GOVT. TOOL ROOM AND TRAINING CENTRE
KARNATAKA

REFERENCE NOTES

PRODUCTION TECHNOLOGY - III (MILLING OPERATION)

3rd SEMISTER

FOR
: DIPLOMA IN TOOL AND DIE MAKING : III SEMESTER
: DIPLOMA IN PRECISION MANUFACTURING : III SEMESTER

SYLLABUS FOR
PRODUCTION TECHNOLOGY-III (MILLING)

Contact Hrs. /Week: 3 **Contact Hrs. / Semester: 64**

SPECIFIC INSTRUCTIONAL OBJECTIVES:

1. General safety
   1. Safety precautions
2. Classifications of Milling
   2. Definition
   3. Types and parts description
3. Specification and Work Holding devices
   - Specification and example
   1. Work Holding Devices
   2. T- bolts and clamps
   3. Angle plates
   4. V-blocks
   5. Vices
   6. Special fixtures
4. Milling cutters
   1. Definition
   2. Types of cutters
   3. Cutters geometry
   4. Nomenclature of plain milling cutter
   5. Nomenclature of side milling cutter
5. Tool holding device
   1. Arber
   2. collets
   3. Adaptor
   4. Spring collets
   5. Bolted cutters
6. Milling operations
   - Plain milling and Face milling
   - Side milling and Straddle milling
   - Angular milling and Gang milling
   - Form milling and Profile milling
   - End milling and Saw milling
   - Milling key ways, grooves and slots
   - Gear cutting and Helical milling
   - Cam milling and Thread milling

7. Dividing Head and Rotary table
    1. Definition
    2. Working process and applications of dividing head
    3. Definition of rotary table
    4. Working process and applications of rotary table
8. Indexing and methods of indexing
    - Definition
    - Direct or rapid indexing
    - Plane or simple indexing
    - Compound indexing
    - Differential indexing
    - Angular indexing
9. Milling attachment
    - Vertical milling attachment
    - Universal milling attachment
    - High speed milling attachment
    - Slotting attachment
    - Universal spiral milling attachment
    - Rack milling attachment
    - Circular milling attachment
    - Dividing head milling attachment
10. Problems and Machining time calculations
    - Definition of speed, feed and Depth of cut
    - Machining time calculations
11. Coolant
    - Necessity of coolant
    - Mixing ratio
12. Safety
    - Safety precautions

UNIT: GENERAL SAFETY

Objectives:

*Safety rules.

Aim: At the end of the class the trainee will be able to know, about safety to be followed in workshop.

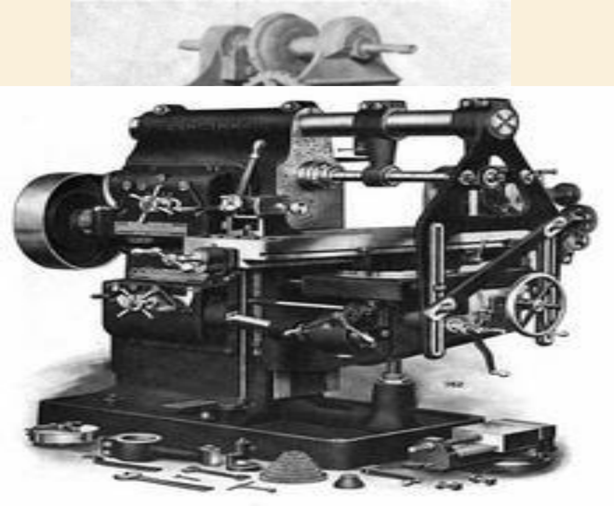
Safety to be followed in workshop

1. Always wear shoes in the workshop.
2. Do not work alone in the workshop.
3. Wear proper workshop dress.
4. Do not keep long hair.
5. Do not work during ill health
6. Wear safety goggles while working in a machine shop.
7. Do not play with the machines.
8. Always maintain discipline and do not indulge in mischief with co-workers.
9. Do not run in the workshop while going for an urgent call.
10. Do not walk below the load carried by a crane.
11. Do not lift heavy jobs without the uses of cranes.
12. Protect yourself from welding arcs.
13. Report to the doctor in case of any injury and learn first aid treatment.
14. Take care of moving machines and walk within the prescribed work path.
15. Wear a helmet in a big fabrication shop.
16. Wear gloves while moving sheet metal or stock with sharp edges.
17. Keep your hands away from the moving cutter or work piece.
18. Don’t touch the chips generated from machine it will be too hot.
19. Do not touch the tool tip during grinding the tool.
20. Keep always know the position of fire extinguisher & first aid box in the shop.

UNIT 2: MILLING MACHINE

Milling machine history: -

This milling machine was long credited to Eli Whitney and dated to circa 1818. From the 1910s through the 1940s, this version of its provenance was widely published. In the



1950s and 1960s, various historians of technology mostly discredited the view of this machine as the first miller and possibly even of Whitney as its builder. Nonetheless, it is still an important early milling machine, regardless of its exact provenance

A typical universal milling machine of the early 20th century. Suitable for tool room, jobbing, or production use.

In these decades, Brown & Sharpe and the Cincinnati Milling Machine Company dominated the milling machine field. However, hundreds of other firms also built milling machines at the time, and many were significant in various ways. Besides a wide variety of specialized production machines, the archetypal multipurpose milling machine of the late 19th and early 20th centuries were a heavy knee-and-column horizontal-spindle design with power table feeds, indexing head, and a stout over arm to support the arbor. The evolution of machine design was driven not only by inventive spirit but also by the constant evolution of milling cutters that saw milestone after milestone from 1860 through World War.

Classification of milling machine

1. Size and shape of work piece.
2. Capacity of the machine.
3. Nature of the work.
4. Operation to be performed

TYPES OF MILLING MACHINE:-

Column and knee type milling machine: -

1. Hand milling machine.
2. Plain milling machine.
3. Universal milling machine.
4. Omniversal milling machine.
5. Vertical milling machine.

Manufacturing or fixed bed type milling machine: -

7. Simplex milling machine
8. Duplex milling machine
9. Triplex milling machine

Planer type milling machine: -

Special type milling machine: -

1. Rotary table milling machine.
2. Drum milling machine.
3. Planetary milling machine.
4. Pantograph, profiling and tracer controlled milling machine

Parts of the milling machine:-

1. Base
2. knee
3. elevating screw
4. handle
5. saddle
6. table
7. support
8. oil level
9. Arbor
10. Over hanging
11. Cutter
12. Column
13. Gear mechanism

The basic components of these machines are as follows:

1. **Worktable:** on which the work piece is clamped using T-slots. The table moves longitudinally relative to the saddle.

2. **Saddle**: supports the table and can move in the transverse direction.

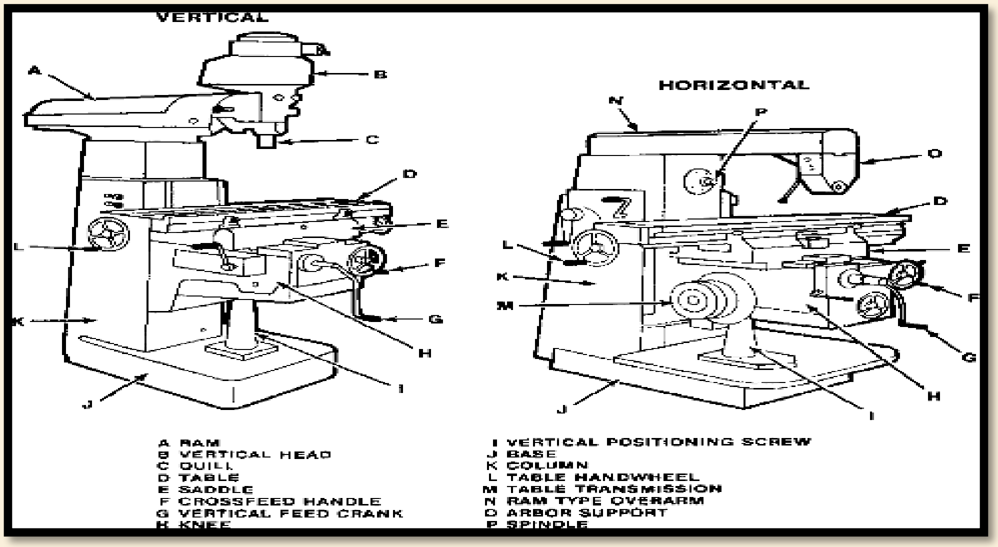
3. **Knee:** supports the saddle and gives the table vertical movement so that the depth of cut can be adjusted and work pieces with various heightscan be accommodated.

4. **Overhead arm:** used on horizontal machines; it is adjustable to accommodate different arbor lengths.

5. **Head:** contains the spindle and cutter holders. In vertical machines, the head may be fixed or can be adjusted vertically, and it can be swiveled in a vertical plane on the column for cutting tapered surfaces.

Column and knee type:-

- It is commonly used milling machine in the general workshop. The table is mounted on knee casting.
- Table can be moved up and down vertically.
- It consists of a column, which is hollow structure housing the driving motor, speed change gears for controlling the table and knee movement. Base of the machine is made hollow and used for storing coolant. The saddle is mounted on the knee and moves horizontally.



Hand milling machine:-

It consists of all types of milling. In which the feeding movement of the table is supplied by hand control. The cutter is mounted on a horizontal arbor and is rotated by power. It is small and suitable for light works. It produces slots, grooves and keyways.

Plain milling machine:-

These machines are rigid and sturdy than hand millers. The machine table may be fed by hand or power control against a rotating multipoint cutter. The plain milling machine have horizontal spindle, so that it is called as horizontal spindle milling machine. Vertical milling attachment convertsthe horizontal spindle to the vertical spindle. It is suitable for heavy and bulky work pieces.

Universal milling machine :-

It is similar to the plain milling with the difference the table is placed on the swivel. The swivel is placed on the saddle. The table can be swiveled to any angle up to 45 degrees on either side of the normal position. It is widely used in Tool room for performing very accurate work. The table is mounted on a circular base, which has graduations in degrees.

1. Accuracy increases
2. It has four table movements such as longitudinal, cross, vertical and the table can be swiveled.
3. The capacity of milling machine is increased by the use of special attachments such as indexing head, vertical milling attachment, rotary attachment etc.
4. It performs any operations, with better surface finish.

Omniversal milling machine:-

This machine having all the movements of a universal milling machine, along with the table can be tilted in a vertical plane by the knee. It may be fed in a longitudinal direction horizontally. It is widely used in tool room works and experimental machine shop.

Applications:-

It produces tapered spiral grooves and reamers It cuts bevel gears etc.

Vertical milling machine:-

Vertical milling machine is so called because of the position of the cutter spindle. The table movements are horizontal, transverse, vertical. In this machine over arm is small and provides a strong support for the spindle. The spindle can be moved up and down to perform the operations like grooving, slotting, facing, drilling, boring etc. Generally vertical milling machine is used to perform end milling and face milling operation.

Manufacturing or fixed bed type milling machine:-

These are big bed type machines used for large production works. The machines yield high production of interchangeable jobs. The solid base provides inherent rigidity. The table is directly mounted on the main body of the machines place of knee, so that is becomes more robust. It canwithstand heavy cutting loads for long time in production work.

Classification of fixed bed type milling machine:-

Depending upon the number of spindle, these are also classified as follows**.**

Simplex: - This machine is provided single spindle head for performing specific operation.

Duplex: - This machine is provided double spindle head for performing specific operation. In this machine the spindle heads are arranged one on each of the table.

Triplex: - The machine is provided triple spindle head for performing specific operation. In this the third spindle is mounted on a cross rail.

Planer type:-

1. A planer type machine is designed for large jobs requiring heavy cuts and powerful feed.
2. It is widely used in heavy industries.
3. The planer milling machine is equipped with one or more cutting heads which can be located and adjusted horizontally or vertically.
4. Table movement is slightly slower than the actual planer.
5. Transverse and vertical movements are provided on the cutter spindle
6. Rate of metal removal is very high.
7. It has overall length 102 feet and can machine work weighing 175 tons.

SPECIAL TYPE MILLING MACHINES:-

ROTARY TABLE MACHINE:-

It is an adoption to the vertical milling machine. It consists of two vertical spindles each equipped with a facing mill. Cylinder heads are roughed at one station and finish milled as they pass the second station. The operation is continuous and there is an ample time for the operator to load and unload the machine during the milling operation. The machine is fast in operation but is limited to milling of the flat surfaces.

Drum milling machine:-

Drum milling machines are used for production work only. This type of machine has a vertical central drum, which rotates on a horizontal axis much like a ferry's Wheel. In operation, the drum fixture rotates slowly, carrying the work against the rotating cutter. It is having four cutter spindles. Automobile cylinder heads and small shafts are milled on this machine. These machines are employed to face the two ends of a work piece simultaneously.

Planetary milling machine:-

It is unique machine in the sense that the work is stationary while the revolving cutter. The cutters are revolved in a planetary path to finish a circular surface on the work either internally or externally. The cutter may be plain, form or thread cutter and may work on either the inside or the outer of the work or inside and outside simultaneously. Application of this machine are milling of internal and external threads on all kind of tapered surface, bearing surface. These machines are available in either in horizontal or vertical spindle

Pantograph milling machine:-

A mechanical controlled tracing machine with 2 and 3 dimensional copying capacities is known as pantograph milling machine. Its purpose is to copy irregular 2 or 3 dimensional shape form a master work piece. The reproduced job can either be an enlargement or reduction of the size the masterwork piece. Two dimensional pantographs is used for engraving letter or design.

Three dimensional pantographs are employed for copying any shape and contour of the work piece. The tracing stylus is moved manually on the contour of the model to be duplicated and the milling cutter mounted on the spindle moves in a similar path on the work piece.

2 D Applications, 3D Applications
Engraving, Moulds, Stamps, Hobs, Drilling, Contouring, Slotting, Beveling.

Profile milling :-

A profiling machine duplicates the full size of the template attached to the machine. The cutter is a small diameter shank type end mill. The path of stylus or tracer has the same diameter, and shape as that of cutter, controls cutter movement either by hand or automatically. A good commercial finish and a tolerance of within 0.1 mm can be expected from this machine

UNIT 3: SPECIFICATION & WORK HOLDING DEVICES

Work holding device:-

1. T-bolt clamps
2. Bulky work piece of irregular shapes is clamped directly on the milling machine table by using T-bolts and clamps.
3. T-bolts having T-head are fitted in the T-slots of the table
4. The length of threaded portion is sufficiently long in order to accommodate different heights of works.
5. The clamps are made up of steel having slots at the center for fitting the bolt.
6. One end of the clamp rest on the side of the work while the other end rests on the fulcrum block

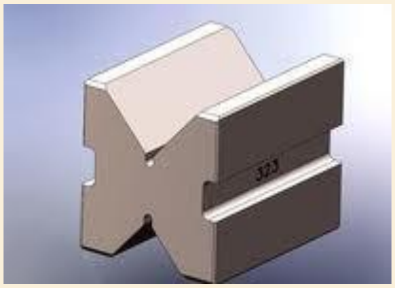
Angle plates: -

1) When work surface is to be milled at right angle to another face angle plates are used for supporting the work.
2) The angle plates are bolted on the table work piece is supported on its face by bolts and clamps
3) Angle plates are usually made of cast iron having two faces at right angle to each other.

A tilting type angle plate in which one face can be adjusted relative to another for milling at a required angle.

V-blocks:-

1) The V-blocks are used for holding round work piece on milling machine table in which key ways, slot and flats are to be milled
2) The V-block is clamped on the machine table by strap clamps and bolts.
3) V-block is made up of cast iron or steel
4) The angle of "V "is 90 degrees.



Special fixture: -

1. The fixture is a special device, designed to hold work for specific operation more efficiently than standard work holding devices.
2. Fixtures are specially used for large number of identical parts are to be produced
3. By using fixture loading, locating, clamping and unloading time is greatly reducing

Vice: -

Vice is the most versatile work holding device on milling machine table due to its quick loading and unloading arrangement.

There are mainly 3 types of vices commonly used in milling machine, they are as follows:

1) Plain vice
2) Swivel vice
3) Toolmaker vice

Tool makers universal vice:-

1) The universal vice can be swilled in a horizontal plain similar to a swivel vice

2) It can also be tilted in any vertical position for angular cuts.

3) The vice is not rigid in construction.

4) It is mainly used in tool room works.

UNIT 4: MILLING CUTTERS

Standard milling cutter: -

Plain milling cutter:

1) Light duty plain milling cutter
2) Heavy duty plain milling cutter
3) Helical plain milling cutter

Side milling cutter:

1) Plain side milling cutter
2) Staggered teeth side milling cutter
3) Half side milling cutter

Metal slitting saw:

1) Plain metal slitting saw
2) Staggered teeth metal slitting saw

Angle milling cutter:

1) Single angle milling cutter
2) Double angle milling cutter

Milling cutter materials:- Cutter characteristics:-

1. Harder than metal being machined
2. Strong enough to withstand cutting pressures
3. Tough to resist shock resulting from contact

4. Resist heat and abrasion of cutting
5. Available in various sizes and shapes

High-speed steel:-

1. Iron with additives
2. Carbon: hardening agent
3. Tungsten and Molybdenum: enable steel to retain hardness up to red heat
4. Chromium: increases toughness and wear resistance
5. Vanadium: increases tensile strength
6. Used for most solid milling cutters

Cemented-carbide:-

1. Higher rates of production (3-10 times faster)
2. Must select proper type of carbide
3. Straight tungsten carbide: cast iron, plastics
4. Tantalum carbide: low/medium-carbon steel

- Tungsten-titanium
- Carbide:
- High-carbon steel

PLAIN MILLING CUTTER:-

It has straight or helical teeth cut on the periphery.

It may be of solid inserted blade or tip type and it is usually sharpened profile. Generally helical teeth are used if the width of the outer exceeds 15mm.

The plain milling cutter is generally used to milling flat surface parallel to the cutter axis.

Helical teeth cutter is generally used where large stock removal is required.

Light-duty plain milling cutter:-

The light duty plain milling cutters have face width less than 20 mm and are made with straight teeth and parallel to the axis. The wider cutter is made with helical teeth, with helix angle of less than 25 degree. These are relatively fine tooth cutter.

Heavy-duty plain milling cutters:-

The half side milling cutters have straight or helical teeth on its circumferential surface and on one of its sides only. The peripheral teeth do the actual cutting, whereas the side teeth are finish the work. While straddle milling two half side milling cutters are mounted on the arbor.

Metal slitting saw:-

The metal slitting saws resemble a plain milling cutter or a side milling cutter in appearance but they are of very small width. The cutters are used for parting-off operation or slotting operation.

Plain metal slitting saw:-

- The plain metal slitting saws are thinner in construction and the width of the cutter is limited to 5 mm. The side of the cutter is relieved in order that the side faces may not rub against the work.

Staggered teeth metal slitting saw:-

-

The staggered teeth metal slitting saw resembles a staggered teeth side milling cutter, but the width of the cutter is limited to 6.5 to 7 mm. These cutters are used for heavy sawing in steel.

Angle milling cutter:-

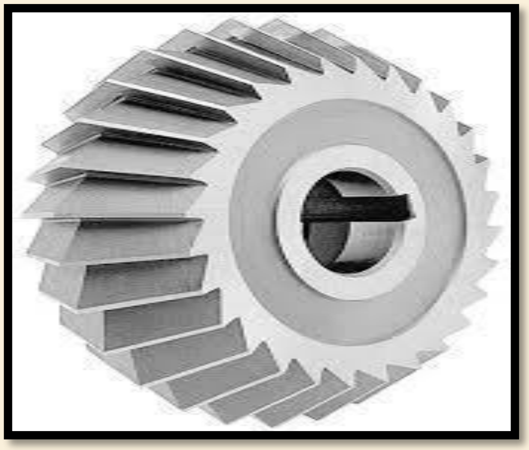
The angle milling cutters are made as single or double angle cutters and are used to machine angles other than 90 degree. The cutting edges are formed at the conical surface around the periphery of the cutter.

Single angle milling cutter:

- The single angle cutters have teeth on the conical or angular face the cutter and also on the large flat side. The angle of the cutter is designed by the included angle between the conical face and the large flat face of the cutter. The cutter having different included angles 30, 45, 60,70,75,80 and 85 degrees. The diameter of the cutter 50 mm and width of 12 mm.

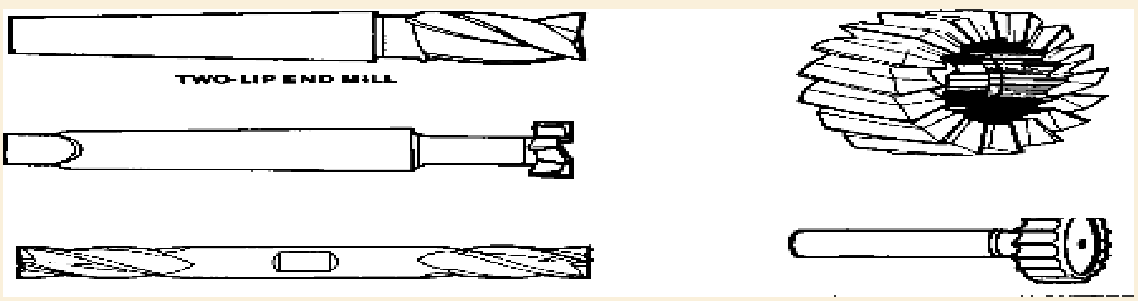
Double angle milling cutter:

- The double angle milling cutters have 'V' shaped teeth with both conical surfaces at an angle to their end faces. The angle of teeth may not be symmetrical with respect to plain right angles to the cutter axis



End mill:-

End mills have teeth on the periphery and on the end with a straight or tapered shank. The end mills are used for light milling operations like cutting slots, machining accurate holes, producing narrow flat surfaces and for profile milling operations.



Taper shank end mill

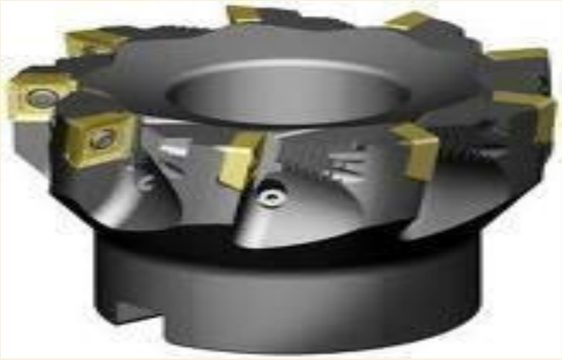
These end mills have a tapered shank or extension on one side for mounting and driving the cutters. The taper shank end mills are available from 10 to 63 mm in diameter.

Straight shank end mill:-

The straight shank end mills have round shanks for mounting and driving the cutters. The diameter of the cutter ranges from 2 to 63 mm.

Shell end mill:-

The shell end mills are larger and heavier end mills provided with a central hole for mounting the cutter on a short arbor. The cutting edges are provided at the end and around the periphery of the cutter. Face milling operations are usually performed with these cutters. The diameter of the cutters ranges from 40 to 160 mm and width from 32 to 50 mm.



T" slot milling cutter:-

The "T" slot milling cutters are the special form of end mills for producing "T" slots. The teeth are provided on the periphery as well as on both sides of cutter.

Wood ruff key slot milling cutter:

The woodruff key slot milling cutters are small standard cutters similar in construction to a small diameter plain milling cutter. These are intended for producing of woodruff key slots. This type of cutters is provided with a shank and may have straight or staggered teeth. "

Fly cutter:-

The fly cutter is simplest form of cutters and are mainly used in experimental shops or in tool room works. This type of cutter consists of a single point cutting tool attached to the end of an arbor. The cutting edge may be formed to produce contoured surface. The cutter may be considered as "EMERGENCY TOOL" when the standard cutters are not available

Formed cutters:-

These type of cutters have irregular profiles on the cutting edges in order to generate an irregular profile or out time of the work. The different types of formed cutters are:

Concave milling cutters:

The concave milling cutters have teeth’s curved inwards on the circumferential surface to form a contour of a semicircle. The concave milling cutter produces a convex semicircular surface on a work piece. The diameter of the cutter ranges from 56 to 110 mm and the radius of the semicircle vary from 1.5 to 20mm.

Convex milling cutters:

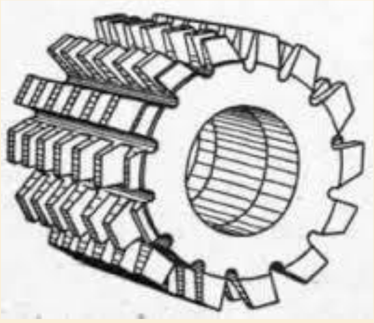
These types of cutters have teeth curved outwards on the circumferential surface to form the contour of a semicircle. The cutter produces a concave semicircular surface on a work piece. The diameter of the semicircle vary from 1.6 to 20 mm.

Corner rounding milling cutters:

The corner rounding milling cutters has teeth curved inwards on the circumferential surface to form the contour of a quarter circle. The cutter produces a convex surface having a contour of a quarter circle. The cutters are used for cutting a radius on the corners or edges of the work. The diameter of the cutters ranges from 1.5 to 20 mm.

Gear cutter:-

The gear cutters form cutting edges, which reproduce the shape of the cutter teeth on the gear blank. The shape of the cutter teeth may be in volute or cycloid according to the gear tooth profile.



Thread milling cutter:

These are special type of cutter to mill threads of specific form and size on a work piece. Generally, worms and acme threads are produced by thread milling cutter. The cutters may have parallel shank. Thread milling cutters are available in diameters ranging from 8 to 20 mm and the threaded portion vary from 8 to 33 mm. The pitch of thread corresponds to the diameter of the cutter. The taper shank thread milling cutters are available in diameter ranging from 16 to 25 mm and the length of the threaded portion vary from 16 to 40 mm.

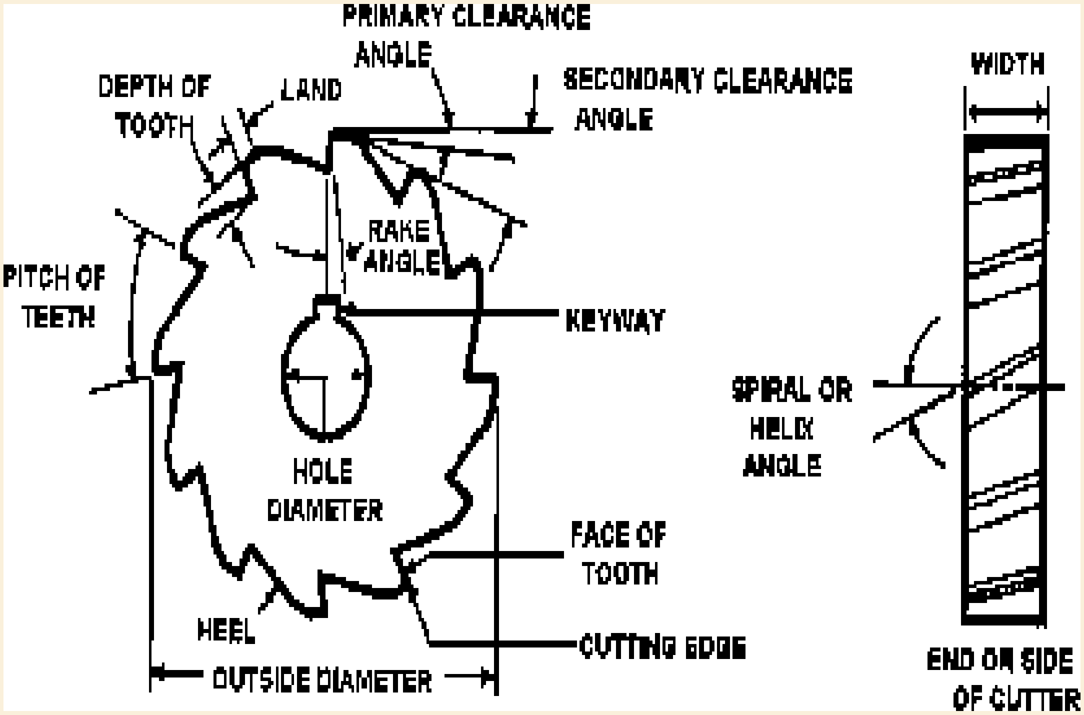
Tap and reamer cutter:-

The tap and reamer cutters are special type double angle cutters intendedfor producing grooves or flutes in taps and reamers. The point end of the tool is rounded and the tooth profile corresponds to the type of grooves that is to be machined.

Single lip cutter:-

The cutters having only one cutting edge such cutter is called as single lip cutter. It is most widely used in industries. It is designed with sharp edges to minimize rubbing contact between tool and work piece. Factors like cutting tool life, surface finish on work piece, force required to shear a chip are, affected by variations in shape of cutting tool. Such a tool is available in two forms. In one form it is solid tool and in the other form it is tipped tool. The tip either brazed or mechanically held on an alloy steel shank.

Nomenclature of a common milling cutter:-



UNIT 5: TOOL HOLDING DEVICE

Cutter holding device:-

1) Arbors.

2) Collets.

3) Adapter.

4) Spring collets.

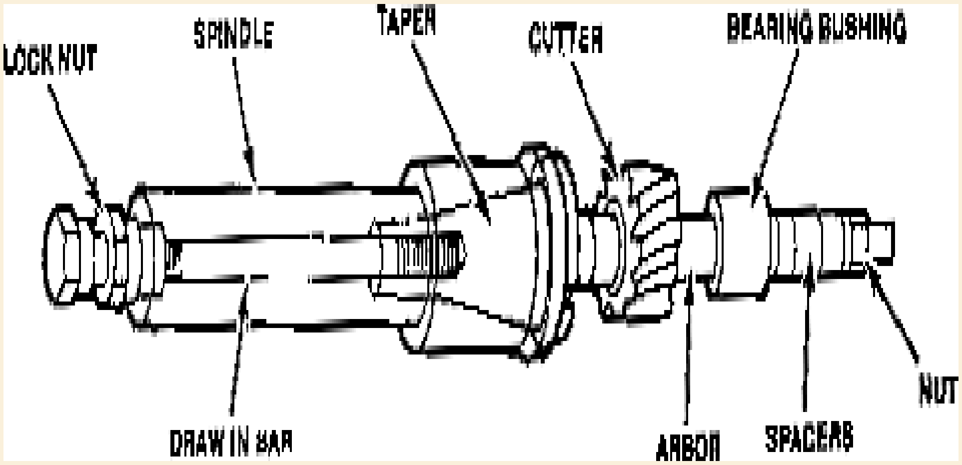
5) Bolted cutters.

6) Screwed on cutter

Arbors:-

The cutter has a bore at the center are mounted and keyed on a short shaft called ARBOR

It is connected with the milling machine spindle by a draw bolt and driving keys. One end of the arbor is inserted in milling machine spindle and other end supported by over arm. The arbors are made with taper shank forproper alignment with the machine spindle having taper hole at it nose is 7:25. The Morse taper shanks are available from 13 to 60 mm in diameter.

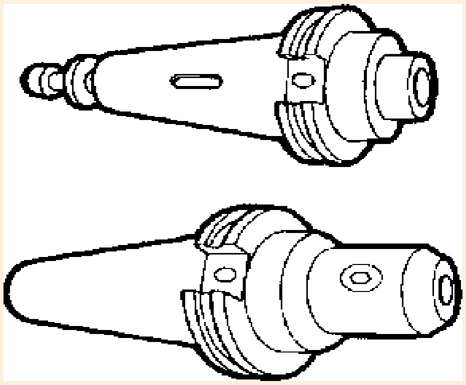


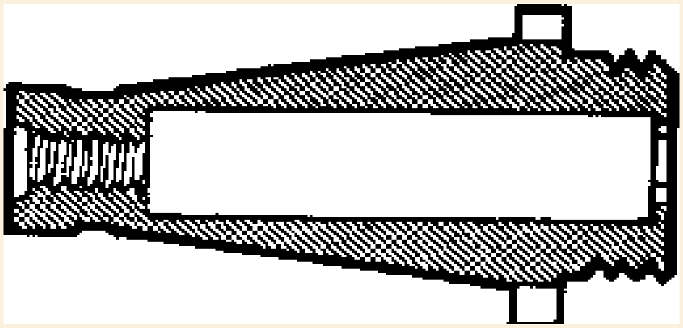
Collets:-

Milling machine collets is a form of sleeve bushing for reducing the size of the taper at the nose of the milling machine spindle, so that an arbor or milling cutter having a smaller shank than the spindle taper can be fitted in it.

Adapter:-

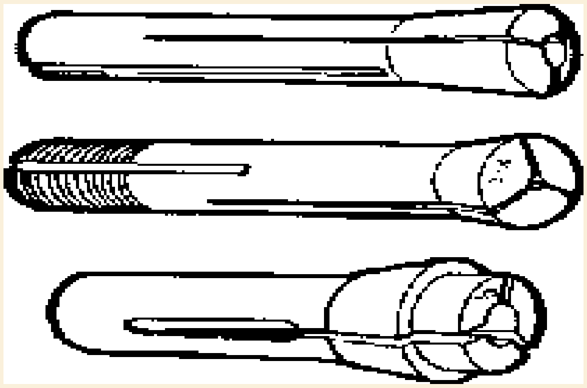
An adapter is form of collets used on milling machine having standardized spindle end. Cutter having shanks are usually mounted on adapter. An adapter can be connected with the milling machine spindle by a draw bolt or it may be directly bolted it.





Spring collet:-

Straight shank cutters are usually held on a special adapter called SPRING COLLET or SPRING CHUCK. The nose end of the adapter is tapered and threaded for small distance and also spilt by three equally spaced slots. The cutter shank is inserted in the cylindrical hole provided at the end of the



adapter and then the nut is tightened this causes the split jaws of the adapter to spring inside grip the shank firmly.

UNIT 5: TOOL HOLDING DEVICE

Milling machine operation

a) Plain milling.

b) Face milling.

c) Side milling.

d) Straddle milling.

e) Angular milling.

f) Gang milling.

g) Form milling.

h) Profile milling.

i) End milling.

j) Saw milling.

k) Milling key way, grooves and slots.

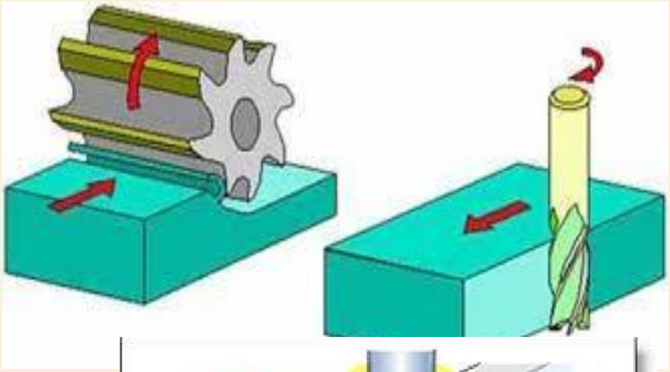
l) Gear milling.

m) Helical milling.

n) Cam milling.

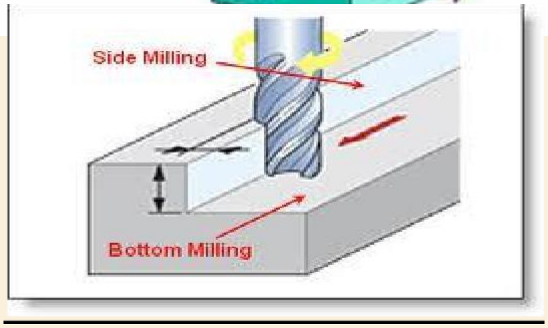
o) Thread milling.

Plain milling



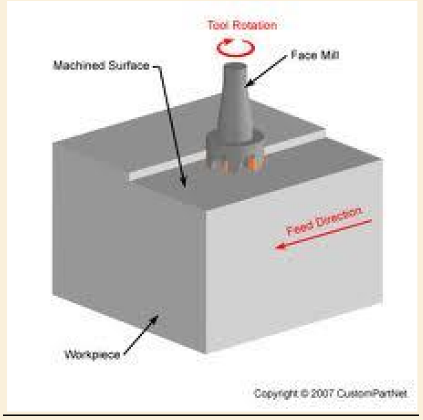
The plain milling operation is also called as slab milling. The plain milling is the operation of production of plain, flat, horizontal surface parallel to the axis of rotation of the plain milling cutter. In this operation the work andthe cutter are secured properly on the machine. The depth of cut is adjusted by rotating the vertical feed screw of the table.

Side milling



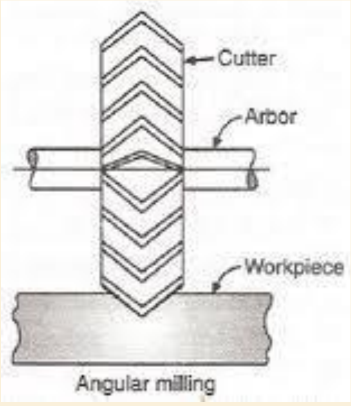
The side milling operation produces flat vertical surface on the side of the work by using a side-milling cutter. The depth of cut is adjusted by rotating the vertical feed screw of the table

Face milling



Face milling operation is performed by face milling cutter about an axis perpendicular to the work surface. The operation is carried out in plain milling machine. The cutter is mounted on a stub arbor to produce flat surface. The depth of cut is adjusted by rotating the cross feed screw of the table.

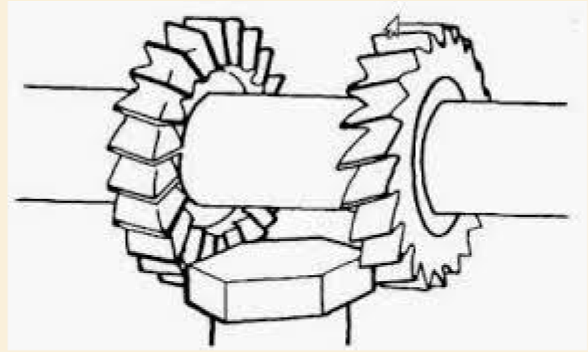
Angular milling



This is the operation of a production of angular surfaces on a work piece other than at right angles to the axis of machine spindle. The angular groove is may be single or double and may varying angle according to the shape of the component. The one of the best example for angular milling operation is “V” block.

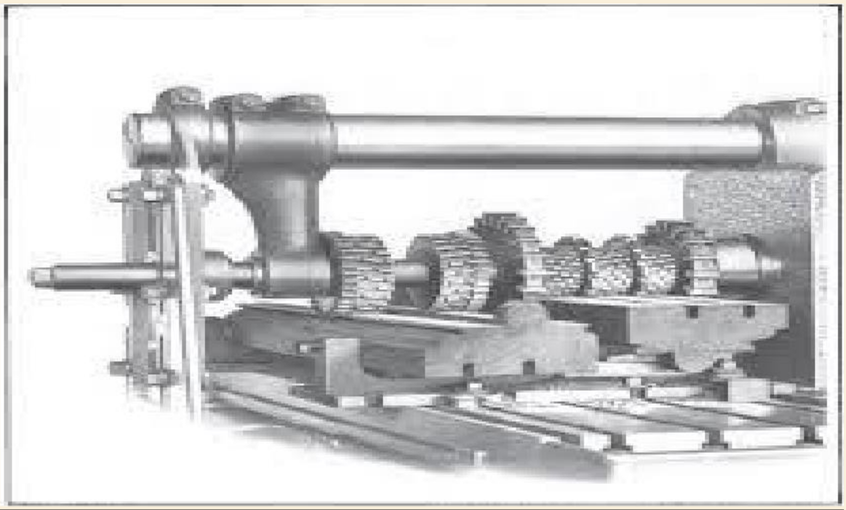
Straddle milling

This is the operation which produces flat vertical surfaces on both side of the work piece by using two side-milling cutters mounted on same arbor. The distance between the cutters is adjusted by suitable collars. This operation is commonly used for production of square or hexagonal surfaces.



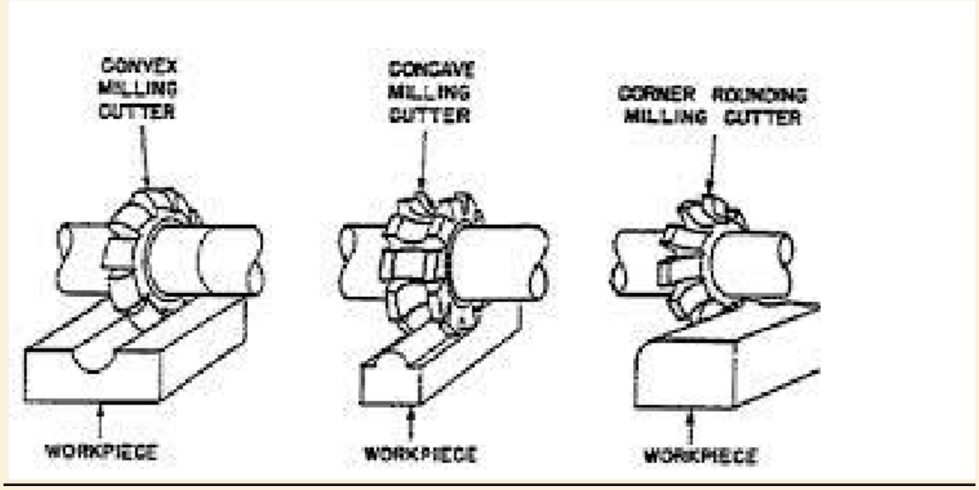
Gang milling

The gang milling is an operation of machining several surfaces of a work piece simultaneously by feeding the table against a number of cutter having same or different diameter mounted on arbor of the machine. This method saves much time and widely used for repetitive work. The cutter speed is calculated by diameter of the largest cutter.



Form milling

Form milling is the operation for production of irregular contour by using form cutter. The irregular surfaces may be convex, concave or of an any other shape. In the form milling operation, the cutting speed of the form milling is 20% to 30% less than plain milling.

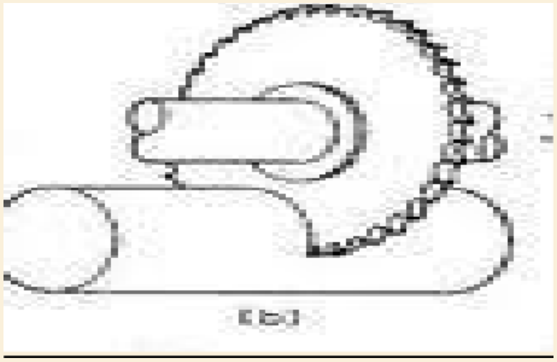


End milling:-

This is the operation of producing a flat surface on the vertical, horizontal or at angle in reference to the table surface. This is also used for producing slots, grooves, or key ways. The vertical milling machine is mostcommonly used for end milling operation.

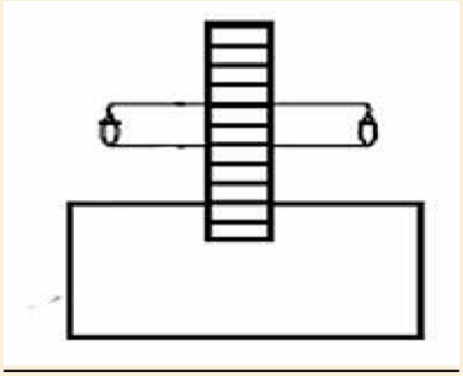
Saw milling:-

This is the operation for producing of narrow slots or grooves on a work piece by using a saw milling cutter or slitting saw. It can be performed for complete parting off operation. The work piece is directly placed over one of the T-slot of the table.



Milling key ways, rooves and slots:-

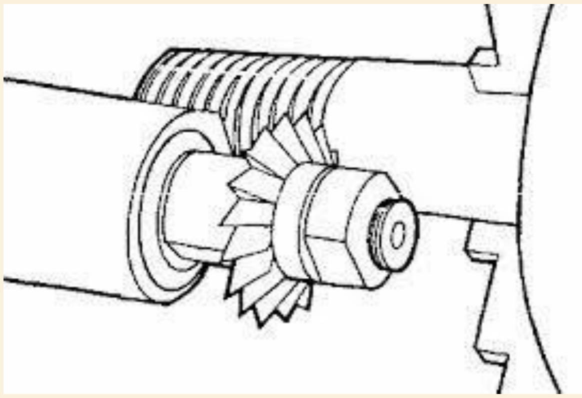
These operations are performed by using plain milling cutter, slitting saw and end mill or by side milling cutter. Closed slots are produces by end mills. A dovetail slot or T-slot is manufactured by using special type of cutters. T- slot is produced by first milling a plain slot on the work piece and then the shank of the T-slot milling cutter is introduced through the first machined slot.



Gear cutting:-

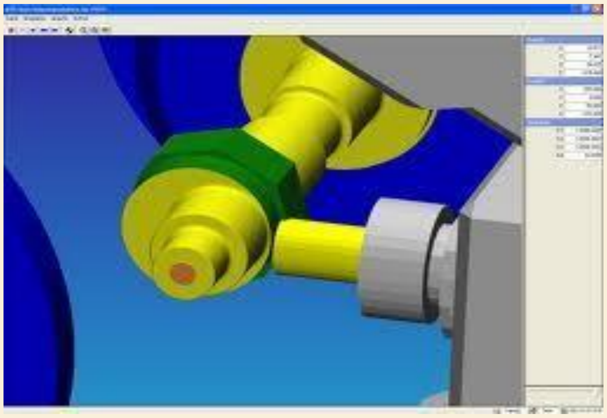
The gear cutting operation is performed in milling by using a form relieved cutter. The cutter may be cylindrical type or end mill type. The cutter profile corresponds exactly with the tooth space of the gear. Equally spaced gear teeth are cut on a gear blank by holding work on universal dividing head and then indexing it.

Helical milling:-



The helical milling is the operation of production of the helical flutes or grooves around the periphery of a cylindrical or conical work pieces. The operation is performed by swiveling the table to the required helix angle and then by rotating and feeding the work against rotary cutting edges of a milling cutter. The usual examples of work performed by helical milling operations are the production of helical milling cutter, helical gears, cutting helical grooves or flutes on a drill blank or a reamer.

Cam milling :-



The cam milling is the operation of producing of cams in milling machine by using universal dividing head the cam blank is mounted on dividing head and end mill held vertically, the axis of cam blank and cutter must be parallel. The dividing head is geared to the table feed screw so that the cam is rotated about its axis while it is feed against the end mill. The axis of the cam can be set from 0 to 90 degrees in reference to the surface of the table for obtaining different rise of the cam.

Thread milling:-

Thread milling is the operation of production of threads by using single or multiple thread-milling cutters. This operation is performed special thread milling machines. This operation requires three driving motions one for the cutter, second for the work, and third for the longitudinal movement of the cutter.

UNIT 7: DIVIDING HEAD & ROTARY TABLE

Circular or rotary milling attachment:-

This is a rotary table provided with “T” slots its circumference is divided into degrees and may be hand indexed for spacing or locating slots, grooves, or holes. For the purpose of milling a circular are or groove on the job an arrangement can be used to make it power operated to provide continuous motion. It is bolted to the top of the table of a plain or universal milling machine. It provides rotary motion to the work piece in addition to the longitudinal, cross and vertical movements of the table. The dividing mechanism of a circular milling attachment consists of a vertical shaft, which keyed to a worm gear fitted with a circular table. The horizontal worm meshes with the worm gear and produces rotary movements to the table when the worm is rotated.

Dividing head attachment:-

It is special work holding device, which is bolted on the machine table. The work piece may be mounted on a chuck fitted on the dividing head spindle or may be supported between a live center and a dead center. The dead center is mounted on a footstock as in a lathe tailstock that is bolted on the machine table after correctly aligning its spindle axis with the dividing head spindle. The attachment principally used for dividing the periphery of a work piece into a required number of equal divisions, for machining equally spaced slots or grooves. The worm and worm gear driving mechanism of the attachment can be linked with the table lead screw for cutting equally spaced helical grooves on the periphery of a cylindrical work piece.

UNIT 8: INDEXING & METHODS OF INDEXING

Methods of Indexing

1. Direct
2. Simple
3. Angular
4. Differential

Direct Indexing

1. Simplest form of indexing
2. Performed by disengaging worm shaft from worm wheel by means of eccentric device in dividing head
3. Spring-loaded tongue lock engages numbered slots in index plate
4. Used for quick indexing of work piece when cutting flutes, hexagons, squares, etc.
5. Direct indexing plate usually contains three sets of hole circles or slots: 24, 30, and 36
6. Number of divisions possible to index limited to numbers that are factors of 24, 30, 36
7. Slots Direct indexing divisions

   24 2 3 4 _ 68 __________12_________24_____

   30 2 3 _ 5 6 __ 10__________15_________30_

   36 2 3 4 _ 6_ 9_________12_____18_________36

Example: Direct Indexing: -

1. What direct indexing is necessary to mill eight flutes on a reamer blank?
2. Since the 24-hole circle is the only one divisible by 8 (the required number of divisions), it is the only circle that can be used in this case.
3. **Slots Direct indexing divisions**
4. 24 2 3 4 _ 6 8 _ 12 24
5. 30 2 3 _ 5 6 _ _ 10 15 30
6. 36 2 3 4 _ 6 _ 9 12 18 36

Never count the hole or slot in which the index pin is engaged.

Milling a Square with Direct Indexing -

1. Disengage worm and worm shaft by turning worm disengaging shaft lever if dividing head is so equipped
2. Adjust plunger behind index plate into the 24-hole circle or slot
3. Mount work piece in dividing head chuck or between centers
4. Adjust cutter height and cut first side
5. Remove plunger pin using plunger pin lever
6. Turn plate attached to dividing head spindle one-half turn and engage plunger pin
7. Take second cut
8. Measure work across flats and adjust work height if required
9. Cut remaining sides by indexing every six holes until all surfaces cut
10. Check for finish size

Simple Indexing

1. Work positioned by means of crank, index plate, and sector arms
2. Worm attached to crank must be engaged with worm wheel on dividing head spindle
3. 40 teeth on worm wheel
4. One complete turn on index crank cause spindle and work to rotate one- fortieth of a turn (ratio of 40:1)

Calculating the indexing or number of turns of crank for most divisions, simply divide 40 by number of divisions to be cut or,

Indexing = 4 0 / N

1. The indexing required to cut eight flutes:

   40/8=5 full turns of index crank

2. The indexing required to cut seven flutes:

   40/7=5 5/7 full turns of index crank

The five-sevenths turn involves use of an index plate and sector arms.

Index Plate and Sector Arms

1. Index plate
2. Circular plate provided with series of equally spaced holes into which index crank pin engages
3. Sector arms
4. Fit on front of plate and may be set to any portion of a complete turn

Finishing Indexing for Seven Flutes Index-

plate hole circles

Brown & Sharpe

Plate 1	15-16-17-18-19-20
Plate 2	21-23-27-29-31-33
Plate 3	37-39-41-43-47-49

Cincinnati Standard Plate

One side 24-25-28-30-34-37-38-39-41-42-43

Other side 46-47-49-51-53-54-57-58-59-

Choose any hole circle that is divisible by denominator

5/7 = 15 /21

So, 5 full turns plus15 holes on 21-hole circle!

Cutting Seven Flutes

- Mount B&S Plate 2 index plate on dividing head
- Loosen index crank nut and set index pin into hole on 21-hole circle
- Tighten index crank nut and check to see that the pin enters hole easily
- Loosen setscrew on sector arm
- Place narrow edge of left arm against index pin
- Count 15 holes on 21-hole circle
- Do not include hole in which index crank pin is engaged.
- Move right sector arm slightly beyond fifteenth hole and tighten sector arm setscrew
- Align cutter with work piece
- Start machine and set cutter to top of work by using paper feeler

- Move table so cutter clears end of work
- Tighten friction lock on dividing head before making each cut and loosen lock when indexing for spaces
- Set depth of cut and take first cut
- After first flute has been cut, return table to original starting position
- Withdraw index pin and turn crank clockwise five full turns plus the 15 holes indicated right sector arm
- Release index pin between 14^{th} and 15^{th} holes and gently tap until it drops into 15^{th} hole
- Turn sector arm farthest from pin clockwise until it is against index pin
- The arm farthest from the pin is held and turned. If the arm next to the pin were held and turned, the spacing between both sector arms could be increased when the other arm hits the pin. This could result in an indexing error not noticeable until the work was completed.
- Lock dividing head; continue machining and indexing for remaining flutes

ANGULAR INDEXING

1. Setup for simple indexing may be used
2. Must calculate indexing with angular distance between divisions instead number of divisions
3. One complete turn of index crank turns work 1/40 of a turn
4. 1/40 of 360º equals 9 degrees
5. Indexing in degrees = $\frac{\text{No of degrees required}}{9}$

Calculate indexing for 45º

Indexing = 45/9= 5 complete turns

Calculate indexing for 60º

Indexing = 60/9=62/3 complete turns

6 full turns plus 12 holes on 18 hole circle

Calculate indexing for 24’

Divide 24'/540' = 4/90

4/90 = 1/22.5

1 hole on a 22.5-hole circle

The nearest is a 23-hole circle. Indexing would be 1 hole on a 23-hole circle with a slight error (approximately 1/2 minute). A need for higher accuracy requires differential indexing.

Calculate indexing for 24º30'

1. First, convert angle into minutes

2. 24 x 60') = 1440' now add 30' =1470‘

3. Convert 9°to minutes 9°x90’ = 540’ 4.

Divide 1470'/540' = 2 13/18

2 full turns and 13 holes on 18-hole circle

DIFFERENTIAL INDEXING

- Used when 40/N cannot be reduced to a factor of one of the available hole circles
- Index plate must be revolved either forward or backward part of a turn while index crank turned to attain proper spacing (indexing)
- Change of rotation effected by idler gear or gears in gear train
- Number chosen close to required divisions that can be indexed by simple indexing
- Example: Assume index crank has to be rotated $1/9^{th}$ of a turn and only 8-hole circle
- Crank moved $1/9^{th}$, index pin contacts plate at spot before first hole
- Exact position would be the difference between $1/8^{th}$ and $1/9^{th}$ of a revolution of the crank

DIFFERENTIAL METHOD CONT.

one-seventy-second of a turn short of first hole

Since there is no hole at this point, it is necessary to cause plate to rotate backward by means of change gears one-seventy-second of a turn of pin will engage in hole.

Method of Calculating the Change Gears

A = appr

$$\text{Change gear ratio} = (A - N) \times \frac{40}{A}$$

N = requi

$$= \frac{\text{driver (spindle) gear}}{\text{driven (worm) gear}}$$

5. If A is greater than N, resulting fraction is positive and the index plate must move in same direction as crank (clockwise). This positive rotation uses an idler gear.
6. If N is greater than A, resulting fraction is negative and index plate must move counterclockwise. This negative rotation required use of two idler gears.

Gearing

Simple

One idler for positive rotation of index plate and two idlers for negative rotation

Compound

One idler for negative rotation of index plate and two idlers for positive rotation

Example:

Calculate the indexing and change gears required for 57 divisions. The change gears supplied with the dividing head are as follows:

24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86

The available index plate hole circles are as follows: Plate 1: 15, 16,

17, 18, 19, 20

Plate 2: 21, 23, 27, 29, 31, 33

Plate 3: 37, 39, 41, 43, 47, 49

$$\text{Indexing} = \frac{40}{N} = \frac{40}{57} \qquad \frac{40}{56} = \frac{5}{7}$$

Choose plate 2: 21 holes

5/7 would be 15 holes on 21-hole circle

No 57 hole circle so select number close to 57

$$\text{Gear ratio} = (A - N) \times \frac{40}{A}$$

$$= (56 - 57) \times \frac{40}{56} = -1 \times \frac{40}{56} = -\frac{5}{7}$$

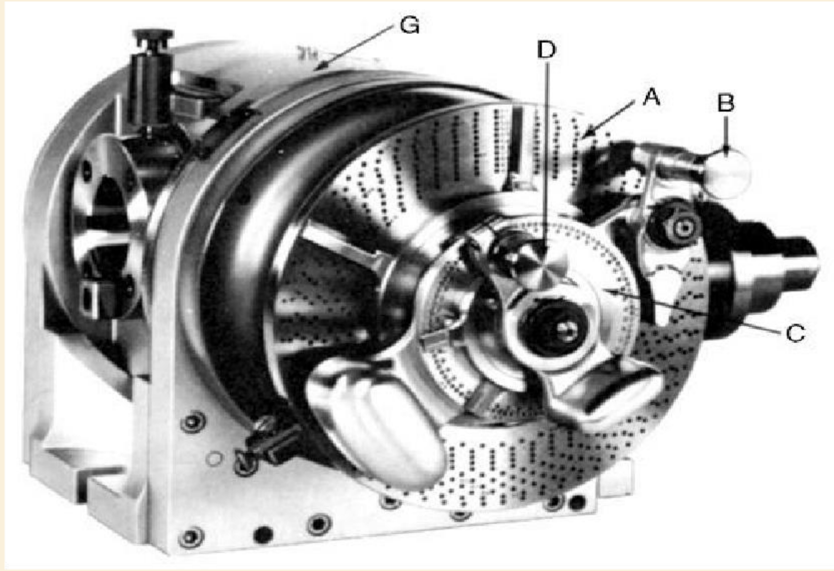
$$\text{Change gears} = -\frac{5}{7} \times \frac{8}{8} = -\frac{40 \text{ (spindle gear)}}{56 \text{ (worm gear)}}$$

The fraction is negative and simple gearing is to be used, the index plate rotation is counterclockwise and two idlers must be used.

1. For indexing 57 divisions, a 40-tooth gear is mounted on the dividing head spindle and a 56-tooth gear is mounted on the worm shaft.
2. Index idlers must be used. plate rotation is negative and two
3. After proper gears installed, the simple indexing for 56 divisions should be followed

Wide-Range Dividing Head

1. Possible for 2 to 400,000 divisions
2. Large index plate contains 11 hole circles on each side
3. Small index plate mounted in front of large, contains a 54 hole and a 100-hole circle
4. 40:1 ratio between worm and dividing head spindle



G – Gear housing D - crank A – large index plate B - crank C – Small index plate

Speed Formulas for Calculation:-

V=πdn/1000 N=vx1000/πxd Where as
V=cutting speed meters/min
N=revolution/min D=diameter of
cutter in mm Π=3.142

UNIT 9: MILLING ATTACHMENTS

Milling machine attachaments:-

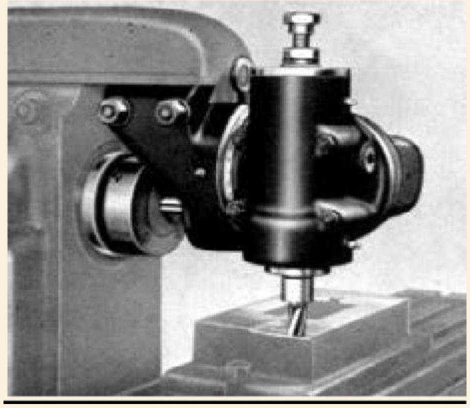
1. Vertical milling attachment
2. Universal milling attachment
3. High speed milling attachment
4. Slotting attachment
5. Universal spiral milling attachment
6. Rack milling attachment
7. Circular milling attachment
8. Dividing head attachment

Vertical milling attachment:-

- A vertical milling attachment can convert a horizontal milling machine in to a vertical by changing the cutting spindle axis from horizontal to vertical performing specific operation.
- This attachment consists of a right angle gearbox, which is attached to the nose of the horizontal milling spindle. It is bolted on the column of the face
- The speed of the vertical spindle is same as that of the machine spindle. It can be swiveled at an angle other than at right angle to the table for machining angular surfaces

UNIVERSAL MILLING ATTACHMENT: -

It is similar to the vertical milling attachment, but it has an added arrangement swiveling the spindle above two mutually perpendicular axes. The attachment is supported by the angular surface of the work. It operates at either the same speed or at higher speed than machine spindle, in this attachment the spindle is swiveled at any angle to machine any Compound angular surface of the work.



High speed milling attachment: -

With the help of this attachment the speed of the spindle can be increased three to four times, so that the operation with small cutters could be carried out efficiently. This attachment is mounted on the column with four bolts and can be swiveled also at any angle. It consists of a gearing attachment with in its casting.

Slotting attachment:-

With the help of these attachment square holes, slots and a variety of jobs can be machined on milling machine, which a rotary tool cannot do. It converts the rotary motion of the spindle into reciprocating motion of the ram by means an eccentric or crank housed within the attachment. It converts the milling machine into a spotter by accepting a single point slotted tool at the bottom end of the ram. This attachment is bolted on the face of the column.

Universal spiral milling attachment: -

This attachment is used in plain milling machine or universal milling machine for cutting a spiral groove on a cylindrical work piece. This attachment is bolted on the face of the column. Its spindle head may be swiveled in the vertical or horizontal plane. While using on a plain milling machine the cutter mounted on the attachment may be swiveled to the required helix angle for cutting a spiral. This attachment is used in a universal milling machine for cutting spiral grooves having a helix angle of more than 45 degrees.

Rack milling attachment:-

It is used for milling straight or inclined racks or cross-slotted pieces of large length on horizontal or universal milling machine. It consists of a milling unit a fixture and a rack-indexing unit. The milling unit is mounted on the column face and is supported at the front by an over arm. The successive rack teeth are out by using a rack indexing attachment. The slated rack teeth or a screw rack may be machined where the table may

Circular or rotary milling attachment:-

This is a rotary table provided with “T” slots its circumference is divided into degrees and may be hand indexed for spacing or locating slots, grooves, or holes. For the purpose of milling a circular are or groove on the job an arrangement can be used to make it power operated to provide continuous motion. It is bolted to the top of the table of a plain or universal milling machine. It provides rotary motion to the work piece in addition to the longitudinal, cross and vertical movements of the table. The dividing mechanism of a circular milling attachment consists of a vertical shaft, which keyed to a worm gear fitted with a circular table. The horizontal worm meshes with the worm gear and produces rotary movements to the table when the worm is rotated.

UNIT 10: COOLANT FOR MACHINING OPERATIONS

The critical functions of coolant in the machining process include: Reducing and removing the heat build-up in the cutting zone and work piece. Provides lubrication to reduce friction between the tool and removal of the chips. Flushes away chips and small abrasive particles from the work area.

A machine coolant is applied during machining operation; it removes heat by caring it away from the cutting tool or work peace interface. This cooling effect prevents tools from exciding their critical temperature range beyond which the tool softness and wears rapidly.

There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gasses. Cutting fluid are made from petroleum distillates, animal fats, plant oil, water & air, or other raw ingredients.

Generally, coolant ratio is 1:20