III Year - I Semester

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METAL CUTTING & MACHINE TOOLS

Course objectives:

1. The course provides students with fundamental knowledge and principles in material removal processes.

2. In this course, the students apply the fundamentals and principles of metal cutting to practical applications through multiple labs using lathes, milling machines, grinding machines, and drill presses, Computer Numerical Control etc

3. To demonstrate the fundamentals of machining processes and machine tools.

4. To develop knowledge and importance of metal cutting parameters.

5. To develop fundamental knowledge on tool materials, cutting fluids and tool wear mechanisms.

6. To apply knowledge of basic mathematics to calculate the machining parameters for different machining processes.

UNIT – I

FUNDAMENTAL OF MACHINING:

Elementary treatment of metal cutting theory – element of cutting process – geometry of single point cutting tool, tool angles, chip formation and types of chips – built up edge and its effects, chip breakers, mechanics of orthogonal cutting –Merchant's force diagram, cutting forces, cutting speeds, feed, depth of cut, tool life, tool wear, machinability, economics of machining, coolants, tool materials and properties.

UNIT – II

LATHE MACHINES:

Engine lathe – principle of working, specification of lathe – types of lathe – work holders tool holders – box tools taper turning, thread turning – for lathes and attachments, constructional features of speed gear box and feed gear box. Turret and capstan lathes – collet chucks – other work holders – tool holding devices – box and tool layout. Principal features of automatic lathes – classification – single spindle and multi-spindle automatic lathes – tool layout and cam design for automats.

UNIT – III

SHAPING, SLOTTING AND PLANNING MACHINES: Principles of working – principal parts – specifications, operations performed, machining time calculations.

DRILLING & BORING MACHINES: Principles of working, specifications, types, operations performed – tool holding devices – twist drill – Boring Machines – fine Boring Machines – jig boring machine, deep hole Drilling Machine.

UNIT – IV

MILLING MACHINES: Principles of working – specifications – classification of Milling Machines – principal features of horizontal, vertical and universal Milling Machine, machining operations, types of cutters, geometry of milling cutters – methods of indexing, accessories to milling machines.

UNIT –V

FINISHING PROCESSES: Theory of grinding – classification of grinding machines, cylindrical and surface grinding machines, tool and cutter grinding machines, different types of abrasives, bonds, specification and selection of a grinding wheel. Lapping, Honing & Broaching operations, comparison to grinding.

UNIT - VI

JIGS & FIXTURES: Principles of design of jigs and fixtures and uses, classification of jigs & fixtures, principles of location and clamping, types of clamping & work holding devices, typical examples of jigs and fixtures.

CNC MACHINE TOOLS: CNC Machines, working principle, classification, constructional features of CNC machines, CNC controller, types of motion controls in CNC machines, applications of CNC machines.

Text Books:

1. Manufacturing Processes / JP Kaushish/ PHI Publishers-2nd Edition
2. Manufacturing Technology Vol-II/P.N Rao/Tata McGraw Hill

References:

1. Metal cutting and machine tools /Geoffrey Boothroyd, Winston A.Knight/ Taylor & Francis
2. Production Technology / H.M.T. Hand Book (Hindustan Machine Tools).
3. Production Engineering/K.C Jain & A.K Chitaley/PHI Publishers
4. Technology of machine tools/S.F.Krar, A.R. Gill, Peter SMID/ TMH
5. Manufacturing Processes for Engineering Materials-Kalpakjian S & Steven R Schmid/Pearson Publications 5th Edition

Course Outcomes:

Upon successful completion of this course, the students will be able to:

1) Apply cutting mechanics to metal machining based on cutting force and power consumption.

2) Operate lathe, milling machines, drill press, grinding machines, etc.

3) Select cutting tool materials and tool geometries for different metals.

4) Select appropriate machining processes and conditions for different metals.

5) Learn machining economics.

6) Design jigs and Fixtures for simple parts.

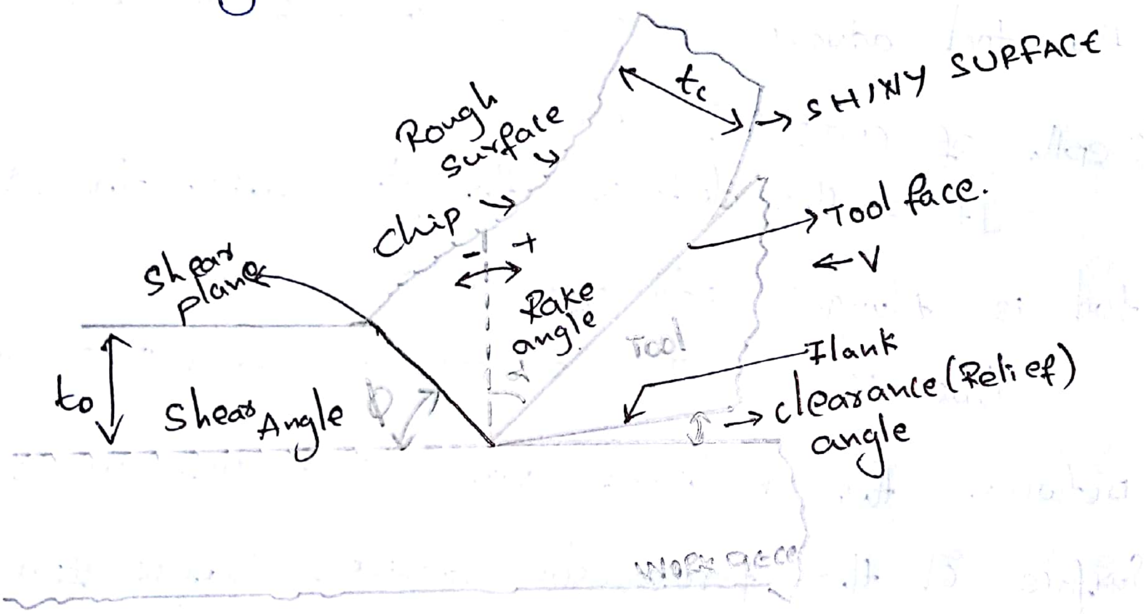
7) Learn principles of CNC Machines

UNIT-1

FUNDAMENTALS OF MACHINING

Elements of cutting process:-

Any cutting process involves work piece, tool (including holding device) chips and cutting fluid. For Removing the metal. A wedge shaped tool is constrained to move relative to the work piece, so that it Removes metal in the form of chips. It will be seen that there are three basic angle of importance, Rake angle clearance angle and setting angle.



SCHEMATIC ILLUSTRATION OF A 2-D CUTTING (ORTHOGONAL)

$\alpha \rightarrow$ Rake angle.

$\phi \rightarrow$ shear angle

$t_c \rightarrow$ thickness of chip.

$t_o \rightarrow$ Depth of cut

CUTTING PARAMETERS.

Cutting Speed: (v) → m/min

Cutting Speed is the distance traveled by the work surface in unit time with Reference to the cutting edge of the tool. expressed in m/min.

FEED: (f) mm/rev feed Rate mm/min.

The feed is the distance advanced by the tool into or along the workpiece each time the tool point passes a certain position in its travel over the surface.

In case of turning, feed is the distance that the tool advance in one Revolution of the workpiece.

Depth of CUT: (d) mm

It is the distance through which the cutting tool is plunged into the workpiece Surface.

Thus it is the distance measured perpendicularly between the machined surface and unmachined (uncut) surface or the previously machined surface of the workpiece.

SELECTION of cutting speed and feed:

→ This depends on following parameters
- → Workpiece material.
- → Tool material
- → Tool geometry and dimensions
- → Size of chip cross-section
- → Types of finish Desired
- → Rigidity of the machine, Types of coolant used.

CUTTING TOOLS & ITS CHARACTERISTICS:

Cutting tool is a device, used to remove the unwanted material from given workpiece. For carrying out the machining process, cutting tool is fundamental and essential Requirement. It must have following characteristics

Hardness → Tool material must be harder than the work piece material. Higher the hardness, easier to tool to penetrate the work material.

Hot hardness → is the ability of the cutting tool must to maintain its hardness and strength at elevated temps.

Toughness → Inspite of tool being tough, It should have enough toughness to withstand the impact loads that come in the start of the cut to force fluctuations due to imperfections in the work material.

Wear Resistance → Wear Resistance means the attainment of acceptable tool life before tools need to be Replaced.

Low friction → Coefficient of friction between tool and chip should be low. This lower wear Rates and allow better chip flow.

Thermal characterstics →
Since a lot of heat is generated at the cutting zone, the tool material should have higher Thermal conductivity to dissipate the heat in shortest possible time.

CUTTING TOOL MATERIALS :-

Carbon and Medium alloy steels → (High carbon steel 0.9 to 1.3% Carbon)

ADV
→ Inexpensive
→ easily shaped
→ sharpened

Limits
→ NO sufficient hardness and wear Resistance
→ limited to low cutting speed operations.

High Speed steel (1900) → plane high carbon steel + Alloying elements (Mangnese, chromium, tungsten, vanadium, Molybdenum, cobalt, niobium) to get high harden, strength, Resistant to heat.

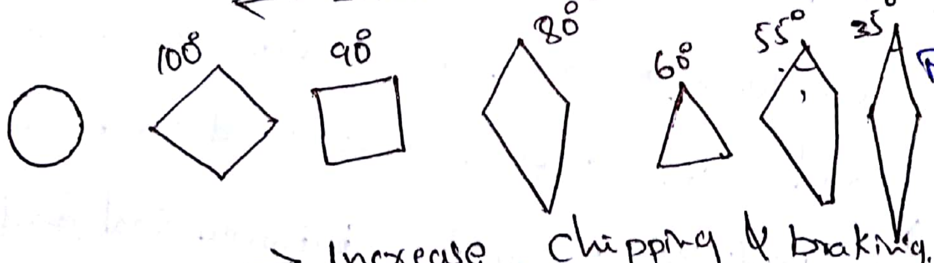
types → Tungsten HSS (T)
→ Molybdenum HSS (M)

CEMENTED CARBIDE (or) Sintered CARBIDES (1926-30):
→ produced By powder Metallurgy

Types → 1) Tungsten carbide (WC)
2) Tantalum " (TaC)
3) Titanium " (TiC)

Bare upto 1000°C
Available as brazed tip tools. (Triangular, Square, Diamond, Round shapes)

← Increase strength



→ Increase chipping & braking.

COATED CEMENTED CARBIDE (1960): Tool life 200 to 300%

A thin chemically stable hard Refractory coating of TiC, TiN, Al_2O_3. tool is tough, shock Resistance, high temps.

CAST COBALT ALLOYS OR STELLITES (1915):

Non ferrous Alloy + Cobalt, Tungsten, Chromium + others
(38 to 53% Co, 30% to 33% Cr, 4 to 20% Tungsten)

others → Molybdenum, Manganese, Silicon & carbon.

Good shock & wear Resistance, Retain hardness upto 900°C

Can operate speed about 25% higher than HSS.

~~Non metal~~
CEMENTED OXIDES or CERAMIC Cutting tools (1950 S)

Non metallic Materials Made of pure Aluminium oxide by powder Metallurgy with limited Application because of extreme Brittleness.

upto 1200°C, Capable of high speeds.

CERMETS: CERAMICS + Metal Binders
(TiC, TiN, Nickel, Carbides)

→ higher hardness
→ Oxidation Resistance
→ less tough
→ used for finishing operation.

DIAMONDS: → Industrial grade Natural Diamonds
↳ Synthetic polycrystallin Diamonds.

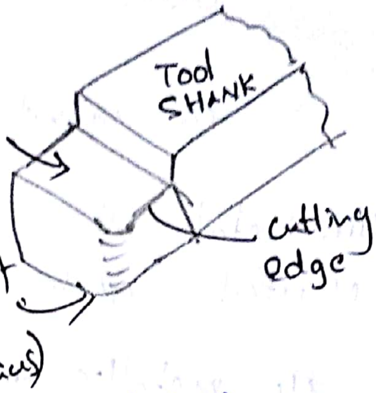
They can be used in Non-ferrous Metals

feed should be very light and high speeds

setup is very critical Because extreme hardness & Brittles of Diamond.

SINGLE POINT CUTTING TOOL GEOMETRY:

1) one cutting edge
2) Turning uses Single point tools
3) point is usually rounded to form a nose radius.



SHANK

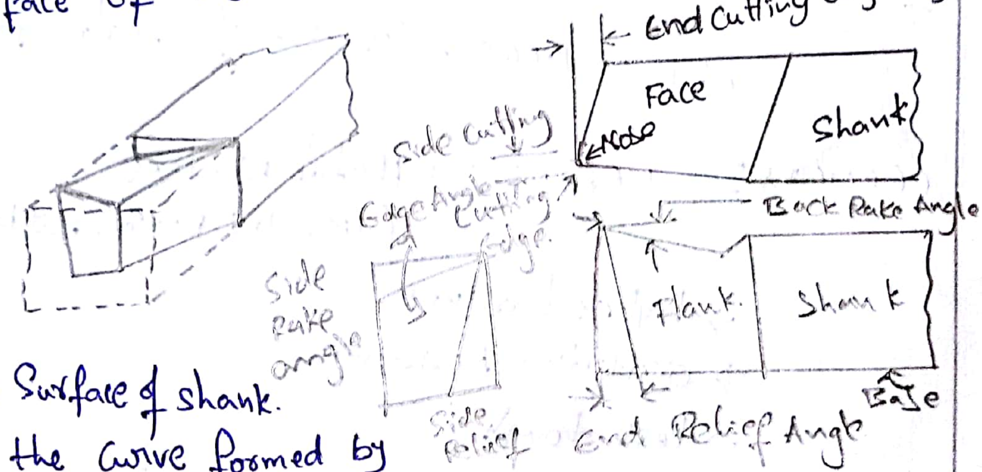
It is the body of the tool, on one end of which cutting point is formed.

Face

The Surface over which the Chip impinges as it is removed from workpiece.

Flank

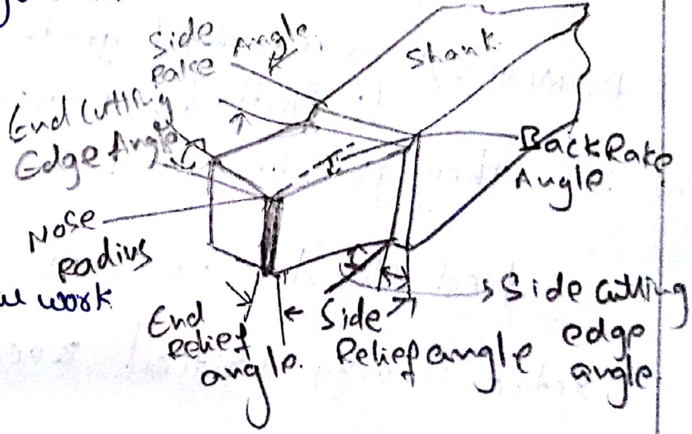
The Surface of the tool which is facing the workpiece.



Base Bottom Surface of shank.

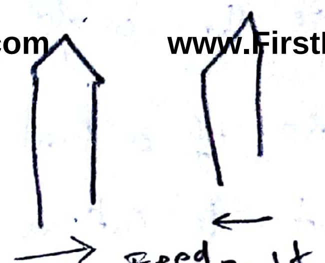
NOSE: It is the curve formed by joining the Side cutting edge and end cutting edge.

Cutting Endge: The portion of the face edge along which the chip is Seperated from the work



CUTTING EDGE

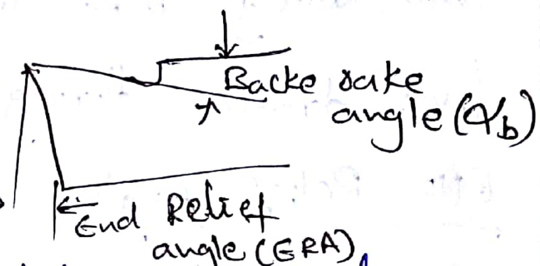
It is the edge or the face of the tool which removes the material from the work piece.



The total cutting edge consists of Side cutting edge (major cutting edge), end cutting edge (minor cutting edge) nose.

Single point cutting tool may be either or left or Right hand cutting tool depends on feed direction.

In Right handed cutting tool the side cutting edge is on the side of the thumb when the right a hand is placed on the tool with the palm downward and fingers pointed.

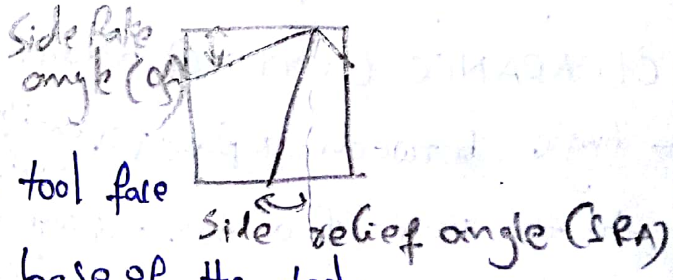


BACK RAKE ANGLE:

It is the angle b/w the face of the tool and the parallel to the base of the tool. Measured in a plane parallel to the centre line of point and right angles to the base.

'+ve' = face slopes downward ; '-ve' = face slopes upward

It controls the formation of chip and guides its direction of flow.



Side Rake angle:

→ It is the angle b/w the tool face and line parallel to the base of the tool.

→ Measured in a plane perpendicular both the centre line of point and the base.

→ 6-15° → It also controls the direction of chip flow

Relief Angle:-

→ It is the angle b/w a plane perpendicular to the Base of a tool and the flank immediately adjacent to Cutting edge.

→ It controls the rubbing at tool-workpiece interface.

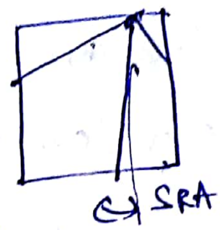
→ Higher the relief angle, the tool may be chip-off

→ Smaller the relief angle, greater will be the flank wear.

(a) Side relief angle

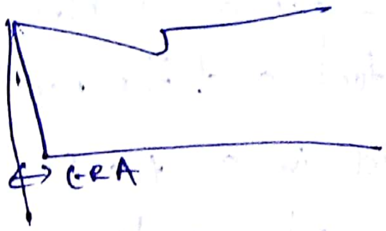
(b) end relief angle.

<u>SIDE Relief Angle</u> :-



Angle b/w the portion of the flank immediately below the cutting edge and a line drawn through the cutting edge/point.

<u>END Relief Angle</u> :-



Angle b/w the portion of the end flank immediately below the cutting edge and a line drawn through the that cutting edge perpendicular to base → 8-15°

CLEARANCE (CUTTING) ANGLE:

→ Angle between a plane perpendicular to the base of a tool and that of flank immediately adjacent to the base.

END CLEARANCE ANGLE:

Angle between a plane perpendicular to the base of a tool and that of end flank (Surface below the end cutting edge) immediately adjacent to the base.

SIDE CLEARANCE ANGLE:

Angle between a plane perpendicular to the base of a tool and that of side flank (Surface below the cutting edge) immediately adjacent to the base.

NOSE RADIUS:

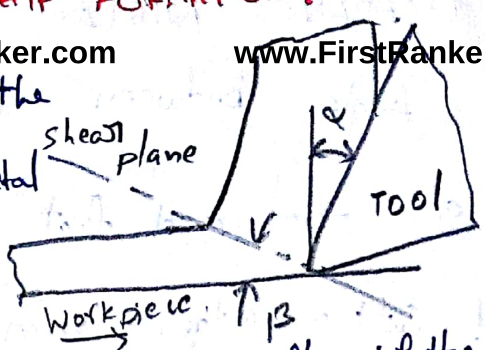
It is curve formed by joining side cutting edge and the end cutting edge.

Larger nose radius, greater will be the surface finish

LIP ANGLE:

It is the angle between the tool surface and the ground end surface of flank. It is usually between 60° to 80°.

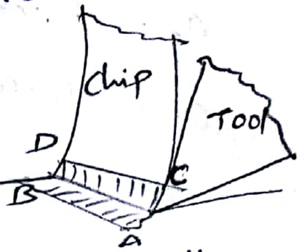
MECHANICS OF CUTTING AND CHIP FORMATION:



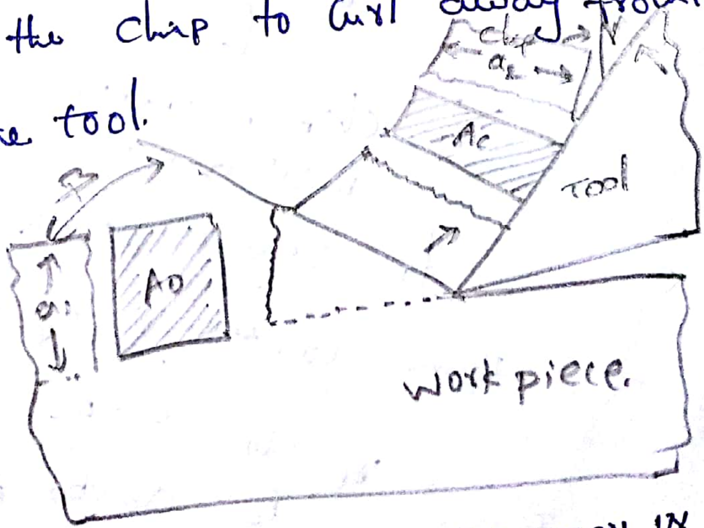
Tool is considered stationary, and the workpiece moves to the right. The metal is severely compressed in the area in front of the cutting tool. This causes high temperature shear, and plastic flow if the metal is ductile. When the stress in the workpiece just ahead of the cutting tool reaches a value exceeding the ultimate strength of the metal, particles will shear to form a chip element which moves up along the face of the work. The outward or shearing movement of each successive element is arrested by work hardening and the movement transferred to the next element. The process is repetitive and a continuous chip is formed having a highly compressed and burnished underside, and a minutely serrated top side caused by the shearing action. The place along which the element shears is called the shear plane.

Thus chip is formed by plastic deformation of the grain structure of the metal along the shear plane as shown.

Actually, the deformation does not occur sharply across the shear plane, but rather it occurs along a narrow band. The structure begins elongation along ~~the line AB below the shear plane and~~ continue to do so until it is completely deformed along the line CD above the shear plane in fig. The region between the lower surface AB, where elongation of the grain structure begins, and the upper surface CD, where it is completed and the chip is Born, is called the Shear Zone or primary deformation zone.



The shear zone is included between two parallel lines AB and CD. Actually, however, these two lines may not be parallel but may produce a wedge-shaped zone which is thicker near the tool face at the right than at the left. This is one of the causes of curling of chips in metal cutting. In addition, owing to the non-uniform distribution to the non-uniform distribution of forces at the chip tool interface and on the shear plane the shear plane must be slightly curved concave downward. This also causes the chip to curl away from the cutting face of the tool.



GEOMETRY OF CHIP FORMATION IN ORTHOGONAL CUTTING

Chip thickness ratio:

→ The outward flow of the metal causes the chip to be thicker after separation from the parent metal. That is the chip produced is thicker than the depth of cut as shown in fig.

a_2 = thickness of chip

a_1 = uncut thickness (feed - in case of turning)

$$a_2 = a_1 \frac{\cos(\beta-\gamma)}{\sin\beta}$$

if the degree of reduction or chip reduction coefficient is designated r_c,

$$r_c = \frac{a_2}{a_1} = \frac{\cos(\beta-\gamma)}{\sin\beta} \quad \text{—— (1)}$$

from which

$$\tan\beta = \frac{\cos\gamma}{r_c - \sin\gamma} \quad \text{—— (2)}$$

The chip reduction coefficient can also be estimated in a different manner by measuring the length of the chip (l_c) when:

$$r_l = \frac{l_0}{l_c}$$

r_l = chip reduction coefficient from length measurements

l_0 = original length of uncut material in mm

From constancy of volume removal

$$r_l = \frac{l_0}{l_c} = \frac{a_c \cdot b_c}{a_0 \; b_0} = \frac{A_c}{A_0} = r_a$$

A_0 = uncut area of layer to be removed mm^2

A_c = Area of the chip cross-section in mm^2

r_a = chip reduction coefficient from area measurement no side flow of the chips,

$b_c = b_0$

$r_l = r_a = r_c$

It is difficult to measure the cross-section of chip accurately since one side of the chip is usually rough. Hence r_c is often determined from length measurement.

The density of metal may be used to find the chip reduction coefficient thus:

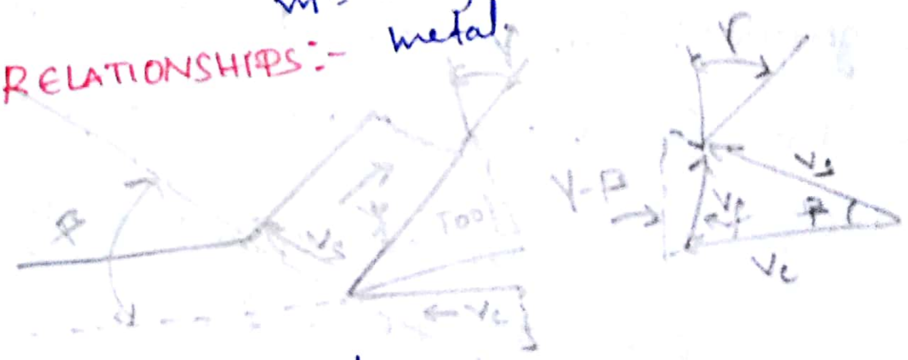
$$r_c = \frac{t w \rho}{m}$$

w = width of chip

ρ = density of metal

m = weight per unit length of the metal.

VELOCITY RELATIONSHIPS:-



V_c – cutting velocity

V_s — velocity of shear

V_f – velocity of chip flow up the tool face

$$V_s = V_c \frac{\cos \gamma}{\cos(\beta-\gamma)} \qquad V_f = \frac{V_c}{r_c}$$

$$V_f = V_c \frac{\sin\beta}{\cos(\beta-\gamma)}$$

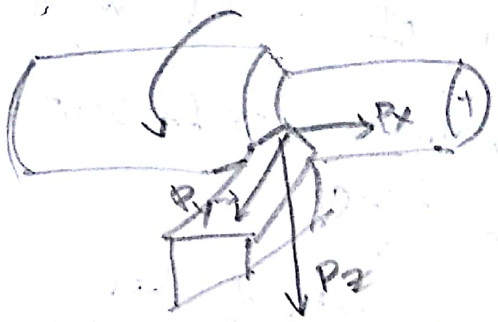
It can be inferred from the principle of kinematics that the relative velocity of two bodies is equal to the vector difference b/w their velocities relative to the reference body (work piece).

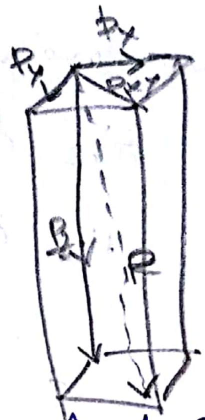
So,

$$V_c = V_s + V_f \quad \text{———} (3)$$

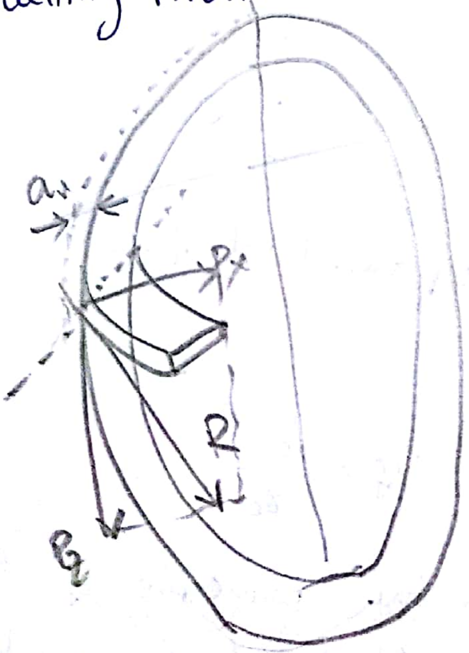
CUTTING FORCES IN ORTHOGONAL CUTTING:-

In the process of turning the resultant cutting force R may be resolved into three components, known as the "feed force" acting in a horizontal plane.





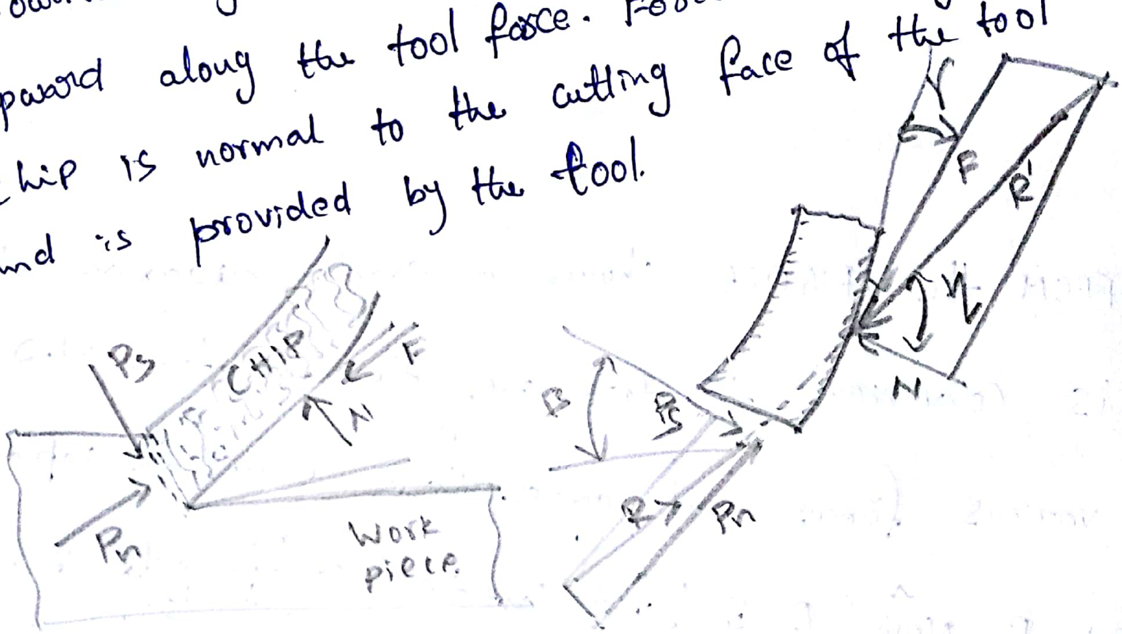
But in the direction opposite to the feed; P_y called "Thrust force" acting in the direction perpendicular to the generated surfaces; and P_z, the "cutting force" or the "main force" acting in the direction of the main cutting motion.



The largest in magnitude is the vertical force P_z which, in turning, is about 2 or 3 times larger than thrust force P_y and from 4 to 10 times larger than feed force P_x.

In case of orthogonal cutting when $\lambda = 0$, $\phi = 90°$, the force system is reduced to a 2-Dimentional system as indicated in fig.

The forces acting on the chip in orthogonal cutting are in fig. they are as follow: P_s, which acts along the shear plane, is the resistance to shear of the metal in forming the chip. P_n is normal to the shear plane. This is a "backing-up" force on the chip provided by the workpiece. Force "F" is the frictional resistance of the tool acting downward against the motion of the chip as it moves upward along the tool face. Force "N" acting on the chip is normal to the cutting face of the tool and is provided by the tool.



FORCES ON CHIP

Forces acting on chip P_n, P_s replaced by their Resultant R of Forces F, N repleated by R',

R, R' are same in magnitude, opposite in direction, collinear.

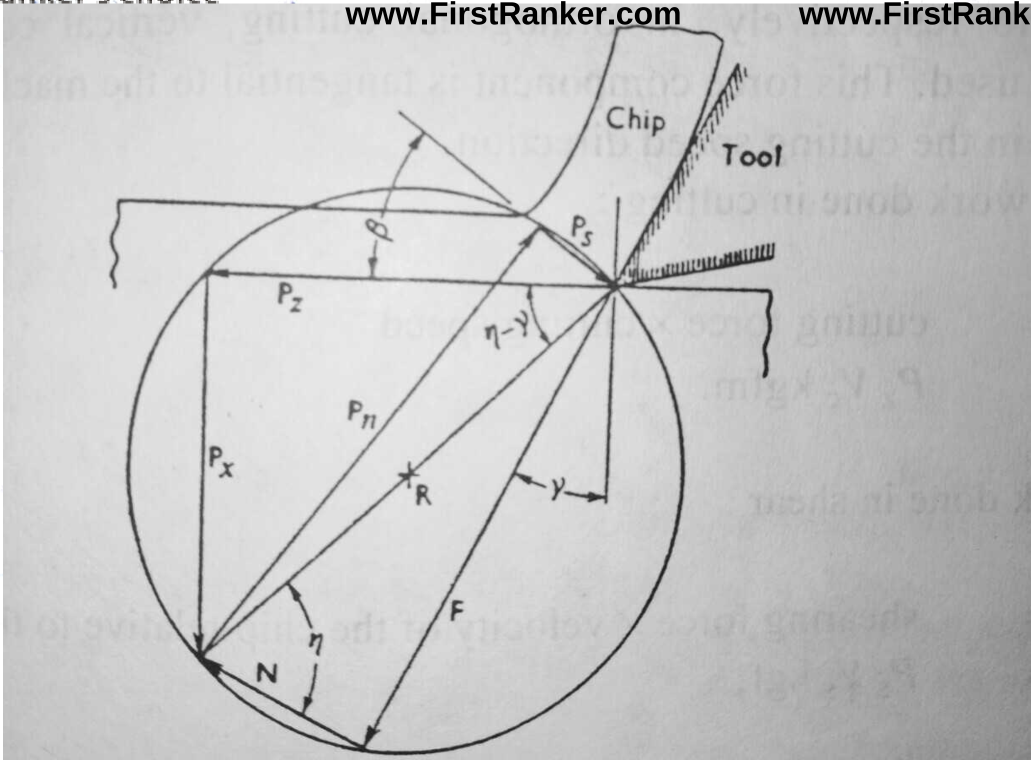
By the Mechanical equilibrium.

R is force which the workpiece exerts on chip

R' " " " Tool "

$\vec{R'} = \vec{N} + \vec{F}$ and $R = P_s + P_n$

MERCHANT'S CIRCLE DIAGRAM FOR CUTTING FORCES:



2.11 Merchant's circle diagram for cutting forces

FROM the FIGURE shows a Circle diagram which is convenient to determine the Relation b/w various forces and angles. Here R & R' are Replaced By R. Now R Resolved into two components forces

P_s → the cutting force of the tool on the work piece

P_x → Feed force.

The cutting force P_z and feed force P_x can be determined by the use of Force dynamometer.

After P_z and P_x are determined they can be Laid of as shown in fig. and their Resultant is the diameter R of circle.

$$\vec{R} = \vec{P_z} + \vec{P_x}$$

... can be laid off of measure ... the tool, and forces F and N can then be determined.

The shear angle β can be measured approximately from a photomicrograph of from the relation. $\tan\beta = \frac{r_c \cos\gamma}{1 - r_c \sin\gamma}$

After these forces are known, all the component forces on the chip may be determined from the geometry of fig. from the fig following relationships are evident

$$F = P_x \cos\gamma + P_z \sin\gamma$$

$$N = P_z \cos\gamma + P_x \sin\gamma.$$

F → Frictional resistance at the rake surface in kgf.

N → Normal force on the rake surface in kgf.

Hence, average kinetic coefficient of (μ) can be estimated

$$\mu = \tan\eta = \frac{F}{N} = \frac{P_x + P_z \tan\gamma}{P_z - P_x \tan\gamma}$$

where η = mean angle of friction at the rake surface.

$$P_s = P_z \cos\beta - P_x \sin\beta$$

$$P_n = P_x \cos\beta + P_z \sin\beta$$

$$= P_s \tan(\beta + \eta - \gamma)$$

Merchant has developed a relationship between the shear angle β, the angle of friction η and the cutting Racke angle γ as follows

$$2\beta + \eta - \gamma = C$$

C = Machining const for the work material dependent on the ... degree of the shear strength ...

of the metal with applied compressive stress, besides taking the internal coefficient of friction into account 18

STRESS IN SHEAR PLANE:

Let A_0 = area of chip before removal

A_s = area of the shear plane

P_s = Shearing force

S = Shear stress on shear plane in kgf/mm²

$$S = \frac{P_s}{A_s}$$

but $A_s = \frac{A_0}{\sin\beta}$

$$S = P_s \frac{\sin\beta}{A_0}$$

$$S = \frac{(P_z \cos\beta - P_x \sin\beta)\sin\beta}{A_0} = \frac{(P_z \cos\beta \sin\beta - P_x \sin^2\beta)}{A_0}.$$

WORK DONE :-

W_c (work done in cutting) = Cutting force × Cutting Speed

$= P_z V_c$ kgf m.

W_s (work done in shear) = Shearing force × velocity of the chip relative to work

$= P_s V_s$ kgf

W_f (work done in friction) = friction force × velocity of the chip relative to cutting force

$= V_f$ kgfm.

total work in cutting: $W_c = W_s + W_f$

$$hp_c = \frac{P_z V_c}{60 \times 75 \times 1.36} \text{ kw}$$

But the cutting power h.Pc can be estimated by measuring the gross horse-power h.Pg and tare horse power h.Pt when

$$h.P_c = h.P_g - h.P_t$$

$$P_z = h.P_c \times 6120 / V_c \quad kgf$$

$$\eta = \frac{h.P_c}{h.P_g}$$

TORQUE AND POWER IN DRILLING

$$T = Q \frac{d}{2} \text{ kg.mm}$$

Q:- Circumferential force

(or) $T = c d^{1.9} s^{0.8}$

Thrust $B = k d s^{0.78}$

d:- dia of the drill in mm

S:- feed , c = 34 , k = 85 for steel

Power $h.P_c = \frac{2\pi T n}{1000 \times 60 \times 102} + \frac{B s n}{1000 \times 60 \times 102}$ kW

TORQUE AND POWER IN MILLING

$$T = \frac{P_z d}{2}$$

d = diameter of the cutter in mm

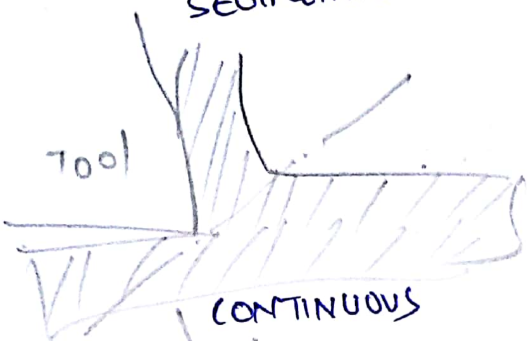
$$h.P_c = \frac{2\pi T n}{1000 \times 60 \times 102} \text{ kW}$$

TYPES OF Chips

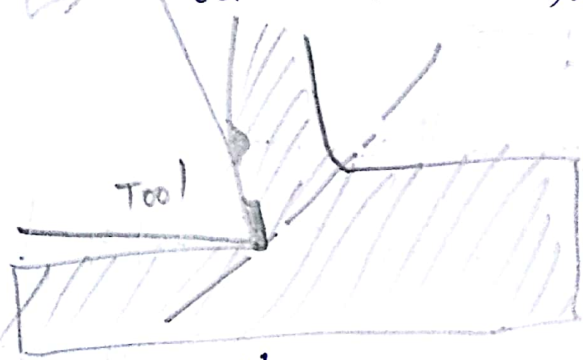
→ chip formation is Based on variout Cutting conditions and Material properties.

→ Three general types
1) The discontinuous &/Segmental
2) The continuous & Ribbon
3) The continuous with built-up edge.

SEGMENTAL



CONTINUOUS



BUILT-UP

Discontinuous & Segmental chips consists of elements fractured into fairly small pieces ahead of the cutting tool. This type of chip is obtained in Machining most brittle materials, such as cast iron and bronze. These materials rapture during plastic deformation, and form chips as seperate small pieces. As these chips are produced, the cutting edge smoothes over the irregularities, and a fairly good finish is obtained. Tool life is also reasonably good, and the power consumption low. Discontinuous chips can also be formed on some ductile metals only under certain conditions particularly at very low speeds and if the coeffciect of friction is low. with ductile metals, however, the surface finish is bad and the tool life is short.

~~Brittle metal, greater depth of cut, low cutting speed and small rake angle.~~

Continuous chips consists of elements bonded firmly together without being fractured. Under the best conditions the metal flow by means of plastic deformation, and gives a continuous ribbon of metal which, under the microscope, shows no signs of tears or discontinuities. The upper side of a chip has small notches while the lower side is smooth and shiny.

It is most desirable for low friction at the tool-chip interface, low power consumption, long tool life and good surface finish.

Ductile metal, such as mild steel, copper etc. fine feed, high cutting speed, large rake angle, keen cutting edge, smooth tool face and an efficient lubrication system.

The term built-up edge implies the building up of a ridge of metal on the top surface of the tool and above the cutting edge. It appears that, when the cut is started in ductile metals, a pile of compressed and highly stressed metal forms at the extreme edge of the tool. Owing to the high heat and pressure generated there, this piled up metal is welded to the cutting tip and form a "false" cutting edge to the tool.

This is usually referred to as the "built up edge."

This metal very strain hardned and brittle. So

the weaker chip metal tears away from the weld as

the chip moves along the tool face. The built up

becoming unstable, breaks down and some fragments

leave with the chip as it passes off and the rest

adheres to the work surface producing the

Rough Surface, The builtup edge appears to be rather

Permanent structure as along as the cut is

continuous at relatively high Speeds and has the

effect of slightly altering the rake angle. At very

high speeds, usually associated with Sintered carbide

tools, the built up edge is very small or nonexistent,

and a Smooth machined Surface results —

conditions tending to promote the formation

of builtup edges include: low cutting Speed, low

rake angle, high feed, lack of cutting fluid and

Large depth of cut.

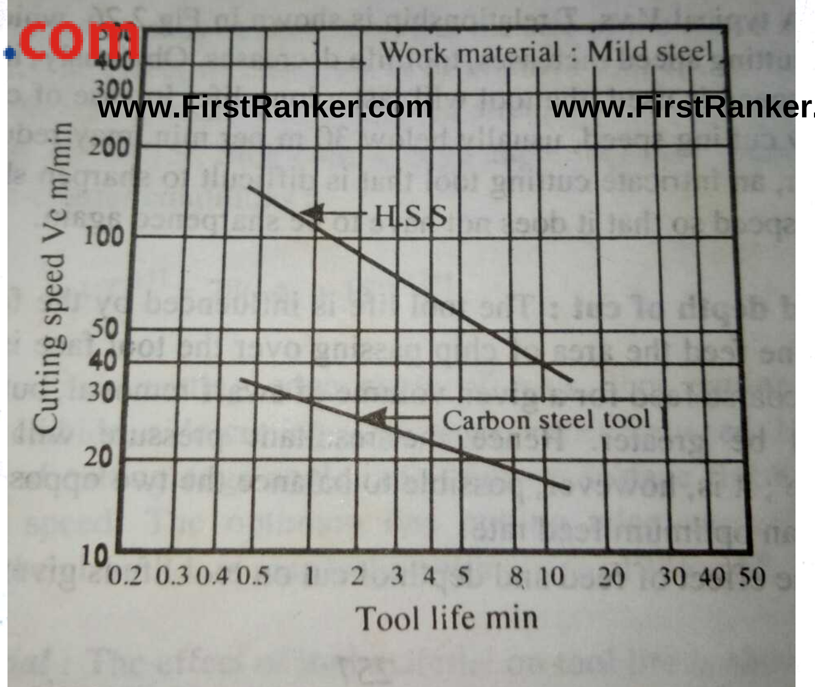


Figure 2.26 Tool life vs cutting speed

CUTTING SPEED:

$$V T^n = C$$

V = cutting Speed in m per min

T = tool life in minutes

n = exponent which depends on the tool and the workpiece. The value of exponent n is about 0.1 for high-speed tool steel, 0.20 to 0.25 for carbide tools, 0.4 to 0.55 for ceramic tools.

C = Constant which is numerically equal to cutting speed that gives a tool life of one minute.

which mean cutting speed ↑ tool life decreases.

Feed and depth of cut:

$$V = \frac{257}{T^{0.19} \times S^{0.36} \times t^{0.08}} \text{ m per min}$$

S = feed mm/min, t = depth of cut in mm

$V_t = \frac{C_v}{t^x s^y}$ m per min

V_t = cutting speed for a given tool life in m per min.

C_v = a coefficient depending upon machine and work pieces variables

x, y = exponents which depend on the mechanical properties of the material being machined.

TOOL GEOMETRY:

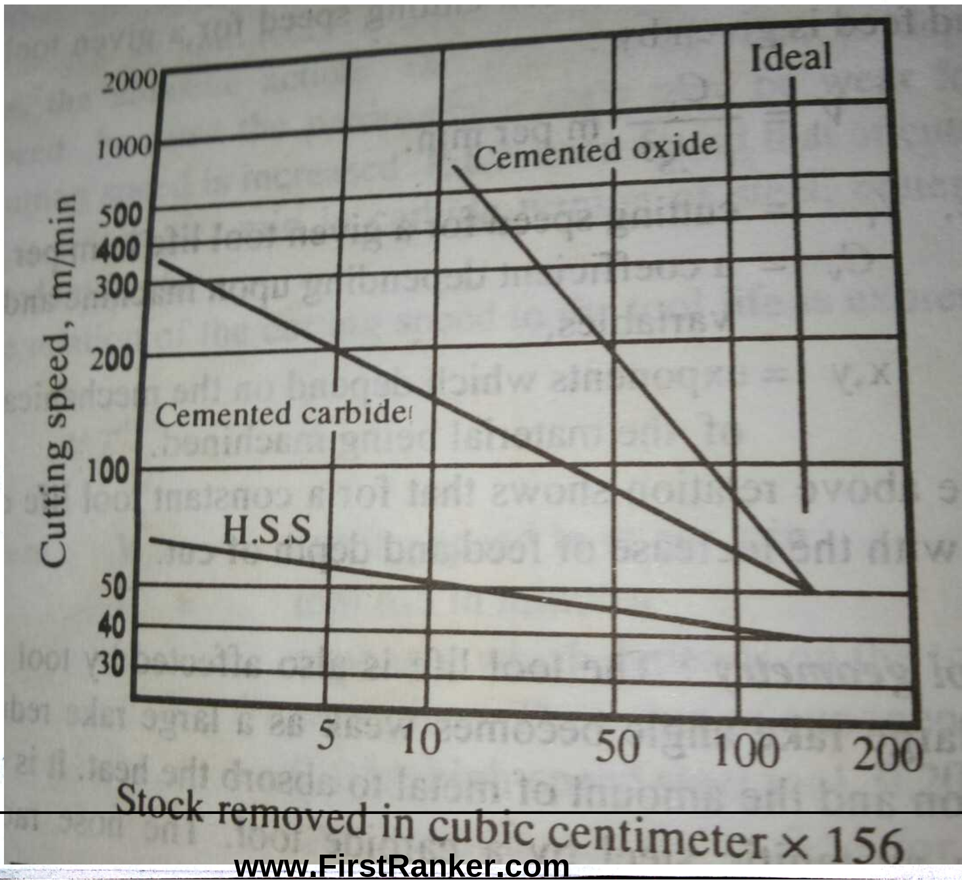
$$V T^{0.0927} = 331 R^{0.244}$$

R = Nose Radius

$$V T^{0.11} = 78 (\phi_s + 15°)^{0.264}$$

ϕ_s = Side cutting edge angle.

TOOL Material:



Cutting fluids affect tool life to a great extent.
A cutting fluid does not carry away the heat generated and keep the tool chip and workpiece cool, but reduces the coefficient of friction at the chip tool interface and increases tool life.

Measuring tool-life:-

Notation:

t = depth of cut in mm

S = feed in mm per rev

d = diameter of the work piece in mm

V = cutting speed in m per min

T = time to tool failure in min.

n = revolution per min of the workpiece.

L = tool life in terms of metal removed until tool fails in mm^3

Cross sectional area of chip = ts mm^2

Length of chip in one revolution = πd mm

∴ volume of metal removed/rev = $\pi d ts$ mm^3

Volume of metal removed/min = $\pi d t s n$ mm^3/min

Volume of metal removed until tool fails = $\pi d t s n T$ mm^3

$$\therefore L = \pi d t s n T$$

$$V = \frac{\pi d n}{1000} \ m/min$$

∴ T... = 1000 ts VT mm^3/min.

MACHINABILITY:

The 'ease' with which a given material may be worked with a cutting tool is machinability. Machinability depends on:

1. Chemical composition of workpiece material.
2. Micro-structure
3. Mechanical properties
4. physical properties
5. Cutting conditions.

In evaluating machinability the following criterion may be considered:

1. Tool life between grinds
2. Value of cutting forces
3. Quality of surface finish
4. Form and size of chips
5. Temperature of cutting
6. Rate of cutting under a standard force
7. Rate of metal index

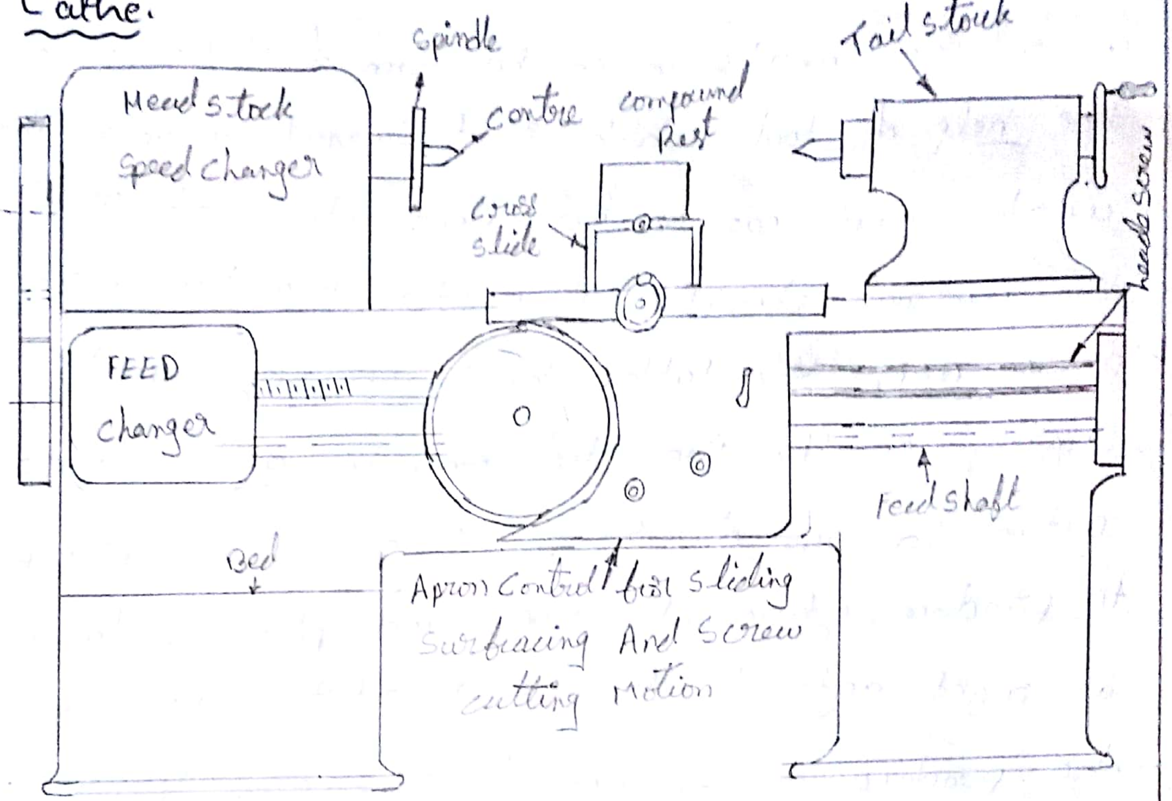
Some factors that are used to predict and calculate machinability are tensile strength, Brinell hardness and shear angle. This can calculated by

$$\tan\beta = \frac{\cos\gamma}{\gamma_c - \sin\gamma}$$

$$\text{Machinability Index} = \frac{\text{Cutting Speed of metal investigated for 20 min tool life}}{\text{Cutting Speed of standard steel for 20 min tool life.}}$$

2. LATHE

Lathe:-



Lathe

working principle of lathe :-

lathe removes undesired material from a rotating workpiece in the form of chips with the help of tool which is traversed across the work and can be fed deep into work. The tool material should be harder than the work piece. and the latter held securely and rigidly on it. The tool may be given linear motion in any direction. A lathe is used principally to produce cylindrical surfaces and plane surfaces, at right angles to the axis of rotation. It can also produce tapers and bellows etc. Operation of turning is done on small parts as small as those used in watches to huge parts weighing several tons.

A lathe basically consists of a bed to provide support, a head stock, a cross slide to traverse the tool, a tool post mounted on the cross slide. The spindle is driven by a motor through a gear box, to obtain a range of speeds. The carriage moves over a bed guide ways parallel to the work piece and the cross slide provides the transverse motion. A feed shaft and lead screw are also provided to power the carriage and for cutting the threads respectively.

Specifications of lathe :-

A lathe is generally designated by

(a) swing i.e., the largest work diameter that can be swung over the lathe bed.

(b) Distance between head stock and tail stock centre.

(c) Bar automatic lathes are specified by the maximum diameter of the bar which can be accomodated.

In order to specify a lathe completely, the following specifications should be included

① (a) Height of centres (b) Type of bed i.e., straight, semi gap, or gap type (c) Centre distance

② (a) Swing over bed (b) swing over cross slide. (c) swing in gap (d) Gap infront of face plate (e) width of bed

③ (a) spindle speeds range (b) spindle Nose (type) (c) spindle bore (d) Taper in nose

④ (a) Metric thread pitches (b) lead screw pitch (c) longitudinal feeds (d) cross feeds

⑤ (a) cross slide travel (b) Top slide travel (c) Tool section.

⑥ (a) Tail stock sleeve travel (b) Taper in sleeve bore

(7) Motor horse power and rpm.

(8) Shipping dimensions — length x width x height x weight.

Classification (or) Types of lathe :-

It is difficult to make a suitable classification of lathe as there are so many variables in the size, design, method of drive, arrangement of gears, different precision classes and purpose. In general, the following classifications covers most of the lathes used today.

(i) Speed lathe
(ii) Engine lathe
(iii) Turrent lathe
(iv) Capstan lathe
(v) Tool room lathe
(vi) Bench lathe
(vii) Gap bed lathe
(viii) Hollow spindle lathe
(ix) Vertical turrent lathe

① Bench lathe:- It is a very small lathe and is mounted on a separately prepared bench or cabinet. It is used for small and precision work since it is very accurate. It is usually provided with all the attachments, which a larger lathe carries, and is capable of performing almost all the operations which a larger lathe can do.

② Speed lathe:- These lathes may be of bench type or they may have the supporting legs cast and fitted on the bed. These lathes have most of the attachments which the other types of lathe carry but have no provision for power feed. They have no gear box, carriage and the lead screw. with the result, the tool is fed and actuated by hand. Usually the tool is either mounted on a tool post or supported on a T-shaped support. Such lathes are usually employed for wood turning, polishing, centering and metal spinning, etc.

③ Engine lathe :- It is probably the most widely used type of lathe. The name engine lathe is a little confusing in modern practice as all these lathes are now made to have an individual motor drive. However, it carries a great historical significance that in the very early days of its development it was driven by a steam engine. From this, it developed the name which is popular even today. Although it practically resembles a speed lathe in most of its features, but its construction is relatively more robust. Its head stock is bigger in size and is more robust, incorporating suitable mechanism for providing multiple speeds to the lathe spindle. The head stock spindle may recieve power, from a lathe shaft or an individual motor, through belts. In that case, it will have a cone pulley with back gears combination, the lathe is known as geared lathe and the headstock as all geared head stock.

Tool Room lathe:- It is nothing but same
engine lathe but equipped with some extra attachments to make it suitable for a relatively more accurate angle of speeds and feeds. The usual attachments provided on a tool room lathe are taper turning attachment, follower rest, collets, chucks, etc. This lathe is made to have a comparatively smaller bed length than the usual engine lathe. The most commonly used lengths are 135 to 180 cm.

5) Capstan and Turret lathe:- These lathes form as very important and useful group and are vastly used in mass production. These machines are actually of semi-automatic type and a very little skill is required of the operator. whatever skill is needed of the operator is only in the setting of tools in the turret or capsten head, and once this setting has been successfully accomplished further operation of these machines is more or less automatic. They carry special mechanisms for indexing of their tool heads.

chuck, combination chuck.

⑥ Automatic lathe:- These lathes help a long way in enhancing the quality as well as the quantity of production. They are so designed that all the working and job handling movements of the complete manufacturing process for a job are done automatically. No participation of the operator is required during the operation. Another variety of this type of lathes includes the semi automatic lathes, in which the mounting and removal of work is done by operator whereas all the operations are performed by the machine automatically. Automatic lathes are available having single or multi spindles. They fall in the category of heavy duty, high speed lathes mainly employed in mass production.

7. Special purpose lathes:- A large no. of lathes are designed to suit a definite class of work and to perform certain specified operations only. They prove to be more efficient and effective as compared to the common engine lathe so far as this specified class of work is connected. A brief description of these machines will be given.

Work holding devices of lathe:-

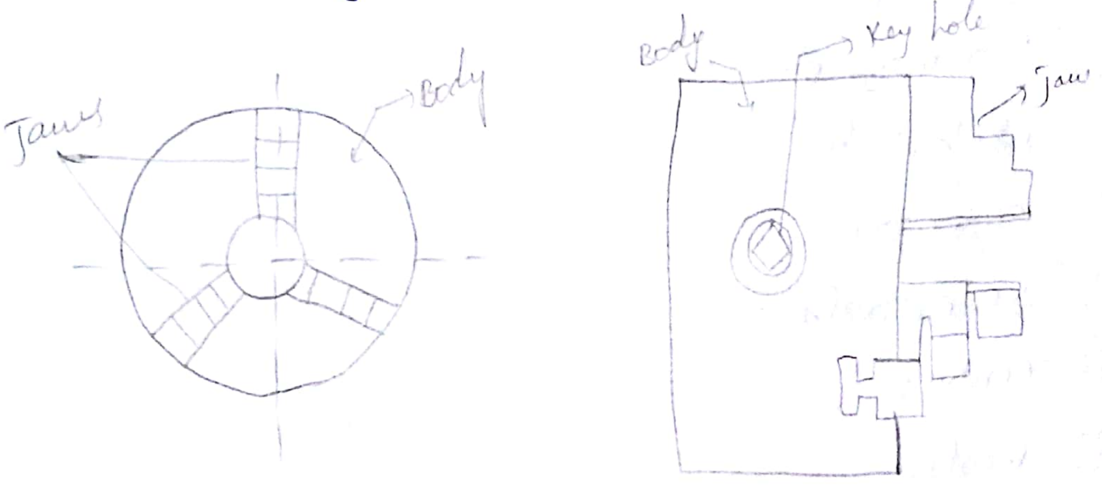
The work holding devices are used to hold and rotate the work piece along with spindle. Different work holding devices are used according to the shaper, length, diameter and width of the workpiece and the location of turning on the work. They are.

1. Chucks
2. Face plate
3. Driving plate
4. catch plate
5. Carriers
6. Mandrels
7. Centres
8. Rests.

Chucks:- work pieces of short length, larger diameter and the irregular shapes, which cannot be mounted b/w the centres, are held quickly and rigidly in chuck. There are different types of chucks namely, Three jaw universal chuck, four jaw independent chuck, magnetic chuck, collect chuck, combination chuck.

Three jaw universal chuck:-

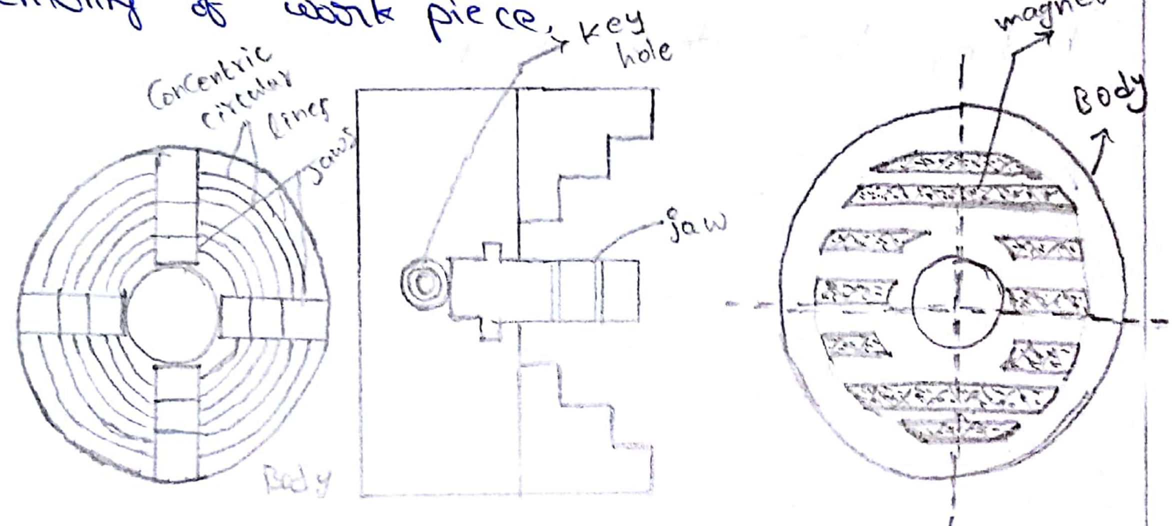
The three jaws fitted in the 3 slots may be made to slide at the same time by an equal amount by rotating any one of the three pinions by a chuck key. This type of chuck is suitable for holding and rotating regular shaped work piece like round or hexagonal rods about the axis of the lathe. work pieces of the irregular shapes cannot be held by this chuck.



The work is held quickly and easily as the three jaws move at the same time.

Four jaw independent chuck:- There are 4 jaws in this chuck. Each jaw is moved independently by rotating a screw with help of a chuck key. A particular jaw may be moved according to the shape of work.

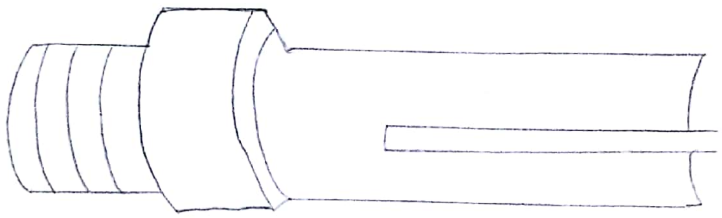
Hence this type of chuck can hold works of irregular shapes. But it requires more time to set the work aligned with the lathe axis. Experienced turners can set the work about the axis quickly. Concentric circles are inscribed on the face of chuck to enable quick centering of work piece.



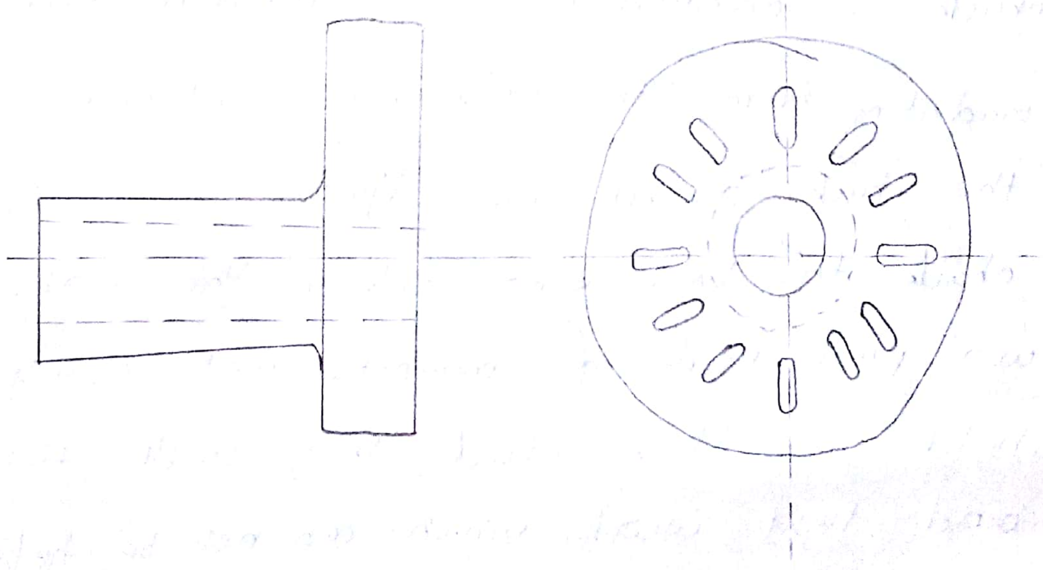
Magnetic chuck :- The holding power of this chuck is obtained by the magnetic flux radiating from the electromagnets placed inside the chuck. Magnets are adjusted inside the chuck to hold or release the work. Work piece made of magnetic material only are held in this chuck. Very small, thin and light works which can not be held in a ordinary chuck are held in this chuck.

Collect chuck:-

Collect chuck has a cylindrical bushing known as collet. It is made of spring steel and has slots cut lengthwise on its circumference. so, it holds the work with more grip. Collect chucks are used in capstan lathes and automatic lathes for holding bar stock in production work.

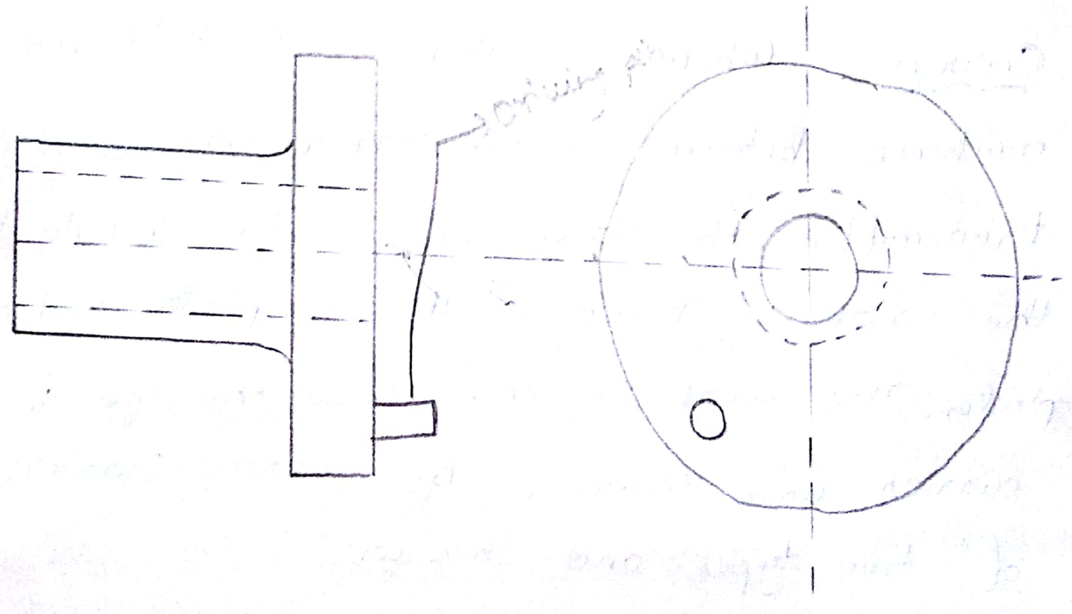


Face plate:-

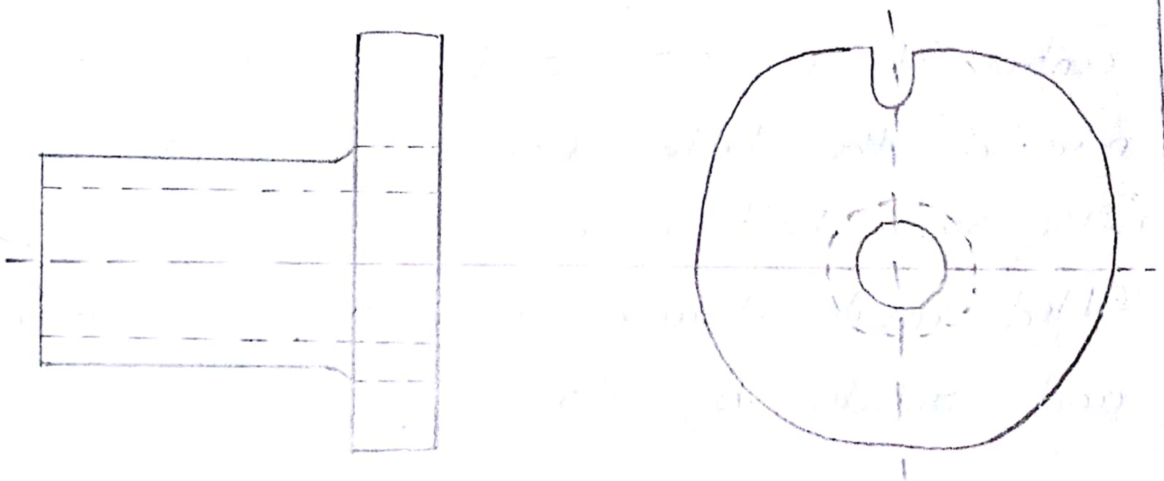


Face plate is used to hold large, heavy and irregular shaped workpieces which can not be conveniently held b/w centres. It is a circular disc bored out and threaded to fit to the nose of the lathe spindle. It is provided with radial plain and 'T' slots for holding the work by bolts and clamps.

Driving plate:- The driving plate is used to drive a work piece when it is held b/w centres. It is a circular disc screwed to the nose of the lathe spindle. It is provided with small bolts or pins on its face. workpieces fitted inside straight tail carriers are held and rotated by driving plates.



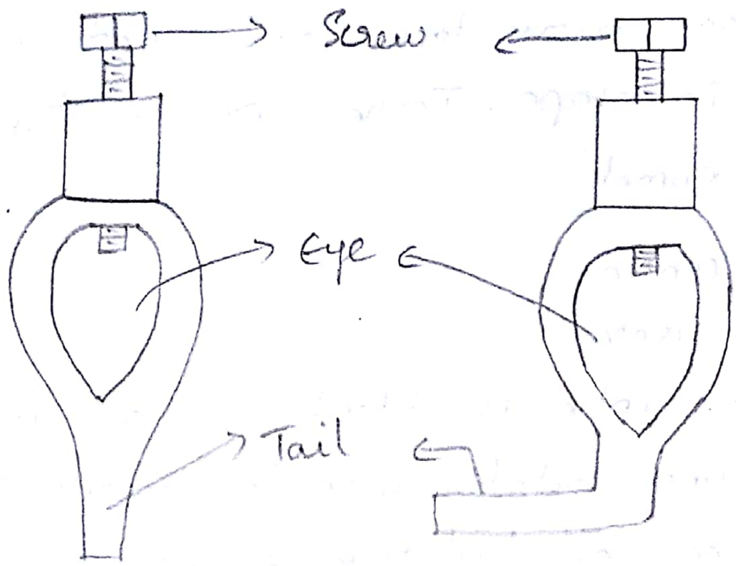
Catch plate:- When a work piece is held between centres, the catch plate is used to drive it. It is a circular disc bored and threaded at the centre. catch plates are designed with 'U'- slots or elliptical slots to recieve the bent tail of the carrier. Positive drive between the lathe spindle and the work piece is effected when the work piece fitted with the carrier fits into the slot of the catch plate.



Carrier:- When a work piece is held and machined between centres, carriers are useful in transmitting the drive force of the spindle to the work by means of driving plates and catch plates. The work is held inside the eye of the carrier and tightened by a screw. Carriers are of two types and they are:

1. Straight tail carrier
2. Bent tail carrier

straight tail carrier is used to drive the work by means of the pin provided in the driving plate. The tail of the bent tail carrier fits into the slot of the catch plate to drive the work.



Mandrel:- A previously drilled or bored work piece is held on a mandrel to be driven in lathe and machined. There are centre holes provided on both sides of mandrel. The live centre and the dead centre fit into the centre holes. A carrier is attached at the left side of the mandrel. The mandrel gets the drive either through a catch plate or a driving plate. The work piece rotates along with the mandrel. There are several types of mandrels they are:

1. Plain mandrel
2. Collar mandrel
3. Step mandrel
4. Cone mandrel

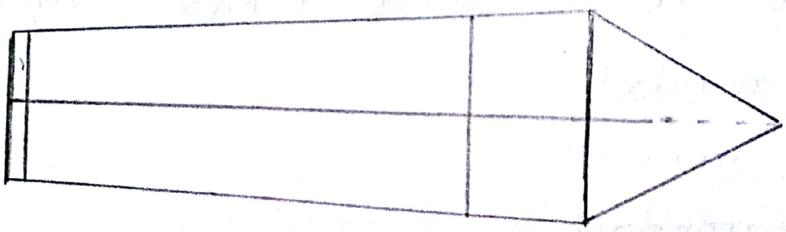
⑤ Gang mandrel
⑥ Expansion mandrel.

Centres :- Centres are useful in holding the work in a lathe b/w centres. The shank of a centre has morse taper on it and the face is conical in shape. There are 2 types of centres namely

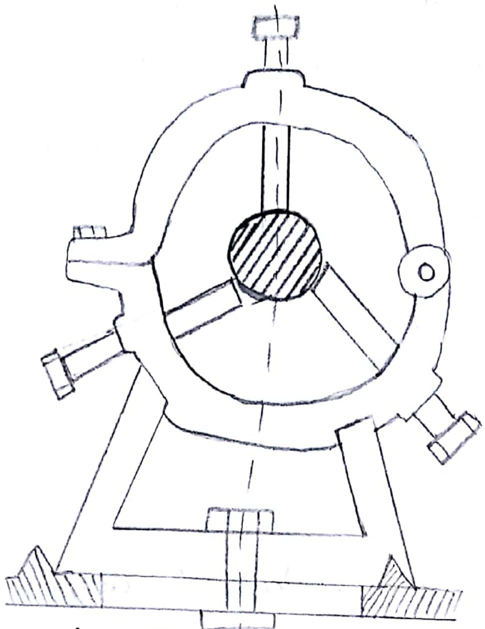
* Live centre
* Dead centre.

The live centre is fitted on the head stock spindle and rotates with the work. The centre fitted on the tailstock spindle is called dead centre. It is useful in supporting the other end of the work. Centres are made of high carbon steels and hardened and then tempered. So the tip of the centres are wear resistant. Different types of centres are available according to the shape of the work and the operation to be performed. They are

* Ball centre



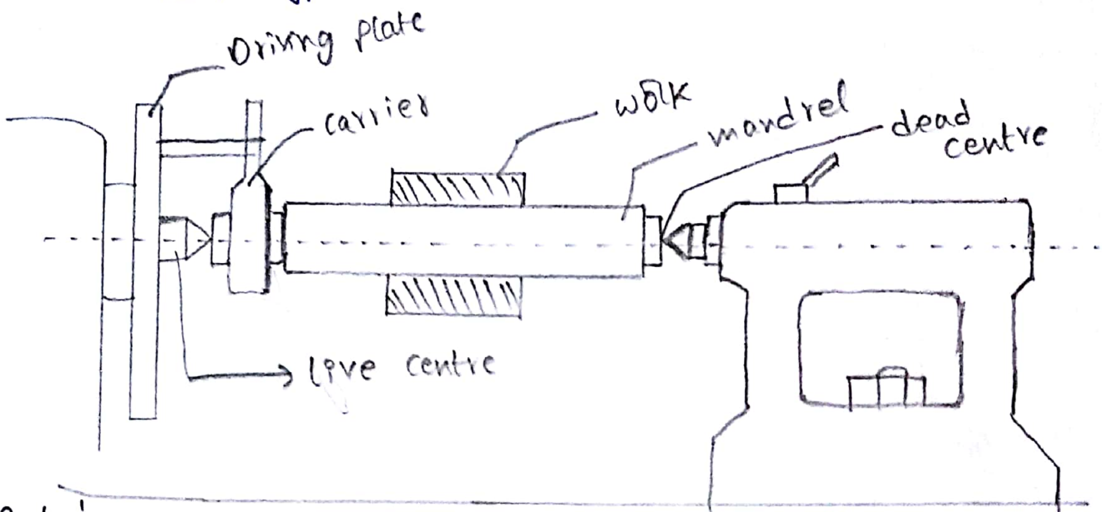
according to the diameter of the work. Machining is done upon the distance starting from the headstock to the point of support of the rest. One or more steady rests may be used to support the free end of a long work.



Follower rest :- It consists of a 'c' like casting having two adjustable jaws to support the work piece. The rest is bolted to the back end of the carriage. During machining, it supports the work and moves with the carriage. So, it follows the tool give continuous support to the work to be able to machine along the entire length of the work.

In order to reduce friction b/w the work and the jaws, proper lubricant should be used.

* Ordinary centre
* Half centre
* Tipped centre
* Pipe centre
* Revolving centre
* Inserted type centre



Rests:- A rest is a mechanical device to support a long slender workpiece, when it is turned between centres or by a chuck. It is placed at some intermediate point to prevent the workpiece from bending due to its own weight and vibrations setup due to the cutting force. There are 2 different types of rests.

* Follower rest
* Steady rest.

Steady rest:- steady rest is made of cast iron It may be made to slide on the lathe bedways and clamped at any desired position where the work piece needs support. It has three -jaws. These jaws can be adjusted

Tool Holders:- When the cutting tool is made of expensive material like High speed steel, it is not necessary that the whole shank be made of same material. Instead the cutter can be made quite small and inserted in a tool holder. A common and useful type of tool holder for high speed steel cutters is shown in fig. It may be noted that is also possible to adjust the cutting edge for height without shifting the tool holder.

The square hole in the nose of the holder to take the cutter is usually set at an angle of 15–20° with the horizontal. A flat faced cutter when in position will have an effective front rake equal to the angle of tool. The actual front clearance, however will have to be increased in order to obtain the necessary effective front clearance.

Tool Box:- A tool box is mounted on the turret of a turret lathe, or screw machine. It is essentially a tool post that brings its follower rest along with it. A tool bit and a compact follower rest are mounted opposite each other in a body which surround the workpiece. As the tool bit puts a lateral deflecting force on the work-piece, the follower rest opposes it, providing rigidity. A different and popular type of box tool uses two rollers rather than a follower rest. One roller is called a "sizing roller" and the other roller is called a "burnishing roller". The rollers turn with the stock to reduce scarring on the finished turn. Opposing tool bits may be used to cancel each others deflecting forces, in which case the box tool begins to overlap in form, function, and identity with a hollow mill.

Instructional objectives

At the end of this lesson, the students will be able to;

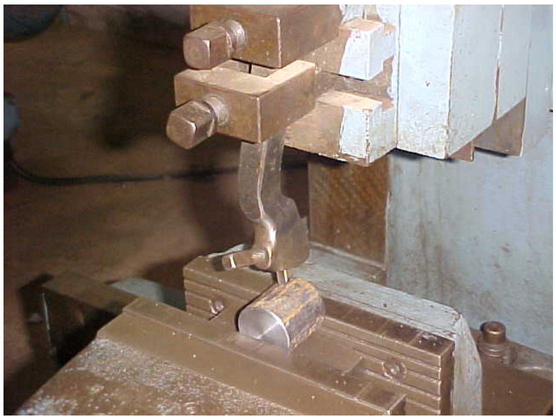
(i) Demonstrate the configurations and functions of shaping machine, planing machine and slotting machine
(ii) Illustrate the kinematic systems and explain the working principles of shaping machine, planing machine and slotting machine
(iii) Show and describe the various machining applications of shaping, planing and slotting machines.

(i) Configurations and basic functions of

- **Shaping machines**
- **Planing machines**
- **Slotting machines**

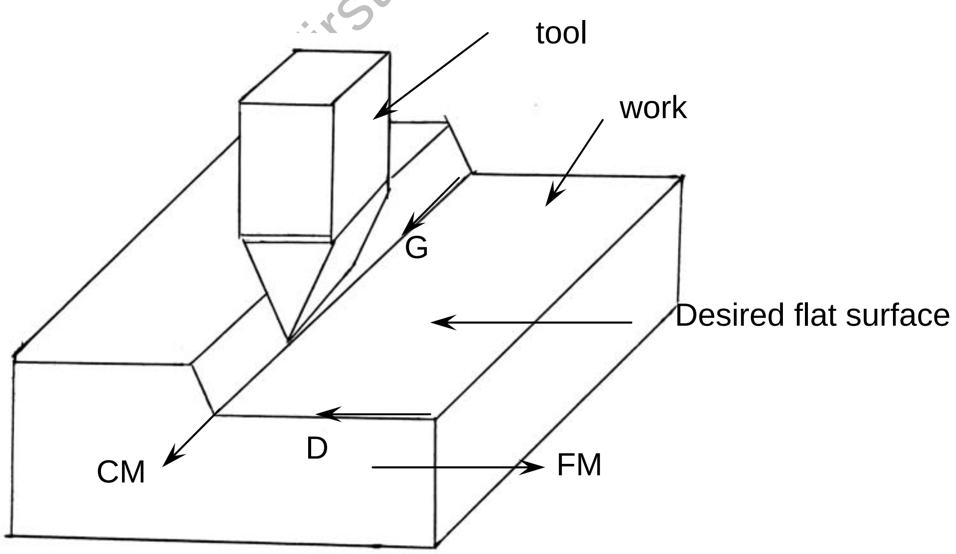
- Shaping machine

A photographic view of general configuration of shaping machine is shown in Fig. 4.4.1. The main functions of shaping machines are to produce flat surfaces in different planes. Fig. 4.4.2 shows the basic principle of generation of flat surface by shaping machine. The cutting motion provided by the linear forward motion of the reciprocating tool and the intermittent feed motion provided by the slow transverse motion of the job along with the bed result in producing a flat surface by gradual removal of excess material layer by layer in the form of chips. The vertical infeed is given either by descending the tool holder or raising the bed or both. Straight grooves of various curved sections are also made in shaping machines by using specific form tools. The single point straight or form tool is clamped in the vertical slide which is mounted at the front face of the reciprocating ram whereas the workpiece is directly or indirectly through a vice is mounted on the bed.



Cutting tool in action

Photographic view of a shaping machine



Principle of producing flat surface in shaping machine

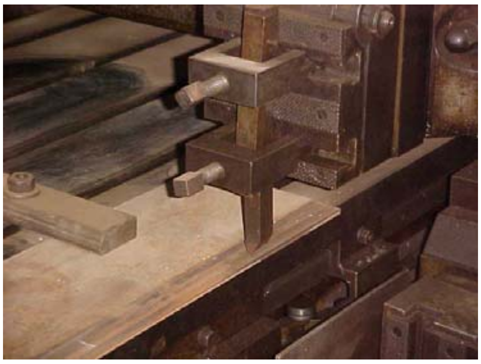
- Planing machine

The photographic view in Fig. 4.4.3 typically shows the general configuration of planing machine. Like shaping machines, planing machines are also basically used for producing flat surfaces in different planes. However, the major differences between planing machines from shaping machines are :

- o Though in principle both shaping and planing machines produce flat surface in the same way by the combined actions of the Generatrix and Directrix but in planing machine, instead of the tool, the workpiece reciprocates giving the fast cutting motion and instead of the job, the tool(s) is given the slow feed motion(s).
- o Compared to shaping machines, planing machines are much larger and more rugged and generally used for large jobs with longer stroke length and heavy cuts. In planing machine, the workpiece is mounted on the reciprocating table and the tool is mounted on the horizontal rail which, again, can move vertically up and down along the vertical rails.
- o Planing machines are more productive (than shaping machines) for longer and faster stroke, heavy cuts (high feed and depth of cut) possible and simultaneous use of a number of tools.

As in shaping machines, in planing machines also;

- The length and position of stroke can be adjusted
- Only single point tools are used
- The quick return persists
- Form tools are often used for machining grooves of curved section
- Both shaping and planing machines can also produce large curved surfaces by using suitable attachments.

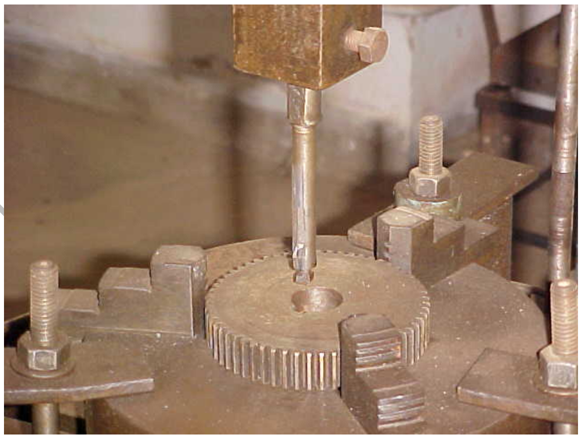


Cutting tool in action

Photographic view of a planing machine

- Slotting machine

Slotting machines can simply be considered as vertical shaping machine where the single point (straight or formed) reciprocates vertically (but without quick return effect) and the workpiece, being mounted on the table, is given slow longitudinal and / or rotary feed as can be seen in Fig. 4.4.4. In this machine also the length and position of stroke can be adjusted. Only light cuts are taken due to lack of rigidity of the tool holding ram for cantilever mode of action. Unlike shaping and planing machines, slotting machines are generally used to machine internal surfaces (flat, formed grooves and cylindrical). Shaping machines and slotting machines, for their low productivity, are generally used, instead of general production, for piece production required for repair and maintenance. Like shaping and slotting machines, planing machines, as such are also becoming obsolete and getting replaced by plano-millers where instead of single point tools a large number of large size and high speed milling cutters are used.



Cutting tool in action

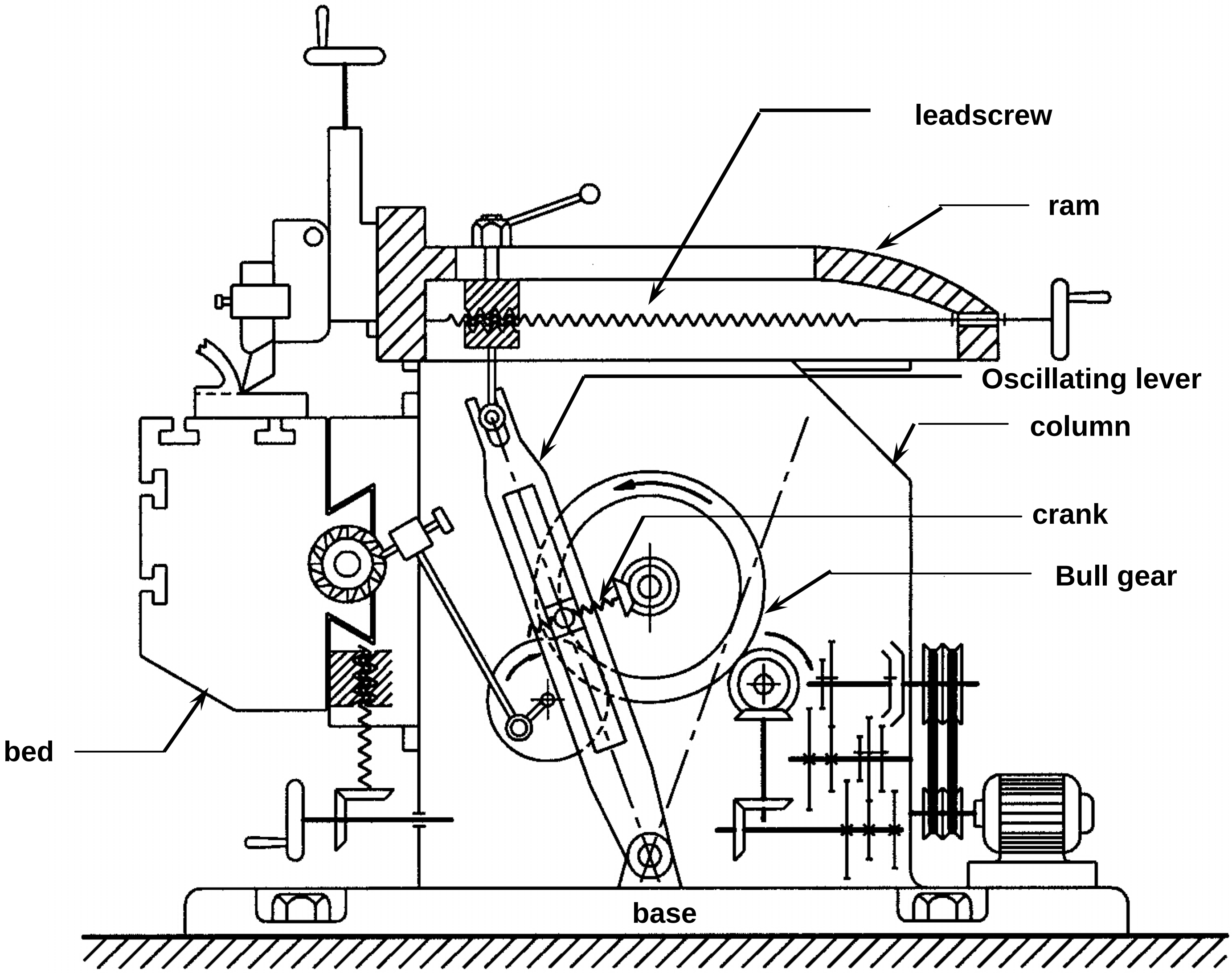
Photographic view of a slotting machine

(ii) Kinematic system and working principles of

- **Shaping machine**
- **Planing machine**
- **Slotting machine**

- Shaping machine

The usual kinematic system provided in shaping machine for transmitting power and motion from the motor to the tool and job at desired speeds and feeds is schematically shown in Fig. 4.4.5.



Kinematic diagram of a shaping machine.

The central large bull gear receives its rotation from the motor through the belt-pulley, clutch, speed gear box and then the pinion. The rotation of the crank causes oscillation of the link and thereby reciprocation of the ram and hence the tool in straight path. Cutting velocity which needs to be varied depending upon the tool-work materials, depends upon

- The stroke length, S mm
- Number of strokes per min., N_s and
- The Quick return ratio, QRR (ratio of the durations of the forward stroke and the return stroke)

As, $V_C = \frac{sxN_s}{1000}\left(1+\frac{1}{QRR}\right) m/\min$ (4.5.1)

To reduce idle time, return stroke is made faster and hence QRR > 1.0 (4.5.2)

Since $QRR = \frac{2L+s}{2L-s}$ (4.5.3)

where, L = length (fixed) of the oscillating lever
and s = stroke length

The benefit of quick return decreases when S becomes less.

The changes in length of stroke and position of the stroke required for different machining are accomplished respectively by

- Δ Adjusting the crank length by rotating the bevel gear mounted coaxially with the bull gear
- Δ Shifting the nut by rotating the leadscrew as shown in Fig. 4.4.5.

The value of N_s is varied by operating the speed gear box.

The main (horizontal) feed motion of the work table is provided at different rate by using the ratchet – paul systen as shown in Fig. 4.4.5. The vertical feed or change in height of the tool tip from the bed can be obtained either by lowering the tool or raising the bed by rotating the respective wheel as indicated in Fig. 4.4.5.

- **Planing machine**

The simple kinematic system of the planing machine enables transmission and transformation of rotation of the main motor into reciprocating motion of the large work table and the slow transverse feed motions (horizontal and vertical) of the tools. The reciprocation of the table, which imparts cutting motion to the job, is attained by rack-pinion mechanism. The rack is fitted with the table at its bottom surface and the pinion is fitted on the output shaft of the speed gear box which not only enables change in the number of stroke per minute but also quick return of the table.

The blocks holding the cutting tools are moved horizontally along the rail by screw-nut system and the rail is again moved up and down by another screw-nut pair as indicated in Fig. 4.4.3.

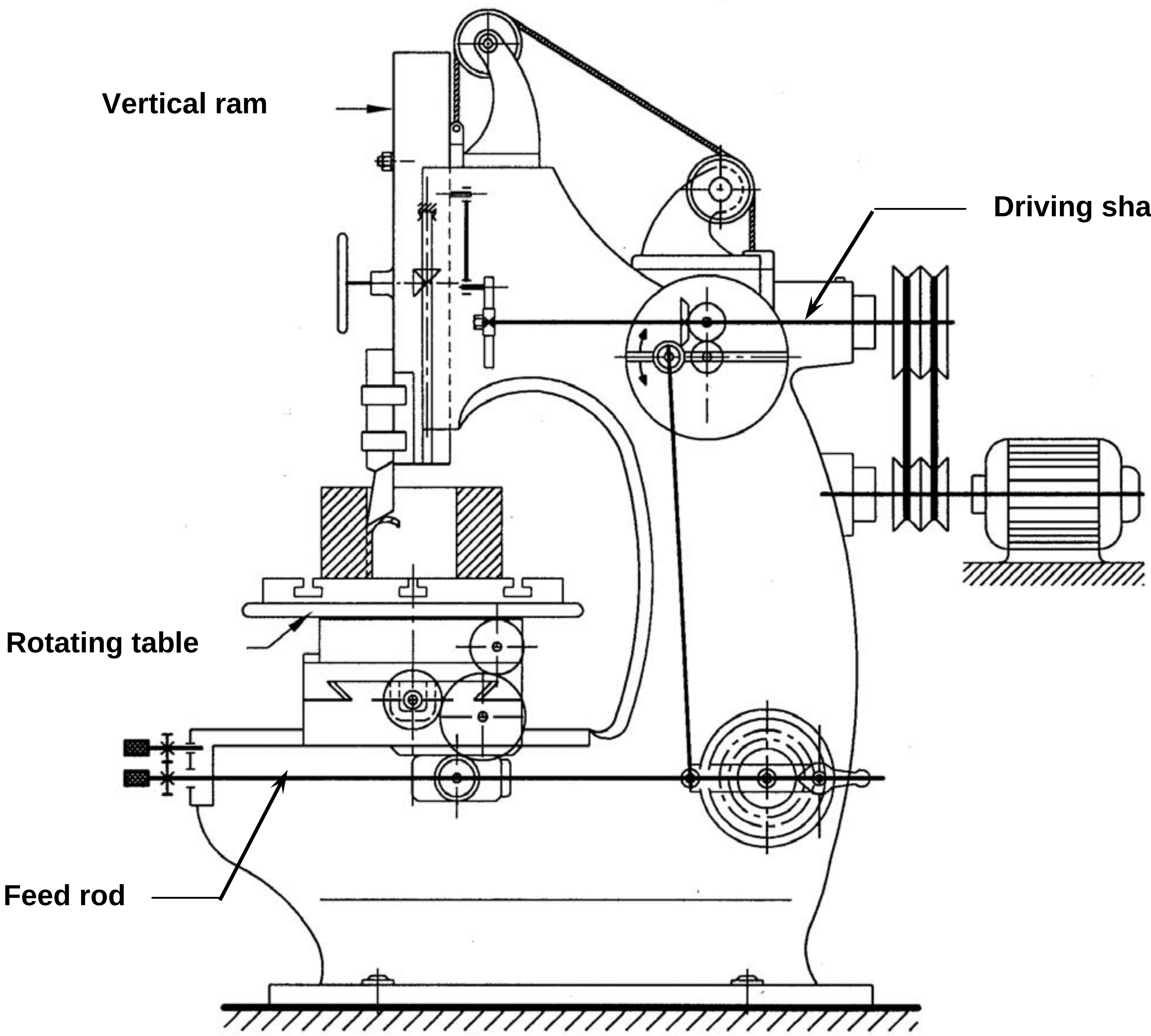
- **Slotting machine**

The schematic view of slotting machine is typically shown in Fig. 4.4.6

The vertical slide holding the cutting tool is reciprocated by a crank and connecting rod mechanism, so here quick return effect is absent. The job, to be machined, is mounted directly or in a vice on the work table. Like shaping machine, in slotting machine also the fast cutting motion is imparted to the tool and the feed motions to the job. In slotting machine, in addition to the longitudinal and cross feeds, a rotary feed motion is also provided in the work table.

The intermittent rotation of the feed rod is derived from the driving shaft with the help of a four bar linkage as shown in the kinematic diagram.

It is also indicated in Fig. 4.4.6 how the intermittent rotation of the feed rod is transmitted to the leadsrews for the two linear feeds and to the worm – worm wheel for rotating the work table. The working speed, i.e., number of strokes per minute, N_s may be changed, if necessary by changing the belt-pulley ratio or using an additional "speed gear box", whereas, the feed values are changed mainly by changing the amount of angular rotation of the feed rod per stroke of the tool. This is done by adjusting the amount of angle of oscillation of the paul as shown in Fig. 4.4.6. The directions of the feeds are reversed simply by rotating the tapered paul by 180^o as done in shaping machines.



Kinematic system of a slotting machine.

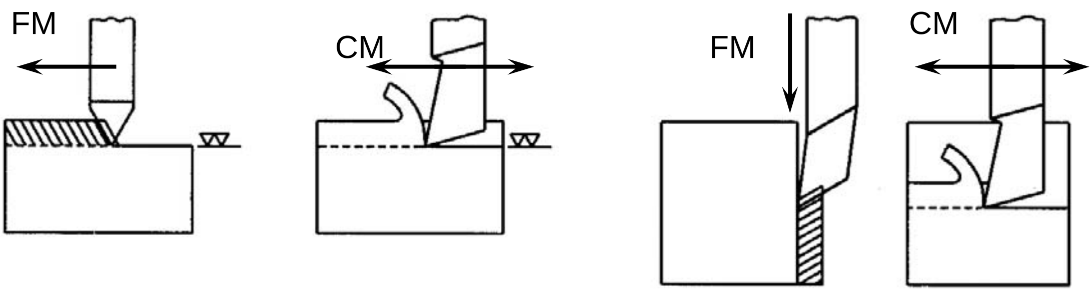
(iii) Various applications of

- **Shaping machine**
- **Planing machines**
- **Slotting machines**

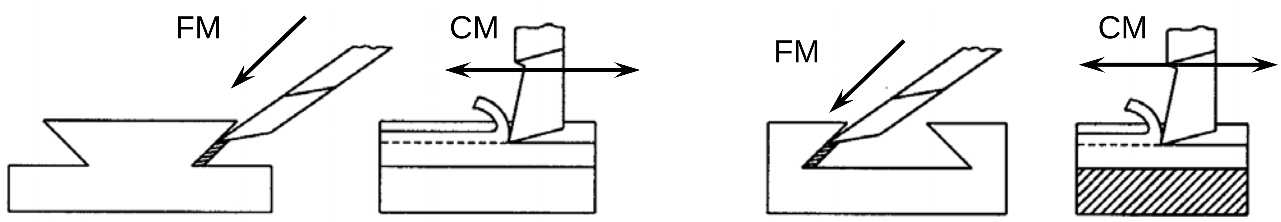
- **Shaping machines**

It is already mentioned that shaping machines are neither productive nor versatile.
However, its limited applications include :

∆ Machining flat surfaces in different planes. Fig. 4.4.7 shows how flat surfaces are produced in shaping machines by single point cutting tools in (a) horizontal, (b) vertical and (c) inclined planes.



(a) horizontal surface (b) vertical surface



(c) inclined surfaces (dovetail slides and guides)

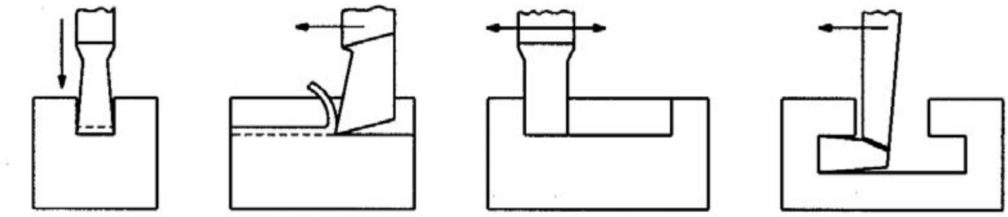
Machining of flat surfaces in shaping machines

∆ Making features like slots, steps etc. which are also bounded by flat surfaces. Fig. 4.4.8 visualises the methods of machining (a) slot, (b) pocket (c) T-slot and (d) Vee-block in shaping machine by single point tools.

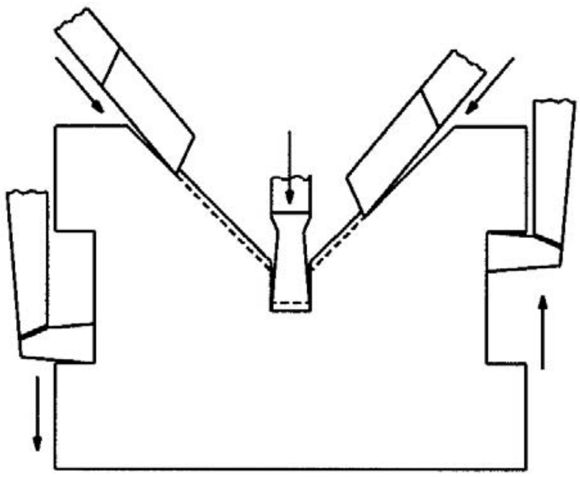
∆ Forming grooves bounded by short width curved surfaces by using single point but form tools. Fig. 4.4.9 typically shows how (a) oil grooves and (b) straight tooth of spur gears can be made in shaping machine

∆ Some other machining applications of shaping machines are cutting external keyway and splines, smooth slitting or parting, cutting teeth

of rack for repair etc. using simple or form type single point cutting tools.
Some unusual work can also be done, if needed, by developing and using special attachments.

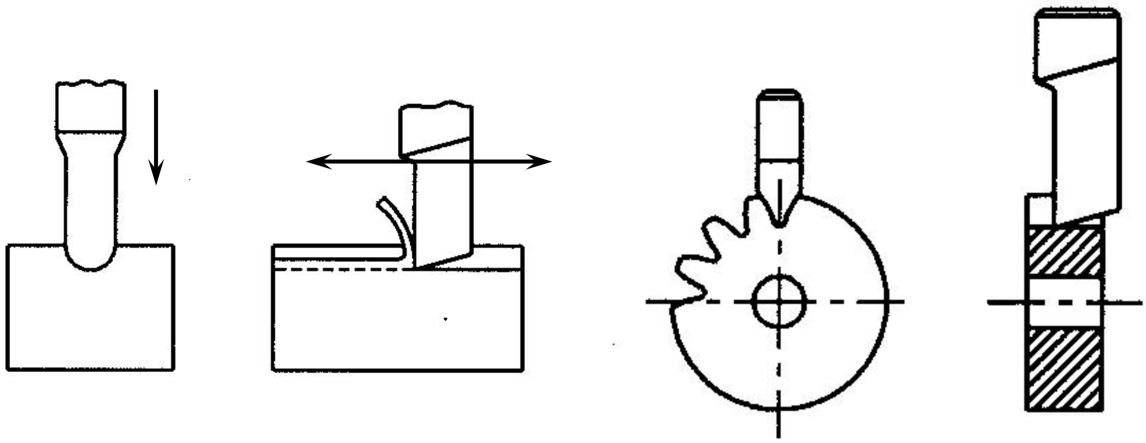


(a) slotting (b) pocketing (c) T-slot cutting



(d) Vee-block

Machining (a) slot, (b) pocket (c) T-slot and (d) Vee block in shaping machine



(a) grooving (b) straight tooth cutting for spur gears

Making grooves and gear teeth cutting in shaping machine by form tools.

However, due to very low productivity, less versatility and poor process capability, shaping machines are not employed for lot and even batch production. Such low cost primitive machine tools may be reasonably used only for little or few machining work on one or few pieces required for repair and maintenance work in small machine shops.

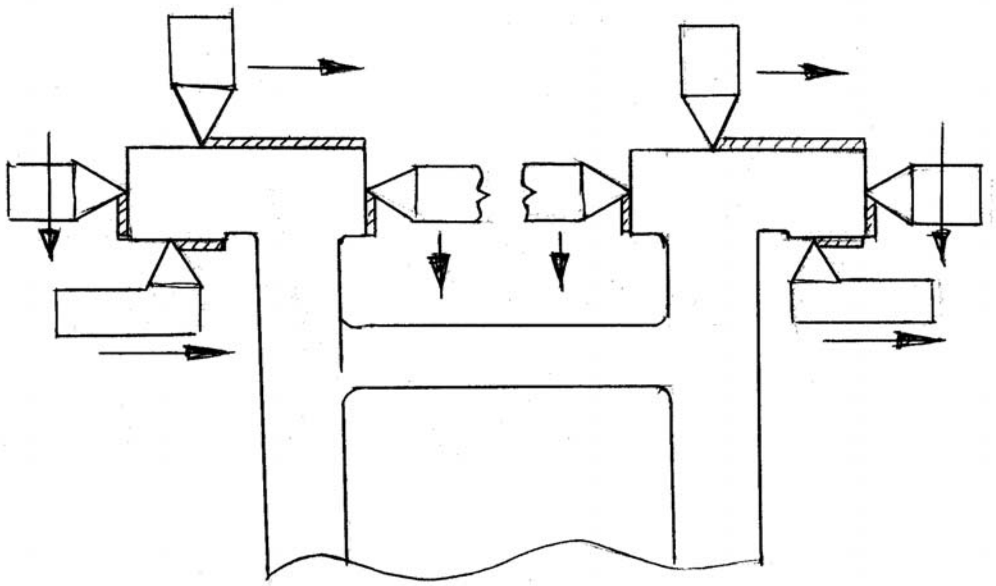
- **Planing machines**

The basic principles of machining by relative tool-work motions are quite similar in shaping machine and planing machine. The fast straight path cutting motion is provided by reciprocation of the tool or job and the slow, intermittent transverse feed motions are imparted to the job or tool. In respect of machining applications also these two machine tools are very close. All the operations done in shaping machine can be done in planing machine. But large size and stroke length and higher rigidity enable the planing machines do more heavy duty work on large jobs and their long surfaces. Simultaneous use of number of tools further enhances the production capacity of planing machines.

The usual and possible machining applications of planing machines are

- ∆ The common machining work shown in Fig. 4.4.7, Fig. 4.4.8 and Fig. 4.4.9 which are also done in shaping machines
- ∆ Machining the salient features like the principal surfaces and guideways of beds and tables of various machines like lathes, milling machines, grinding machines and planing machines itself, broaching machines etc. are the common applications of planing machine as indicated in Fig. 4.4.10 where the several parallel surfaces of typical machine bed and guideway are surfaced by a number of single point HSS or carbide tools. Besides that the long parallel T-slots, Vee and inverted Vee type guideways are also machined in planing machines.

Δ Besides the general machining work, some other critical work like helical grooving on large rods, long and wide 2-D curved surfaces, repetitive oil grooves etc. can also be made, if needed, by using suitable special attachments.



Machining of a machine bed in planing machine

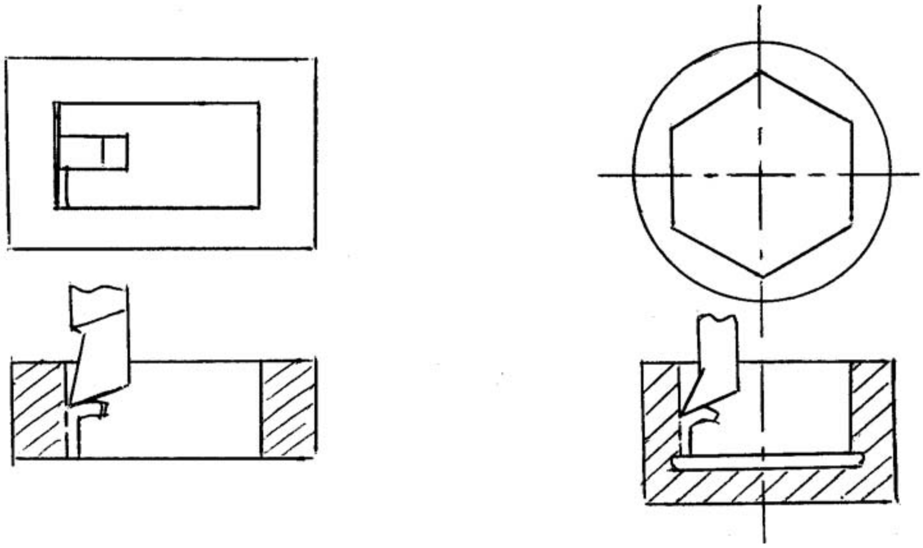
- **S**lotting machine

Slotting machines are very similar to shaping machines in respect of machining principle, tool-work motions and general applications. However, relative to shaping machine, slotting machines are characterised by :

Δ Vertical tool reciprocation with down stroke acting
Longer stroke length
 Less strong and rigid
 An additional rotary feed motion of the work table
Used mostly for machining internal surfaces.

The usual and possible machining applications of slotting machines are :

- o Internal flat surfaces
- o Enlargement and / or finishing non-circular holes bounded by a number of flat surfaces as shown in Fig.
- o Blind geometrical holes like hexagonal socket as shown in Fig.
- o Internal grooves and slots of rectangular and curved sections.
- o Internal keyways and splines, straight tooth of internal spur gears Internal curved surface of circular section, internal oil grooves etc. which are not possible in shaping machines.



(a) through rectangular hole (b) hexagonal socket

Typical machining application of slotting machine.

However, it has to be borne in mind that productivity and process capability of slotting machines are very poor and hence used mostly for piece production required by maintenance and repair in small industries. Scope of use of slotting machine for production has been further reduced by more and regular use of broaching machines.

Instructional Objectives

At the end of this lesson, the students will be able to :
(i) State the basic purposes of use of drilling machines
(ii) Classify the types of drilling machines
(iii) Illustrate the general kinematic system of drilling machine and explain its working principle
(iv) State and visualise the various common and other possible applications of drilling machines

(i) Basic purposes of use of drilling machines

Drilling machines are generally or mainly used to originate through or blind straight cylindrical holes in solid rigid bodies and/or enlarge (coaxially) existing (premachined) holes :

- of different diameter ranging from about 1 mm to 40 mm
- of varying length depending upon the requirement and the diameter of the drill
- in different materials excepting very hard or very soft materials like rubber, polythene etc.

(ii) Classification of drilling machines.

(a) General purpose drilling machines of common use

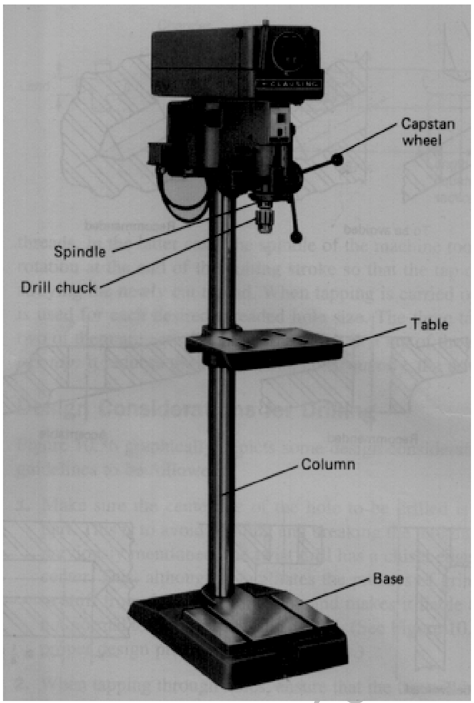
- Table top small sensitive drilling machine

These small capacity (□ 0.5 kW) upright (vertical) single spindle drilling machines are mounted (bolted) on rigid table and manually operated using usually small size (□□ 10 mm) drills. Fig. 4.2.1 typically shows one such machine.

Table top sensitive drilling machine

- Pillar drilling machine

These drilling machines, usually called pillar drills, are quite similar to the table top drilling machines but of little larger size and higher capacity (0.55 ~ 1.1 kW) and are grouted on the floor (foundation). Here also, the drill-feed and the work table movement are done manually. Fig. 4.2.2 typically shows a pillar drill. These low cost drilling machines have tall tubular columns and are generally used for small jobs and light drilling.



Pillar Drilling machine

- Column drilling machine

These box shaped column type drilling machines as shown in Fig. 4.2.3 are much more strong, rigid and powerful than the pillar drills. In column drills the feed gear box enables automatic and power feed of the rotating drill at different feed rates as desired. Blanks of various size and shape are rigidly clamped on the bed or table or in the vice fitted on that. Such drilling machines are most widely used and over wide range (light to heavy) work.

Column drilling machine

- Radial drilling machine

This usually large drilling machine possesses a radial arm which along with the drilling head can swing and move vertically up and down as can be seen in Fig. 4.2.4. The radial, vertical and swing movement of the drilling head enables locating the drill spindle at any point within a very large space required by large and odd shaped jobs. There are some more versatile radial drilling machines where the drill spindle can be additionally swivelled and / or tilted.

Radial drilling machine

- CNC column drilling machine

In these versatile and flexibly automatic drilling machine having box-column type rigid structure the work table movements and spindle rotation are programmed and accomplished by Computer Numerical Control (CNC). These modern sophisticated drilling machines are suitable for piece or batch production of precision jobs.

(b) General purpose drilling machines with more specific use.

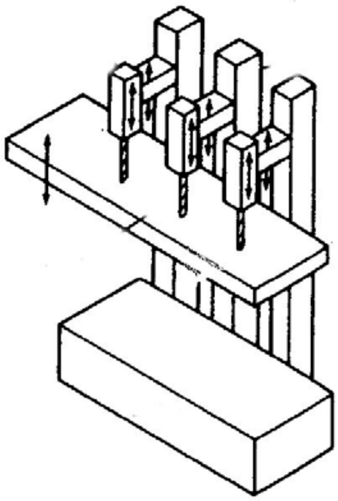
- Hand drills

Unlike the grouted stationary drilling machines, the hand drill is a portable drilling device which is mostly held in hand and used at the locations where holes have to be drilled as shown in Fig. 4.2.5. The small and reasonably light hand drills are run by a high speed electric motor. In fire hazardous areas the drill is often rotated by compressed air.

Hand drill in operation

- Gang drilling machine

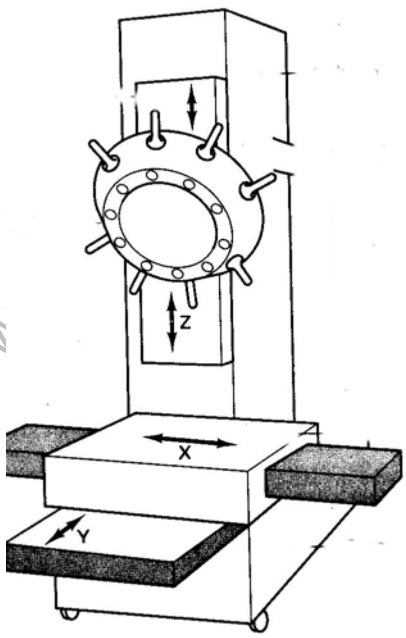
In this almost single purpose and more productive machine a number (2 to 6) of spindles with drills (of same or different size) in a row are made to produce number of holes progressively or simultaneously through the jig. Fig. 4.2.6 schematically shows a typical gang drilling machine.



Schematic view of a gang drilling machine

- Turret (type) drilling machine

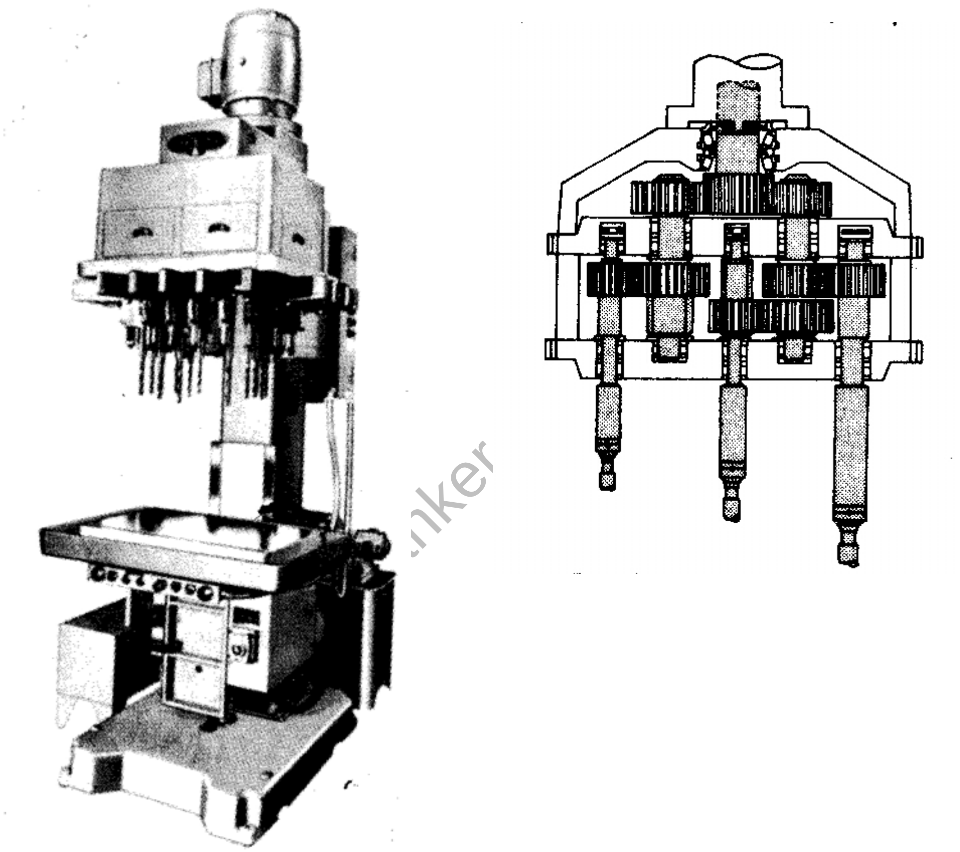
Turret drilling machines are structurally rigid column type but are more productive like gang drill by having a pentagon or hexagon turret as shown in Fig. 4.2.7. The turret bearing a number of drills and similar tools is indexed and moved up and down to perform quickly the desired series of operations progressively. These drilling machines are available with varying degree of automation both fixed and flexible type.



Schematic view of turret type drilling machine

- Multispindle drilling machine

In these high production machine tools a large number of drills work simultaneously on a blank through a jig specially made for the particular job. The entire drilling head works repeatedly using the same jig for batch or lot production of a particular job. Fig. 4.2.8 shows a typical multispindle drilling machine. The rotation of the drills are derived from the main spindle and the central gear through a number of planetary gears in mesh with the central gear) and the corresponding flexible shafts. The positions of those parallel shafts holding the drills are adjusted depending upon the locations of the holes to be made on the job. Each shaft possesses a telescopic part and two universal joints at its ends to allow its change in length and orientation respectively for adjustment of location of the drills of varying size and length. In some heavy duty multispindle drilling machines, the work-table is raised to give feed motion instead of moving the heavy drilling head.



A typical multi spindle drilling machine

- Micro (or mini) drilling machine

This type of tiny drilling machine of height within around 200 mm is placed or clamped on a table, as shown in Fig. 4.2.9 and operated manually for drilling small holes of around 1 to 3 mm diameter in small workpieces.

Photographic view of a micro (or mini) drilling machine

- Deep hole drilling machine

Very deep holes of L/D ratio 6 to even 30, required for rifle barrels, long spindles, oil holes in shafts, bearings, connecting rods etc, are very difficult to make for slenderness of the drills and difficulties in cutting fluid application and chip removal. Such drilling cannot be done in ordinary drilling machines and b ordinary drills. It needs machines like deep hole drilling machine such as gun drilling machines with horizontal axis which are provided with

- high spindle speed
- high rigidity
- tool guide
- pressurised cutting oil for effective cooling, chip removal and lubrication at the drill tip.

Deep hole drilling machines are available with both hard automation and CNC system.

(iii) Kinematic System of general purpose drilling machine and their principle of working

Kinematic system in any machine tool is comprised of chain(s) of several mechanisms to enable transform and transmit motion(s) from the power source(s) to the cutting tool and the workpiece for the desired machining action. The kinematic structure varies from machine tool to machine tool requiring different type and number of tool-work motions. Even for the same type of machine tool, say column drilling machine, the designer may take different kinematic structure depending upon productivity, process capability, durability, compactness, overall cost etc targeted. Fig. 4.2.10 schematically shows a typical kinematic system of a very general purpose drilling machine, i.e., a column drilling machine having 12 spindle speeds and 6 feeds.

The kinematic system enables the drilling machine the following essential works;

- Cutting motion:

The cutting motion in drilling machines is attained by rotating the drill at different speeds (r.p.m.). Like centre lathes, milling machines etc, drilling machines also need to have a reasonably large number of spindle speeds to cover the useful ranges of work material, tool material, drill diameter, machining and machine tool conditions. It is shown in Fig. 4.2.10 that the drill gets its rotary motion from the motor through the speed gear box (SGB) and a pair of bevel gears. For the same motor speed, the drill speed can be changed to any of the 12 speeds by shifting the cluster gears in the SGB. The direction of rotation of the drill can be changed, if needed, by operating the clutch in the speed reversal mechanism, RM-s shown in the figure.

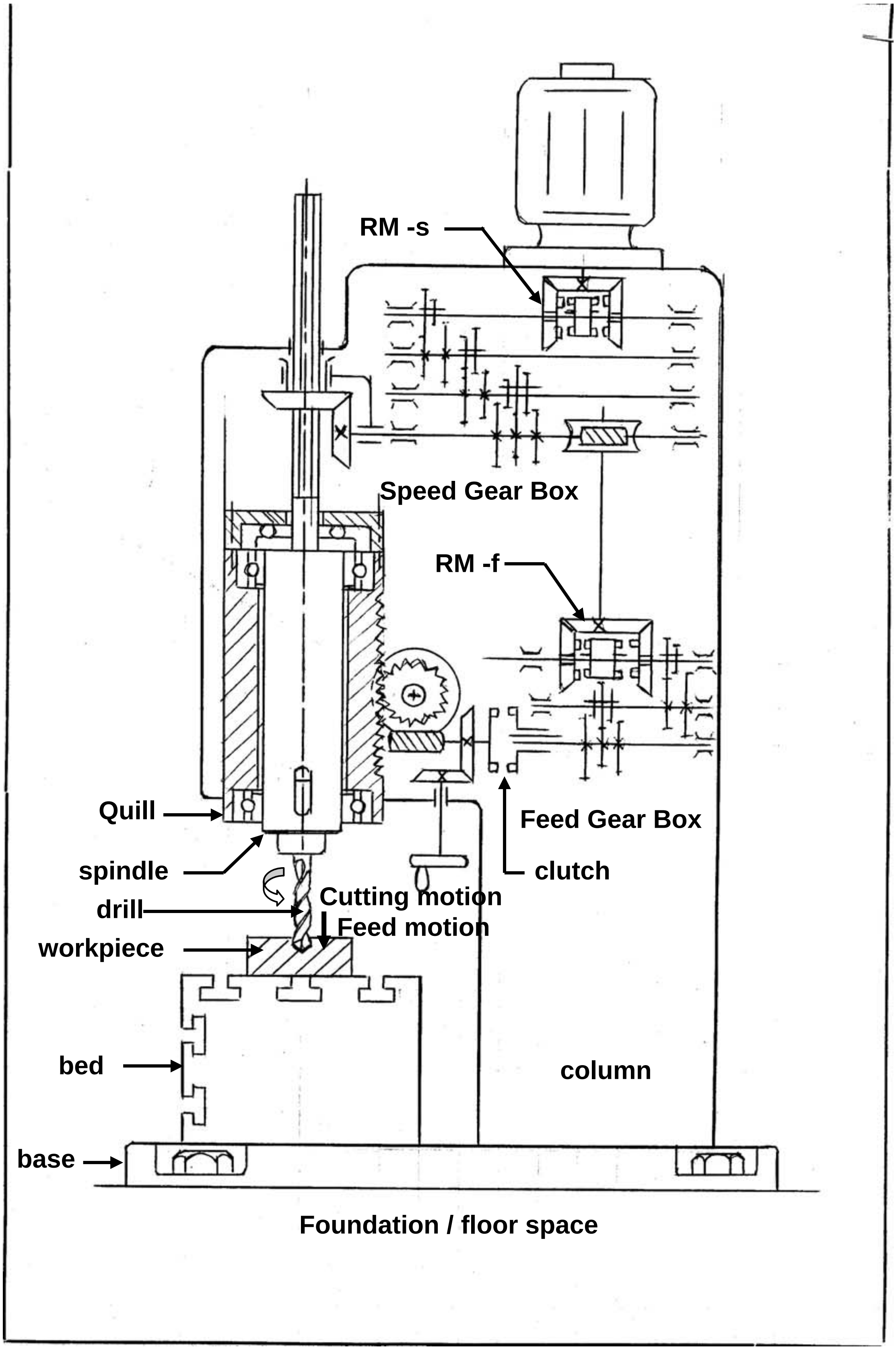
- Feed motion

In drilling machines, generally both the cutting motion and feed motion are imparted to the drill. Like cutting velocity or speed, the feed (rate) also needs varying (within a range) depending upon the tool-work materials and other conditions and requirements.
Fig. 4.2.10 visualises that the drill receives its feed motion from the output shaft of the SGB through the feed gear box (FGA), and the clutch. The feed rate can be changed to any of the 6 rates by shifting the gears in the FGB. And the automatic feed direction can be reversed, when required, by operating the speed reversal mechanism, RM-s as shown. The slow rotation of the pinion causes the axial motion of the drill by moving the rack provided on the quil.

The upper position of the spindle is reduced in diameter and splined to allow its passing through the gear without hampering transmission of its rotation.

- **Tool work mounting**

The taper shank drills are fitted into the taper hole of the spindle either directly or through taper socket(s). Small straight shank drills are fitted through a drill chuck having taper shank. The workpiece is kept rigidly fixed on the bed (of the table). Small jobs are generally held in vice and large or odd shaped jobs are directly mounted on the bed by clamping tools using the T-slots made in the top and side surfaces of the bed as indicated in Fig. 4.2.10.



Schematic view of the drives of a drilling machine

(iv) Application of drilling machines

Drilling machines of different capacity and configuration are basically used for originating cylindrical holes and occasionally for enlarging the existing holes to full or partial depth. But different types of drills are suitably used for various applications depending upon work material, tool material, depth and diameter of the holes.

General purpose drills may be classified as;

- **According to material :**
  - ∆ High speed steel – most common
  - ∆ Cemented carbides
    - Without or with coating
    - In the form of brazed, clamped or solid
- **According to size**
  - ∆ Large twist drills of diameter around 40 mm
  - ∆ Microdrills of diameter 25 to 500 μm
  - ∆ Medium range (most widely used) diameter ranges between 3 mm to 25 mm.

- **According to number of flutes**
  - ∆ Two fluted – most common
  - ∆ Single flute – e.g., gun drill (robust)
  - ∆ Three or four flutes – called slot drill

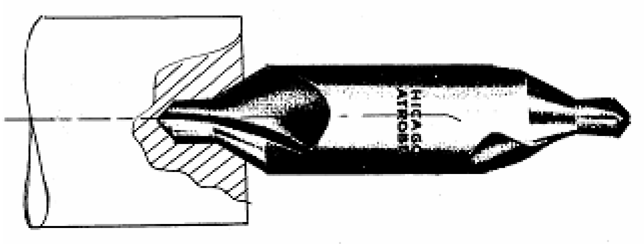
- **According to helix angle of the flutes**
  - ∆ Usual – 20^0 to 35^0 – most common
  - ∆ Large helix : 45^o to 60^o suitable for deep holes and softer work materials
  - ∆ Small helix : for harder / stronger materials
  - ∆ Zero helix : spade drills for high production drilling micro-drilling and hard work materials.

- **According to length – to – diameter ratio**
  - ∆ Deep hole drill; e.g. crank shaft drill, gun drill etc.
  - ∆ General type : $L/\phi \cong 6$ to 10
  - ∆ Small length : e.g. centre drill

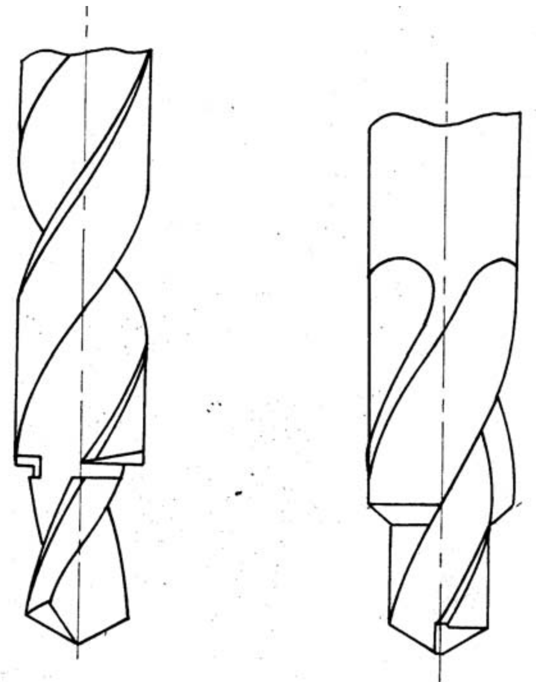
- **According to shank**
  - ∆ Straight shank – small size drill being held in drill chuck
  - ∆ Taper shank – medium to large size drills being fitted into the spindle nose directly or through taper sockets

- **According to specific applications**
  - ∆ Centre drills (Fig. 4.2.11) : for small axial hole with 60^o taper end to accommodate lathe centre for support

∆ Step drill and subland drill (Fig. 4.2.12) : for small holes with two or three steps



Centre Drill



(a) (b)

(a) Stepped drill and (b) subland drill

∆ Half round drill, gun drill and crank shaft drill (for making oil holes) – shown in Fig. 4.2.13

∆ Ejector drill for high speed drilling of large diameter holes

∆ Taper drill for batch production

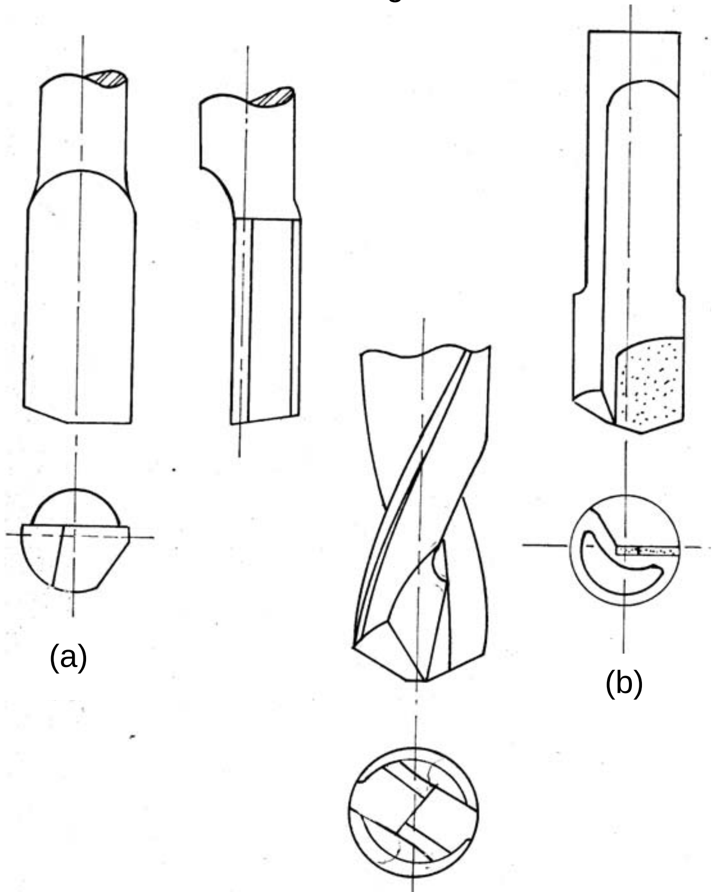
∆ Trepanning tool (Fig. 4.2.14) : for large holes in soft materials

Besides making holes, drilling machines may be used for various other functions using suitable cutting tools.

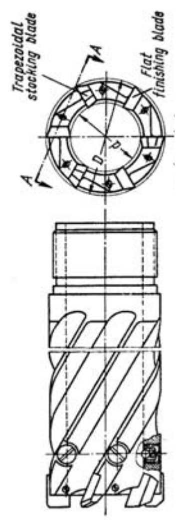
The wide range of applications of drilling machines include :

- Origination and / or enlargement of existing straight through or stepped holes of different diameter and depth in wide range of work materials – this is the general or common use of drilling machines

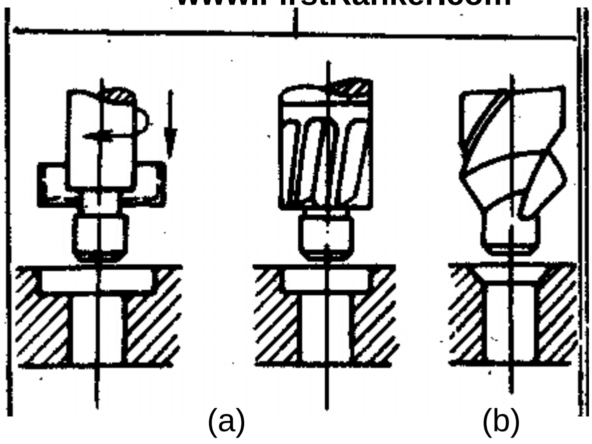
- Making rectangular section slots by using slot drills having 3 or four flutes and 180^0 cone angle
- Boring, after drilling, for accuracy and finish or prior to reaming
- Counterboring, countersinking, chamfering or combination using suitable tools as shown in Fig. 4.2.15



Schematic views of (a) half round drill, (b) gun drill and (c) crank shaft drill

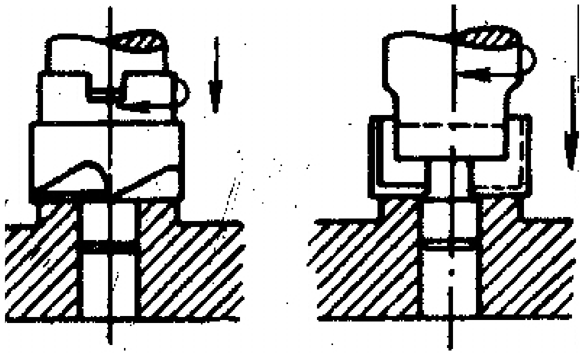


Schematic view of a trepanning tool.

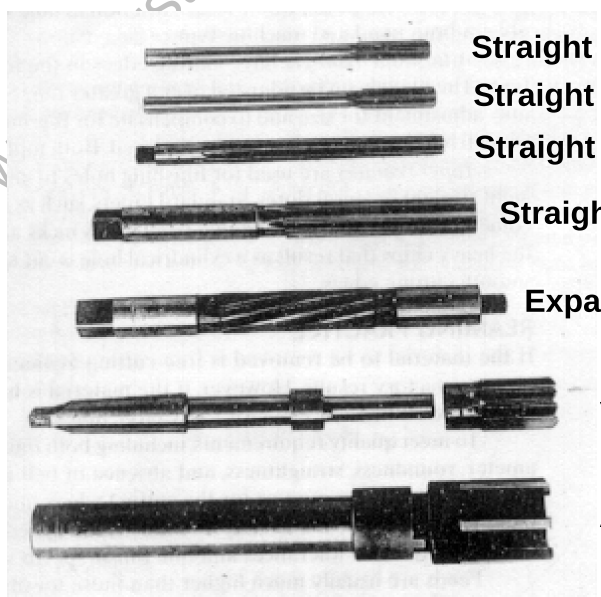


Schematic view of (a) counter boring and (b) countersinking

- Spot facing by flat end tools (Fig. 4.2.16)
- Trepanning for making large through holes and or getting cylindrical solid core.
- Reaming is done, if necessary, after drilling or drilling and boring holes for accuracy and good surface finish. Different types of reamers of standard sizes are available as shown in Fig. 4.2.17 for different applications.



Schematic view of spot facing



Different types of reamers.

- Cutting internal screw threads mounting a tapping attachment in the spindle.

Several other operations can also be done, if desired, in drilling machines by using special tools and attachments.

UNIT-4
MILLING

1.INTRODUCTION

Milling machine is one of the most versatile conventional machine tools with a wide range of metal cutting capability. Many complicated operations such as indexing, gang milling, and straddle milling etc. can be carried out on a milling machine.

This training module is intended to give you a good appreciation on the type of milling machines and the various types of milling processes. Emphasis is placed on its industrial applications, operations, and the selection of appropriate cutting tools.

On completion of this module, you will acquire some of these techniques from the training exercises as illustrated in figure 1. However, to gain maximum benefit, you are strongly advised to make yourself familiar with the following notes before undertaking the training activities, and to have a good interaction between yourself and the staff in charge of your training.

Assessment of your training will be based on a combination of your skill and attitude in getting the work done.

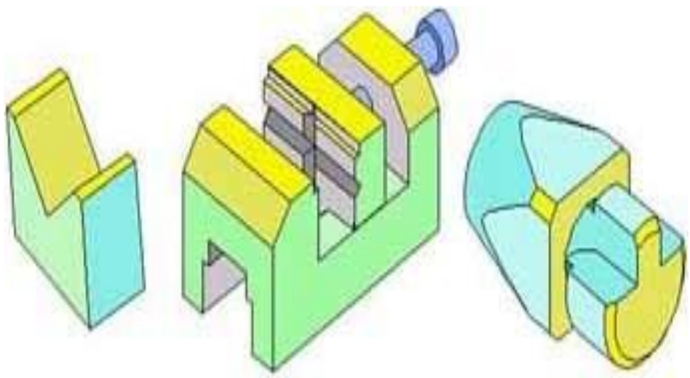


Figure 1 Milling Products.

2. TYPES OF MILLING MACHINE

Most of the milling machine are constructed of ¡¥column and knee¡¦ structure and they are classified into two main types namely Horizontal Milling Machine and Vertical Milling Machine. The name Horizontal or Vertical is given to the machine by virtue of its spindle axis. Horizontal machines can be further classified into Plain Horizontal and Universal Milling Machine. The main difference between the two is that the table of a Universal Milling Machine can be set at an angle for helical milling while the table of a Plain Horizontal Milling Machine is not.

2.1. Horizontal Milling Machine

Figure 2 shows the main features of a Plain Horizontal Milling Machine. Their functions are: -

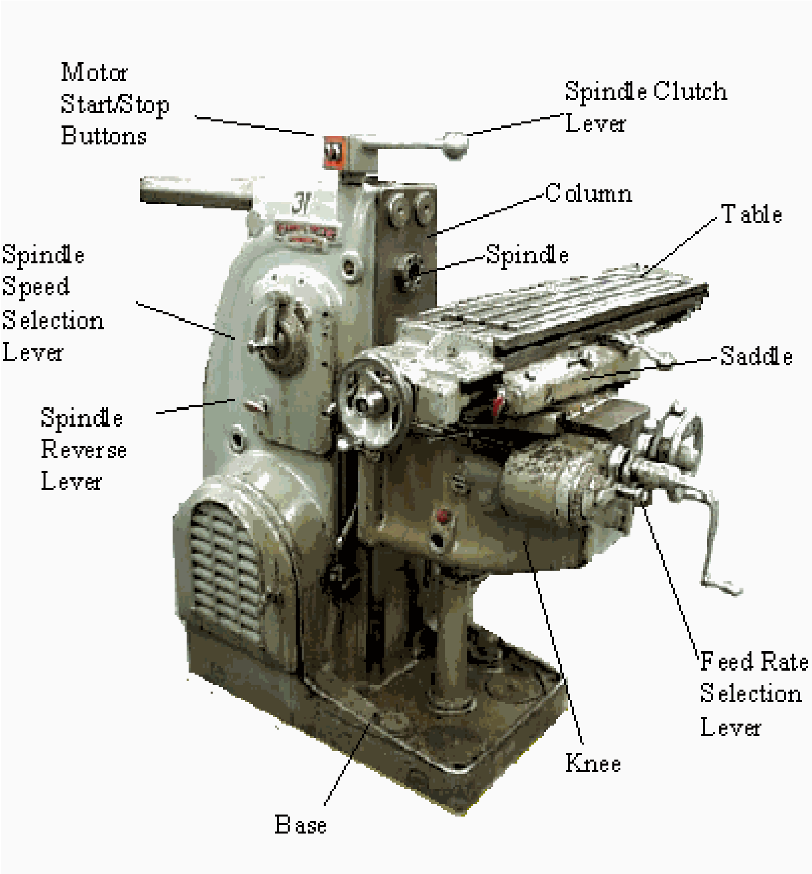


Figure 2MILLING MACHINE

a. Column

The column houses the spindle, the bearings, the gear box, the clutches, the shafts, the pumps, and the shifting mechanisms for transmitting power from the electric motor to the spindle at a selected speed.

b. Knee

The knee mounted in front of the column is for supporting the table and to provide an up or down motion along the Z axis.

c. Saddle

The saddle consists of two slideways, one on the top and one at the bottom located at 90º to each other, for providing motions in the X or Y axes by means of lead screws.

d. Table

The table is mounted on top of the saddle and can be moved along the X axis. On top of the table are some T-slots for the mounting of workpiece or clamping fixtures.

e. Arbor

The arbor is an extension of the spindle for mounting cutters. Usually, the thread end of an arbor is of left hand helix.

f. Base

The base of the milling machine, along with the column, are the major structural components. They hold, align, and support the rest of the machine.

g. Spindle

The spindle holds the tool and provides the actual tool rotation.

h. Spindle Reverse Lever

The position of this lever determines the spindle direction. The three positions of the handle are; In, Middle, and Out. The middle position is the neutral position. Never move the spindle reverse lever when the spindle is turning.

ı. Spindle Speed Selection Lever

The spindle speed selection lever is used to change the spindle R.P.M. setting. This type of machine has a geared head so the spindle speed can only be changed when the spindle is stopped.

j. Spindle Clutch Lever

The spindle clutch lever engages the spindle clutch to the motor. By manipulating the spindle clutch lever the operator can start and stop the spindle.

k. Feed Rate Selection Lever

The feed rate selection lever is used to change the feed rate setting. The feed rate settings are expressed in inches per minute.

m. Motor Start and Stop Buttons-

The motor start and stop buttons control the power to the main motor for the machine

2.2. Vertical Milling Machine

Figure 3 shows a vertical milling machine which is of similar construction to a horizontal milling machine except that the spindle is mounted in the vertical position.

Its additional features are: -

a. Milling head

The milling head consisting the spindle, the motor, and the feed control unit is mounted on a swivel base such that it can be set at any angle to the table.

b. Ram

The ram on which the milling head is attached can be positioned forward and backward along the slideway on the top of the column.

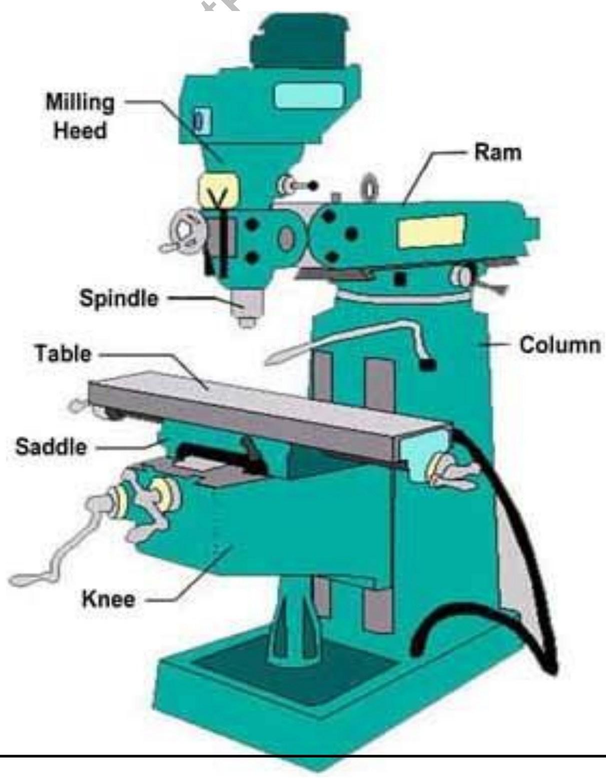


Figure 3 Vertical Milling Machine

3. CUTTING TOOLS

3.1. Cutting Tools for Horizontal Milling

a. Slab Mills

For heavy cutting of large and flat surfaces.

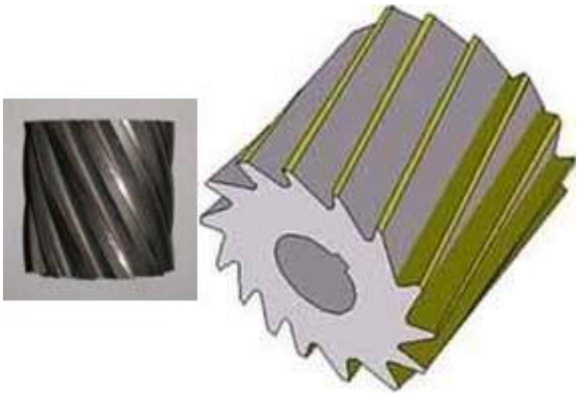
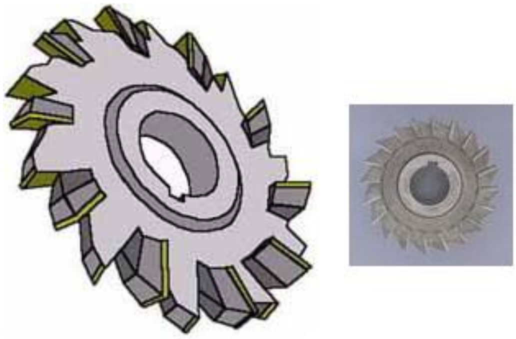


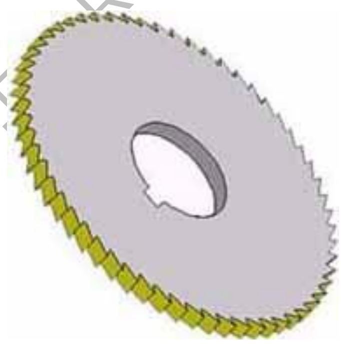
Figure 4 SLAB MILL

b. Side and Face Cutters

This type of cutters has cutting edges on the periphery and sides of the teeth for cutting shoulders and slots.



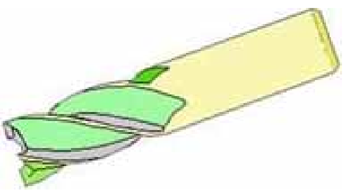
c. Slitting Saws

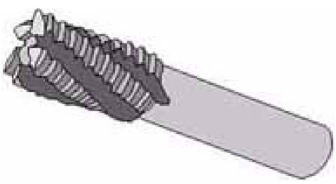


For cutting deep slots or for parting off.

3.2. Cutting tools for Vertical Milling a. End Mills

Commonly used for facing, slotting and profile milling.





b. Rough Cut End Mills

For rapid metal removal.

c. Slot Drills

For producing pockets without drilling a hole before hand.

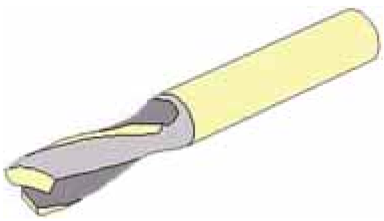
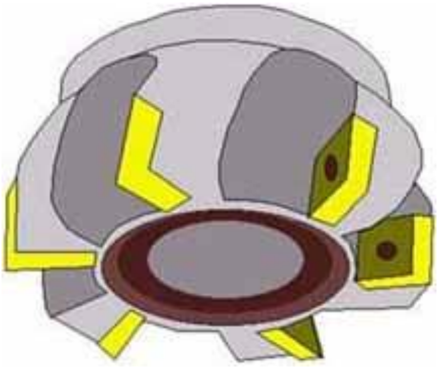


Figure 5. Side and Face Cutter



Involute gear cutter

Involute gear cutter - No. 4

The image shows a *Number 4* cutter from an involute gear cutting set. There are 7 cutters (excluding the rare half sizes) that will cut gears from 12 teeth through to a rack (infinite diameter). The cutter shown has markings that show it is a

- 10 DP (diametrical pitch) cutter
- That it is No. 4 in the set
- that it cuts gears from 26 through to 34 teeth
- It has a 14.5degree pressure angle

Hobbing cutter

Fig. Hobbing cutter

These cutters are a type of form tool and are used in hobbing machines to generate gears. A cross section of the cutters tooth will generate the required shape on the workpiece, once set to the appropriate conditions (blank size). A hobbing machine is a specialised milling machine.

4. INDUSTRIAL APPLICATIONS

Milling machines are widely used in the tool and die making industry and are commonly used in the manufacturing industry for the production of a wide range of components as shown in figure 11. Typical examples are the milling of flat surface, indexing, gear cutting, as well as the cutting of slots and key-ways.

5. MILLING PROCESSES

Milling is a metal removal process by means of using a rotating cutter having one or more cutting teeth as illustrated in figure 13. Cutting action is carried out by feeding the workpiece against the rotating cutter. Thus, the spindle speed, the table feed, the depth of cut, and the rotating direction of the cutter become the main parameters of the process. Good results can only be achieved with a well-balanced setting of these parameters.

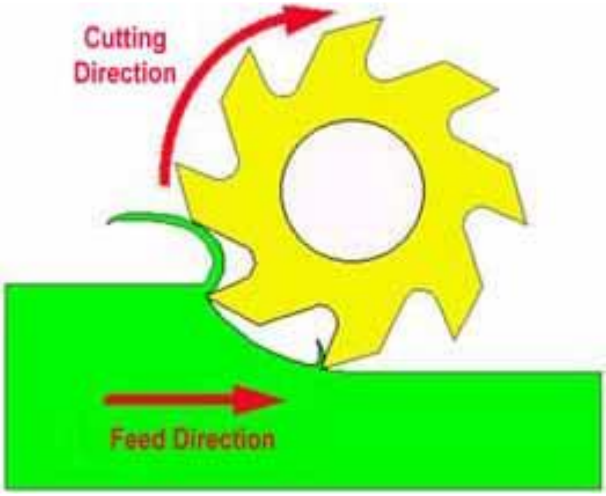


Figure 13. Milling Process

5.1. SPINDLE SPEED

Spindle speed in revolution per minute (R.P.M.) for the cutter can be calculated from the equation :-

$$N = \frac{CS \times 1000}{\pi d}$$

where -- **N** = R.P.M. of the cutter
CS = Linear Cutting Speed of the material in m/min. (see table 1)
d = Diameter of cutter in mm

5.2. Feed Rate

Feed rate (F) is defined as the rate of travel of the workpiece in mm/min. But most tool suppliers recommend it as the movement per tooth of the cutter (f). Thus,

$$\mathbf{F = f \cdot u \cdot N}$$

where -- **F** = table feed in mm/min
f = movement per tooth of cutter in mm (see table 1)
u = number of teeth of cutter
N = R.P.M. of the cutter

where

C.S. and feed rate for some common material :-

Tool Material	**High Speed Steel**		**Carbide**	
Material	Cutting Speed	Feed (f)	Cutting Speed	Feed (f)
Mild Steel	25	0.08	100	0.15
Aluminium	100	0.15	500	0.3
Hardened Steel	---	---	50	0.1

Table 1

5.3. Depth of Cut

Depth of cut is directly related to the efficiency of the cutting process. The deeper the cut the faster will be the production rate. Yet, it still depends on the strength of the cutter and the material to be cut.

For a certain type of cutter, a typical range of cut will be recommended by the supplier. Nevertheless, it should be noted that a finer cut is usually associated with a better surface finish as well as a long tool life.

5.4. Direction of Cutter Rotation

a. Up Cut Milling

In up cut milling, the cutter rotates in a direction opposite to the table feed as illustrated in figure 14. It is conventionally used in most milling operations because the backlash between the leadscrew and the nut of the machine table can be eliminated.

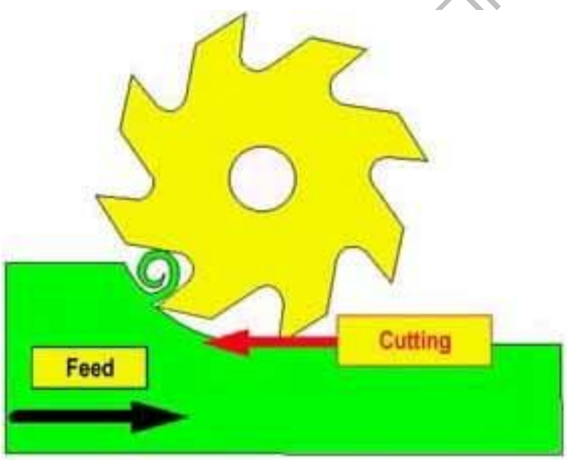


Figure 14. Up Cut Milling

b. Down Cut Milling

In down cut milling, the cutter rotates in the same direction as the table feed as illustrated in figure 15. This method is also known as Climb Milling and can only be used on machines equipped with a backlash eliminator or on a CNC milling machine. This method, when properly treated, will require less power in feeding the table and give a better surface finish on the workpiece.

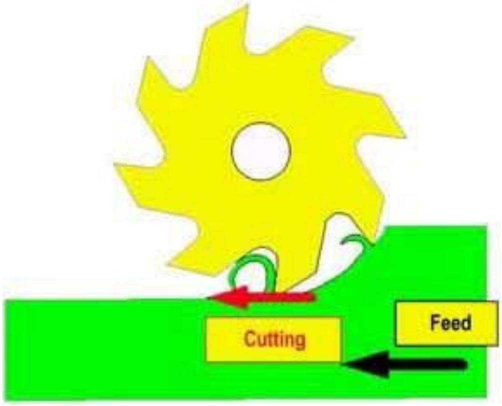


Figure 15. Down Cut Milling

6. TYPICAL MILLING OPERATIONS

6.1. Plain Milling

Plain milling is the milling of a flat surface with the axis of the cutter parallel to the machining surface. It can be carried out either on a horizontal machine or a vertical machine as shown in figure 16.

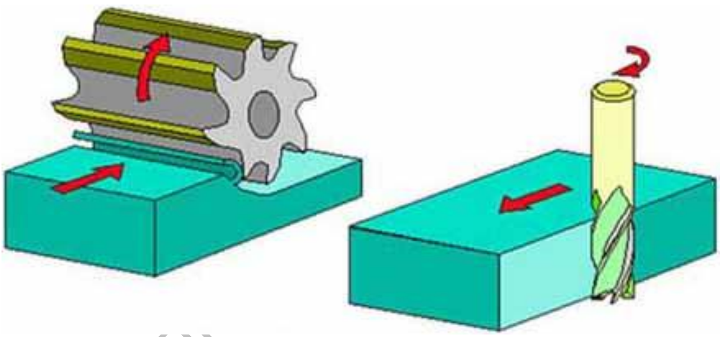


Figure 16. Plain Milling

6.2. End Milling

End Milling is the milling of a flat surface with the axis of the cutter perpendicular to the machining surface as shown in figure 17.

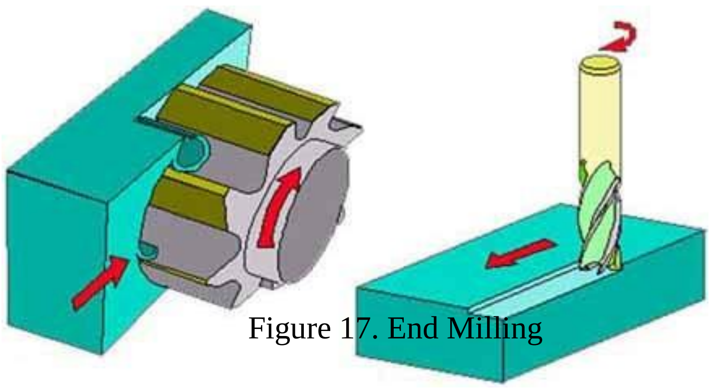


Figure 17. End Milling

6.3. Gang Milling

Gang milling is a horizontal milling operation that utilizes three or more milling cutters grouped together for the milling of a complex surface in one pass. As illustrated in figure 18, different type and size of cutters should be selected for achieving the desire profile on the workpiece.

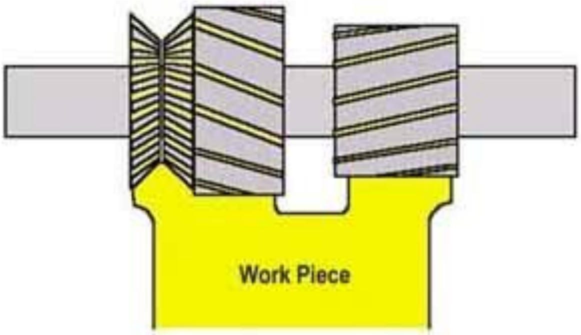


Figure 18. Gang Milling

6.4. Straddle Milling

In straddle milling, a group of spacers is mounted in between two side and face milling cutters on the spindle arbor as shown in figure 19. for the milling of two surfaces parallel to each other at a given distance.

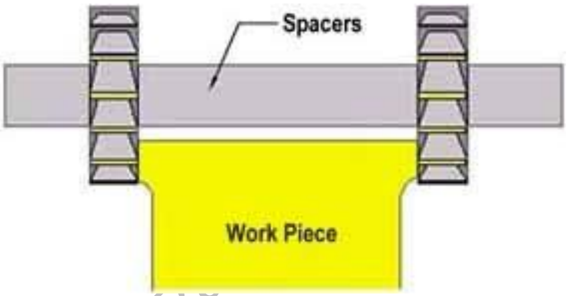


Figure 19. Straddle Milling

7. MILLING MACHINE VICES

The milling machine vise is the most common type of work holding devise used on the milling machine (Figure 1).

Figure 1: Plain Milling Machine Vise

The plain milling machine vise is used for holding work which has parallel sides. The vise is bolted directly to the table using the T-slots in the machine table. The plain vise can be accompanied by a swivel base (Figure 2).

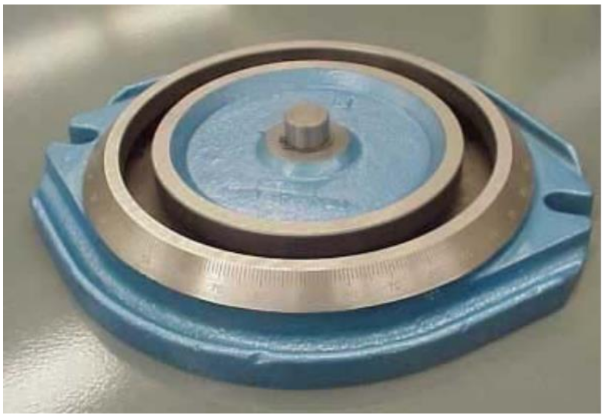


Figure 2: Swivel Base

Figure 3: Swivel Base and Vise

The swivel base is graduated in degrees and allows the vise to swivel in the horizontal plane. The swivel base gives the vise a greater degree of versatility but should be avoided when doing heavy rough cutting operations because it reduces the rigidity of the setup.

For machining operations involving compound angles, a universal vise is commonly used (Figure 4).

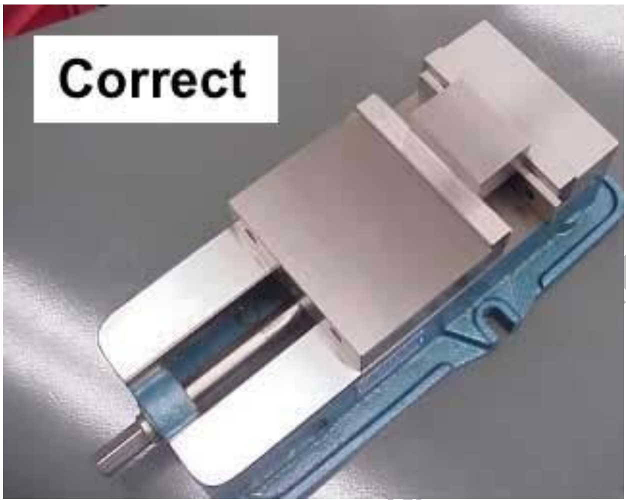
Figure 4: Universal Angle Milling Vise

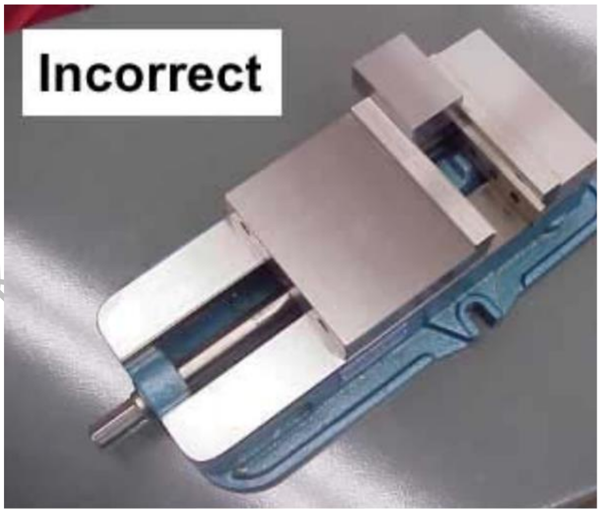
The universal vise allows the operator to tilt the workpiece 90 degrees in the vertical plane as well as swivel it 360 degrees in the horizontal plane.

In high production situations an air or hydraulically actuated vise may be used. These types of vises are quick acting. They also maintain consistent clamping pressures from one part to the next. However, on most manual type milling machines the vise is opened or closed using a handle. When tightening a plain type milling machine vise it is **not** necessary to strike the handle of the vise (Figure 5).

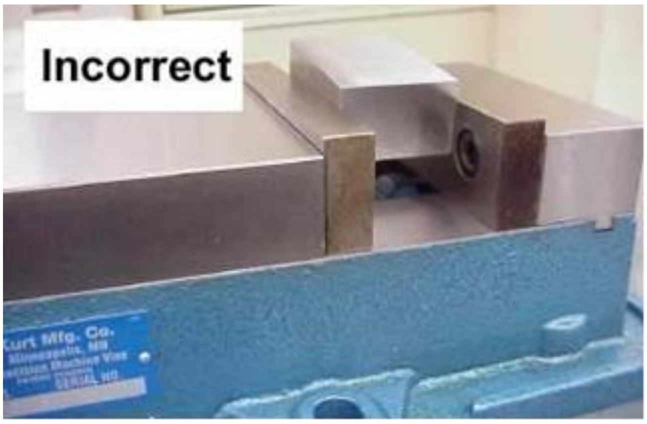
Striking the vise handle with a hammer can either cause the vise to become over- tightened or cause the vise handle to break. If it becomes apparent that the vise is not holding properly, check with your instructor for other possible causes to the problem.

In Figure 6 please study the correct and incorrect vise clamping practices.



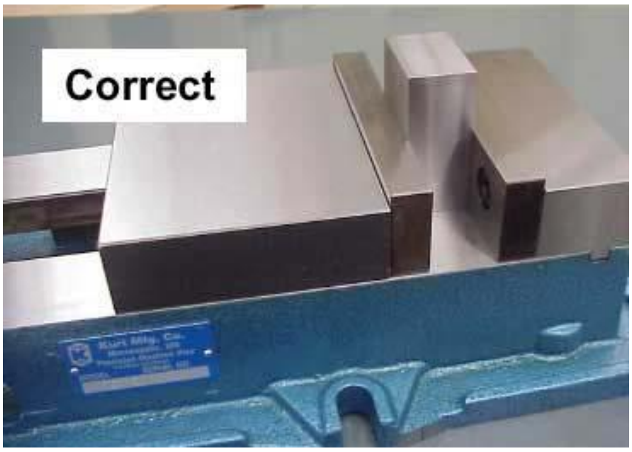


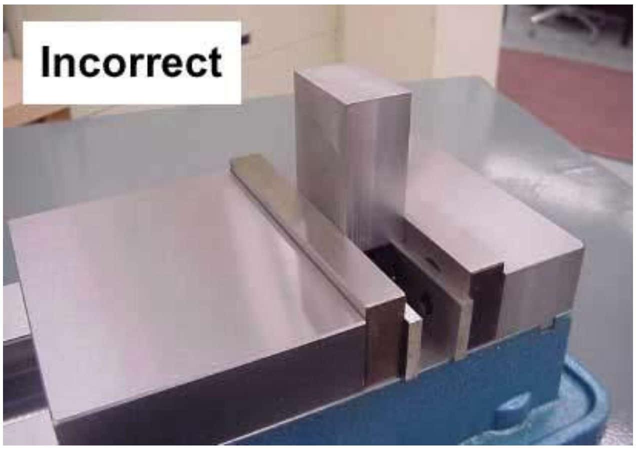
Locate the part in the center of the vise. This equalizes the pressure on the vise jaws.



The workpiece should always be supported by the bottom of the vise or by parallels.

Holding the workpiece off center puts unequal pressure on the vise jaws. This can cause the piece to loosen up.





Work pieces that are not supported will move under the pressure of the cutting forces.

Keep the workpiece as low in the vise as possible. Work that extends out of the vise has a greater chance of loosening up under cutting conditions.

Figure 6: Vise Clamping Principles For Milling

V - Blocks

V-Blocks hold and support round work for milling or drilling (Figure 7). V-Blocks come in many different sizes. On milling machines, V-Blocks are typically clamped directly to the table (Figure 8).

Figure 7: V-Blocks

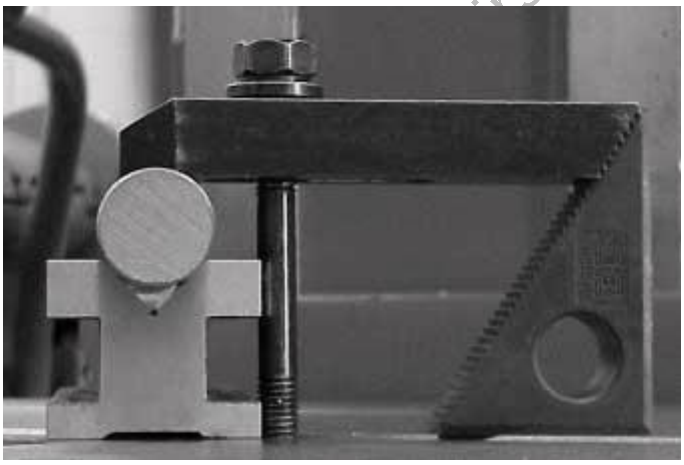


Figure 8: A V-Block and a strap clamp being used to clamp a round part to the table.

Angel plates

An angle plate is an L shaped piece of Cast Iron or Steel that has tapped holes or slots to facilitate the clamping of the workpiece (Figure 9).Angle plates are used when parts need to have machining operations performed at a 90 degree angle to the axis of the table(Figure 10).

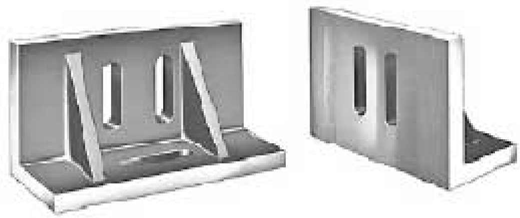


Figure 9: Angle Plates

Figure 10: Angle plate being used to machine

Mounting to the table

Work that is too large or has an odd configuration is usually bolted directly to the table (Figure 11). This method of work holding takes the most ingenuity and expertise.

There are a number of accessories that can be used to help you set up the workpiece.

Figure 11: Direct Clamping using strap clamps-Notice the stop block. It is used to align the work as well as prevent the part from slipping.

A variety of commercially available clamp sets are available for directly mounting workpieces (Figure 1)

Figure 12: Clamping Sets

Parallels are pieces of steel bar stock accurately machines so that the opposing sides are parallel to each other (Figure 13). Parallels are provided in sets of two with identical dimensions.

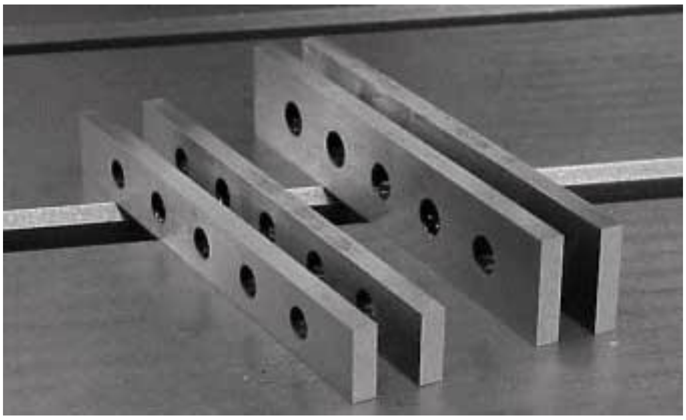


Figure 13: Parallels come in sets of two.

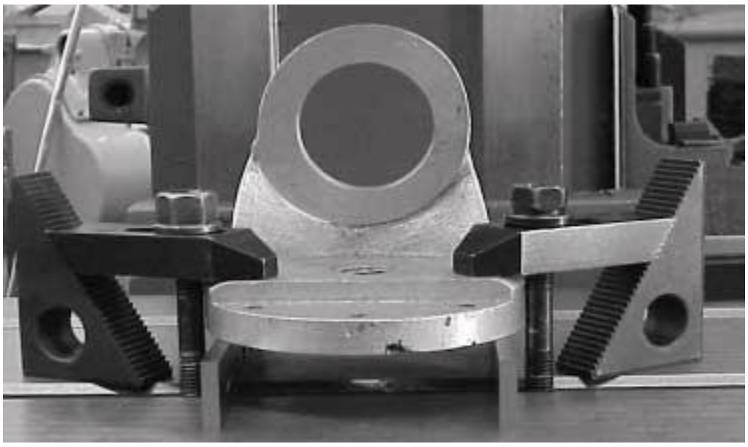
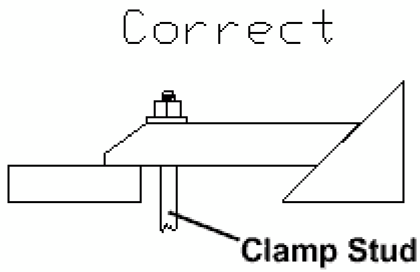


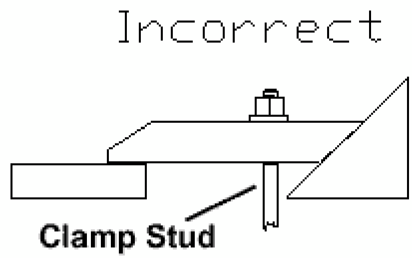
Figure 14: Parallels being used to raise the workpiece above the table surface**.**

Parallels are used in order to provide clearance under the work so the cutting tool does not damage the machine table or the vise base (see Figure 14).

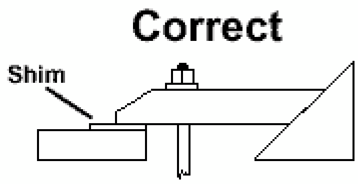
In Figure 15 please study the correct and incorrect direct clamping practices.



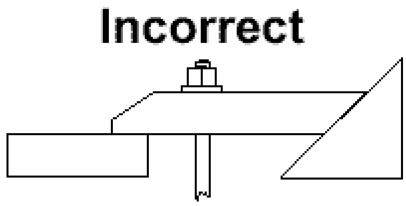
Place clamp stud close to the workpiece.



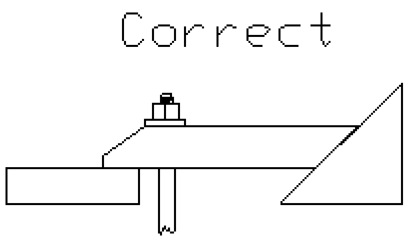
Do not place clamp stud closer to the support



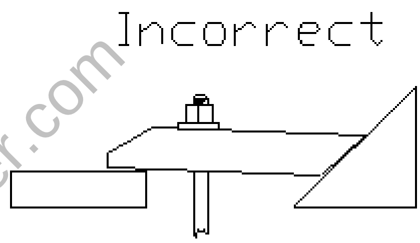
Use shims between finished surfaces and clamps



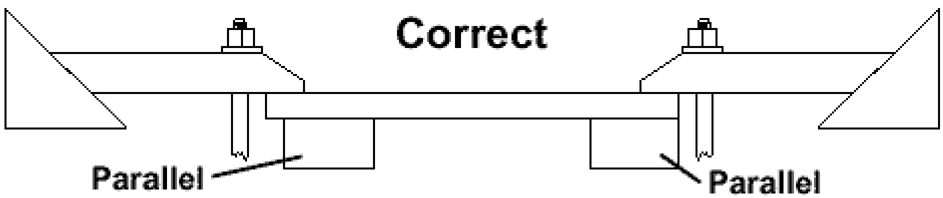
Clamps in contact with finished surfaces will mar the workpiece.



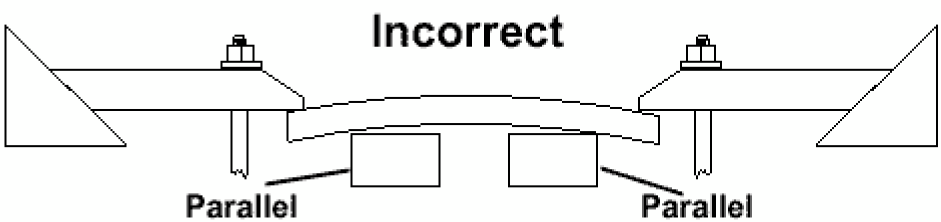
Clamps that are level or with a slight decline toward the workpiece will equalize the clamping pressure.



Angling clamps incorrectly puts pressure on the support, not the workpiece.



Place support parallels directly under clamps.



The spring caused by improper parallel placement will cause the part to bow.

Figure 15: Correct and Incorrect Clamping Practices

7.1. Vice Alignment

In the setting up of the vice onto the machine table, the fix jaw of the vice must be set parallel to the machine table using a Parallel Bar and a Dial Indicator. Adjustments can only be made by using a hide face hammer to correct its position such that a near zero indicator movement is achieved at all positions along the parallel bar.

7.2. Work Holding Method

In the machining of a complex component, it is usually started off with the milling of a rectangular block. To ensure that each surface of the rectangular block is perpendicular to its neighbouring surfaces, the following points should be noted:-

- The vice jaws and the workpiece must be free from burrs, chips, and cutting fluid.
- Smaller workpiece should be supported by parallel bars to provide the supporting datum.
- Round bar must be placed between the workpiece and the movable jaw to ensure that the workpiece is in perfect contact with the fix jaw.
- The vice handle should be tightened by hand to avoid over clamping of the workpiece as well as the vice. Hide face hammer should be used to assure that the workpiece is in perfect contact with the supporting base.
- On completion of the milling of the first face, the workpiece should be unloaded, deburred, and cleaned before the next operation.
- To machine the second and the third faces, the workpiece should be clamped with its preceding machined surface facing against the fix jaw of the vice.
- Similar clamping method can be applied in the machining of the fourth face.
- Yet it can also be clamped on the vice without the round bar.
- Both ends of the workpiece can be machined with the periphery flutes of the cutter using up cut milling as shown in figure below.

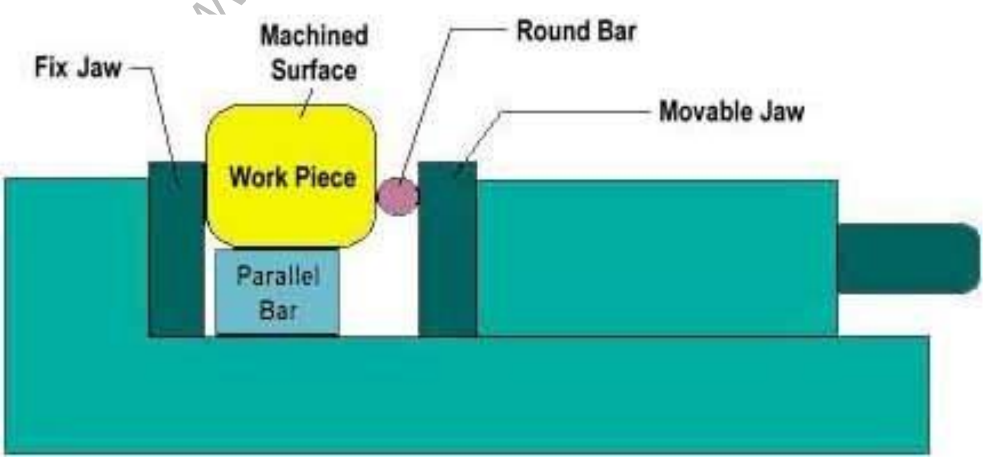


Figure . Holding Method by Using a Machine Vice

8. SAFETY

Safety practices of a machine shop should be followed. A complete understanding of the Safety Rules would enable the students to identify potential hazards that may occur under different working conditions such that appropriate preventive actions can be taken to avoid the happening of accidents.

9. INDEXING

In many milling operations, the job is required to be rotated correct to the fractions on minutes, such as in milling gear teeth, splines, grooves slots, hexagonal or square heads, of bolts and nuts, etc. the operation of rotating the job through the required angle between the two successive cuts is called indexing. This angle between the two successive cuts is called indexing. This is accomplished with the help of the indexing head or dividing head.

Methods of Indexing

The principle methods of indexing are as follows.

1) Direct indexing
2) Simple or plain indexing.
3) Compound indexing
4) Differential indexing
5) Angular indexing.

Direct Indexing

Direct indexing is accomplished by using the index plate attached to the work spindle. The index plate has 24 divisions, and can be divided in to 2, 3, 4, 6, 8 and 12 equal parts directly. It is engaged by a plunger pin on the head and can be turned the required amount by hand. The use of worm and worm wheel is avoided. This method of indexing limited only to those divisions that are factor or 24. It is a quick method of indexing and used when only a few cuts are required in a revolution.

Simple or Plain Indexing

It is accomplished by turning the crank a number of turn to rotate the work the desired amount, the indexing plate being held in a fixed position. Different index plates with varying number of holes are used to increase the range of indexing.

With a ratio of 40 to 1, on revolution of the crank will rotate the work $\frac{1}{40}$ of a revolution. Hence to cut a gear with 40 teeth the crank would be locked the plate by the index pin and a cut would be made. After one cut, the handle would be turned one revolution and another cut taken and so on. To cut a gear with 20 teeth would require 2 turns of the handle. The cut 8 flutes on a reamer, 5turns of the handle would be made. As long as the number of cuts to be taken is factor of 40, it is a simple matter to calculate the number of handle turns. By following these simple calculations, we conclude the following rule:

$$\text{Turns of index handle} = \frac{\text{turns of handle to produce one turn of work (usually 40)}}{\text{cuts to be made in one revolution of work}}$$

5.24 s

$$\text{or } T = \frac{40}{N}$$

If 24 teeth are to be cut on a gear blank, then

$$T = \frac{40}{N} = 1\frac{16}{24} = 1\frac{2}{3}$$

First, select a circle on the index plate that is divisible by 3. If a 24-space circle is available, then the worm is to be rotated by the handle through one complete rotation and 16 spaces of 24 space circle. In setting the arms, space and not holes should be counted.

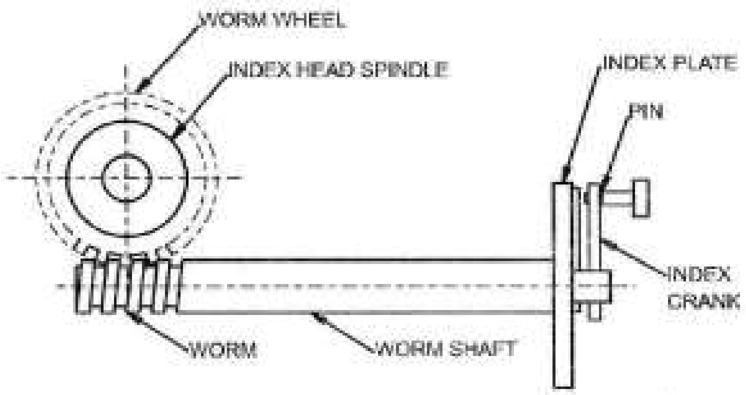


Fig. 5.33. Simple indexing mechanism

Compound Indexing

It is accomplished on the same principle as the simple indexing, but the only difference is that is used two different circles of one plate and hence also sometimes referred to as hit and trial method. The principle of compound indexing is to obtain the required division by two stages.

(i) By rotating the crank or handle in useual way keeping the index plate fixed. (ii) By releasing the back-pin and then rotating the index plate with the handle.

Let 27 teeth are to be cut on a gear blank,

$$\text{Then } T = \frac{40}{N} = \frac{18}{27} + \frac{22}{27}$$

$$= \frac{6}{9} + \frac{22}{27}$$

$$= \frac{12}{18} + \frac{22}{27}.$$

Thus, for each tooth, rotate the worm by 12 spaces of 18 space circle with the help of crank and then rotate the index plate by 22 spaces of 27 space circle.

Differential Indexing

Plain indexing is sometimes limited to a certain extent due to the available number of index plates with different space circles. If the work is to be turned an amount that cannot be obtained by plain indexing the differential indexing is adopted. In such a case, the index plate is unlocked and connected to a train of gears, which receive their motion from the worm gear spindle. As the handle is turned, the index plate also turns, but at a different rate. Its movement depends on these gear used to drive it. After the gears are set up, the operation is similar to simple indexing. By the method of indexing, the work may be rotated by any fraction of revolution with the usual indexing plates.

The following relation is used for calculating the necessary gears to be placed between the spindle and the worm shaft.

$$\frac{\text{Driver}}{\text{Driven}} = (n - N) \times \frac{40}{n}$$

and a crank movement $T = \frac{40}{n}$ ....(10.1)

Where N = no. of divisions to be indexed and P = a no. of slightly more or less than N.

The equation (5.1) gives the gear ratio to be placed on the spindle (driver) and the worm shaft (Driven). The arrangement of gears may be simple or compound train depending upon the suitability.

If (n-N) is positive, then rotate the index plate in the direction in which crank is rotated. If it is negative, then rotate the index plate in opposite direction to that of the crank.

Angular Indexing

Sometimes the work is to be rotated through a certain angle instead of rotating it through certain division of its periphery. Angular indexing gives the rotation of work through certain angle. Since the crank and spindle ratio is 40:1 by moving the crank

1 through one revolution, the spindle or the work move through —lh of revolution.

i.e. -rr- = 9 degrees.

Cutting Speed, Feed and Depth of cut

Cutting speed

The speed of milling cutter is its peripheral linear speed resulting from rotation. It is expressed in meters per minute. The cutting speed can be derived from the formula:

$$V = \frac{\Pi dn}{1000} \text{ meters per min} ....(10.2)$$

where, V = The cutting speed in m per min d = The diameter of the cutter in mm. n = The cutter speed in r.p.m.

The spindle speed of a machine is selected to give the desired peripheral speed of the cutter. The average values of cutting speed for different materials are given in table

Feed

The feed in a milling machine is defined as the rate with which the work piece advances under the cutter. The feed is expressed in a milling machine by the following three different methods.

1) Feed Per Tooth (S_Z)

The feed per tooth is defined by the distance the work advances in the time between engagement by the two sucessive teeth. It is expressed in millimeters per tooth of the cutter.

2) Feed Per Cutter Revolution (S_{rev})

The feed per cutter revolution is the distance the work advances in the time when the cutter turns through one complete revolution. It is expressed in millimeters per revolution of the cutter.

3) Feed Per Minute (SJ

The feed per minute is defined by the distance the work advances in one minute. It is expressed in millimeters per minute. The feed per tooth, the feed per cuttter revolution, and the feed per minute are related by the formula which is given below.

$S_m = n \times S_{rev} = S_Z \times Z \times n$ ....(3)

where,

Z = number of teeth in the cutter and n = the cutter speed in r.p.m The average values of feed are given in Table.

Table: Averge cutting speed and feed of different materials.

Work material	Face milling							
	Tool steel		h.s.s		Tool steel		h.s.s	
	Cuttin 8 speed	Feed mm/	Cutt in g	Feed mm/	Cutt in g	Feed mm/	Cuttin g	Feed mm/m
Mild steel 37	7.2-18	150-15	24-42	300-30	7.2-18	50-10	18-36	80-15
Grey cast iron	6-15	250-15	18-36	250-25	6-15	60-20	15-30	100-30
Mild steel 50	7.2-15	150-15	18-36	250-25	7.2-15	40-10	15-30	70-15
Bronze or brass	18-36	200-20	42-72	300-30	18-36	100-20	36-60	180-30

Cutting speed is in m/min.

Depth of cut

The depth of cut in milling is the thickness of the material removed in one pass of the work under the cutter. It is the perpendicular distance measured between the original and final surface of the work piece, and is expressed in min,

5.18 Calculation of Machining Time

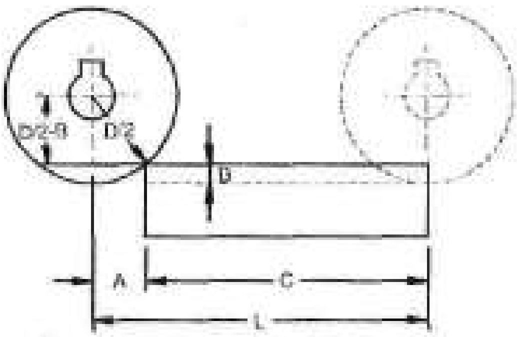
The time required to mill a surface for any operation can be calculated from the formula:

$$T = \frac{L}{S_z \times Z \times n} \text{ ....(10.4)}$$

Where T = The time required to complete the cut in minutes.

L = The length of the table travel to complete the cut in mm. S_Z = The feed per tooth in mm
Z = The number of teeth in the cutter

n = The r.p.m. of the cutter.
In Fig. the length of the table travel 'L' is composed of two parts: the length of the work 'C and the approach length A' is the distance through which the cutter must be moved before the full depth of cut is reached.



Approach length for plain milling cutter.

Approach length for Plain Milling Cutter

The approach A for a plain milling cutter can be calculated from the equation:

$$A^2 = \left(\frac{D}{2}\right)^2 - \left(\frac{D}{2} - B\right)^2$$

or $$A = \sqrt{B(D-B)} \quad \text{...(10.5)}$$

where, A = The approach in mm.

B = The depth of cut in mm

D = The diameter of the cutter in mm. Approach length for face milling cutter
Referring to the Fig.5.38 the approach length for a face milling cutter can be calculated from the equation.

$$A = \frac{D}{2} - C \quad \text{...(10.6)}$$

where A = The approach length in mm D

= The diameter of the cutter.

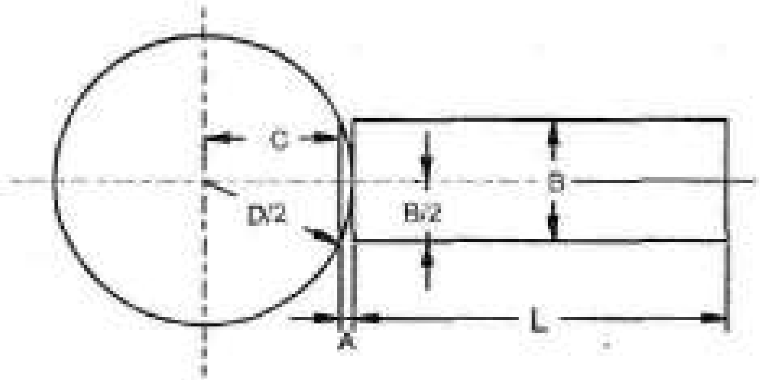
$$C = \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{B}{2}\right)^2}$$

B = The width of the work

Putting the value of 'C in the equation

$$A = \frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{B}{2}\right)^2}$$

$$A = \frac{1}{2}\left(D\sqrt{D^2 - B^2}\right) \quad \text{.................................(10.7)}$$



Approach length for face milling cutter

UNIT-5.

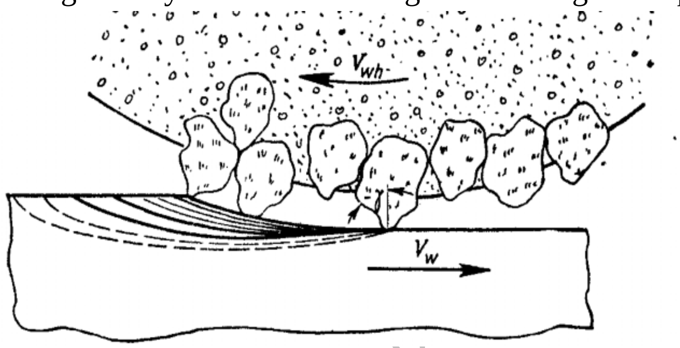
GRINDING MACHINES

INTRODUCTION:

Grinding is a process of removing metal, but in a smaller volume. To 'grind' means to 'abrade', to wear away by friction or to sharpen. In grinding, the material is removed by means of a rotating abrasive wheel. The action of grinding wheel is very similar to that of a milling cutter. The wheel is made up of a large number of cutting tools constituted by projected abrasive particles in the grinding wheel.

Grinding is the most common form of abrasive machining. It is a material cutting process which engages an abrasive tool whose cutting elements are grains of abrasive. material known as grit. These grits are characterized by sharp cutting points, high hot hardness, chemical stability and wear resistance.

The grits are held together by a suitable bonding material to give shape of an abrasive tool.



Major advantages and applications of grinding

Advantages:

A grinding wheel requires two types of specification

- Dimensional accuracy
- Good surface finish
- Good form and locational accuracy applicable to both hardened and unhardened material

Applications:

- Surface finishing
- Slitting and parting
- De-scaling, De-burring
- Stock removal (abrasive milling) finishing of flat as well as cylindrical surface
- Grinding of tools and cutters and re-sharpening of the same.

GRINDING MACHINES:

Grinding Machines are also regarded as machine tools. A distinguishing feature of grinding machines is the rotating abrasive tool.

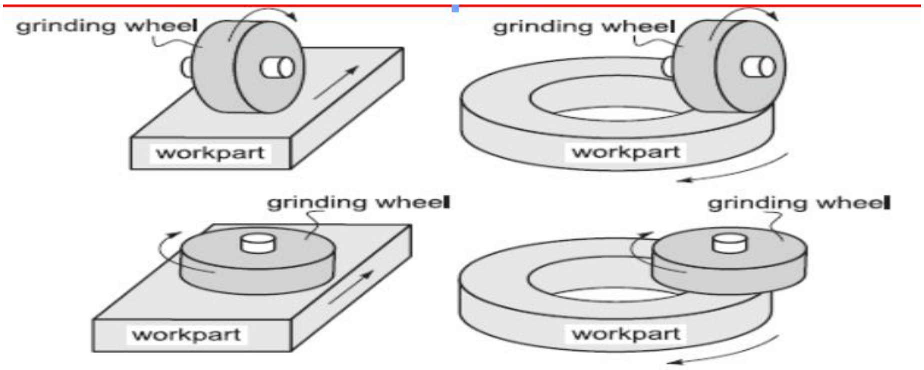
 Grinding machine is employed to obtain high accuracy along with very high class of surface finish on the work piece. However, advent of new generation of grinding wheels and grinding machines, characterized by their rigidity, power and speed enables one to go for high efficiency deep grinding (often called as abrasive milling) of not only hardened material but also ductile materials.

 Conventional grinding machines can be broadly classified as:

- Surface grinding machine
- Cylindrical grinding machine
- Center less grinding

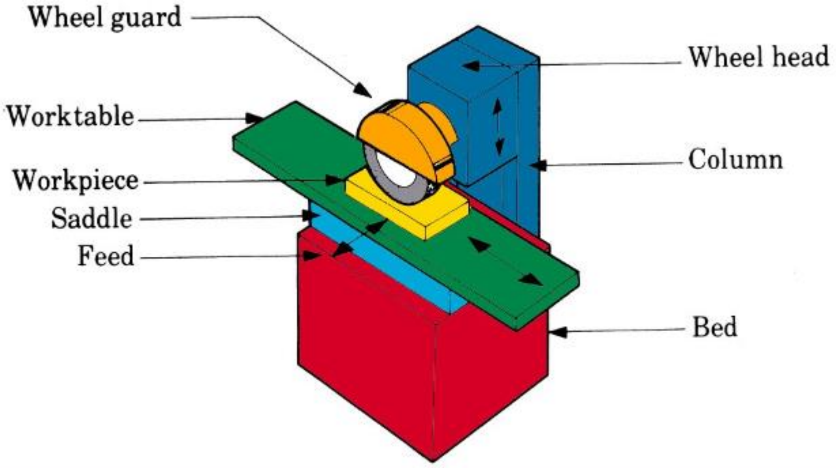
Surface grinding:

 In surface grinding, the spindle position is either horizontal or vertical, and the relative motion of the work piece is achieved either by reciprocating the work piece past the wheel or by rotating it. The possible combinations of spindle orientations and work piece motions yield four types of surface grinding processes illustrated in the figure.



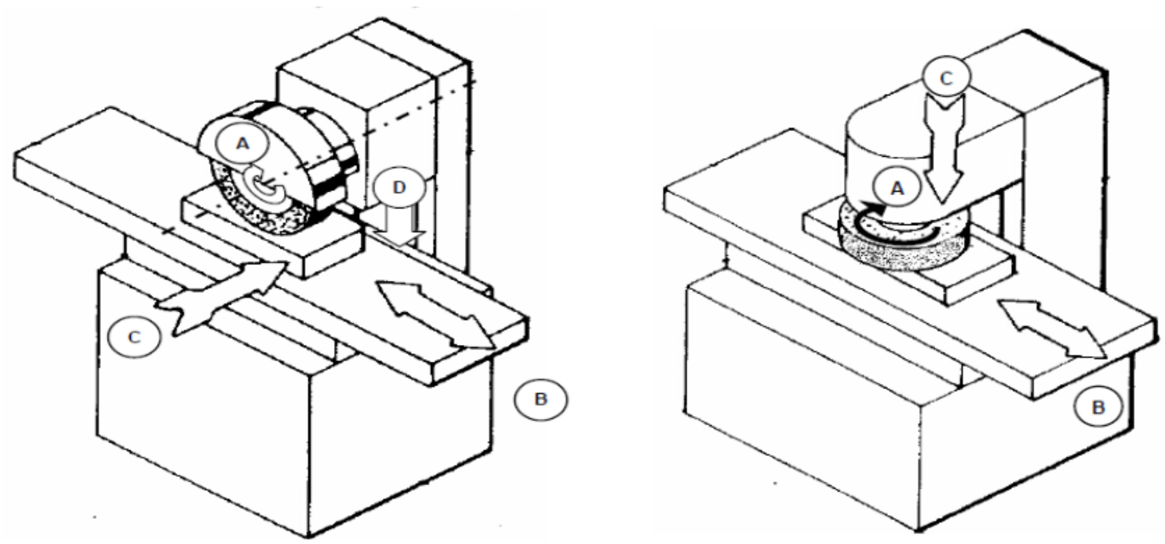
Four types of surface grinding with horizontal or vertical spindles, and with reciprocating linear motion or rotating motion of the workpiece.

Surface grinding machine:



Schematic illustration surface grinding Machine

This machine may be similar to a milling machine used mainly to grind flat surface. However, some types of surface grinders are also capable of producing contour surface with formed grinding wheel.



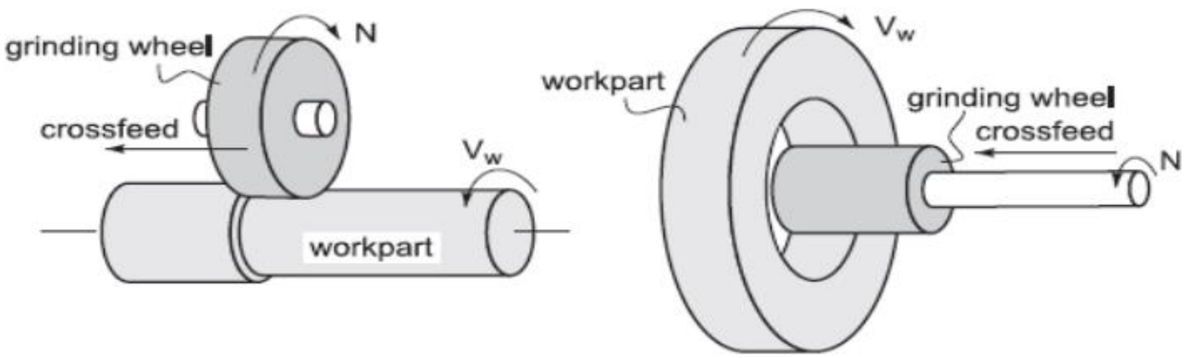
Horizontal Grinding Machine Vertical Grinding Machine

A: rotation of grinding wheel B: reciprocation of worktable C: transverse feed D: down feed

Cylindrical grinding:

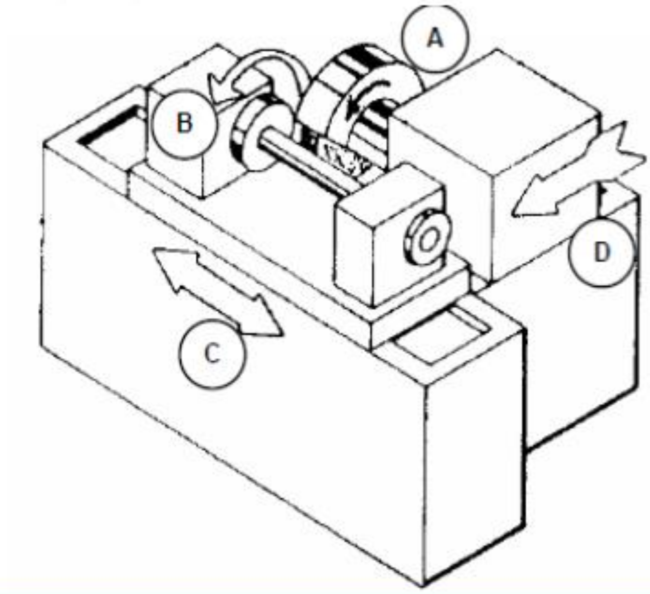
In this operation, the external or internal cylindrical surface of a work piece are ground. In external cylindrical grinding (also center-type grinding) the work piece rotates and reciprocates along its axis, although for large and long work parts the grinding wheel reciprocates. In internal cylindrical grinding, a small wheel grinds the inside diameter of the part.

The work piece is held in a rotating chuck in the headstock and the wheel rotates at very high rotational speed. In this operation, the work piece rotates and the grinding wheel reciprocates.



Two types of surface grinding, (*Left*) external, and (*Right*) internal.

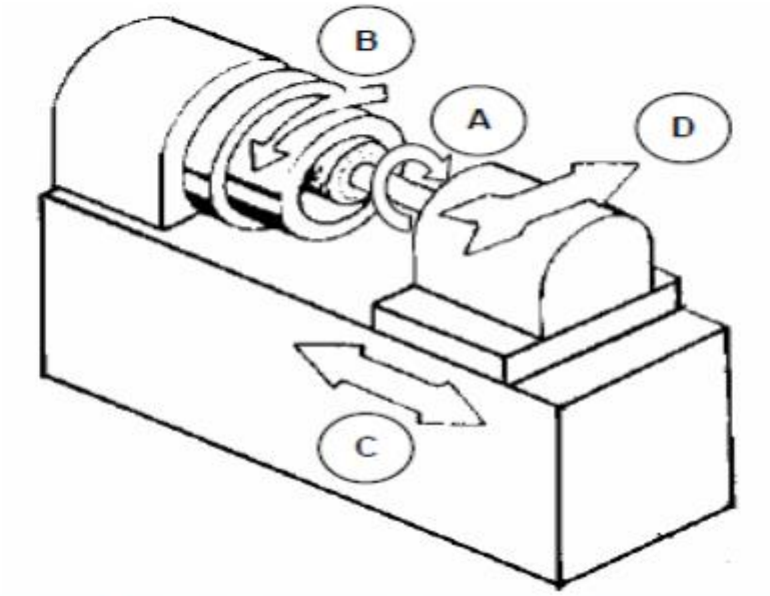
This machine is used to produce external cylindrical surface. The surfaces may be straight, tapered, steps or profiled.



A: rotation of grinding wheel B: work table rotation C: reciprocation of worktable D: infeed

INTERNAL GRINDING MACHINE:

 This machine is used to produce internal cylindrical surface. The surface may be straight, tapered, grooved or profiled.



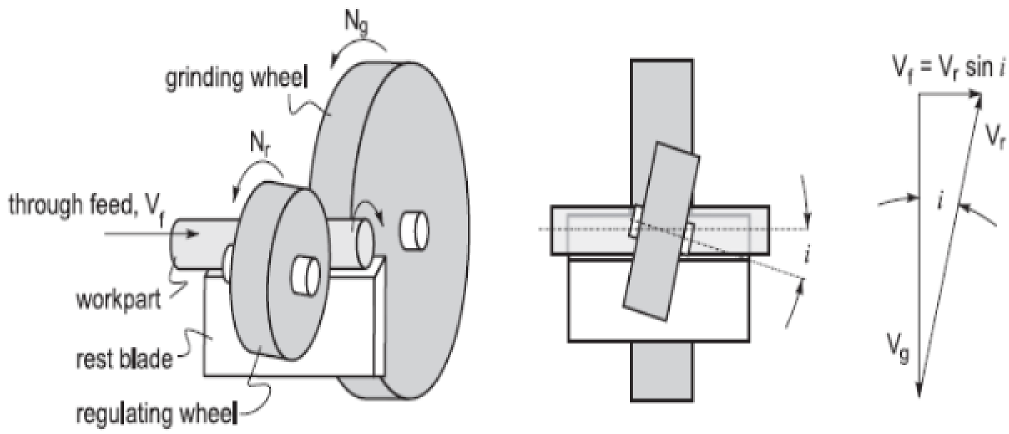
A: rotation of grinding wheel B: workpiece rotation
C: reciprocation of worktable D: infeed

CENTER LESS GRINDING:

Center less grinding is a process for continuously grinding cylindrical surfaces in which the work piece is supported not by centers or chucks but by a rest blade. The work piece is ground between two wheels. The larger grinding wheel does grinding, while the smaller regulating wheel, which is tilted at an angle i, regulates the velocity Vf of the axial movement of the work piece.

 Center less grinding can also be external or internal, traverse feed or plunge grinding. The most common type of center less grinding is the external traverse feed grinding.

Center less grinding Machine



External traverse feed centerless grinding. The regulating wheel is tilted at an angle *i* to control the velocity of through feed.

Grinding wheel:

 Grinding wheel consists of hard abrasive grains called grits, which perform the cutting or material removal, held in the weak bonding matrix. A grinding wheel commonly identified by the type of the abrasive material used. The conventional wheels include aluminium oxide and silicon carbide wheels while diamond and CBN (cubic boron nitride) wheels fall in the category of super abrasive wheel.

Specification of grinding wheel:

- A grinding wheel requires two types of specification
- Geometrical specification
- Compositional specification

Geometrical specification:

 This is decided by the type of grinding machine and the grinding operation to be performed in the workpiece. This specification mainly includes wheel diameter, width and depth of rim and the bore diameter.

Compositional specifications:

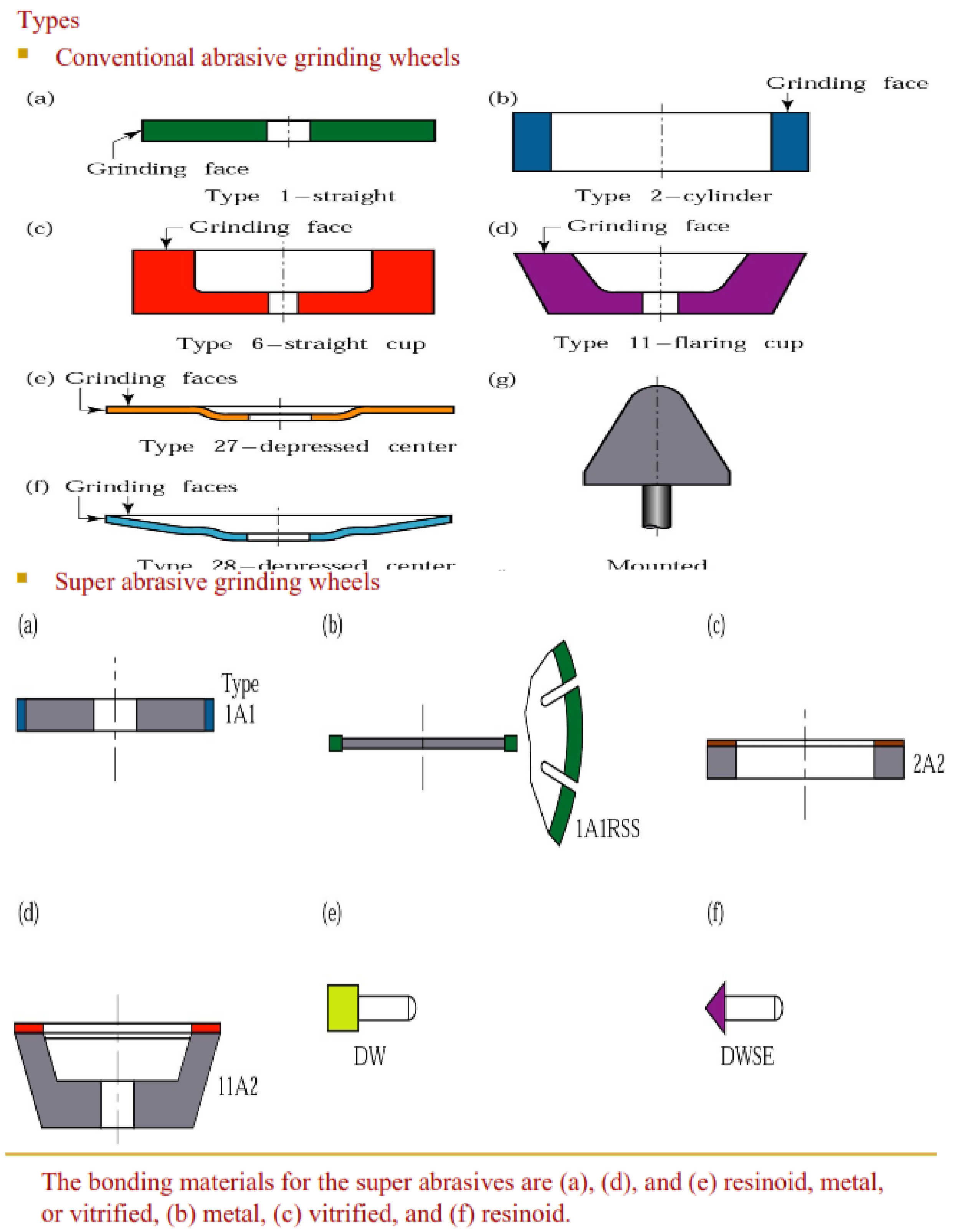
Specification of a grinding wheel ordinarily means compositional specification. Conventional abrasive grinding wheels are specified encompassing the following parameters.

- The type of grit material
- The grit sizes
- The bond strength of the wheel, commonly known as wheel hardness
- The structure of the wheel denoting the porosity i.e. the amount of inter grit spacing
- The type of bond material

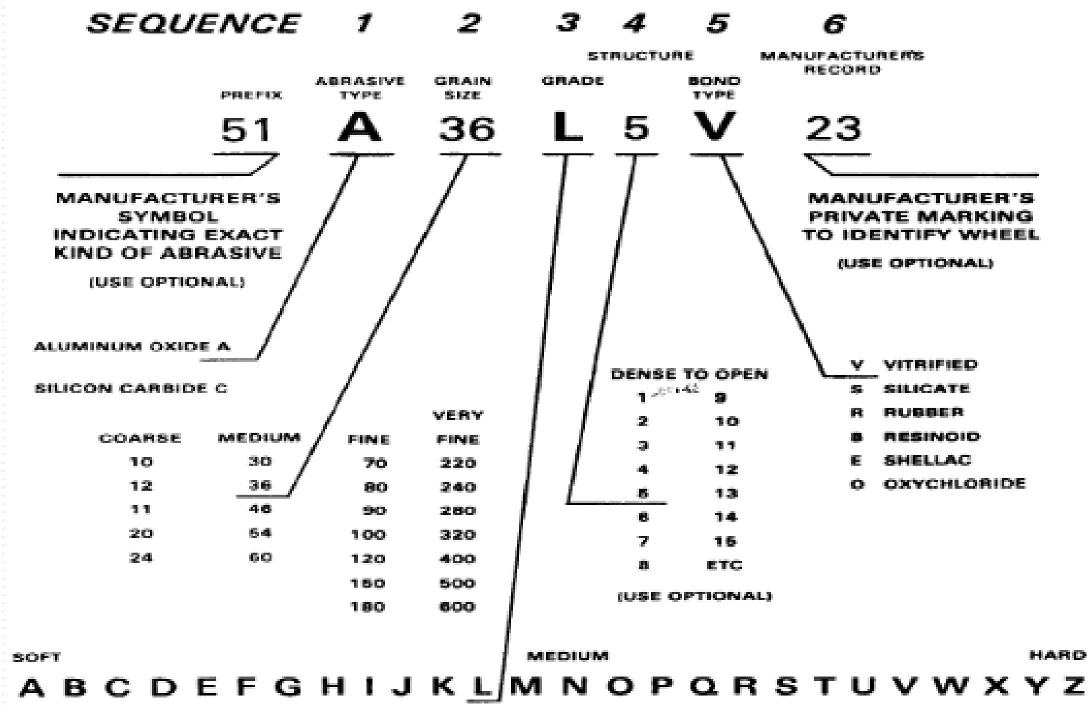
- Other than these parameters the wheel manufacturer may add their own identification code prefixing or suffixing (or both) the standard code.

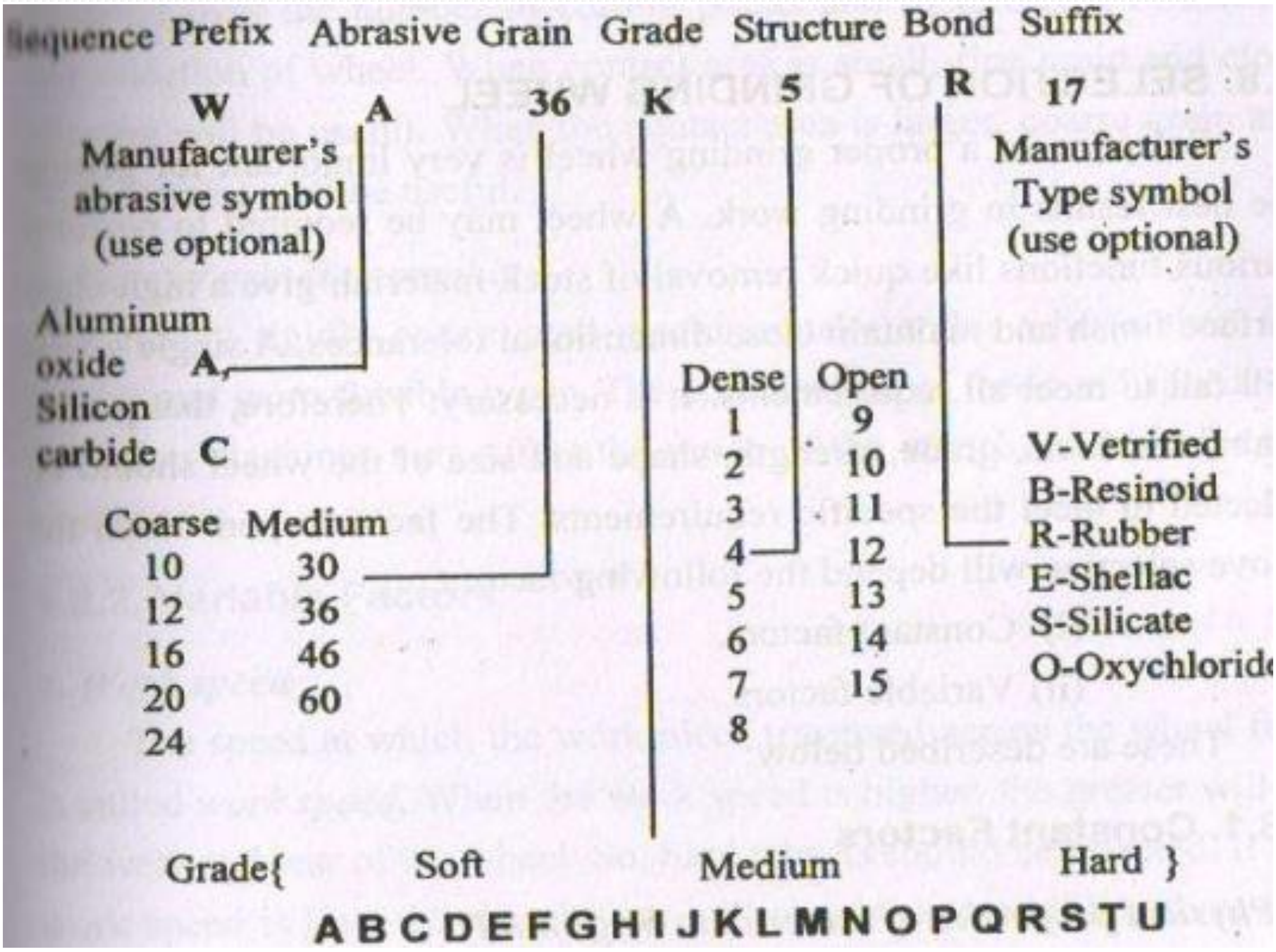
Types

Conventional abrasive grinding wheels



Grade


SEQUENCE 1 2 3 4 5 6
PREFIX
ABRASIVE TYPE
GRAIN SIZE
GRADE
STRUCTURE
BOND TYPE
MANUFACTURER'S RECORD
51 A 36 L 5 V 23
MANUFACTURER'S SYMBOL INDICATING EXACT KIND OF ABRASIVE
(USE OPTIONAL)
ALUMINUM OXIDE A
SILICON CARBIDE C
COARSE MEDIUM FINE VERY FINE
10 30 70 220
12 36 80 240
14 46 90 280
20 54 100 320
24 60 120 400
150 500
180 600
DENSE TO OPEN
1 9
2 10
3 11
4 12
5 13
6 14
7 15
8 ETC
(USE OPTIONAL)
MANUFACTURER'S PRIVATE MARKING TO IDENTIFY WHEEL
(USE OPTIONAL)
V VITRIFIED
S SILICATE
R RUBBER
B RESINOID
E SHELLAC
O OXYCHLORIDE
SOFT
MEDIUM
HARD
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z


Sequence Prefix Abrasive Grain Grade Structure Bond Suffix
W A 36 K 5 R 17
Manufacturer's abrasive symbol (use optional)
Aluminum oxide A
Silicon carbide C
Coarse Medium
10 30
12 36
16 46
20 60
24
Dense Open
1 9
2 10
3 11
4 12
5 13
6 14
7 15
8
Manufacturer's Type symbol (use optional)
V-Vetrified
B-Resinoid
R-Rubber
E-Shellac
S-Silicate
O-Oxychloride
Grade{ Soft Medium Hard }
A B C D E F G H I J K L M N O P Q R S T U

Examples of Bonded Abrasives:

 Conventional abrasives

 Al_2O_3

 SiC

 Super abrasives

 Cubic boron nitride (CBN)

 Diamond

Abrasive Material

Abrasive material	Work material	Color
Aluminum oxide		
97-99% Al_2O_3	hardened steels, HSS	white
87-96% Al_2O_3	steels, cast iron	pink to brown
Silicon carbide		
96-99% SiC	HSS, cemented carbides	green
<96% SiC	aluminum, brass, brittle materials	black
Cubic boron nitride (CBN)	tool steels, aerospace alloys	
Synthetic diamond	ceramics, cemented carbides	

Selection of Cutting speed and Working speed is based on:

- Material to be ground and its hardness.
- Amount of stock removal and finish required.
- Whether the grinding is done wet or dry.
- Wheel speed.
- Area of grinding contact.
- Severity of the grinding operation.

TRUING AND DRESSING OF GRINDING WHEEL

Truing:

 Truing is the act of regenerating the required geometry on the grinding wheel whether the geometry is a special form or flat profile. Therefore, truing produces the macro-geometry of the grinding wheel.

 Truing is also required on a new conventional wheel to ensure concentricity with specific mounting system. In practice the effective macro-geometry of a grinding wheel is of vital importance and accuracy of the finished work piece is directly related to effective wheel geometry.

Dressing:

 Dressing is the conditioning of the wheel surface which ensures that grit cutting edges are exposed from the bond and thus able to penetrate into the work piece material. Also, in dressing attempts are made to splinter the abrasive grains to make them sharp and free cutting and also to remove any residue left by material being ground.

 Dressing therefore produces micro-geometry. The structure of micro- geometry of grinding wheel determine its cutting ability with a wheel of given composition. Dressing can substantially influence the condition of the grinding tool.

 Truing and dressing are commonly combined into one operation for conventional abrasive grinding wheels but are usually two distinctly separate operation for super abrasive wheel.

Finishing Operation:

 To ensure reliable performance and prolonged service life of modern machinery, its components require to be manufactured not only with high dimensional and geometrical accuracy but also with high surface finish.

 The surface finish has a vital role in influencing functional characteristics like wear resistance fatigue strength corrosion resistance and power loss due to friction. The finishing operations are assigned as the last operations in the single part production cycle usually after the conventional or abrasive machining operations, but also after net shape processes such as powder metallurgy, cold flash less forging, etc.

- Lapping
- Buffing
- Honing
- Super finishing
- Wire brushing
- Polishing
- Electro polishing
- Magnetic-field-assisted polishing

LAPPING:

 In lapping, instead of a bonded abrasive tool, oil-based fluid suspension of very small free abrasive grains (aluminum oxide and silicon carbide, with typical grit sizes between 300 and 600) called a lapping compound is applied between the work piece and the lapping tool.

 The lapping tool is called a lap, which is made of soft materials like copper, lead or wood. The lap has the reverse of the desired shape of the work part. To accomplish the process the lap is pressed against the work and moved back and forth over the surface.

 Lapping is sometimes performed by hand, but lapping machines accomplish the process with greater consistency and efficiency. Lapping is regarded as the oldest method of obtaining a fine finish. Lapping is basically an abrasive process in which loose abrasives function as cutting points finding momentary support from the laps. Material removal in lapping usually ranges from .003 to .03 mm but many reaches 0.08 to 0.1mm in certain cases.

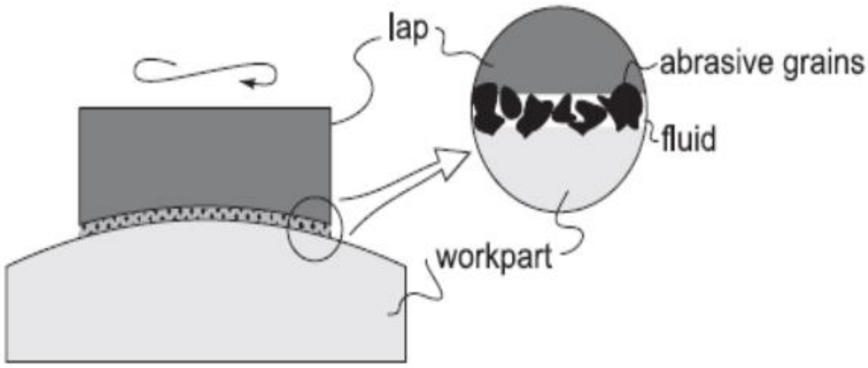
 The cutting mechanism in lapping is that the abrasives become embedded in the lap surface and the cutting action is very similar to grinding, but a concurrent cutting action of the free abrasive particles in the fluid cannot be excluded. Lapping is used to produce optical lenses, metallic bearing surfaces, gages, and other parts requiring very good finishes and extreme accuracy.

Characteristics of lapping process:

Use of loose abrasive between lap and the work piece

Usually lap and work piece are not positively driven but are guided in contact with each other

Relative motion between the lap and the work should change continuously so that path of the abrasive grains of the lap is not repeated on the work piece.



Schematics of lapping process showing the lap and the cutting action of suspended abrasive particles.

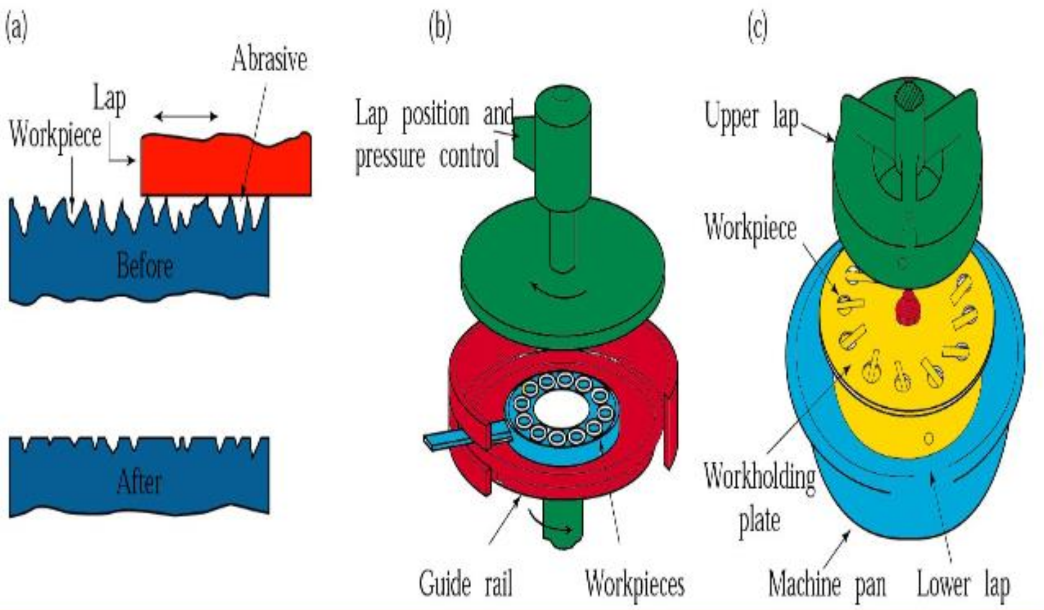


Figure (a) Schematic illustration of the lapping process. (b) Production lapping on flat surfaces.(c) Production lapping on cylindrical surfaces.

Abrasives of lapping:

- Al_2O_3 and SiC, grain size 5~100µm
- Cr_2O_3, grain size 1~2 µm
- B_4C_3, grain size 5-60 µm
- Diamond, grain size 0.5~5 V

Lubricating materials of lapping:

- Machine oil
- Rape oil
- grease

Technical parameters affecting lapping processes are:

- unit pressure
- the grain size of abrasive
- concentration of abrasive in the vehicle
- lapping speed

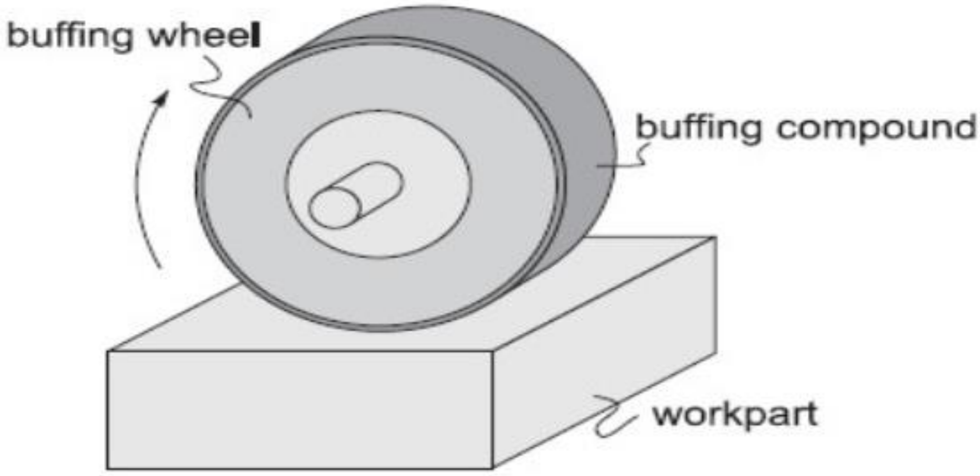
POLISHING:

 Polishing is a finishing operation to improve the surface finish by means of a polishing wheel made of fabrics or leather and rotating at high speed. The abrasive grains are glued to the outside periphery of the polishing wheel. Polishing operations are often accomplished manually.

BUFFING:

 Buffing is a finishing operation similar to polishing, in which abrasive grains are not glued to the wheel but are contained in a buffing compound that is pressed into the outside surface of the buffing wheel while it rotates. As in polishing, the abrasive particles must be periodically replenished.

 As in polishing, buffing is usually done manually although machines have been designed to perform the process automatically. Buffing wheels are made of discs of linen, cotton, broad cloth and canvas.



Schematics of the buffing operation.

HONING:

 Honing is a finishing process, in which a tool called hone carries out a combined rotary and reciprocating motion while the work piece does not perform any working motion. Most honing is done on internal cylindrical surface, such as automobile cylindrical walls.

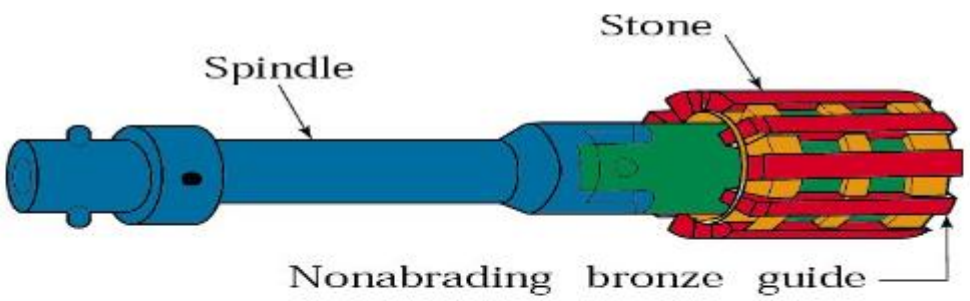
 The honing stones are held against the work piece with controlled light pressure. The honing head is not guided externally but, instead, floats in the hole, being guided by the work surface

 It is desired that

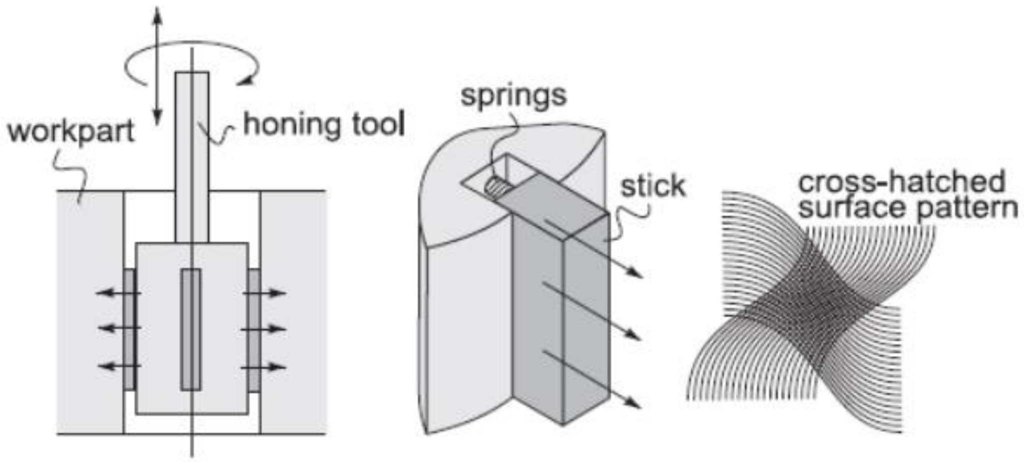
- honing stones should not leave the work surface
- stroke length must cover the entire work length.

 Honing is a finishing process performed by a honing tool, which contains a set of three to a dozen and more bonded abrasive sticks. The sticks are equally spaced about the periphery of the honing tool. They are held against the work surface with controlled light pressure, usually exercised by small springs.

 The honing tool is given a complex rotational and oscillatory axial motion, which combine to produce a crosshatched lay pattern of very low surface roughness.



Honing tool



Schematics of honing process showing the honing tool, how the abrasive sticks are pressed against the work surface by springs, and the resulting surface pattern.

 Stone:

- Al2O3 or SiC bonded abrasives

 The critical process parameters are:

- Rotation speed
- Oscillation speed
- Length and position of the stroke
- Honing stick pressure

 Parameters that affect material removal rate (MRR) and surface roughness (R) are:

- Unit pressure, p
- Peripheral honing speed, Vc
- Honing time, T

SUPER FINISHING:

 Super finishing is a micro finishing process that produces a controlled surface condition on parts which is not obtainable by any other method. The operation which is also called 'micro stoning' consist of scrubbing a stone against a surface to produce a fine quality metal finish.

 The process consists of removing chatter marks and fragmented or smear metal from the surface of dimensionally finished parts. As much as 0.03 to 0.05 mm of stock can be efficiently removed with some production applications, the process becomes most economical if the metal removal is limited to 0.005 mm

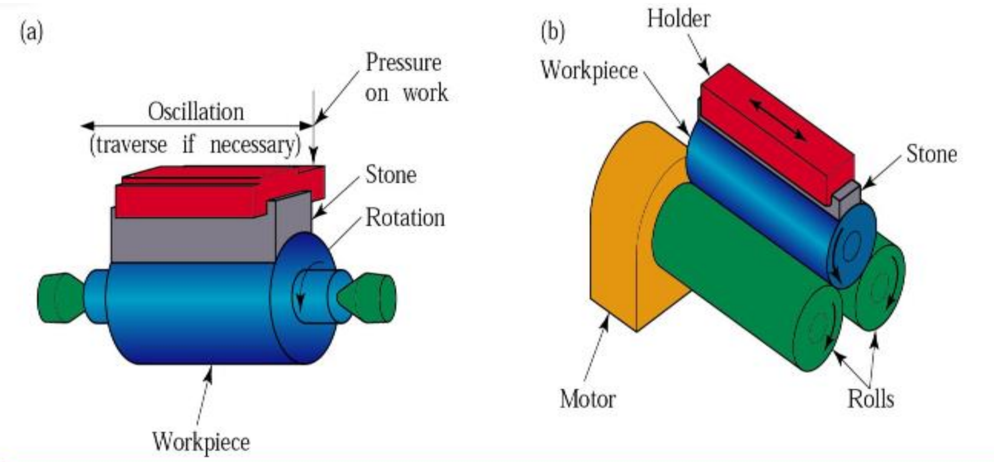


Figure Schematic illustrations of the super finishing process for a cylindrical part. (a) Cylindrical mircohoning, (b) Centerless microhoning.

BROACHING:

• Broaching is the process of removing metal with a tool which has "teeth" arranged in a row. Each tooth is successively higher than the previous tooth and removes more material. In broaching, one stroke or cycle of the machine produces a finished part.

• Broaching is used to produce both internal and external features. Production rates are high and tolerances of +/- .0005" are possible.

Broaching machine is a process of machining surface with a special multipoint cutting tool

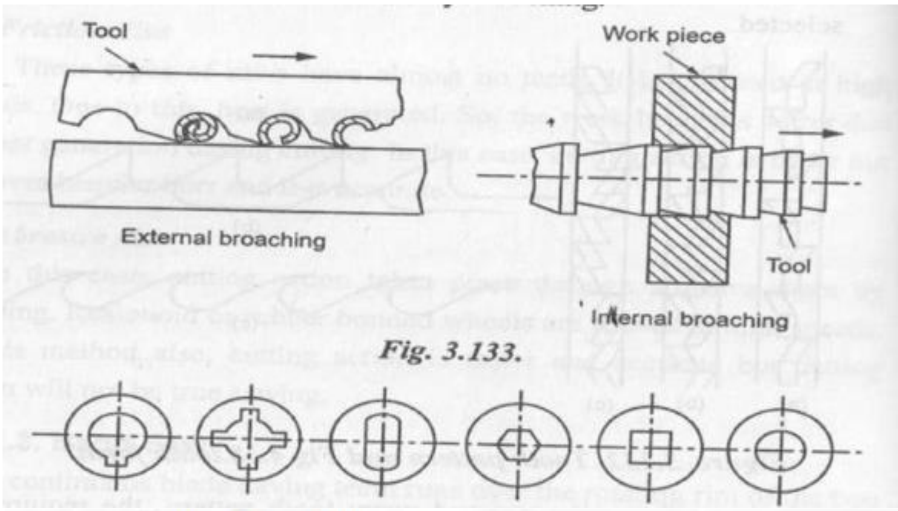
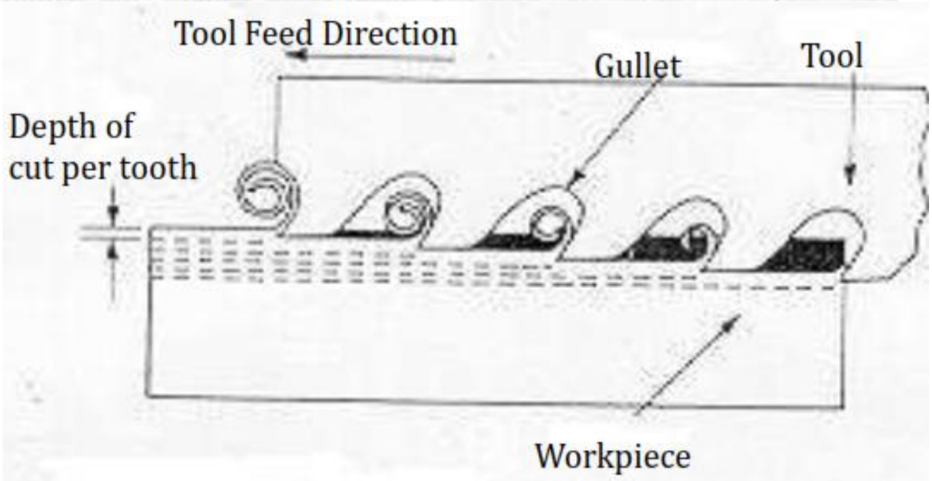


Fig. 3.133.



Specification of broaching machine:

- Max length of the stoke
- Max force developed by the slide in tonnes
- Types of drives
- Power rating of electrical motor in HP
- Speed and feed• Weight of the machine
- Floor space required

Advantages:

- Rough to finish in one pass
- Production rates are high
- Cutting time is quick
- Rapid load and unload of parts
- External and internal features
- Any form that can be produced on a broaching tool can be produced
- Production tolerances are excellent
- Surface finishes are equal to milling
- Operator skill is low

Disadvantages:

- Tooling cost can be high
- In some cases--not suited for low production rates
- Parts to be broached must be strong enough to withstand the forces of the process
- Surface to be broached must be accessible

TYPES OF BROACHING MACHINE

According to the nature and direction of primary cutting motion:

▫ Horizontal broaching machine

▫ Vertical broaching machine

▫ Continuous broaching machine

According to the purpose

▫ Internal broaching machine

▫ External surface broaching machine

According to method operation

▫ Pull broaching machine

▫ Push broaching machine

According to the construction of the broach tool

▫ Solid broaching machine

▫ Inserted tooth broaching machine

▫ Progressive cut broaching machine

▫ Built-up broaching machine

According to the function

▫ Keyway broaching machine

▫ Burnishing broaching machine

▫ Spline broaching machine

▫ Round hole broaching machine

▫ Surface broaching machine

According to the number of main slides or stations

▫ Single broaching machine

▫ Double broaching machine

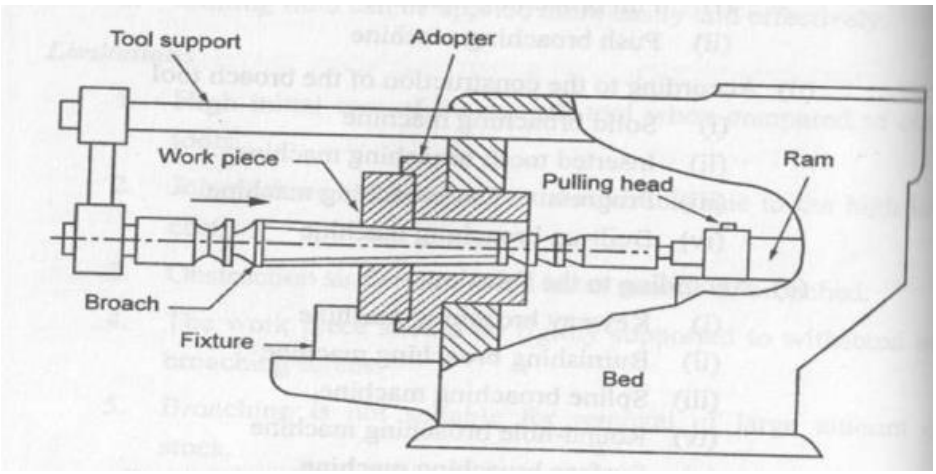
▫ Multiple slides broaching machine

According to the motion of the broach tool relative to the work

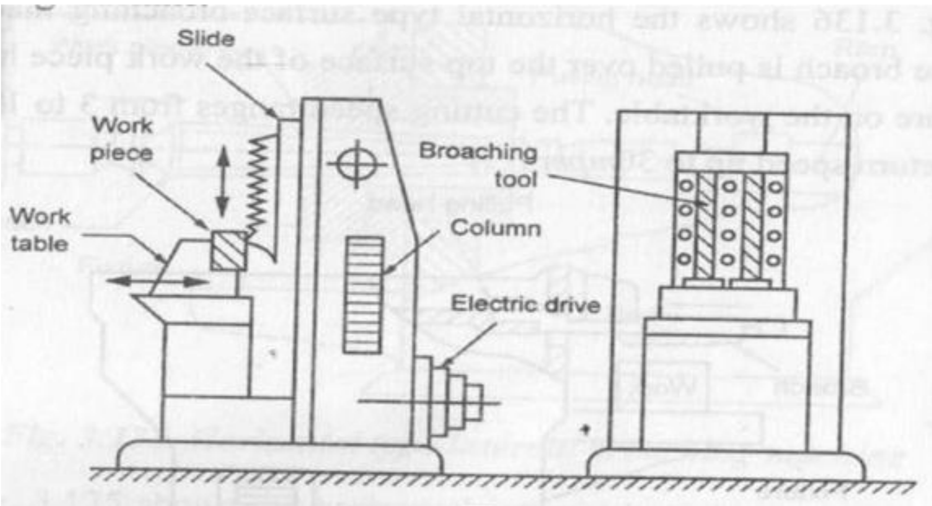
▫ Straight line motion broaching machine

▫ Stationary broach tool broaching machine

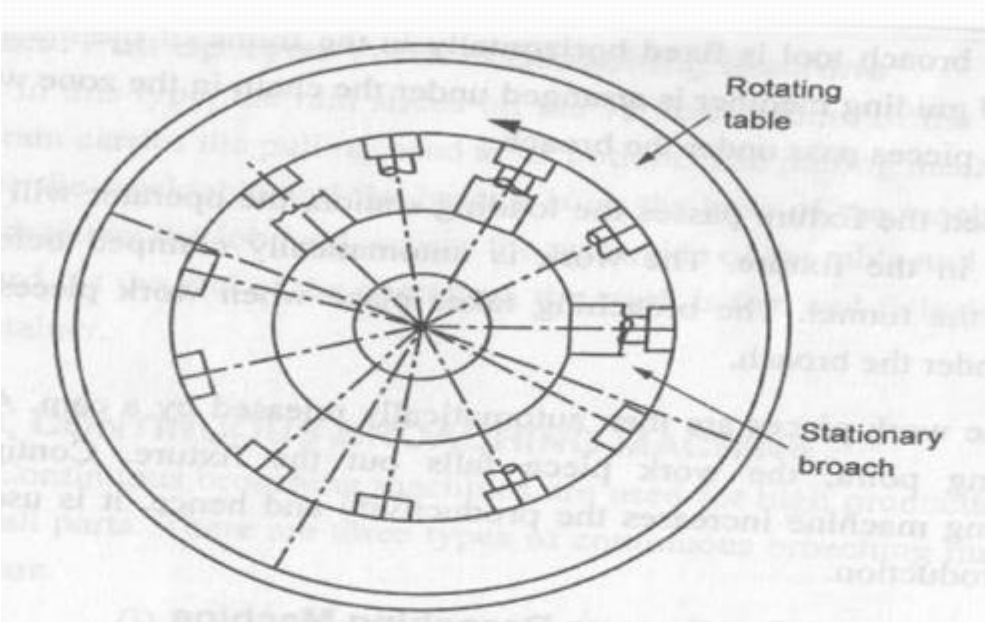
Horizontal broaching machine:



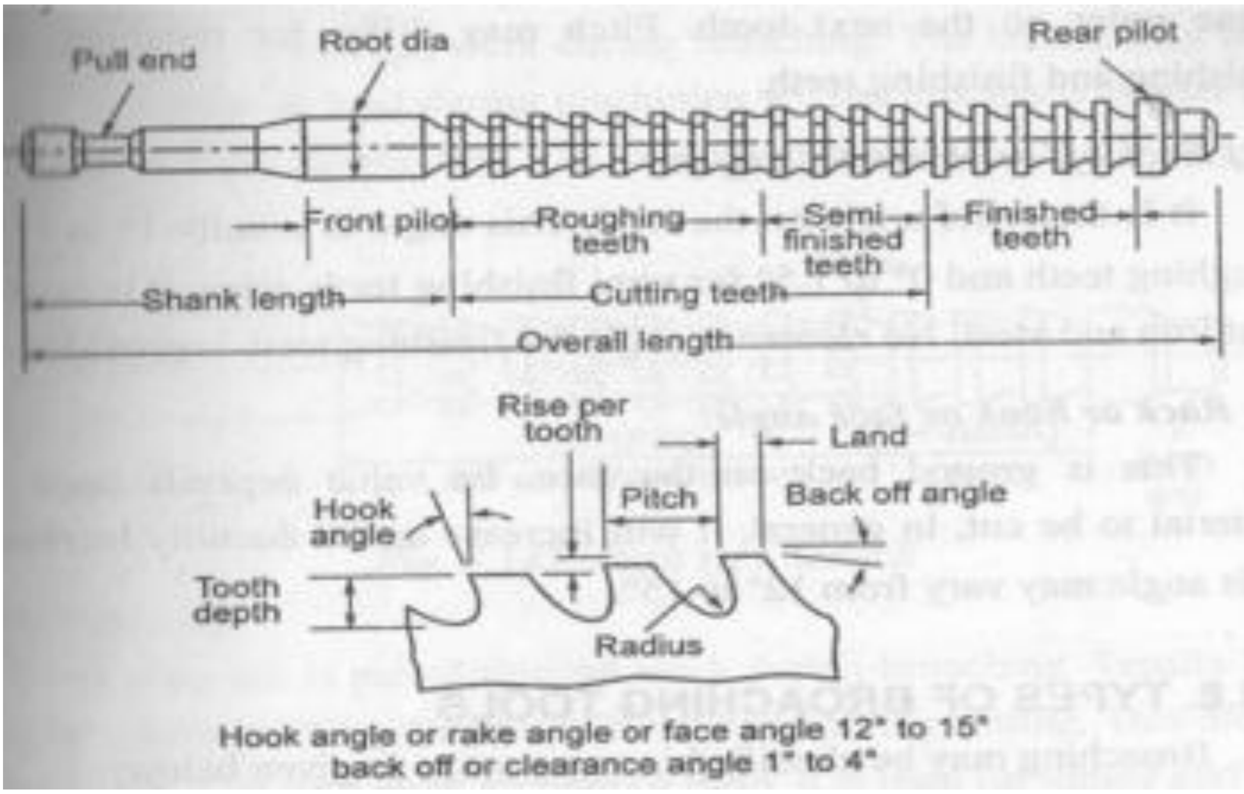
Vertical broaching machine:



Continuous broaching machine:



Nomenclature of Broaching tool:



TYPES OF BROACHING TOOL:

According to the method of operation

- Push Broach
- Pull Broach

According to the kind of operation

▫ Internal Broach

▫ External Broach

According to their construction

▫ Solid Broach

▫ Built up of replaceable section

▫ Inserted tooth Broach

▫ Overlapping teeth Broach

▫ Progressive cut Broach

GRINDING RATIO:

G = Volume of material removed / Volume of wheel wear

Vary greatly (2-200 or higher) depending on the type of wheel, grinding fluid, and process parameters

Higher forces decrease the grinding ratio

Cutting Speed and Work Speed The Cutting speed (V) is the relative speed of the wheel Vw (Peripheral speed) and the work piece. It is expressed in m per sec with sufficient approxmation, it may be considered that

Where Dw is the diameter of grinding wheel in mm, and nw is the speed of the wheel in r.p.s. The work speed Vp is expressed in m/min and is determined by the formula:

$$V_p = \frac{cd^z.p}{T_m t^x s^y} \text{m/min.}$$

Where, c is the coefficient which depends on the type of grinding and the material to be ground, T = is the wheeel life in min. betweeen dressings

d = is the work diameter in min,

t = is the depth of cut s = is the feed per work revolution in mm per revolution.

Z, Y, X and m are exponents which are determined, together with C.from hand work data. The speed in r.p.m of the work is determimed from the formula

$$n_p \frac{1000V_p}{\Pi d_p}$$

Feed:

The feed (S) in cylindrical grinding in the longitudinal movement of the workpiece per revolution, it is expressed in mm per revolution of the work piece. Longitudeinal feed's usually from 0.6 to 0.9 of the face with for finish grinding.

The longitudinal feed (Si) of the work per revolution should be less than the face width of the wheel and depends on whether rough or finish grinding is being performed. The feed is plunge-cut grinding (SP) is in a radial direction and the operation is done in one pass. In this case, the face width is equal to the length of the work to be ground.

Depth of Cut:

The depth of cut (t) is the thickness of the layer of metal removed in one pass. It is expressed in mm. The depth of cut is taken in a range from 0.005 to 0.04 mm.

Machining Time in Grinding Machining time for cylindrical grinding is determined from the formula:

Where L = is the length of longitudinal travel in mm.

i = is the number of pass,

S = is longitudinal feed in mm per revolution,

np = is the speed of the work piece in r.p.m,

k is a coefficient depending on the specified grade of accuracy and class of surface finish (for rough grinding k = 1 to 1.2 for finish grinding k = 1.3 to 1.7). For plunge-cut cylindrical grinding

where a is the grinding allowance n each side in mm. Sc is the cross feed in **mm per revolution**

UNIT-6

JIGS AND FIXTURES

INTRODUCTION:

There are different views on what jigs and fixtures are some of these are follows:

1) Broadly speaking, a jig or fixture is any device that guides drill or other tools, so as to produce work that is interchangeable with in the tolerance set by manufacturing requirements.
2) The terms jigs and fixtures are also used for devices or frames that hold pieces in their proper position while being welded or otherwise joined together.
3) A distinguishing definition for jigs and fixtures that seems to be generally holding is as follows. A jig is a work holding device, which is not fastened to the machine on which it is used. A fixture is also a work holding device, but one that is bolted or otherwise fastened to the machine. That is the jig may be moved around on the table of a drill press to bring each bushing under the drill spindle. A fixture on the other hand is fastened to the table or base of a machine, and either the tool is moved to the point of operation, as in the case of a radial drill, or table is moved under the cutting tool as in a milling machine.

Uses of Jigs and Fixtures:

The jigs and fixtures are useful in the following ways:

1) In increasing the production.
2) In ensuring high accuracy of parts
3) For providing inter-changeability
4) In reducing expenditures involved in quality control
5) In reducing the cost of production
6) In saving labour
7) In increasing the versatility of the machine tool or in a way, it widens the technological capacity of machine tools.

The jigs and fixtures should possess the following components to fulfill their basic functions.

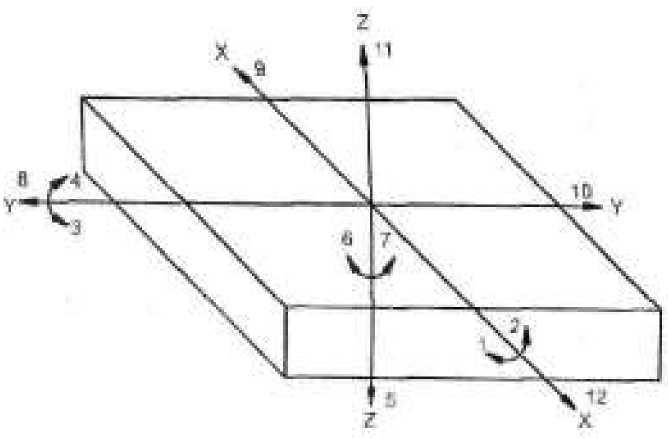
1) Locating elements.
2) Clamping elements.
3) Tool guiding elements (for jigs) or tool setting elements (for fixtures).
4) Base plate for holding together the entire assembly.

Locating elements are generally in the form of locating pins. Locating pins are pins, which are inserted in the body of jig and fixture. The work piece is pushed against this pin to establish relation between work piece and the jigs and fixture. The purpose of clamping element is to exert a force to press a work piece against the locating elements and hold it there against the action of cutting forces.

Difference Between a Jig and a Fixture:

S.No	Jig	Fixture
1	Jig holds and positions the work and locates or guides the cutting tool with respect to the work piece.	A fixture only holds and positions the work but does not guide for locate the cutting tool.
2	Usually a jig is not fixed to the machine table.	A fixture is bolted or clamped to the machine table.
3	It is usually lighter in construction.	It is usually heavy in construction.

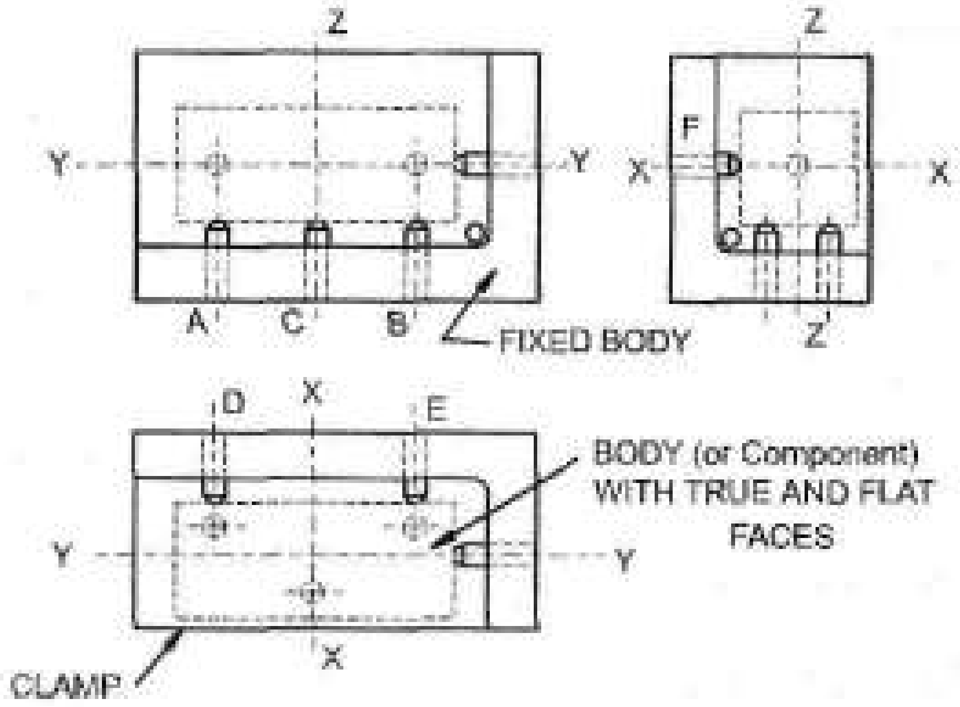
Principle of Location:



Work piece in Space

Assume a workpiece in a space as shown in Fig. 8.1. In a free state, it can move in either of the two opposite directions along XX, YY, or ZZ axes. These six movements are called 'movements of translation'. The workpiece can also rotate in either of two opposite directions around each axis. These six movements are called rotational movements. It means we have twelve degrees of freedom of a work piece in space. To confine the workpiece accurately, all these degrees of freedom must be restricted.

a) The work piece is made to rest on three pins A,B and C inserted in the base of the body as shown in Fig. 8.2. This restricts the rotational movement along XX, YY, and also downward movement i.e. 1,2,3,4,5 shown in Fig.8.1 have been arrested.



Six-point location principle

b) Insertion of two move pins D and E restricts the rotational movement about Z-axis and movement towards left, i.e. 6,7,8 have been arrested.

c) Insertion of one pin F stops the movement 9. In this way, six locating pins restrict nine degrees of freedom. Three degrees of freedom are still free and for that three pins are needed, but this will lead to a complete enclosure of the work piece making it's loading and unloading difficult, so a clamping device is used to restrict the rest three degrees of freedom. The method is called '3-2-1' or 'six-point location' principle.

Principles of Jig and Fixture Design:

The basic principles of jig and fixture design are listed below.

Locating:

1) It must be ensured that the work piece is given the desired constraint.
2) The locators must be positioned in such a way that swarf will not cause misalignment.
3) If a rough casting or forging is being machined, the location points should be made adjustable.

4) Introduce tool proofing devices, e.g. fouling pins, projections etc. to prevent incorrect positioning of the work piece.
5) Make all the location points visible to the operator from his working position.
6) Make the location progressive (i.e. locate on one locator and then to the other.

Clamping:

1) The clamps should be positioned to give best resistance to the cutting forces.
2) The clamping should be done in such a way that no deformation of the work piece in caused.
3) If possible, make the clamps integral with the fixture body.
4) Make all clamping and locating motions easy and natural to perform.

Clearance:

1) Enough clearance should be provided to allow for variation of work piece size.
2) Ample clearance should be provided for the operator's hands.
3) Ensure that there is enough sward clearance.

Stability and Rigidity:

1) Provide four feet so that uneven seating will be avoided.
2) Make the equipment as rigid as is necessary for the operation.
3) Provide means of positioning and bolting the equipment to the machine table or spindle, if required.

Handling:

Make the equipment light and easy to handle. It must be ensured that no sharp corners are present. If it is heavy, provide lifting points.

General:

1) Keep the design simple to minimize cost.
2) Use standard parts as much as possible.
3) Method of location and clamping should be such that idle time is minimum.
4) Design for safety.

General Fixture Design Considerations:

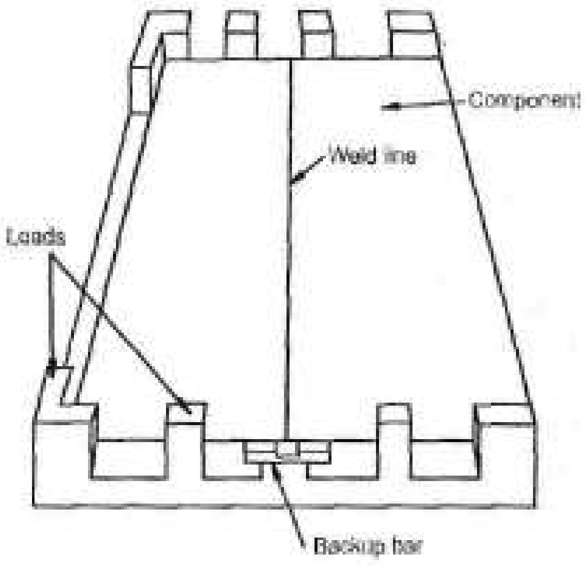
Simple fixtures may have the part located visually with scribed lines as a guide. This is quite similar to locating parts for gas welding. For higher production a quicker locating method is needed. A locating land may be used in the fixture to locate the edge position of the part to be welded (Fig. 8.3). dowel pins, V-blocks can also be used as locators.

Materials for Jigs and Fixtures:

The material of a component of jig or fixture depends upon the use and stresses ii undergoes while in duty.

The essential components of jigs and fixtures and its material are as follows:

1) Locating devices: Like locating pins, locating vee, rest buttons have hardened surfaces.
2) Clamping devices are made of high carbon steel to with stand the clamping loads.
3) Tool guiding devices like drill bushes, liner bushes are generally made from hardened, silver steel, cast steel, case hardened mild steel.
4) Body is fabricated from cast iron or mild steel.



Locating lands

Jigs and Fixture Types:

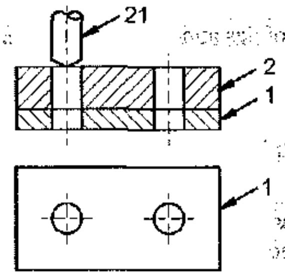
The quality, type and complexity of jigs and fixtures used depend solely on the type of work to be machined and the scale of production required. A few simple type drill jigs are described below.

1) Template jig

2) Plate jig
3) Channel jig
4) Diameter jig
5) Leaf jig
6) Ring jig
7) Box jig

Template Jig:

The template jig is the simplest of all types. A plate 2 having holes at the desired positions serves as template, which is fixed on the component 1 to be drilled. The drill 21 is guided through these holes of the template 2 and the required holes are drilled on the work piece at the relative position with each other as on the template. A template jig is illustrated in Fig

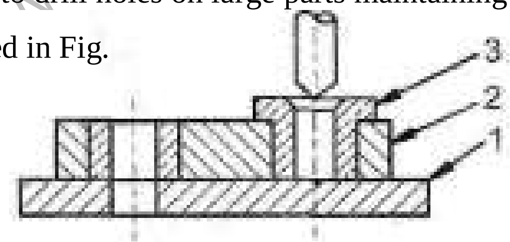


1. Work, 2. Template, 21. Drill

Fig.14.4. Template jig

Plate Jig:

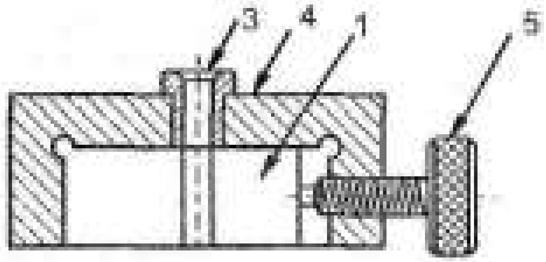
A plate jig is an improvement of the tem- plate jig by incorporating drill bushes on the template. The plate jigs are employed to drill holes on large parts maintaining accurate spacing with each other. A plate jig is illustrated in Fig.



1. Work, 2. Template, 3. Drill Bush.

Channel Jig:

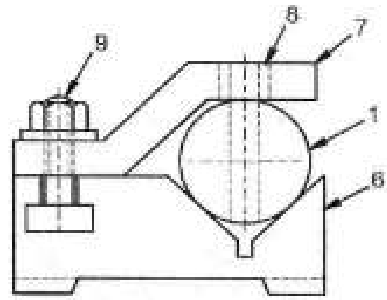
The channel jig illustrated in Fig.8.6 is a simple type of jig having channel 1 is fit- ted with in the channel 4 and is located and clamped by rotating the knurled knob5. The tool is guided through the drill bush 3.



1. Work, 3. Drill Bush, 4. Channel,
5. Knurled knob

Diameter Jig:

The diameter jig is illustrated in Fig.8.7 is used to drill radial holes on a cylindrical or spherical work pieces. The work 1 is placed on the fixed V-block 6 and then clamped by the clamping plate 7, which also locates the work. The tool is guided through the drill bush 8, which is said radially with the work.

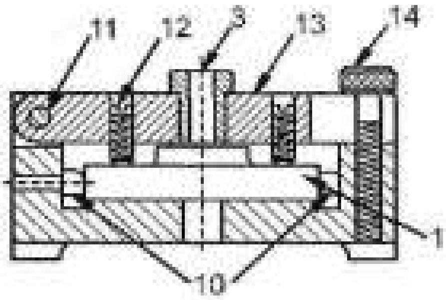


1. Work, 6. V-block, 7. Clamping plate,
8. Drill bush, 9. Clamping bolt.

Fig.14.7. Diameter jig

Leaf Jig:

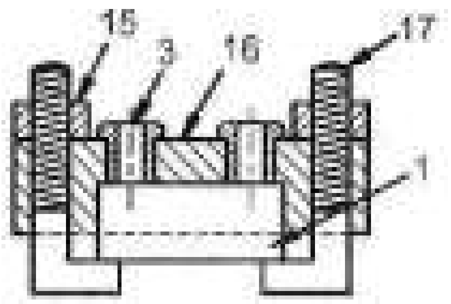
The leaf jig illustrated in Fig.8.8 has a leaf or a plate 13 hinged on the body at 11 and leaf may be swung open or closed on the work for loading or unloading proposes. The work 1 is located by the button 10 and is clamped by set screws 12. The drill bush 3 guides the tool.



1. Work, 3. Drill Bush, 10. Buttons,
11. Hinge pin, 12. Set screw, 13. Leaf
14. Leaf clamping screw.

Ring Jig:

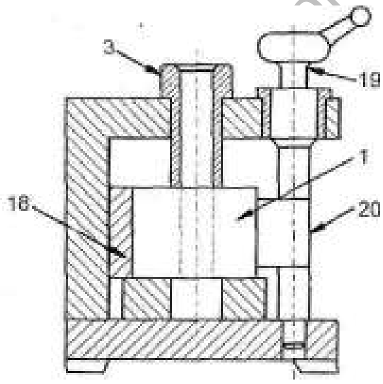
The ring jigs illustrated in Fig. is employer to drill holes on circular flanged parts. The work is securely clamped on the drill body and the holes are drilled by the tool through drill bushes.



1. Work, 3. Drill Bush, 15. Nut, 16. Jig plate, 17. Clamping bolt.

Box Jig:

The box jig illustrated in Fig. is of box like construction with in which the components is located the buttons 18. The work 1 is clamped by rotating the cam handle, which also locates it. The drill bush 3 guides the tool. The jigs are generally employed to drill a number of holes on a component from different angles.



CNC MACHINE TOOLS

HISTORY:

1955 - John Parsons and US Air Force define a need to develop a machine tool capable of machining complex and close tolerance aircraft parts with the same quality time after time (repeatability). MIT is the subcontractor and builds the machine for the project.

1959- MIT announces Automatic Programmed Tools (APT) programming language. 1960 - Direct Numerical Control (DNC). This eliminates paper tape punch programs and allows programmers to send files directly to machine tools. 1968 - Kearney & Trecker machine tool builders market first machining center. 1970's - CNC machine tools & Distributed Numerical Control. 1980's - Graphics based CAM systems introduced. Unix and PC based systems available. 1990's - Price drop in CNC technology. 1997 - PC- Windows/NT based "Open Modular Architecture Control (OMAC)" systems introduced to replace "firmware" controllers.

CONTROL SYSTEMS:

l Open-Loop Control

- Stepper motor system
- Current pulses sent from control unit to motor
- Each pulse results in a finite amount of revolution of the motor

Open-Loop Limitations

- Control unit "assumes" desired position is achieved
- No positioning compensation
- Typically, a lower torque motor

Open-Loop Advantages

- Less complex, Less costly, and lower maintenance costs

2. Closed-Loop Control

- **Variable DC motors - Servos**
- **Positioning sensors -Resolvers**

- Feedback to control unit
- Position information compared to target location
- Location errors corrected

Closed-Loop Advantages

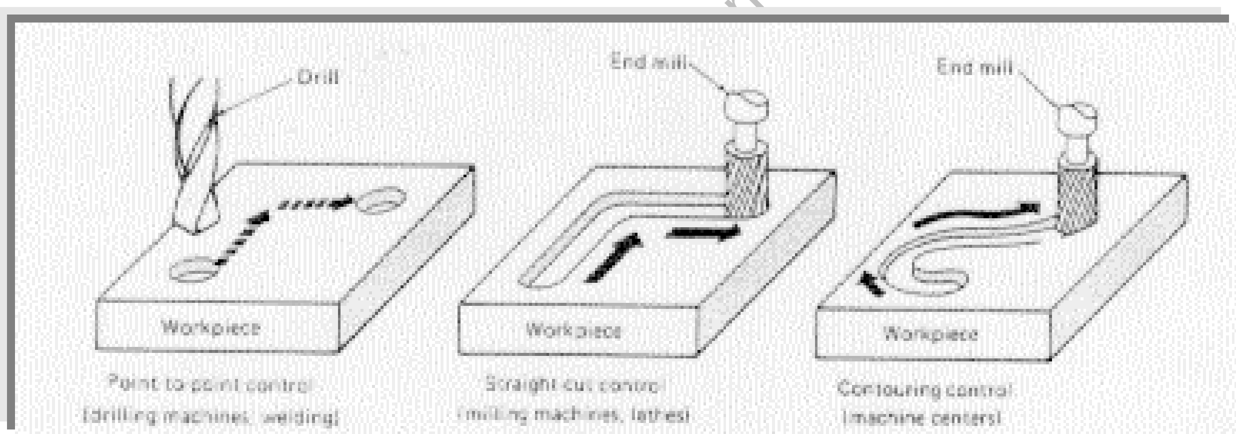
- DC motors have the ability to reverse instantly to adjust for position error
- Error compensation allows for greater positional accuracy (.0001”)
- DC motors have higher torque ranges vs.. stepper motors

Closed-loop limitations

- Cost

THREE BASIC CATEGORIES OF MOTION SYSTEMS:

- Point to Point - No contouring capability
- Straight cut control - one axis motion at a time is controlled for machining
- Contouring - multiple axis’s controlled simultaneously



Based on the motion type ' Point-to-point & Contouring systems:

There are two main types of machine tools and the control systems required for use with them differ because of the basic differences in the functions of the machines to be controlled. They are known as point-to-point and contouring controls.

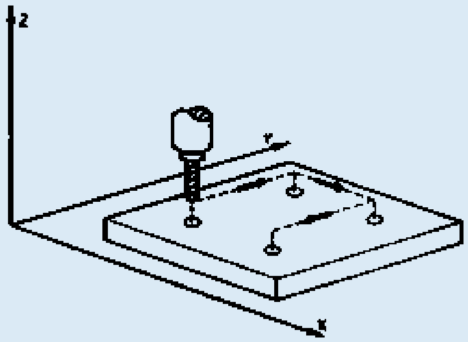
Point-to-point systems:

Some machine tools for example drilling, boring and tapping machines etc, require the cutter and the work piece to be placed at a certain fixed relative positions at which they must remain while the cutter does its work. These machines are known as point-to-point machines as shown in figure 22.1 (a) and the control equipment for use with them are known as point-to-point control equipment. Feed rates need not to be programmed. In theses machine tools, each axis is driven separately. In a point-to-point control system, the dimensional information that must be given to the machine tool will be a series of required position of the two slides. Servo systems can be used to move the slides and no attempt is made to move the slide until the cutter has been retracted back.

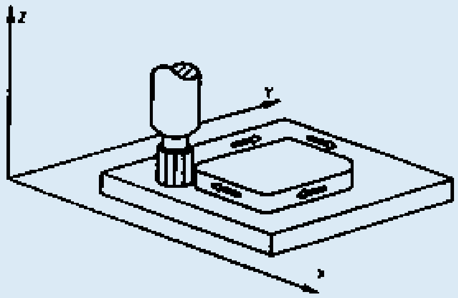
Contouring systems (Continuous path systems):

Other type of machine tools involves motion of work piece with respect to the cutter while cutting operation is taking place. These machine tools include milling, routing machines etc. and are known as contouring machines as shown in figure 22.1 (b) and the controls required for their control are known as contouring control.

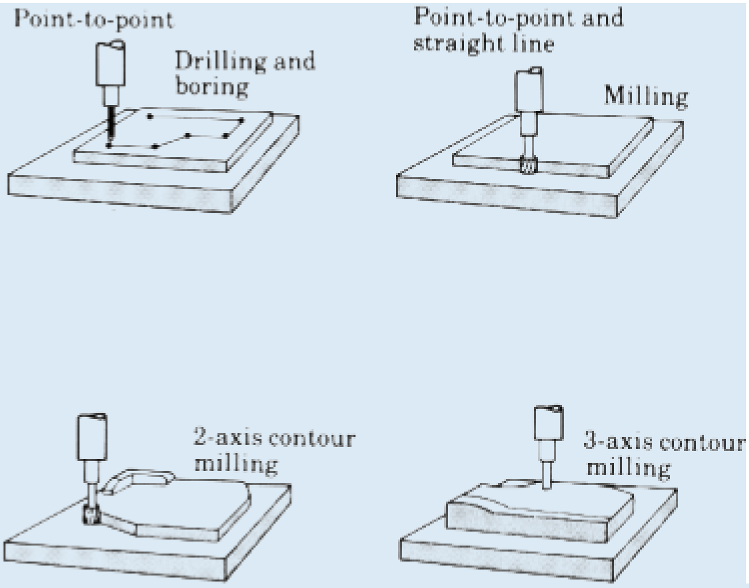
Contouring machines can also be used as point-to-point machines, but it will be uneconomical to use them unless the work piece also requires having a contouring operation to be performed on it. These machines require simultaneous control of axes. In contouring machines, relative positions of the work piece and the tool should be continuously controlled. The control system must be able to accept information regarding velocities and positions of the machines slides. Feed rates should be programmed.



(a) Point-to-point system

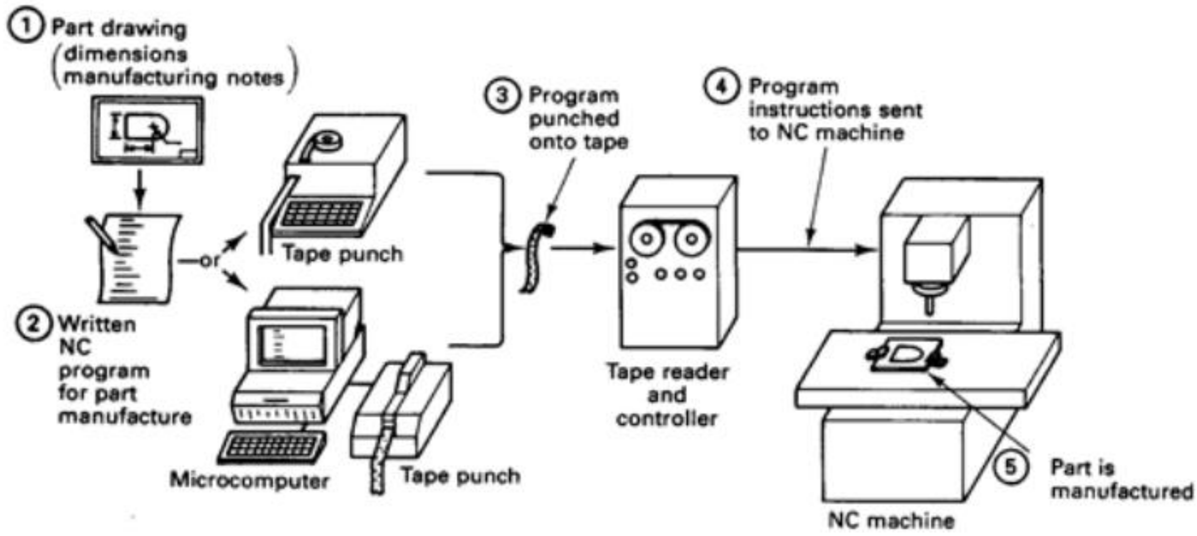


(b) Contouring system

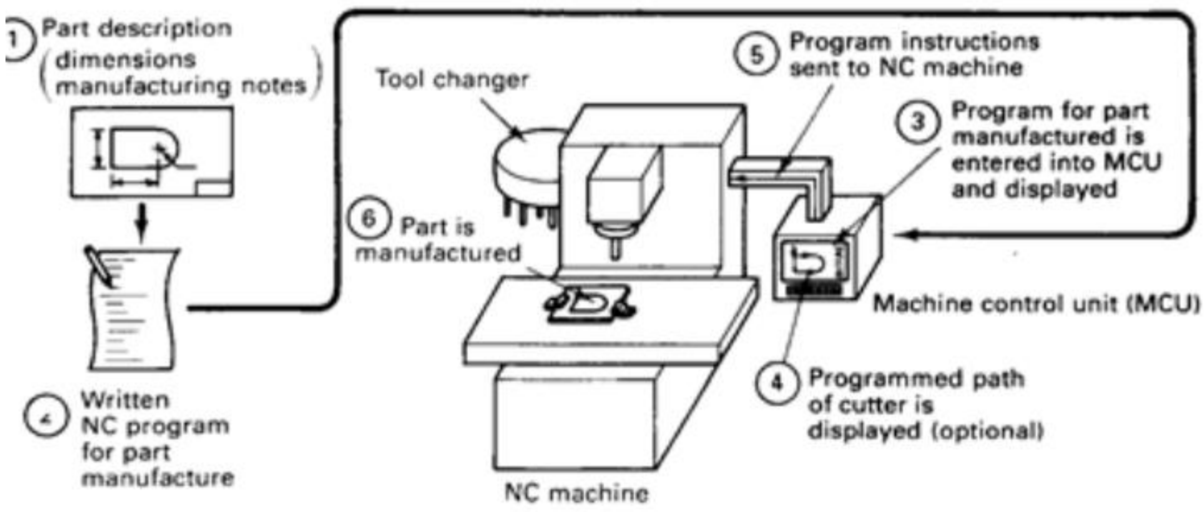


(c) Contouring systems

Components of traditional NC systems



Components of modern CNC systems



Different components related to CNC machine tools

Any CNC machine tool essentially consists of the following parts:

Part program:

A part program is a series of coded instructions required to produce a part. It controls the movement of the machine tool and on/off control of auxiliary functions such as spindle rotation and coolant. The coded instructions are composed of letters, numbers and symbols.

Program input device:

The program input device is the means for part program to be entered into the CNC control. Three commonly used program input devices are punch tape reader, magnetic tape reader, and computer via RS-232-C communication.

Machine Control Unit:

The machine control unit (MCU) is the heart of a CNC system. It is used to perform the following functions:

To read the coded instructions.

To decode the coded instructions.

To implement interpolations (linear, circular, and helical) to generate axis motion commands.

To feed the axis motion commands to the amplifier circuits for driving the axis mechanisms.

To receive the feedback signals of position and speed for each drive axis.

To implement auxiliary control functions such as coolant or spindle on/off and tool change.

Drive System:

A drive system consists of amplifier circuits, drive motors, and ball lead-screws. The MCU feeds the control signals (position and speed) of each axis to the amplifier circuits. The control signals are augmented to actuate drive motors which in turn rotate the ball lead-screws to position the machine table.

Machine Tool:

CNC controls are used to control various types of machine tools. Regardless of which type of machine tool is controlled, it always has a slide table and a spindle to control of position and speed. The machine table is controlled in the X and Y axes, while the spindle runs along the Z axis.

Feed Back System:

The feedback system is also referred to as the measuring system. It uses position and speed transducers to continuously monitor the position at which the cutting tool is located at any particular instant. The MCU uses the difference between reference signals and feedback signals to generate the control signals for correcting position and speed errors.

CNC SYSTEMS - ELECTRICAL COMPONENTS

(1) Power units

In machine tools, power is generally required for

For driving the main spindle

For driving the saddles and carriages.

For providing power for some ancillary units.

The motors used for CNC system are of two kinds

Electrical - AC , DC or Stepper motors

Fluid - Hydraulic or Pneumatic

Electric motors are by far the most common component to supply mechanical input to a linear motion system. Stepper motors and servo motors are the popular choices in linear motion machinery due to their accuracy and controllability. They exhibit favourable torque-speed characteristics and are relatively inexpensive.

CNC SYSTEMS - MECHANICAL COMPONENTS

The drive units of the carriages in NC machine tools are generally the screw & the nut mechanism. There are different types of screws and nuts used on NC machine tools which provide low wear, higher efficiency, low friction and better reliability.

(1) Recirculating ball screw

The recirculating ball screw assembly shown in figure 25.1 has the flanged nut attached to the moving chamber and the screw to the fixed casting. Thus the moving member will move during rotational movement of the screw. These recirculating ball screw designs can have ball gages of internal or external return, but all of them are based upon the "Ogival" or "Gothic arc".

In these types of screws, balls rotate between the screw and nut and convert the sliding friction (as in conventional nut & screw) to the rolling friction. As a consequence wear will be reduced and reliability of the system will be increased. The traditional ACME thread used in conventional machine tool has efficiency ranging from 20% to 30% whereas the efficiency of ball screws may reach up to 90%.

There are two types of ball screws. In the first type, balls are returned through an external tube after few threads. In another type, the balls are returned to the start through a channel inside the nut after only one thread. To make the carriage movement bidirectional, backlash between the screw and nut should be minimum. One of the methods to achieve zero backlash is by fitting two nuts. The nuts are preloaded by an amount which exceeds the maximum operating load. These nuts are either forced apart or squeezed together, so that the balls in one of the nuts contact the opposite side of the threads.

These ball screws have the problem that minimum diameter of the ball (60 to 70% of the lead screw) must be used, limiting the rate of movement of the screw.

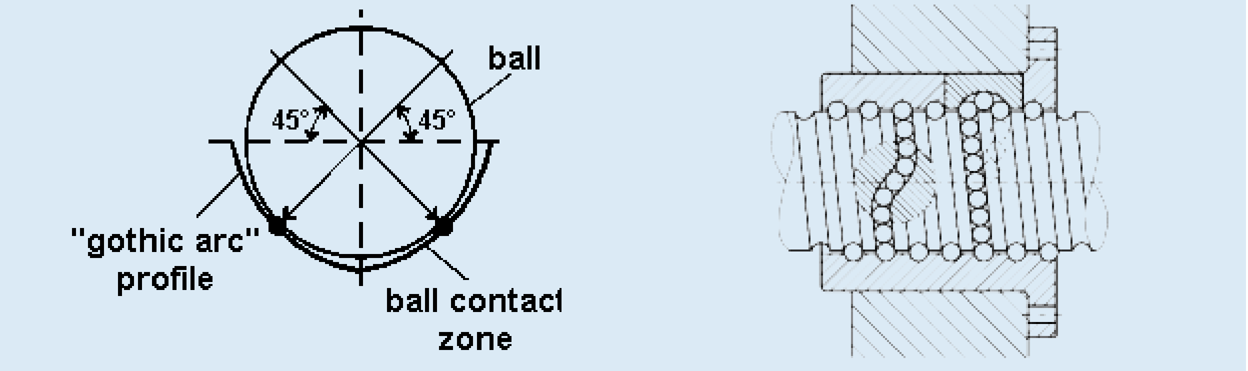


Figure 25.1: Recirculating ball screw assembly

Figure 25.2: Preloaded recirculating ball screw

CNC VS. NC MACHINE TOOLS:

Computer Numerical Control (CNC) - A numerical control system in which the data handling, control sequences, and response to input is determined by an on-board computer system at the machine tool.

Advantages CNC

- Increased Program storage capability at the machine tool
- Program editing at the machine tool
- Control systems upgrades possible
- Option -resident CAM system at machine tool
- Tool path verification

NC

Numerical Control (NC) - A control system which primarily processes numeric input. Limited programming capability at the machine tool. Limited logic beyond direct input. These types of systems are referred to as "hardwire controls" and were popular from the 1950's to 1970's.

MACHINING CENTERS:

l A machining center can be defined as a machine tool capable of:

– Multiple operation and processes in a single set-up utilizing multiple axis

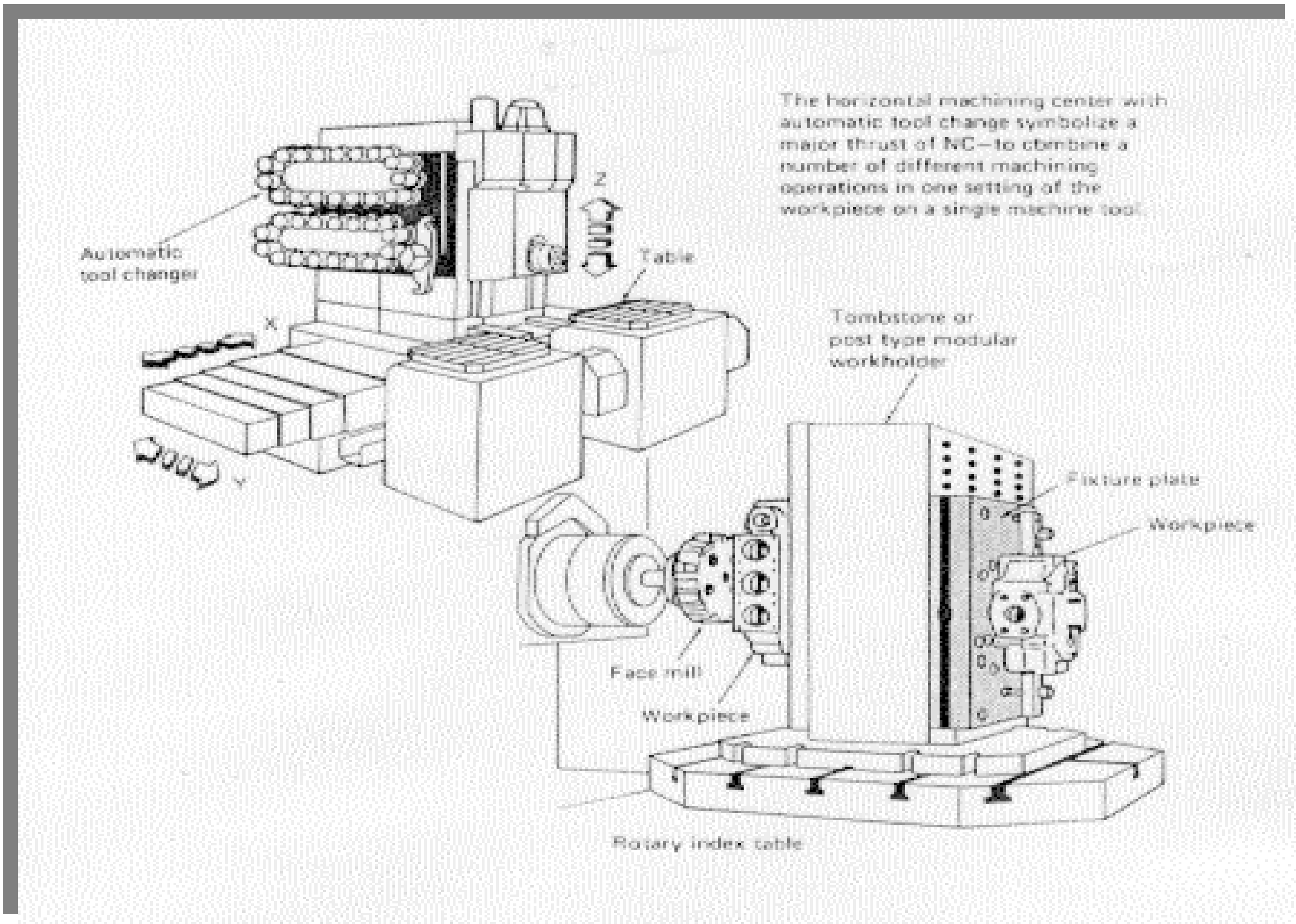
– Typically has an automatic mechanism to change tools

– Machine motion is programmable

– Servo motors drive feed mechanisms for tool axis's

– Positioning feedback is provided by resolvers to the control system

Example - A turning center capable of OD turning, external treading, cross-hole drilling, engraving, and milling. All in machining is accomplished in one "set-up." Machine may have multiple spindles.



PROGRAMMING METHODS:

Automatically Programmed Tools (APT)

- A text-based system in which a programmer defines a series of lines, arcs, and points which define the overall part geometry locations. These features are then used to generate a cutter location (CL) file.
- Developed as a joint effort between the aerospace industry, MIT, and the US Airforce
- Still used today and accounts for about 5 -10% of all programming in the defense and aerospace industries
- Requires excellent 3D visualization skills
- Capable of generating machine code for complicated part programs

5 axis machine tools

Part definition

- P1=Point/12,20,0
- C1=Circle/Center,P1,Radius,3
- LN1=Line/C1. ATANGL,90

Cutter Commands

- TLRT,GORT/LN1.TANTO,C1
- GOFWD/C1,TANTO,L5

PROGRAMMING METHODS-CAM:

Computer Aided Machining (CAM) Systems

- Graphic representation of the part
- PC based
- Integrated CAD/CAM functionality
- "Some" built-in expertise
- Speed & feed data based on material and tool specifications

- Tool & material libraries
- Tool path simulation
- Tool path editing
- Tool path optimization
- Cut time calculations for cost estimating
- Import / export capabilities to other systems
  - » Examples:
    - l Drawing Exchange Format (DXF)
    - l Initial Graphics Exchange Standard (IGES)

The Process CAD to NC File:

Start with graphic representation of part

- Direct input
- Import from external system
  - » Example DXF / IGES
- 2D or 3D scan
  - » Model or Blueprint

(At this point you have a graphics file of your geometry)

Define cutter path by selecting geometry

- Contours
- Pockets
- Hole patterns
- Surfaces
- Volume to be removed

(At this point the system knows what you want to cut)

Define cut parameters

- Tool information
  - » Type, Rpm, Feed
- Cut method
  - » Example - Pocket mill zig-zag, spiral, inside-out
  - » Rough and finish parameters

(At this point the system knows how you want to cut the part)

Execute cutter simulation

- Visual representation of cutter motion

Modify / delete cutter sequences

(At this point the system has a "generic" cutter location (CL) file of the cut paths)

Post Processing

- CL file to machine specific NC code

Filters CL information and formats it into NC code based on machine specific parameters

- Work envelope
- Limits - feed rates, tool changer, rpm's, etc.
- G & M function capabilities

Output: NC Code:

Numerical Control (NC) Language

- A series of commands which "direct" the cutter motion and support systems of the machine tool.
- G-Codes (G00, G1, G02, G81)
- Coordinate data (X,Y,Z)
- Feed Function (F)
- Miscellaneous functions (M13)
- N - Program sequence number

- T - Tool call
- S - Spindle command

NC Program Example

- N01G90 G80
- N03 GOO T12 M06
- N05 GOO X0 Y0 Z.1 F10 S2500 M13
- N07 G1Z-.5
- N09 G02 X-10. I0J0F20
- N13 X0Y10
- N17 X10Y0
- N19 X0Y-10
- N21 X-10Y0
- N23 M2

Advantages of CNC Machine Tools:

- Ease of part duplication
- Flexibility
- Repeatability
- Quality control through process control
- Accommodates simple to complex parts geometry
- Improved part aesthetics
- Increased productivity
- Technology costs are decreasing
- Reduced set-up time
- Reduced lead times
- Reduced inventory
- Better machine utilization
- Job advancement opportunities
- CNC machine tools are more rigid than conventional machine tools

- $$$- Climb milling requires about 10 - 15 % less horsepower vs. conventional cutting, but requires a ridged machine tool with no backlash
- Increased Rpm's and feeds

APPLICATION OF CNC MACHINE TOOLS:

The machines controlled by CNC can be classified into the following categories:

CNC mills and machining centers,

CNC lathes and turning centers

CNC electrical discharge machining (EDM)

CNC grinding machines

CNC cutting machines (laser, plasma, electron, or flame)

CNC fabrication machines (sheet metal punch press, bending machine, or press brake)

CNC welding machines