**Exp. No: 1**

**Date:**

# STUDY OF MILLING, GRINDING AND GEAR CUTTING MACHINES

## OBJECTIVES

- Identify the important components and controls on the milling, grinding and gear cutting machines.
- Identify and select from commonly used machine cutting tools**.**
- Identify safe machine practices.

## MILLING MACHINE

### INTRODUCTION

Milling is a machining operation in which a work part is fed past a rotating cylindrical tool with multiple cutting edges. The axis of rotation of the cutting tool is perpendicular to the direction of feed. This orientation between the tool axis and the feed direction is one of the features that distinguish milling from drilling. In drilling, the cutting tool is fed in a direction parallel to its axis of rotation. The cutting tool in milling is called a milling cutter and the cutting edges are called teeth. The machine tool that traditionally performs this operation is a milling machine.

The geometric form created by milling is a plane surface. Other work geometries can be created either by means of the cutter path or the cutter shape. Owing to the variety of shapes possible and its high production rates, milling is one of the most versatile and widely used machining operations.

### MILLING MACHINES

Milling machines must provide a rotating spindle for the cutter and a table for fastening, positioning, and feeding the work part. Milling machines can be classified as horizontal or vertical.

A horizontal milling machine has a horizontal spindle, and this design is well-suited for performing peripheral milling (e.g., slab milling, slotting, side and straddle milling) on work parts that are roughly cube-shaped.

A vertical milling machine has a vertical spindle, and this orientation is appropriate for face milling, end milling, surface contouring, and die sinking on relatively flat work parts. The Type of milling machines are shown in Fig. 1.1:

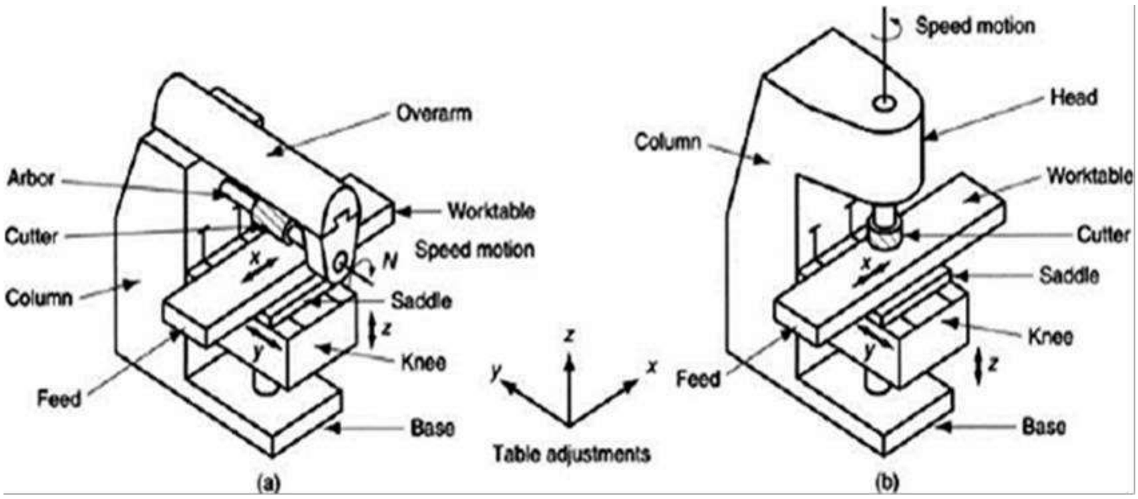



**Fig 1.1 Type of Milling Machine**

## PRINCIPAL PARTS OF A MILLING MACHINE

1. **Base:** It is the foundation of the machine upon which all other parts are mounted. It is generally made of grey cast iron to absorb shock and vibration. Sometime it also serves as a reservoir for cutting fluid.
2. **Column:** It is the main supporting frame mounted vertically on one side of the base. The motor and other driving mechanisms are contained in it. It supports and guides the knee in its vertical travel. It carries the jack for elevating the knee.
3. **Knee:** The Knee projects from the column and slides up and down on its face. It supports the saddle and table. It is partially supported by the elevating screw which adjusts its height. It carries the table feed mechanism and controls to feed in longitudinal, cross, vertical, and rotation etc., by hand power or machine power.
4. **Saddle:** The saddle supports and carries the table and is adjustable transversely on ways on top of the knee. It is provided with graduation for exact movement and can be operated by hand or power.
5. **Table:** The table rests on ways on the saddle and travels longitudinally in a horizontal plane. It supports the work pieces fixtures etc.

## DIRECTION OF FEED

One final consideration concerning feed is the direction in which the work is fed into the cutter. The most commonly used method is to feed the work against the rotation direction of the cutter (conventional or up milling) (Fig. 1.2a). However, if the machine is equipped with a backlash eliminator, certain types of work can best be milled by climb milling (Fig. 1.2b).

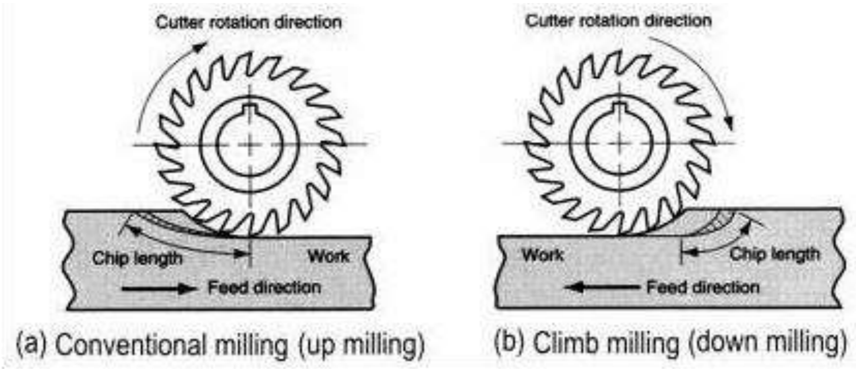
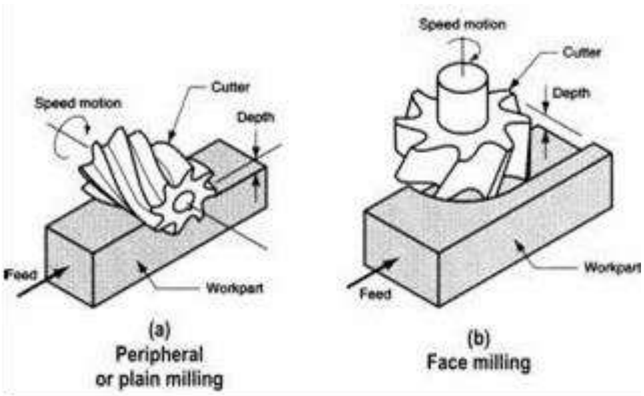



**Fig. 1.2 Direction of Feed**

Climb milling, which can increase cutter life up to 50 percent, is effective for most milling applications. To know whether climb or conventional milling is being used, look at the relationship between the cutter rotation and the direction of the machine table/work feed. Climb milling is being used when the cutter and the work piece are going in the same direction (Fig. 1.2b). Conventional milling is when the cutter and the work piece are going in opposite directions.

## TYPES OF MILLING OPERATIONS

There are two basic types of milling operations, shown in Figure 1.3: (a) peripheral milling and (b) face milling.




**Fig, 1.3 Milling Operations**

### a) Peripheral Milling

In peripheral milling, also called plain milling, the axis of the tool is parallel to the surface being machined, and the operation is performed by cutting edges on the outside periphery of the cutter.

Several types of peripheral milling are shown in Figure 1.4:

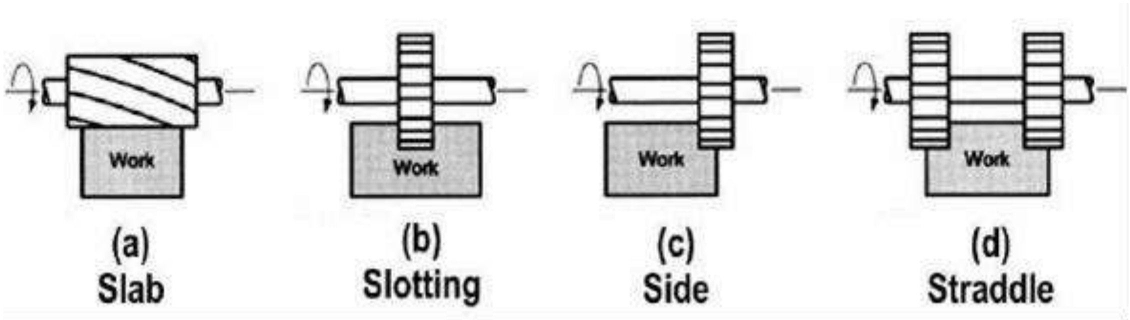



**Fig. 1.4 Peripheral Milling**

**b) Face Milling**

In face milling, the axis of the cutter is perpendicular to the surface being milled, and machining is performed by cutting edges on both the end and outside periphery of the cutter. As in peripheral milling, various forms of face milling exist, several of which are shown in Figure 1.5:

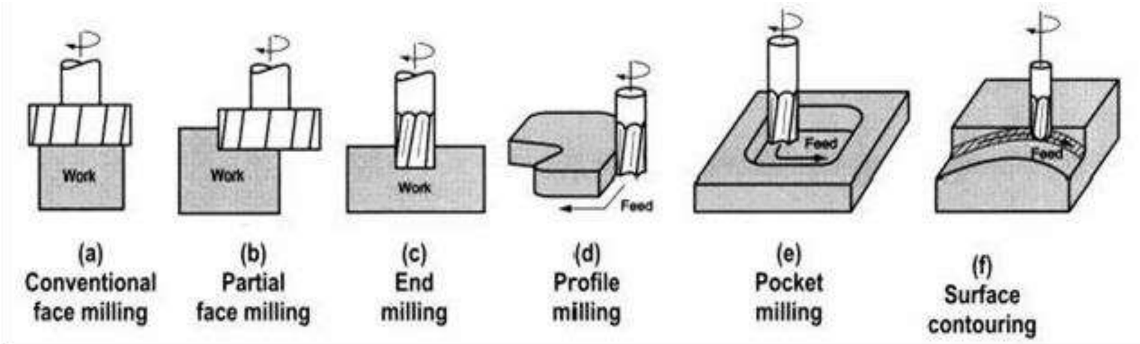



**Fig. 1.5 Face Milling**

**WORK HOLDING DEVICES ON THE MILLING MACHINE**

1. **Vise**

The most common method of work holding on a milling machine is a vise. Vises are simple to use and can quickly be adjusted to the size of the work piece. A vise should be used to hold work with parallel sides if it is within the size limits of the vise.

2. **V Blocks**

V-Blocks hold and support round work for milling or drilling, V-Blocks come in many different sizes. On milling machines, V-Blocks are typically clamped directly to the table.

3. **Angles Plates**

An angle plate is an L shaped piece of Cast Iron or Steel that has tapped holes or slots to facilitate the clamping of the work piece.

4. **Parallels**

Parallels are pieces of steel bar stock accurately machines so that the opposing sides are parallel to each other.

5. **Clamps**

Work that is too large or has an odd configuration is usually bolted directly to the table This method of work holding takes the most ingenuity and expertise.

**PRECAUTIONS:**

1. The milling machine must be stopped before setting up or removing a work piece, cutter or other accessory
2. Never stop the feeding of job when the cutting operation is going on, otherwise the tool will cut deeper at the point where feed is stopped.
3. All the chips should be removed from the cutter. A wiping cloth should be placed on the cutter to protect the hands.
4. The cutter should be rotated in the clockwise direction only for right handed tools.
5. The work piece and cutter should be kept as cool as possible (i.e. coolant should be used where necessary to minimize heat absorption).
6. The table surface should be protected with a wiping cloth.
7. Tool must be mounted as close to the machine spindle as possible.

## GRINDING MACHINE

### INTRODUCTION

Grinding is a process of material removal in the form of small chips by the mechanical action of abrasive particles bonded together in a grinding wheel. It is basically a finishing process employed for producing close dimensional and geometrical accuracies and smooth surface finish. However in same applications, the grinding process is also applied for higher material removal rates and is referred to as abrasive machining. Generally, in other methods of machining, the work piece is shaped by removing chips using cutting tools having designed geometry, with the tool material is harder than the work material. In such types of machining the process has the following limitations.

1. The difference in the hardness of the tool and of the work is often limited, resulting tool wear and tool failure.

2. In the process of removing materials by way of chips, a considerable amount of heat is generated which, when it exceeds a specific level, affects the tool hardness. These conditions always limit the applicable cutting speed.

**TYPES OF GRINDING**

Grinding is done on surfaces of almost all conceivable shapes and materials of all kinds. Grinding may be classified broadly into two groups.

1. Rough or non-precision grinding.
2. Precision grinding.

**1. Rough Grinding**

The common forms of rough grinding are snagging and off-hand grinding where the work is held in the operators hand. The work is pressed hard against the wheel, or vice -versa. The accuracy and surface finish obtained are of secondary importance. Snagging is done where; a considerable amount of metal is removed without regard to the accuracy of the finished surface.

**2. Precision Grinding**

This is concerned with producing good surface finish and high degree of accuracy. Grinding in accordance with the type of surface to be ground is classified as

1. External cylindrical grinding
2. Internal cylindrical grinding
3. Surface grinding
4. Form grinding

**GRINDING MACHINES**

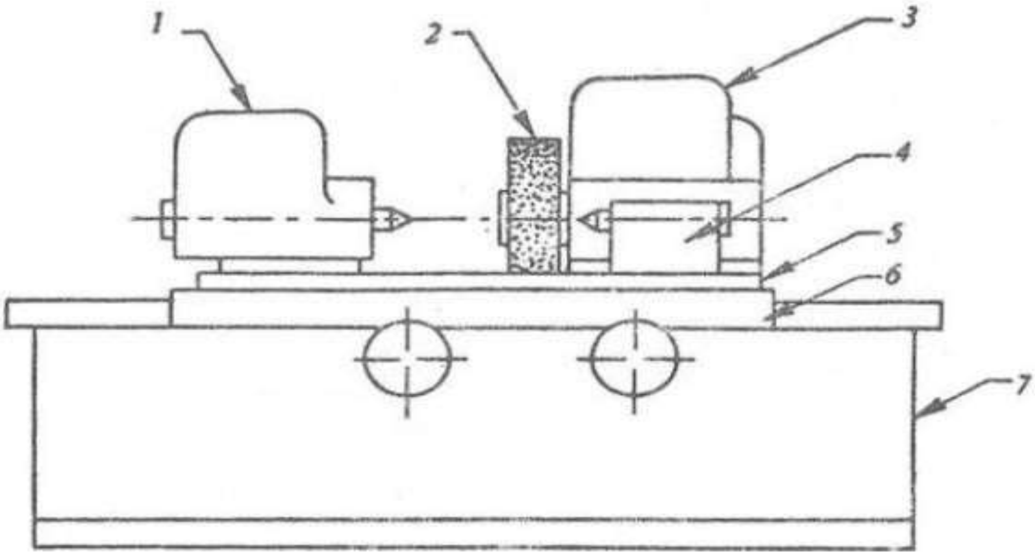
Grinding machines are broadly classified into cylindrical grinding machines, internal grinding machines, surface grinding machines and tool & cutter grinding machine, depending on the shape of the ground surface and the type of grinding they do.

**1. Cylindrical Grinding Machines**

Cylindrical grinding machine is performed to remove material, to produce precise geometry, and to obtain the desired surface finish on external surfaces of round work pieces. These surfaces may be cylindrical, tapers, fillets, grooves, shoulders and other formed surfaces of revolution.

**a. Centre Type Cylindrical Grinding Machine**

Centre type grinding machine is used for single and multi-diameter shafts, especially when the concentricity must be held between diameters ground in the separate operations. In these type of machines, the work piece is supported in between the centre for stock removal. Such machines basically consists of a bed, a wheel head (swiveling or non- swiveling type) and a tail stock. The head stock and tail stock are mounted on a swivel table which is moves to and fro in the bed guide ways. Centre type grinding machines may be manually operated, semi- automatic or fully automatic.

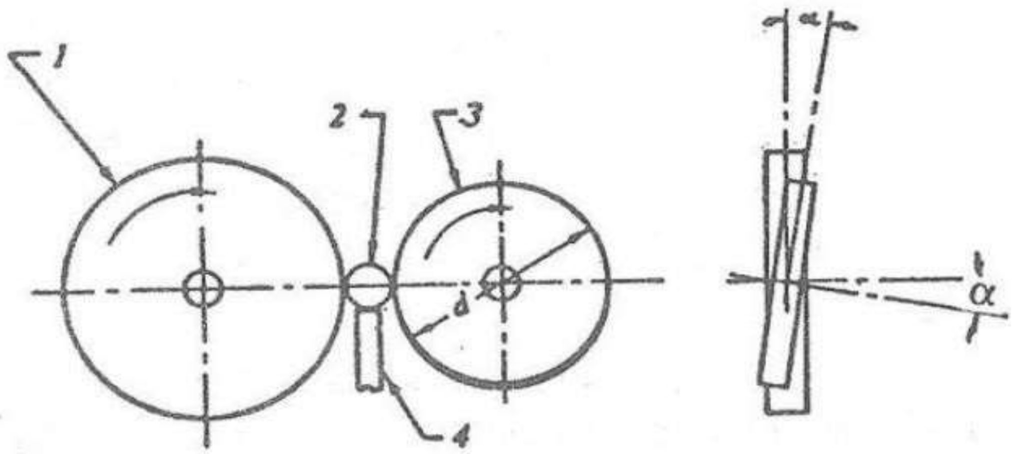



1. Head stock 2. Grinding wheel 3. Wheel head 4. Tail stock 5. Upper table 6. Lower table 7. Base

**Fig. 1.6 Centre Type Cylindrical Grinding Machine**

### b. Centreless Grinding Machines

Centreless grinding is a method of grinding exterior cylindrical, tapered, formed surfaces on work pieces that are not held and rotated on centre's. The principal elements of an external centreless grinder are the grinding wheel, regulating or back up wheel, and the work-rest. Both wheels are rotated in the same direction..




1. Grinding wheel 2. Work 3. Regulating wheel 4. Work rest

**Fig. 1.7 Centre Centreless Grinding Machine**

The work-rest is located between the wheels. The work is placed upon the work-rest and the latter, together with the regulating wheel is fed forward, forcing the work against the grinding wheel. The axial movement of the work past the grinding wheel is obtained by tilting the regulating wheel at a slight angle from horizontal. An angular adjustment of 0 to 8 or 10 degrees is provided in the machine for this purpose. It is useful for grinding long, slender shafts or bars. The layer of metal removed by the grinding wheel in one pass reduces the diameter of the work piece by 0.02 to 0.03mm.

**2. Internal Grinding Machines**

Internal grinders are used to finish straight, tapered or formed holes to the correct size, shape and finish. The depth of cut depends upon the diameter of the hole being ground and may vary from 0.02 to 0.05 mm in roughing and from 0.002 to 0.01 mm in finishing operations. Most internal grinders are horizontal, although there are a relatively few vertical ones in use. There are three general types of internal grinders:

a. Chucking
b. Planetary
c. Centreless

**a. Chucking Grinders:** In chucking grinders the work piece is chucked and rotated about its own axis to bring all parts of the bore or other surfaces to be ground in contact with the grinding.

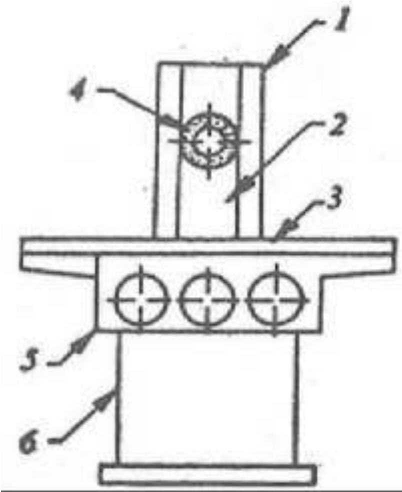
**b. Planetary Grinders:** In a planetary grinder the work piece is mounted on the reciprocating table and is not revolved. Instead, the grinding wheel is given rotary and planetary motions to grind cylindrical holes. Planetary grinding is usually limited to large and awkward work pieces that cannot be conveniently rotated by a chuck.

**c. Centreless Grinders:** The external centerless grinding principle is also applied to internal grinding. In internal centreless grinding, the work is supported by three rolls. One is the regulating roll, and the other is a pressure roll to hold the work piece firmly against the support and regulating rolls.

**3. Surface Grinding Machines**

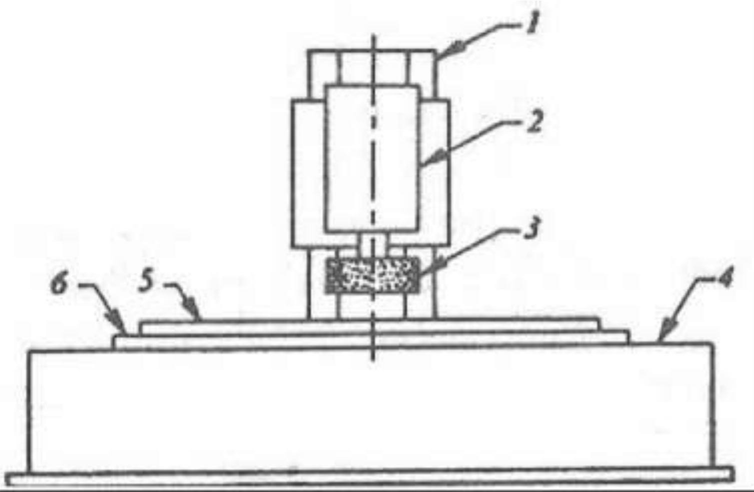
Surface grinding machines are employed to finish plane or flat surfaces. They are also capable of grinding irregular, curved, convex, and concave surfaces. Conventional surface grinders may be divided into two classes: One class has reciprocating tables for work ground along straight lines, while the other covers the machines with rotating work tables for continuous rapid grinding. Surface grinders may also be classified according to whether they have horizontal or vertical grinding wheel spindles. So there may be four different types of surface grinders:

a. Horizontal spindle reciprocating table
b. Horizontal spindle rotary table
c. Vertical spindle reciprocating table
d. Vertical spindle rotary table




1. Column, 2. Wheel head, 3. Table
4. Wheel, 5. Saddle 6. Base.

**Fig. 1.8 (a). Horizontal Spindle Surface Grinder**




1. Column, 2. Wheel head, 3. Wheel, 4. Base,
5.Magnetic chuck, 6. Rotary table

**Fig. 1.8 (b). Vertical Spindle Surface Grinder**

The majority of surface grinders are of the horizontal table type. In the horizontal type of machine, grinding is normally done on the periphery of the wheel. The area of contact is small, and the speed is uniform over the grinding surface. Small grain wheels can be used, and the finest finishes obtained. In the vertical type, surface grinders apply the face or side of the wheel, and cupped, cylindrical, or segmented wheels are used. The area of contact may be large, and stoke can be removed rapidly.

**4. Tool and Cutter Grinders (Form Grinder)**

Tool and cutter grinders are used mainly to sharpen and recondition multiple tooth cutters like reamers, milling cutters, drills, taps, hobs and other types of tools used in the shop.With various attachments they can also do light surface, cylindrical, and internal grinding to finish such items as jig, fixture , die and gauge details and sharpen single point tools .

**PRECAUTIONS:**

1. Never stand in line with the wheel because the material of the wheel is quite brittle. If there is any accident causing wheel breakage the wheel will shatter and the pieces will fly along paths in line with the wheel.

2. Coolant usage is compulsory as the speeds employed are very high and continuous application of coolant is necessary for ductile materials like-steel etc.
3. The grinding tools are first dressed properly.
4. Care has to be taken so as to maintain the right feed of the material.
5. Work-wheel interface zone is to be flooded with coolant
6. Dressing of grinding wheel to be done before commencement of cutting action, intermittent dressing also to be done if wheel is loaded.

## GEAR GENERATION METHODS

### INTRODUCTION

Gear is one of the important machine tool elements which is an integral and inevitable part of power transmission system. A gear is a round blank having teeth along its periphery. Gears are used to transfer power or torque from prime mover to the place where it is to be used. Along with the transmission of power gears also transfer the accurate velocity ratio between two shafts. Velocity ratio is defined as the ratio of rpm (revolution per minute) of driven shaft to the rpm of driver shaft. Power is normally transferred with the help of pair of gears in mesh together, each of these two are mount on driven shaft and driver shaft.

$$\text{Velocity Ratio} = \frac{\text{RPM of driven shaft or driven gear}}{\text{RPM of gear driver shaft or driver}}$$

The gear mounted on the driver shaft is called driver gear and an other gear mounted on the driven shaft is called driven gear.

### METHOD OF GEAR MANUFACTURING

The gears can be manufactured by the following three methods.

**1. Casting**

For casting of gears sand moulds or permanent moulds are prepared, then molten metal is poured into the mold cavity to get the required gear. Cast iron gears are made by this method comfortably. These gears (casted gears) cannot be very fine, these are rough, low strength, and with some inaccuracies in operation. There cost of production is very low. This method is recommended for manufacturing of large sized gears where cost and power transmission are important than operating accuracy and noise level.

**2. Plastic Moulding**

Plastic mould is also one of the way of gear manufacturing. In plastic moulding gears of plastic material can be manufactured by using injection moulding or compression moulding. These are the very light duties gears used for transmission of very low amount of power but maintains velocity ratio accurately. Plastic moulding is also used for making gears of metal. In this process the metallic work piece is heated first to bring it to a plastic state and then it is moulded to the required shape with the help of mechanical tools, die, and application of pressure. This process is used to make light duty smaller gears with accuracy. Non-ferrous metals can also be used as raw material for gear making by plastic moulding methods.

**3. Machining**

This is most widely used gear manufacturing method. Gear blank of accurate size and shape is first prepared by cutting it from metal stock. The gear blank can also be the metal casting. This method lies under the category of chip forming process. Gear is prepared by cutting one by one tooth in the gear blank of desired shape and size along it periphery. Different gear cutting methods are used in this category.

**a. Gears Shaping**

Gear shaping is one of the gear generating methods. In this process gear tooth are accurately sized and shaped by cutting them by a multipoint cutting tool. Various gear shaping processes are listed below:

(i) Gear cutting by gear shaper.

(ii) Hobbing process.

**(i). Gear Cutting by Gear Shaper**

This process uses a pinion shaped cutter carrying clearance on the tooth face and sides and a hole at its centre for mounting it on a stub arbor or spindle of the machine. The cutter is mounted by keeping its axis in vertical position. It is also made reciprocating along the vertical axis up and down with adjustable and predecide amplitude. The cutter and the gear blank both are set to rotate at very low rpm about their respective axis. The relative rpm of both (cutter and blank) can be fixed to any of the available value with the help of a gear train. This way all the cutting teeth of cutter come is action one-by-one giving sufficient time for their cooling and incorporating a longer tool life. The specific advantages of the process over other processes, its product cycle time is very low and negligible dimensional variability from one unit to other in case of mass production. The principle of gear cutting by this process as explained above is depicted in the Figure 1.9 (a).

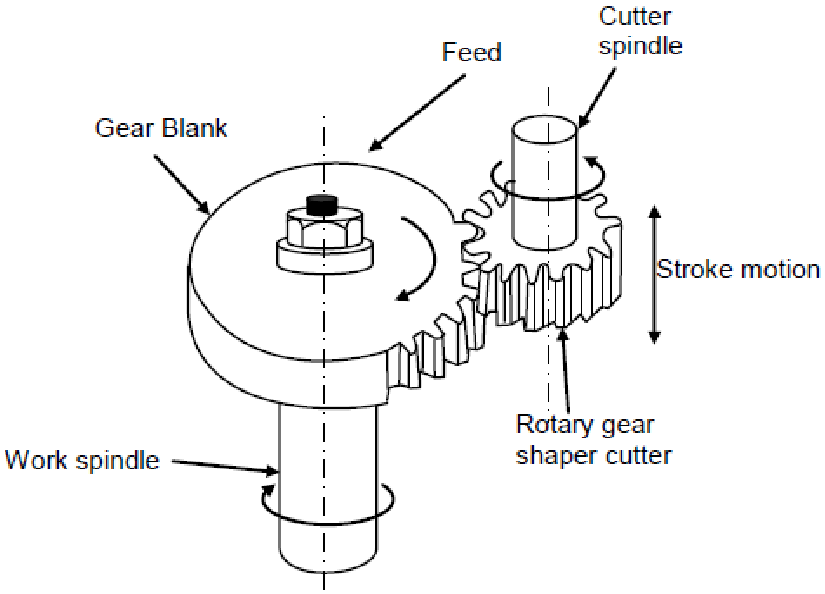



**Fig. 1.9(a). Process of Gear Cutting by Shaper Cutter**

The whole process is carried out an a gear shaping machine which is of the shape of a column and knee type milling machine. All the motions Gear Blank Feed Cutter spindle Stroke motion Rotary gear Work spindle shaper cutter given to gear blank and gear cutter are set controlled very precisely. A setup of gear shaping machine is shown in Figure 1.9 (b).

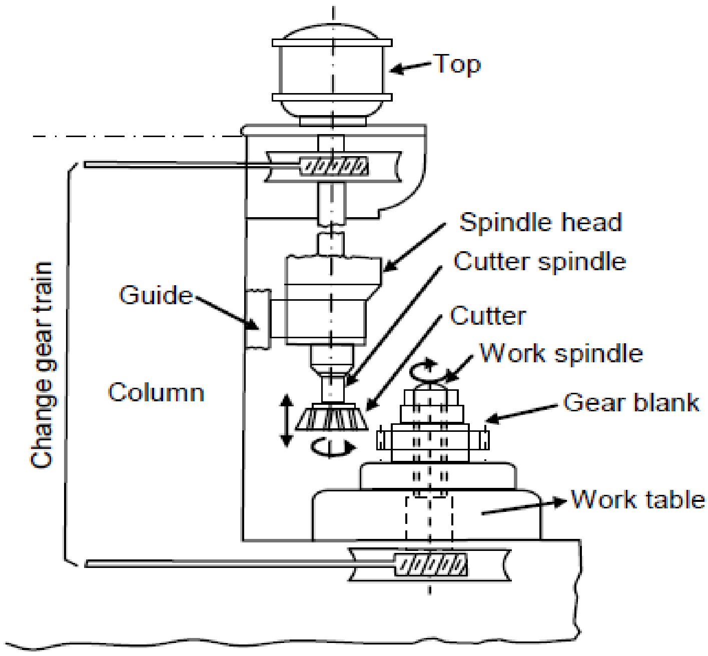



**Fig. 1.9(b). Setup for Gear Shaping Machine**

### (ii). Gear Hobbing Process

In addition to the gear shaping process another process used for gear generation is gear hobbing. In this process, the gear blank is rolled with a rotating cutter called hob. Gear hobbing is done by using a multipoint cutting tool called gear hob. It looks like a worm gear having a number of straight flutes all around its periphery parallel to its axis. These flutes are so shaped by giving proper angles to them so that these work as cutting edges. In gear hobbing operation, the hob is rotated at a suitable rpm and simultaneously fed to the gear blank. The gear blank is also kept as revolving. Rpm of both, gear blank and gear hob are so synchronized that for each revolution of gear bob the gear blank rotates by a distance equal to one pitch distance of the gear to be cut. Motion of both gear blank and hob are maintained continuously and steady. A gear hob is shown in Figure 2.0(a). The hob teeth behave like screw threads, having a definite helix angle. During operation the hob is tilted to helix angle so that its cutting edges remain square with the gear blank. Gear hobbing is used for making a wide variety of gears like spur gear, helical, hearing-bone, splines and gear sprockets, etc.

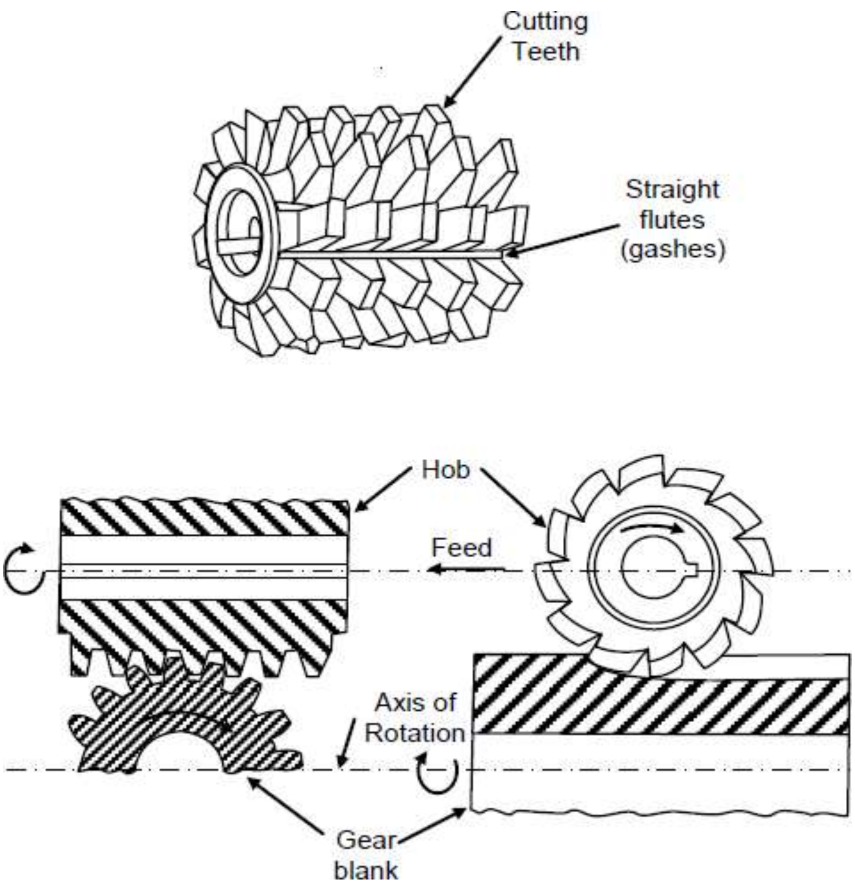



**Fig. 2.0 (a). Gear Hob**

Three important parameters are to be controlled in the process of gear hobbing indexing movement, feed rate and angle between the axis of gear blank and gear hobbing tool (gear hob). A schematic diagram of the setup of a gear hobbing machine is illustrated in Figure 2.0(b). The aims of hob are set at an inclination equal to the helix angle of the hob with the vertical axis of the blank. If a helical gear is to be cut, the hob axis is set at an inclination equal to the sum of the helix angle of the hob and the helix angle of the helical gear. Proper gear arrangement is used to maintain rpm ratio of gear blank and hob.

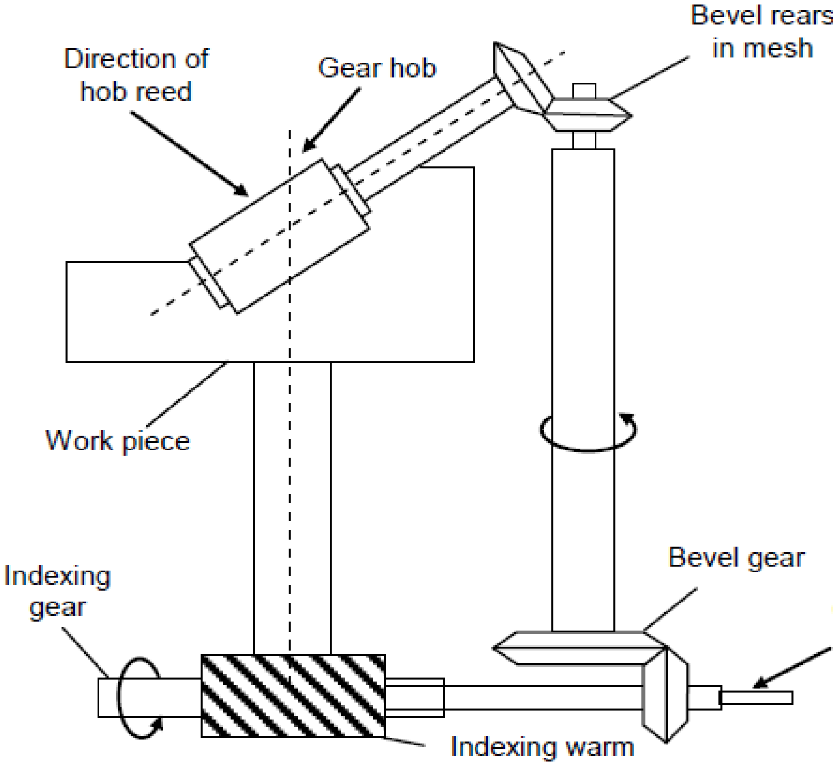



**Fig. 2.0 (b). Setup for Gear Hobbing Machine**

The operation of gear hobbing involves feeding the revolving hob till it reaches to the required depth of the gear tooth. Simultaneously it is fed in a direction parallel to the axis of rotation.

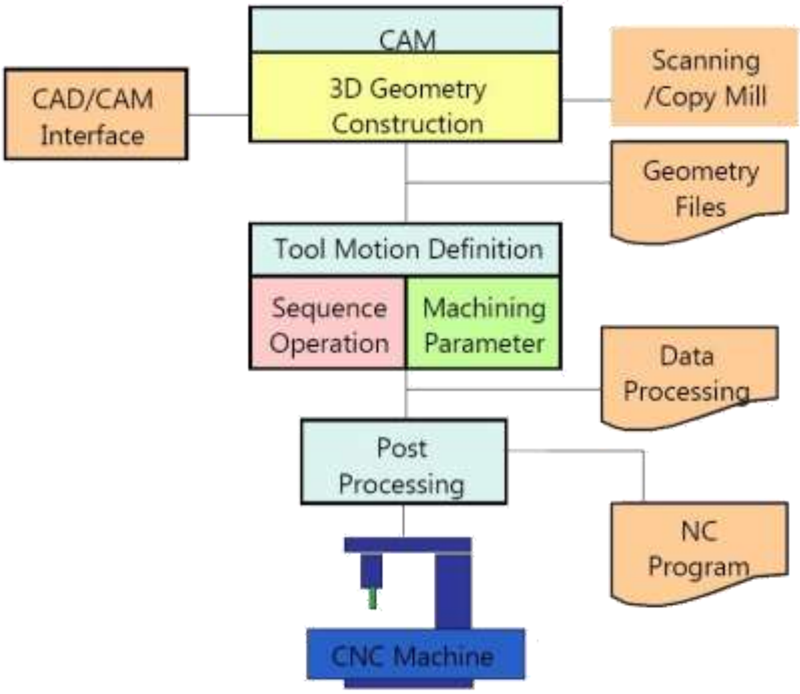
## CNC PART PROGRAMMING

### INTRODUCTION

A Part program is a set of instructions given to a Computerized numerical control (CNC) machine. If the complex-shaped component requires calculations to produce the component are done by the programming software contained in the computer. The programmer communicates with this system through the system language, which is based on words. There are various programming languages developed in the recent past, such as APT (Automatically Programmed Tools), ADAPT, AUTOSPOT, COMPAT-II, 2CL, ROMANCE, SPLIT is used for writing a computer programme, which has English like statements. A translator known as compiler program is used to translate it in a form acceptable to MCU.

The programmer has to do only following things :

(a) Define the work part geometry.
(b) Defining the repetition work.
(c) Specifying the operation sequence.




**STANDARD G AND M CODES**

The most common codes used when programming NC machines tools are G-codes (preparatory functions), and M codes (miscellaneous functions). Other codes such as F, S, D, and T are used for machine functions such as feed, speed, cutter diameter offset, tool number, etc. G-codes are sometimes called cycle codes because they refer to some action occurring on the X, Y, and/or Z-axis of a machine tool. The G-codes are grouped into categories such as Group 01, containing codes G00, G01, G02, G03, which cause some movement of the machine table or head. Group 03 includes either absolute or incremental programming. A G00 code rapidly positions the cutting tool while it is above the workpiece from one point to another point on a job. During the rapid traverse movement, either the X or Y-axis can be moved individually or both axes can be moved at the same time. The rate of rapid travel varies from machine to machine

**G-Codes (Preparatory Functions)**

Code Function

G00 Rapid positioning
G01 Linear interpolation
G02 Circular interpolation clockwise (CW)
G03 Circular interpolation counterclockwise (CCW)
G20 Inch input (in.)
G21 Metric input (mm)
G24 Radius programming
G28 Return to reference point
G29 Return from reference point
G32 Thread cutting
G40 Cutter compensation cancel
G41 Cutter compensation left
G42 Cutter compensation right
G43 Tool length compensation positive (+) direction
G44 Tool length compensation minus (-) direction
G49 Tool length compensation cancels
G 53 Zero offset or M/c reference
G54 Settable zero offset
G84 canned turn cycle

G90 Absolute programming
G91 Incremental programming

**M-Codes (Miscellaneous Functions)**

M or miscellaneous codes are used to either turn ON or OFF different functions, which control certain machine tool operations. M-codes are not grouped into categories, although several codes may control the same type of operations such as M03, M04, and M05, which control the machine tool spindle. Some of important codes are given as under with their functions.

Code Function

M00 Program stop
M02 End of program
M03 Spindle start (forward CW)
M04 Spindle start (reverse CCW)
M05 Spindle stop
M06 Tool change
M08 Coolant on
M09 Coolant off
M10 Chuck – clamping
M11 Chuck – unclamping
M12 Tailstock spindle out
M13 Tailstock spindle in
M18 Tool post rotation reverse
M30 End of tape and rewind or main program end
M98 Transfer to subprogram
M99 End of subprogram

**Note :** On some machines and controls, some may be differ.

**Exp. No: 2**

**Date:**

## SPUR GEAR MILLING

### OBJECTIVES:

To perform spur gear milling on a given cylindrical work piece using horizontal milling machine.

### MATERIAL REQUIRED:

A mild steel bar of 50 mm diameter and 20 mm length.

### TOOLS AND EQUIPMENT USED:

1. Lathe machine
2. H.S.S. single point cutting tool
3. Multi point cutting tool
4. V-block
5. Chuck key
6. Tool post key
7. Vernier caliper
8. Vernier height gauge
9. Steel rule.

### SEQUENCE OF OPERATIONS:

1. Facing
2. turning
3. Milling

### PROCEDURE:

1. Calculate the gear tooth proportions.

Blank diameter = ( Z + 2 ) m

Tooth depth = 2.25 m

Tooth width = 1.5708 m

where,

Z = Number of teeth required

m = module

Indexing calculation

Index crank movement = 40 / Z

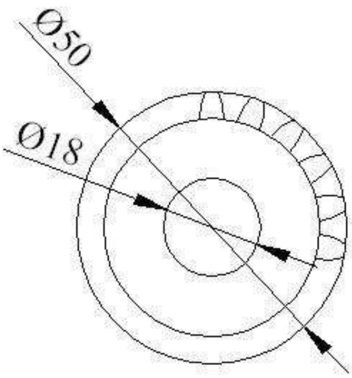
3. The dividing head and the tail stock are bolted on the machine table. Their axis must be set parallel to the machine table.
4. The gear blank is held between the dividing head and tailstock using a mandrel. The mandrel is connected with the spindle of dividing head by a carrier and catch plate.
5. The cutter is mounted on the arbor. The cutter is centred accurately with the gear blank.
6. Set the speed and feed for machining.
7. For giving depth of cut, the table is raised till the periphery of the gear blank just touches the cutter.
8. The micrometer dial of vertical feed screw is set to zero in this position.
9. Then the table is raised further to give the required depth of cut.
10. The machine is started and feed is given to the table to cut the first groove of the blank.
11. After the cut, the table is brought back to the starting position.
12. Then the gear blank is indexed for the next tooth space.
13. This is continued till all the gear teeth are cut.

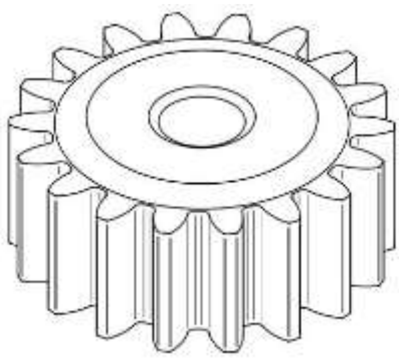
**PRECAUTIONS:**

1. The milling machine must be stopped before setting up or removing a work piece, cutter or other accessory
2. Never stop the feeding of job when the cutting operation is going on, otherwise the tool will cut deeper at the point where feed is stopped.
3. All the chips should be removed from the cutter. A wiping cloth should be placed on the cutter to protect the hands.
4. The cutter should be rotated in the clockwise direction only for right handed tools.
5. The work piece and cutter should be kept as cool as possible (i.e. coolant should be used where necessary to minimize heat absorption).
6. The table surface should be protected with a wiping cloth.
7. Tool must be mounted as close to the machine spindle as possible.

## SPUR GEAR MILLING

**MACHINING JOB** **FINISHED JOB**



**CALCULATION :**

| | |
|---|---|
| No. of teeth, Z | = 23 |
| Module, m | = 2 mm |
| Blank Diameter, D | = (Z + 2) m |
| | = (23 + 2) 2 |
| | = 50 mm |
| Tooth Depth | = 2.25 m |
| | = 2.25 * 2 |
| | = 4.5 mm |
| Indexing Calculation | = 40 / Z |
| | = 40 / 23 |
| | = 1 17/23 |

**RESULT:**

Required specimen successfully obtained according to specified operation (spur gear milling) with given dimensions.

**Exp. No: 3**

**Date:**

## HELICAL GEAR CUTTING IN MILLING MACHINE

**OBJECTIVES:**

To perform Helical gear milling on a given cylindrical work piece using horizontal milling machine.

**MATERIAL REQUIRED:**

A Cast iron block of 50 mm diameter and 20 mm length.

**TOOLS AND EQUIPMENT USED:**

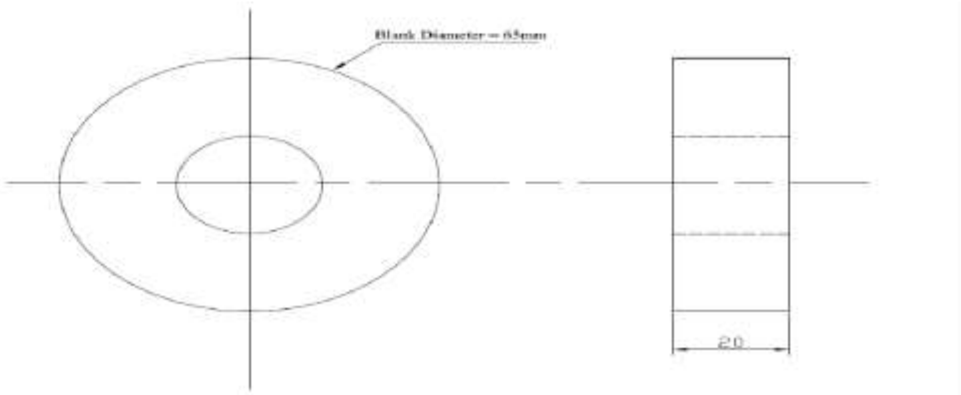
1. Vertical Milling machine
2. vernier caliper
3. Holding Materials
4. Milling Tools

**PROCEDURE:**

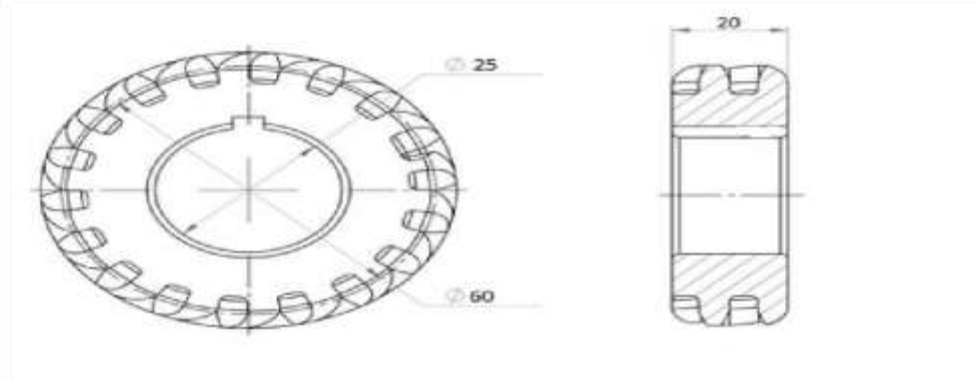
1. The M10 milling cutter is set on the mandrel
2. The table is swivelled to an inclination of α ( Helix Angle ) with the axis of work piece
3. The required gear ratio is set between the work table and the mandrel holding the work piece so that movement of the work table rotates the work piece through the proper helix angle progressively
4. The spindle is switched on and the required depth of cut is set before the tool cuts the work piece.
5. Single teeth cavity is cut through the work piece.
6. After Indexing the next tooth is cut in similar fashion and so on
7. The gear tooth dimensions are checked using a gear tooth Vernier

**PRECAUTIONS:**

1. The milling machine must be stopped before setting up or removing a work piece, cutter or other accessory
2. Never stop the feeding of job when the cutting operation is going on, otherwise the tool will cut deeper at the point where feed is stopped.
3. All the chips should be removed from the cutter. A wiping cloth should be placed on the cutter to protect the hands.
4. The cutter should be rotated in the clockwise direction only for right handed tools.
5. The work piece and cutter should be kept as cool as possible (i.e. coolant should be used where necessary to minimize heat absorption).
6. The table surface should be protected with a wiping cloth.
7. Tool must be mounted as close to the machine spindle as possible.




Before Machining




## Calculation:

**Pitch circle Diameter DP** = Diameter of the Blank(**D**) – ( 2 X Module(**m**)) = 65-(2X2.5)=60

**Number of teeth Z**= Pitch circle Diameter / module = 60 / 2.5 = 24

**Circular Pitch PC** = $\pi$DP / Z

The relationship between **normal pitch** and **transverse pitch** is given by

$$PN = PC \times \cos\alpha$$

**Helical Gear considerations:**

Helix Angle $\alpha$ is related to Pitch circle diameter (DP) and the lead of the helix (L) by the following relation

$$\tan\alpha = \pi DP / L =$$

With any of the two known values, the third value can be found

**Indexing Calculation:** Indexing = 40 / Z =

**Result:** Thus a helical gear is cut out of the given blank using horizontal milling machine

**Exp. No: 4**

**Date:**

## GEAR GENERATION IN GEAR HOBBING MACHINE

---

**OBJECTIVES:**

To perform Helical gear milling on a given cylindrical work piece using Gear Hobbing machine.

**MATERIAL REQUIRED:**

A Cast iron block of 50 mm diameter and 20 mm length.

**TOOLS AND EQUIPMENT USED:**

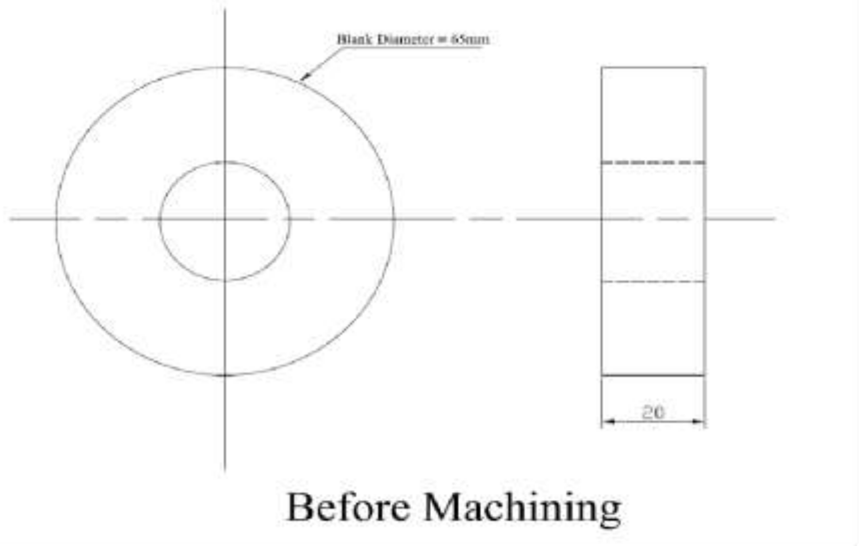
5. Vertical Milling machine
6. vernier caliper
7. Holding Materials
8. Milling Tools
9. Gear Hobbing machine
10. Hob
11. Gear Tooth Vernier
12. Spanners

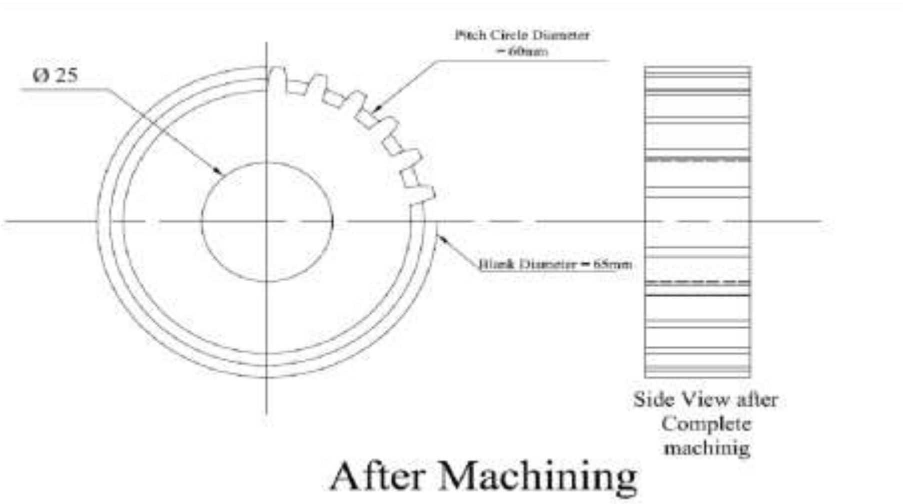
**PROCEDURE:**

1. The given work piece is held firmly on the spindle of the gear Hobbing machine
2. The Hob is set at an angle equal to its helix angle, with the axis of the blank for cutting spur gear
3. Gear ratio is set at a desired value to achieve the required speed of the hob and the work piece
4. The machine is switched on. The work piece and the hob are allowed to rotate, at the desired speed
5. The hob or the work piece is given full depth of cut equal to the tooth depth
6. The cutter is given feed for full width of the work piece
7. After machining all the teeth the machine is switched off
8. The dimensions of the teeth are checked using a gear tooth Vernier

**PRECAUTIONS:**

1. The milling machine must be stopped before setting up or removing a work piece, cutter or other accessory
2. Never stop the feeding of job when the cutting operation is going on, otherwise the tool will cut deeper at the point where feed is stopped.
3. All the chips should be removed from the cutter. A wiping cloth should be placed on the cutter to protect the hands.
4. The cutter should be rotated in the clockwise direction only for right handed tools.
5. The work piece and cutter should be kept as cool as possible (i.e. coolant should be used where necessary to minimize heat absorption).
6. The table surface should be protected with a wiping cloth.
7. Tool must be mounted as close to the machine spindle as possible.




## Calculation:

**Module of the Hob (m)** = 2.5 mm

**Blank Diameter** = 65 mm

**Pitch Circle Diameter:**

For any gear, Outer Diameter( OD ) = Pitch circle diameter + ( 2 X module )

For the given conditions, Pitch circle diameter (PCD ) = OD – ( 2 X m )

= 65 – (2 X 2.5)

= 60 mm

**Number Of teeth:**

Number of Teeth (Z) = PCD / m

= 60 / 2.5

= 24

Therefore number of teeth = 24

**Indexing Calculation**:

Indexing = 40 / Z = 40 / 24 = 1 2/3

**Result:** Thus the given blank ( work piece ) is converted into a gear of required dimensions by gear generation operation in a gear Hobbing machine

**Exp. No: 5**

**Date:**

## SURFACE GRINDING

**OBJECTIVES:**

To grind the given square plate using horizontal spindle surface grinding machine

**MATERIAL REQUIRED:**

A mild steel plate of 50X50X5mm

**TOOLS AND EQUIPMENT USED:**

1. Surface grinding machine
2. Vernier caliper

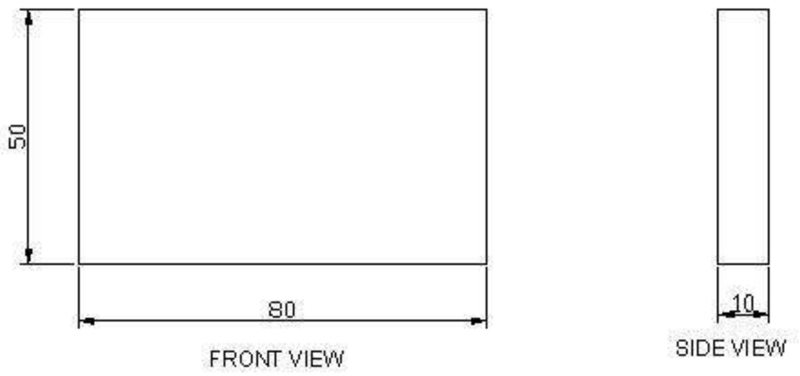
**PROCEDURE:**

1. Measure the given job for the dimensions and by studying the drawing calculates the amount of material to be removed from the existing job.
2. Place the job on the machine table and actuate the magnetic hold of the table.
3. Raise the table to the level of the grinding wheel and by providing the necessary depth of cut and feed remove the material surface.
4. Remove the job and verify for the required dimension with the help of vernier caliper. If required repeat the procedure with appropriate depth of cut.

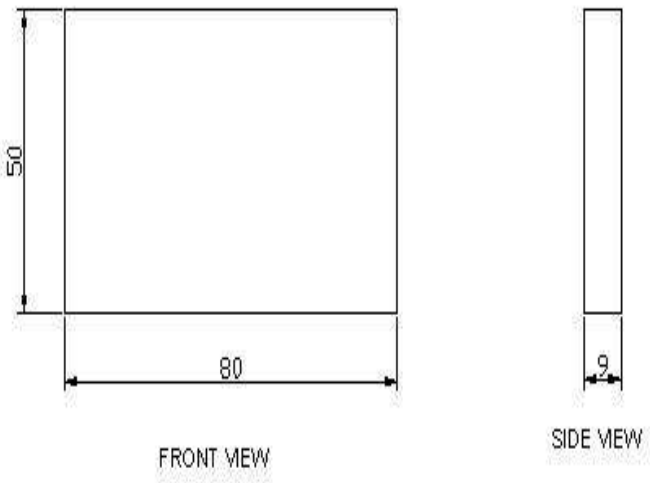
**PRECAUTIONS:**

1. The grinding tools are first dressed properly.
2. Care has to be taken so as to maintain the right feed of the material.
3. Work-wheel interface zone is to be flooded with coolant
4. Dressing of grinding wheel to be done before commencement of cutting action, intermittent dressing also to be done if wheel is loaded.

## BEFORE GRINDING




## AFTER GRINDING




ALL DIMENSIONS ARE IN MM

**RESULT:**

Required specimen successfully obtained according to specified operation (surface grinding ) with given dimensions.

**Exp. No: 6**

**Date:**

## CYLINDRICAL GRINDING

**OBJECTIVES:**

To grind the given cylindrical work piece using cylindrical grinding machine

**MATERIAL REQUIRED:**

A mild steel bar of 25 mm diameter and 75 mm length.

**TOOLS AND EQUIPMENT USED:**

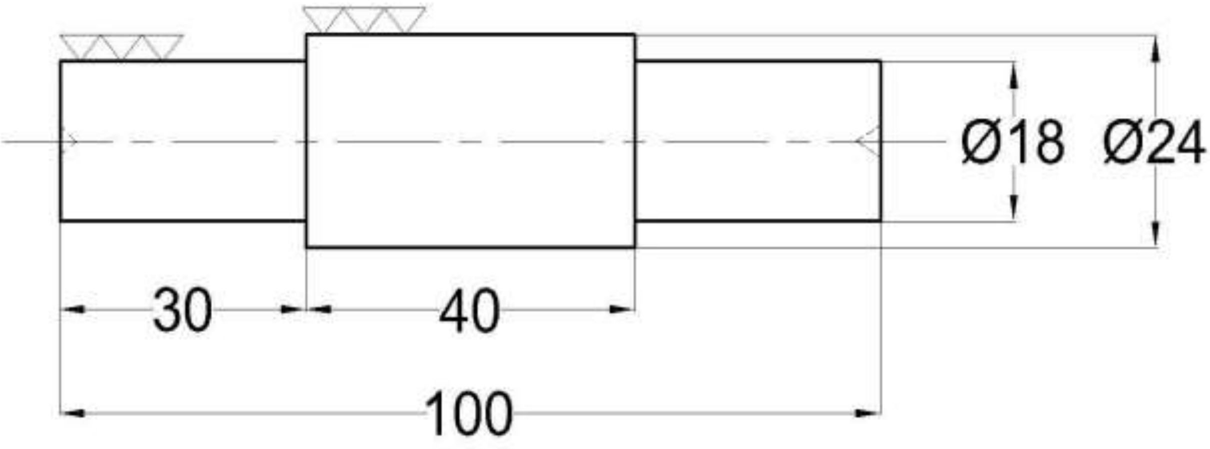
1. Cylindrical grinding machine
2. Vernier caliper
3. Outside caliper
4. Steel rule

**PROCEDURE:**

1. The given work piece is taken and checked for its dimensions.
2. The work piece is fired in between the live and dead centres and is rotated.
3. Raise the table to the levels of the grinding wheel and by providing the necessary depth of cut and feed remove the material surface.
4. Machining is done by the movement of grinding wheel head into the work piece.
5. Remove the job and check its dimensional accuracy

**PRECAUTIONS:**

1. The grinding tools are first dressed properly.
2. Care has to be taken so as to maintain the right feed of the material.
3. Work-wheel interface zone is to be flooded with coolant
4. Dressing of grinding wheel to be done before commencement of cutting action, intermittent dressing also to be done if wheel is loaded.




ALL DIMENSIONS ARE IN MM

**RESULT:**

Required specimen successfully obtained according to specified operation (cylindrical grinding ) with given dimensions.

**Exp. No: 7**

**Date:**

## MEASUREMENT OF FORCES USING LATHE TOOL DYNAMOMETER

---

**OBJECTIVES:**

To measure the forces for the given parameters by using lathe tool dynamometer.

**MATERIAL REQUIRED:**

A mild steel bar of 25 mm diameter and 75 mm length.

**TOOLS AND EQUIPMENT USED:**

1. Lathe machine
2. H.S.S. single point cutting tool
3. Lathe Tool Dynamometer.
4. Chuck key
5. Tool post key
6. Vernier caliper
7. Steel rule.

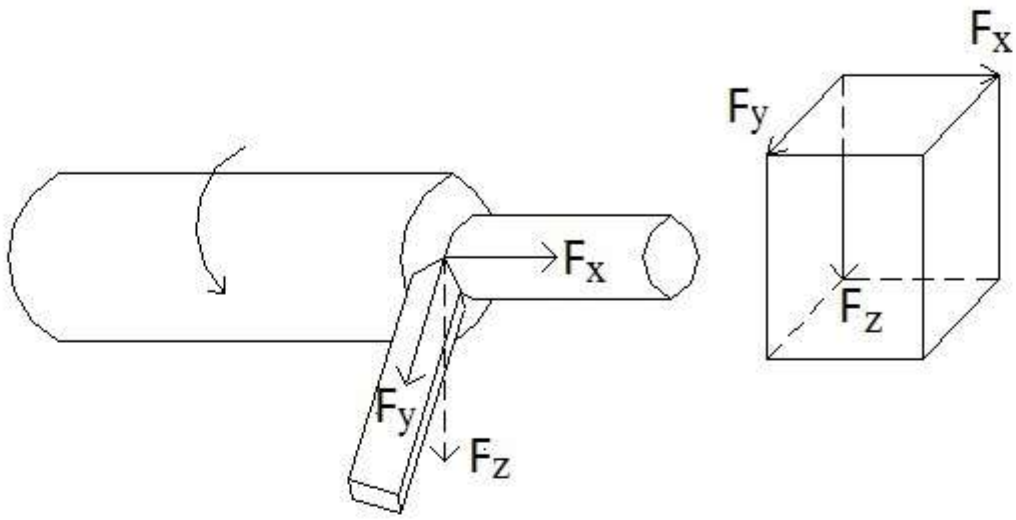
**PROCEDURE:**

1. The Lathe Tool Dynamometer is initially set to zero reading.
2. The known parameter ( Speed, Feed and Depth of cut) is given and take the readings of Fx, Fy and Fz force components from the Lathe Tool Dynamometer.
3. Calculate the resultant cutting force
   $F = Sqrt\ (Fx^2 + Fy^2 + Fz^2)$
4. Repeat the same procedure to get few more readings and calculate the mean cutting force.
5. Repeat the same procedure for different depth of cuts.

**NOTE :**

1. Fz – the main or tangential component, determines the torque on main drive mechanism, the deflection of the tool and the required power. This component acts in the direction of the cutting speed.
2. Fx – the axial component, acts in the direction of the tool traverse and it is at right angles to Fz. It contributes very little to the power consumption.
3. Fy – the radial component, acts along the tool shank and perpendicular to the other two components. It has no share in the power consumption.

**MEASUREMENT OF CUTTING FORCE**




**TABULATION**

| S.No | Depth of cut (mm) | Speed (RPM) | $F_C$ KgF | $F_T$ KgF |
|---|---|---|---|---|
| 1 | 0.2mm | | | |
| 2 | 0.5mm | | | |
| 3 | 0.8mm | | | |

25

**RESULT:**

Required specimen successfully obtained according to specified parameter. Thus the cutting forces are measured for different parameters.

**Exp. No: 8**

**Date:**

## CONTOUR MILLING ON A VERTICAL MILLING MACHINE

### OBJECTIVES:

To perform contour milling on a given cylindrical work piece using vertical milling machine.

### MATERIAL REQUIRED:

Cast iron block of 50X50X50mm.

### TOOLS AND EQUIPMENT USED:

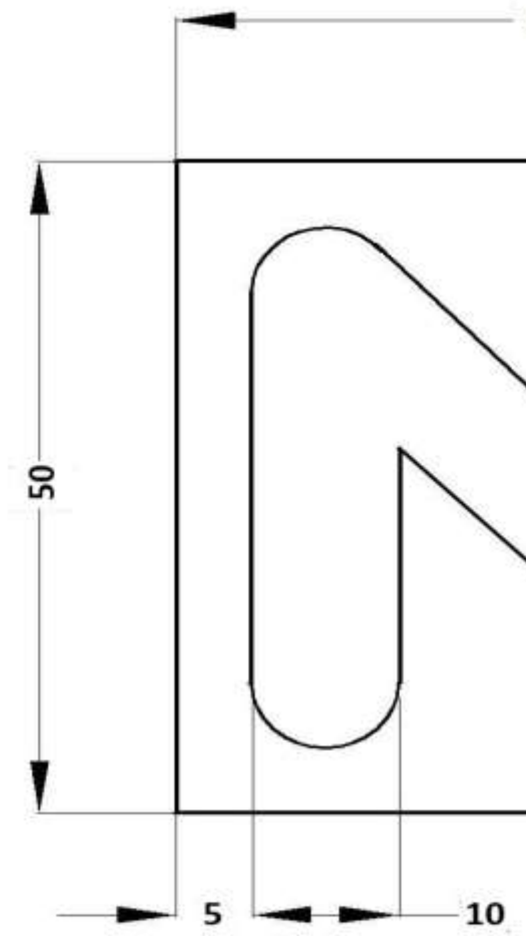
1. Vertical milling machine.
2. End mill cutter
3. Steel rule.

### PROCEDURE:

1. The dimensions of the given work piece is measured using the help of vernier caliper.
2. Then the work piece is held in the vice of the vertical milling machine.
3. The machine is switched on and cutter gets revolved and then feed is given.
4. Finally, the work piece is checked for the dimensions.

### PRECAUTIONS:

1. The milling machine must be stopped before setting up or removing a work piece, cutter or other accessory
2. Never stop the feeding of job when the cutting operation is going on, otherwise the tool will cut deeper at the point where feed is stopped.
3. All the chips should be removed from the cutter. A wiping cloth should be placed on the cutter to protect the hands.
4. The cutter should be rotated in the clockwise direction only for right handed tools.
5. The work piece and cutter should be kept as cool as possible (i.e. coolant should be used where necessary to minimize heat absorption).
6. The table surface should be protected with a wiping cloth.
7. Tool must be mounted as close to the machine spindle as possible.




ALL DIMENSIONS ARE IN MM

**RESULT:**

Required specimen successfully obtained according to specified operation (contour milling) with given dimensions.

**Exp. No: 9**

**Date:**

## TOOL ANGLE GRINDING USING TOOL AND CUTTER GRINDER

**OBJECTIVES:**

To perform facing, turning, drilling, tapping, grooving and parting-off operations on a given cylindrical work piece using Capstan Lathe.

**MATERIAL REQUIRED:**

HSS bar of 60 mm length

**TOOLS AND EQUIPMENT USED:**

Tool and cutter grinder machine

**PROCEDURE:**

1. The given work piece is taken and checked for its dimensions.
2. Grinding wheel and grinding spindle are kept in position with the work piece.
3. For proper grinding process wheel speed, work speed, transverse speed of the wheel in feed, area of contact is to be noted.
4. While running the area of contact is adjusted accordingly to the spindle in order to remove the surface.
5. It is done slowly to remove the materials on all surface of the tool.

**PRECAUTIONS:**

1. The grinding tools are first dressed properly.
2. Care has to be taken so as to maintain the right feed of the material.
3. Dressing of grinding wheel to be done before commencement of cutting action, intermittent dressing also to be done if wheel is loaded.

## SINGLE POINT CUTTING TOOL ANGLES

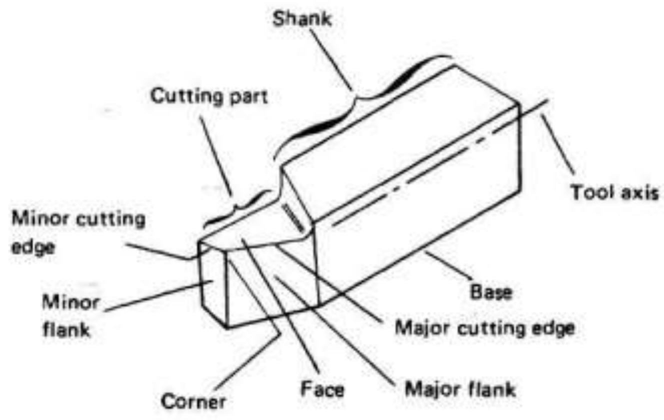
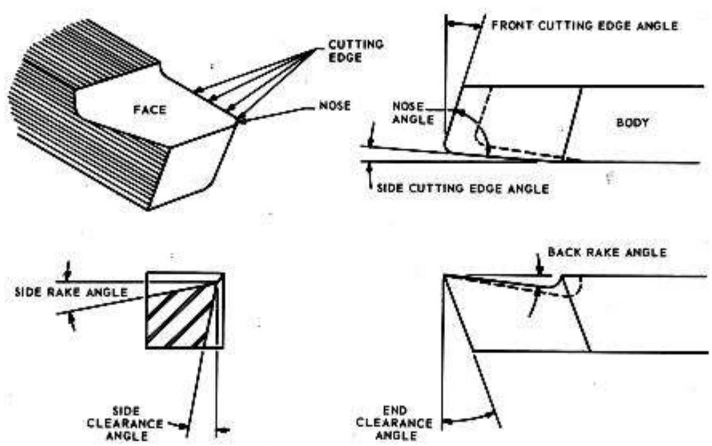



Figure 1.4 Typical single-point tool.




### GRINDING ANGLES TO BE FOLLOWED:

| Back Rake angle | Side Rake Angle | End cutting edge angle | Side cutting edge angle | End Clearance angle | Side Clearance Angle |
|---|---|---|---|---|---|
| 8° | 10° | 15° | 15° | 5° | 5° |

**RESULT:**

Required specimen successfully obtained according to specified operations (tool angle grinding) with given dimensions.

**Exp. No: 10**

**Date:**

## FACING, TURNING, TAPER TURNING AND CHAMFERING OPERATIONS ON A CNC LATHE

### OBJECTIVES:

To perform facing, turning, taper turning and chamfering operations by using a CNC lathe machine.

### MATERIAL REQUIRED:

Aluminium billet of 28 diameter and 70 mm length.

### TOOLS AND EQUIPMENT USED:

1. CNC lathe machine.
2. CNC Edge cam Software

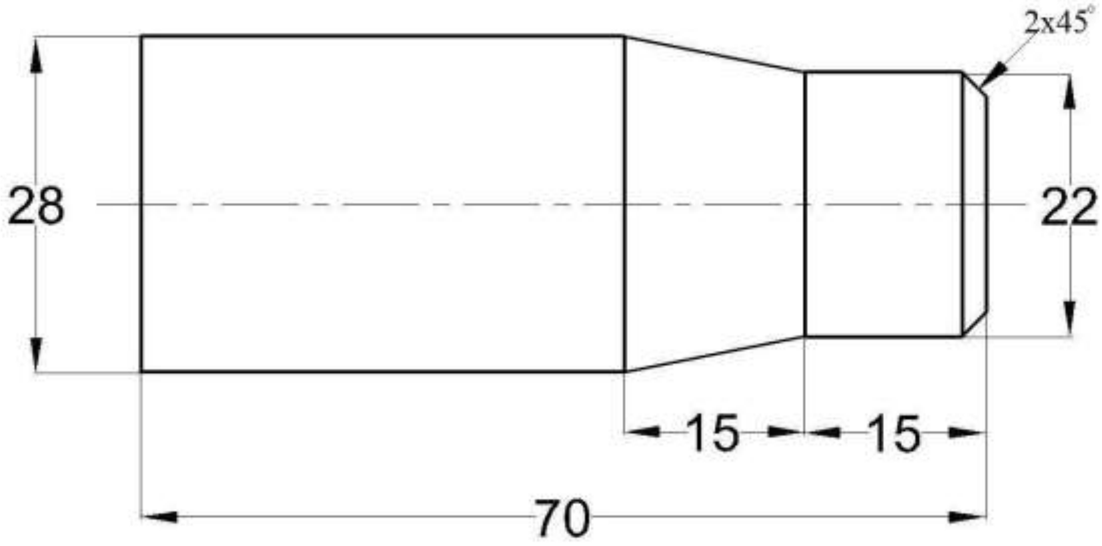
### SEQUENCE OF OPERATIONS:

1. Facing
2. Turning
3. Chamfering
4. Taper turning

### PROGRAM:

```
[BILLET X28 Z70]
G21 G98
G28 U0 W0
M06 T01
M03 S1500
G00 X28 Z1
G90 X27 Z-15 F40
        X26
        X25
        X24
        X23
        X22
G00 X22 Z1
G01 Z0
G90 X22 Z-2 R-0.5 F30
        X22 R-1
G00 X28 Z-14
```

```
G01 Z-15
G90 X28 Z-30 R-1 F30
        X28 R-2
        X28 R-3
G28 U0 W0
M05
M30
```




ALL DIMENSIONS ARE IN MM

**RESULT:**

Required specimen successfully obtained according to specified operations (facing, turning, taper turning and chamfering) with given dimensions.

**Exp. No: 11**

**Date:**

## CONTOUR MILLING ON A CNC MILLING

### OBJECTIVES:

To perform contour milling operation on a given workpiece by using a CNC milling machine.

### MATERIAL REQUIRED:

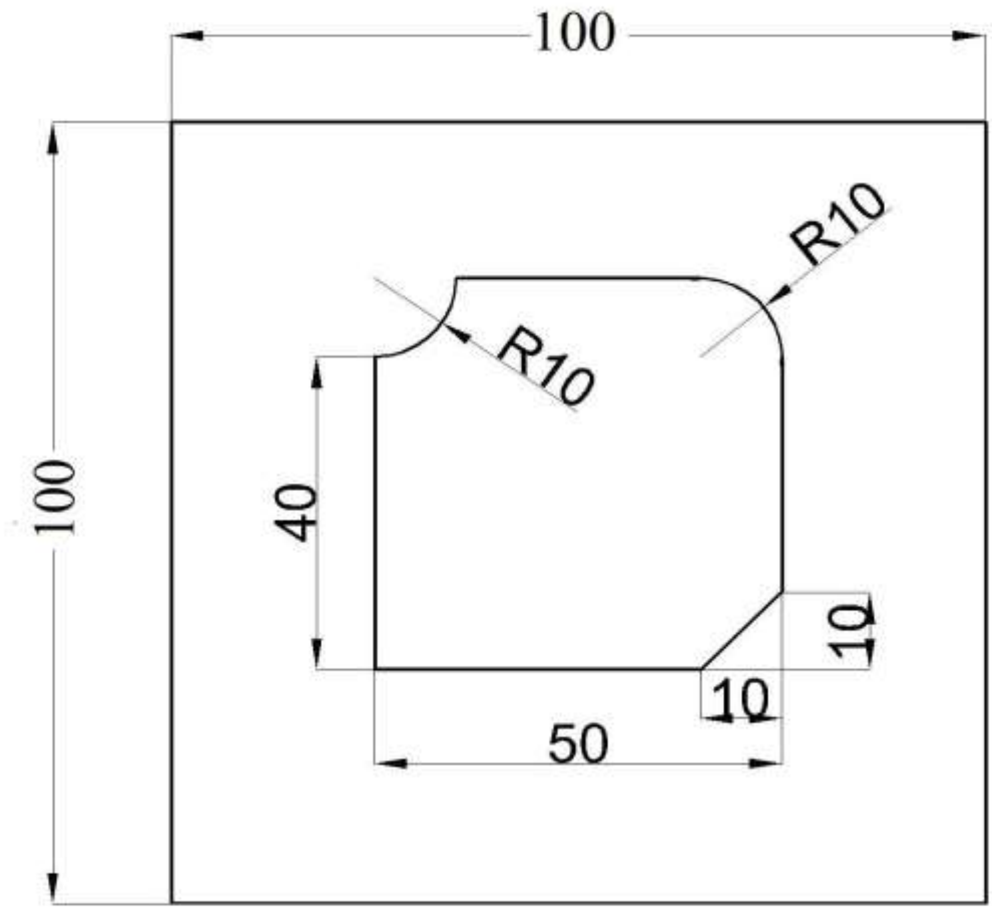
Aluminium billet of 100X100X10mm..

### TOOLS AND EQUIPMENT USED:

1. CNC milling machine.
2. CNC Edge cam Software

### PROGRAM:

```
[BILLET X100 Y100 Z10]
EDGE MOVE X50 Y50
TOOL DEF T1 D06
G21 G94
G91 G28 Z0
M03 S1500
G00 X28 Z1
G90 G40 G00 X-25 Y-25 Z5
G01 Z-2 F30
G01 X15 Y-25
G01 X25 Y-15
G01 X25 Y15
G03 X15 Y25 R10
G01 X-15 Y25
G02 X-25 Y15 R10
G01 X-25 Y-25
G01 Z5
G91 G28 Z0
G28 U0 W0
M05
M30
```




ALL DIMENSIONS ARE IN MM

**RESULT:**

Required specimen successfully obtained according to specified operation (contour milling) with given dimensions.