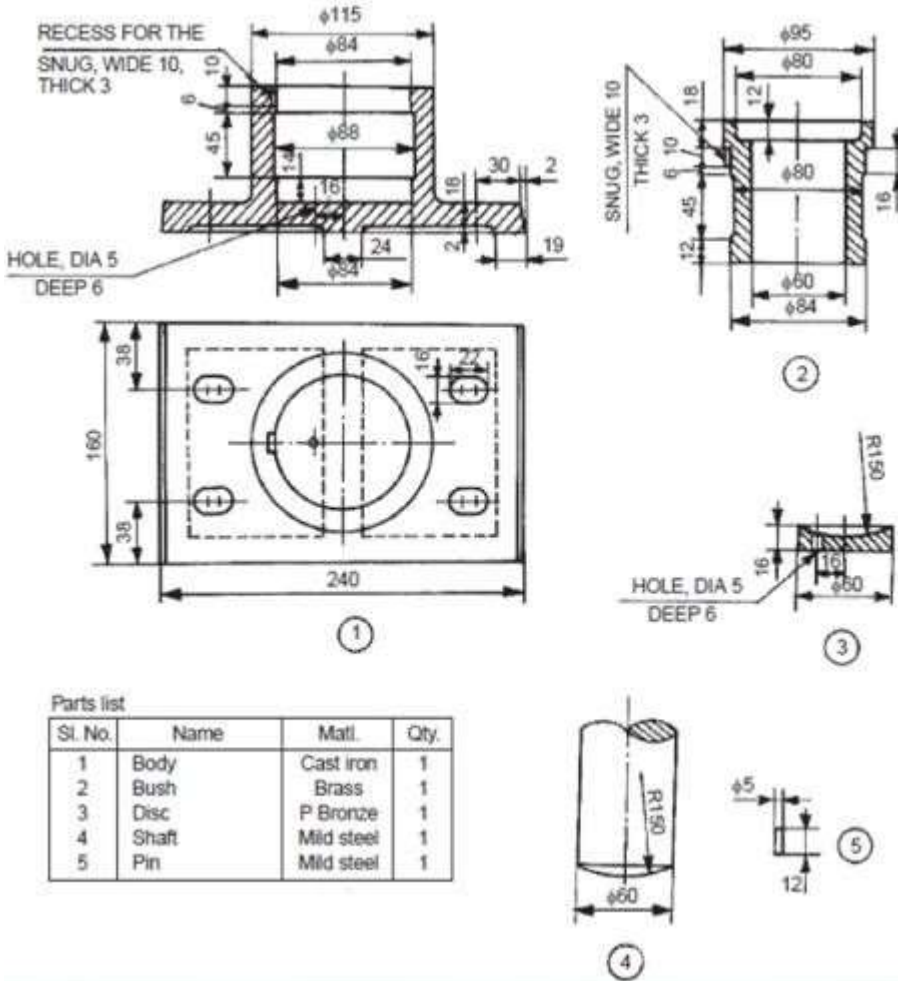
dimensions.



**RESULT:** Thus, the part drawing of connecting rod is drawn in orthographic view.

## EXERCISE-4

**AIM** - To develop the part drawing of foot step bearing in the orthographic representation using Auto cad.



Parts list

Sl. No.	Name	Matl.	Qty.
1	Body	Cast iron	1
2	Bush	Brass	1
3	Disc	P Bronze	1
4	Shaft	Mild steel	1
5	Pin	Mild steel	1

Foot-step bearing

### List of commands:

**Line**-To draw a line of required dimension.

**Circle**- To draw a circle of required radius.

**Polyline**- To draw multiple lines of required dimensions.

**Arc**- To draw arc of required dimensions.

**Trim-** To remove unwanted or excess dimensions of the element.

**Zoom-** To enlarge or reduce the view of component.

**Fillet-** To join sharp corners with a curve.

**Mirror-** To reflect the image on other side of the object.

**Offset-** To draw the image of the object at required distance.

**Erase-** To erase any object.

**Block-** To convert into single entity.

**Hatch-** Used to hatch enclosed area.

**Join-** To join two objects.

**Break-** To cut the object to required dimensions.

**RESULT:** Thus, the part drawing of foot step bearing is drawn in orthographic view.

## **PART-B. CNC Programming and Machining**

### **INTRODUCTION**

#### **CNC MILLING/LATHE MACHINE**

Numerical control has been developed out of the need for higher productivity, lower cost and more precise manufacturing. This is the latest machine tools control system since the industrial revolution and can be considered as the most sophisticated form of automation for controlling machine tools, equipment or processes.

In NC system, operation instructions are input to the machine as numbers which are suitably coded for storing on tapes. These instructions are then automatically carried out in the machine tool in predetermined sequence with pre-set or self-adjusted speed, feed, etc., without human intervention. Avoidance of human intervention, omission of conventional tooling and fixturing and quick-change capability of NC system are the primary factors considered to decide the level of acceptance of NC machine tools for a particular job. Other maintainable advantages identified of NC machine tools over conventional machine tools with automation are : (i) optimization of cutting tool life and quality of jobs, (ii) possibility of making parts which are impossible in conventional machining systems, and (iii) quick and more accurate inspection and detection of error in design and fabrication.

#### **NC AND ITS COMPONENTS**

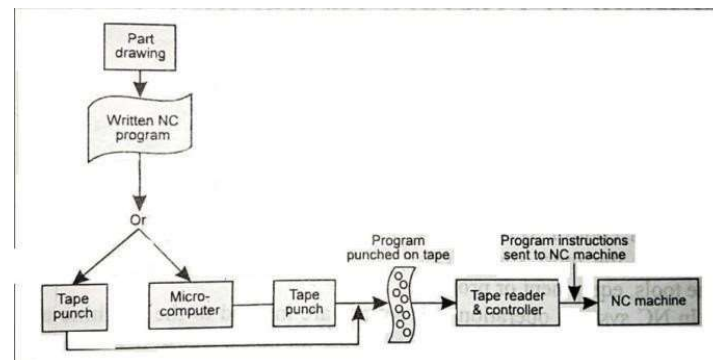
Numerical control is a technique of automatically facility, based on a code of letters, numbers; an complete set of coded instructions, responsible for executing an operation (or a set of



operations) called a part program. This program is translated into electrical signals to drive various motors to operate the machine to carry out the required operations.

The components of a traditional NC machine are:

1. **Program of instructions:** The program of instruction, often called part program is the detailed set of directions for producing a component by the NC machine. Each line of instruction is a mixture of alphabetic codes and "numeric data and is punched in a input media (usually paper tape) in a specified format. The input is read by a tape reader which transfers the instructions, to a machine controller to operate the machine slides and to generate specific surfaces on the job.



Components of a NC System

2. **Tape punch:** Usually it is a paper tape of 1" width. Paper-mylar, aluminium mylar or plastics are also used as tape materials. Paper tapes are cheap and popular but cannot last long. It is treated to resist oil and water. 'Mylar tapes are expensive but durable. Presently tapes are prepared by micro-computers by keying in the information from the manuscript. Once the entire program has been entered, it is checked and corrected if needed, and then the computer activates the tape punching unit to produce the tape. The computer can also generate the program print-out through its printer.
3. **Tape reader :** A tape reader reads the hole pattern on the tape and converts the patterns to a corresponding electrical signal
4. **Machine controller:** Controller receives the electrical signals from tape reader or an operating panel and causes NC machine to respond. It contains a decoder/encoder, an interpolator and facilities to execute auxiliary functions which are machine dependent. The decoder/encoder receives the data and stores them in two separate memory locations. One for the part geometry data and the other for the process data. Process data includes switching functions for adjusting feed rates, spindle speeds, tool changes, cutting fluid applications etc.. Geometric data consists information about tool motions, tool length, tool radius, tool compensation etc.. As the machine is to shape complex surfaces at a constant feed rate, signals must be given to various slides and spindles so that the individual motions can be integrated to produce the required shape which can be represented by complex curve or simple lines. The interpolator breaks down these curves into small individual increments for each controlled motion of the machine tool. Controller also interfaces various machine units like drive motors, transducers and other control functions of the machine tools.
5. **NC machine:** NC machine responds to the electrical signals from the controller. Accordingly the machine executes various slide motions and spindle rotations to manufacture a part. Any NC machine can be considered as a general purpose machine tool fitted with drive motors and other auxiliary functions of the machine. It consists as usual the work table, spindle and other hardwares as a general purpose machine contains. Transducers are fitted to feed back data on the positions of the slideways, for the r.p.m. of the spindle and for the amount of cut on the job. NC machine tools range from single spindle drilling machine to complex machines having multiple motions, tool changers, high capacity tool magazines and multi-axis control.

(The drive units of a NC machine tool mainly consist of stepping motor, d.c. motors or hydraulic motors, gear trains and transducers, etc. All these units, taken as a group or series of different elements, are together known as servocontrols or servomechanisms. The original commands from MCU are received by the servocontrols in the form of electrical signals, or more precisely as electrical pulses, and these are the servo-controls which convert these electrical commands into controlled mechanical movements of various slides and other parts of the machine tool. In case of a closed-loop servocontrol, it should also essentially contain some sort of a monitoring and feed-back device to ensure that the position of the machine tool slide is truly in conformity with that desired by the MCU.)

## **CNC LATHE**

Lathe is the most productive machine tool to manufacture round parts. Lathes are programmed on two axes: X axis controls the cross motion of the cutting tool and Z axis controls the carriage travel towards and away from the head stock.

A CNC lathe is a computer controlled machinery mainly for **CNC turning services** and process, including tapered turning, hard turning, spherical generation, facing, parting, knurling, drilling, grooving, etc. These operations can be carried out like conventional lathe machine, while CNC turning lathe is designed to utilize modern technology and tooling to improve the productivity and quality of CNC turning parts.

### **Benefits of CNC lathes:**

- a. Stronger capacity
- b. Higher precision
- c. Improved efficiency
- d. Shorter turnaround time

### **Components of CNC Lathes**

Different types of CNC lathes will different configuration, but a CNC turning lathe are basically composed of several of the following parts: machine bed, main spindle, sub-spindle, chuck, guide way, headstock, tailstock, tool turret, monitor, carriage, CNC control panel and drive motor. Modern CNC lathe machines often mounted with live tools that can work in multiple axis, like both X and Y-axis, a second turret with different tools, and more.

### **WORKING ON A CNC TURNING LATHE:**

CNC turning lathe are used to produce precise turned parts with round or cylinder shapes, the finished product is complete, and does not need second operation on other CNC machining equipment. Follow the following procedures while working on a CNC lathe

1. Check out whether there is any faults and abnormal situations, make troubleshooting.
2. Upload the G-Code computer file to the CNC lathe.
3. Install a cylindrical material block and secured in the chuck.
4. Set the spindle at required speed, then to rotate the chuck and workpiece.
5. Check the rotating workpiece and spindle speed, ensure there is no discrepancy.
6. Move the tool turret and carriage to locate the cutting tool as specific feed
7. Move the carriage to perform the cutting operation, remove all excess materials to get final CNC lathe part.

## **TYPES OF CNC LATHE MACHINES**

As the typical CNC turning machine, lathes can be classified as different standards.

### **Based on the number of axes:**

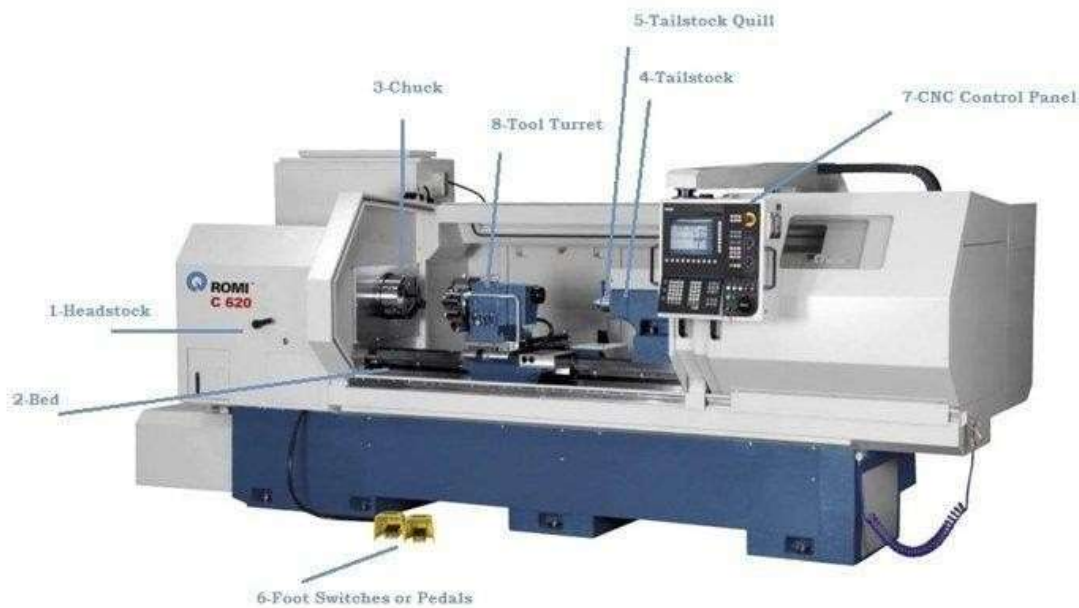
- 1) 2-axis CNC Lathe: can perform outer/inner diameter machining, facing, drilling and tapping.
- 2) 3-axis CNC Lathe: X and Z axis, C axis and live tool system, allowed to perform milling, boring, etc.
- 3) 4-axis CNC Lathe: add Y-axis based on 3-axis machine, for off-center machining operation and complex part
- 4) 5-axis CNC Lathe: add a second turret, allows two tools work at the same time

**Based on the work requirements:**

- 1) Speed Lathes: simple design, composed of headstock, tailstock and tool post, can operate in three and four speeds.
- 2) Engine Lathes: most common lathe machine, can operate with diverse metals at a wide range of speeds, length up to 60 feet.
- 3) Turret Lathes: many different types of tool holders can be mounted on it
- 4) Tool Room Lathes: produce parts with good accuracy and finish

**Based on the position of lathe spindle:**

- 1) Vertical CNC lathe: the lathe spindle is perpendicular to the horizontal, with a large diameter circular table used to clamp workpiece
- 2) Horizontal CNC lathe: can be divided into flat guide rail CNC lathe and slant guide way CNC lathe, the slant guide way structure can make lathe more rigid and easy to discharge chips



CNC lathe machine

**CNC MILLING MACHINE:**

Milling machine has been accepted as one of the most versatile machine tools used in manufacturing industry. Milling machines are programmed on three axes: X axis controls the table movement left or right, Y axis controls the table movement towards and away from the column and Z axis controls the vertical movement of the knee or spindle. CNC Milling Machines are machine operated cutting tools that are programmed and managed by Computer Numerical Control (CNC) systems to accurately remove materials from a workpiece. The end result of the machining process is a specific part or product that is created using a Computer Aided Design (CAD) software. These machine tools are normally equipped with a main spindle and three-linear-axes to position or move the part to be machined. More advanced versions may have a

4<sup>th</sup> or 5<sup>th</sup> rotational axis to allow for more precise shapes of varying dimensions and sizes to be machined.

CNC milling machines / machining centers normally employ a process of material cutting termed milling or machining – the milling process involves securing a piece of pre-shaped material (also known as the workpiece) to a fixture attached to a platform in the milling machine. A rapidly rotating tool (or a series of interchangeable tools) is then applied to the material to remove small chips of the material until the desired shape for the part is achieved. Depending on the material used for the part, as well as the complexity of the machined part, varying axes, cutting head speeds, and feed rates may be applied.

## **WORKING ON CNC MILLING MACHINE**

The general principle for a CNC milling machine or CNC machining center is that the part to be machined is clamped on top of the machine table. It could be clamped directly on the table itself, or held in place by a vice or fixture.

The spindle (moving section) including the cutting tool is then either vertically or horizontally positioned. In that configuration, the tool can reach various X-Y-Z positions on the work piece and commence cutting and shaping actions. As it does so, the work piece or part may either be fixed, mounted, or moved/positioned by the table in a linear direction to the spindle with the cutting tool. This allows material to be removed according to the desired shape needed for the machined part.

## **COMPONENTS OF A CNC MILLING MACHINE**

### **Frame**

The frame is the main structure that supports the milling machine and helps to give it stability and rigidity. It usually comes with a base and detachable column/s. An important part of the frame is the machine headstock where the main spindle is mounted on. The headstock, while important, is often overlooked. If the headstock is not rigid and fails to provide stability and support to the spindle, you could get vibrations and chattering during the machining operation. This could result in machining errors and a shorter lifespan to your cutting tool.

### **Spindle**

The spindle can be considered as the “heart” of a CNC milling machine. It normally comprises a rotating assembly, and a tapered section where tool holders may be positioned. The shaft of the spindle is normally where the tool is attached to, usually via a tool holder. A motor with different levels of transmission is used to rotate the spindle. To keep your spindle in good condition over the long-term, various forms of lubrication are used. They may include Grease Lubrications (not suitable for long durations of high speed operations), Air-Oil Lubrications (sufficient for longer cycle runs at higher speeds) or the Hwacheon Oil-Jet-Lubrication (ideal for all conditions – even extreme, long and high speed applications). Depending on the machine type, the spindle can be vertically or horizontally positioned.

### **Axes**

In general, CNC milling machines have X / Y / Z as well as additional rotational axis or C / A or B (subject to configuration). These can be programmed using g-code in the CNC controller.

### **Column/s**

The columns of the CNC machining center can be single, C-Frame or double. This depends on the level of complexity needed in the machining task.

### **CNC Control Panel**

This is the main “nervous system” of the machine tool. It contains the electronics that helps to control the different cutting actions through programming functions. The control panel has a CNC monitor and programming buttons where data and codes can be punched in. It usually also offers a manual function. For ease of machine operation, the control panel should be easily accessible and within easy reach.

### **Tool / Tool Changers (Automatic Tool Changer Or ATC)**

These are either mounted at the column or separately mounted to the machine. The latter is preferred if larger tool changers are needed with 40 up to 300 different tools. Doing so not only helps to save time and effort – it also helps your operators to avoid unnecessary vibrations during operation.

### **Tool Holders**

These come in many different sizes, systems and for various applications. The standard sizes for tool holders are BT 30 to BT 40 and BT 50 (BT refers to the taper angle of the cone on the holder).

(In Europe, the term used is SK 30, SK 40 or SK 50, which has the same angle as BT holder but with an additional orientation groove at the flange. Together with a key-stone mounted at spindle nose, SK holders can be orientated in a specific position. Eg.: boring bridges, boring bars, angular milling heads etc.)

For higher rigidity and balanced fast rotations, BBT versions are recommended or the HSK System.

### **Table**

The table provides a solid base to clamp the work piece directly on, and can be used to mount fixtures or vice to hold the piece in place. Most of the tables use T-slots for easy clamping of vice, fixture or part.

On Horizontal CNC milling machines, pallets are also available with Tap-holes. These allow greater flexibility in moving different work pieces to be machined. Increasingly, magnets are also being used for easy, fast and secured clamping. These should preferably be built into the machines table to avoid the loss of Z-axis height.

### **Coolant Tank**

Most CNC machining centers have a coolant tank to help supply coolant to the cutting surface or the spindle with tool during machining action. This helps to lengthen the life-span of the machine and its parts. Beyond this, the coolant will also remove heat generated by the machining action, and hence keep temperatures under control.

## **TYPES OF MILLING MACHINE**

Here are some of the types that you may find in the market:

- a. Horizontal Milling Machines
- b. Vertical Milling Machines
- c. Bed Mill
- d. Turret Mill (for manual machines only)
- e. Travelling Column
- f. Double Column
- g. C-Frame

- h. Drill & Tap
- i. Five Axis Machining Centers
- j. Double Spindle

In general, CNC milling machines can deploy a wide range of cutting and shaping tools. These tools help to remove material by virtue of how they move within the machine or directly from the cutter's shape. These may include the following:

- i. End Mills, Flat or Ballnose, Straight or Form Tools.
- ii. Face Mills
- iii. Drills, U-Drills, Spiral Borer.
- iv. Taps
- v. Reamers
- vi. Tool Holders and Hydraulic Tool Holders, Shrink-Fit or Press-Fit holders.



CNC milling machine

### **Study of international codes; G-Codes and M –Codes**

G-codes, also called preparatory codes, are any word in a CNC program that begins with the letter G. Generally it is a code telling the machine tool what type of action to perform, such as:

- Rapid movement (transport the tool as quickly as possible in between cuts)
- Controlled feed in a straight line or arc
- Series of controlled feed movements that would result in a hole being bored, a workpiece cut (routed) to a specific dimension, or a profile (contour) shape added to the edge of a work piece
- Set tool information such as offset
- Switch coordinate systems

#### **G Codes for CNC Milling**

- G00: Rapid Motion

- G01: Linear Interpolation Motion
- G02: CW Interpolation Motion
- G03: CCW Interpolation Motion
- G04: Dwell
- G09: Exact Stop
- G10: Programmable Offset Setting
- G12: CW Circular Pock Milling (Yasnac)
- G13: CCW Circular Pock Milling (Yasnac)
- G17: XY Plane Selection

M-code controls **miscellaneous functions**, and typically these can be thought of as non-geometry **machine functions**. Examples include spindle rotation start and stop, coolant on and off, pallet change, etc. Some of these functions may vary by the **specific machine**. Similar to G-code, M-code consists of a “**M**” and a number. Unlike G-code, however, M-code can be more specific for different machines and is more **customizable**. Both types are needed to have a CNC machine perform its functions. Like any language, CNC has many other aspects to it. This chart is just a sampling of all the **program lines** that could be included in the code.

#### **M Codes for CNC Milling**

- M00: Program Stop
- M01: Optional Program Stop
- M02: Program End (Setting 39)
- M03: Spindle On, Clockwise (S) (Setting 144)
- M04: Spindle On, Counterclockwise (S) (Setting 144)
- M05: Spindle Stop



- M06: Tool Change (T) (Setting 42, 87, 155)
- M08: Coolant On (Setting 32)
- M09: Coolant Off
- M10: 4th Axis Brake On

## (5) Editing the programme in the CNC MACHINES

Edit mode is very important in CNC. This mode is used to enter and store programs in a CNC machine. If you want to copy, cut, delete a program, you can do it in this mode. Also, this mode is used to replace any code or command in the program.

### Insert a new program into the system

**Step 1** – Press “EDIT” key.

**Step 2** – ON “PROGRAM PROTECT ”.

**Step 3** - Press “PROG” key.

**Step 4** – Write new program number which is start from alphabet O

Like: **O0123**

Press “INSERT” key. ( new window opens )

Press “EOB” key. (for complete block)

Press “ INSERT” key.

**Step 5** – write the program

- (1. If anything wrong while writing then uses “CAN” key to cancel.
2. If wrong command or code insert in a block then cursor on these and press “DELETE” key . )

[Note: Program store automatically in system ]

## **Program COPY, CUT and PASTE**

**Step 3** – Press “PROG” key. Select the program you want to copy.

**Step 4** – Press soft key “LEFT-HAND ARROW” button. Pressing this key will bring up the “SELECT” option at the bottom of the screen. Then

Press “soft key just below the SELECT option “

**Step 5** - After that, you have to select the program you want to copy. To select Press “CURSOR DOWN” key.

**Step 6** – Then the bottom of the screen there is COPY, CUT option. Depending on your convenience, you can use a copy for copy OR cut for delete. But here we have to select the copy.

Press “ soft key just below the COPY”

**Step 7** - To paste the copied program, type the program no. of the program you want to paste in.ex. we want to paste in Prog NO. O0123

Type program no.(O0123) in the system then

Press “ INSERT” key.

**Step 8** – Set cursor position where you want to paste.

**Step 9** – Then the bottom of the screen there is PASTE option.

Press “ soft key just below the PASTE”.

## **For Replace code or command**

**Step 4** – Select code or command which is want to replace.  
Ex. Here we want to change T0202 take cursor on this command.  
And want to replace with T0101.

**Step 5** – Type “T0101”.

**Step 6** – Press “ALTER” key.

### **Deleted total program**

**Step 4** – Select cursor on Program no. here we select program no O0123 in following image.

**Step 5** – Press “ DELETE” key.

**Step 6** – After press delete key then machine asks confirmation the message will show in the screen as below image. There is two option

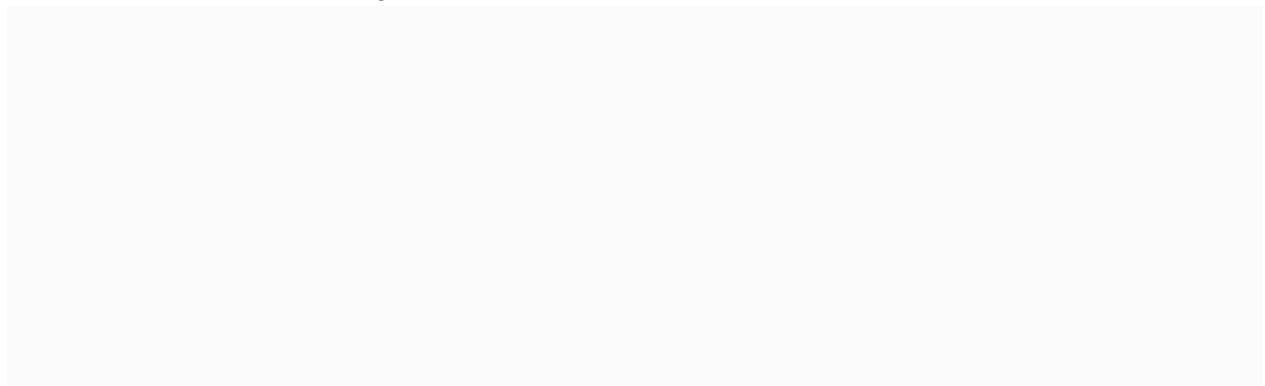
**CAN** (Cancel for deletion process)

**EXEC** (Execute for deletion process)

**Step 7** – Press “soft key just below EXEC”.

### **Execute the programme in the CNC machines**

1. Start the CNC program
2. Load the required tool.
3. Turn the coolant on.
4. Turn the spindle on.
5. Move to a position above a part.
6. Start the machining process.
7. Turn the coolant off.
8. Turn the spindle off.
9. Move away from the part to a safe location.
10. End the CNC program.



## PROGRAMMING VARIOUS OPERATIONS IN VERTICAL CNC MILLING MACHINE

**Print the programme and make the component in the CNC machine**

```
N10 ("DIA_50.0 MM FACEMILL CUTTECR)
N20G0 G17G64 G71 G94 G90
N30 G75 Z0.0
N40 G75 X0.0 Y0.0
N50T06M6
N60 D1
N70 M03S900
N80 F300
N90 G0 G40 G56 X150Y-35
N100 G0 Z50
N110 G0 Z1.0
N120 G01 Z0.0
N130 G01 X-95.0Y-35.0
N140 G01 X-95.00 Y0.0
N150 G01 X95.00 Y0.0
N160 G01 X95.0 Y35.0
N170 G01 X-150.0 Y35.0
N180 G0 Z50.0
N190 G0 X150.0Y-35.0
N200 G0 Z1.0
N210 G01 Z0.0
N220 G01 Z-0.05
N230 G01 X-95.0Y-35.0
N240 G01 X-95.00 Y0.0
N250 G01 X95.00 Y0.0
N260 G01 X95.0 Y35.0
N270 G01 X-150.0 Y35.0
N280 G0 Z50.0
N290 G75 Z0.0
N300 G75 X0.0Y0.0
N310 M05
N320 M09
N330 M01
```

```
N10 MSG("DIA 50.0 MM FACEMILL CUTTECR, 2)
N20G0 G17G64 G71 G94 G90
N30 G75 Z0.0
N40 G75 X0.0 Y0.0
N50T06M6
N60 D1
N70 M03S900
N80 F300
N90 G0 G40 G56 X150Y-35
N100 G0 Z50
```

```
N110 G0 Z1.0
N120 G01 Z0.0
N130 G01 X-95.0Y-35.0
N140 G01 X-95.00 Y0.0
N150 G01 X95.00 Y0.0
N160 G01 X95.0 Y35.0
N170 G01 X-150.0 Y35.0
N180 G0 Z50.0
N190 G0 X150.0Y-35.0
N200 G0 Z1.0
N210 G01 Z0.0
N220 G01 Z-0.05
N230 G01 X-95.0Y-35.0
N240 G01 X-95.00 Y0.0
N250 G01 X95.00 Y0.0
N260 G01 X95.0 Y35.0
N270 G01 X-150.0 Y35.0
N280 G0 Z50.0
N290 G75 Z0.0
N300 G75 X0.0Y0.0
N310 M05
N320 M09
N330 M01
```

**(PROGRAMMING FOR DRILLING OPERATION)**

```
N360 G0 G17G64 G71 G94 G90
N370 G75 Z0.0
N380 G75 X0.0 Y0.0
N390 T05M6
N400 D1
N410 M03S900
N420 F200
N430 M08
N440 G0 G40 G56 X75Y-20.0
N450 G0 Z50
N460 G0 Z1.0
N470 G01 Z0.0
N480 G01 Z-1.5
N490 G01 Z0.0
N500 G01 Z-5.0
N510 G01 Z-2.0
N520 G01 Z-10.0
N530 G01 Z0.0 F200
N540 G00 Z50
N550 G0 G40 G56 X75Y20.0
N560 G0 Z50
N570 G0 Z1.0
N580 G01 Z0.0
N590 G01 Z-1.5
N600 G01 Z0.0
N610 G01 Z-5.0
N620 G01 Z-2.0
N630 G01 Z-10.0
N640 G01 Z0.0 F200
```

N650 G0 Z50  
N660 G0 G40 G56 X-75Y-20.0  
N670 G0 Z50  
N680 G0 Z1.0  
N690 G01 Z0.0  
N700 G01 Z-1.5  
N710 G01 Z0.0  
N720 G01 Z-5.0  
N730 G01 Z-2.0  
N740 G01 Z-10.0  
N750 G01 Z0.0 F200  
N760 G0 Z50  
N770 G0 G40 G56 X-75Y20.0  
N780 G0 Z50  
N790 G0 Z1.0  
N800 G01 Z0.0  
N810 G01 Z-1.5  
N820 G01 Z0.0  
N830 G01 Z-5.0  
N840 G01 Z-2.0  
N850 G01 Z-10.0  
N860 G01 Z0.0 F200  
N870 G0 Z50  
N880 G75 Z0.0  
N890 G75 X0.0 Y0.0  
N900 M09  
N910 M05  
N920 M01  
N930

**N940 (MILLING WITH CIRCULAR INTERPOLATION)**

N950 G64 G71 G94 G90  
N960 G75 Z0.0  
N970 G75 X0.0 Y0.0  
N980 T02M6  
N990 D1  
N1000 G0G90 G56 X95.Y-40.S2000M3  
N1010 G0 Z50.  
N1020 Z10.  
N1030 G1Z-.2F50.  
N1040 X-95.F700.  
N1050 G2X-100.0Y-35.CR=5.  
N1060 G1Y35.  
N1070 G2X-95.Y40.CR=5.  
N1080 G1X95.  
N1090 G2X100.Y35.CR=5.  
N1100 G1Y-35.  
N1110 G2X95.Y-40.CR=5.  
N1120 G1Z-.4F50.  
N1130 X-95.F700.  
N1140 G2X-100.Y-35.CR=5.  
N1150 G1Y35.  
N1160 G2X-95.Y40.CR=5.  
N1170 G1X95.

N1180 G2X100.Y35.CR=5.  
N1190 G1Y-35.  
N1200 G2X95.Y-40.CR=5.  
N1210 G1Z-.6F50.  
N1220 X-95.F700.  
N1230 G2X-100.Y-35.CR=5.  
N1240 G1Y35.  
N1250 G2X-95.Y40.CR=5.  
N1260 G1X95.  
N1270 G2X100.Y35.CR=5.  
N1280 G1Y-35.  
N1290 G2X95.Y-40.CR=5.  
N1300 G1Z-.8F50.  
N1310 X-95.F700.  
N1320 G2X-100.Y-35.CR=5.  
N1330 G1Y35.  
N1340 G2X-95.Y40.CR=5.  
N1350 G1X95.  
N1360 G2X100.Y35.CR=5.  
N1370 G1Y-35.  
N1380 G2X95.Y-40.CR=5.  
N1390 G1Z-1.F50.  
N1400 X-95.F700.  
N1410 G2X-100.Y-35.CR=5.  
N1420 G1Y35.  
N1430 G2X-95.Y40.CR=5.  
N1440 G1X95.  
N1450 G2X100.Y35.CR=5.  
N1460 G1Y-35.  
N1470 G2X95.Y-40.CR=5.  
N1480 G1Z-1.2F50.  
N1490 X-95.F700.  
N1500 G2X-100.Y-35.CR=5.  
N1510 G1Y35.  
N1520 G2X-95.Y40.CR=5.  
N1530 G1X95.  
N1540 G2X100.Y35.CR=5.  
N1550 G1Y-35.  
N1560 G2X95.Y-40.CR=5.  
N1570 G1Z-1.4F50.  
N1580 X-95.F700.  
N1590 G2X-100.Y-35.CR=5.  
N1600 G1Y35.  
N1610 G2X-95.Y40.CR=5.  
N1620 G1X95.  
N1630 G2X100.Y35.CR=5.  
N1640 G1Y-35.  
N1650 G2X95.Y-40.CR=5.  
N1660 G1Z-1.6F50.  
N1670 X-95.F700.  
N1680 G2X-100.Y-35.CR=5.  
N1690 G1Y35.  
N1700 G2X-95.Y40.CR=5.  
N1710 G1X95.

```

N1720 G2X100.Y35.CR=5.
N1730 G1Y-35.
N1740 G2X95.Y-40.CR=5.
N1750 G1Z-1.8F50.
N1760 X-95.F700.
N1770 G2X-100.Y-35.CR=5.
N1780 G1Y35.
N1790 G2X-95.Y40.CR=5.
N1800 G1X95.
N1810 G2X100.Y35.CR=5.
N1820 G1Y-35.
N1830 G2X95.Y-40.CR=5.
N1840 G1Z-2.F50.
N1850 X-95.F700.
N1860 G2X-100.Y-35.CR=5.
N1870 G1Y35.
N1880 G2X-95.Y40.CR=5.
N1890 G1X95.
N1900 G2X100.Y35.CR=5.
N1910 G1Y-35.
N1920 G2X95.Y-40.CR=5.
N1930 G0Z50.
N1940 M5
N1950 G75 Z0.0
N1960 G75 X0.0 Y0.0
N1970 M01

```

**Using linear interpolation and Circular Interpolation-Create a part programme for grooving and produce component in the CNC Milling Machine.**

```

N870 G0G90G64G40;MILLING WITH CIRCULAR INTERPOLATION-2
N880 G75X0Y0
N890 T04M06
N900 G0G55X-125Y15M03S1200
N910 G0Z50.M08
N920 G01Z10.F1000
N930 G01Z0.F500
N940 G01X125.F160
N950 Y-15.
N960 X-125.
N970 G0Z100.M09
N980 G75X0Y0
N990 G75Z0.
N1000 M05
N1010 M01
N1340 G0G90G64G40
N1350 G75X0Y0
N1360 T03M06
N1370 G0G57X0Y0M03S2500
N1380 G0Z50.M08
N1390 G01Z10.F1000
N1400 G01Z-.5F150
N1410 G01X170F300
N1420 G03X180Y10CR=10

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N1430 G01Y50  
N1440 G01X170Y60  
N1450 G01X5  
N1460 G03X0Y55CR=5  
N1470 G01Y0  
N1480 G01X-30Y-30  
N1490 G0Z100  
N1500 G75X0Y0Z0  
N1510 M01  
N1520 M30

**PROGRAMMING FOR SLOTING/GROOVING**

N10 G0G90G64G40  
N20 G75X0Y0  
N30 T07M06  
N40 D1  
N50 M06  
N60 G0G55X0Y0M03S2000  
N70 G0Z50.M08  
N80 G0X-85Y-50  
N90 G0Z5.  
N100 G01Z-.5F300  
N110 G01Y50.  
N120 Z-1.  
N130 Y-50.  
N140 Z-1.5  
N150 Y50.  
N160 Z-2  
N170 Y-50  
N180 Z-2.5  
N190 Y50  
N200 Z-3  
N210 Y-50  
N220 Z-3.5  
N230 Y50  
N240 Z-4  
N250 Y-50  
N260 Z-4.5  
N270 Y50  
N280 Z-5  
N290 Y-50  
N300 G0Z5M09  
N310 G0Z100M05  
N320 G75X0Y0Z0  
N330 M01  
N340 M30