

# ***IPE 402***

## Experiment No. 1

### **STUDY AND OPERATION OF SURFACE GRINDING MACHINE**

#### **1.1 Abrasive Machining Processes**

Abrasive machining is the basic process in which chips are formed by very small cutting edge that is integral parts of the abrasive particles. The results that can be obtained by abrasive machining range from the finest and smoothest surfaces produced by any machining processes, in which very little material is removed, to rough, coarse surfaces and accompany high material removal rate (MRR). The abrasive particles may be (1) Free, (2) Mounted in resin on a belt, or (3) close packed into wheels or stones, with abrasives held together by bonding material (called bonded product). The metal removal process is basically the same in all three cases but with important differences due to spacing of active grains (grains in contact with the work piece) and the rigidity and degree of fixation of the grains. The following table describes the primary abrasive process.

Process	Particle Mounting	Features
Grinding	Bonded	Uses wheels, accurate sizing, finishing, low MRR
Abrasive Machining	Bonded	High MRR, to obtain desired shapes and approximate sizes
Snagging	Bonded	High MRR, rough rapid technique to clean up castings, forgings
Honing	Bonded	“Stones” containing fine abrasives; primarily a hole finishing process
Lapping	Free	Fine particles embedded in soft metal or cloth; primarily a surface-finishing process

#### **1.2 Abrasives**

An abrasive is a hard and tough substance. It has many sharp edges. An abrasive cuts or wears away materials that are softer than it. Abrasives are used as cutting tools or cutting materials.

##### **1.2.1 Properties of Abrasives**

**1. Penetration Hardness:** This property refers to tire ability of the scratch or cut a softer material. The following table shows hardness values of Abrasive materials and other materials.

	Moh Scale	Knoop Scale
Common glass (depending on composition)		300-500
Hard Steel (Rockwell C. 60.5)		740
Quartz	7	820
Synthetic blue spinel		1270
Topaz	8	1350
Garnet		1350
Cemented carbides		1400-1800
Tungsten carbide		1800
Aluminum oxide or corundum	9	2000
Silicon carbide		2500
Boron carbide		2800
Diamond (Mined or manufactured)	10	Greater than 7000

**2. Fracture Resistance:** This property refers to the ability of an abrasive material to resist breaking or cracking under load.

**3. Wear Resistance:** It refers to the ability of the abrasive grain to maintain sharpness. Wear resistance is largely related to penetration hardness and tensile strength of the abrasive.

### 1.2.2 Types of Abrasives

Abrasives are broadly classified in two groups. They are: a) Natural Abrasives and b) Artificial or Manufactured abrasives.

**a) Natural Abrasives:** Natural abrasives are obtained from nature. They are being replaced rapidly by artificial abrasives. Except for diamond, the natural abrasives are relatively soft in comparison with the artificial abrasives. Some of the natural abrasives that are used to work metal are listed below with brief description:

- I) Crocus: Crocus is a reddish-brown oxide of iron and may be natural or synthetic.
- II) Emery: Emery used for abrasives usually is composed corundum (Al<sub>2</sub>O<sub>3</sub>) and 40% iron oxide and other impurities.
- III) Diamond: Diamond, the hardest material known, is used in the form of grains bonded together to form an abrasive stick or grinding wheel.

**b) Artificial Abrasives:** The manufactured or artificial abrasives are harder and have greater impact toughness than any of the natural abrasives except diamond. The commonly used artificial abrasives are: I) Silicon Carbide, II) Aluminum Oxide, III) Boron Carbide, IV) Synthetic diamond etc.

### 1.3 Grinding wheels and their selection

Grinding wheels are made of thousands of crushed abrasive grains held together by a substance called BOND. Between the abrasive and the bonding material are pores or air space. These spaces provide clearance for chips removed in the grinding process, and they minimize wheel loading.

### 1.3.1 Cutting action of a grinding wheel

Each abrasive grain in a grinding wheel is a cutting tool. Each has sharp cutting edge which cutoff tiny particles from the metal being ground. The following figure shows the magnified view of metal chips produced by abrasive wheels.

**I) Finish-grinding:** On finish-grinding operations, grinding wheels remove metal relatively slowly in comparison with other cutting tools. Finish grinding usually follows other rough-machining operations, and it generally involves machining to very close tolerance.

**II) Abrasive machining operations:** On abrasive-machining operations, metal is removed more rapidly than on finish-grinding operations. The term abrasive machining is used for grinding applications which involve the removal the removal of a relatively large amount of metal, usually 1.5 mm or more in depth.

### 1.3.2 Classification of grinding wheels

Grinding wheels are classified according to their size and shape, type of abrasive used, grain size, type of bond (Vitrified, Silicate, Rubber, Shellac, Resinoid etc.), grade or hardness and structure (closely packed or open packed). The following self explanatory figures show some of the classifications:

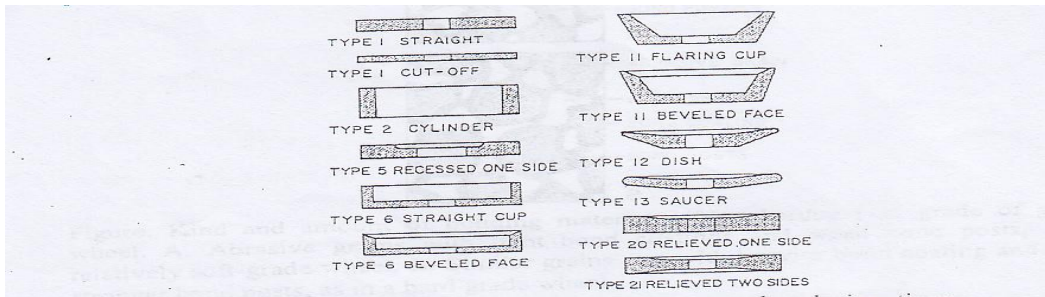


Figure: Some standard grinding wheel shapes with type number designations

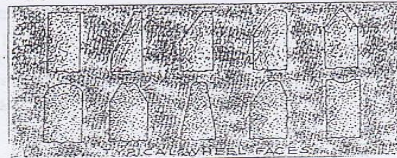


Figure: Typical standard wheel faces

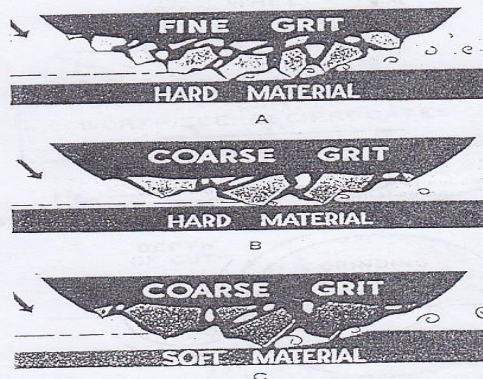


Figure: Comparison of grain size and rate of metal removal with grinding wheels

Figure: Kind and amount of bonding material affects hardness or grade of grinding wheel. A. Abrasive grains with light bond coatings and weak bond posts, as in a relatively soft-grade wheel. B. Similar grains, but with heavier bond coating and thicker, stronger bond posts, as in a hard grade wheel.

## 1.4 Grinding and grinding machines

Grinding machines are precision machine tools. They machine metal parts to very close tolerances. They produce high-quality surface finishes. Grinding machines are available for grinding flat surfaces, external and cylindrical surfaces, tapered surfaces and irregular surfaces, Internal grinding, Form grinding, Plunge grinding, Center less grinding, Tool and cutter grinding, Offhand grinding etc.. The following figures show some of them.

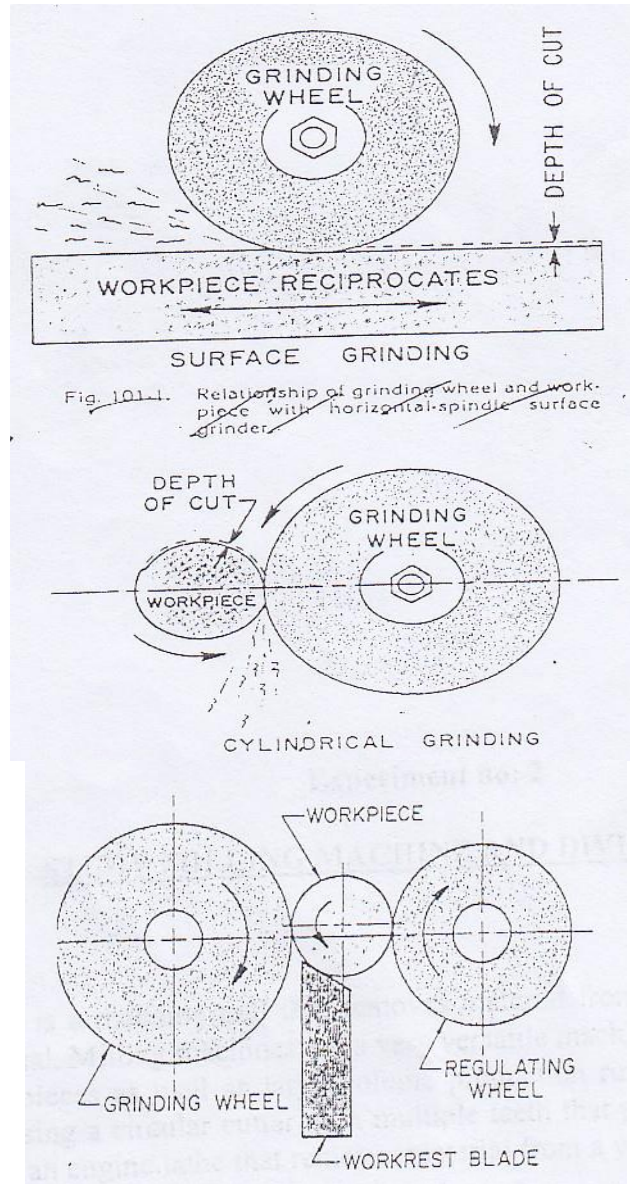


Figure: Surface grinding and cylindrical grinding

### **1.5 Tiring or Dressing of Wheels**

A grinding wheel should be trued each time it is put on the spindle. It should be dressed whenever it becomes dull, loaded or grazed, with use. Tiring refers to correcting an out of round condition of the wheel. A dressing tool is used to remove particles of the abrasive from the high part of the wheel. Tiring also refers to forming the wheel to a particular shape, such as a concave or convex surface. To be in good condition, the wheel must be sharp and run true on both the periphery and the sides.

Dressing produces a sharp grinding surface. A diamond tool is used to remove the dull or loaded surface of the wheel. Dressing is necessary whenever the wheel cuts poorly, usually resulting in burning the work (the dark surface being caused by heat oxidation).

## Experiment no: 2

### **STUDY MILLING MACHINE AND DIVIDING HEAD**

#### **2.1 Introduction**

Milling machine is a machine tool that removes material from a work piece by rotating a cutter and moving it into the material. Milling machines are a very versatile machine tool. Milling machines are capable of machining one or two pieces as well as large volume production runs. The milling machine can produce a variety of surfaces by using a circular cutter with multiple teeth that progressively produce chips as the cutter rotates. Compare this to an engine lathe that removes material from a work piece by rotating the work piece and not the tool.

#### **2.2 Types of Milling Machine**

There are two major types of milling machines, the vertical milling machine and the horizontal milling machine. As their names imply, a vertical milling machine spindle axis is vertical and the horizontal milling machine spindle axis is horizontal. In addition the vertical milling machine has a machine table that moves perpendicular to the spindle axis of rotation and the horizontal milling machine has a work table that moves parallel to the spindle axis of rotation.

The vertical milling machine is the most common type found in the machine shop today. However, during the first half of the 20th century the horizontal milling machine was the primary machine tool used for milling purposes. There are far fewer horizontal milling machines in production today than vertical machines. Another type of mill is the combination milling machine. This milling machine is a hybrid of the vertical and the horizontal. Still another type of specialty milling machine is the universal milling machine. It is usually a horizontal milling machine with a swiveling table.

#### **2.3 Parts of Milling Machine**

The vertical knee mill is the most common milling machine found in machine shops today. Therefore it will be used as an example to describe the general parts of all mills.

The head (drive) is that part of the drive system that transforms electrical power from a motor to mechanical power in the spindle. The drive system also allows the machinist to change the speed of the spindle (RPM) and therefore the cutting tool. The quill moves vertically in the head and contains the spindle in which cutting tools are installed. The quill feed hand wheel moves the quill up and down within the head as does the quill feed lever. The knee moves up and down by sliding on ways that are parallel to the column. The saddle sits on the knee and allows translation of the worktable sitting on the base is the column whose main function is to hold the turret. The turret allows the milling head to be rotated around the column's center. The over arm (ram) slides on the turret and allows the milling head to be repositioned over the table.

The longitudinal traverse hand wheel moves the worktable to the left and right, the cross traverse hand wheel moves the work table in and out, the vertical movement crank moves the knee, saddle, and worktable up and down.

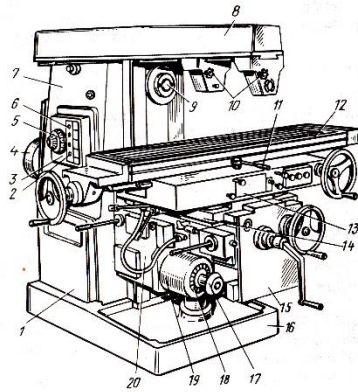


Fig. 12.2. Horizontal universal knee-type milling machine, model 6P82: 1 — column; 2, 6 — pushbutton control panel; 3 — speed-change panel; 4 — main motor; 5 — spindle speed selection dial; 7 — speed gearbox (inside column); 8 — overarm; 9 — spindle; 10 — bearing brackets; 11 — longitudinal-feed control lever; 12 — work table; 13 — swivel plate; 14 — cross slide; 15 — knee; 16 — base plate; 17 — feed selection knob; 18 — feed dial; 19 — feed change mechanism; 20 — feed gearbox

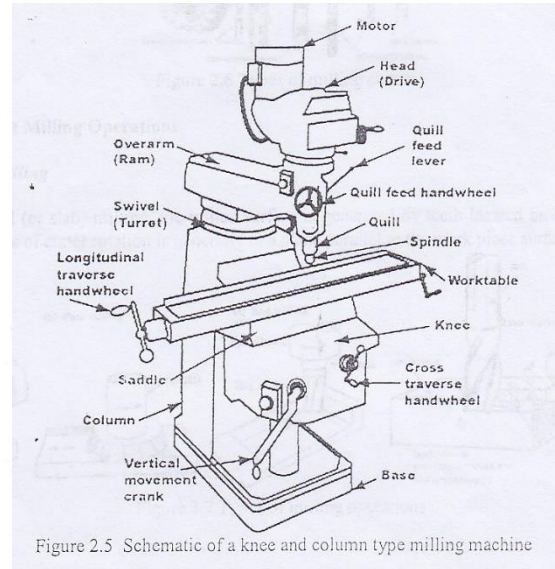


Figure 2.5 Schematic of a knee and column type milling machine

## 2.4 Milling Cutters

A milling cutter is a cutting tool that is used on a milling machine. Milling cutters are available in many standard and special types, forms, diameters, and widths. The teeth may be straight (parallel to the axis of rotation) or at a helix angle. The helix angle helps a slow engagement of the tool distributing the forces. The cutter may be right-hand (to turn clockwise) or left-hand (to turn counterclockwise). The figure shows a typical end milling cutter.

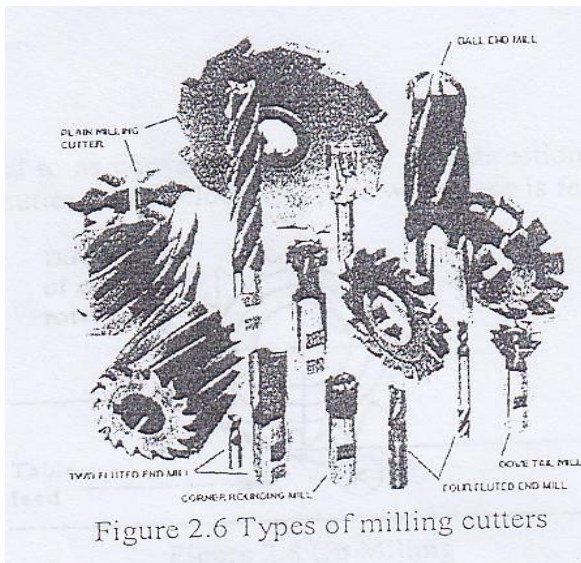


Figure 2.6 Types of milling cutters

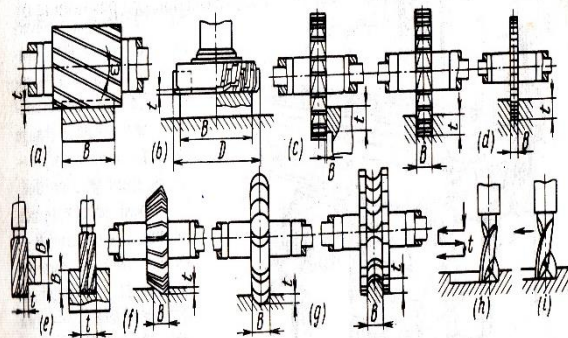
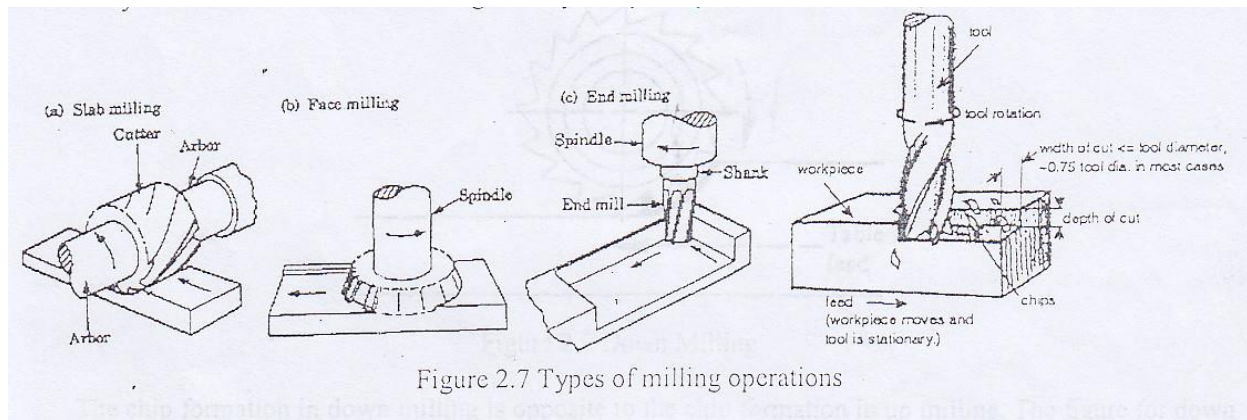


Fig. 12.1. Types of milling operations and milling cutters used ( $t$  — depth of cut;  $B$  — width of cut): (a) cylindrical spiral cutter; (b) face cutter; (c) disc cutter; (d) slitting saws; (e) end cutters; (f) angle cutter; (g) form cutters; (h) keyway cutter for milling machines with intermittent vertical feed of cutter; (i) keyway cutter for one-pass milling on vertical milling machines

## 2.5 Classification of Milling Operations

### 2.5.1 Peripheral Milling

In peripheral (or slab) milling, the milled surface is generated by teeth located on the periphery of the cutter body. The axis of cutter rotation is generally in a plane parallel to the work piece surface to be machined.



### 2.5.2 Face Milling

In face milling, the cutter is mounted on a spindle having an axis of rotation perpendicular to the work piece surface. The milled surface results from the action of cutting edges located on the periphery and face of the cutter.

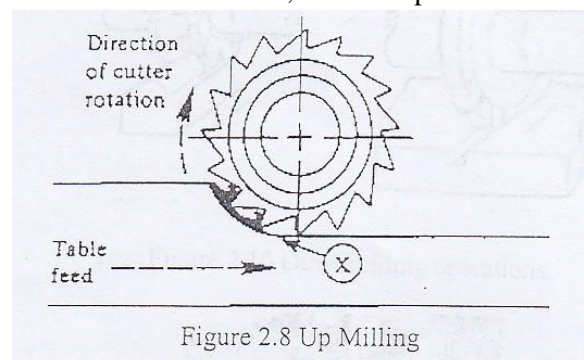
### 2.5.3 End Milling

The cutter in end milling generally rotates on an axis vertical to the work-piece. It can be tilted to machine tapered surfaces. Cutting teeth are located on both the end face of the cutter and the periphery of the cutter body.

## 2.6 Methods of Milling

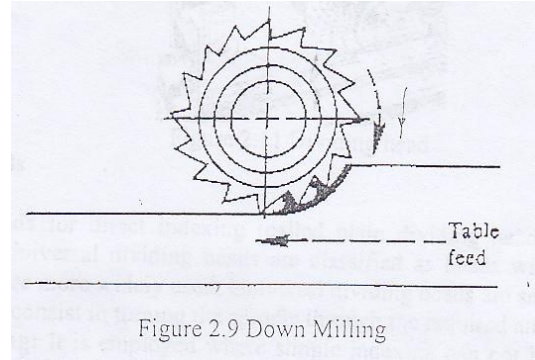
### 2.6.1 Up Milling

Up milling is also referred to as conventional milling. The direction of the cutter rotation opposes the feed motion. For example, if the cutter rotates clockwise, the work-piece is fed to the right in up milling.



## 2.6.2 Down Milling

Down milling is also referred to as climb milling. The direction of cutter rotation is same as the feed motion. For example, if the cutter rotates counterclockwise, the work-piece is fed to the right in down milling.



The chip formation in down milling is opposite to the chip formation in up milling. The figure for down milling shows that the cutter tooth is almost parallel to the top surface of the work piece. The cutter tooth begins to mill the full chip thickness. Then the chip thickness gradually decreases.

## 2.7 Dividing Heads

A dividing head is a tool that is used to divide a circle into equal divisions. Dividing heads are employed in operations on knee type milling machine for setting the work piece at the required angle to the table of the machine, turning the work piece through a pre determined angle, dividing circle into the required number of parts (indexing) and also for continuous rotation of the work piece in milling helical grooves with a large lead.

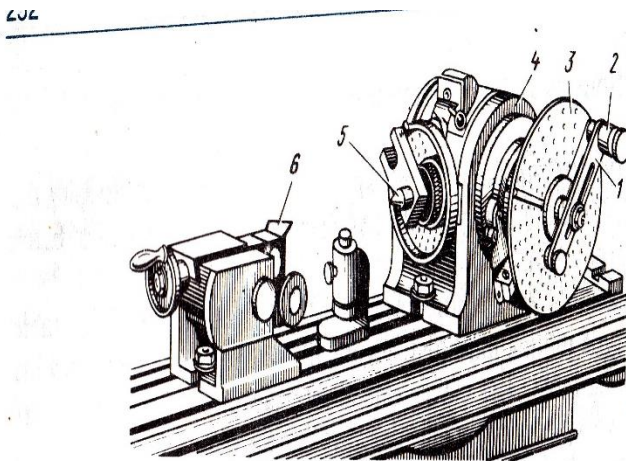


Fig. 12.15. Index-plate universal dividing head: 1 — index crank; 2 — index-crank pin; 3 — index plate; 4 — housing; 5 — spindle; 6 — tailstock

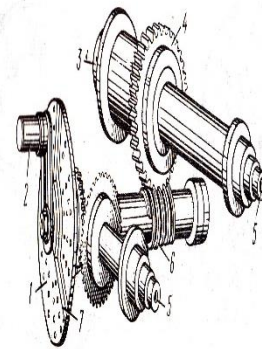


Fig. 12.16. Index-plate universal dividing head: 1 — index plate; 2 — index crank; 3 — spindle; 4 — worm wheel ( $z = 40$ ); 5 — necks to receive pick-off gears; 6 — worm ( $Z = 1$ ); 7 — sector finger

## 2.8 Types of dividing heads

There are dividing heads for direct indexing (called plain dividing heads), optical dividing heads and universal dividing heads. Universal dividing heads are classified as heads with and without an index plate. Index plate dividing heads are more widely used. Universal dividing heads are setup for:

- a. Simple indexing:** It consists in turning the spindle through the required angle by rotating the index crank.
- b. Differential Indexing:** It is employed where simple indexing can not be effected i.e. where an index plate with the number of holes required for simple indexing is not available.
- c. Cutting helical grooves:** In milling helical grooves, a complex helical movement is imparted to the work-piece, which involves a straight movement along the work piece axis and rotation of the work-piece about the same axis.

## 2.9 Setting up a universal dividing head for milling helical grooves

In milling helical grooves, a complex helical movement is imparted to the work piece, which involves a straight movement along the work piece axis and rotation of the work piece about the same axis. The work piece receives the straight movement with the work table of the machine, and rotation, from the work-table lead screw through the change gears. The table is set to the spindle axis at an angle  $\omega$  equal to the helix angle of the groove being cut. In milling a left-hand groove, the table is swiveled clock-wise at an angle  $\omega$ , and in cutting a right hand groove, counterclockwise (Figure 2.12)

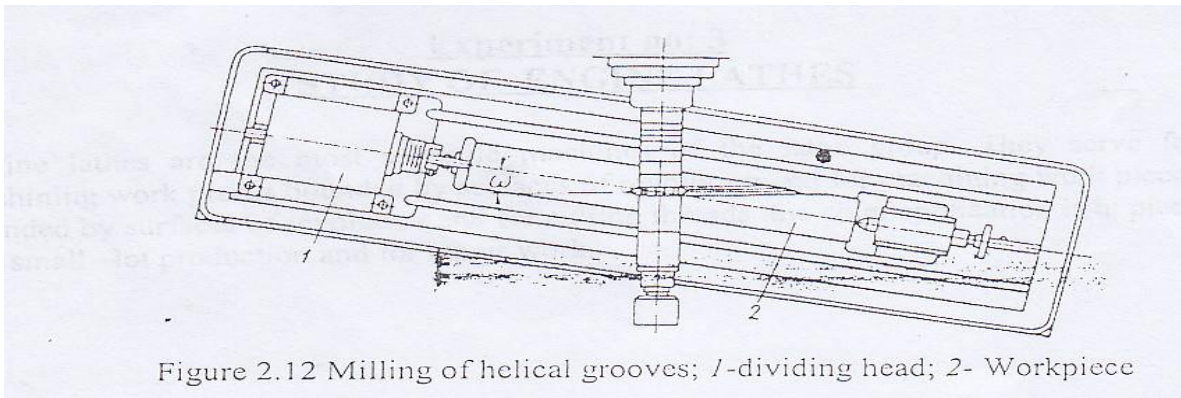


Figure 2.12 Milling of helical grooves; 1-dividing head; 2- Workpiece

The set angle for the table is,

$$\omega = \arctan \frac{\pi D}{P_{h.g}}$$

Where  $D$  = diameter of the work piece being cut;  $P_{h.g}$  = Lead of helical groove. If the helix is determined by the lead angle  $\alpha$ , the table should be set at an angle of  $90^\circ - \alpha$ . Slow rotation is imparted to the diving

head spindle along the kinematic balance equation of this chain for setting up change-gear train  $\frac{a_1}{b_1} \frac{c_1}{d_1}$

worked out provided that for every revolution of the work-piece the work table of the machine travels by an amount equal to the lead  $P_{h.g}$ . of the groove being cut.

$$\frac{z_0}{Z} 1.1.1 \frac{a_1}{b_1} \frac{c_1}{d_1} P_{L.S} = P_{h.g}$$

With  $Z=1m$  we obtain,

$$\frac{a_1}{b_1} \frac{c_1}{d_1} = \frac{P_{h.g}}{z_0 P_{L.S}}$$

Where  $P_{L.S}$  is the lead of work table lead screw, mm.

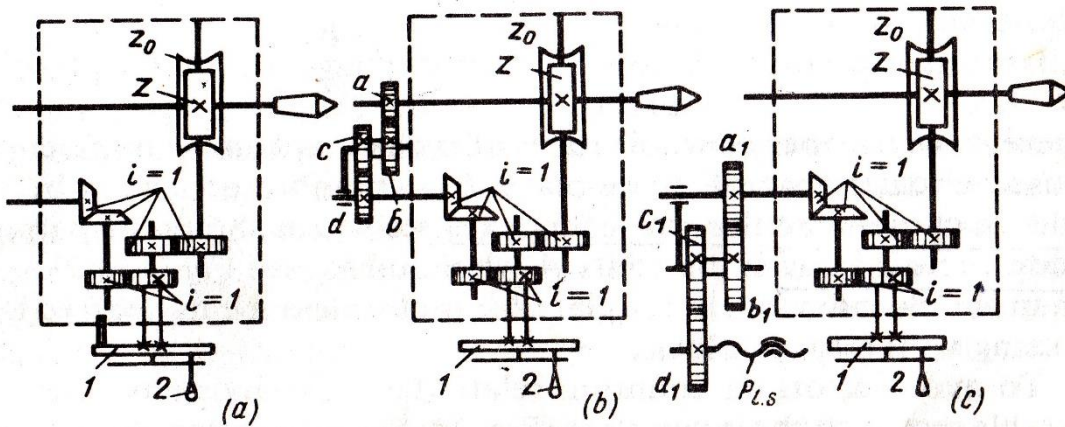


Fig. 12.17. Diagrams of universal dividing-head set-up

### Reference

1. Boothroyd G. & Knight., Fundamentals of Machining and Machine Tools
2. Kalpagjian S., Introduction to Manufacturing processes
3. Chernov S., Machine tools
4. DeGarmo E. paul, Material and process engineering



### **3.1 CONSTRUCTION ARRANGEMENT AND PRINCIPAL UNITS OF ENGINE LATHES**

All engine lathes have practically the same arrangement of the principal units. In a typical Engine Lathe the principal units are:

1. Headstock, 2. Tailstock, 3. Spindle, 4. Slide Ways, 5. Saddle, 6. Tool post, 7. Compound Rest, 8. Power Feed Clutch, 9. Feed Rod, 10. Bed, 11. Lead Screw, 12. Break Clutch Control, 13. Half Nut, 14. Apron, 15. Rack, 16. Motor Drive, 17. Gear Box.

### **3.2 LATHE ACCESSORIES**

1. Lathe Centers, 2. Lathe Dogs, 3. Tool holder, 4. Cutting Tools, 5. Steady Rest, 6. Follow Rest, 7. Knurling Tools, 8. Chucks, 9. Faceplates, 10. Mandrels, 11. Taper Attachments.

### **3.3 MODERN LATHE OPERATION**

All Lathes have same basic basis design. Their components serve one of three primary Functions:

- a) Driving the lathe-line of power.
- b) Holding and rotating work
- c) Holding and moving tool.

### **3.4 PROCEDURE FOR TAPER TURNING**

1. Turing a taper by setting over the Tailstock.
2. Turning a taper by Taper turning attachment.
3. Turning a taper by the two feeds method.
4. Turning a taper by swiveling the swiveling the swivel plate with the top slide.

### **ASSIGNMENTS**

- Q. How to center work in a four -Jaw independent Chuck.
- Q. Discuss about Feeds in Engine Lathe.
- Q. Discuss about Speeds in Engine Lathe.

### **References**

1. Machine tool Technology by Repp/McCarthy
2. Machine Tool by N. Chernov
3. Machine Tool by N. Acherkan

## Experiment no: 4

### **STUDY OF DIFFERENT COMPONENTS OF TURRET LATHES**

#### **4.1 OBJECTIVE**

To study the working principles of different parts of Turret Lathe and to set up the tool for operation.

#### **4.2 MODEL**

LHT32, Hexagonal turret lathe.

#### **4.3 DESCRIPTION**

The feature that distinguishes turret lathes from the other lathe machines is the turret. In the turret lathe machine the longitudinal slide or saddle carries hexagonal and cross slide a square turret. Various kinds of tools can be mounted on the turret and thus enhanced production rate with reduced tool handling time can be achieved.

Turret lathes are expedient when a considerable number of work tools having axes aligned to the work axis are required for machining. They are also used for doing turning operations for without making test cuts and measurements since the turrets are fed to the preset positive stops. The machining possibilities of turret lathes are very extensive. The use of multiple tool holders on turret lathes enables them to take multiple cuts simultaneously. The two main groups of turret lathes are those with vertical and those with horizontal axes of turret rotation. Hexagon turrets that index about a vertical axis have six tool holes. Tools, which can be used in a standard setup, are mounted in the tool holes of the turrets to the best advantage.

The advantages offered by the turret lathe as compared to conventional lathes are:

- Machining of complex shapes
- Both internal and external surfaces can be machined simultaneously
- Reduced tool-handling time due to the use of turret.
- Effective in lot production

In a hexagonal turret lathe 6 tools can be mounted and indexed simultaneously in order to facilitate high production rate and in case of square turret the number of tool that can be mounted is four. The main dimensions of a turret lathe is

- Bar capacity
- Maximum diameter machined over the bed

The main parts are:

- The bed
- Head stock
- Feed gear box
- Aprons
- Turret saddle
- Cross slide

#### **4.4 WORKING MOTIONS OF A TURRET LATHE**

Figure 2 shows the working motions of a turret lathe.

$v$  = Primary cutting motion (rotation of the spindle)  
 $s_1$  = Feed motion (longitudinal travel of the turret)  
 $s_2$  = Cross travel

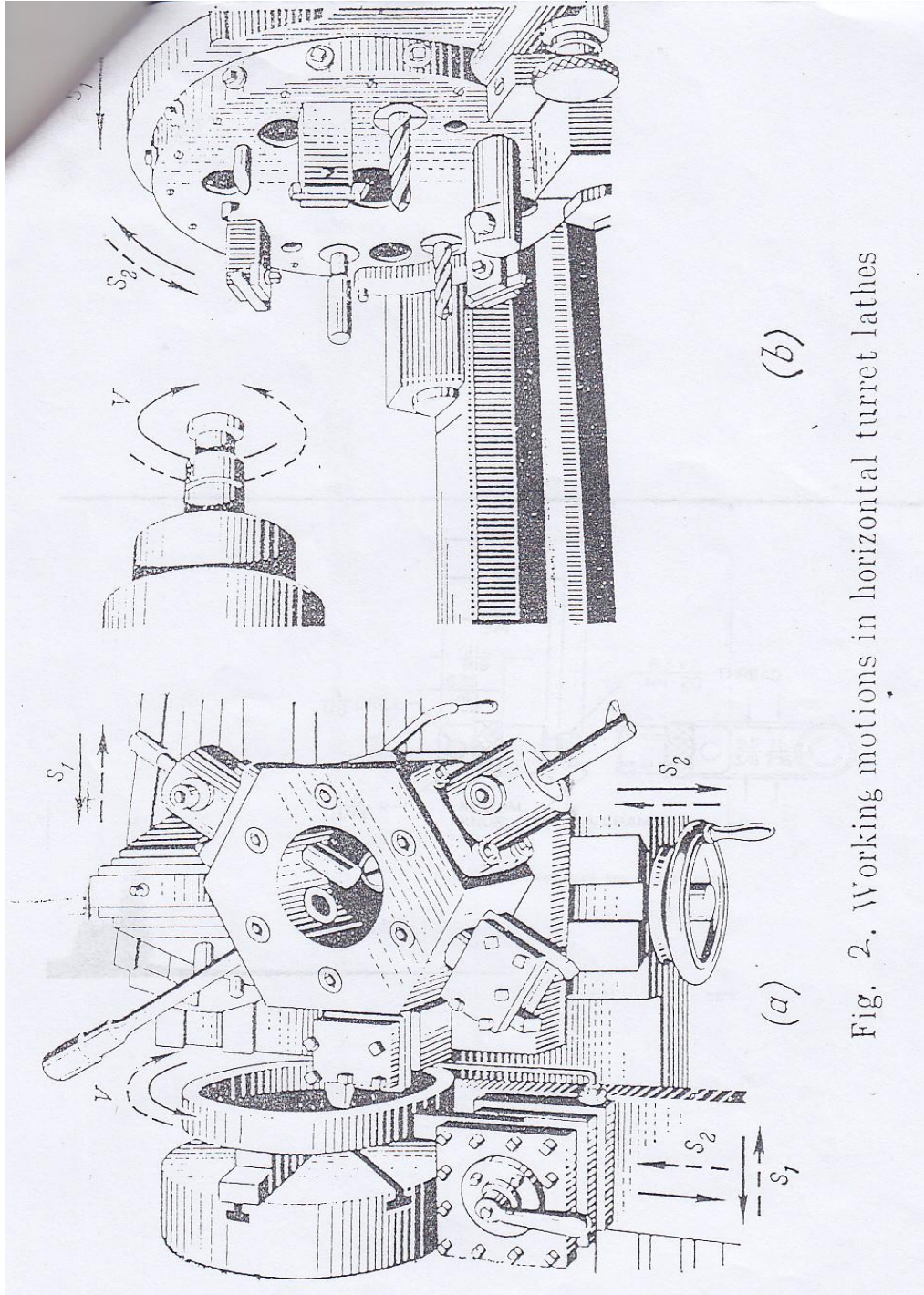


Fig. 2. Working motions in horizontal turret lathes

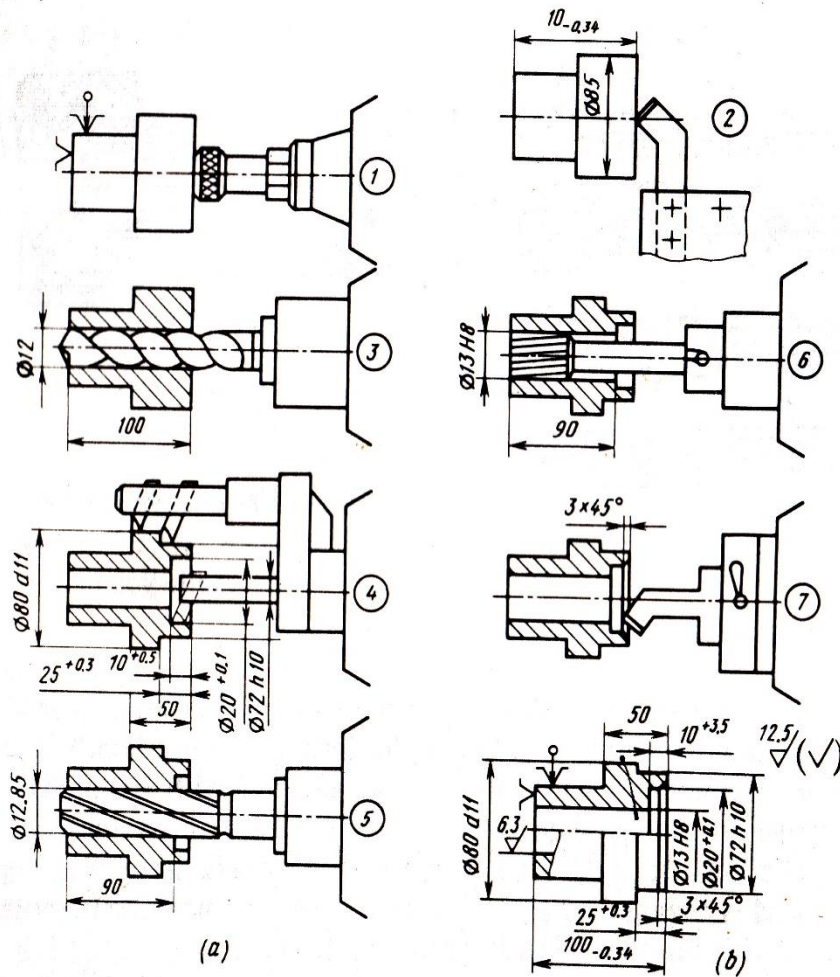
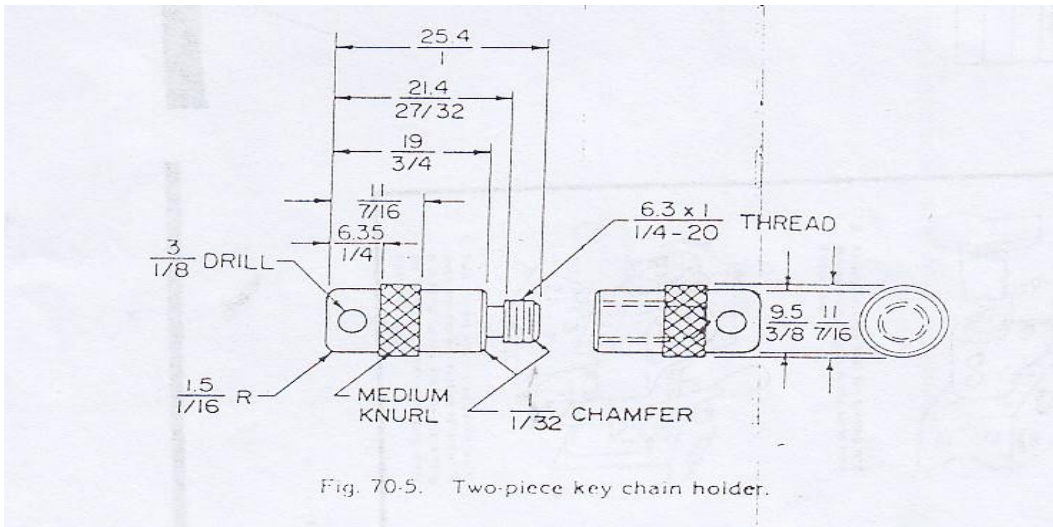


Fig. 9.5. Setup of turret lathe with vertical-axis turret: (a) machining sequences; (b) workpiece

## Experiment no: 5

### **STUDY AND OPERATION OF GEAR SHAPER**

#### **5.1 Main Gear-Cutting Methods**

Depending upon the principle of tooth-flank forming, the cutting of cylindrical gear wheels is mainly performed either by the form or generating methods.

a) The form cutting method: in form cutting, each tooth space on the gear blank is machined by a cutting tool whose cutting edge shape is identical with the tooth-space shape of the gear being machined. Cutting tools commonly used for this purpose are form-disk and end-mill gear milling cutters, the process is accomplished on milling machines with the application of index heads.

b) The generating method: This method provides a high productive output and accuracy of gears being cut, and also makes it possible to use one cutting tool for machining gears of a given module with a varying number of teeth.

#### **5.2 Types of gear-cutting machines:**

Gear-cutting machines are classified with respect to the following features:

a) Purpose: Machines for cutting spur and helical gears; straight bevel gears and curved-tooth bevel gears, worm wheels, herringbone gears, gear racks, special machines (gear-tooth rounding machines, gear-lapping machines, gear-burnishing machines etc.)

b) Type of machining and tool: Gear-hobbing machines (gear hobbers), gear-shaping machines (gear shapers), gear-planning machines (gear planners), gear-broaching machines, gear-shaving machines, gear-grinding machines (gear grinders), etc.

c) Machining accuracy and finish of gear-tooth surface: Machines for roughing the teeth, for finishing the teeth, and for micro finishing the teeth.

#### **5.3 Gear shaping**

A gear is shaped by a reciprocating cutter in the form of a single tooth, rack, or pinion. The gear blank and cutter move together as though in mesh, and a series of cuts are taken. Gear shaping cutter I (Figure) receives reciprocating movement which is the principle movement, and the circular feed movement which is a slow rotation (arrow III) interrelated with the blank rotation (Arrow II). The radial movement in the direction of arrow IV (radial in feed) is imparted to the shaping cutter when it is to be fed in to the depth of cut. To prevent the flanks of the cutter from scoring the blank as the cutter is returned upwards, the blank (or the shaping cutter) is withdrawn radially in the direction of arrow V.

#### **Reference:**

1. Machine tools by Chernov
2. Manufacturing processes and material for engineers by Doyle

## **5.4 Gear shaper (Model 5M14)**

There are following motions involved in cutting gears in gear shaper:

- 1) Reciprocating motion of the cutter,
- 2) Rotary feed motion of the cutter and the blank,
- 3) Withdrawal motion of the blank (during return stroke of the cutter the table with blank is withdrawn and at the start of the next cutting stroke table returns to original position),
- 4) Radial infeed of the cutter.

### **5.4.1 Reciprocating motion of the shaping cutter:**

The motion is transmitted as follows Motor III (3kw, 1430 rpm) → V-belt drive (  $\phi 100/\phi 280$ ) → Shaft I with cluster gears G1 & G2 → Shaft II with a crank disk linked with a connecting rod, on which a rack is cut → A rack and pinion → shaft III → A pinion 13 and a rack 14, the rack being secured to the cutter sleeve.

The basic displacements for the kinematic chain are:

$n$  rpm of the motor →  $n_1$  double strokes per minute of the shaping cutter.

The kinematic balance equation is:

$$1430 \cdot 100/280 \cdot (0.985) \cdot 22/88 \text{ (or } 29/81 \text{ or } 38/72 \text{ or } 49/61) = n_1$$

$$n_1 = 125, 179, 265 \text{ and } 400 \text{ double strokes/min}$$

### **5.4.2 Rotary feed motion of the cutter:**

Rotary feed of the cutter is expressed as the travel of the cutter along the pitch circle. The rotary feed gear train relates the rotation of the cutter to the cutter reciprocating motion. The motion is transmitted as follows-

Shaft II (1 rev of shaft II  $\equiv$  1 rev of the crank disk  $\equiv$  1 double stroke of cutter) → chain drive (sprockets 9 & 19, both having 28 teeth) → Shaft IV → worm 20 (3 starts) & wheel 21 (23 teeth) bevel gears 22 (28 teeth) & 23 (42 teeth) → rotary feed change gears having a & b no. of teeth → shaft V → worm 15 (single start) & wheel 16 (100 teeth) → Cutter.

The basic displacements for the kinematic chain are:

1 double stroke of the cutter →  $S$  mm travel of the cutter along the pitch circle are.

The kinematic balance equation is:

$$1. \quad 28/28, 3/23, 28/42. a/b. 1/100. \pi d_c = S$$

$$\text{Or } a/b = 366 S/d_c$$

And  $a+b = 89$  [distance of the two shafts.  $L =$  sum of the pitch circle radii of the change gears =  $\frac{1}{2}(d_1+d_2) = (m/2)(a/b)$  ]

From the above two equations a & b are selected for the rotary feed change gear box.

### 5.4.3 Indexing motion:

Indexing gear train relates the rotation of blank with the rotation of the cutter. The motion is transmitted as follows shaft V → bevel gears 24 & 25 (both having 30 teeth) → bevel gears 26 & 27 (both having 30 teeth) → index change gears A,B,C&D → Shaft VI → single start worm 28 & wheel 29 (240 teeth) → blank.

The basic displacements are:

$1/Z_c$  rev of the cutter →  $1/Z$  rev. of the blank, (Where, the  $Z_c$  &  $Z$  are the no. of teeth of cutter and blank)

Or, 1 rev. of the cutter →  $Z_c/Z$  rev. of the blank.

The kinematic balance equation for the indexing gear train is:

$$1. \quad 100/1. 30/30. 30/30. A/B. C/D. 1/240 = Z_c/Z$$

$$\text{Or } A/B. C/D = 2.4 Z_c/Z$$

### 5.4.4 Radial infeed:

Infeed of the cutter into the blank is controlled by the automatic infeed mechanism. The infeed per one cutter double stroke, selected to suit the hardness of the material, module, and required surface finish, is set up by change gears. When the required and preset depth of cut is reached, infeed is automatically disengaged and the counting mechanism is automatically engaged. The latter counts the number of full revolutions made by the blank (when preset depth of cut is reached. infeed stops and the blank makes one full revolution).

A roller 4 at the right hand end of shaft 3 is held tightly against feed cam 2 by a spring located at the left hand end of the machine. At the beginning of each cycle the roller is in the recess of the cam. Upon rotation of the cam, the roller follows its rising profile, moving shaft 3, and with it the saddle, to the right, i.e., feeding the cutter into the blank.

To drive the cam, rotation is transmitted from shaft 5, through the change gears, bevel gearing 6, and worm 7 to worm wheel 8, having a jaw clutch member on its end face and mounted freely and mounted freely on shaft 9.

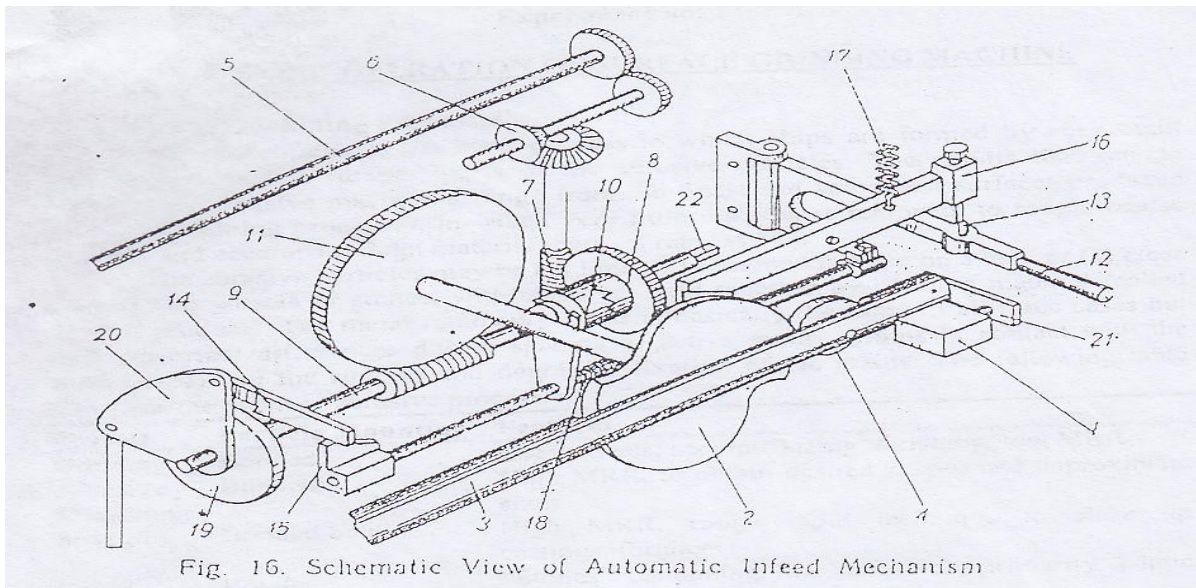


Fig. 16. Schematic View of Automatic Infeed Mechanism

When Clutch member 10 is shifted to the right (into engagement), rotation is transmitted through worm gearing 11 to the cam 2. Before cam 2 begins to rotate, lever 12 should be shifted to the right to engage latch 13.

Lever 12 shifts clutch member 10 to the right, by means of a tie rod and shifting fork, and engages it. At the same time, dog 15 raises pawl 14 and holds it out of engagement with the ratchet wheel 19.

Lever 16, carrying latch 13, rests on lobe of cam 2. As soon as infeed of the cutter is finished, lever 16 drops from the lobe of cam 2 and, by the action of spring, 17, latch 13 releases lever 12. Under the action of spring 18, lever 12 shifts to the left disengaging clutch member 10 and shifting dog 15 to the left. Dog 15 releases pawl 14 which drops of its own weight onto ratchet wheel 19 and begins to rotate it. Pawl 14 is oscillated by sector 20 on which it is pivoted. Upon each oscillation of the pawl, the ratchet wheel is rotated through one tooth and this rotation is transmitted through shaft 9 and worm gearing 11 to the cam 2. The oscillating movement of sector 20 is obtained from an eccentric cam on the worm shaft of the work spindle index worm gearing.

After the feed in period, shaft 3 remains stationary since the radius of the cam lobe curve is constant following the infeed section. At the end of the full machining cycle, roller 4 drops into the initial recess on cam 2, and shaft 3 is shifted by its spring together with the saddle to the left. In this movement, dog 21 trips the limit switch 1 and stops the machine. If two or three pass cams are used, machining is carried out in two or three passes in a corresponding manner.

The motion is transmitted as follows Shaft II (1 rev of shaft II  $\equiv$  1 rev of the crank disk  $\equiv$  1 double stroke of cutter )  $\rightarrow$  Chain drive (wheels 9 & 19, both having 28 teeth )  $\rightarrow$  Shaft IV  $\rightarrow$  change gears having teeth a & b  $\rightarrow$  bevel gears 30 & 31 (having 24 & 48 teeth)  $\rightarrow$  worm 32 (single start) & wheel 33 (40 teeth)  $\rightarrow$  clutch engaged  $\rightarrow$  worm 34 (double start) & wheel 35 (40 teeth)  $\rightarrow$  cam  $\rightarrow$  roller  $\rightarrow$  lead screw 12  $\rightarrow$  saddle.

## Experiment no: 6

### **STUDY OF A CNC MILLING/LATHE MACHINE**

#### **6.1 Computerized Numerical Control (CNC)**

Computerized Numerical Control means, using computers to create metal parts and products for equipment and machines. In more simple terms, it is a high tech machining technology. Machining and metal working have been around for a very long time, but with the advent of computers in the 1970s, a new industry was born. More efficient output operations with even greater precision resulted from this marriage of machining and computers.

CNC is the control of a machine tool using text string to represent specific motions and actions. It is a system in which programmed numeric values are directly inserted and stored on some form of input medium, and automatically read and decoded to cause a corresponding movement in the machine which it's controlling.

#### **6.2 CNC Milling**

Computer Numerical Control CNC Milling is the most common form of CNC. CNC mills can perform the functions of drilling and often turning. CNC Mills are classified according to the number of axes that they possess. Axes are labeled as x and y for horizontal movement, and z for vertical movement. A standard manual light duty mill is typically assumed to have four axes:

1. Table x
2. Table y.
3. Table z.
4. Milling Head z.

A five axis CNC milling machine has an extra axis in the form of a horizontal pivot for the milling head. this Allows extra flexibility for machining with the end mill at an angle with respect to the table. A six axis CNC milling machine would have another horizontal pivot for the milling head. this time perpendicular to the fifth axis.

CNC milling machines are traditionally programmed using a set of commands known as G-codes (some times M-codes). G-codes represent specific CNC functions in alphanumeric format.

<b>A complete listing of G-Codes with definitions and examples for both turning and milling</b>			
Milling		Turning	
G00	Positioning in Rapid	G00	Positioning in Rapid
G01	Linear Interpolation	G01	Linear Interpolation
G02	Circular Interpolation (CW)	G02	Circular Interpolation (CW)
G03	Circular Interpolation (CCW)	G03	Circular Interpolation (CCW)
G04	Dwell	G04	Dwell
G07	Imaginary axis designation	G07	Feed rate sine curve control
G09	Exact stop check		
G10	Program parameter input	G10	Data setting
G11	Program parameter input cancel	G11	Data setting cancel
G12	Circle Cutting CW		
G13	Circle Cutting CCW		
G17	XY Plane	G17	XY Plane
G18	XZ Plane	G18	XZ Plane
G19	YZ Plane	G19	YZ Plane
G20	Inch Units	G20	Inch Units
G21	Metric Units	G21	Metric Units
G22	Stored Stroke limit ON	G22	Stored Stroke check function ON
G23	Stored Stroke limit OFF	G23	Stored Stroke check function OFF
		G25	Spindle speed fluctuation detection OFF
		G26	Spindle speed fluctuation detection ON
G27	Reference point return check	G27	Reference point return check
G28	Automatic return to reference point	G28	Automatic zero return
G29	Automatic return from reference point	G29	Return from Zero Return Position
G30	Return to 2 <sup>nd</sup> , 3 <sup>rd</sup> , 4 <sup>th</sup> reference point	G30	2 <sup>nd</sup> reference point return
G31	Skip function	G31	Skip function
		G32	Thread cutting
G33	Thread cutting		
G34	Bolt hole circle (canned cycle)	G34	variable lead thread cutting
G35	Line at angle (Canned cycle)		
G36	Arc (Canned Cycle)	G36	Automatic tool compensation
G40	Cutter compensation cancel	G40	Tool Nose Radius Compensation Cancel
G41	Cutter compensation Left	G41	Tool Nose Radius Compensation Left
G42	Cutter compensation Right	G42	Tool Nose Radius Compensation Right
G43	Tool Length Compensation (Plus)		
G44	Tool Length Compensation (Minus)		
G45	Tool offset increase		
G46	Tool offset decrease	G46	Automatic Tool Nose Radius

			Compensation
G47	Tool offset double increase		
G48	Tool offset double increase		
G49	Tool Length Compensation cancel		
G50	Scaling OFF	G50	Coordinate system setting and maximum rpm
G51	Scaling ON		
G52	Local coordinate system setting	G52	Local coordinate system setting
G53	Machine coordinate system selection	G53	Machine coordinate system setting
G54	Work-piece Coordinate System	G54	Work-piece Coordinate System
G55	Work-piece Coordinate System 2	G55	Work-piece Coordinate System 2
G56	Work-piece Coordinate System 3	G56	Work-piece Coordinate System 3
G57	Work-piece Coordinate System 4	G57	Work-piece Coordinate System 4
G58	Work-piece Coordinate System 5	G58	Work-piece Coordinate System 5
G59	Work-piece Coordinate System 6	G59	Work-piece Coordinate System 6
G60	Single direction positioning		
G61	Exact stop check mode	G61	Exact stop check mode
G62	Automatic corner override	G62	Automatic corner override
G63	Tapping mode	G63	Tapping mode
G64	Cutting mode	G64	Cutting mode
G65	Custom macro simple call	G65	User macro simple call
G66	Custom macro modal call	G66	User macro modal call
G67	Custom macro modal call cancel	G67	User macro modal call cancel
G68	Coordinate system rotation ON	G68	Mirror image for double turrets ON
G69	Coordinate system rotation OFF	G69	Mirror image for double turrets OFF
G70	Inch Units	G70	Finishing cycle
G71	Metric Units	G71	Turning Cycle
G72	User canned cycles	G72	Facing Cycles
G73	High speed peck Drilling cycles	G73	Pattern repeating
G74	Counter tapping cycles	G74	Peck Drilling Cycles
G75	User canned cycles	G75	Grooving cycles
G76	Fine boring cycles	G76	Threading cycles
G77	User canned cycles		
G78	User canned cycles		
G79	User canned cycles		
G80	Cancel canned cycles	G80	Canned cycle for drilling cancel
G81	Drilling Cycles		
G82	Counter Boring Cycles		
G83	Deep Hole Drilling cycles	G83	Face Drilling cycles
G84	Tapping cycle	G84	Face tapping cycle
G85	Boring cycle		
G86	Boring cycle	G86	Face Boring cycle
G87	Back Boring cycle	G87	Side Drilling cycle
G88	Boring cycle	G88	Side Tapping cycle

G89	Boring Cycle	G89	Side Boring Cycle
G90	Absolute Positioning	G90	Absolute Programming
G91	Incremental Positioning	G91	Incremental Programming
G92	Reposition Origin Point	G92	Thread Cutting Cycle
G93	Inverse time feed		
G94	Per minute feed	G94	End face Turning Cycle
G95	Per revolution feed		
G96	Constant surface speed control	G96	Constant surface speed control
G97	Constant surface speed control cancel	G97	Constant surface speed control cancel
G98	Set Initial Plane default	G98	Linear Feed rate Per Time
G99	Return to Retract (Rapid) Plane	G99	Feed rate Per Revolution
		G107	Cylindrical Interpolation
		G112	Polar coordinate interpolation mode
		G113	Polar coordinate interpolation mode cancel
		G250	Polygonal turning mode cancel
		G251	Polygonal turning mode
Milling		Turning	

<b>A complete listing of M-Codes with definitions and examples for both turning and milling</b>			
Milling		Turning	
M00	Program Stop	M00	Program Stop
M01	Optional Program Stop	M01	Optional Program Stop
M02	Program End	M02	Program End
M03	Spindle on clockwise	M03	Spindle on clockwise
M04	Spindle on counterclockwise	M04	Spindle on counterclockwise
M05	Spindle stop	M05	Spindle stop
M06	Tool Change	M06	Tool Change
		M07	Coolant 1 On
M08	Coolant On	M08	Coolant 2 On
M09	Coolant Off	M09	Coolant Off
M10	Clamps On		
M11	Clamps Off		
M30	End of Program, Reset to start	M30	End of Program, Reset to start
M98	Call subroutine command	M98	Subprogram call
M99	Return from subroutine command	M99	Return from subprogram

Experiment no: 7

**STUDY AND OPERATION OF A GEAR HOBBIING MACHINE**

**7.1 Hobbing Machines**

A gear is being hobbled on a hobbing machine as shown in the following figure. The hob is set n angle in a horizontal plane so its teeth line up with the tooth spaces of the gear. Motor drives the hob through speed change gears. Generally hob surface speeds are about the same as milling cutter speeds for comparable materials and other conditions and are governed by the same principles.

The hob spindle and work spindle are connected through index change gears that are selected to make the work gear rotate at the proper speed in relation to the hob. Usually the hob is set to cut to depth alongside the gear and then feed across the width of the gear as the gear and hob rotate together.

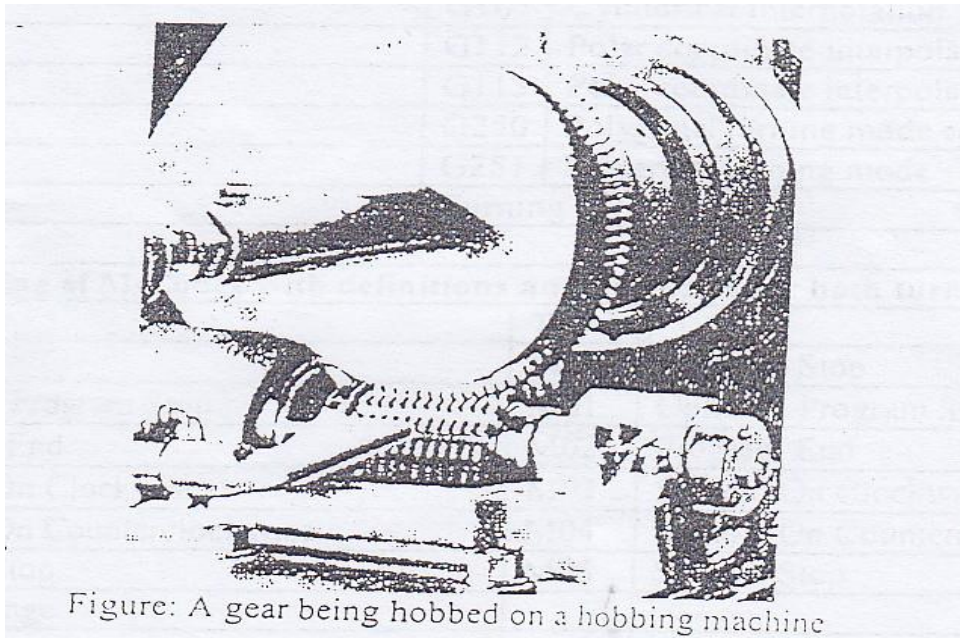


Figure: A gear being hobbled on a hobbing machine

The feed rate is obtained from feed change gears in a drive from the work spindle to the lead screw that moves the hob carriage. Some machines have a hydraulic drive system. The feed must be set in relation to the index ration between the hob and gear to cut a helical gear unless the machine has differential.

Hobbing machines are made in many sizes and styles from small ones for watch and instrument gears to huge ones for gears over 20 ft in diameter. Some are general purpose machines; others are specialized. For large quantity production, hobbing machines are made with several work stations and often are arranged for automatic operation. A medium size general purpose hobbing machine for gears up to 16 in. dia by 16 in. wide has a 5 hp motor, weighs 6300 lb.

## 7.2 Cutting cylindrical gears with gear hobs

When being machined, the gear blank is in mesh with a moving imaginary generating rack which is reciprocated in space with the cutting edges of gear hob I in its rotating I and straight II movements (figure a) Further, for cutting spur gears, the hob axis should be inclined to the gear blank face at the lead angle  $2$  of the hob thread (figure b).

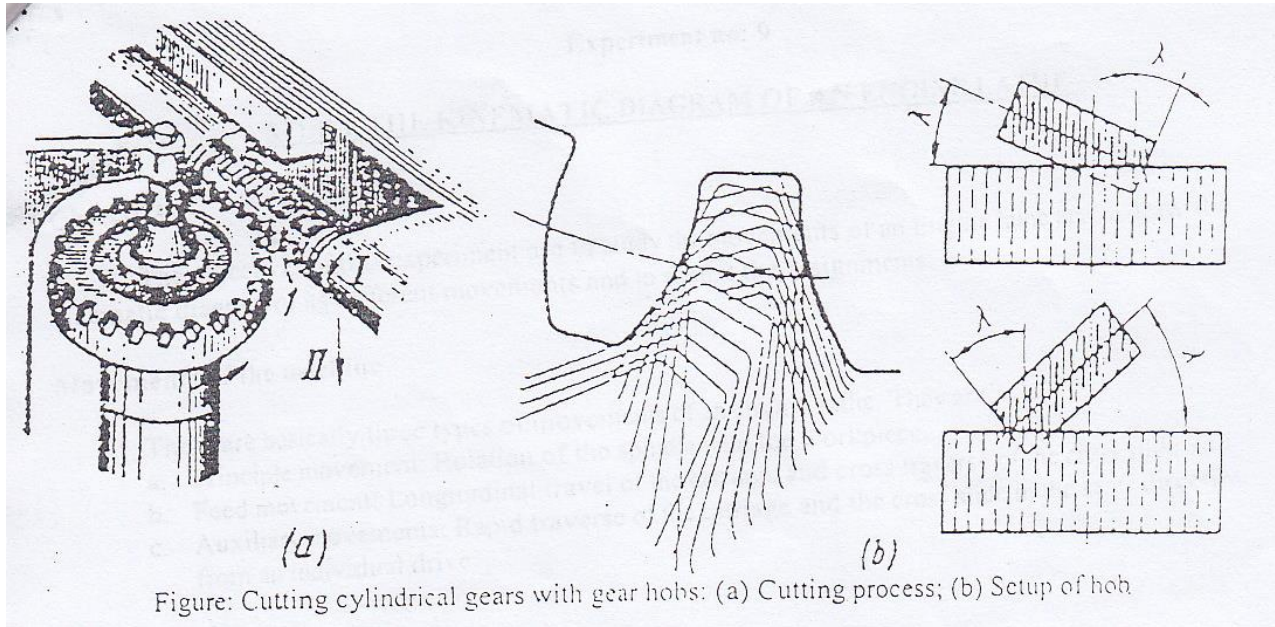


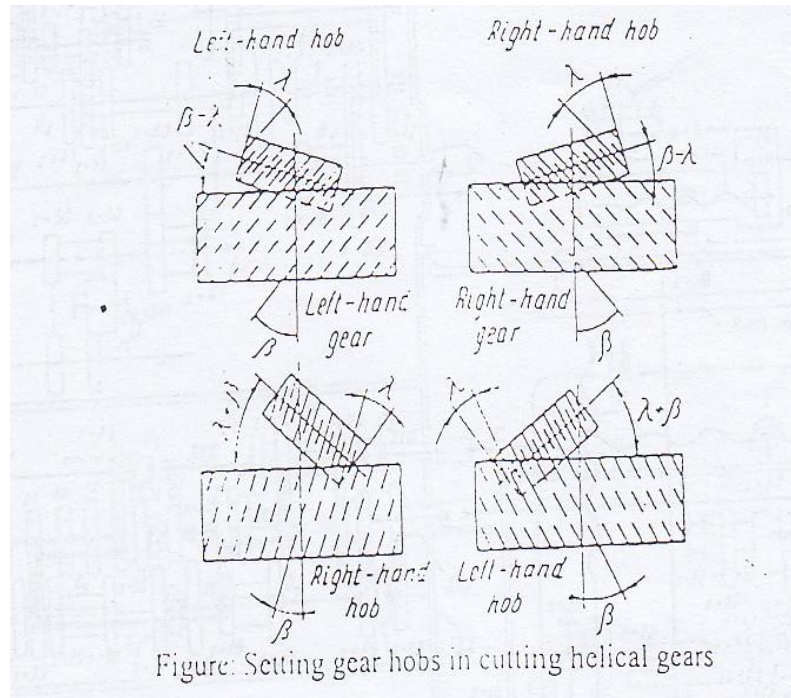
Figure: Cutting cylindrical gears with gear hobs: (a) Cutting process; (b) Setup of hob

## 7.3 Hobbing cylindrical gears with helical teeth

Here, the hob axis is to be inclined at an angle of

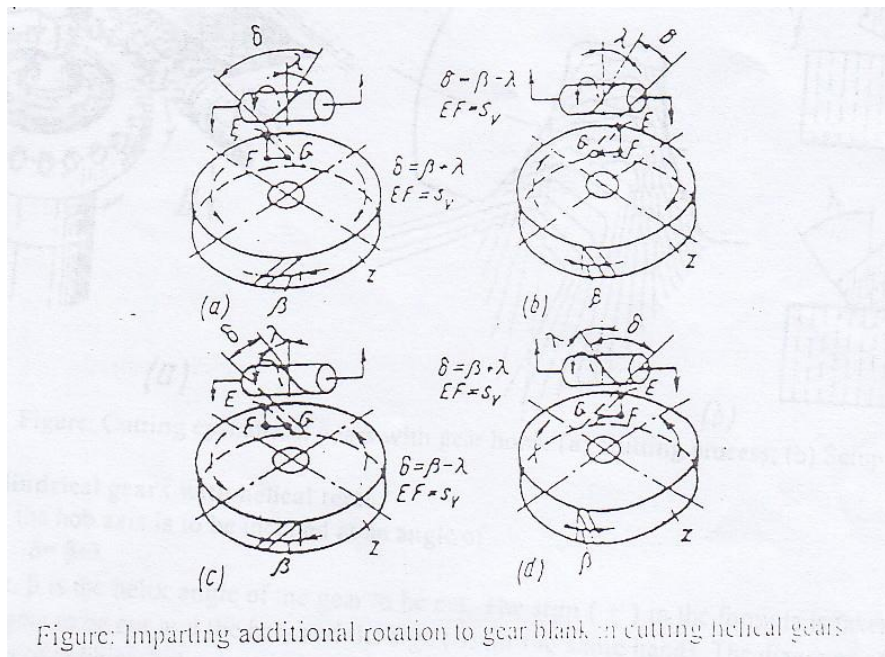
$$\delta = \beta \pm \lambda$$

Where,  $\beta$  is the helix angle of the gear to be cut. The sign (+) in the formula is taken for different helix hands of the gear to be cut and the hob and the sign (-) for the same hands. The diagrams of setting the hob for different cases of hobbing helical gears are shown in the following figures.



To obtain a helical tooth four movements are essential : hob rotation, blank rotation, vertical feed of the hob, and an additional rotation of the blank. The first three are the same as in hobbing spur gears. The necessity

An additional blank rotation is evident from the diagrams shown in the following figure. During the hobbing, the straight movement along the blank axis is imparted to the hob in cutting both spur and helical gears. As the direction of the hob vertical feed movement and the helix hand of the gear being machined do not coincide, the need arises to impart an additional rotation to the gear blank.



#### **7.4 Comparison of gear hobbing and shaping**

Spur, helical, and worm gears, interrupted tooth gears, elliptical gears, face gears, worms, ratchet wheels, and sprockets for chain drives are produced by hobbing and shaping. In addition, the processes are capable of machining a variety of other shapes including straight side and involute splines, square and hexagonal shafts, and cams.

Except for the methods described for production form cutting, gear generating methods are faster and more accurate than form cutting. Many gears semi finished by hobbing and shaping are finished by burnishing, shaving, or grinding, which are described later.

About 70% of all cut gears are hobbled. The continuous action of the hobbing process makes it generally faster and more accurate than competing process. The heat generated in hobbing is dispersed uniformly over the work-piece and cutter. The nature of hobbing requires a relatively simple machine with few motions, but a hobbing machine must be rugged because of the large cutting forces that act in various directions as a gear is cut. Fairly long shafts, splines, or a batch of gears on one mandrel can be accommodated on most hobbing machines. Herringbone gears of the gap type only can be hobbled.

#### **Reference**

1. Machine tools by N. Chernov
2. Manufacturing processes and materials for engineers by Doyle.

The index change gears are calculated from the following formula:

$$\frac{12.G}{z} = \frac{a}{b} \frac{c}{d}$$

G= number of starts of the worm

z= number of teeth of the gear to be cut

If the number of teeth is exactly divisible by the number of starts, the index change gears can be set directly of starts, the index change gears can be set directly from the table of the index change gears in such a way that the quotient of the fraction z/G is substituted as the number of teeth. For instance, it is required to cut a worm wheel

z = 30 teeth for a two start worm.

As  $30/2 = 15$ , the same index change gears as for a spur gear with 15 teeth are put on.

#### G. HOBBING HELICAL GEARS

1. Table for setting the change gears and adjusting the hob and the direction of feed/NO. 23
2. In this table, the setting of the index and the differential change gears as well as the directions of rotation of the table and of the hob is given. Care must be taken that the larger clutch ring k3/Fig. 3/2 is placed on the pin "a", in advance of the index change gear. The index change gears are selected from Tables ..... 24-25
3. Helical gear. See Figs> 12 and 13

### DESIGNATION

Pitch diameter..... do

From this follows:

Outside diameter.....d

$$mn = \frac{tn}{\pi}$$

Normal pitch.....tn

$$m\delta = \frac{t\delta}{\pi}$$

Trans verse pitch.....t

$$= \frac{tn}{\pi \cdot \cos\alpha}$$

Number of teeth.....z

Normal module.....d

$$= do + 2 mn + z.m \delta$$

/measured perpendicularly  
to the angle of teeth/

Transverse module.....m δ

$$H = \frac{z.t\delta}{tg\alpha} \frac{z.tn}{\cos\alpha.tg\alpha}$$

/measured in the transverse

$$= \frac{z.tn}{\sin\alpha}$$

Plane of the gear/

Helix angle of the hob..... β

Pressure angle/normally

10 deg. or 20 deg./..... δ

Helix angle of teeth with axis of the gear.....  $\alpha$   
 Lead.....H

Depth of teeth, the same  
 as with spur gears

### 3. Hobbing helical gears

In hobbing helical gears, it is further necessary to impart to the table a complementary motion which corresponds to the helix angle of the teeth and to the feed. For this reason, differential gearing is built in to the machine; this gearing is set in to engagement with the aid of the larger clutch ring k3/Fkig.32. The setting of the change gears is given in Table 27.

4. In Tables 27032, the sets of differential change gears for normal modules and helix angles of teeth are determined. If it is desired to cut gears having other modules or helix angles of teeth than those given in the tables, the ratio of the differential change gears must be calculated from the following formulae:

1. For the pitch in module: 
$$\frac{2.96831 \cdot \sin \alpha}{m} = \frac{a.c}{b.d}$$

2. For the pitch in mm:  
 /here in must be substituted,

i.e. the normal pitch 
$$\frac{18.75 \cdot \sin \alpha}{tn} = \frac{a.c}{b.d}$$

in mm/

3. For the pitch in inches: 
$$\frac{0.73819 \cdot \sin \alpha}{tn} = \frac{a.c}{b.d}$$

/here tn in inches must  
 be substituted.

As can be seen from these formulae, the number of the teeth of the gear does not affect in any way the differential change gears. It is, therefore possible to use with mating helical gears mounted on parallel shafts, the same set of differential change gears, where by the same mathematical exact helix angle of the teeth is produced regardless of the more or less accurate inclination of the hub spindle.

If it is required to out helical gears in two operations, the procedure must be as follows:

After the first cut has been finished, the column is moved some what to the right so that upon the return vertical motion of the hob slide, the hob does not contact the sides of the teeth. Now the rapid traverse is engaged and the hob is brought to its initial position, then the hob is set to the correct depth of the tooth, and the feed is engaged again. When doing this the differential change gears must not be set out of engagement. As has already been mentioned in the paragraph "Rapid traverse", it is necessary to be careful when using the rapid traverse. If the transmission ration of the differential change gears is in excess of 2:1, the it is preferable to operate the hob slide on its return movement by hand, or-if possible, i.e. if a new gear is to be cut – to set the differential change gears out of engagement.

When helical gears having larger diameters and higher halix angles are to be machined, it is recommended to taper the hobs on one end in order to improve the conditions on entering the cut.

Then hobbing spur gears and worm wheels by using the radial feed method the larger clutch ring K3 is replaced by the angler clutch ring K2 and the differential change gears are set out of engagement.

For cutting helical gears of large diameters and a higher helix angle and for the cutting of worm wheels by the tangential feed method, the fly wheel 139 must be taken down and the end of the shaft covered with the lid 140/see Fig. 6/.

**TECHNICAL DATA**

- Maximum module of the gear to be cut..... mm 6
  
- Maximum diameters of a straight gear to be cut.....mm 600
- Minimum and maximum distance between table and sent e of hob spindle.....mm 40/430
- Vertical displacement of hob slide.....mm 350
- Maximum width of straight teeth to be out with diameters of gear 600 mm.....mm 280
- Maximum width of straight teeth to be out with diameter of gear 75 mm.....mm 200
- Maximum width of teeth and diameters of gears to be cut with helical gears:
  - with helix angle of teeth of about 15 deg. .... tooth width .....mm 250  
dia of gear.....mm 600
  - with helix angle of teeth of about 30 deg..... tooth width.....mm 210  
dia. of gear .....mm 600
  - with helix angle of teeth of about 45 deg..... tooth width .....mm 190  
dia. of gear .....mm 500

with helix angle of teeth  
of about 60 deg. .... tooth width ..... mm 90  
dia of gear..... mm 450

Maximum weight of work-piece..... Kg 500  
Maximum diameter of hob..... mm 120  
Maximum width of hob ..... mm 130  
diameter of work table ..... mm 420  
Bore of work table ..... mm 75  
Depth of bore of work table ..... mm 550  
Diameter of index worm wheel ..... mm 450  
diameter of work arbor ..... mm 30  
Diameter of cutter arbors ..... mm 22,27,32  
Minimum distance between centre  
of hob and surface of work table ..... mm 160  
Number of hob spindle speeds ..... 12  
Range of hob spindle speeds .....r.p.m 15-190  
Number of feeds ..... 9  
Range of feeds for 1 revolution  
of table a/ vertically ..... mm 0.335.2  
b/longitudinally ..... mm 0.1-1.5

Output of the main motor  
/1400/2800 r.p.m/..... kw 3/4  
Output of the motor for the rapid  
traverse/1400 r.p.m/..... kw 0.75  
Output of the coolant pump motor  
motor/1400 r.p.m./..... kw 0.185

Weight of the machine with  
Standard equipment.....approx.. kg 0.1  
Weight of the machine with  
normal Packing..... approx.. kg 4100  
Weight of the normal machine  
with seaworthy packing..... kg 4800  
Weight of the seaworthy packing..... kg 700  
Outside dimensions of seaworthy packing  
length x width x height ..... mm 3050x1600x2260

## **STUDY AND OPERATION OF ELECTRO DISCHARGE MACHINING**

### **8.1 Introduction**

Non-Traditional Processes (NTP)

A group of processes that remove excess material without a sharp cutting tool by various techniques involving mechanical, thermal, electrical, or chemical energy (or combinations of these energies), developed in response to new and unusual machining requirements that could not be satisfied by conventional methods.

Why Nontraditional Processes are Important

- Need to machine newly developed metals and non metals (harder, stronger & tougher) with special properties that make them difficult or impossible to machine by conventional methods
- Need for unusual and/or complex part geometries that cannot easily be accomplished by conventional machining.
- Need to avoid surface damage that often accompanies conventional machining
- Need to achieve stringent surface (finish & texture) requirements not possible with conventional machining.

Classification of Non Traditional Processes by Type of Energy Used:

Mechanical erosion of work material by a high velocity stream of abrasives or fluid (or both) is the typical form of mechanical action

- Ultrasonic machining, water jet cutting (WJC), Abrasive water jet cutting (AWJC) and Abrasive jet machining (AJM)/

Electrical – electrochemical energy to remove material (reverse of electroplating)

- Electrochemical machining (ECM), Electrochemical deburring (ECD) and Electrochemical grinding (ECG)

Thermal – thermal energy usually applied to small portion of work surface, causing that portion to be removed by fusion and or vaporization

- Electric Discharge machining (EDM), Wire EDM, Electron Beam Machining, Laser Beam Protected by a mask.

Chemical- Chemical etchants selectively remove material from portions of work part, while other portions are protected by a mask.

-Chemical Milling, Chemical Blanking, Chemical Engraving and Photochemical Machining diameter (0.1 to 0.4 mm) and thickness.

### **8.2 What is the EDM process?**

Electro Discharge Machining (EDM) is the most widely recognized and used nontraditional (or non conventional) machining process in the industry today. Electrical discharge machining which in its simplest form is machining using an electrical spark. It is the machining method in which voltage is applied through a dielectric medium between the tool electrode and the work piece, using electro discharge generated when the electrode and work piece are positioned close to each other. The mechanism is that a section of the work

piece is melted and removed by the exothermic reaction accompanying the electro discharge. Machining is carried out by repeated melting and removal; therefore it is necessary to use a pulsating electrical discharge.

### **8.3 Types of EDM:**

There are two main types or stream of EDM machines, ram and wire-cut. The primary difference between the two involves the electrode that is used to perform the machining.

In ram EDM some times known as ‘Die Sinking’ a graphite electrode is machined with traditional tools into the desired shape is connected to the power source and slowly fed into the workpiece on the end of a vertical ram. This type of EDM is usually performed submerged in a fluid bath (viz. Kerosene) which is called dielectric.

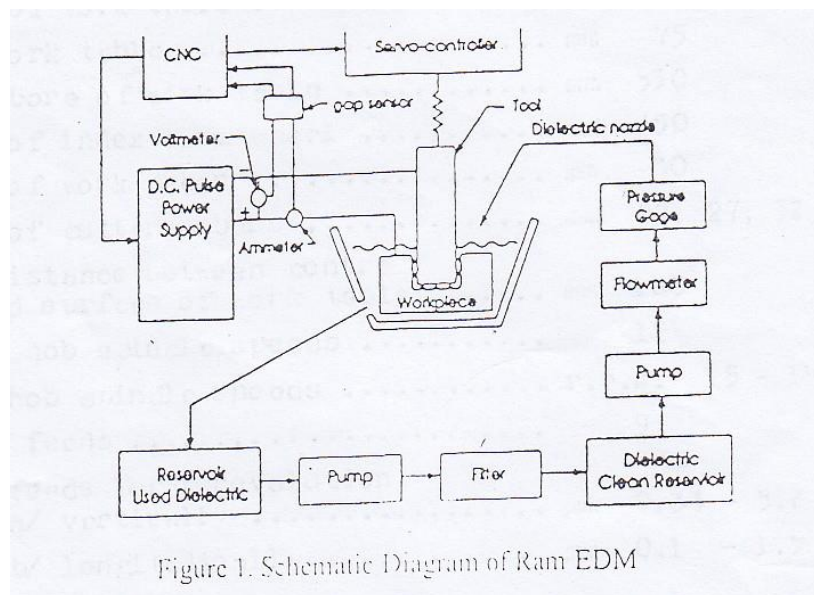


Figure 1. Schematic Diagram of Ram EDM

The fluid serves the following three purposes:

- flushes material away
- serves as a coolant to minimize the heat affected zone (thereby preventing potential damage to the work-piece)
- acts as a conductor for the current to pass between the electrode and the work-piece.
- Provides an inert atmosphere in which the process can take place.

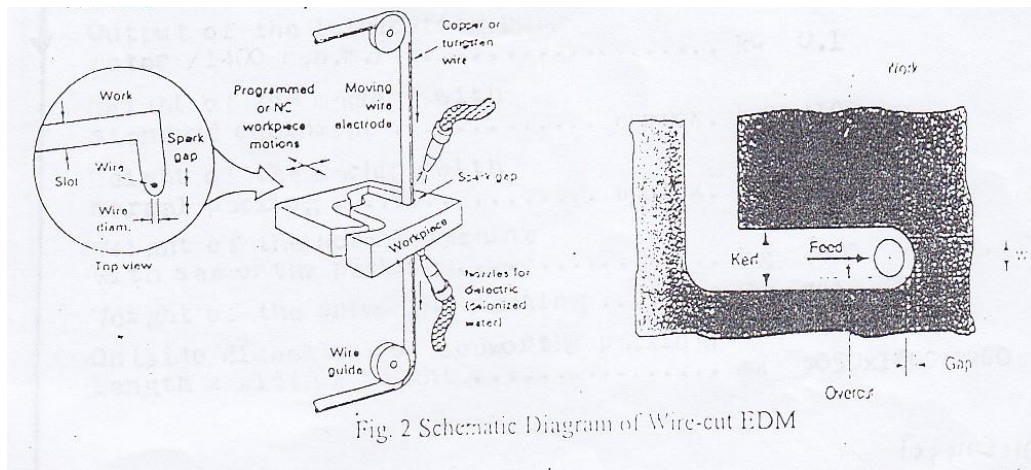


Fig. 2 Schematic Diagram of Wire-cut EDM

In wire cut EDM, a thin single strand metal wire, usually brass serves as the electrode, is fed through the work piece. The wire, which is constantly fed from a spool, is held between upper and lower guides. The guides move in the X-Y plane, and sometimes the upper guide can also move independently giving rise to transitioning shapes (circle on the bottom square at the top). This gives the Wire cut EDM the ability to be programmed to cut different complex shapes. The wire cut uses de-ionized water as its dielectric with the water's receptivity and other electrical properties carefully controlled by filters and de-ionizer units.

Different types of machining processes that use EDM

There are several different types of machines and industrial applications that use the EDM process for high precision machining of metals. Listed below are the most widely used EDM systems/processes:

- a) Micro electro discharge machining (MEDM)
- b) EDM Drilling
- c) Electrical Discharge Milling
- d) Electrical Discharge Grinding (EDG)
- e) Electrical Discharge Dressing (EDD)
- f) Ultrasonic Aided EDM (UEDM)
- g) Abrasive Electrical Discharge Grinding (AEDG)
- h) Mole EDM
- i) Double Rotating Electrodes EDM

### **8.4 Operating principle**

During the EDM process, a series of non stationary, timed electrical pulses remove material from a work piece. The machine tool, which also contains the dielectric, holds both the electrode and the work-piece. A power supply controls the timing and intensity of the electrical charges and the movement of the electrode in relation to the work-piece.

At the spot where the electric field is strongest, a discharge begins to form. Under the effect of this field, electrons and positive free ions accelerate to high velocities and rapidly form an ionized channel that conducts electricity. At this stage, current can flow as a spark forms between the electrode and work-piece, causing a great number of collisions between the particles. During this process, a bubble of gas develops. Its pressure rises very steadily until a plasma zone forms. This plasma zone quickly reaches very high temperatures, in the range of 8,000 to 12,000<sup>0</sup> C. as result of the ever increasing number of particle

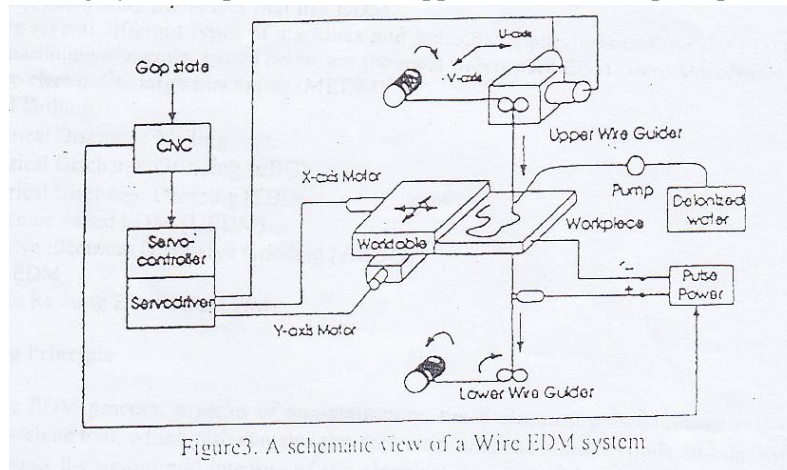
collisions. These high temperatures cause instantaneous local melting of a certain amount of the material at the surface of the two conductors. When the current is cut off, the sudden reduction in temperature causes the bubble to implode, blowing away the melted material from the work-piece surface and leaving a tiny crater. The melted material then solidifies in the dielectric in the form of small spheres and is removed by the dielectric.

### **8.5 Process Mechanism**

EDM is a thermoelectric process that erodes material from the work-piece by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. These electric discharges melt and vaporize minute amounts of the work material, which are then ejected and flushed away by the dielectric. A wire EDM generates spark discharges between a small wire electrode (usually smaller than 0.5 mm diameter) and a work piece, with de-ionized water as the dielectric medium, and erodes the work piece to produce complex two and three dimensional shapes according to a numerically controlled(NC) path. The essential components of die sinking and wire EDM are shown in Figures 1 and 33, respectively.

However, the process mechanism for EDM can be divided into four stages.

1. When a voltage is applied through a dielectric medium across the gap between the tool and work piece, an electric field builds along the path of least resistance. This causes a breakdown of the dielectric initiates the flow of current.
2. In the second stage, electrons and ions migrate toward the cathode and anode at high current density, forming a column of vapor and initiating the melting of the work piece.
3. When a voltage is no longer applied to the gap, the column collapses and a portion of molten metal is ejected from the work piece and a crater is formed.
4. Finally, debris that remains on the work piece is flushed away with the dielectric, and the machining cycle is repeated with the application of subsequent pulse.



### **8.6 Equipment and Machining Parameters**

All EDM systems include the machine (frame, ram, worktable tool and work-piece holders, and clamping devices), pulse-power supply, tool electrode. dielectric system, and servo control system.

**8.7 MRR (Material Removal Rate)**

The material removal rate and the surface roughness increase with increased power in the gap. In this way, rough and fine machining is distinguished. When rough machining is performed, the material removal rate should be as high as possible, while the achieved surface roughness does not play an important role.

Since EDM uses electrical energy to remove material, it stands to reason that the makeup of the material will have a direct impact on the rate of removal. This being the case there are three critical things to keep in mind.

- Electrical Conductivity of the material being machined. Since machining with EDM occurs by using electrical energy the electrical conductivity plays a key role in how fast the spark gap can ionize allowing a spark to occur. Materials that are less electrically conductive will machine slower.
- Thermal Conductivity of the material such as copper or bronze alloys used in plastic molds or parts production can adversely affect machining speed. Pulse energy (heat) is conducted away from the surface of the part and is dissipated through the piece. Material removal will be slower and less efficient when compared to steel.

**8.8 Application**

EDM stands for electrical discharge machining but it might as well stand for Exact Difficult Machining because the applications best suited for this metal removal process are those characterized by extremely exacting tolerances and situations that would be extremely difficult or impossible to handle with any other method of machining.

Material Characteristic	Why
Hardness above Re 38: hardened steel, Stellite, tungsten carbide Toughness: Inconel, Monel, Hastelloy, Nitralloy, Waspaloy, Nimonic, Udimet Tends to leave tough burrs when machined conventionally Frail/fragile (can't take stress of machining) Expensive	EDM vaporizes material rather than cuts it.  EDM is non contact, therefore no adhesion of work-piece to tool. Vaporized material is flushed away, leaving no burr.  No contact, no force.
Certain explosive or flammable materials material with hazardous dust particles	Lower chip/work-piece mass ration. Slugs from wire EDM may be reusable, Where as chips from conventional machining are recyclable at best. EDM takes place under water.  Particles are flushed away to the filter. Reduced risk of fumes.

Note: Workpiece material must be electrically conductive or semi conductive with no non conductive cutting zones.

## **8.9 Handy Checklist**

The following checklist summarizes the characteristics that indicate the use of EDM. The more of these characteristics that are present, the more likely that EDM is the right solution.

Consider EDM when work-piece geometry features

- very thin walls
- Small internal radii
- High depth to diameter ratios
- Very small dimensions
- Fixturing difficulties

Consider EDM when the work-piece material

- Is hard
- Is tough
- Leaves burrs
- Has to be heat treated
- Multiple setups, multiple operations, multiple handling
- Broaching
- Short run stamping

Consider EDM when for other reasons such as

- One wants 24 hour production with only one shift for an operator.
- One wants a process that is not labor intense.

## **8.10 Advantages**

Because of its various advantages, EDM process continues to grow in many manufacturing industries. The following are only a few of its many benefits:

1. Product Finishes no Burrs Cost Advantages
2. Unattended Operation
3. No cutting force generated
4. High Quality Surface Finish & Precision Machining
5. Fairly low Cost of Operation
6. Hardness of material not a concern
7. Odd/Delicate shapes easier to produce

## **8.11 Limitations of EDM**

1. One critical limitation, however, is that EDM only works with materials that are electrically conductive. The conductivity of  $0.1 \text{ (ohm cm)}^{-1}$  is considered as the minimum value for EDM to be effective.

2. Applications of EDM may be restricted by the size of EDM machine.

3. Very low material removal rate.

4. Limitations of EDM to machine sharp corners because of the existence of the gap between the tool and the work piece.

### **Reference**

- 1) Hand Book of Design Manufacturing & Automation: Richard C. Dord & Andrew Kusiak
- 2) Manufacturing Engineering and Technology (4<sup>th</sup> Edition); Serope Kalpakjian
- 3) Manufacturing Processes and materials for Engineers (2<sup>nd</sup> Edition); Doyle
- 4) Material and Processes in Manufacturing (6<sup>th</sup> Edition); E. Paul De Garmo

## Experiment no: 9

### **STUDY THE KINEMATIC DIAGRAM OF AN ENGINE LATHE**

#### **9.1 Objective**

The objectives of this experiment are to study the movements of an Engine lathe and to draw the kinematic diagram of its different movements and to submit the assignments.

#### **9.2 Movements of the machine**

There are basically three types of movements of an engine lathe. They are:

- a. Principle movement: Rotation of the spindle with the work-piece.
- b. Feed movement: Longitudinal travel of the carriage and cross traverse of the cross slide and
- c. Auxiliary movements: Rapid traverse of the carriage and the cross slide in the same direction from an individual drive.

The basic displacements are:

I double stroke of the cutter →  $S_1$  mm infeed of the cutter

The kinematic balance equation for the infeed gear train is:

$$1. \quad 28/28. a'/b'. 24/48. 1/40. 2/40. II = S_1$$

{Here,  $S_r$  is infeed rate, mm/double stroke of cutter,

H is the lead of the Archimedean spiral of cam (for this machine:  $H=76.8\text{mm/rev}$ )}

After the roller has reached the maximum radius of the cam (corresponding to the preset depth of cut), the roller is not displaced for the next  $90^\circ$  rotation of the cam (corresponding to 1 full rev of the blank at that depth of cut). During this period, rotation to the cam is transmitted as follows: shaft VI → cam → connecting rod → sector → pawl & ratchet (48 teeth) → worm 34 (double start) & wheel 35 (40 teeth) → cam.

The basic displacements are: 1 rev. of the blank →  $90^\circ$  rotation of the cam.

$1.240/1. 1/48/ 2/40=1/4$  rev. of the cam.