MACHINE TOOLS ENGINEERING

Course Code: MET 385

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COURSE OUTCOMES

1. Describe basic concepts involved in metal cutting
2. Differentiate between machine tools, their components, operations carried out and their unique metal removing mechanisms
3. Describe how to specify machine tools and cutting tools
4. Calculate the time required for machining
5. Clarify advantages of CNC over manual machine tools
6. Clarify how non-conventional machining techniques are advantageous to finish jobs with intricate profiles and closer tolerances.

Syllabus

Definition of machining−brief history of machining−role of machining in society.

Introduction to metal cutting: Elements of cutting process−orthogonal cutting− mechanism of chip formation−machining variables –

types of chips−chip breaker− geometry of single point cutting tool− tool nomenclature- speed, feed, depth of cut

cutting fluids- effect of machining variables on surface roughness- Cutting tool materials−types−application. Machinability−tool life and wear.

Introduction

- Manufacturing processes can be broadly classified as follows:

(a) Shaping or **forming** Manufacturing a solid product of definite size and shape from a given material taken in three possible states:

- ❑ in solid state – e.g., forging rolling, extrusion, drawing etc.
- ❑ in liquid or semi-liquid state – e.g., casting, injection moulding etc.
- ❑ in powder form – e.g., powder metallurgical process.

(b) Joining process: Welding, brazing, soldering etc.

(c) Removal process: Machining (Traditional or Non-traditional), Grinding etc.

Introduction

- Machine is defined as an assembly of mechanisms that are clustered to perform certain operations by utilizing electrical, mechanical, hydraulic, and/or pneumatic power.

METAL CUTTING

- Metal cutting/Machining – process of removing unwanted material from a block by the use of a tool, in the form of chips.

Objective:

- To form objects of desired shape, size and surface finish
- fulfill its basic functional requirements
- provide better or improved performance
- render long service life

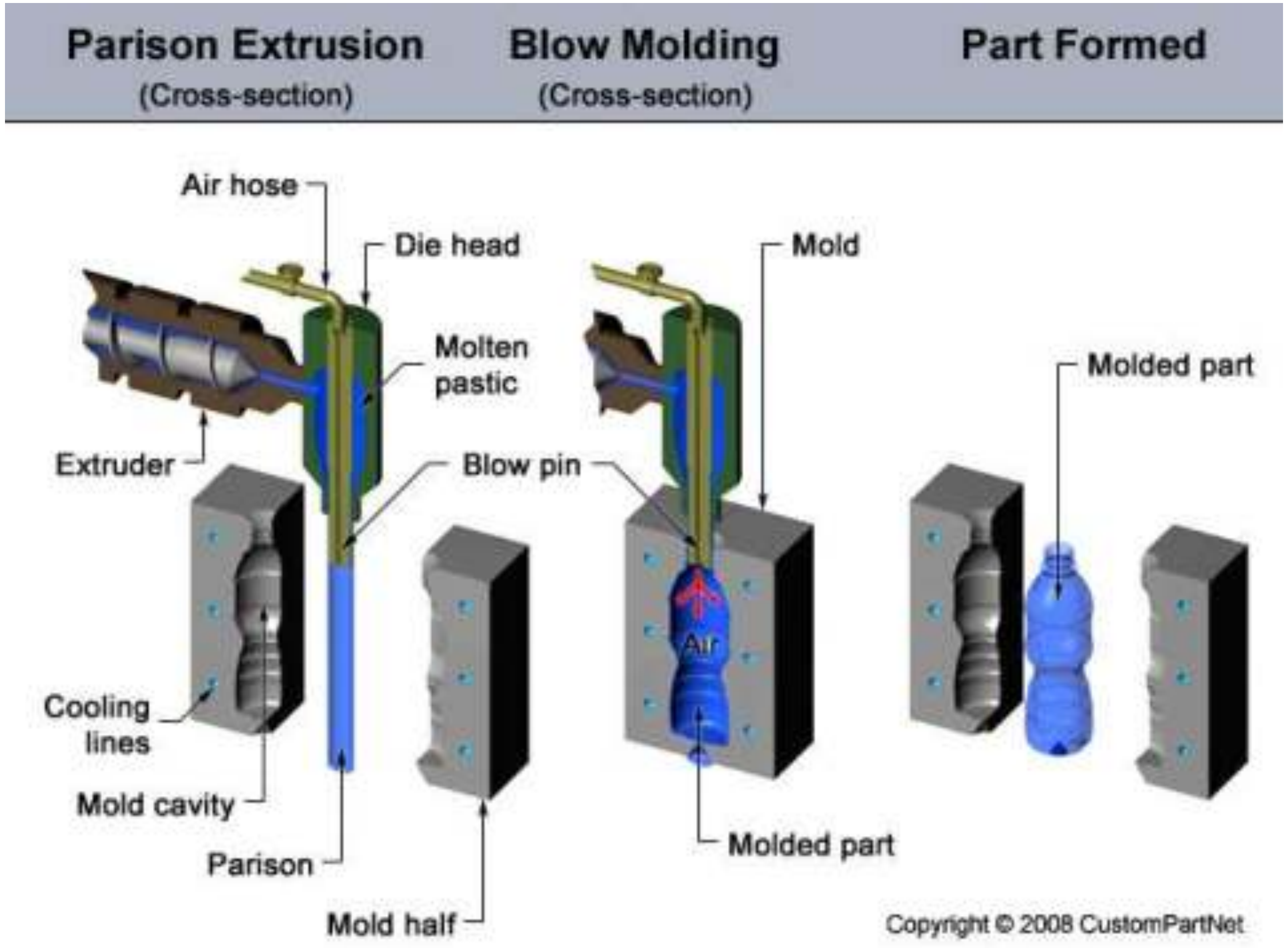
Why Machine Tools not Machines?

- It must be power driven (human operated machines are not machine tools).
- It must be non-portable (portability irrespective of size).
- It must have sufficient value (value in terms of capability and performance, not on the basis of cost).
- It can perform more than one type of machining or metal cutting operations.
- It utilizes a cutting tool to shear off excess materials from workpiece.

- [Bio Medical]

- Automotive

- Consumable Goods



- [Aerospace]

The essential basic requirements for machining work are schematically illustrated in Fig.

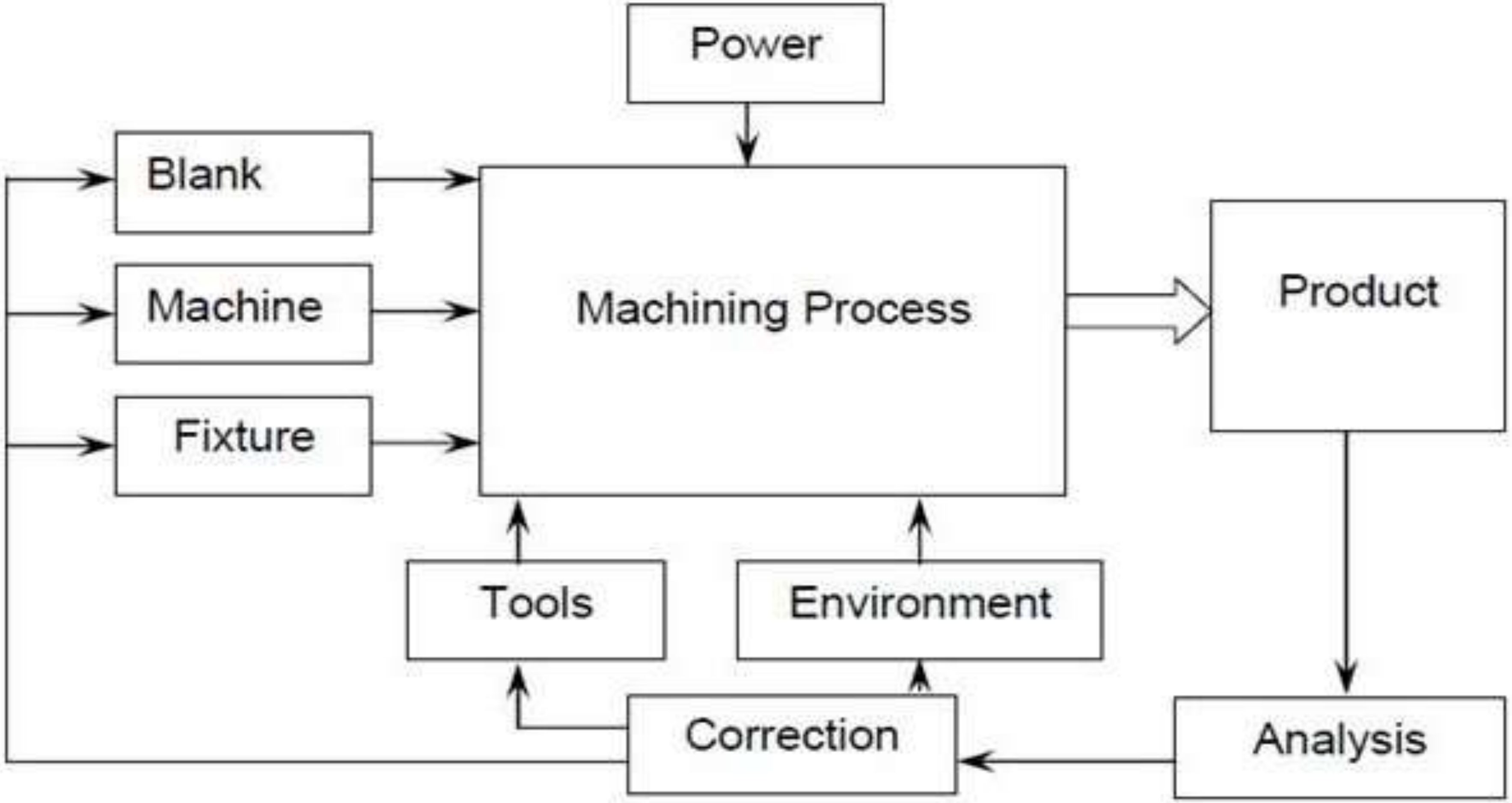


Fig. *Requirements for machining*

Elements of Cutting Process

Cutting process involves:

- Work-piece (material)
- Tool
- Chips
- Cutting Conditions

CUTTING TOOLS

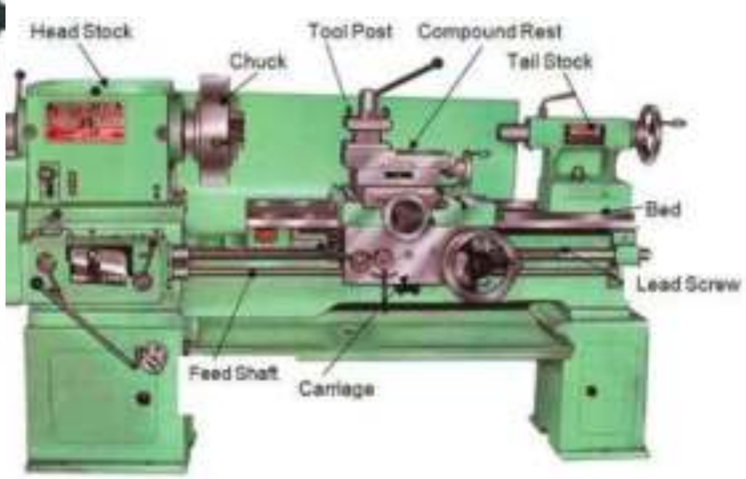
- Cutting tools may be classified according to the number of major cutting edges (points) involved as follows:

- **Single point:** e.g., turning tools, shaping, planning and slotting tools and boring tools
- **Double (two) point:** e.g., drills
- **Multipoint (more thantwo):** e.g., milling cutters, broaching tools, hobs, gear shaping cutters etc.

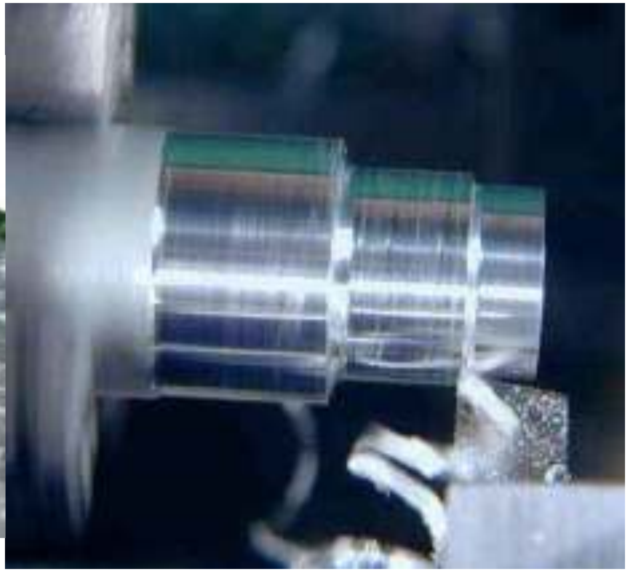
Machining Operations

- Milling

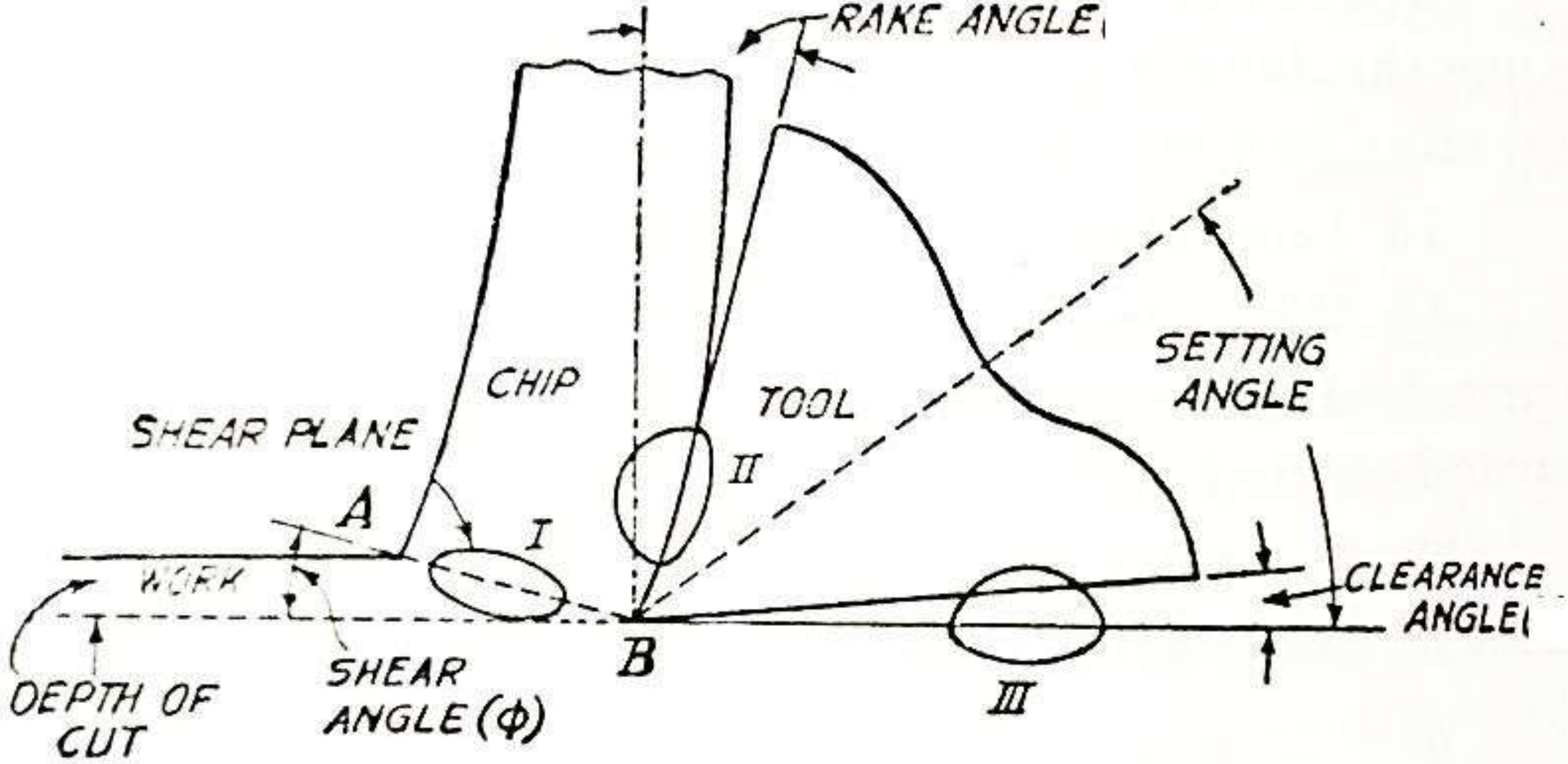
- Grinding



- Drilling



- Turning


RAKE ANGLE
CHIP
TOOL
SHEAR PLANE
SETTING ANGLE
A
I
II
WORK
CLEARANCE ANGLE
B
III
SHEAR ANGLE (Φ)
DEPTH OF CUT

Types of metal cutting

1. Orthogonal cutting/two dimensional cutting (Fig a)

- Cutting edge of the tool is at right angles (90 degrees) to the direction of relative motion b/w tool and the work piece.

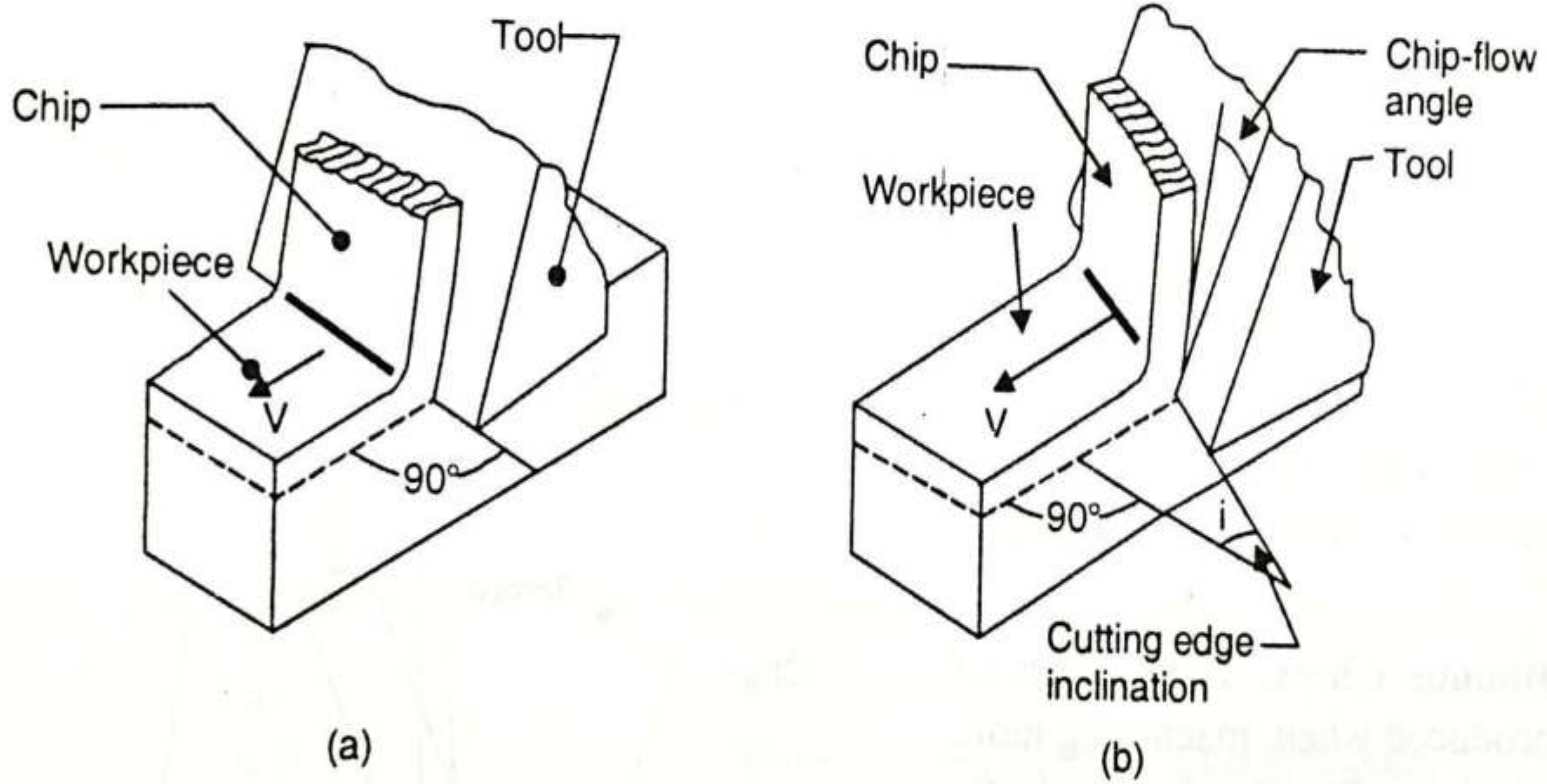
E.g.: turning at the open end of a tube, planning a rib with a tool wider than the rib.

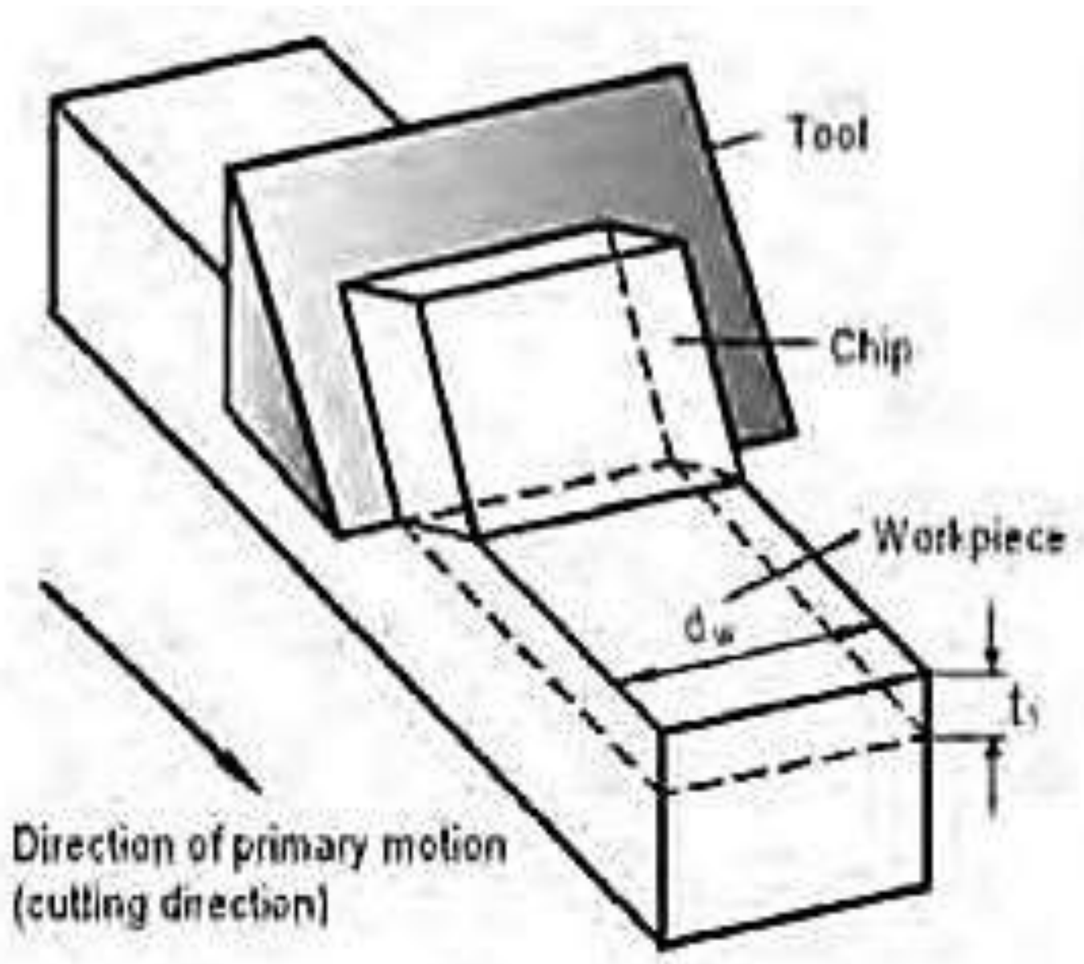
- Simple process (used as the basis for metal cutting study)

2. Oblique cutting/three dimensional cutting (Fig b)

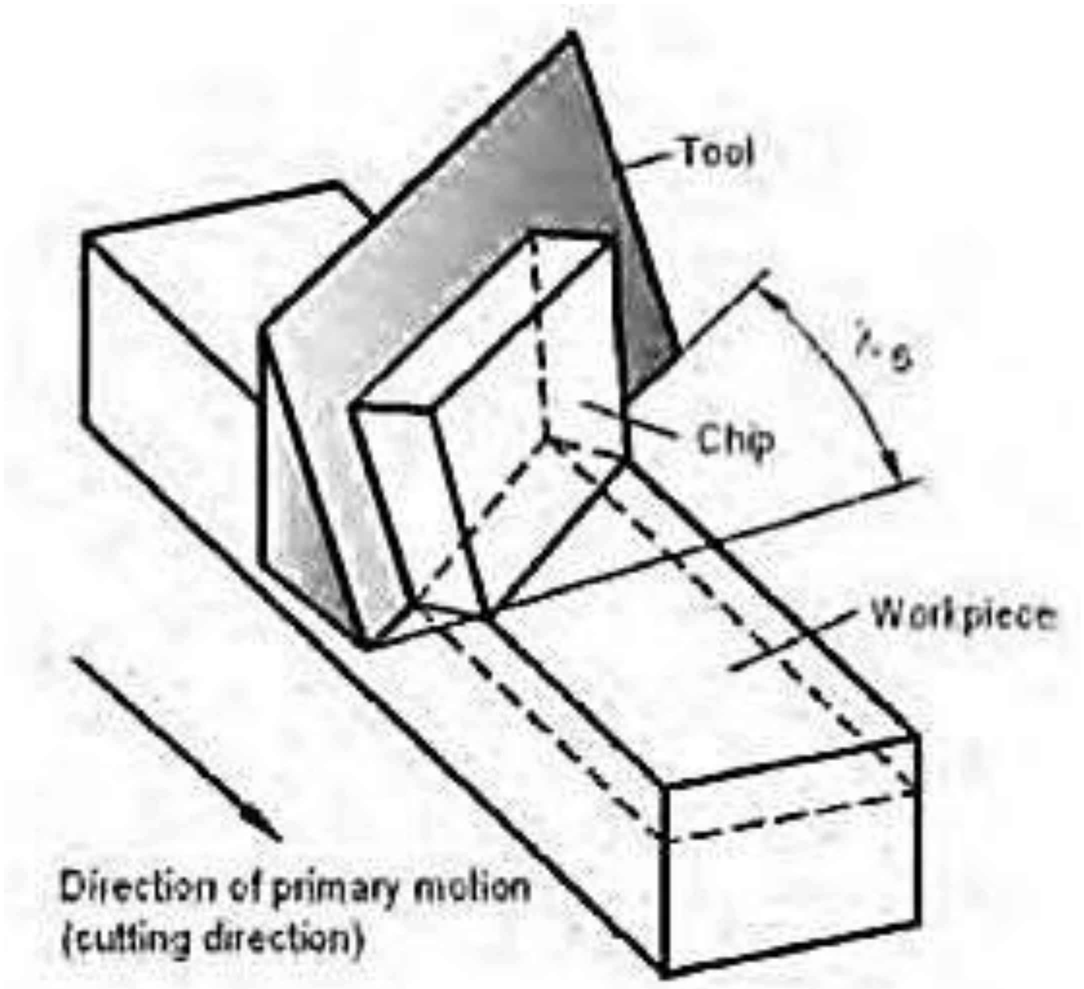
- Cutting edge of the tool is at an angle (not perpendicular) to the direction of relative motion b/w tool and the work piece.

E.g.: Most actual cutting operations - turning


Chip
Tool
Workpiece
V
90°
(a)
Chip
Chip-flow
angle
Tool
Workpiece
V
90°
i
Cutting edge
inclination
(b)

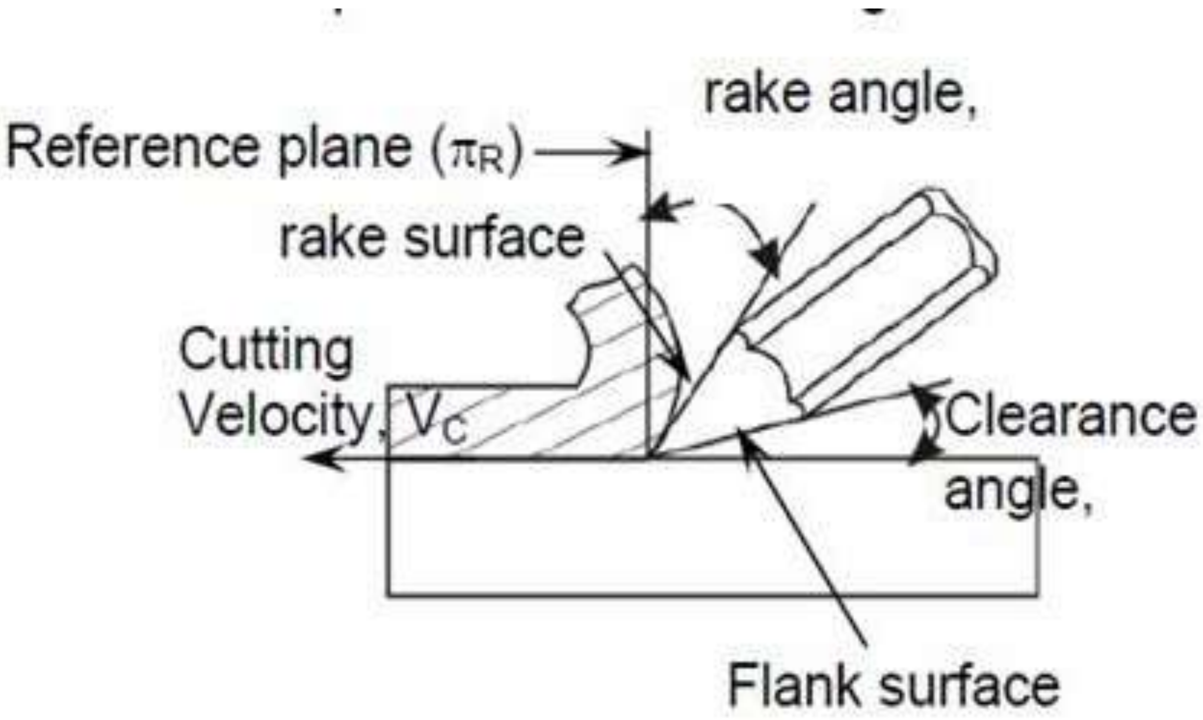


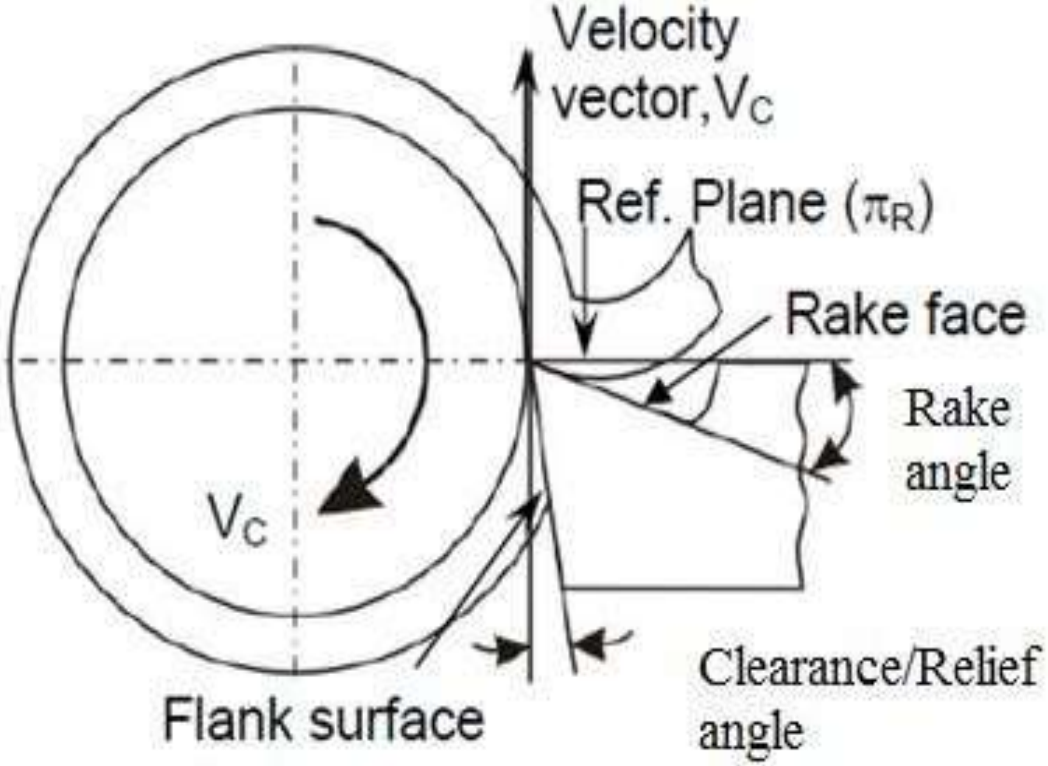
Orthogonal Cutting



Oblique Cutting

Concepts of Rake and Relief Angles

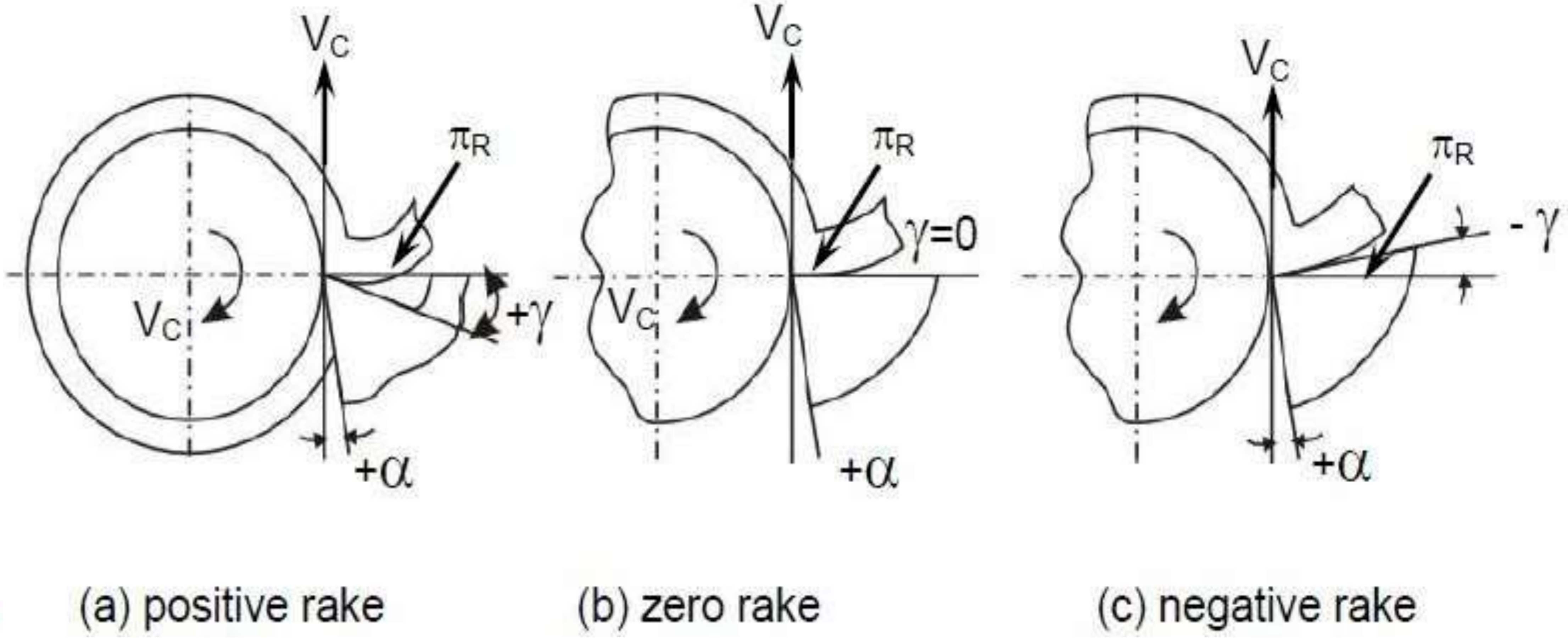




Rake and Clearance/Relief Angle

- Rake angle : Angle of inclination of rake surface from reference plane
  - Relative advantages of such rake angles are:
    1. ***Positive rake – helps reduce cutting force and thus cutting power requirement.***
    2. ***Negative rake – to increase edge-strength and life of the tool***
    3. ***Zero rake – to simplify design and manufacture of the form tools.***
- Clearance angle : Angle of inclination of clearance or flank surface from the finished surface
  - Clearance angle is essentially provided to avoid rubbing of the tool (flank) with the machined surface
  - which causes loss of energy and damages of both the tool and the job surface.
  - Hence, clearance angle is a must and must be positive
  - (3^o ~ 15^o depending upon tool-work materials and type of the machining operations like turning, drilling, boring etc.)

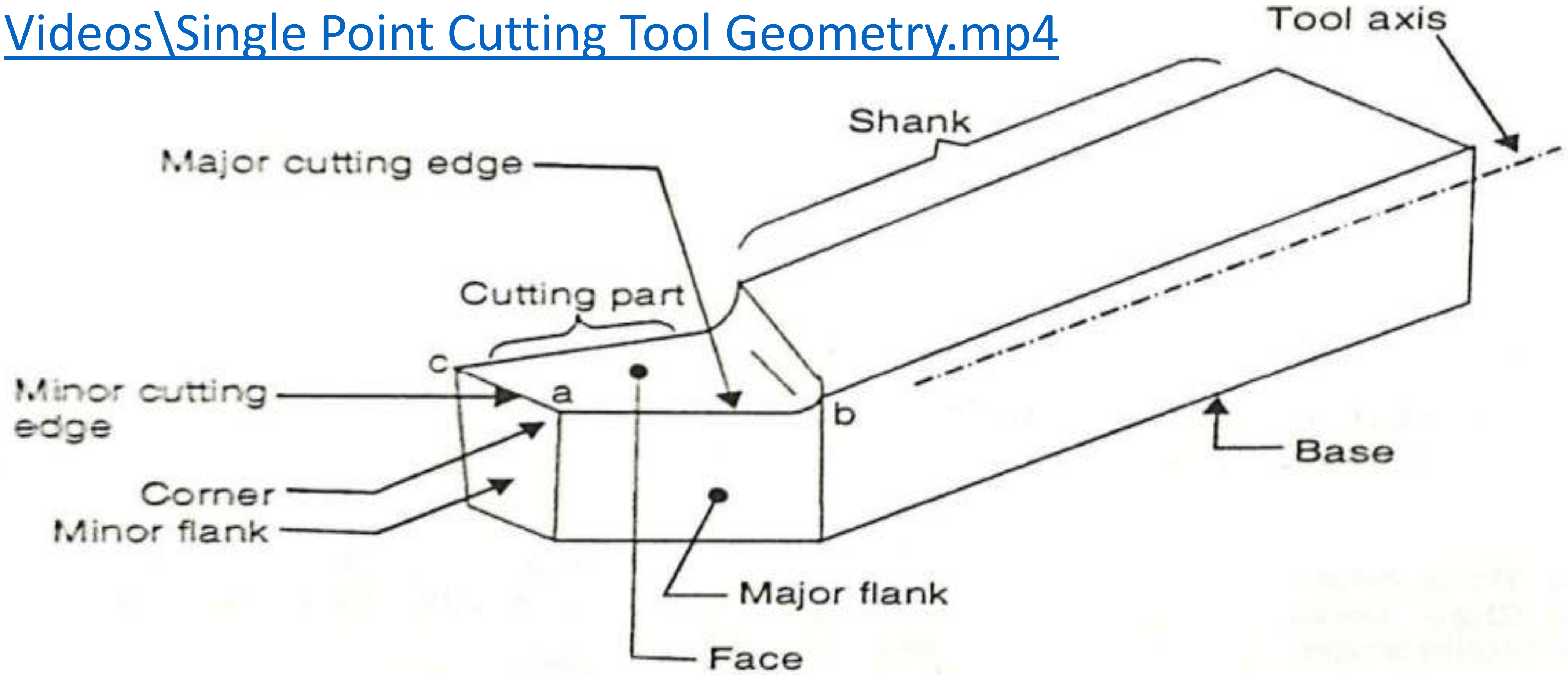
Rake Angle

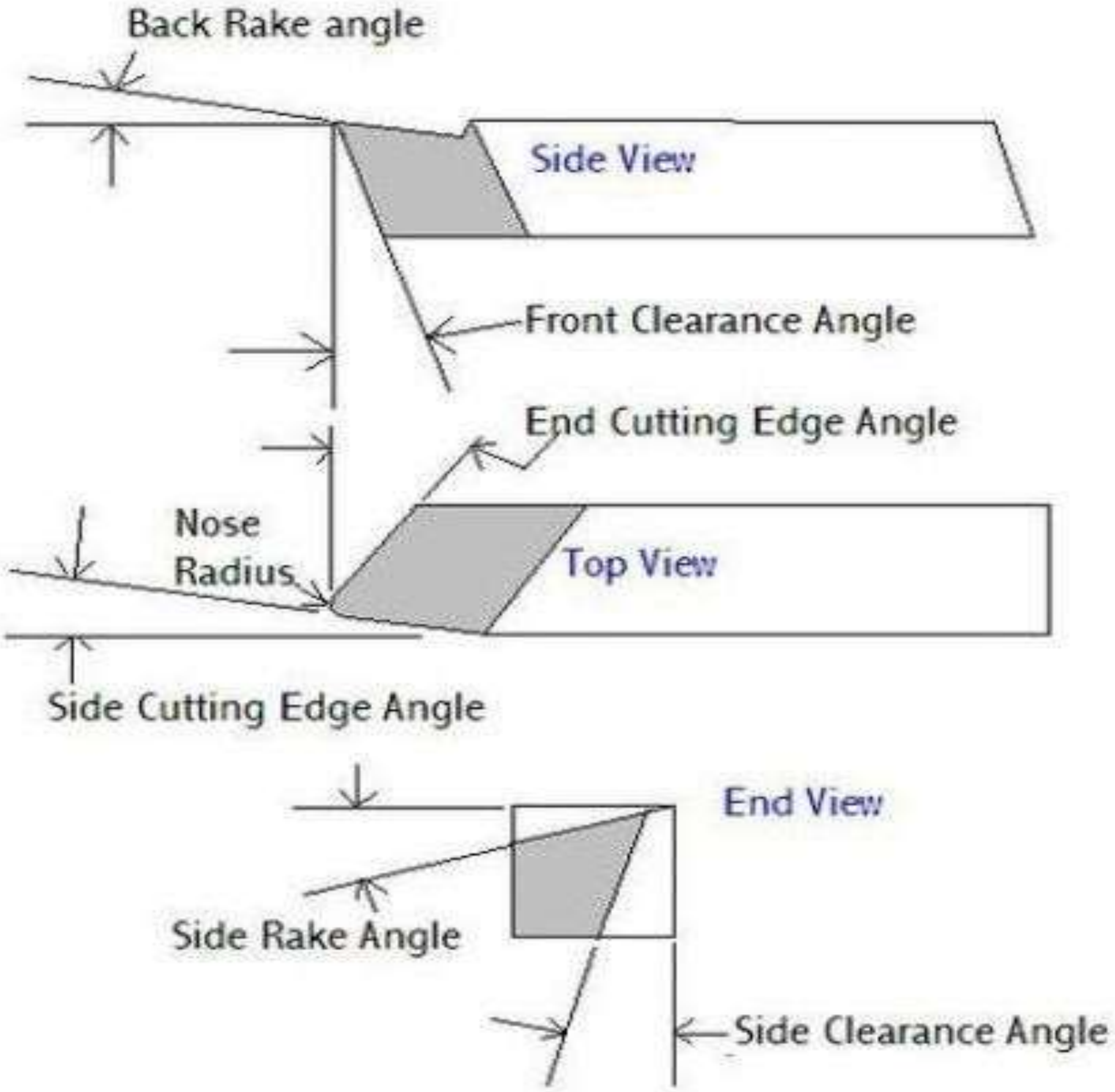


Vc
πR
Vc
+γ
+α
Vc
πR
γ=0
Vc
+α
Vc
πR
- γ
+α
(a) positive rake
(b) zero rake
(c) negative rake

TOOL NOMENCLATURE

- Videos\Single Point Cutting Tool Geometry.mp4




Back Rake angle
Side View
Front Clearance Angle
End Cutting Edge Angle
Nose
Radius
Top View
Side Cutting Edge Angle
End View
Side Rake Angle
Side Clearance Angle

- Side cutting edge angle (SCEA)
  - Angle b/w the **side/major cutting edge** and the side of the tool shank
  - Also called lead angle
  - Protects the tip of the tool at the start of the cut
  - Vary from 0-90 degrees
  - Increased values – gives good tool life, but large values causes tool chatter
  - Typical values- 15-30 degrees
  - To produce a shoulder (necking tool), 90 degree SCEA used.

- End Cutting Edge Angle (ECEA)
  - Provides **<u>relief to the trailing edge (minor cutting edge)</u>** to prevent rubbing or drag
  - b/w the machined surface and the non cutting part of the cutting edge.
  - Too large an angle takes away material supporting the tool tip and conducting the heat, making it fragile.
  - Ranges from 8-15 degrees
  - End cutting tools like necking tools have no ECEA (ECEA= 0)
- Side relief and End relief angles (SRA & ERA)
  - Provided so that the **<u>flank</u>** (<u>major flank for SRA and minor flank for ERA</u>) of the tool clears the workpiece and no rubbing occurs
  - Ranges from 5-15 degrees
  - Makes it easier to penetrate and cut the workpiece more efficiently, thus reducing the
  - cutting forces and power required.
  - Small relief angles necessary to give strength to cutting edge to cut hard materials
  - Too large – weakens the cutting edge, and results in poor heat conduction away.

- Back Rake and Side Rake Angles
  - Affects the cutting angle and the shear angle.
  - Large rake angle (positive):
    - Smaller the cutting angle (larger the shear angle); lower cutting force and power required
  - Small rake angles ensures tool strength
  - Practically is a compromise b/w the two.
- <u>Generally,</u>
  - Hard materials – small rake angles
  - Soft ductile materials – large rake angles (exception is brass- small angles used to prevent digging)

- – Negative rake angles used for carbide inserts (brittle). Positive rake angle directs the cutting force on the tool to the cutting edge.

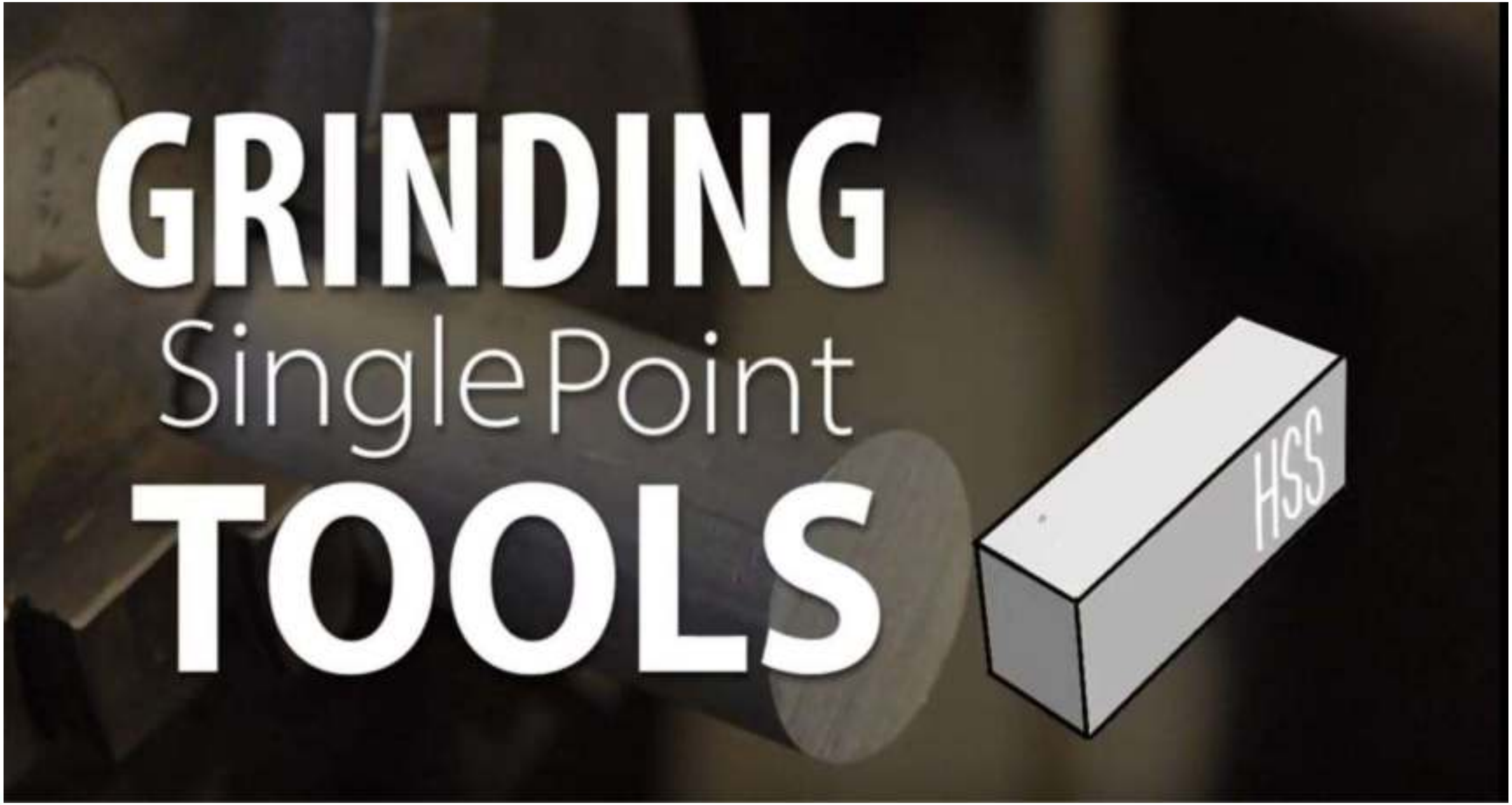
- # Nose radius:

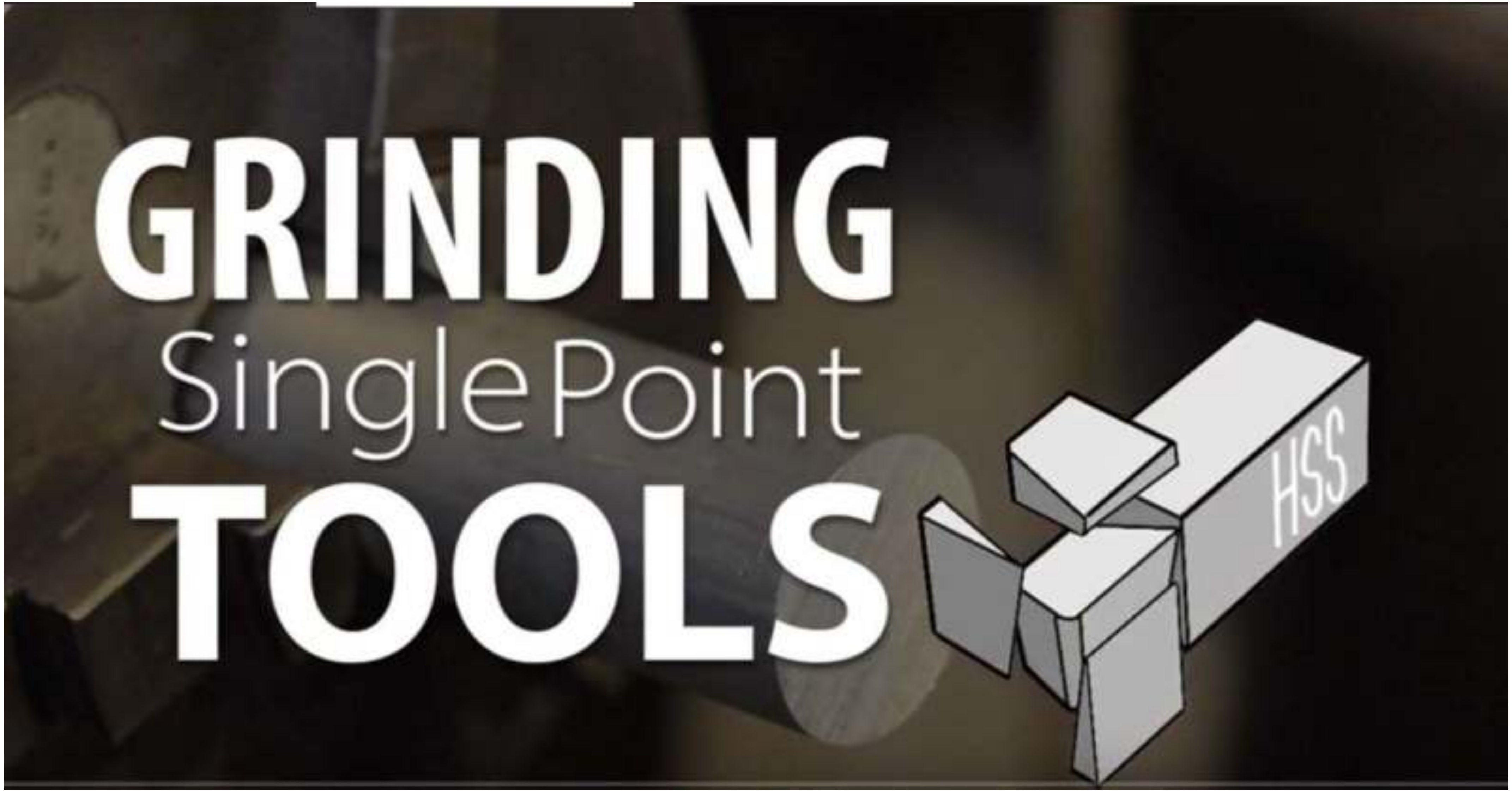
  – Required for long tool life and good surface finish

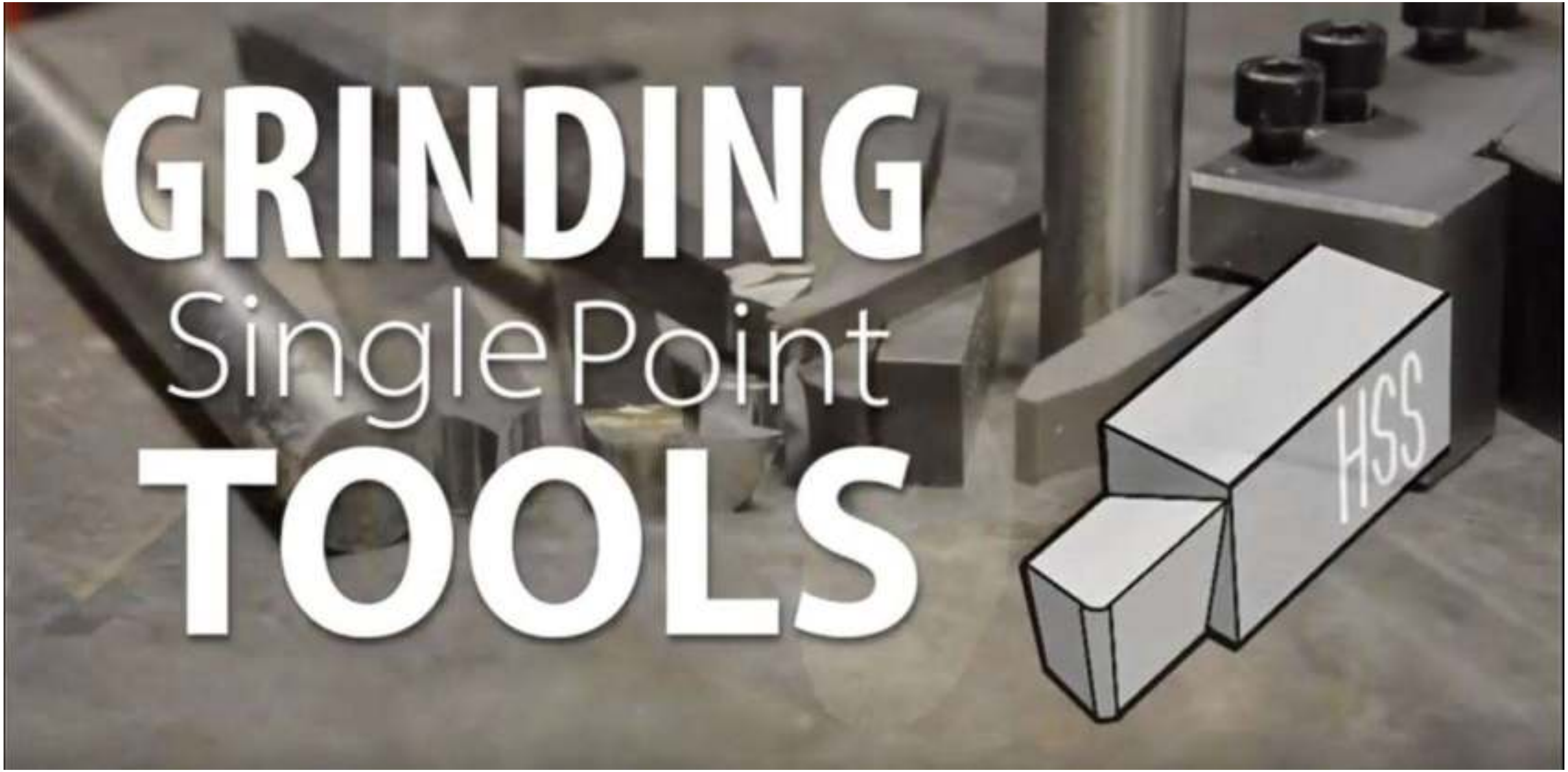
  – Too Small (Sharp tip) – high stress, short tool life and leaves

  - grooves in the path of cut.

  – Too large – result in tool chatter.


GRINDING
Single Point
TOOLS
HSS


GRINDING
Single Point
TOOLS
HSS


GRINDING
Single Point
TOOLS
HSS

Order of geometry specification

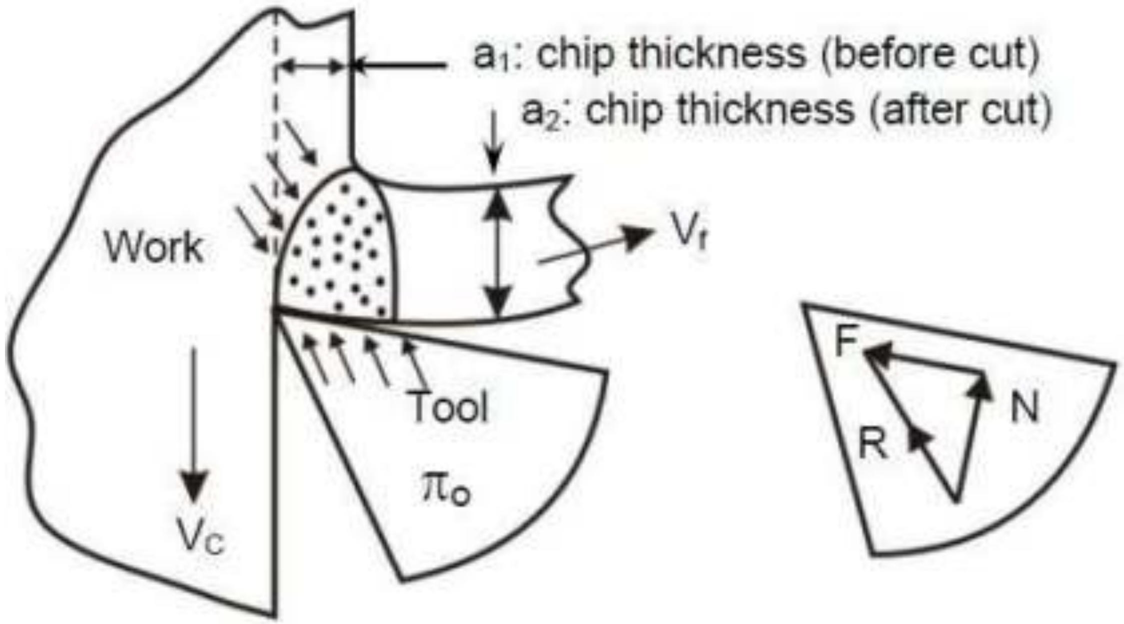
- Back Rake, Side Rake, End relief, Side relief, End cutting edge angle, side cutting edge angle and nose radius.
- E.g.: 8-14-6-6-6-15-1/8

Mechanisms of chip formation

- The basic two mechanisms involved in chip formation are:
  1. **Yielding** – generally for *DUCTILE MATERIALS*
  2. **Brittle fracture** – generally for *BRITTLE MATERIALS*

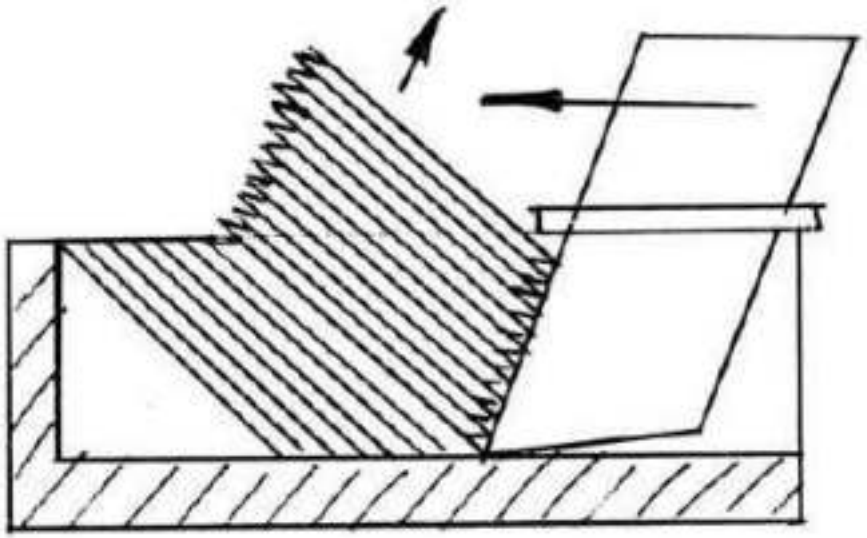
Mechanism of chip formation in machining ductile materials – YIELDING

- During continuous machining the uncut layer of the work material just ahead of the cutting tool (edge) is subjected to almost all sided compression

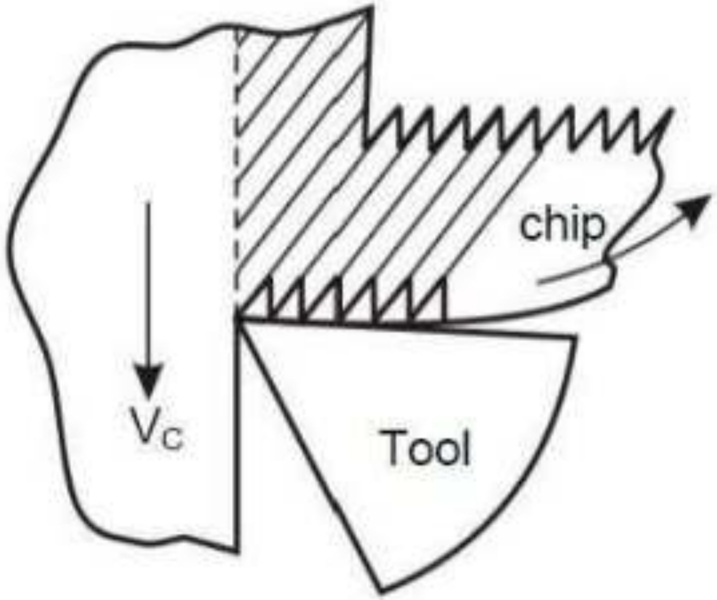


- Due to such compression, shear stress develops, within that compressed region, in different magnitude, in different directions and rapidly increases in magnitude.
- Whenever and wherever the value of the shear stress reaches or exceeds the shear strength of that work material in the deformation region, yielding or slip takes place resulting shear deformation in that region along the plane of maximum shear stress
- But the forces causing the shear stresses in the region of the chip quickly diminishes and finally disappears while that region moves along the tool rake surface towards and then goes beyond the point of chip-tool engagement
- As a result the slip or shear stops propagating long before total separation takes place. In the mean time the succeeding portion of the chip starts undergoing compression followed by yielding and shear. This phenomenon repeats rapidly resulting in formation and removal of chips in thin layer by layer

- This phenomenon has been explained in a simple way by Pispannen [1] using a card analogy as shown in Fig.

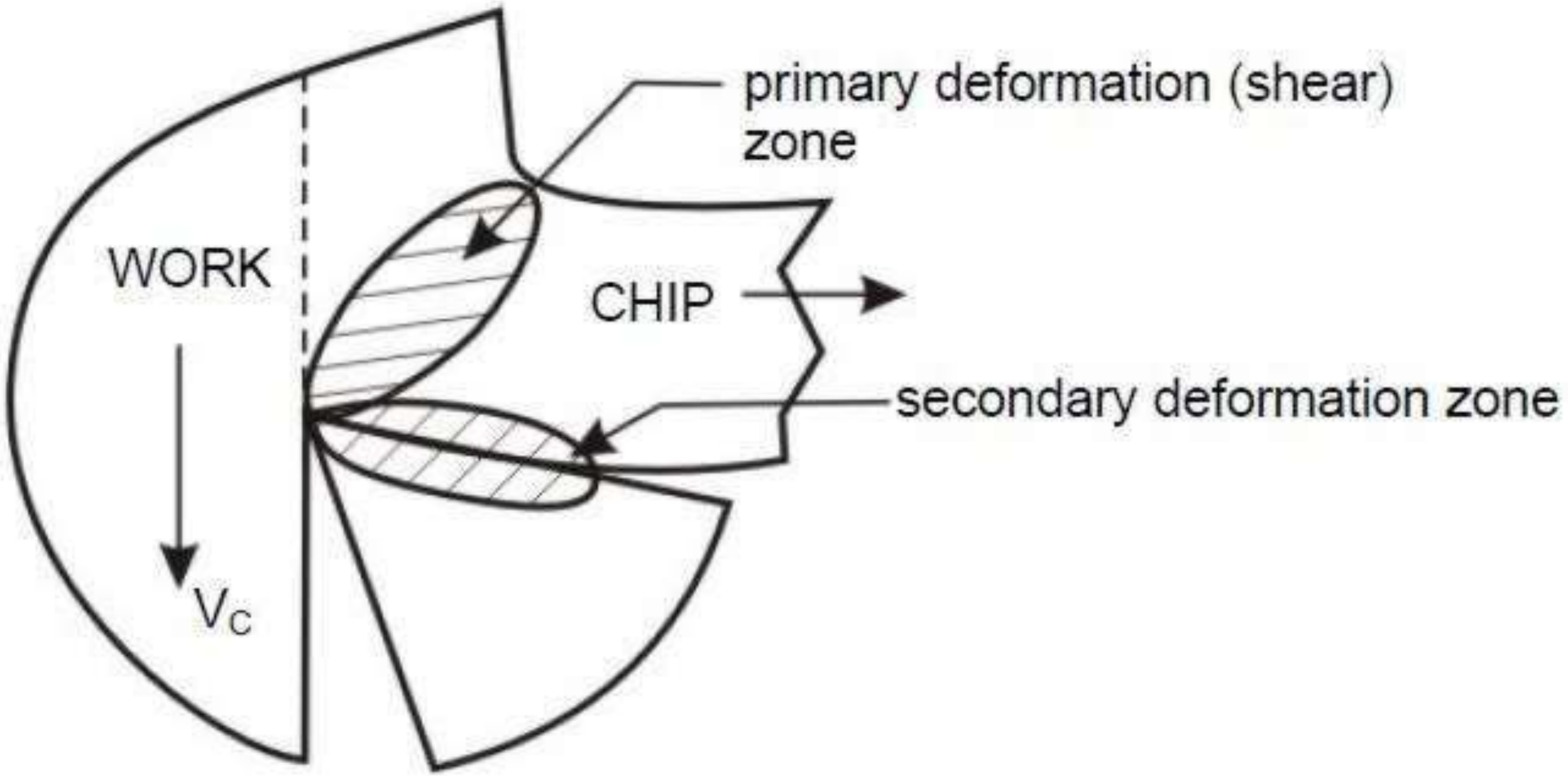


(a) Shifting of the postcards by partial sliding against each other



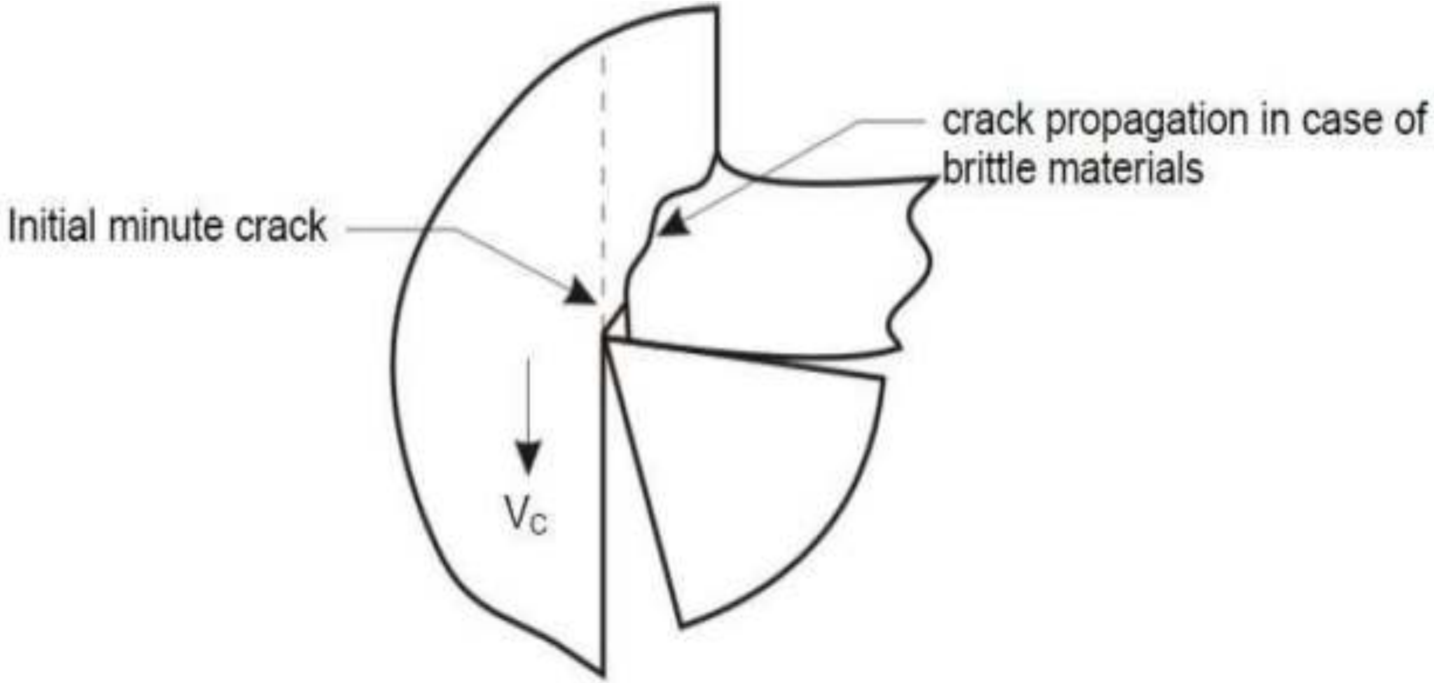
(b) Chip formation by shear in lamella.

The lower surface becomes smooth due to further plastic deformation due to intensive rubbing with the tool rake surface at high pressure and temperature.



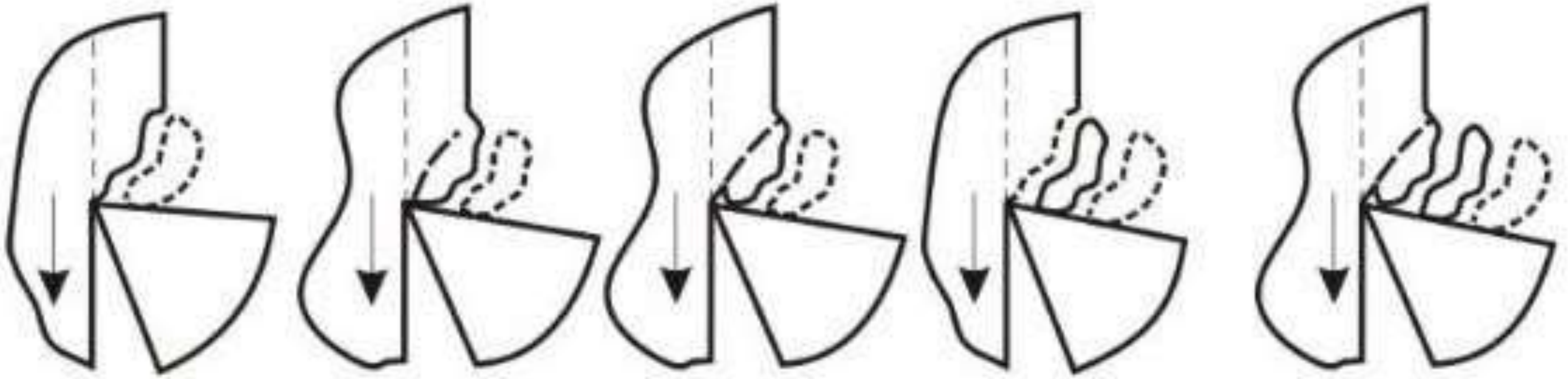
Mechanism of chip formation in machining brittle materials – BRITTLE FRACTURE

- During machining, first a small crack develops at the tool tip as shown in Fig due to wedging action of the cutting edge.



- At the sharp crack-tip stress concentration takes place.
- In case of ductile materials immediately yielding takes place at the crack-tip and reduces the effect of stress concentration and prevents its propagation as crack.
- But in case of brittle materials the initiated crack quickly propagates, under stressing action, and total separation takes place from the parent work piece through the minimum resistance path as indicated in Fig in above slide

- Machining of brittle material produces discontinuous chips and mostly of irregular size and shape. The process of forming such chips is schematically shown in Fig below



(a) separation (b) swelling (c) further swelling (d) separation (e) swelling again

TYPES OF CHIPS

- 4 types:
  1. Discontinuous/Segmental chips
  2. Continuous chips
  3. Continuous chips with BUE (Built up Edge)
  4. Non-homogeneous chips

- **Discontinuous/Segmental chips**
  - **Consists of separate plastically deformed segments**
  - Produced during machining of brittle materials like cast iron, bronze etc.
  - Adv:
    - Easy to handle
    - Low power consumption
    - Reasonable tool life
    - Fair surface finish
  - Produced in machining ductile materials under the following conditions:
    - » High depth of cut
    - » Low speed
    - » Small rake angle
  - **NOT DESIRABLE FOR DUCTILE MATERIALS (poor surface finish and tool life)**

• Continuous chips

- **Metal continuously deforms without fracture and flows over the rake face in the form of a ribbon**

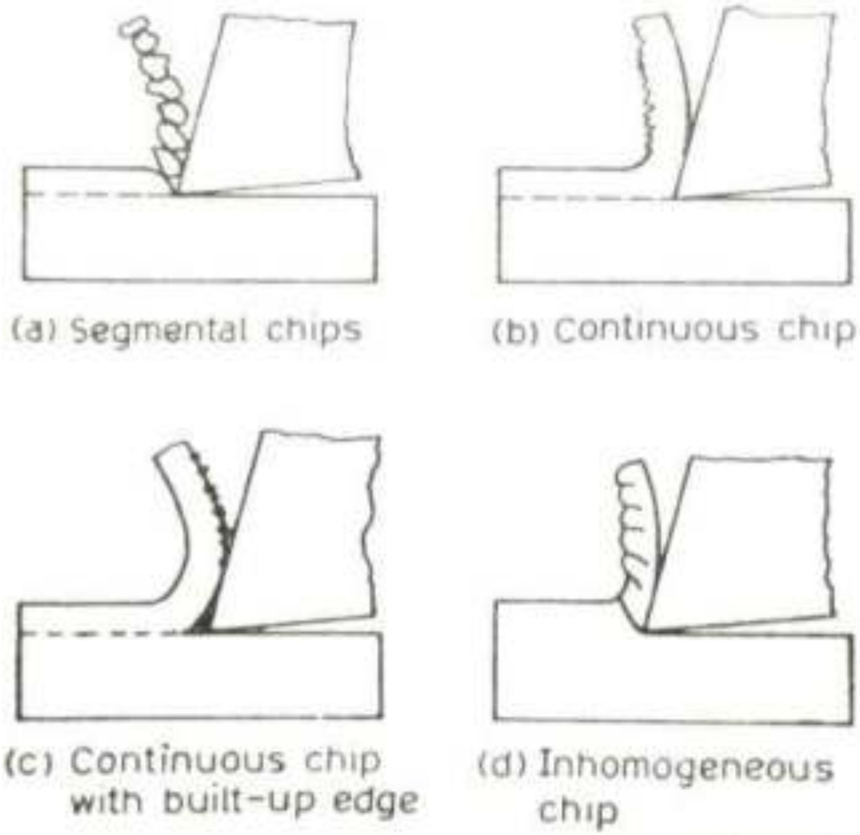
- Produced in machining ductile materials under the normal cutting speeds.
- Produced under:
  - Small depth of cuts
  - Normal to high cutting speeds
  - Large rake angles
  - Reduced friction along chip tool interface.
- Most desirable chip – indicates stable cutting, results in generally good surface finish
- Disadv:
  - Difficult to handle and dispose off..
  - Chips coil in a helix (CHIP CURL), around the work and tool and may cause injury to the operator when it breaks loose.
  - Chip breakers are necessary
  - More frictional heat is generated due to longer durations of chip contact with rake face.

• Continuous chips with BUE

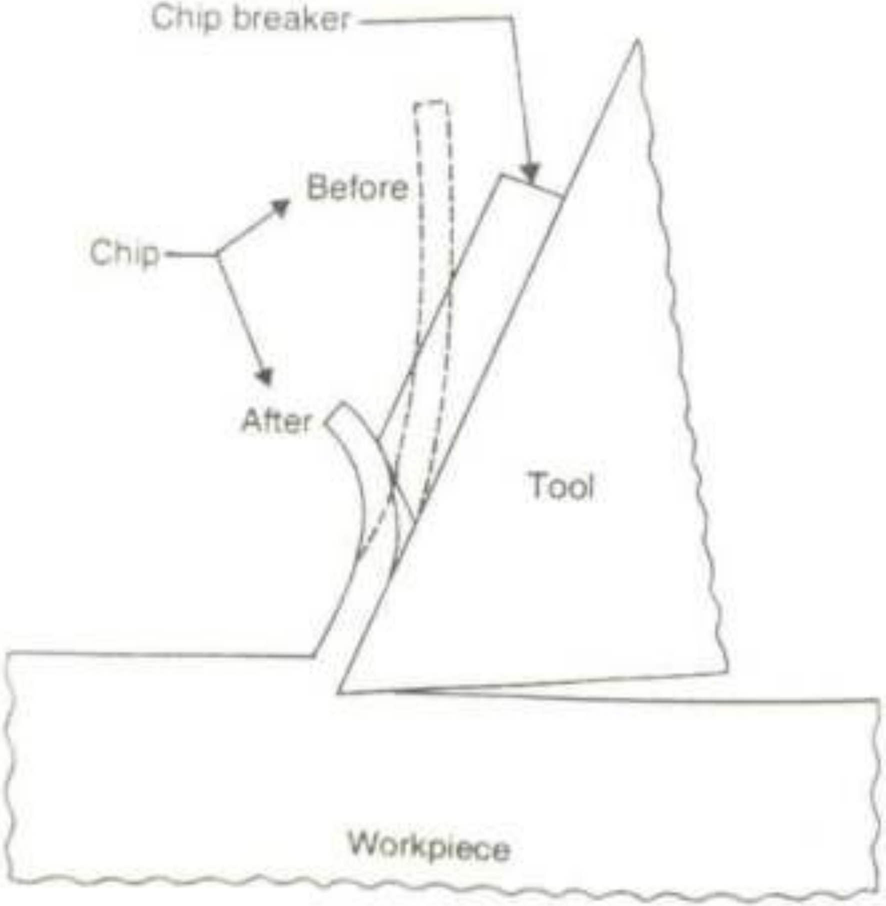
- Produced in machining ductile materials under conditions of:
  – High local temperature and extreme pressures in the cutting zone
  – High friction at the tool-chip interface
  – Low cutting speed.
- Causes work material to adhere/weld to the cutting edge of the tool, forming the BUE (further increasing friction)
- Successive layers of work material are added onto the BUE, till it becomes unstable and breaks off. (some deposited on the work piece; some carried by the chip)
- Causes:
  – **Vibration - Larger power consumption**
  – **Poor Surface Finish - Higher tool wear**
- Can be avoided by:
  – Increasing the cutting speed
  – Increasing the rake angle
  – Use of cutting fluids

- **Non-homogeneous chips**
  - Characterized by notches on the free side of the chip.
  - Observed in:
    - materials in which yield strength decreases with temperature.
    - Materials having poor thermal conductivity.
  - E.g. : Some steels and Ti Alloys at medium cutting speed.

  - During the chip formation by slip along the shear plane, the temperature also rises. This results in lowering of yield strength and causes further strain.
  - As the cutting is continued, a new shear plane will develop at some distance and the deformation shifts to this point.



(a) Segmental chips
(b) Continuous chip
(c) Continuous chip with built-up edge
(d) Inhomogeneous chip



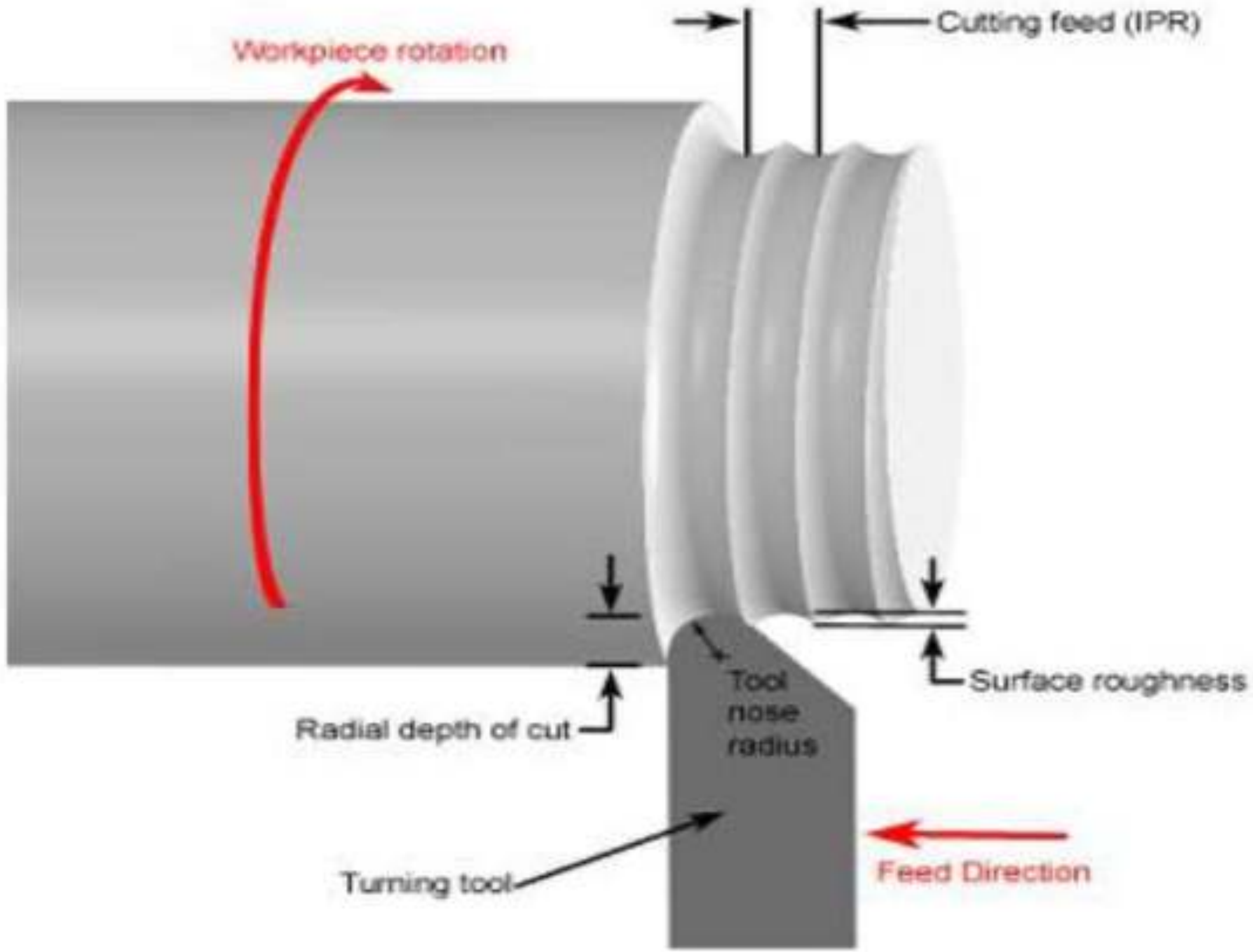
METAL CUTTING PROCESS/PERFORMANCE PARAMETERS

1. **Velocity (speed rate, feed rate):** Affects temp at tool point.
2. **Size/Depth of cut**
3. Tool geometry
4. Tool material
5. Nature of work-material: Ductile or Brittle
6. Cutting fluids

METAL CUTTING PROCESS/PERFORMANCE PARAMETERS

Speed:-

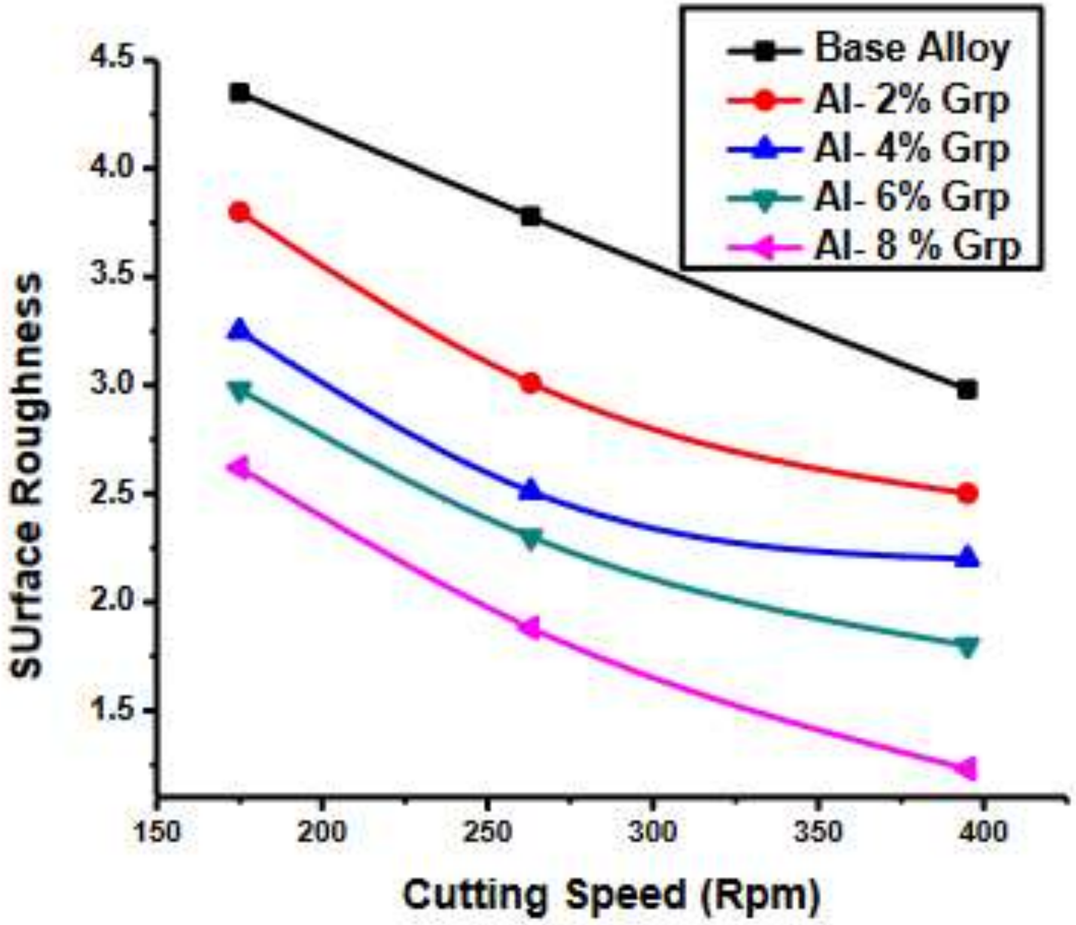
- Cutting velocity is the most important cutting parameter that provides necessary cutting motion (CM).
- In case of either rotating tool (such as milling, drilling, grinding) or rotating workpiece (such as turning), the peripheral velocity of cutter or workpiece (as the case) is considered as the cutting velocity.
- The rotational speed is called the Cutting Speed (denoted by N and measured in rpm); whereas, the tangential velocity is called Cutting Velocity (denoted by Vc and measured in m/min).


Cutting feed (IPR)
Workpiece rotation
Tool nose radius
Surface roughness
Radial depth of cut
Turning tool
Feed Direction

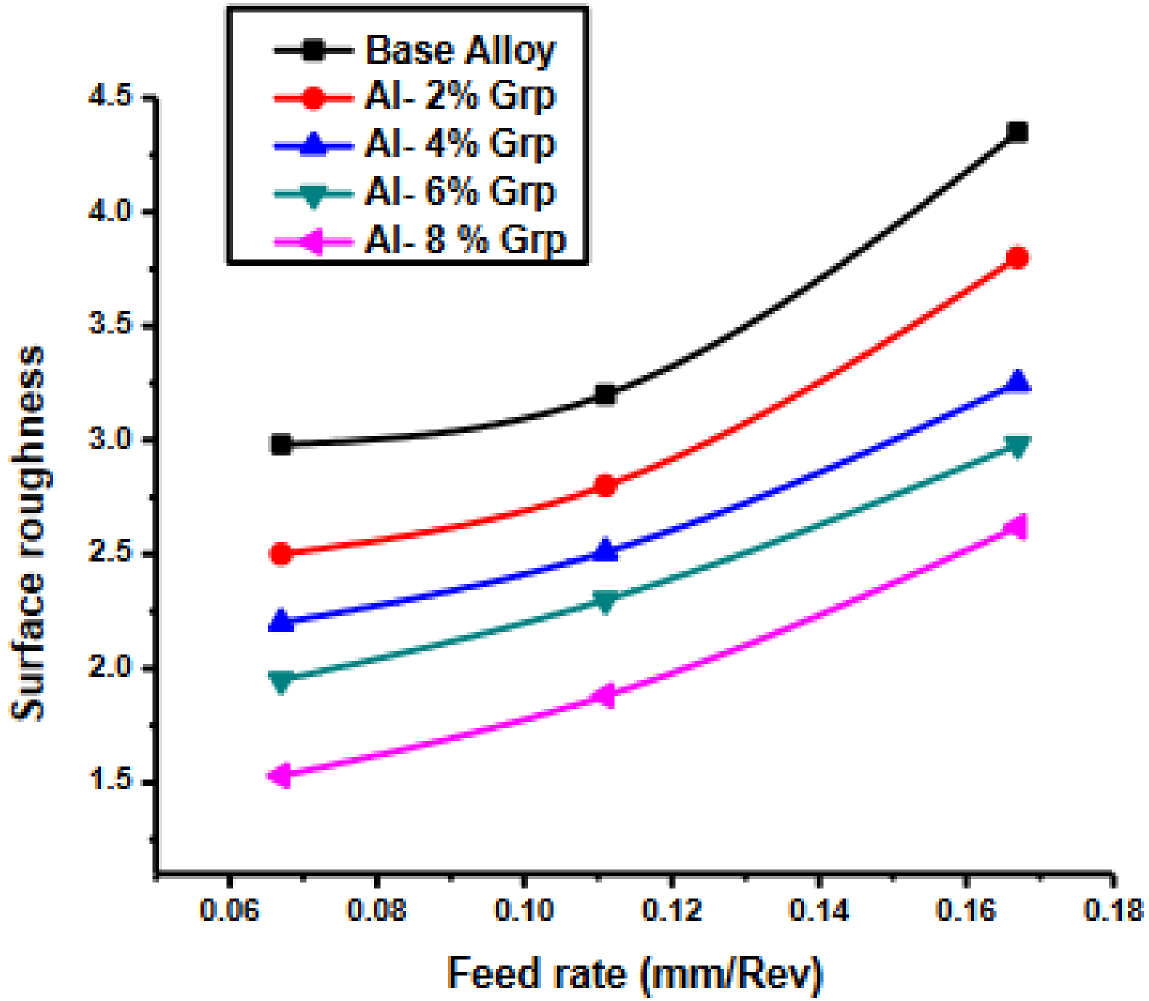
- **Feed rate**
- The auxiliary cutting motion is provided by the feed rate or feed velocity.
- Usually the direction of feed velocity is perpendicular to that of the cutting velocity; however, not necessary.
- The primary objective of feed velocity is to advance the cutter with respect to the workpiece to remove material from a wider surface.
- Basically it helps in covering the entire surface of the workpiece by moving either cutting tool or workpiece.
- Feed rate can be imparted either on the cutter or on the workpiece.

- **Depth of cut (t)**
- The tertiary cutting motion that provides necessary depth within work material that is intended to remove by machining.
- It is given in the third perpendicular direction and the simultaneous action of three cutting parameters results in removal of excess material from workpiece.

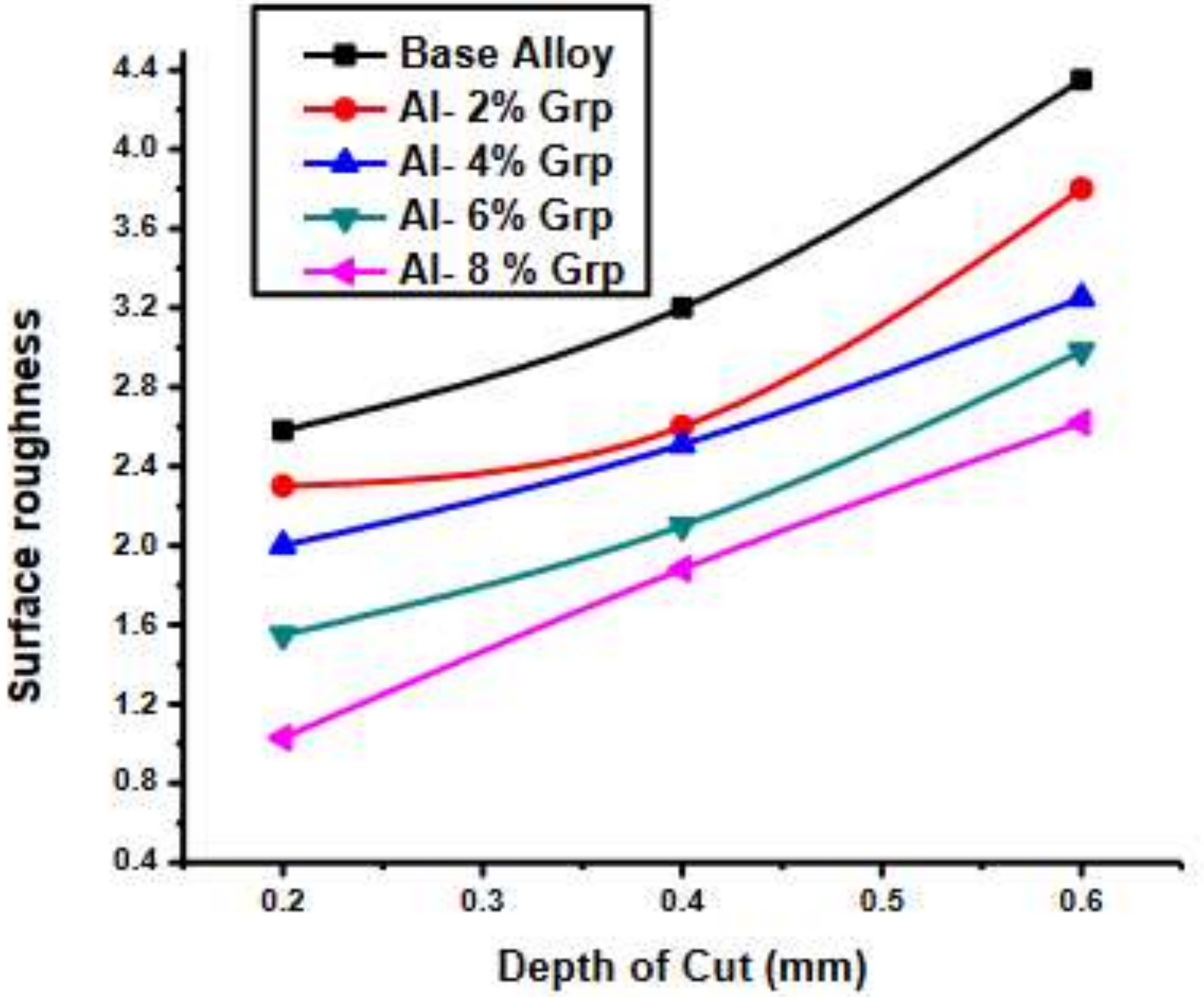
Effect of Cutting Speed on Surface finish



Effect of Feed on surface roughness



Effect of Depth of cut on surface roughness



TOOL MATERIALS

- Different types of materials are used for making tools. Each tool material finds its use under different applications.
- Some of the commonly used cutting tool materials are:
  - Carbon Steel
  - HSS (High Speed Steels)
  - Cemented carbides
  - Ceramics
  - CBN (cubic boron nitride)
  - PCD (poly crystalline diamond) and diamond coated tools

- **Characteristics of a good tool material**

1. **Hot hardness:**
   - ability to withstand high temperatures without losing its cutting edge.
   - Important in high speed cutting
   - Increased by adding Cr, Mo, W and V (forms hard carbides)
   - Good wear resistance, but low toughness and mechanical shock resistance.
2. **Wear resistance:**
   - Ability to resist wear (may causes poor surface finish in its absence)
3. **Toughness:**
   - ability of a material to absorb energy and plastically deform without fracturing
   - Puts limitation to hardness of tool ; high hardness – brittle and weak
   - Important in the case of tools used for interrupted cuts.
4. **Mechanical and thermal shock resistance**

5. Ability to maintain above properties at different temperatures occuring during machining

6. **Low friction**
   - For improved tool life and better surface finish

7. **High thermal conductivity**
   - For quick removal of heat from the chip tool interface

8. **Readily obtainable**

9. **Favourable Cost**
   - Potential savings from its use (reduced labour, increased cutting speed(MRR), increased life) should outweigh its cost

10. **Easy to regrind/modify**

1. Plain High Carbon Tool Steel:

- C - 0.8-1.3%; Si - 0.1-0.4%; Mn - 0.1-0.4%; rest Fe
- Higher C content – increased wear resistance, but will make it brittle
- Two categories: a. Water hardening, b. Oil hardening
- **Characteristics:**
  - Low hot hardness - Will loose hardness above 200^{o}C, will not regain it on cooling
  - Poor hardenability
  - Easy to machine
  - Keen cutting edge can be provided easily
  - High surface hardness with fairly tough core.

- **Use:**
  - Used in tool of small section which operate at relatively small speeds
  - Speed limited to 0.15m/s using large amounts of coolant
  - Used for manufacture of milling cutters, twist drills, turning tools etc. for wood, Mg, Al etc.

2. Low alloy carbon steels:

- Small amounts of Cr and Mo are used to increase hardenability of tools
- Upto 4% of W – used to improve wear resistance
- **Characteristics:**
  - Hot hardness same as that of carbon steels
  - Not suited for high speed operations
- **Use:**
  - Tools that require wear resistance
  - Drills, Taps and reamers

3. High Speed Steels (HSS)

- **Characteristics:**
  - Superior Hot hardness – can maintain hardness temp upto 600^{o,} C (due to presence of W, Mo or Co), but soften rapidly after that.
  - Superior wear resistance
  - Can be used at higher cutting speed – limited to 0.75-1.8 m/s
- **Types:**

a) Tungsten and Molybdenum Type: 3 types

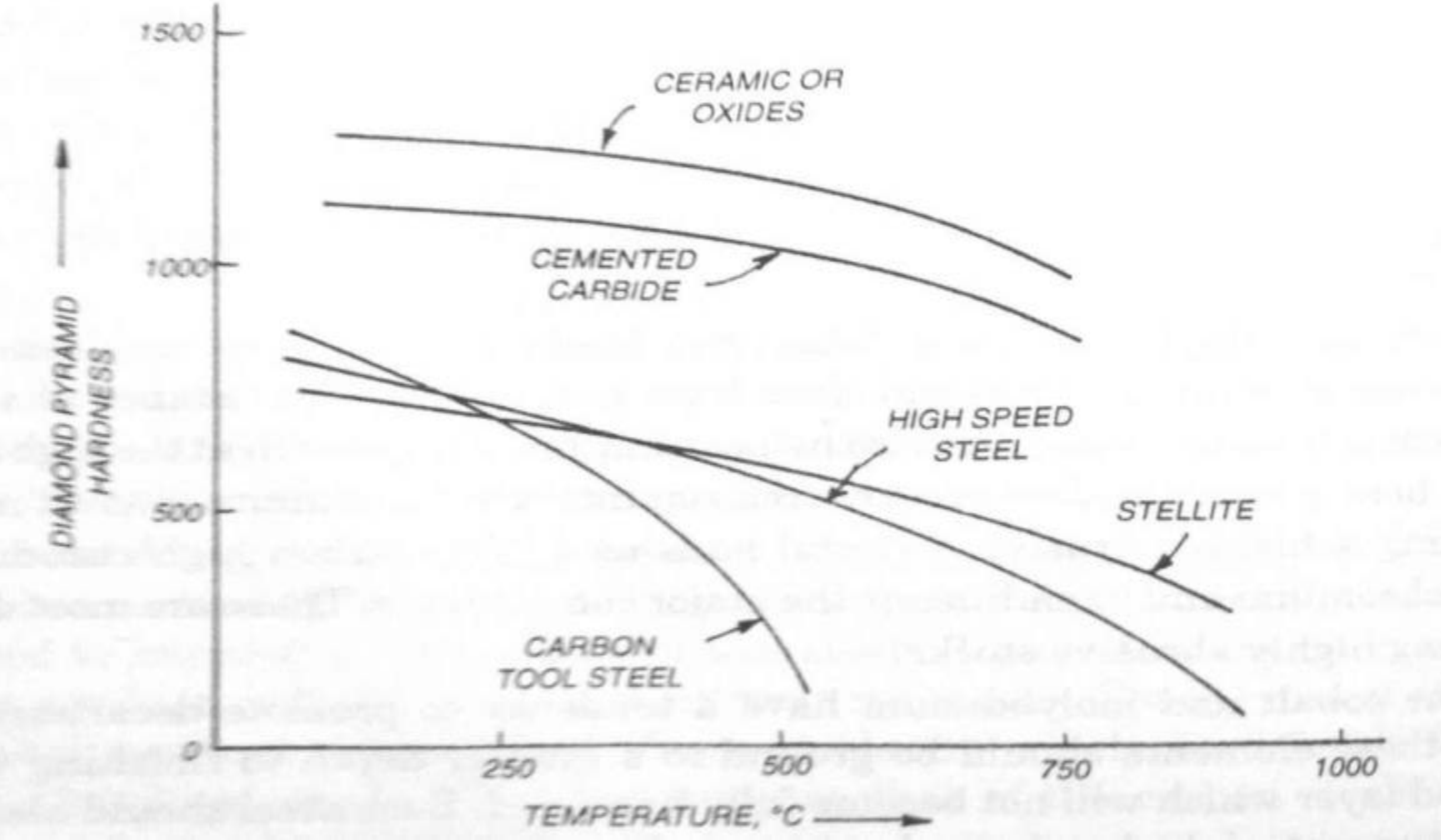
1. High tungsten (T-type)
2. High Molybdenum (M-type)
3. Tungsten-Molybdenum type

b) Cobalt Type

Type	W	Cr	V	Mo	C	Fe
T type	18	4	1	-	0.7	Balance
M type	1.5	4	1	8.5	0.8	Balance
W-Mo type	6	4	1	5	0.8	Balance

- **HSS cont.**
  - All the above Tungsten and Molybdenum types of HSS contain about 0.025% Si and 0.25% Mn.
  - Co may be added (in 4,8 or 12% ratio) to any of the above types of HSS for increases hot hardness
  - W and Mo increase hot hardness by forming complex carbides of high hardness
  - Co forms an alloy going into the solid solution in the ferrite matrix and thus raising the recrystallization temp. (material can retain hardness gained through strain hardening at higher temp)
  - V forms very hard carbides and thus increases the wear resistance at high operating temp. (higher % used in tools used to machine highly abrasive material like High C-High Cr die steel)

- **HSS cont.**
  - Cr and Co have the tendency to promote retention of austenite, which has further tendency to transform into martensite at low temp when the tool is subjected to cold work as by grinding or in use of cutting. This will cause dev. of large internal stresses which frequently cause cracks to develop in tools, leading to premature breakdown of cutting edge.
  - Double tempering done to avoid this.
  - Heat treatment of HSS tools affects its properties.
  - HSS tools manufacture by – Powder metallurgy or electro slag refining process
  - HSS tools can also be coated with layers of refractory metal carbide or nitride by CVD.


1500
1000
500
0
DIAMOND PYRAMID HARDNESS
CERAMIC OR OXIDES
CEMENTED CARBIDE
HIGH SPEED STEEL
STELLITE
CARBON TOOL STEEL
250
500
750
1000
TEMPERATURE, °C

4. Stellites:

- Non-ferrous alloys – high in Co
- 40-50% Co, 27-32% Cr, 14-29% W and 2-4% C
- They are cast alloys
- **Characteristics**
  - Cannot be heat treated.
  - Not as hard as Tool Steels at room temp, but retain hardness at higher temp. (harder than HSS above 500° C)
  - Fragile in nature (weak in tension and hence tend to shatter under shock load or if not properly supported)
- **Used:**
  - For Rapid machining of hard metals.
  - For Making form tools
  - Used in tool or insert form

5. Cemented Carbides

- Fine crystals of WC (very hard) mixed with Co powder (binder), sintered onto tool bits.
- Manufactured by Powder metallurgy
- **Used:**
  - Machining cast irons, certain abrasive non ferrous alloys.
  - Not good for cutting steels (due to face wear; can be reduced by adding Ti and Ta carbides before sintering)
- **Grades:**
  - C-grade: WC with Co as binder (3-16%), greater Co content, greater shock resistance
  - S-grade: WC, TiC (0-10%), Tantalum carbide (0-16%) with cobalt binder; can be used to machine steels

    TiC – helps to reduce tendency of chip welding and increases hot hardness

    Tantalum carbide – helps improve crater wear resistance

5. Cemented Carbides cont.

- **Characteristics:**
  - High hardness over wide range of temp.
  - Very stiff (high Young's Modulus – nearly three times that of steel)
  - Very low thermal expansion
  - Relatively high thermal conductivity
  - Can be used for higher cutting speeds (3-4 m/s with mild steel)

6. Ceramics

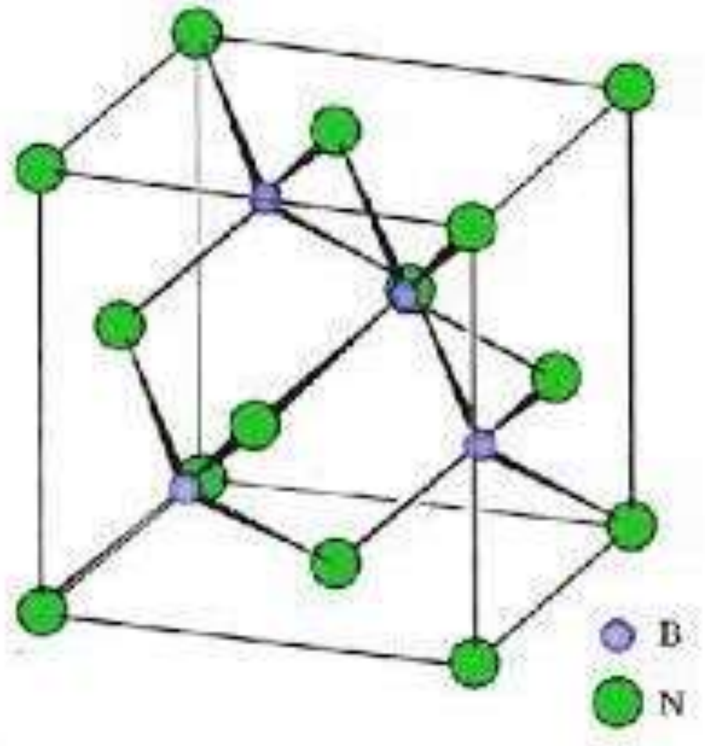
- Mainly consists of sintered oxides (Al_2O_3 mainly and other oxides)
- Sometimes Al_2O_3 may be as high as 97%.
- Sometimes, 80% Al_2O_3 with Ti, Mg and W oxides and carbides
- Prepared in the form of throw away inserts or clamped tips
- **Characteristics**
  - Can be used at very high speed (beyond carbide tools)
  - Resists BUE and produces good surface finish
  - Very hard and good resistance to wearing
  - High hot hardness – can maintain hardness upto 700^{o}C
  - Low friction at rake surface compared to carbide tools
  - Extremely brittle – limited to continuous cuts
  - Poor thermal conductors – high temperatures
  - **Cutting edges are usually chamfered and negative rakes of 15-20^{o} are provided**

7. Sialon

- Word Si Al ON, stands for Silicon Nitride based materials with aluminium and oxygen additions
- Produced by milling (grinding process) Si_3N_4, Aluminium Nitride, Alumina and Yttria (Y_2O_3). The mixture is dried, pressed is shape and sintered at 1800^oC
- **Characteristics and Uses**
  - Tougher than Alumina (ceramics) and thus suited for interrupted cuts
  - Used to machine aerospace alloys and Ni based alloys
  - High cutting speeds of 200-300 m/min (3-5 m/s) can be used

8. Cubic Boron Nitride (cBN)

- It consists of atoms of nitrogen and boron, with special structural configuration similar to diamond.
- Available as indexable inserts
- **Characteristics:**
  - High Hardness (hardest material next to diamond)
  - High thermal conductivity
  - Chemically inert
- **Used:**
  - Machining hardened tool steel and high strength alloys
  - Grinding of HSS and stellites

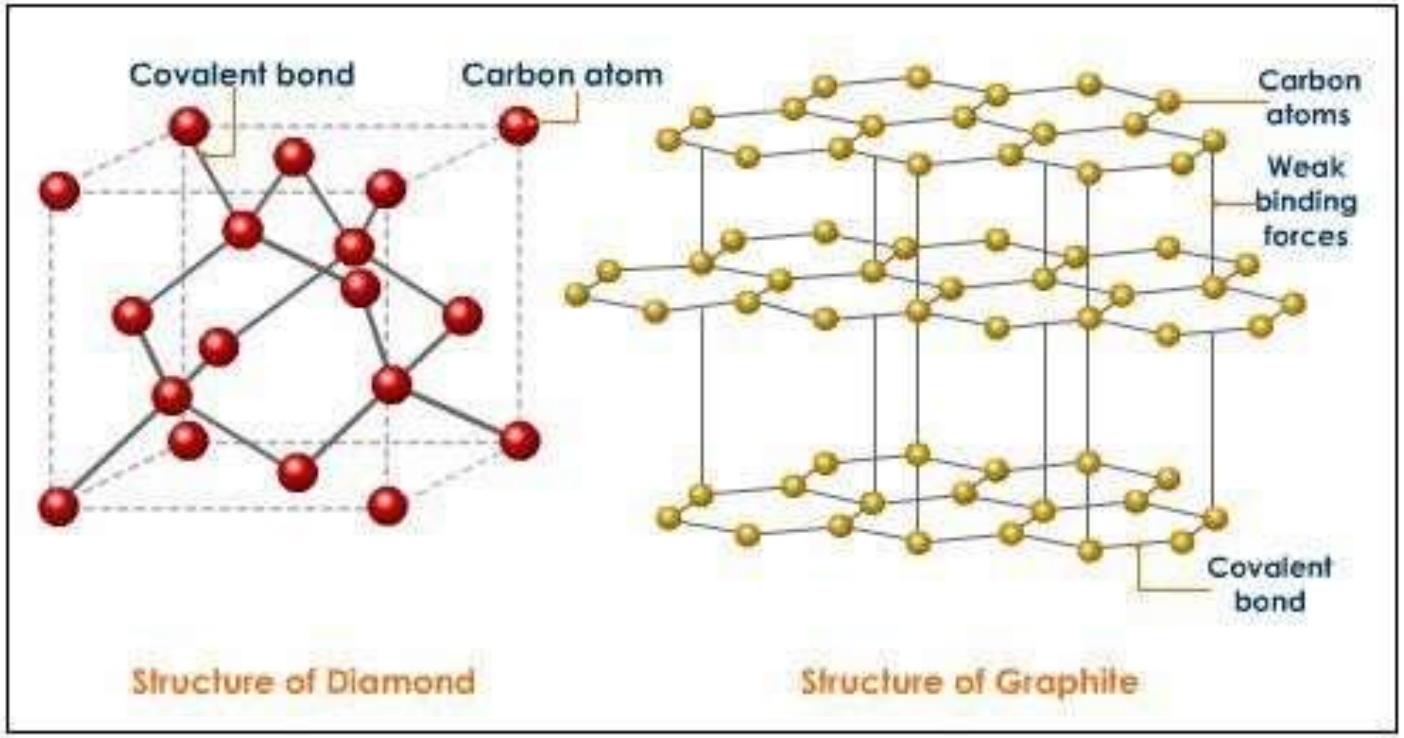


9. Diamond Tools

- It consists of atoms of carbon arranged in a variation of FCC structure called a DIAMOND LATTICE
- **Characteristics:**
  - High Hardness (hardest material)
  - High thermal conductivity (2 times that of steel)
  - Lowest thermal expansion (12% of steel)
  - Very low coefficient of friction
  - Very brittle
- **Used:**
  - Producing high surface finish on soft materials that are difficult to machine (Cu, Al etc.)
  - High cutting speeds can be used (nearly 150 m/min)

8. Diamond Tools cont.

- Diamonds commercially classified as:
  - Carbons (polycrystalline – Less dense and hard)
  - Ballas (polycrystalline – Less dense and hard)
  - Boarts (single crystals – less clear and fault free) – USED FOR CUTTING
  - Ornamental stones



TOOL FAILURE

- Cutting tools generally fail by :

i) **Mechanical breakage** due to excessive forces and shocks. Such kind of tool failure is random and catastrophic in nature and hence are extremely detrimental.

ii) **Quick dulling by plastic deformation** due to intensive stresses and temperature. This type of failure also occurs rapidly and are quite detrimental and unwanted.

iii) **Gradual wear** of the cutting tool at its flanks and rake surface

- The first two modes of tool failure (SUDDEN) are very harmful not only for the tool but also for the job and the machine tool. Hence these kinds of tool failure need to be **prevented by using suitable tool materials and geometry depending upon the work material and cutting condition**.

- But failure by gradual wear, which is inevitable, **cannot be prevented but can be slowed down only to enhance the service life of the tool**

TOOL WEAR MECHANISMS

There are different types of mechanisms responsible for wear.

1. **Adhesion**
2. **Abrasion**
3. **Diffusion & Dissolution**
4. **Chemical Reaction and Oxidation**
5. **Fatigue**

Depending on

- cutting conditions and
- tool-work materials combination,

the mechanism responsible for wear changes.

- At low cutting speeds, adhesive and abrasive wear tend to be dominant.
- Diffusion, dissolution, chemical reaction and oxidation are more relevant at high cutting speeds

TOOL WEAR

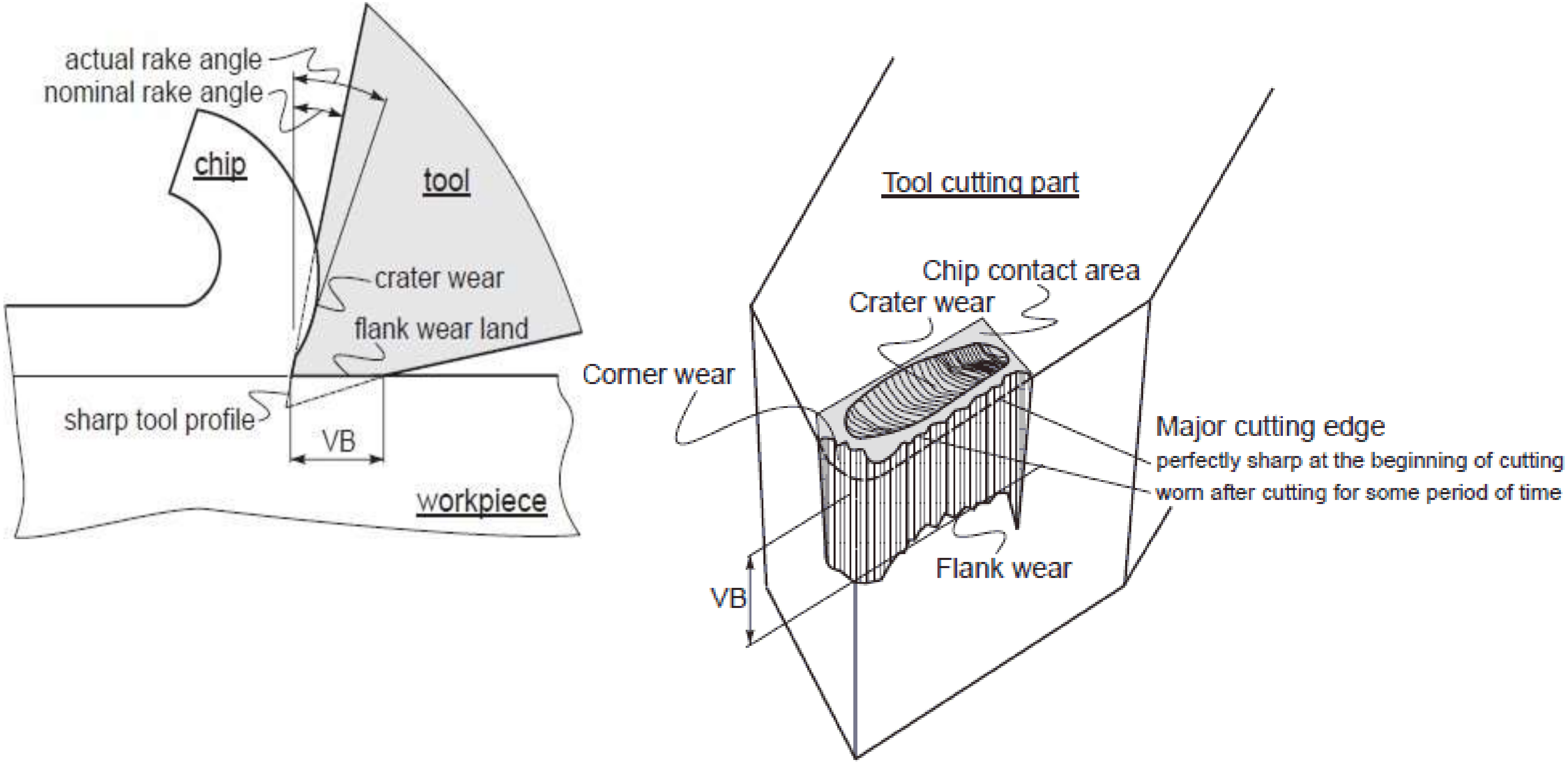
- Gradual wear occurs at two principal location on a cutting tool. Accordingly, two main types of tool wear can be distinguished,

1. **Crater wear:**

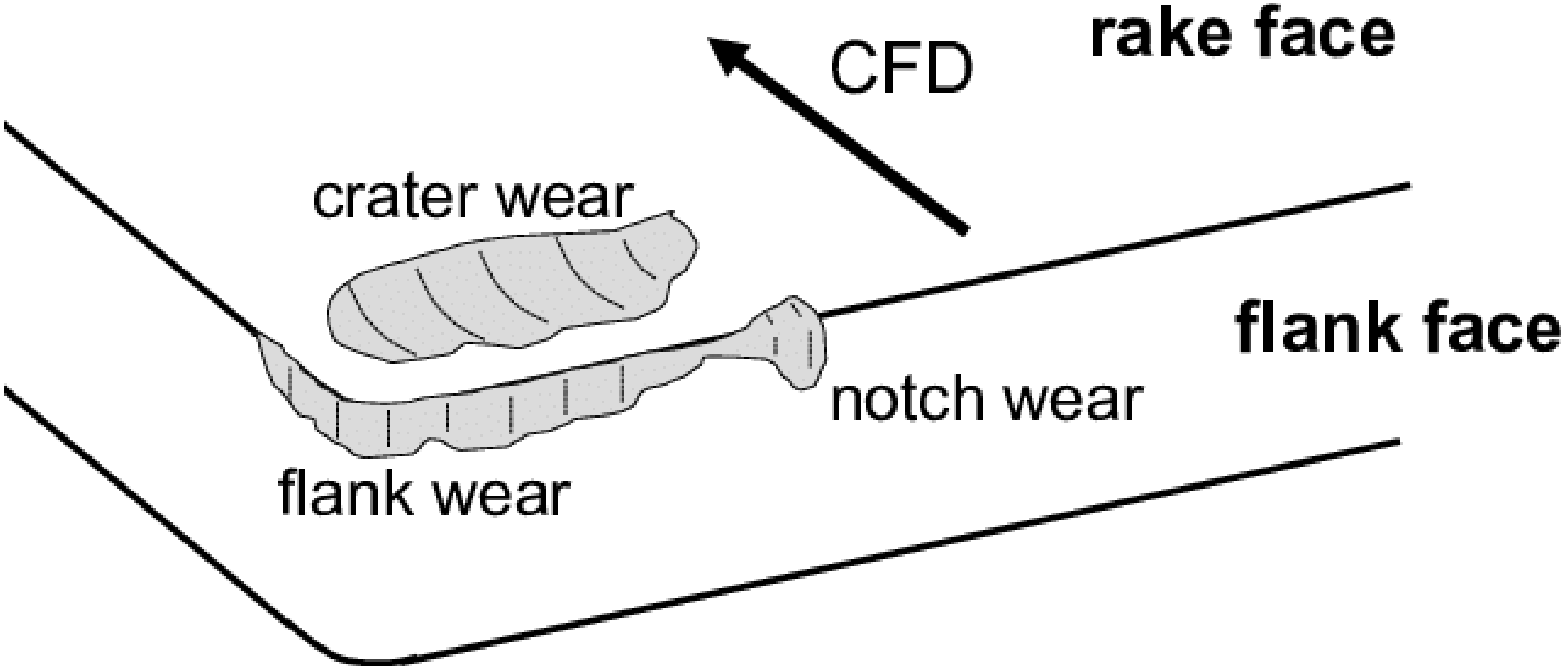
- Consists of a concave section on the tool face formed by the action of the chip sliding on the surface.
- Crater wear affects the mechanics of the process increasing the actual rake angle of the cutting tool and consequently, making cutting easier.
- At the same time, the crater wear weakens the tool wedge and increases the possibility for tool breakage.
- In general, crater wear is of a relatively small concern.

2. Flank wear

- Occurs on the tool flank as a result of friction between the machined surface of the workpiece and the tool flank.
- Flank wear appears in the form of so-called **WEAR LAND** and is measured by the width of this wear land, VB.
- Flank wear affects to the great extend the mechanics of cutting. Cutting forces increase significantly with flank wear.
- If the amount of flank wear exceeds some critical value (VB > 0.5~0.6 mm), the excessive cutting force may cause tool failure.



Types of wear observed in cutting tools

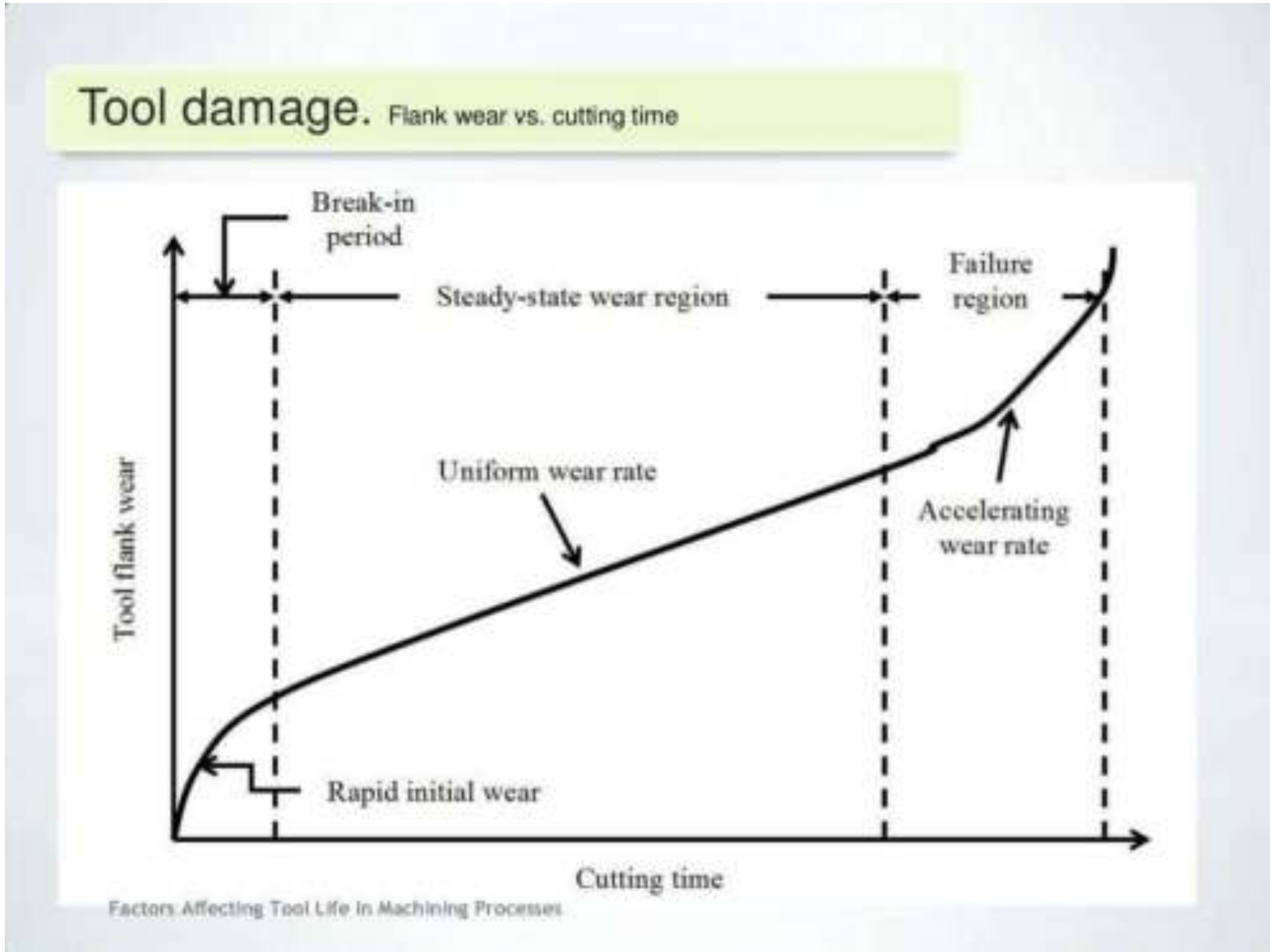


rake face
CFD
crater wear
flank face
notch wear
flank wear

TOOL WEAR

The wear of tools takes place in 3 stages:

1. **Break in (rapid wear)**
2. **Steady-state wear (uniform wear rate)**
3. **Failure (acc. wear)**



Measurement of tool wear

The various methods are :

- by loss of tool material in volume or weight, in one life time – this method is crude and is generally applicable for critical tools like grinding wheels.
- using optical microscope fitted with micrometer – very common and effective method
- using scanning electron microscope (SEM) – used generally, for detailed study; both qualitative and quantitative
- Talysurf, specially for shallow crater wear

TOOL LIFE

- As a machining operation progresses, the cutting edge of the tool gradually wears out and at a certain stage it stops cutting metal efficiently (as per requirement).
- It has to be re-sharpened to make it cut.
- Tool life – useful cutting life of the tool from the start of cut until such a time when the tool no longer performs the designed function defined by the failure criteria. (expressed as time)

OR

- Tool life is defined as **the *length of cutting time* that the tool can be used satisfactorily**

TOOL LIFE cont.

The various possible indicators of end of tool life are:

1. **Failure of Tool**
2. **Extend of Tool wear**
3. **Poor surface finish**
4. **Dimensional instability**
5. **Sudden increase in cutting forces and power**
6. **Overheating and fuming**
7. **Presence of chatter etc.**

TOOL LIFE cont.

The various factors affecting cutting tool life are:

1. **Cutting Tool material**
2. **Workpiece material**
3. **Machining parameters**
4. **Cutting tool geometry**
5. **Cutting fluid**
6. **Nature of cutting (continuous or intermittent)**

Tool life is governed mainly by the level of the machining parameters i.e.,

1. **Cutting velocity (V)**
2. **Feed (f)**
3. **Depth of cut (d)**

Cutting velocity affects maximum and depth of cut minimum

TAYLORS EQUATION (for Tool life)

- The usual pattern of growth of cutting tool wear (mainly V_B), principle of assessing tool life and its dependence on cutting velocity are schematically shown below

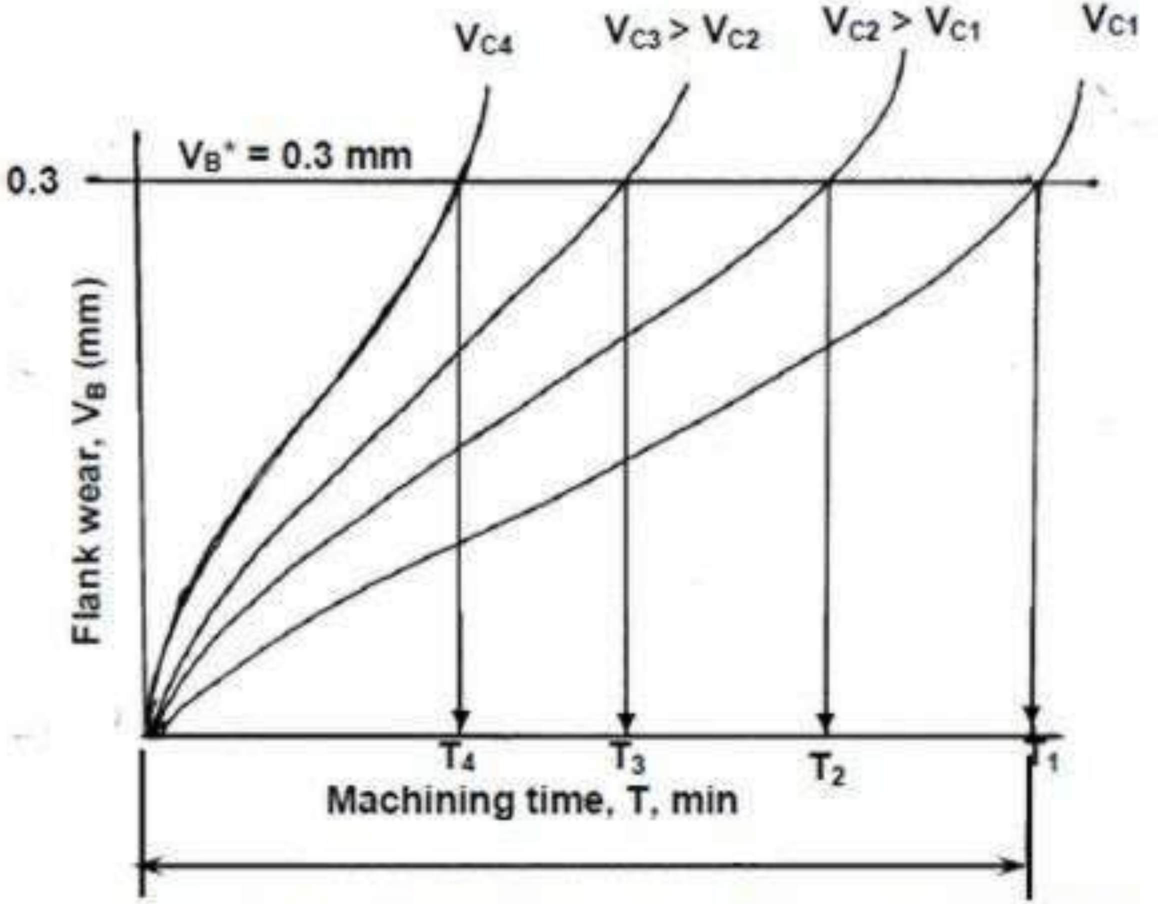
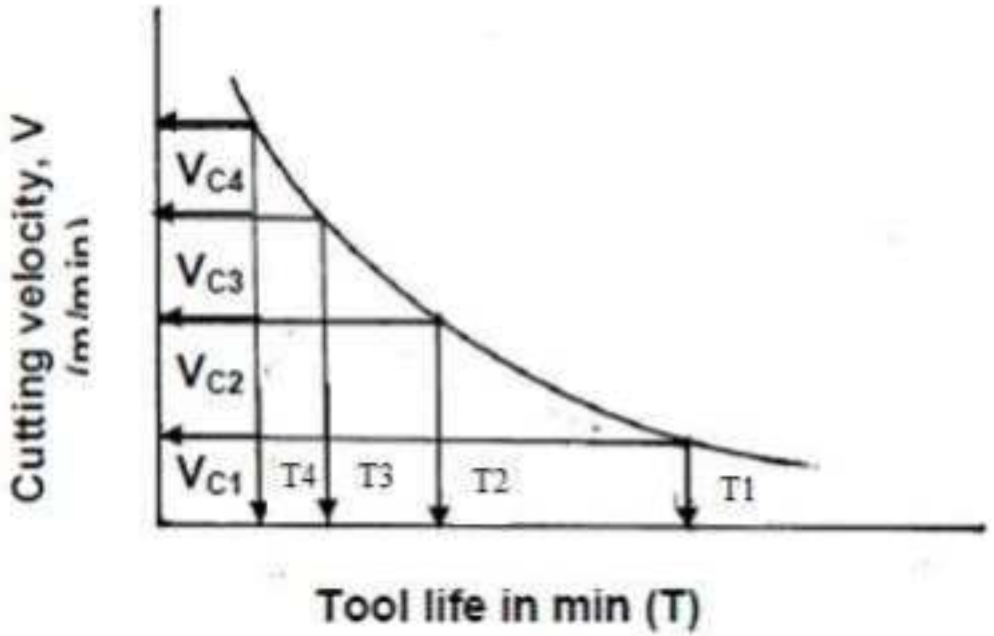
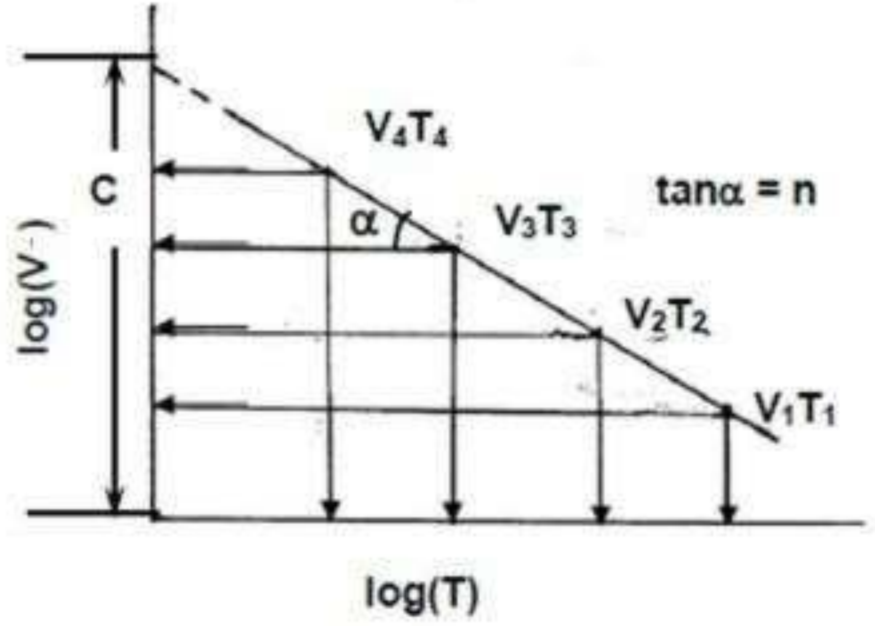


Fig. 3.2.3 Growth of flank wear and assessment of tool life

TAYLORS EQUATION (for Tool life)

- If the tool lives, T_1, T_2, T_3, T_4 etc. are plotted against the corresponding cutting velocities, V_1, V_2, V_3, V_4 etc. as shown in Fig. below, a smooth curve like a rectangular hyperbola is found to appear.
- When Taylor plotted the same figure taking both V and T in log-scale, a more distinct linear relationship appeared





TAYLORS EQUATION (for Tool life)

- With the slope, n and intercept, c, Taylor derived the simple equation as

$$VT^n = C$$

- where, n is called, Taylor's tool life exponent.

the values of both 'n' and 'C' depend mainly upon the tool-work materials and the cutting environment (cutting fluid application). The value of C depends also on the limiting value of V_B undertaken (i.e., 0.3 mm, 0.4 mm, 0.6 mm etc.)

Common Values for n

$$n = 0.1 \text{ to } 0.15 \text{ for HSS tools}$$
$$= 0.2 \text{ to } 0.4 \text{ for Carbide tools}$$
$$= 0.4 \text{ to } 0.6 \text{ for Ceramic tools}$$

CUTTING FLUIDS

- Work in two ways:
  - reduces cutting temperature directly by taking away the heat from the cutting zone and
  - also indirectly by reducing generation of heat by reducing cutting forces and friction.

Cutting Fluids - Purposes of application

1. Cooling of the job and the tool to reduce the detrimental effects of cutting temperature on the job and the tool
2. Lubrication at the chip–tool interface and the tool flanks to reduce cutting forces and friction and thus the amount of heat generation.
3. Cleaning the machining zone by washing away the chip – particles and debris which, if present, spoils the finished surface and accelerates damage of the cutting edges
4. Protection of the nascent finished surface – a thin layer of the cutting fluid sticks to the machined surface and thus prevents its harmful contamination by the gases like SO_2, O_2, present in the atmosphere.
5. The main aim of application of cutting fluid is to improve machinability through reduction of cutting forces and temperature, improvement by surface integrity and enhancement of tool life

Essential properties of cutting fluids

- Cutting fluid should fulfill its functional requirements without harming the Machine – Fixture – Tool – Work (M-F-T-W) system and the operators. Hence, cutting fluid should possess the following properties:

1. For cooling :
   - high specific heat, thermal conductivity and film coefficient for heat transfer
   - spreading and wetting ability
2. For lubrication :
   - high lubricity without gumming and foaming
   - wetting and spreading
   - high film boiling point
   - friction reduction at extreme pressure (EP) and temperature
3. Chemical stability, non-corrosive to the materials of the M-F-T-W system

Essential properties of cutting fluids

4. Less volatile and high flash point
5. Non toxic in both liquid and gaseous stage
6. High resistance to bacterial growth
7. Odourless and also preferably colourless
8. Easily available and low cost.

MACHINABILITY

- Is a term used to assess the ease with which a material could be machined
- Difficult to quantify machinability since a **large number of factors** are involved. The major factors are:
    1. **Cutting forces and power absorbed**
    2. **Tool wear and Tool life**
    3. **Surface finish**
    4. **Dimensional accuracy**
    5. **Machining cost**
- These factor are affected by **variables** like, **work material, tool material & geometry, cutting conditions, machine variables** etc.

MACHINABILITY

VARIABLES AFFECTING MACHINABILITY

1. **work material** - hardness, tensile strength, microstructure etc.
2. **tool material & geometry** – rake angle and nose radius have effect on surface finish and other parameters
3. **cutting conditions** – cutting speed, feed, use of cutting fluids etc.
4. **machine variables** – power, torque, accuracy, rigidity etc.

MACHINABILITY

ASSESSMENT OF MACHINABILITY

- The machinability of a material may be assessed by one or more of the following criteria:
  1. Long tool life at a given cutting speed
  2. Maximum material removal per tool re-sharpening
  3. Cutting force/power: Lowest cutting force on the tool or power consumption per unit vol. of material removed
  4. High Surface finish achieved under specific cutting conditions
  5. Good and uniform dimensional accuracy of successive parts
  6. Easily disposable chips

MACHINABILITY INDEX

- **Tool life** is the most important factor for assessing machinability.
- Since tool life is a direct function of cutting speed, a better machinable metal is one which permits higher cutting speed for a given tool life.
- **Machinability rating/index:**
  - Helps in comparing machinability of different materials
  - It is **relative measure**, comparing to a **index which is standardized**. **(Machinability index of free cutting steel is arbitrarily fixed as 100 %)**
- For other materials:

$$\textbf{Machinability index (\%)} = \frac{\textbf{Cutting speed of material for 20 min tool life}}{\textbf{Cutting speed of free cutting steel for 20 min tool life}} \times 100$$

MACHINABILITY INDEX

- **MI for some common materials:**
  - C-20 steel = 65
  - C-45 steel = 60
  - Stainless steel = 20
  - Copper = 70
  - Brass = 180
  - Aluminium alloys = 300-1500
  - Magnesium alloys = 600-2000

Thank You

MODULE 2

Course Code: MET 385

Prepared by-
Dr. Roja Abraham Raju

General Purpose Machine Tools

General classification of machine tools

- Conventional or traditional machine tools like Lathes, Milling machines, etc. are used more widely for faster material removal by shearing or brittle fracturing.
- Non-conventional or non-traditional machine tools: like EDM, ECM, USM, etc. which remove material from exotic materials slowly by electro-physical, electro-chemical processes.
- Modern numerical and computer controlled machine tools: Like CNC lathe, CNC milling etc.

General Purpose Machine Tools

- Lathes
- Drilling machines
- Shaping machines
- Planning machines
- Slotting machines
- Milling machines
- Boring machines
- Hobbing machines
- Gear shaping machines
- Broaching machines
- Grinding machine

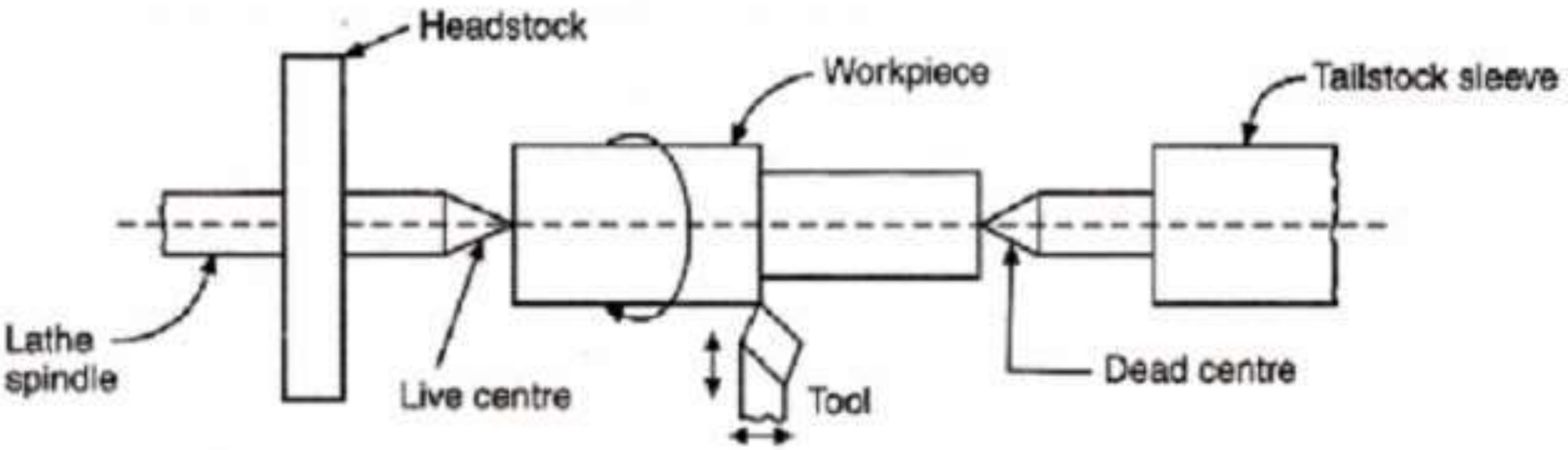
LATHE

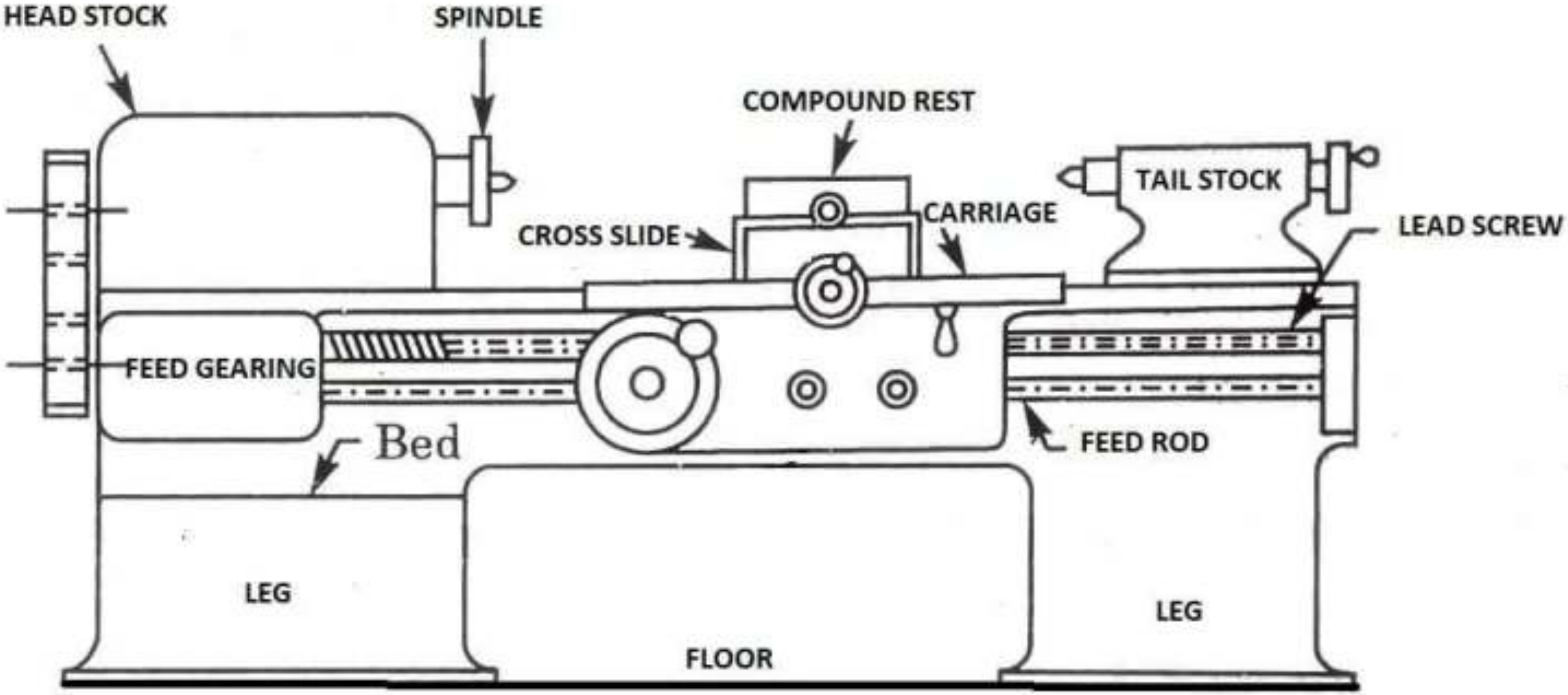
Lathe is a machine, which removes the metal from a piece of work to the required shape and size.

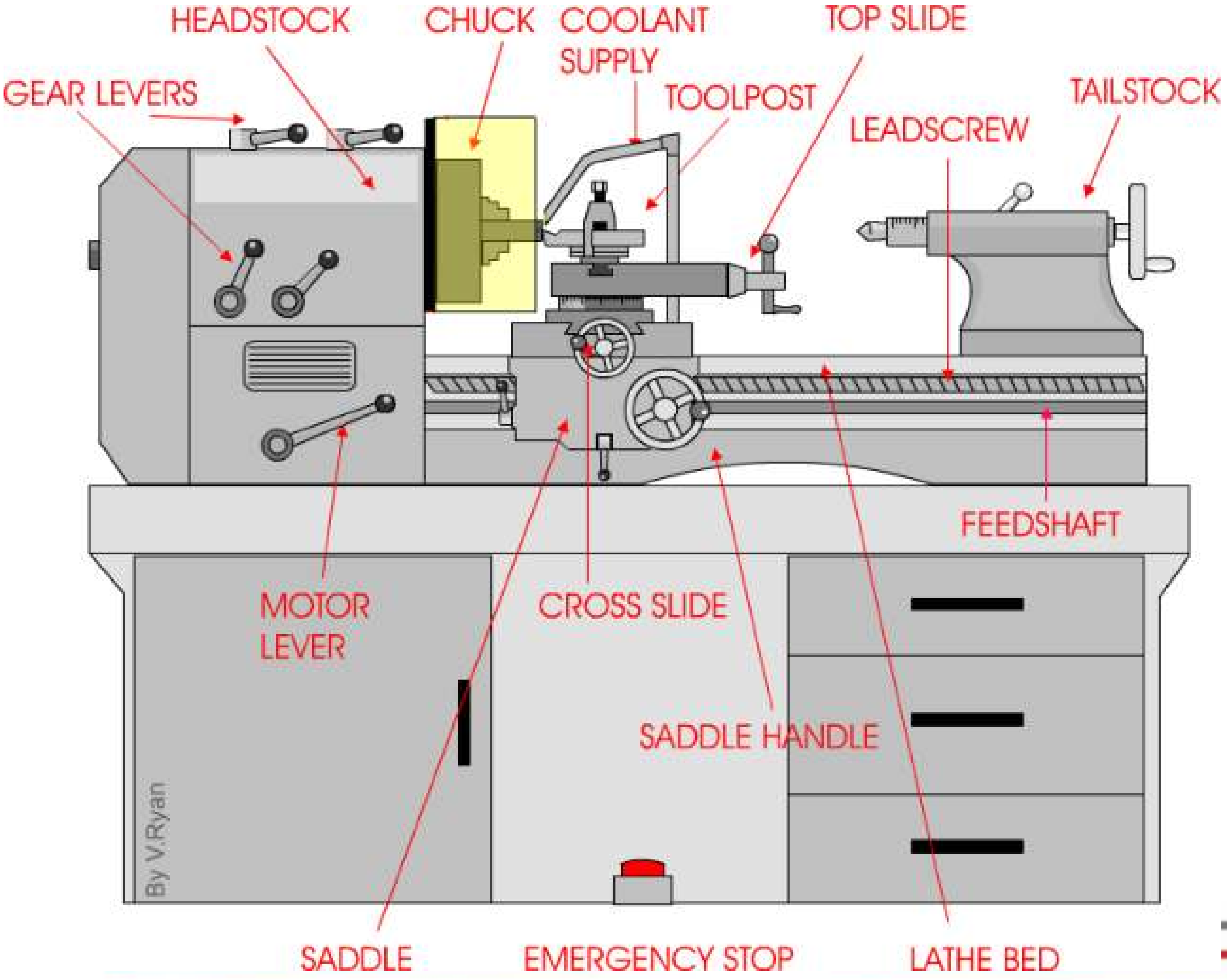
- Lathe is one of the most important machine tools in the metal working industry. A lathe operates on the principle of a rotating workpiece and a fixed cutting tool.
- The cutting tool is feed into the workpiece, which rotates about its own axis, causing the workpiece to be formed to the desired shape.

Working Principle

- The lathe is a machine tool which holds the workpiece between two rigid and strong supports called centers or in a chuck or face plate which revolves.
- The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work.
- The normal cutting operations are performed with the cutting tool fed either parallel or at right angles to the axis of the work.




HEAD STOCK
SPINDLE
COMPOUND REST
TAIL STOCK
CARRIAGE
CROSS SLIDE
LEAD SCREW
FEED GEARING
Bed
FEED ROD
LEG
FLOOR
LEG


HEADSTOCK
CHUCK
COOLANT SUPPLY
TOP SLIDE
GEAR LEVERS
TOOLPOST
TAILSTOCK
LEADSCREW
FEEDSHAFT
MOTOR LEVER
CROSS SLIDE
SADDLE HANDLE
By V.Ryan
SADDLE
EMERGENCY STOP
LATHE BED

How to specify a lathe

Specification of a Lathe

1. Swing- the largest work diameter that can be swung for the lathe bed.
2. The distance between the headstock and tailstock center.
3. Length of the bed in a meter.
4. The pitch of the lead screw.
5. Horsepower of the machine.
6. Speed range and the number of speeds of HS spindle.
7. The weight of the machine in a tonne.

Types of Lathe Machine

- Center or Engine Lathe
- Speed Lathe
- Capstan and Turret Lathe
- Tool Room Lathe
- Bench Lathe
- Automatic Lathe
- Special Purpose and
- CNC Lathe Machine

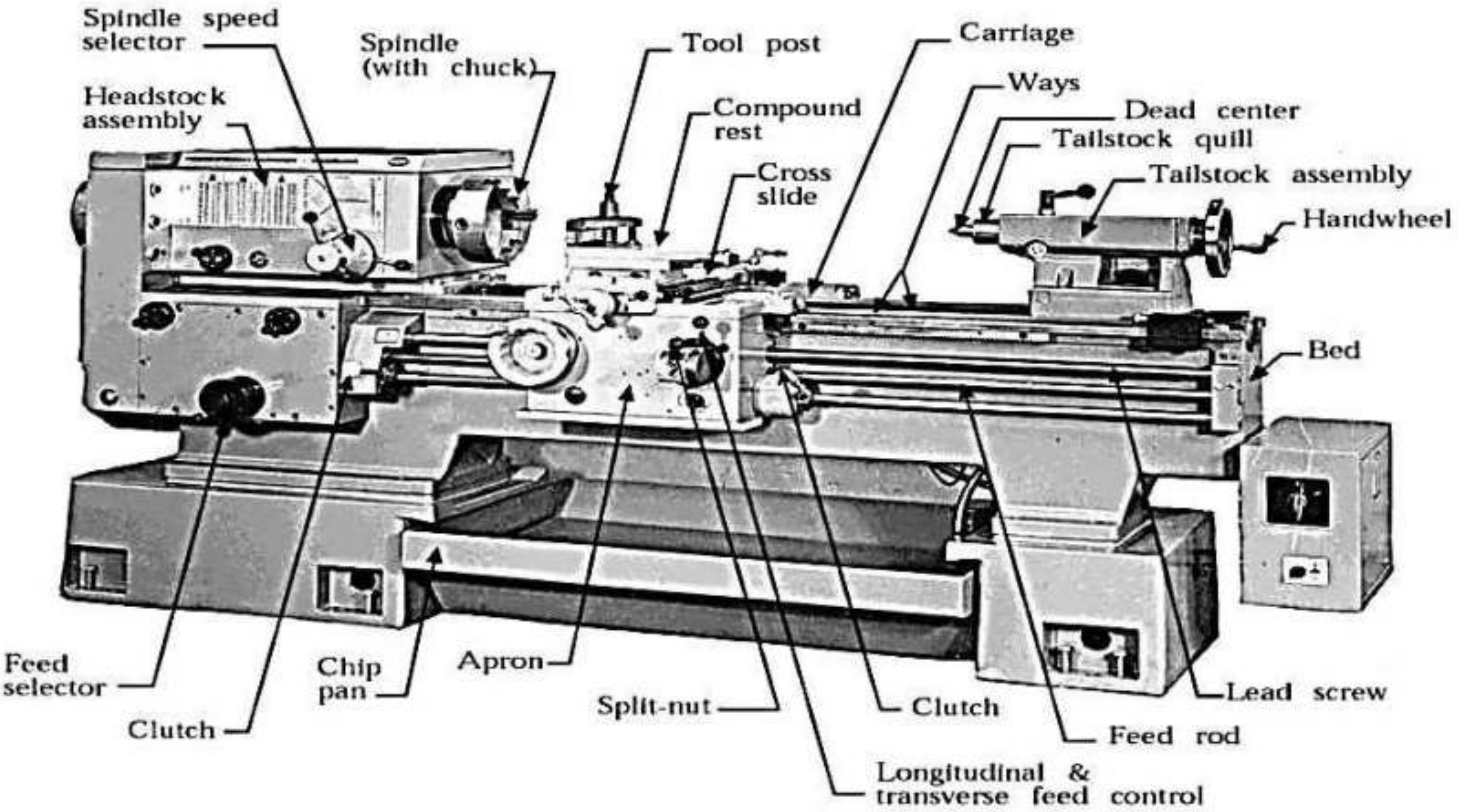
MAIN PARTS

Lathe Machine is also known as “**Centre Lathe**”, because it has two centres between which the job can be held and rotated.

The main parts of centre lathe are:

- Bed,
- Head stock,
- Tail stock,
- Carriage,etc

Lathe



Spindle speed selector
Spindle (with chuck)
Headstock assembly
Tool post
Compound rest
Cross slide
Carriage
Ways
Dead center
Tailstock quill
Tailstock assembly
Handwheel
Bed
Feed selector
Clutch
Chip pan
Apron
Split-nut
Clutch
Lead screw
Feed rod
Longitudinal & transverse feed control

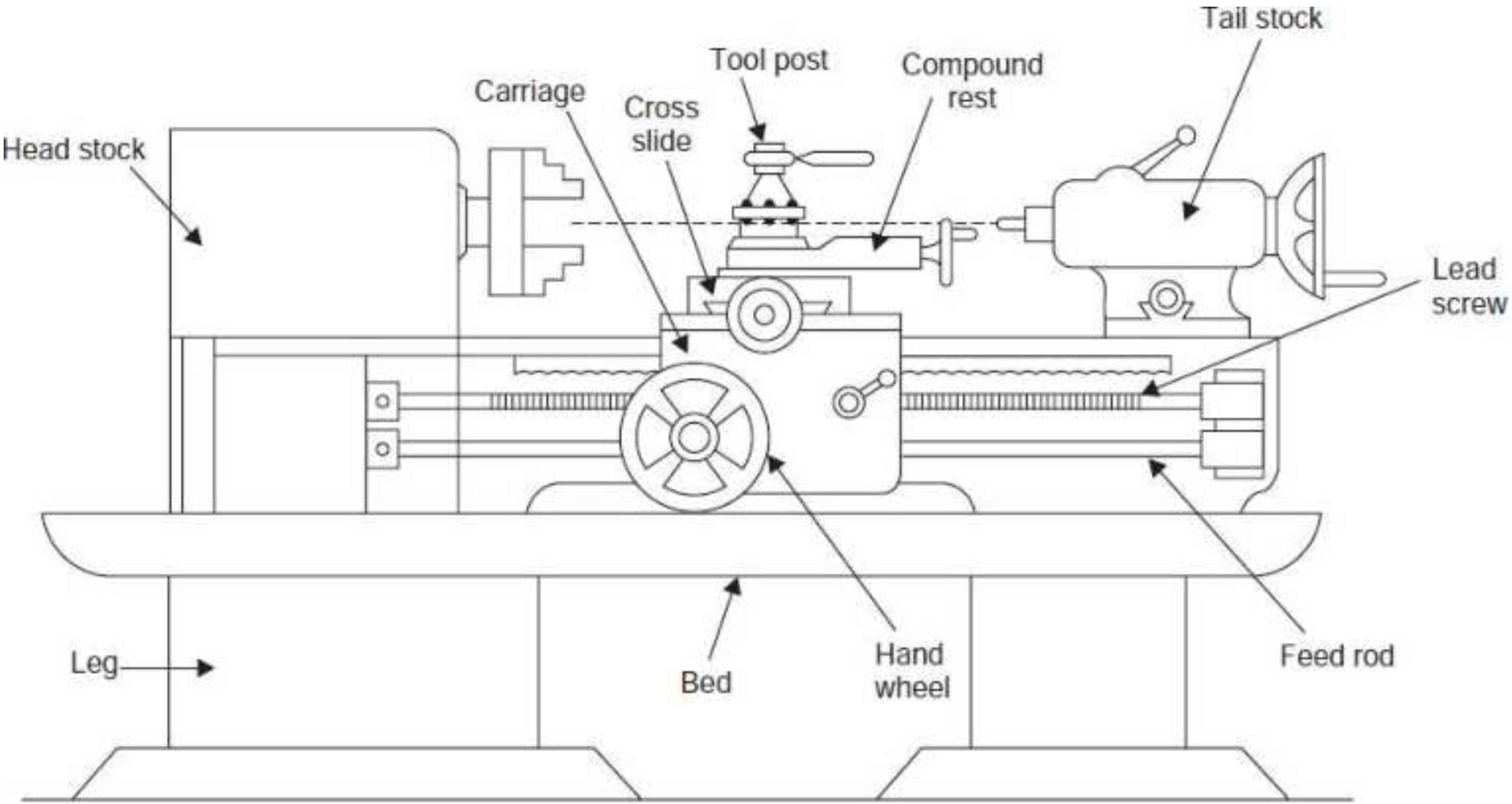


Fig. 1. Lathe Machine.

- Lathe Components
  - Bed: supports all major components
  - Carriage: slides along the *ways* and consists of the *cross-slide, tool post, apron*
  - Headstock – Holds the jaws for the work piece, supplies power to the jaws and has various drive speeds
- Tailstock – supports the other end of the workpiece
- Feed Rod and Lead Screw – Feed rod is powered by a set of gears from the headstock

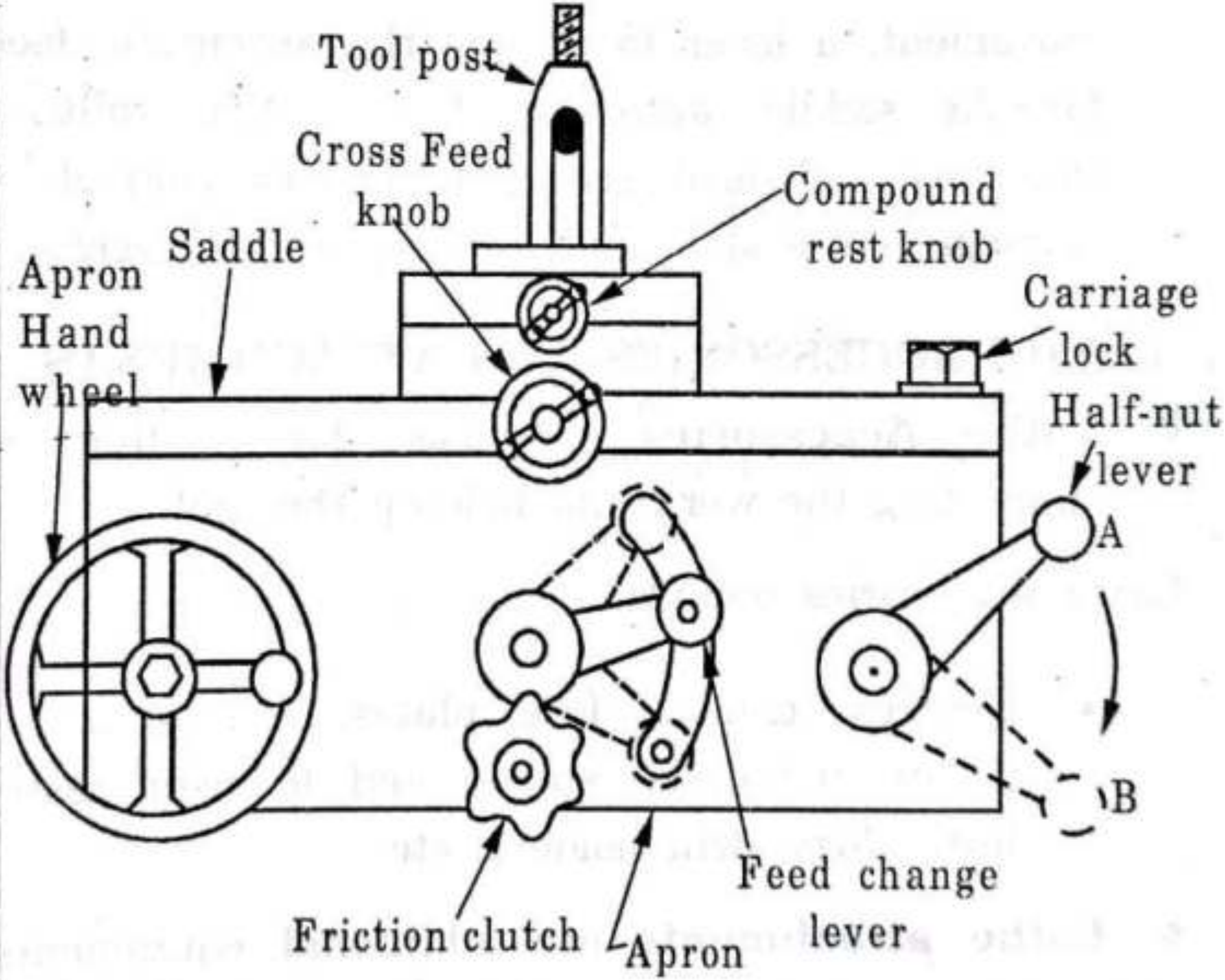


Fig 6.11. Controls on Carriage and Apron Assembly.

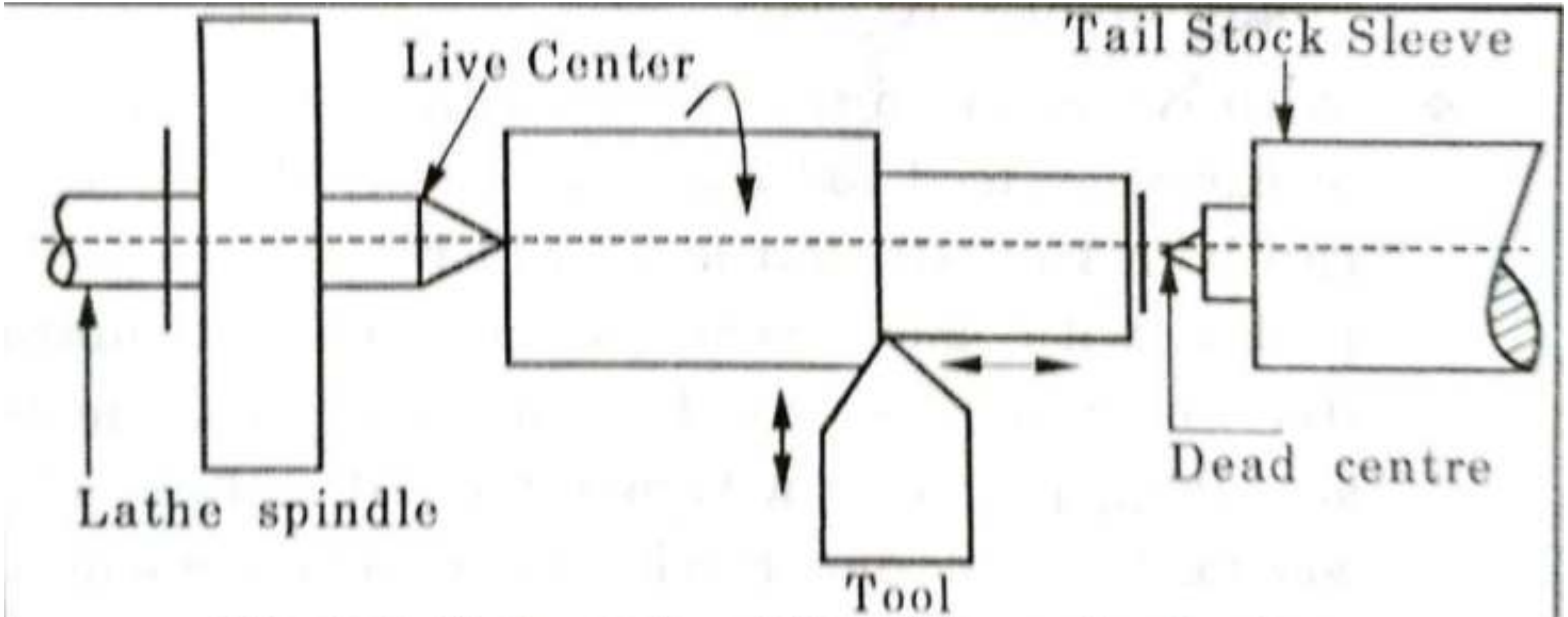


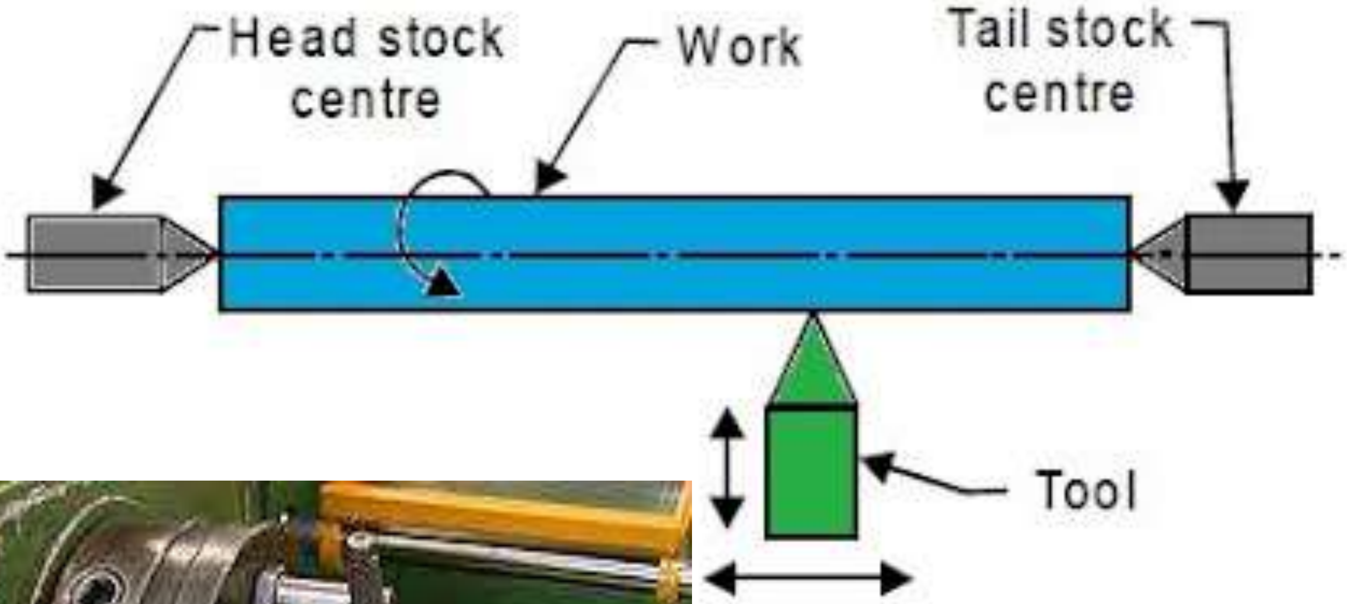
Fig.6.1. Principle of Working of a Lathe

WORKING PRINCIPLE OF LATHE

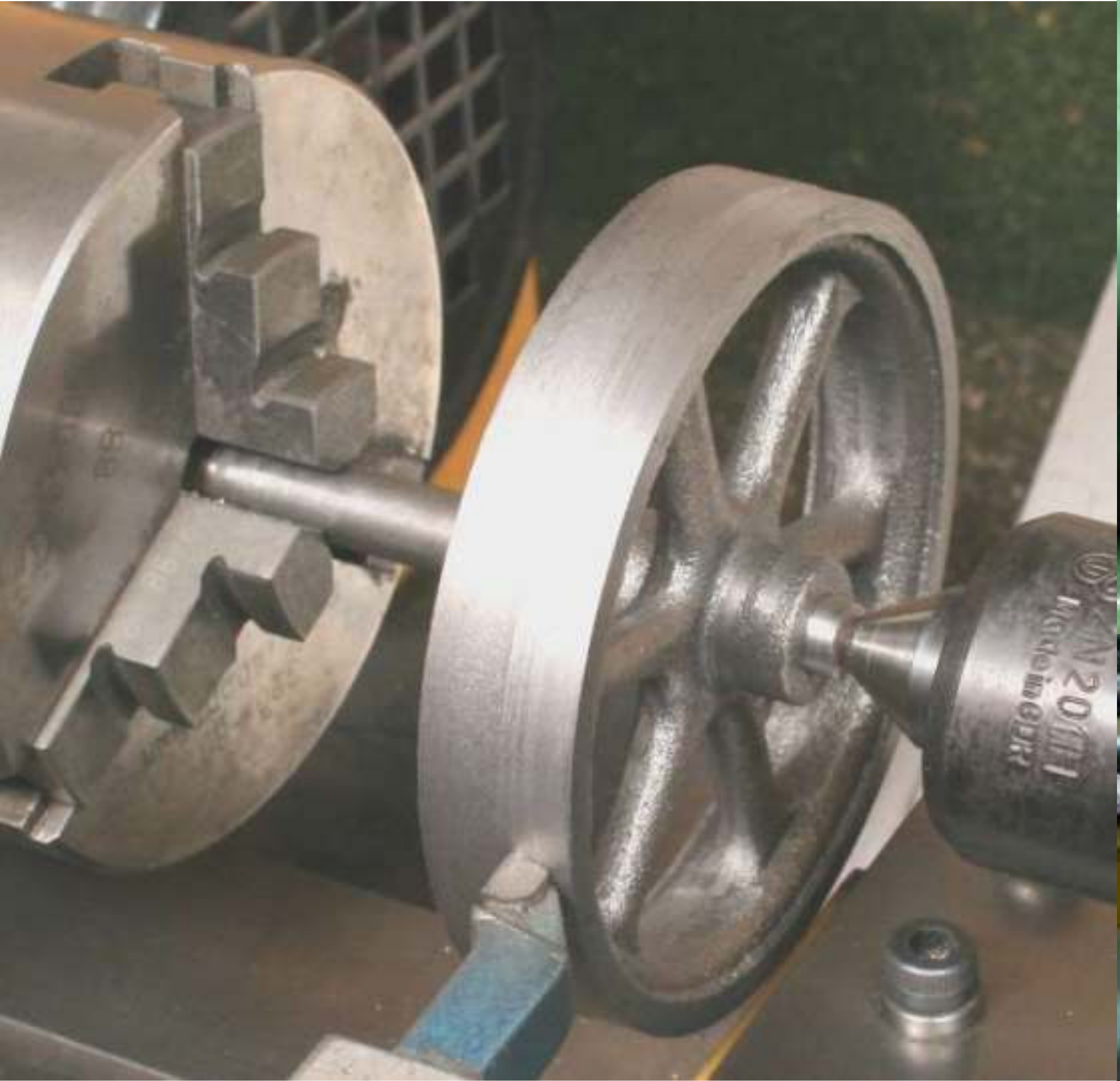
- It holds the work between two supports called centers.
- Chuck or Face plate is also used for holding the work.
- Chuck or face plate is mounted on machine spindle
- Cutting tool is held and supported on a tool post.
- Movement of the job is rotation about spindle axis
- Tool is fed against the revolving work
- Movement of the tool is either parallel to or at any inclination to the work axis

Work Holding Devices in Lathe Machine

- **Chuck -** Chuck is a one of the type of a work holding devices in lathe machine which is used in various operation for holding the work pieces or a job.
- **Centers-** Center is a work holding devices in lathe that is used to support a long jobs in between headstock and tailstock to carry out a lathe operation.
- **Steady Rest-** Steady rest is a type of work holding devices in lathe machine that is used to hold or support long cylinders or thin jobs.
- **Carriers-** The carrier or dog is a work holding devices in lathe machine used to hold a job when it needs to be fixed between the centers.
- **Driving Plate-** It is a circular plate used when turning jobs in between centers.
- **Face Plate-** This is a circular plate fixed on the lathe spindle used to perform various turning operations on large flat, irregular shaped jobs, castings, etc.
- **Mandrel-** The lathe mandrel is used to hold the workpieces or a job that is already bored or drilled. The mandrel is often hardened with tool steel and grinded to a specified size.It is grinded on a 1: 2000 taper.



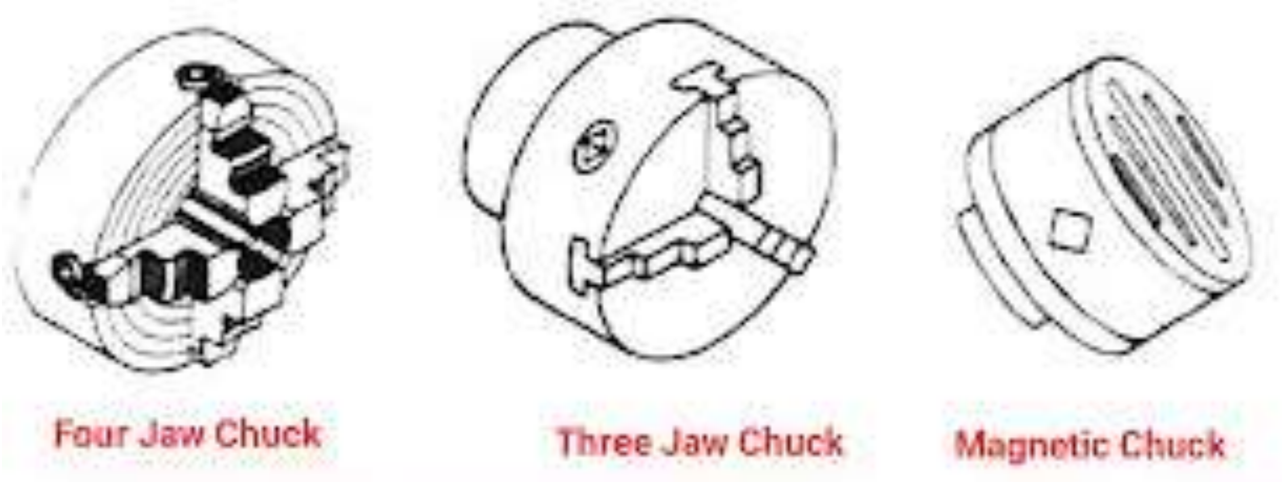
Drive Plate

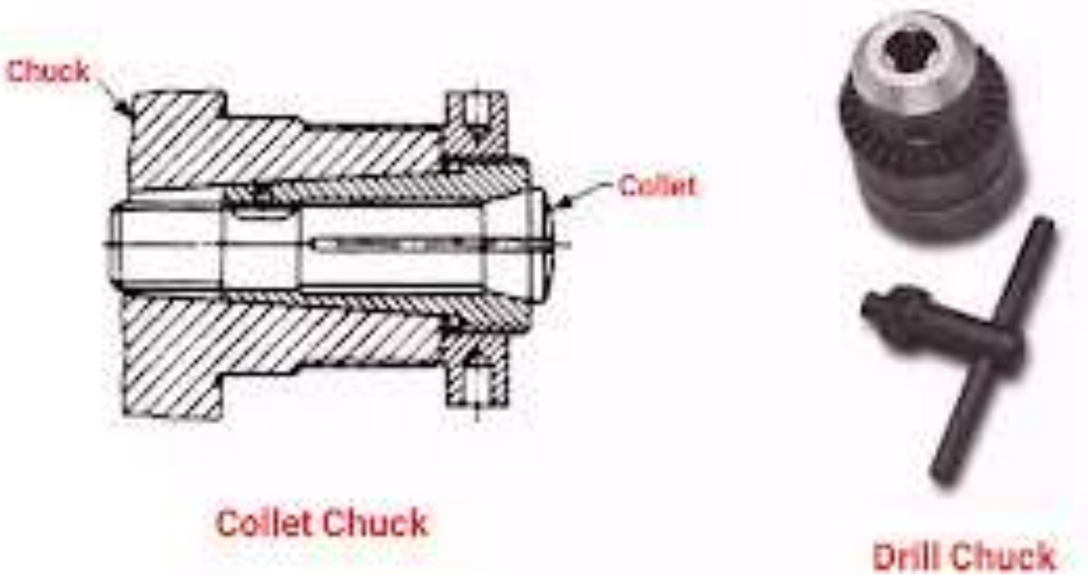


Types of Lathe Chuck

There are following types of chuck are used

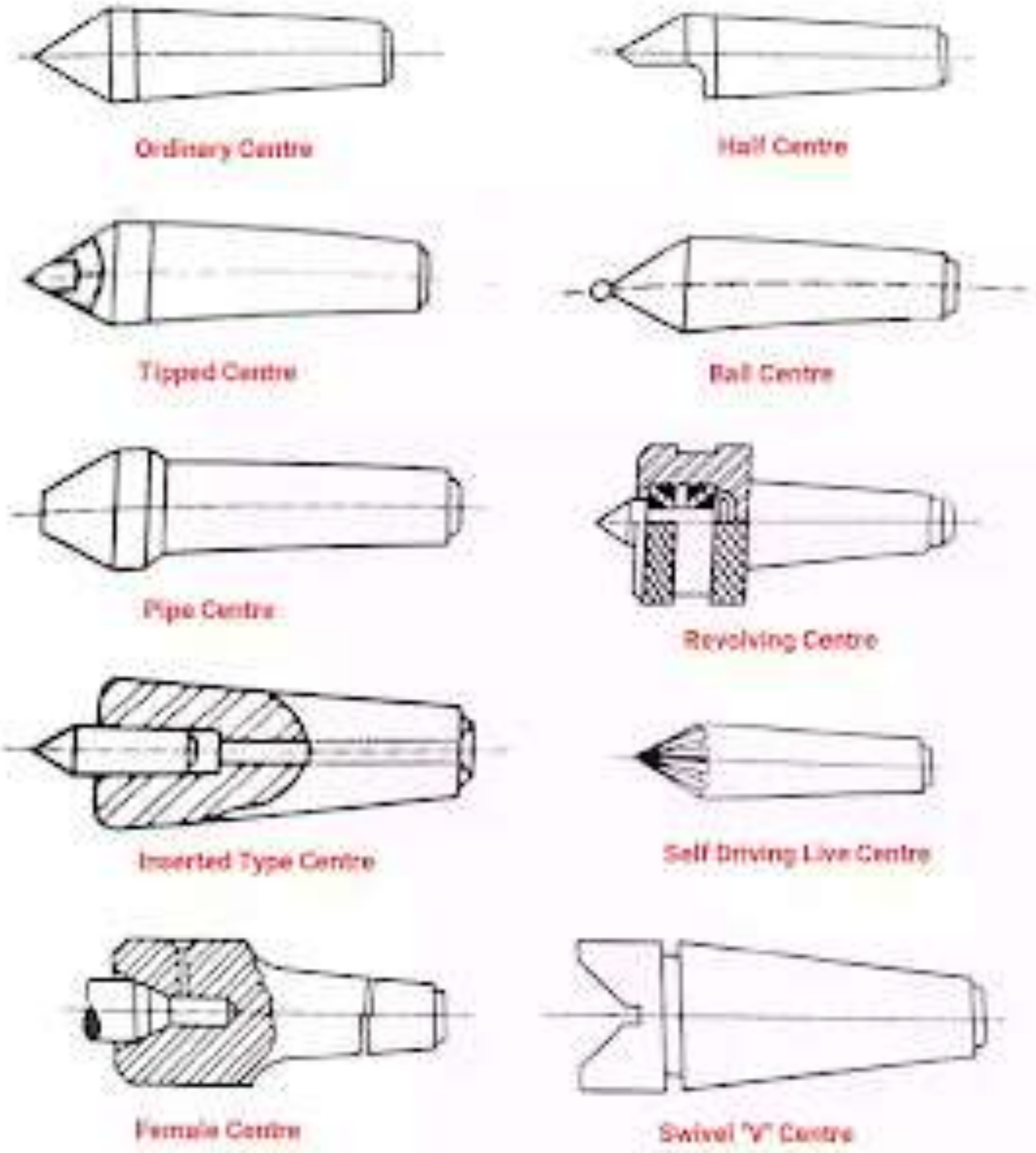
- Four Jaw Chuck
- Three Jaw Chuck
- Magnetic Chuck
- Collet Chuck
- Combination Chuck
- Air Chuck or Hydraulically Operated Chuck
- Drill Chuck





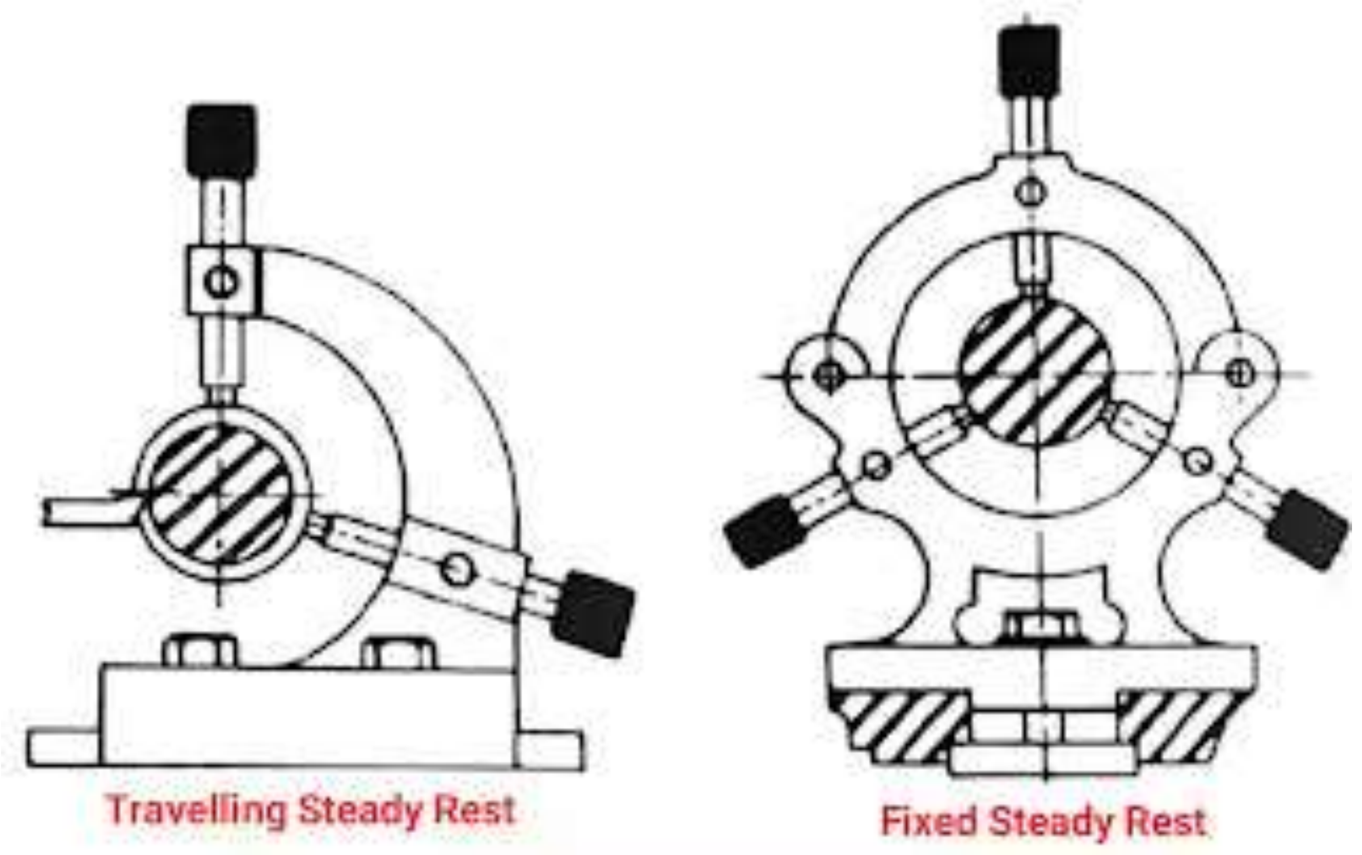
Types of Lathe Centers

- Ordinary Center
- Half Center
- Tipped Center
- Ball Center
- Pipe Center
- Revolving Center
- Inserted Type Center
- Self Driving Live Center
- Female Center
- Swivel 'V' Center



Types of Steady Rest

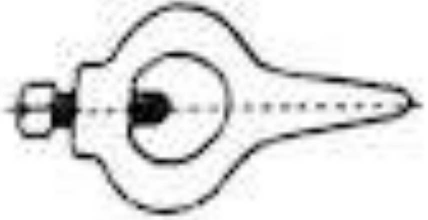
Often the following types of steady rests are used
•Traveling Steady Rest
•Fixed Steady Rest
•Revolving Steady Rest



Types of Lathe Carriers

Often the following types of lathe carriers are used

- Straight Tail Carrier
- Bent Tail Carrier
- Adjustable Carrier



Straight Tail Carrier

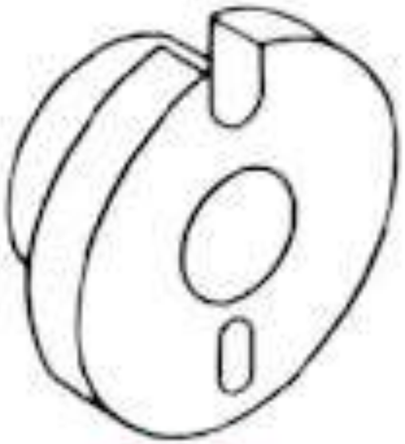
Bent Carrier

Adjustable Carrier

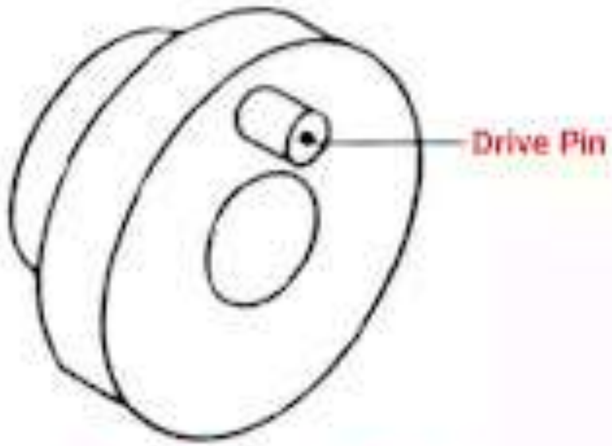
Types of Driving Plate

There are following types of driving plates are used

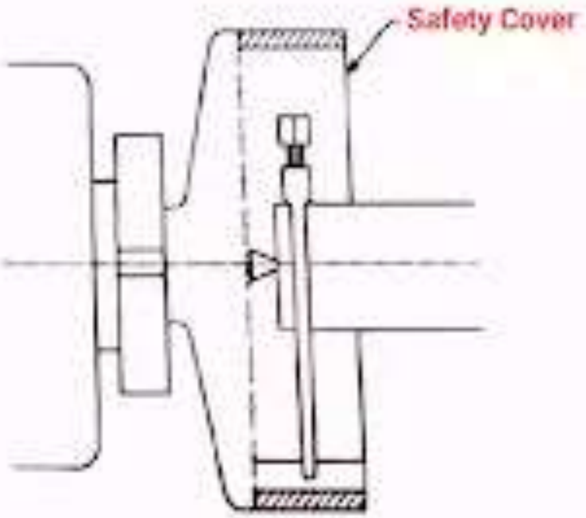
- Catch Plate
- Driving Plate with Pin
- Safety Driving Plate



Catch Plate



Driving Plate with Pin

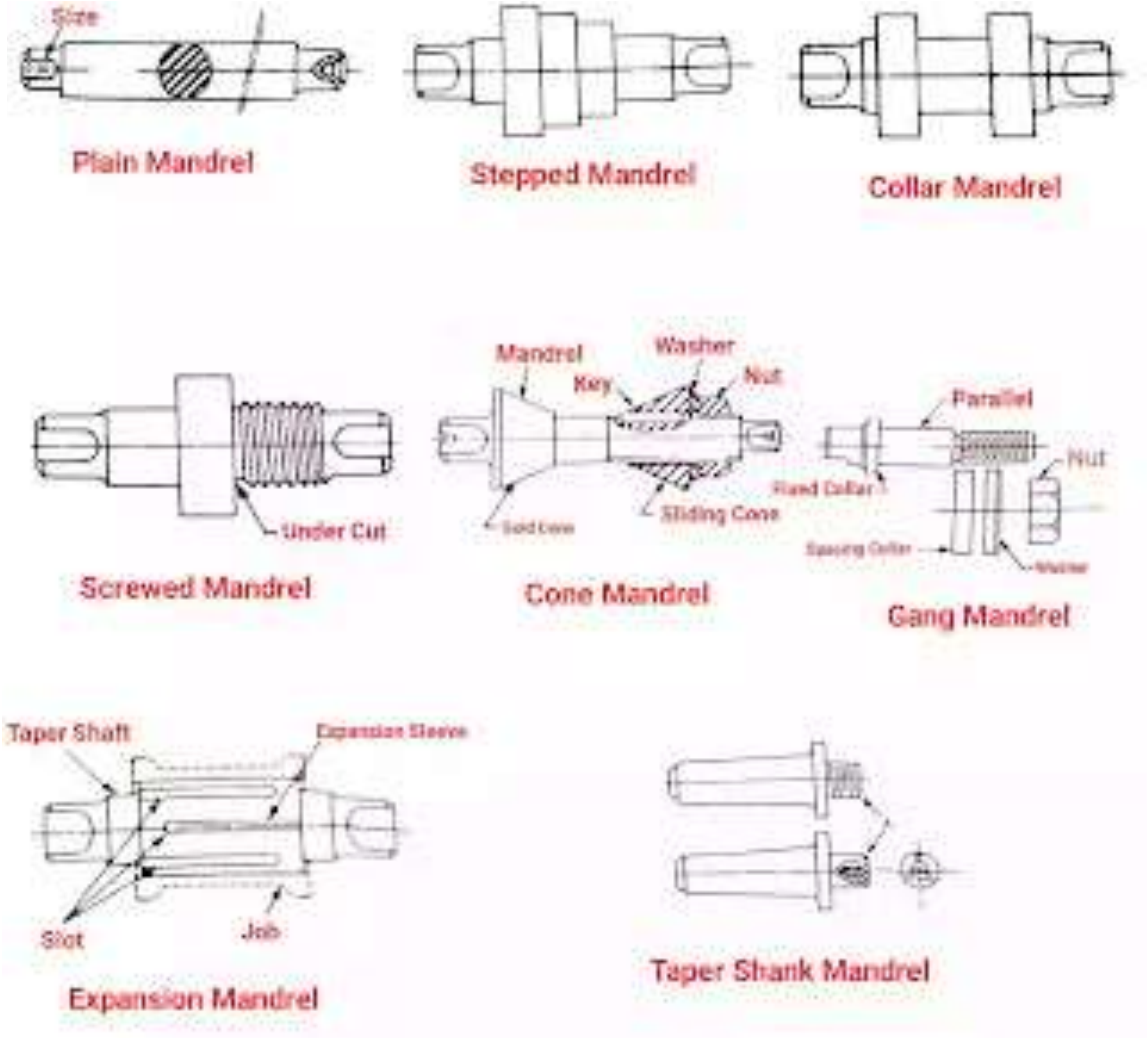


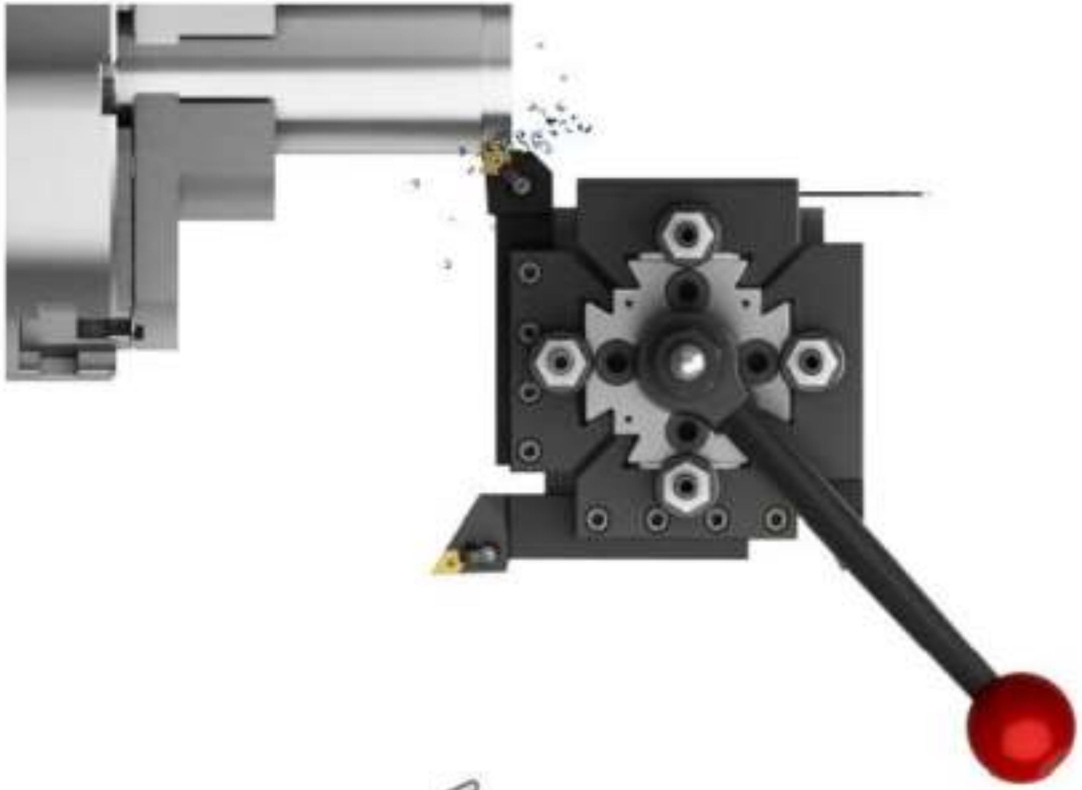
Safety Driving Plate

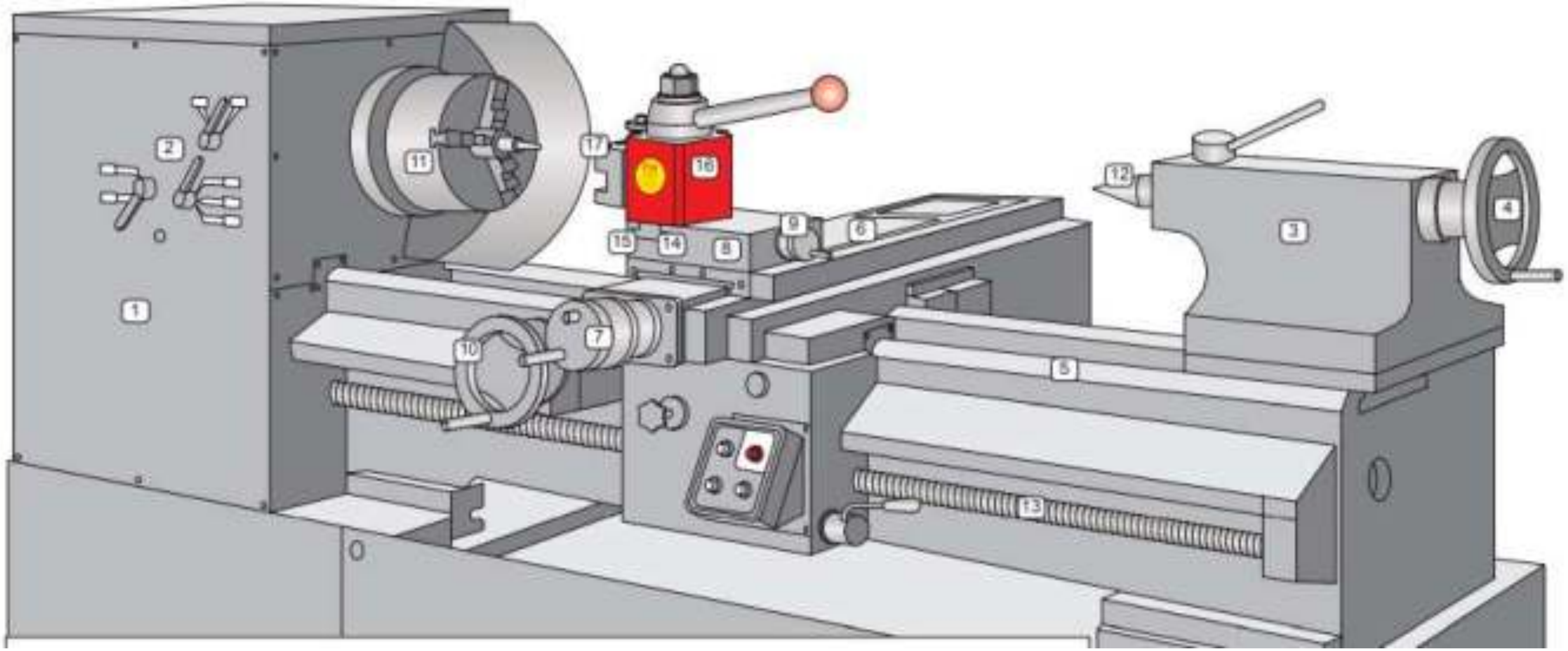
Types of Lathe Mandrel

The following types of mandrel are often used

- Plain Mandrel
- Stepped mandrel
- Collar Mandrel
- Screwed Mandrel
- Cone Mandrel
- Gang Mandrel
- Expansion Mandrel
- Taper Shank Mandrel



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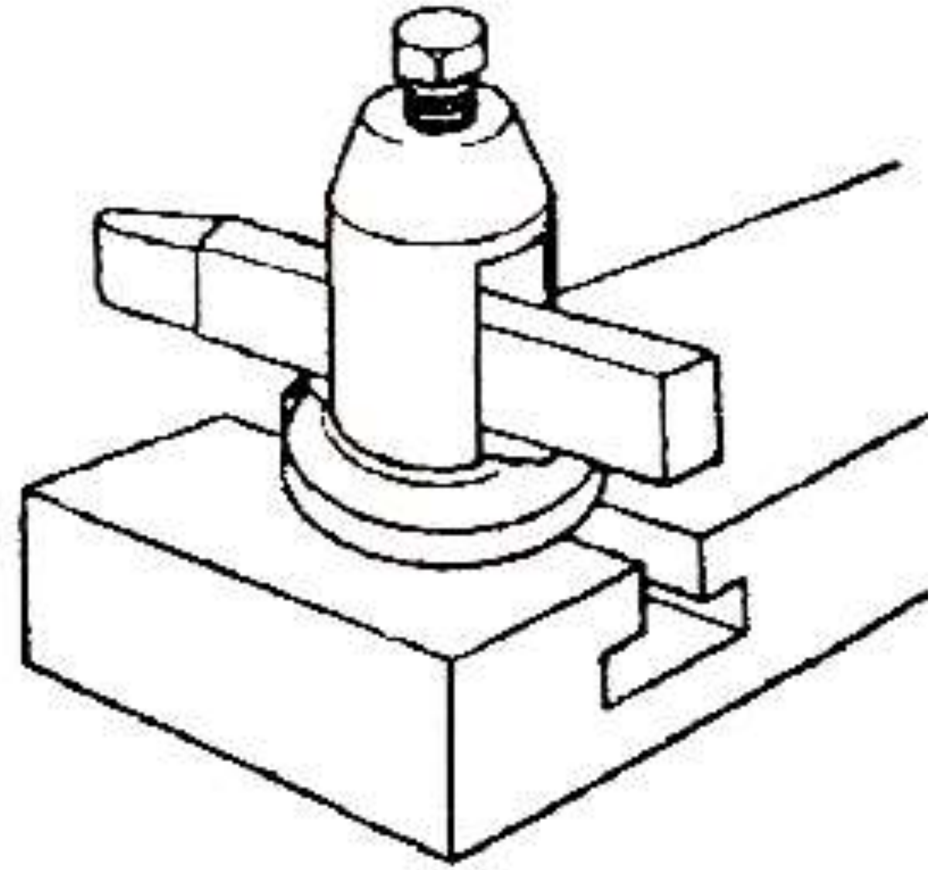
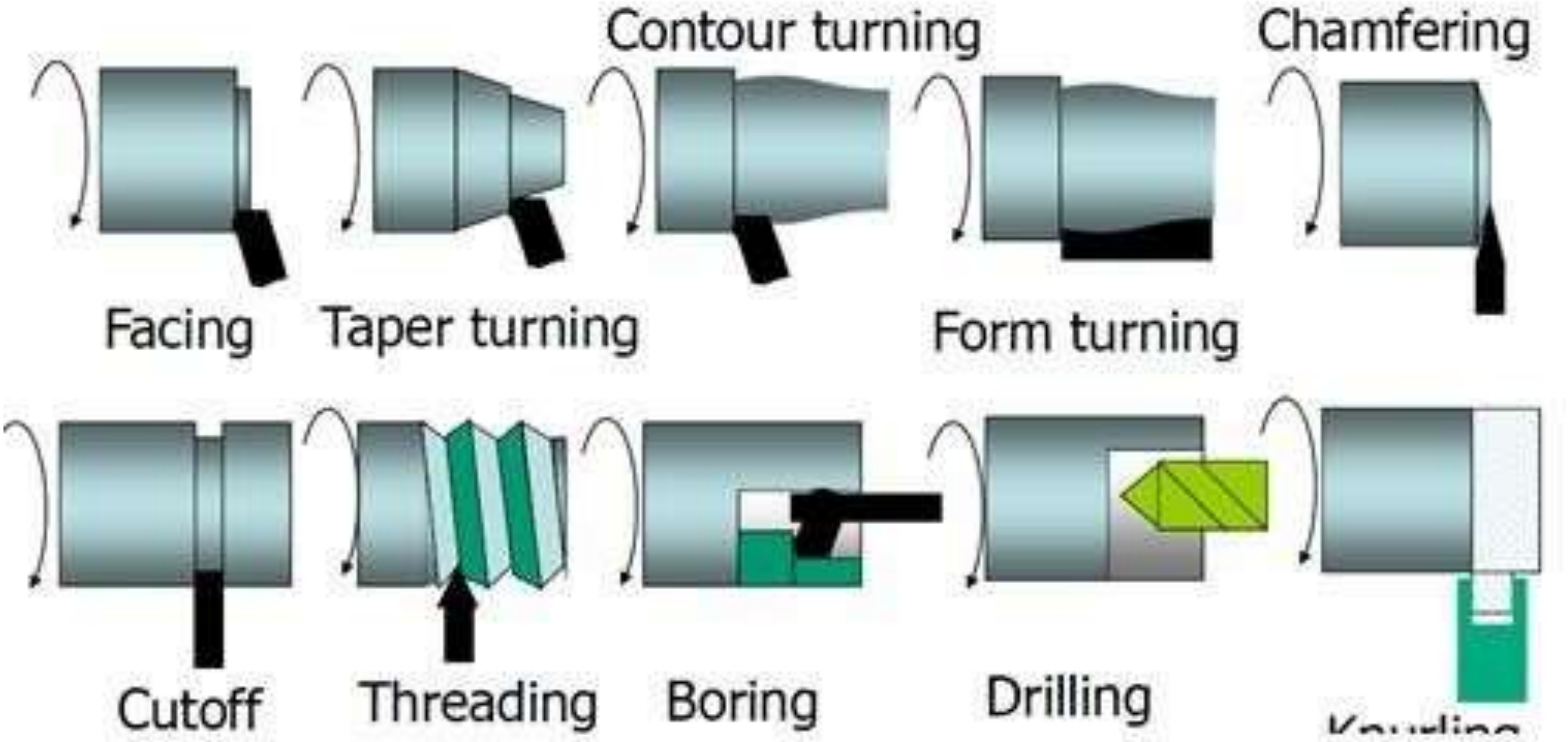
Lathe Machine Tool Post and it Types

- Quick Release Tool Post.
- Index Tool Post.
- Pillar Type Tool Post.
- Clamp Type Tool Post.
- Turret (4-Way) Tool Post.
- Super Six Index Turret.

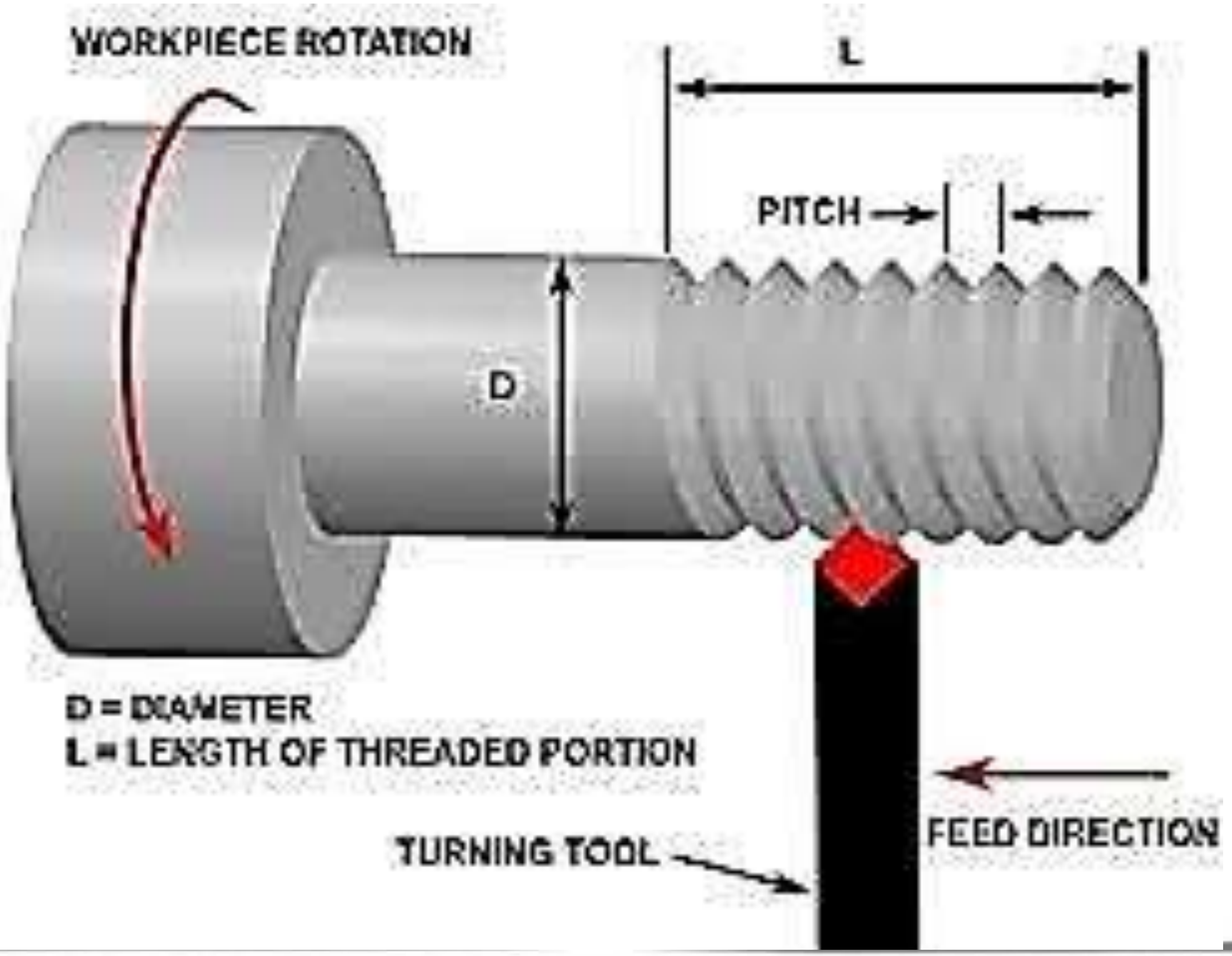


LATHE OPERATIONS

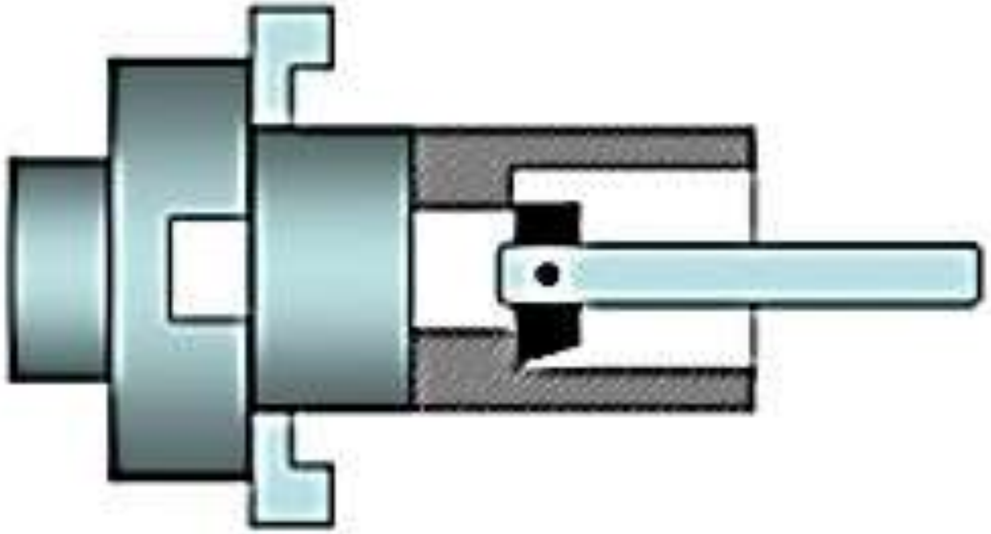
- **Turning**: to remove material from the outside diameter of a workpiece to obtain a finished surface.
- **Facing**: to produce a flat surface at the end of the workpiece or for making face grooves.
- **Boring**: to enlarge a hole or cylindrical cavity made by a previous process or to produce circular internal grooves.
- **Drilling**: to produce a hole on the work piece.
- **Reaming**: to finishing the drilled hole.
- **Threading**: to produce external or internal threads on the work piece.
- **Knurling**: to produce a regularly shaped roughness on the workpiece.


Contour turning
Chamfering
Facing
Taper turning
Form turning
Cutoff
Threading
Boring
Drilling

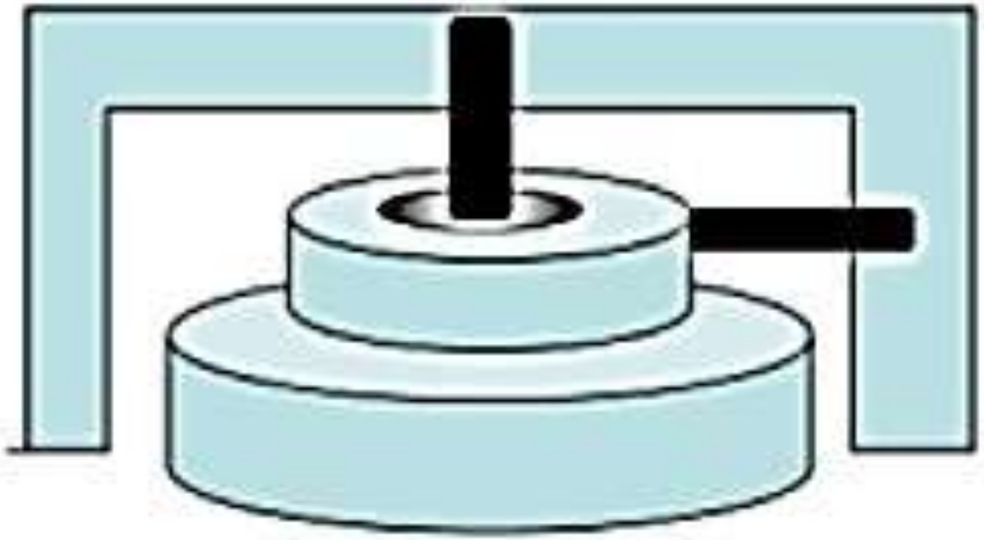
THREADING


WORKPIECE ROTATION
L
PITCH
D
D = DIAMETER
L = LENGTH OF THREADED PORTION
FEED DIRECTION
TURNING TOOL

- Boring – Cutting is done inside diameter of the work material



Horizontal Boring Machining



Vertical Boring Machining

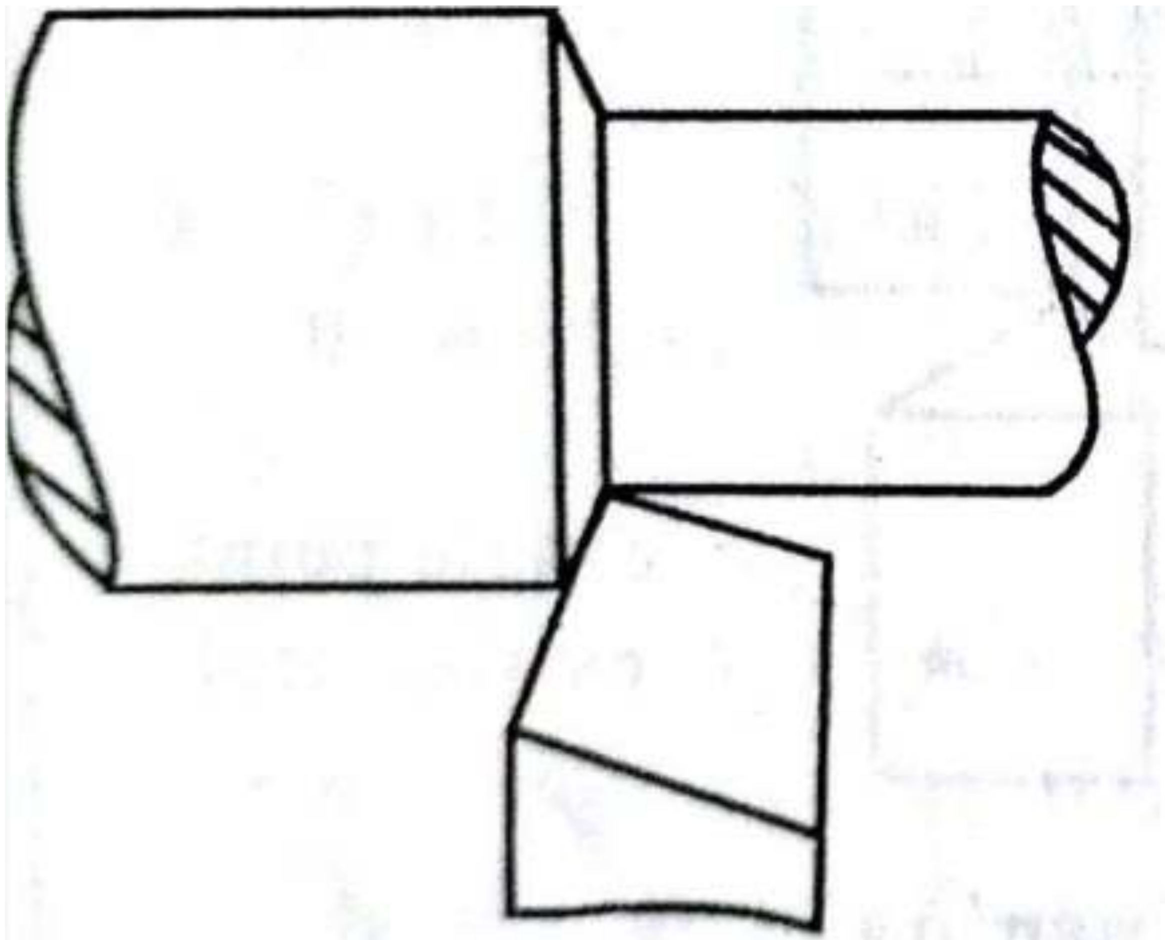


Fig. 6.27 Rough turning operation

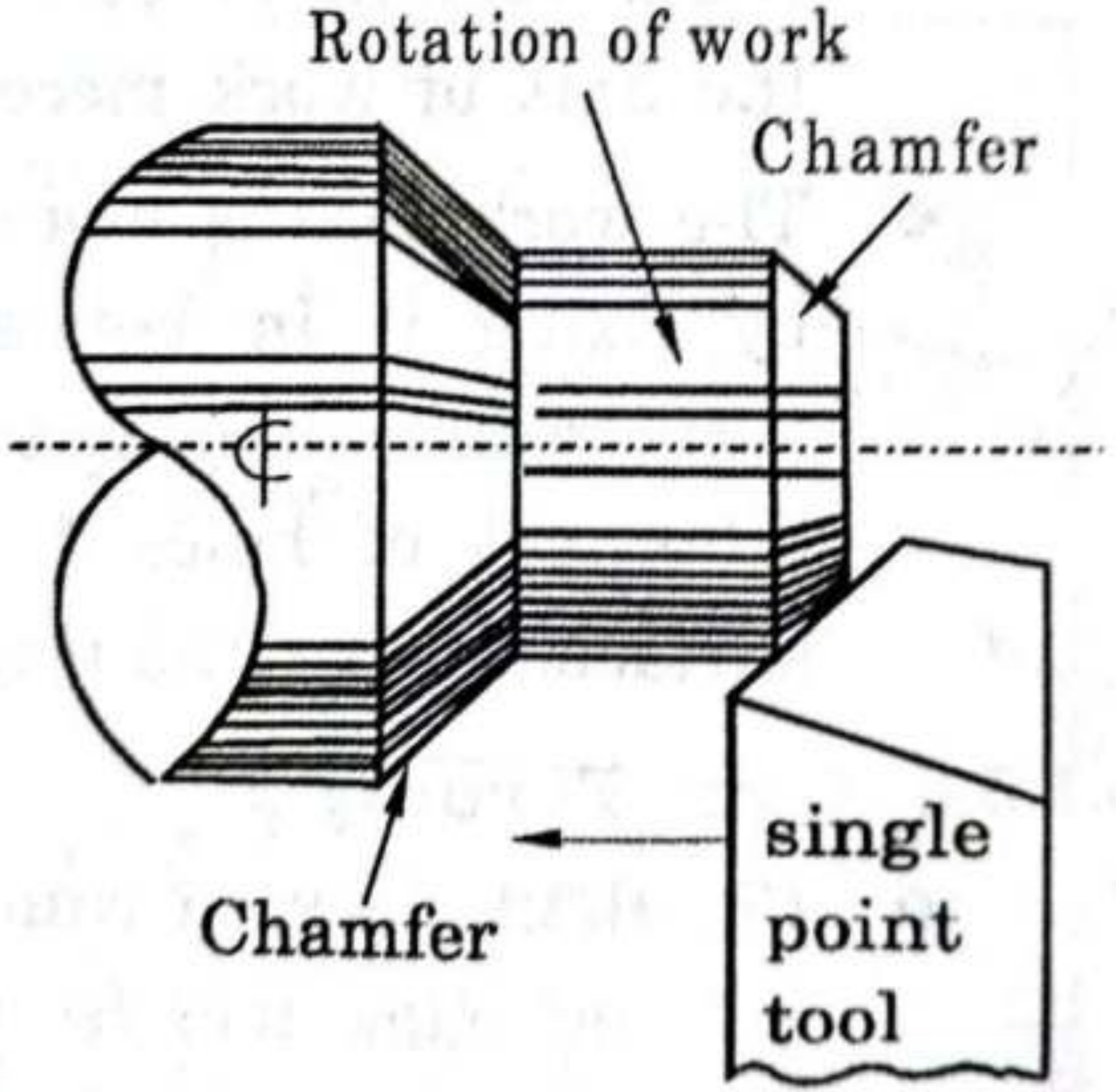


Fig 6.33 Chamfering operation

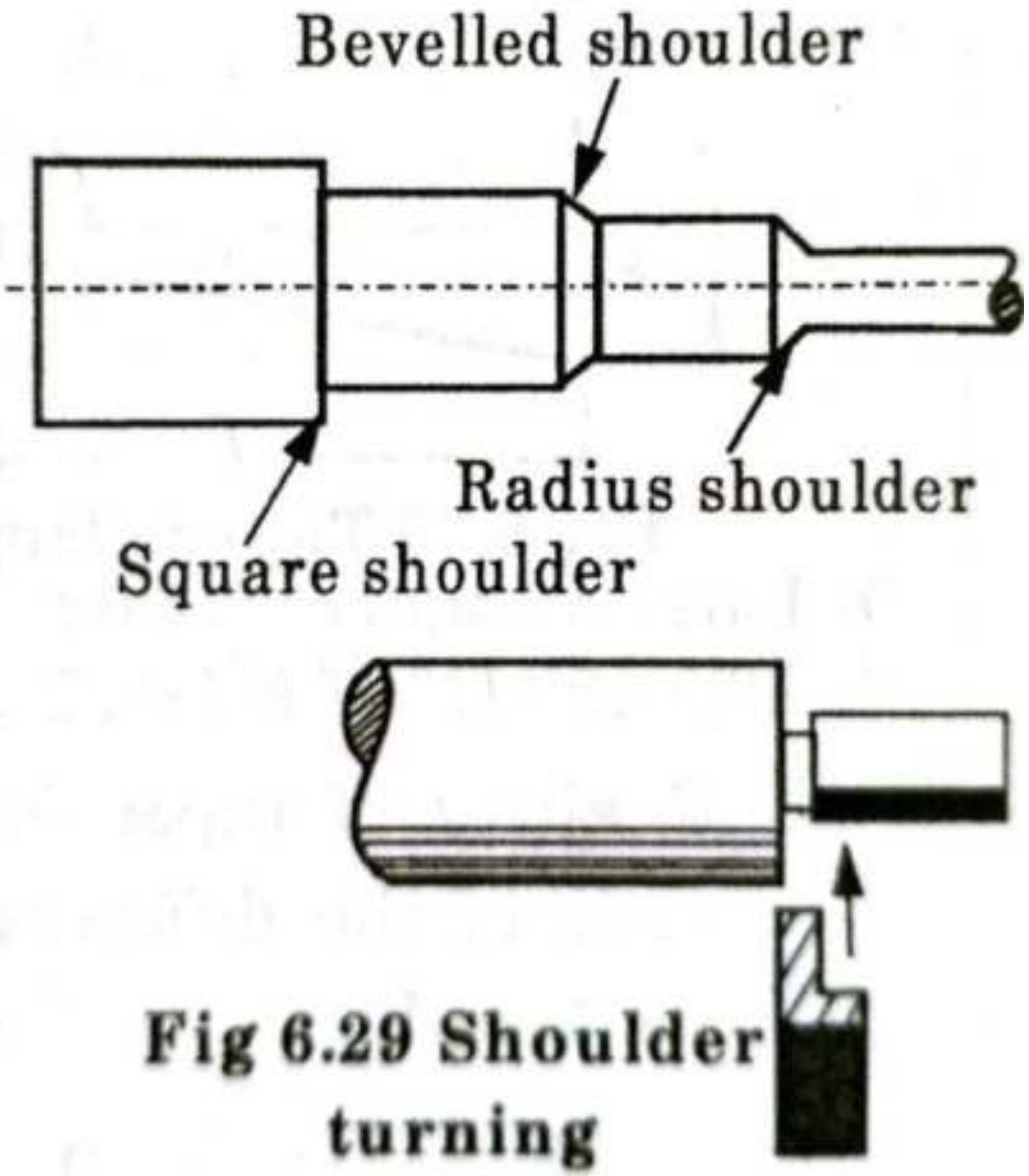


Fig 6.29 Shoulder turning

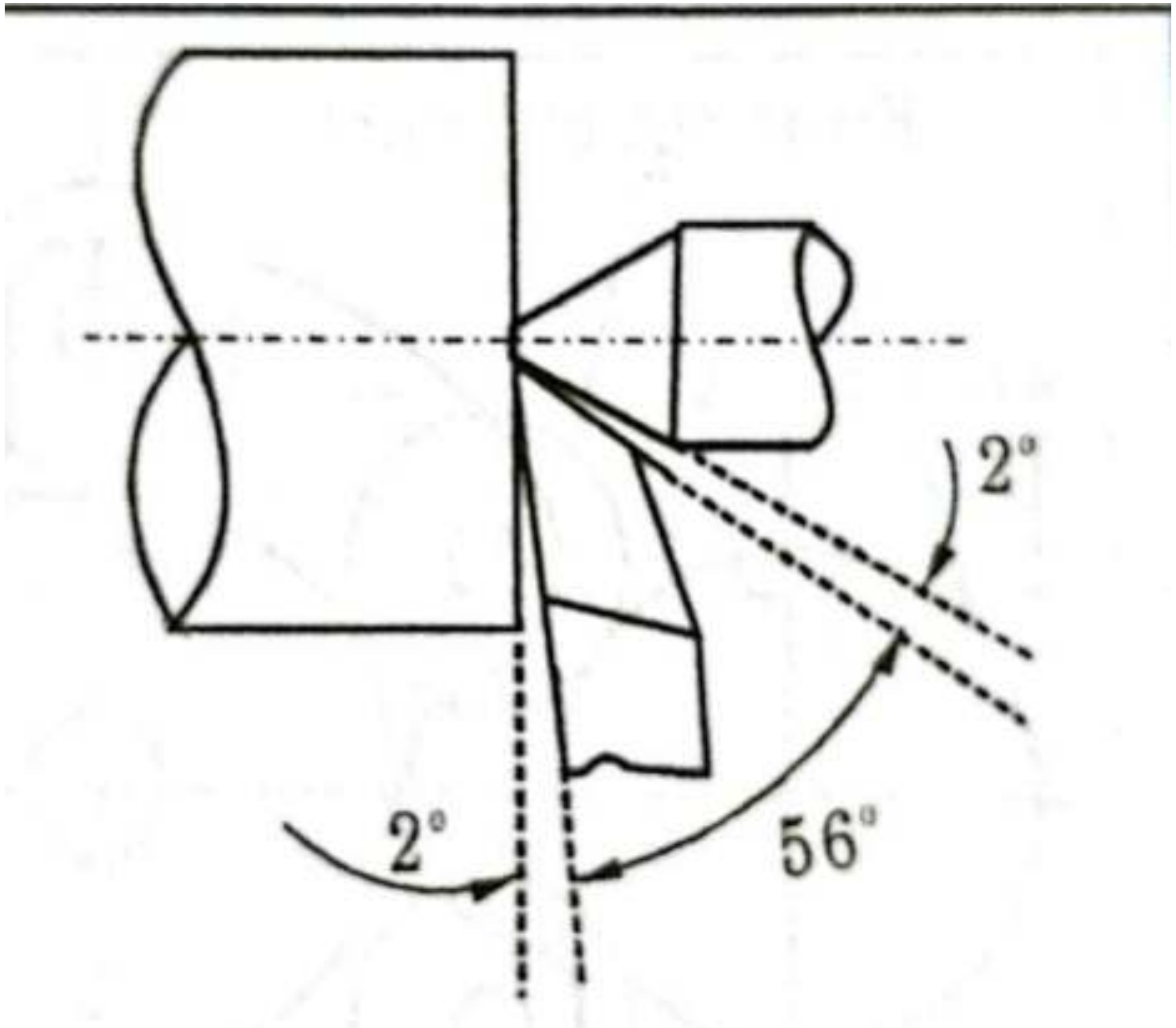


Fig 6.34 Facing operation

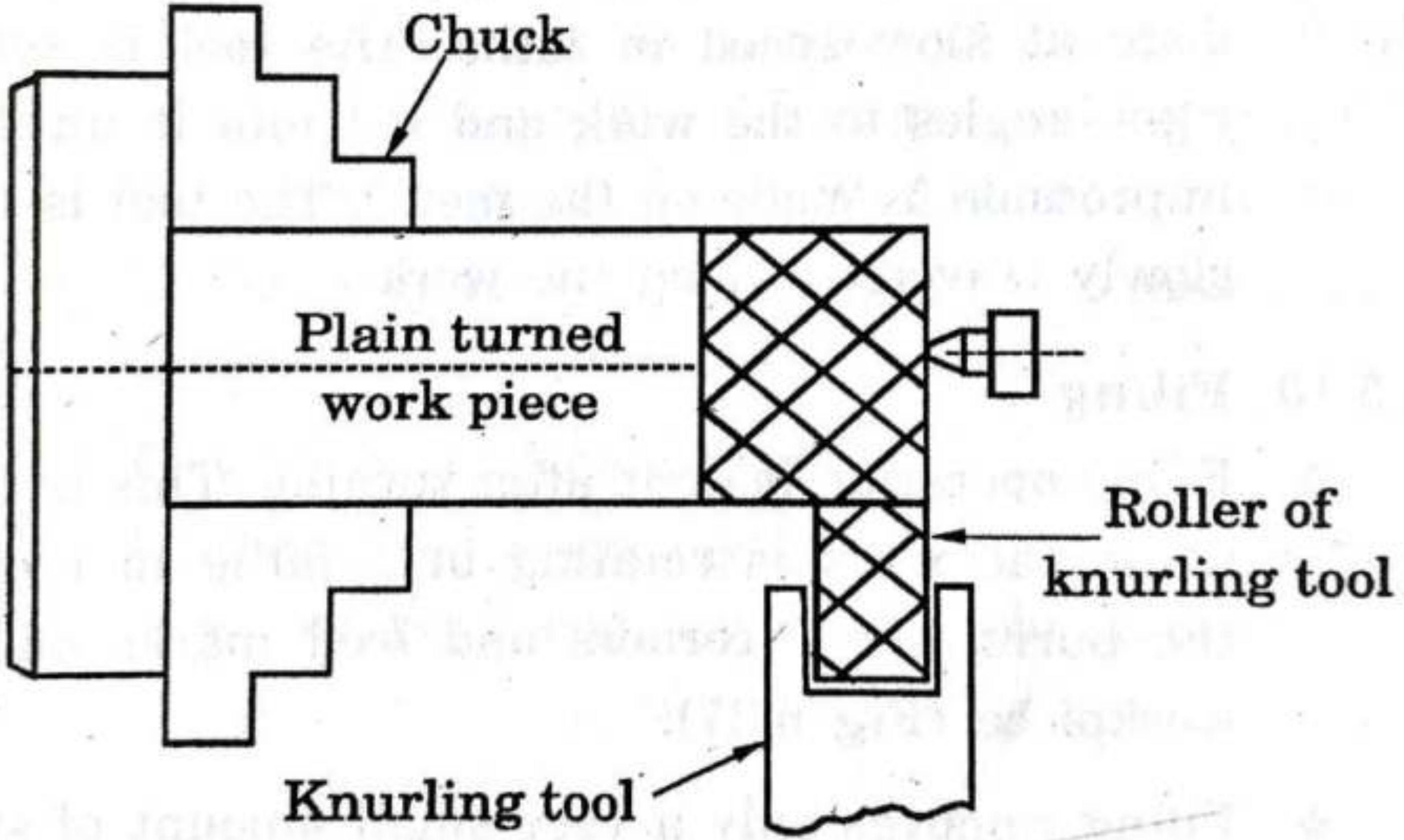
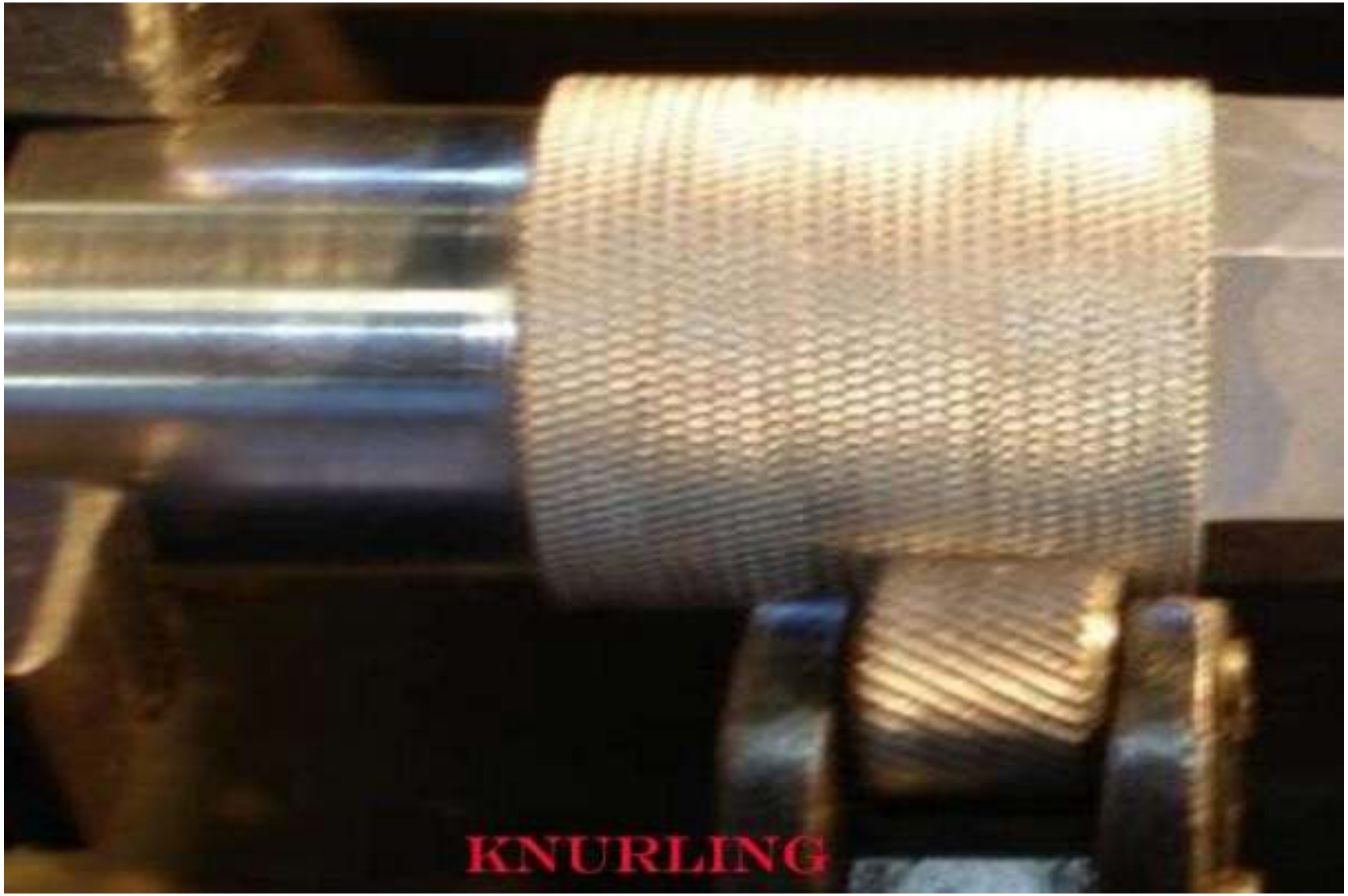


Fig 6.35 Knurling operation


KNURLING

4. Machine Time

The machining time in the lathe work can be calculated for a particular operation if the speed of the job, feed and length of the job is known.

If "s" is the feed of the job per revolution expressed in mm per revolution and "l" the length of the job in mm, then a number of revolutions of the job required for a complete cut will be: **l/s**.

$$\frac{l}{s \times n} \; min$$

Therefore, the time is taken for a complete cut = l / s X n min.

If the r.p.m. of the work is n, the time is taken to revolve the job through **l/s** number of revolutions for a complete cut will be:

Find the time required for one full cut on a workpiece of 350mm long and 50mm in diameter. The cutting speed is 35 metres per minute and the feed is 0.5mm per revolution.

$$Cutting\ speed = \frac{\pi\, dn}{1000} = \frac{\pi \times 50 \times n}{1000} = 35$$

$$= \frac{1000 \times 35}{\pi \times 50} = 222.5$$

Number of revolutions required for complete cut

$$= \frac{350}{0.5} = 700$$

Time required for complete cut $= \frac{700}{22.5} = 3.14\ min$

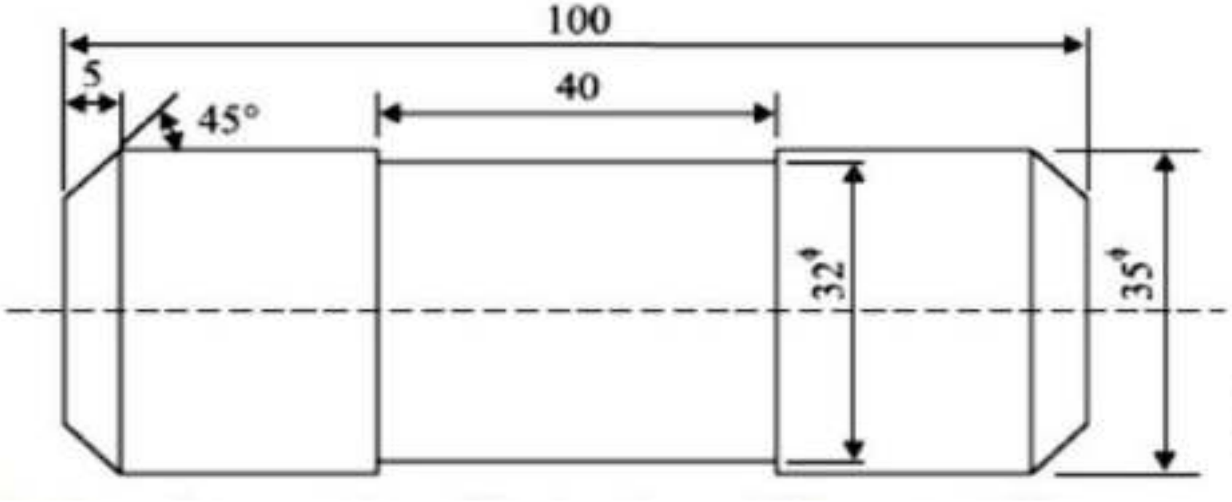
AVERAGE CUTTING SPEED EXPRESSED IN m. PER MINUTE FOR DIFFERENT OPERATIONS IN A LATHE USING A H.S.S. TOOL

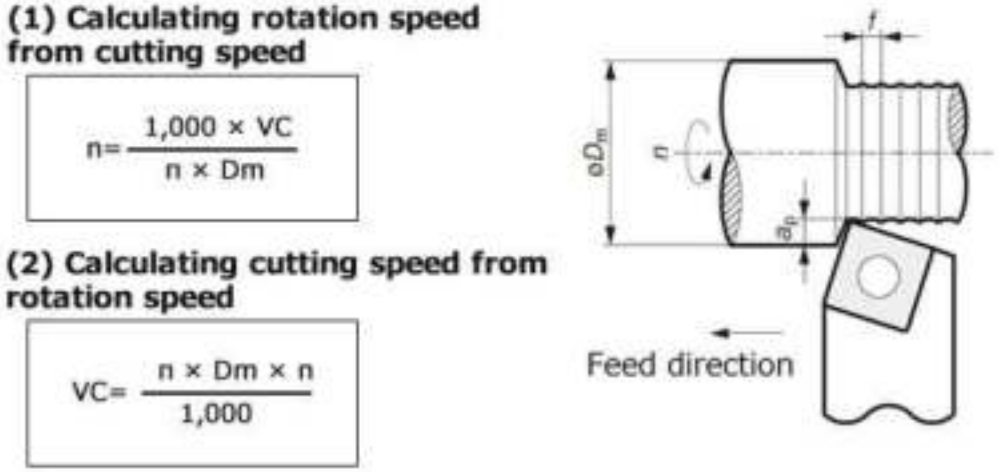
Material	Turning	Thread Cutting	Drilling	Reaming
Cast Iron	15 – 19	7 – 8	22 – 31	6 – 8
Mild Steel	25 – 31	9 – 10	28 – 35	10 – 15
Brass	60 – 90	20 – 25	60 – 90	25 – 30
Aluminium	120	25 – 30	60 – 90	20 – 30

Average cutting speed, feed and depth of cut for different tool materials:

Machining Time

A mild steel bar 100 mm long and 38 mm in diameter is turned to 35 mm dia. And was again turned to a diameter of 32 mm over a length of 40 mm as shown in the Fig. Calculate the machining time. Assume cutting speed of 60 m/min and feed 0.4 mm/rev. The depth of cut is not to exceed 3 mm in any operation.





Solution

Solution : *Ist operation* : Turning from £ 38 mm to £ 35 mm

$$S = 60 \text{ meters/min.}$$

$$D = 38 \text{ mm}$$

$$N = \frac{1{,}000\ S}{\pi D} = \frac{1{,}000 \times 60}{\pi \times 38}$$

$$= 503 \text{ r.p.m.}$$

$$\text{Time taken} = \frac{\text{Length of cut}}{\text{r.p.m.} \times \text{Feed/rev.}}$$

$$= \frac{100}{503 \times 0.4} = 0.5 \text{ min.}$$

2nd operation : External relief

$$L = 40 \text{ mm.}$$

$$D = 35 \text{ mm.}$$

$$S = 60 \text{ m/min.}$$

$$N = \frac{60 \times 1{,}000}{\pi \times 35} = 545 \text{ r.p.m.}$$

$$\text{Time taken for second operation} = \frac{\text{Length}}{\text{r.p.m.} \times \text{Feed/rev.}}$$

$$= \frac{40}{545 \times 0.4} = 0.18 \text{ min.}$$

$$V = \frac{\pi \times D \times N}{1000}$$

$$N = \frac{1000 \times V}{\pi \times D}$$

DRILLING MACHINE

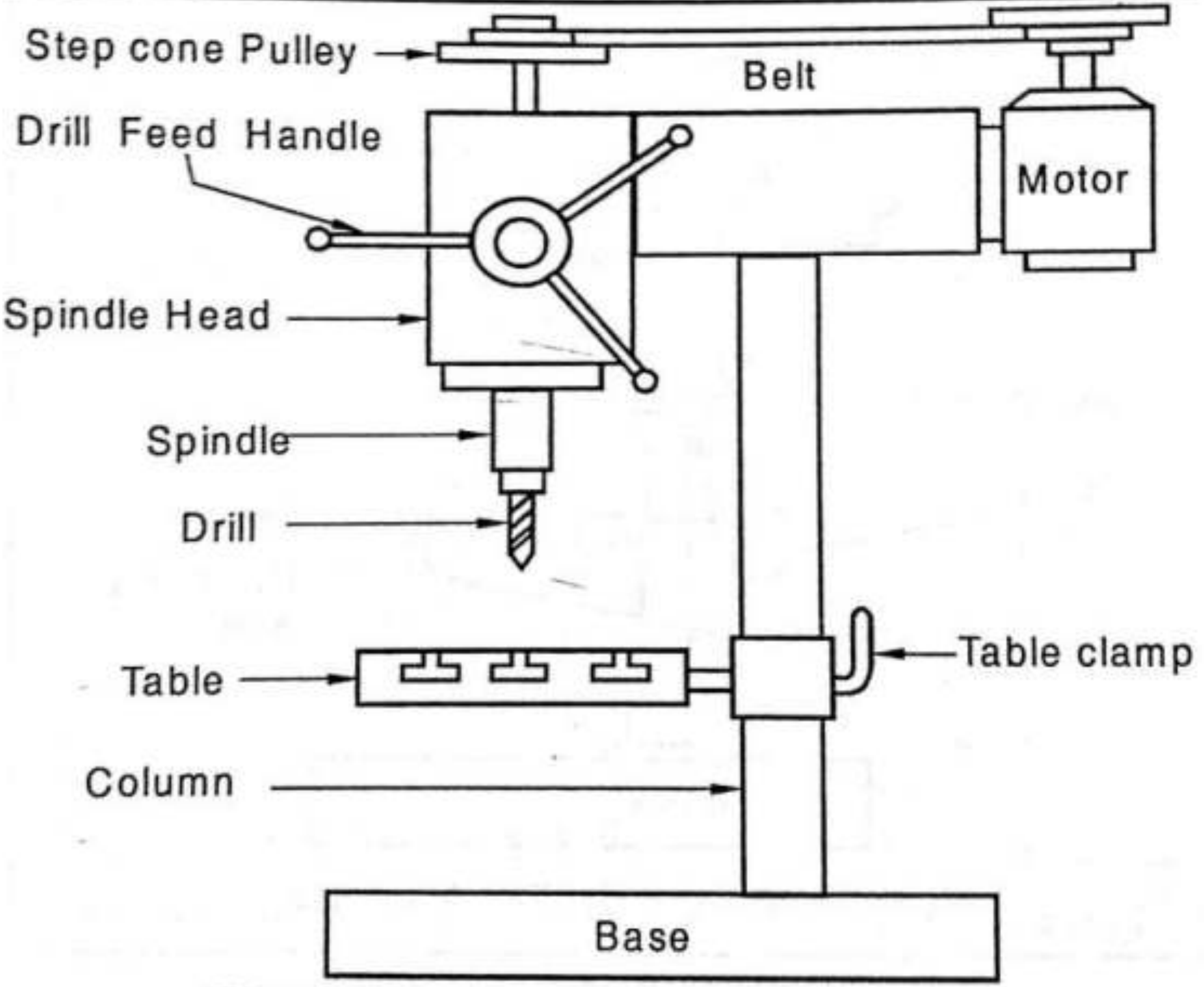


Fig.6.47. Pillar Drilling Machine.

DRILLING MACHINE

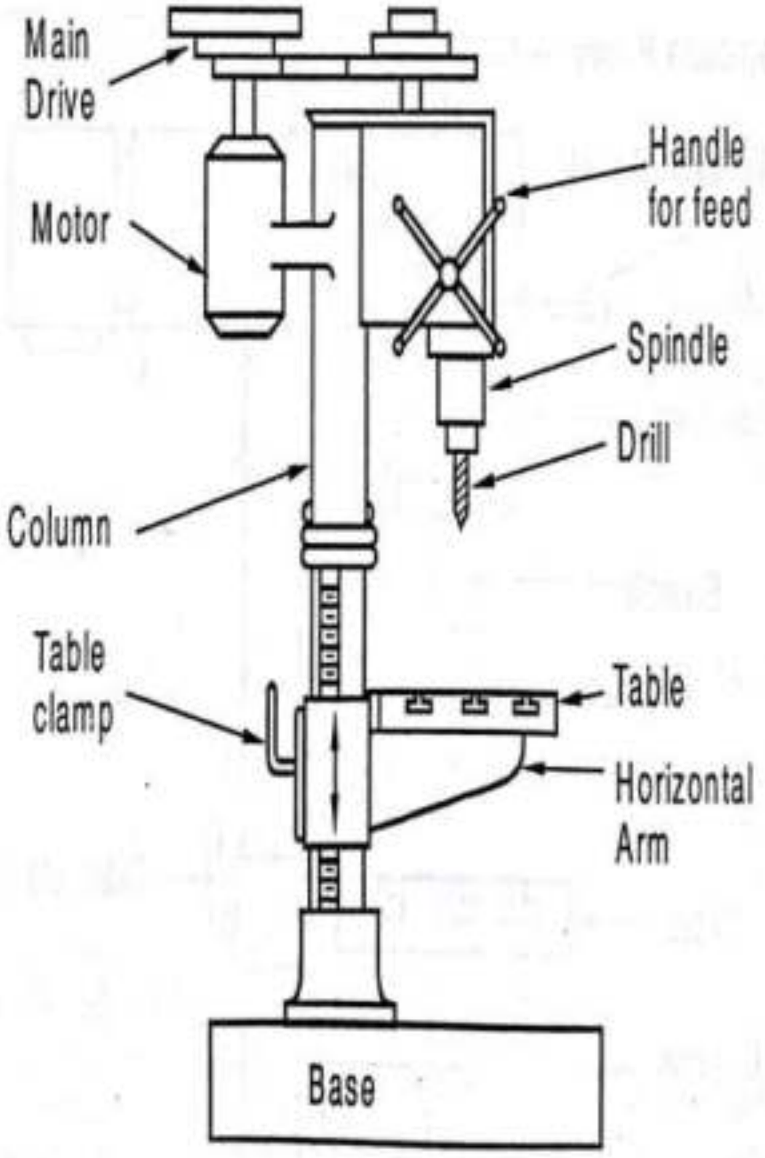
- Drilling machine is one of the most important machine tools in a workshop.
- Designed to produce a cylindrical hole of required diameter and depth on metal work pieces
- Drilling can be done easily at a low cost in a shorter period of time in a drilling machine.

Procedure for Drilling

- Drilling can be called as the operation of producing a cylindrical hole of required diameter and depth by removing metal by the rotating edges of a drill.
- The cutting tool known as drill is fitted into the spindle of the drilling machine.
- A mark of indentation is made at the required location with a centre punch.
- The rotating drill is pressed at the location and is fed into the work.
- The hole can be made upto a required depth.

Construction of a drilling machine

- The basic parts of a drilling machine are a base, column, drill head and spindle.
- The base made of cast iron may rest on a bench, pedestal or floor depending upon the design.
- Larger and heavy duty machines are grounded on the floor.
- The column is mounted vertically upon the base.
- Column is accurately machined and the table can be moved up and down on it.
- The drill spindle, an electric motor and the mechanism meant for driving the spindle at different speeds are mounted on the top of the column.
- Power is transmitted from the electric motor to the spindle through a flat belt or a 'V' belt.



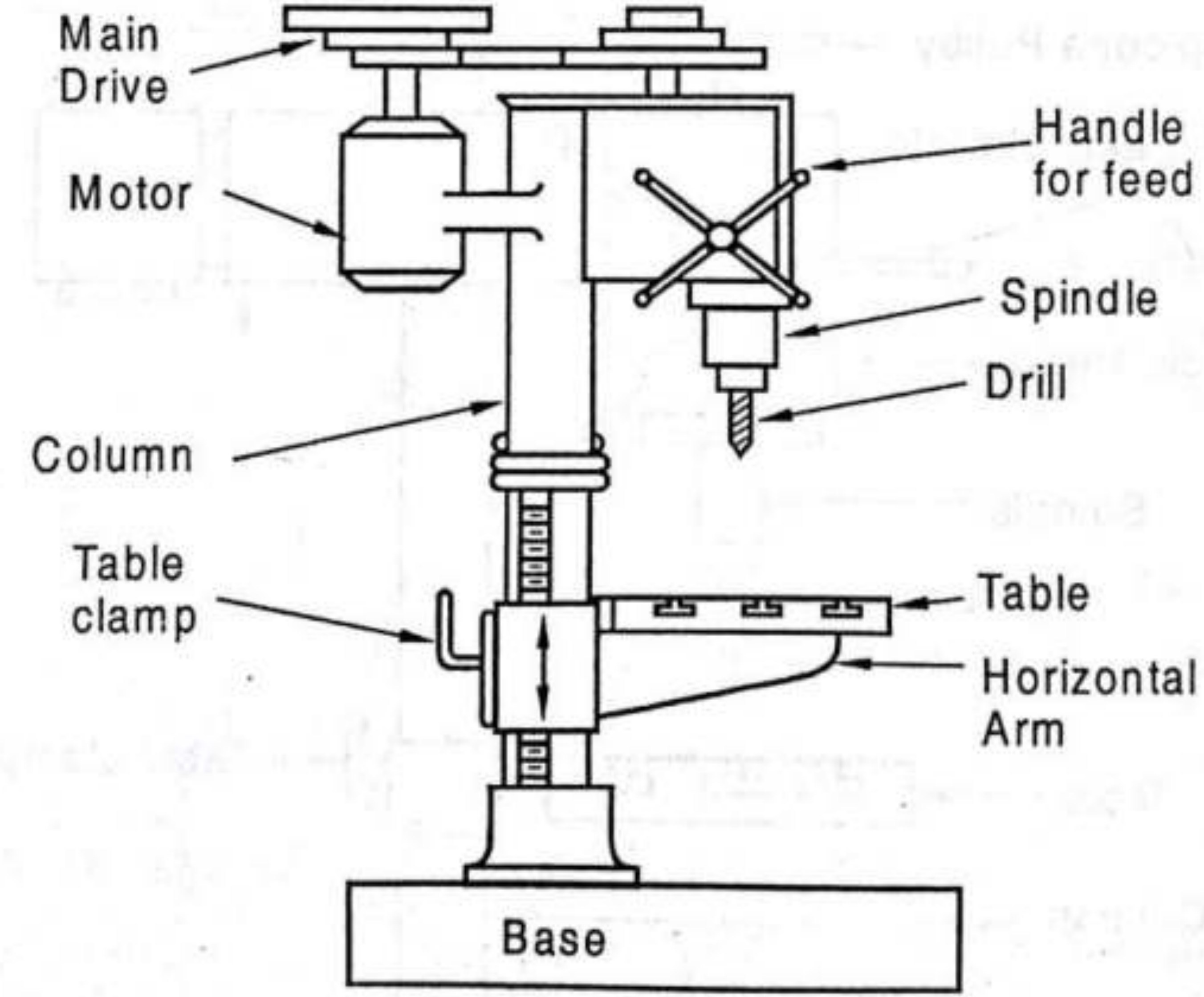


Fig.6.48. Upright Drilling Machine

Types of drilling machines

Drilling machines are manufactured in different types and sizes according to the type of operation, amount of feed, depth of cut, spindle speeds, method of spindle movement and the required accuracy.

The different types of drilling machines are:

1. Portable drilling machine (or) Hand drilling machine
2. Sensitive drilling machine (or) Bench drilling machine
3. Upright drilling machine
4. Radial drilling machine
5. Gang drilling machine
6. Multiple spindle drilling machine
7. Deep hole drilling machine

Types of drilling machines

1. Portable drilling machine (or) Hand drilling machine

- Portable drilling machine can be carried and used anywhere in the workshop.
- It is used for drilling holes on workpieces in any position, which is not possible in a standard drilling machine.
- The entire drilling mechanism is compact and small in size and so can be carried anywhere.
- This type of machine is widely adapted for automobile built-up work.
- These machines can accommodate drills from 12mm to 18 mm diameter.

Types of drilling machines

2. Sensitive drilling machine (or) Bench drilling machine

- It is designed for drilling small holes at high speeds in light jobs. High speed and hand feed are necessary for drilling small holes.
- The base of the machine is mounted either on a bench or on the floor by means of bolts and nuts. It can handle drills upto 15.5mm of diameter.
- The operator can sense the progress of the drill into the work because of hand feed, machine is named so because of this reason.
- A sensitive drilling machine consists of a base, column, table, spindle, drill head and the driving mechanism.

Types of drilling machines

3. Upright drilling machine

- The upright drilling machine is designed for handling medium sized workpieces.
- It looks like a sensitive drilling machine, it is larger and heavier than a sensitive drilling machine.
- Holes of diameter upto 50mm can be made with this type of machine.
- It is supplied with power feed arrangement.
- For drilling different types of work, the machine is provided with a number of spindle speeds and feed.

Types of drilling machines

4. Radial drilling machine

- The radial drilling machine is intended for drilling on medium to large and heavy workpieces.
- It has a heavy round column mounted on a large base.
- The column supports a radial arm, which can be raised or lowered to enable the table to accommodate workpieces of different heights.
- The arm, which has the drill head on it, can be swung around to any position.
- The drill head can be made to slide on the radial arm. The machine is named so because of this reason.
- It consists of parts like base, column, radial arm, drill head and driving mechanism.

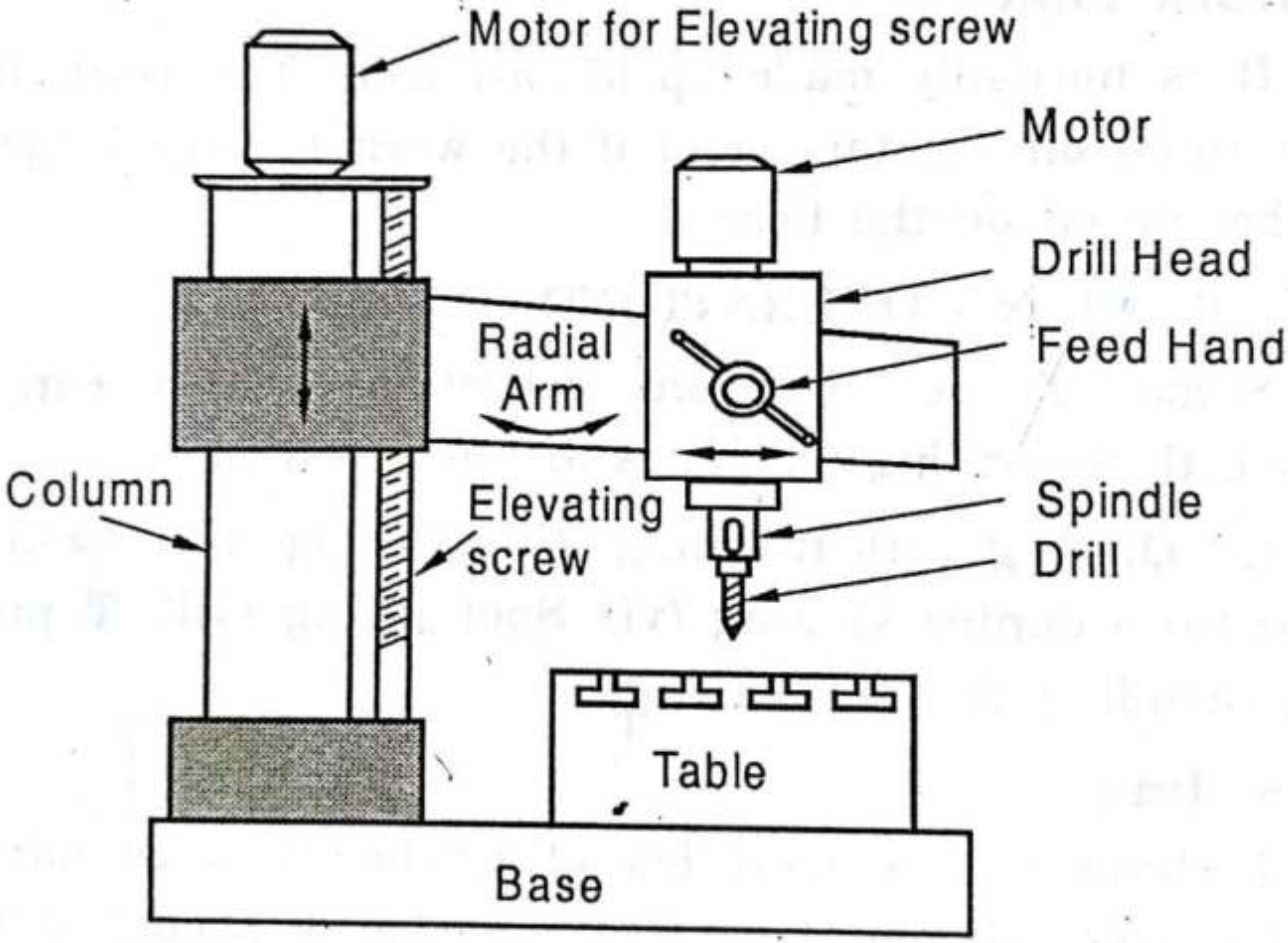


Fig. 6.49 Radial Drilling Machine

Types of drilling machines

5. Gang drilling machine

- Gang drilling machine has a long common table and a base.
- Four to six drill heads are placed side by side.
- The drill heads have separate driving motors.
- This machine is used for production work.
- A series of operations like drilling, reaming, counter boring and tapping may be performed on the work by simply shifting the work from one position to the other on the work table.
- Each spindle is set with different tools for different operations.

Types of drilling machines

6. Multiple spindle drilling machine

- This machine is used for drilling a number of holes in a workpiece simultaneously and for reproducing the same pattern of holes in a number of identical pieces.
- A multiple spindle drilling machine also has several spindles.
- A single motor using a set of gears drives all the spindles.
- All the spindles holding the drills are fed into the work at the same time.
- The distances between the spindles can be altered according to the locations where holes are to be drilled. Drill jigs are used to guide the drills.

Types of drilling machines

7. Deep hole drilling machine

- A special machine and drills are required to drill deeper holes in barrels of gun, spindles and connecting rods.
- The machine designed for this purpose is known as deep hole drilling machine. High cutting speeds and less feed are necessary to drill deep holes.
- A non rotating drill is fed slowly into the rotating work at high speeds.
- Coolant should be used while drilling in this machine.
- There are two different types of deep hole drilling machines

Types of drilling machines

7. Deep hole drilling machine

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- The machine designed for this purpose is known as deep hole drilling machine. High cutting speeds and less feed are necessary to drill deep holes.
- A non rotating drill is fed slowly into the rotating work at high speeds.
- Coolant should be used while drilling in this machine.
- There are two different types of deep hole drilling machines

Size of a drilling machine (Specification)

Drilling machines are specified according to their type.

1. the maximum diameter of the drill that it can handle
2. the size of the largest workpiece that can be centred under the spindle
3. distance between the face of the column and the axis of the spindle
4. diameter of the table
5. maximum travel of the spindle
6. numbers and range of spindle speeds and feeds available
7. Morse taper number of the drill spindle
8. floor space required
9. weight of the machine
10. Power input is also needed to specify the machine completely.

Work holding devices

- The work should be held firmly on the machine table before performing any operation on it.
- As the drill exerts very high quantity of torque while rotating, the work should not be held by hand.
- If the workpiece is not held by a proper holding device, it will start rotating along with the tool causing injuries to the operator and damage to the machine.

The devices used for holding the work in a drilling machine are

1. Drill vise
2. ‘T’ - bolts and clamps
3. Step block
4. V - block
5. Angle plate
6. Drill jigs

Work holding devices

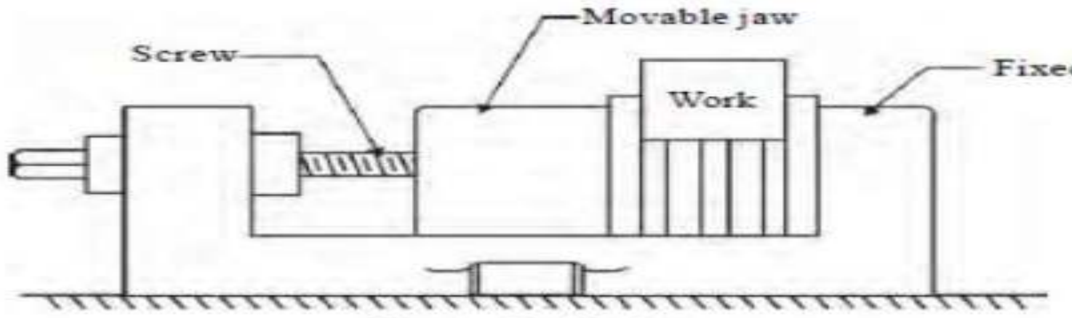


Fig Drill vice

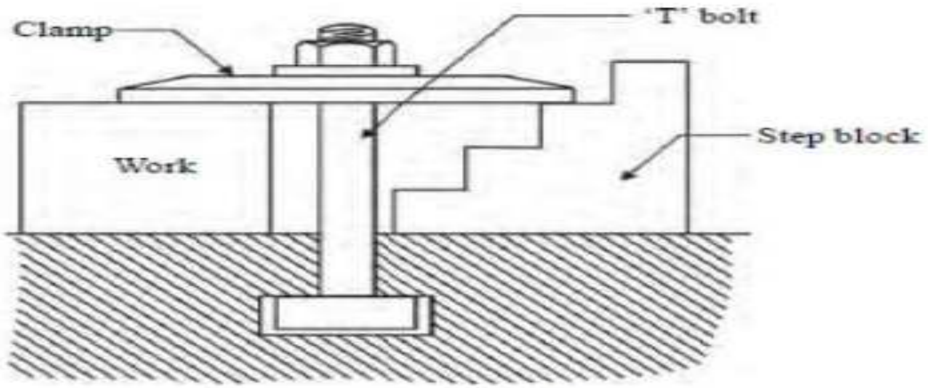


Fig T-bolt & clamp

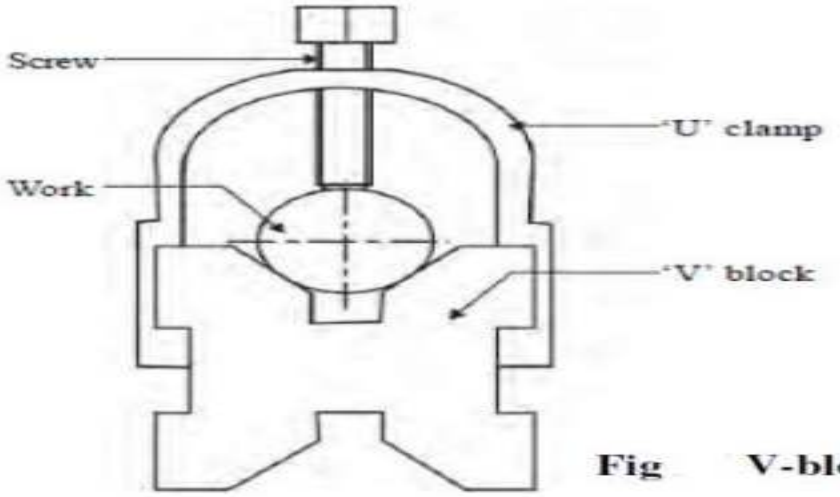


Fig V-block

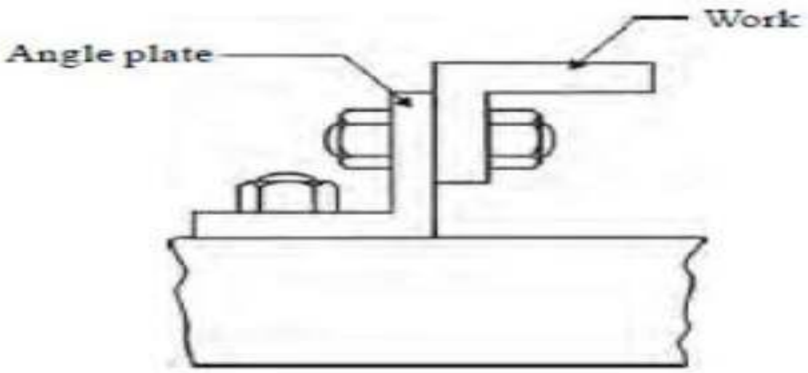


Fig Angle plate

Tool holding devices

- Different tools are used for performing different operations.
- They are fitted into the drill spindle by different methods.

They are

1. By a chuck
2. By a sleeve
3. By a socket
4. Tapping attachment

Work holding devices

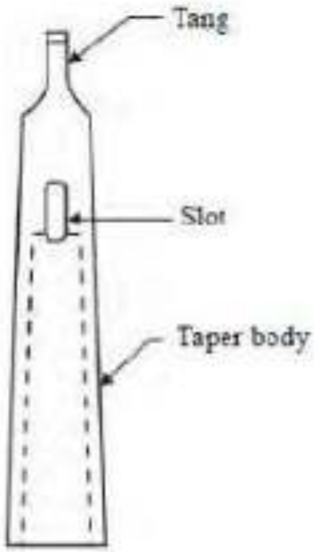


Fig Drill sleeve

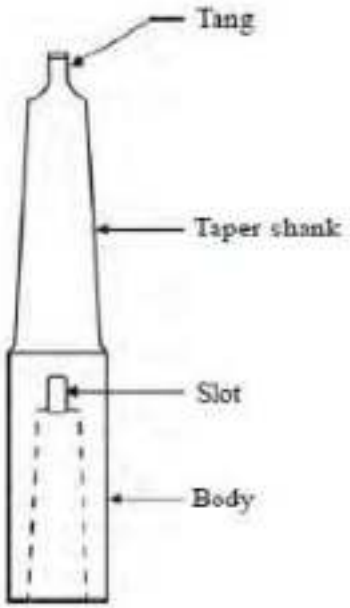


Fig Drill socket

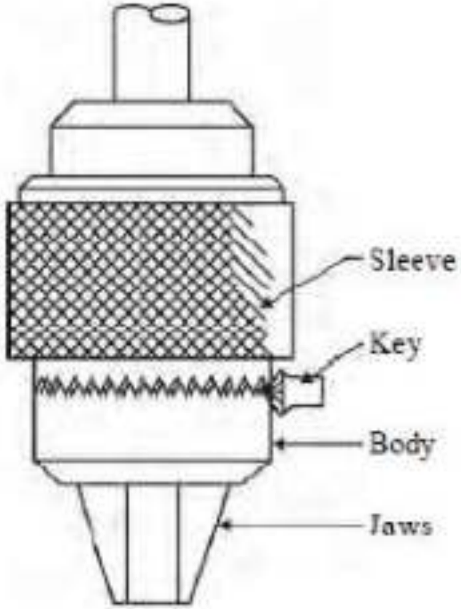


Fig Drill chuck

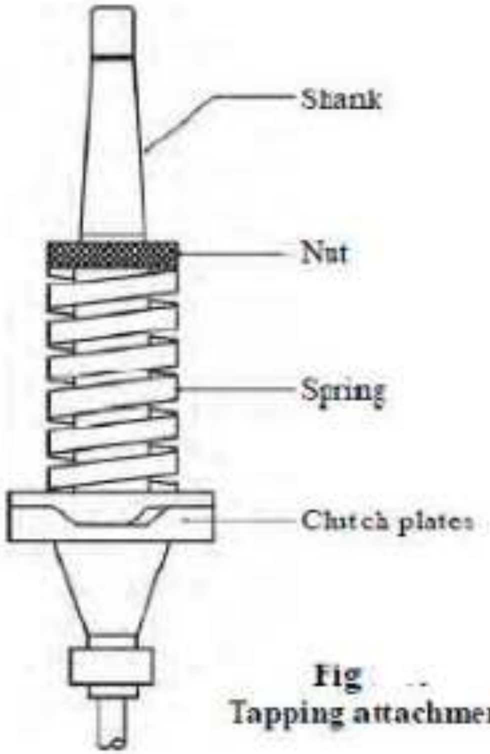
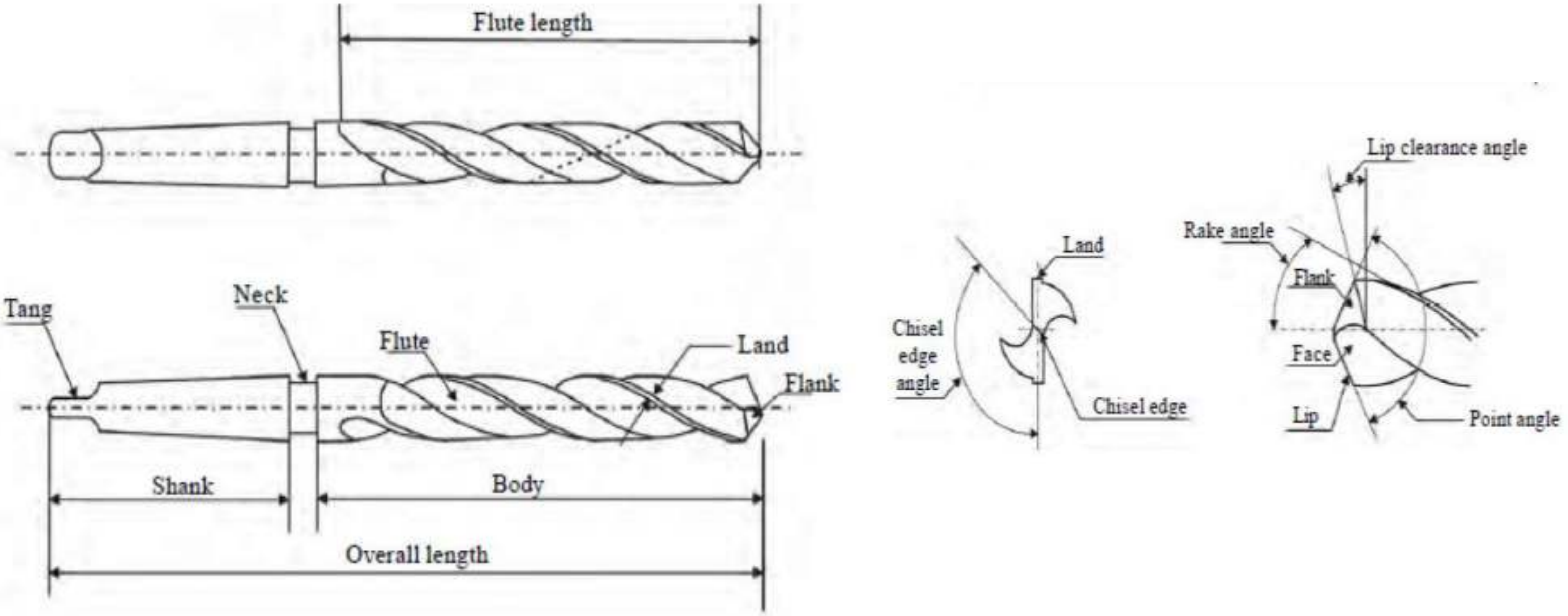


Fig
Tapping attachment

Work holding devices

Twist drill nomenclature



Twist drill nomenclature

Axis

It is the longitudinal centre line of the drill running through the centres of the tang and the chisel edge.

Body

It is the part of the drill from its extreme point to the commencement of the neck, if present. Otherwise, it is the part extending upto the commencement of the shank. Helical grooves are cut on the body of the drill.

Shank

It is the part of the drill by which it is held and driven. It is found just above the body of the drill. The shank may be straight or taper. The shank of the drill can be fitted directly into the spindle or by a tool holding device.

Tang

The flattened end of the taper shank is known as tang. It is meant to fit into a slot in the spindle or socket. It ensures a positive drive of the drill.

Flank

The surface at a drill point that extends behind the lip to the following flute.

Neck

It is the part of the drill, which is diametrically undercut between the body and the shank of the drill. The size of the drill is marked on the neck.

Point

It is the sharpened end of the drill. It is shaped to produce lips, faces, flanks and chisel edge.

Lip

It is the edge formed by the intersection of flank and face. There are two lips and both of them should be of equal length. Both lips should be at the same angle of inclination with the axis (59°).

Land

It is the cylindrically ground surface on the leading edges of the drill flutes adjacent to the body clearance surface. The alignment of the drill is maintained by the land. The hole is maintained straight and to the right size.

Flutes

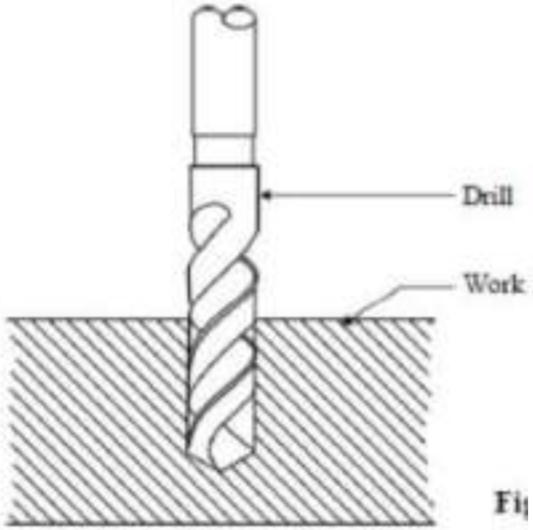
The grooves in the body of the drill are known as flutes. Flutes form the cutting edges on the point. It allows the chips to escape and make them curl. It permits the cutting fluid to reach the cutting edges.

Drilling machine operations

- Though drilling is the primary operation performed in a drilling machine, a number of similar operations are also performed on holes using different tools.
- The different operations that can be performed in a drilling machine are:

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking
6. Spot facing
7. Tapping
8. Trepanning

Drilling machine operations



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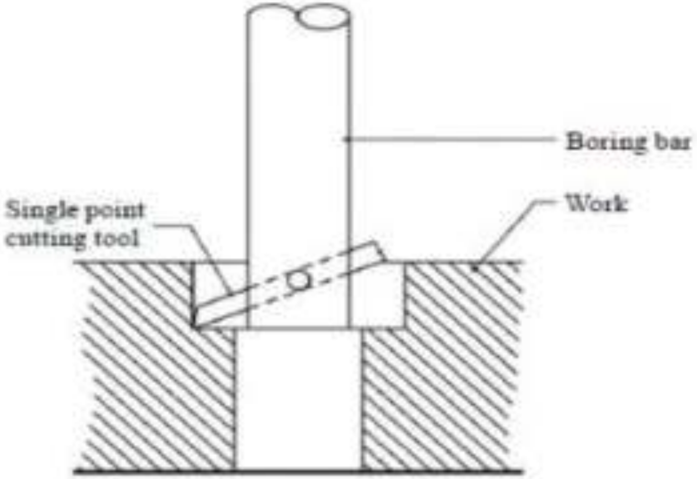


Fig Boring

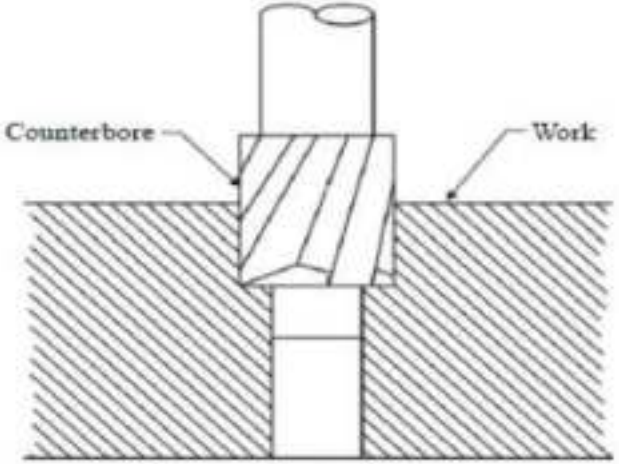


Fig Counterboring

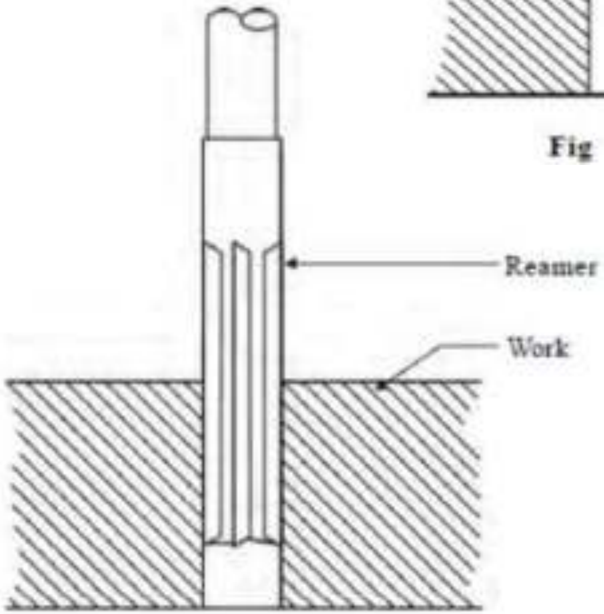


Fig Reaming

Drilling machine operations

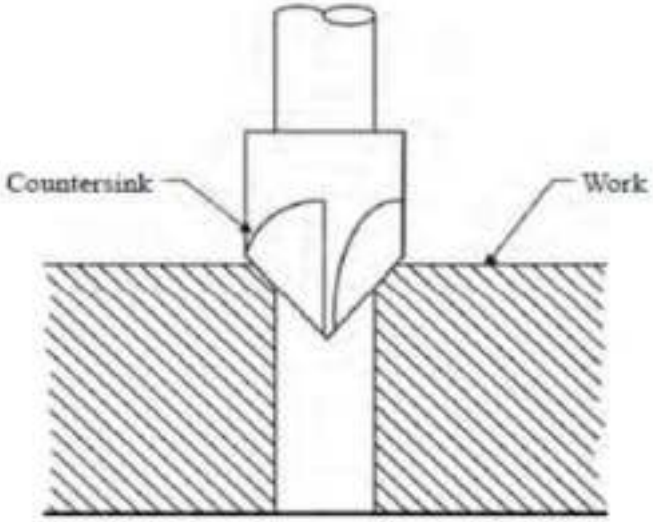


Fig Countersinking

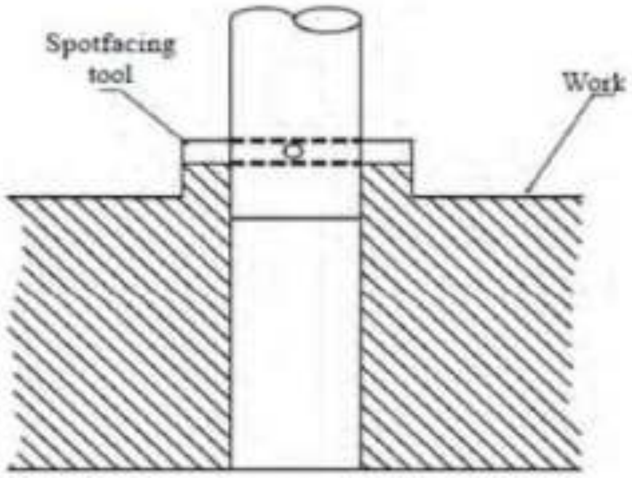


Fig Spotfacing

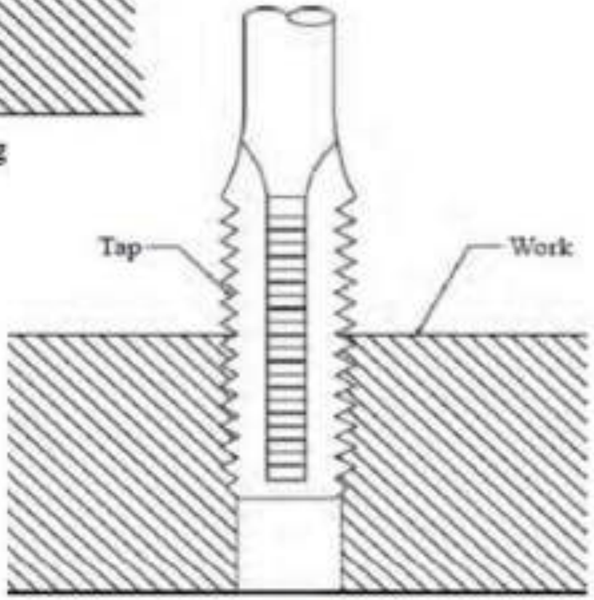


Fig Tapping

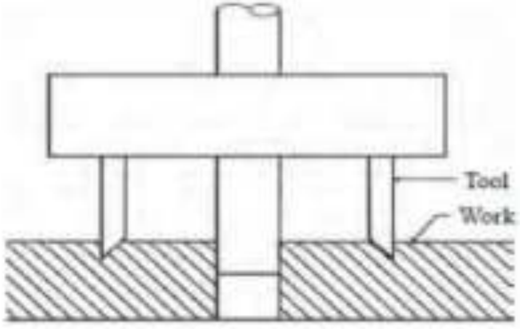
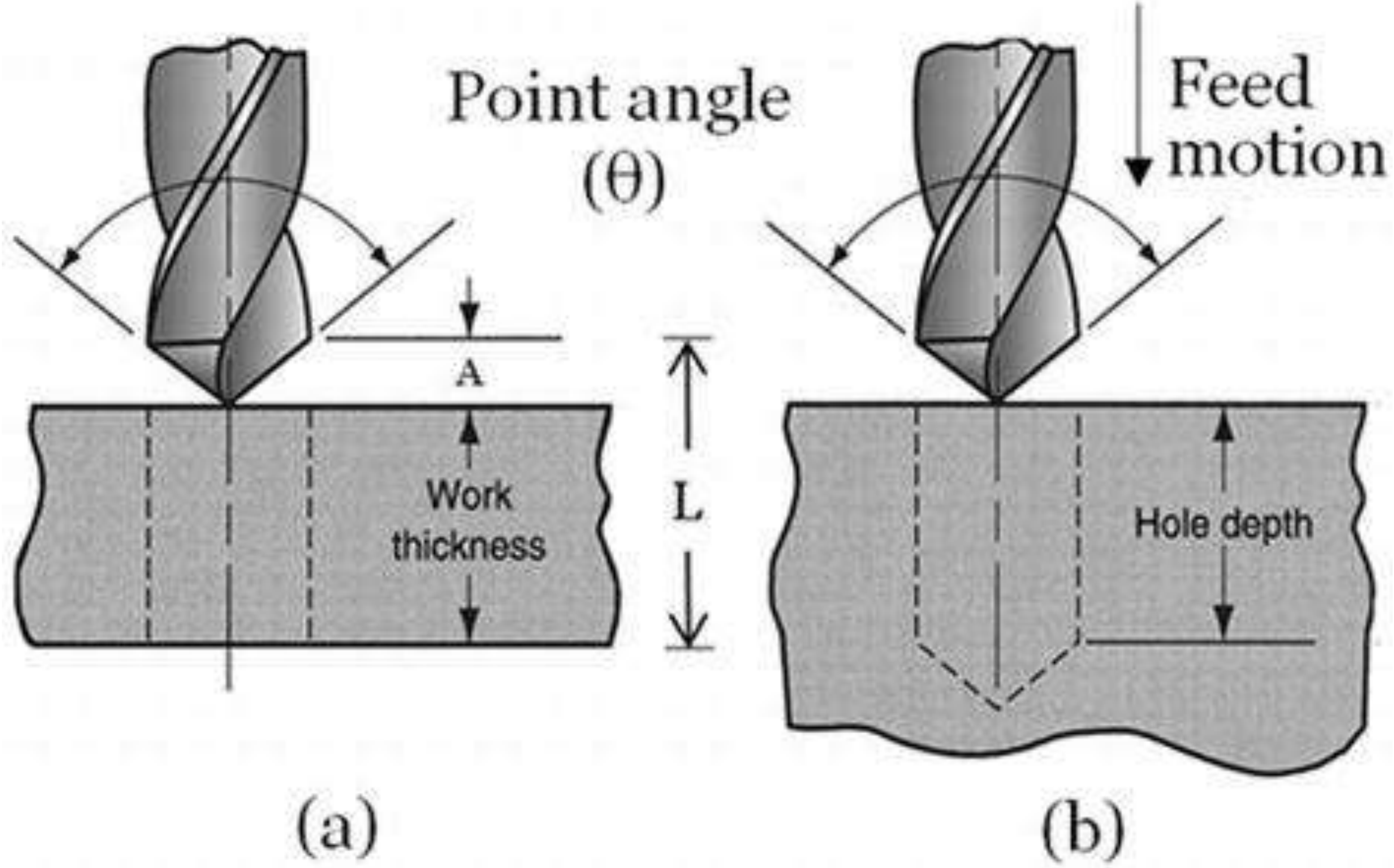


Fig Trepanning

Drilling machining Time Calculation



Drilling machining Time Calculation

- Time for drilling $=\dfrac{Depth\ of\ Hole\ to\ be\ Produced + Approach\ Distance}{\frac{Feed}{Rev}\ X\ RPM}$

- Time for drilling $=\dfrac{Depth\ of\ Hole\ to\ be\ Produced + Approach\ Distance}{\frac{Feed}{Rev}\ X\ RPM}$

A = 0.5 D Tan(90- Ɵ/2)

A = Approach Distance

D = Drill Diameter

Ɵ = Drill Point Angle

Feed Rate (Dist/Min)

fr = N.f

fr = Dist/Min

N = Rotational Speed

f = Feed (Dist./Rev.)

Rotational Speed (RPM's)

N= $\boldsymbol{\dfrac{V}{\pi . D}}$

N = Rotational Speed (RPM's)

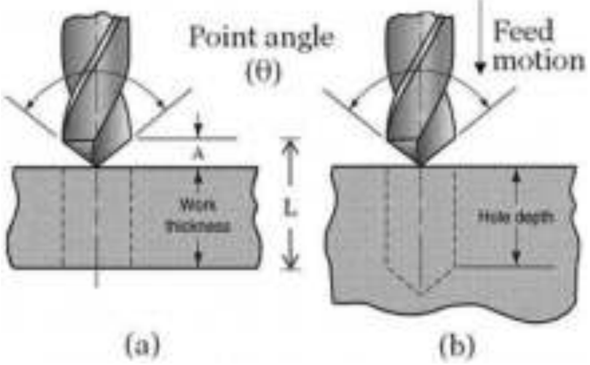
v = Cutting Speed (SFPM)

D = Drill Diameter

Drilling machining Time Calculation

Find the time required to drill 4 holes in a cast iron flange each of 2 cm depth, if the hole diameter is 2 cm. Assume cutting speed as 21.9 m/min. and feed as 0.02 cm/rev

- Time for drilling $=\dfrac{Depth\ of\ Hole\ to\ be\ Produced + Approach\ Distance}{\frac{Feed}{Rev}\ X\ RPM}$



A = 0.5 D Tan(90- 108/2)= 0.726 cm

A = Approach Distance

D = Drill Diameter

Ɵ = Drill Point Angle

Rotational Speed (RPM's)

N= $\dfrac{\mathbf{1000.V}}{\boldsymbol{\pi}\mathbf{.D}}$

N = (1000 x 21.9) / 3.14 x 20 = 350 rpm

Time for Drilling a Hole= ?

Time for Drilling 4 holes= ?

Thank You

MODULE 3

- **Course Code: MET 385**

Prepared by-
Dr. Roja Abraham Raju

MILLING MACHINE

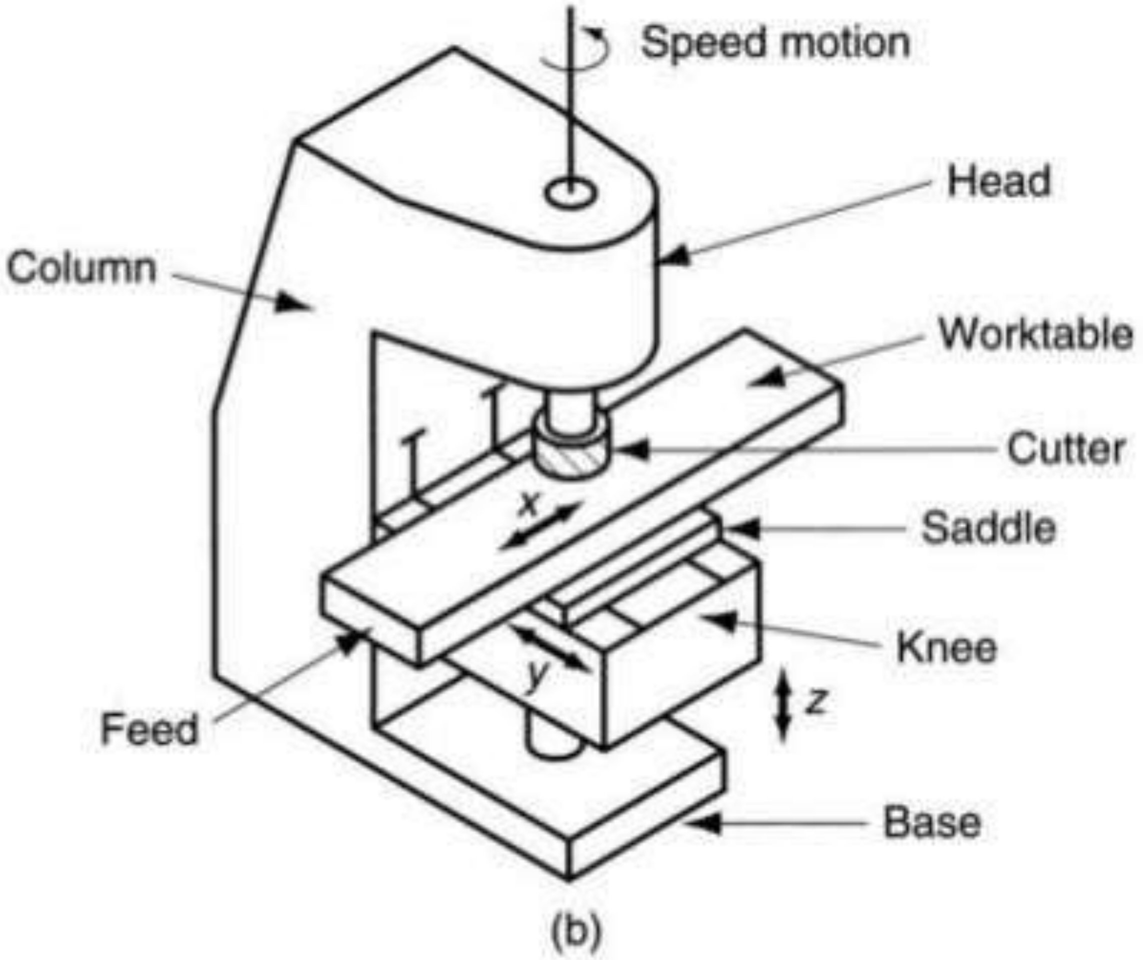
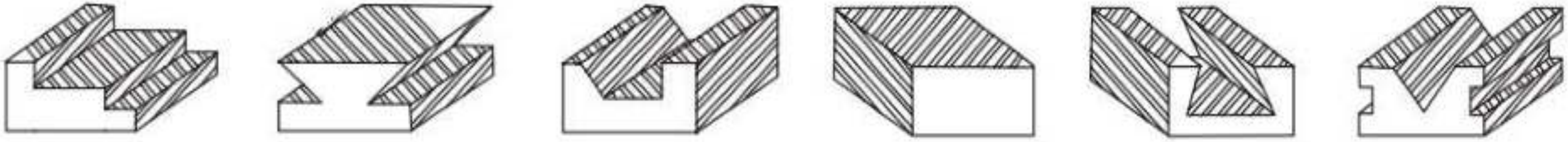


Fig. (b) vertical knee-and-column milling machine

Introduction

- Milling is a process of removing metal by feeding the work against a rotating multipoint cutter.
- The machine tool intended for this purpose is known as milling machine.
- Milling machine is used for machining flat surfaces, contoured surfaces, surfaces of revolution, external and internal threads, and helical surfaces of various cross-sections.
- The surface obtained by this machine tool is superior in quality and more accurate and precise.



Job surfaces generated by milling machine

PRINCIPLE OF MILLING

- In milling machine, the metal is cut by means of a rotating cutter having multiple cutting edges.
- For cutting operation, the workpiece is fed against the rotary cutter. As the workpiece moves against the cutting edges of milling cutter, metal is removed in form chips of trochoid shape. Machined surface is formed in one or more passes of the work.
- The work to be machined is held in a vice, a rotary table, a three jaw chuck, an index head, between centers, in a special fixture or bolted to machine table.
- The rotatory speed of the cutting tool and the feed rate of the workpiece depend upon the type of material being machined.

Types of milling machine

- The milling machines are classified according to the general design of the machine.
    1. Column and knee type
        a) Plain milling machine
        b) Universal milling machine
        c) Omniversal milling machine
        d) Vertical milling machine
    2. Table type milling machine
    3. Planer type milling machine
    4. Special type milling machine

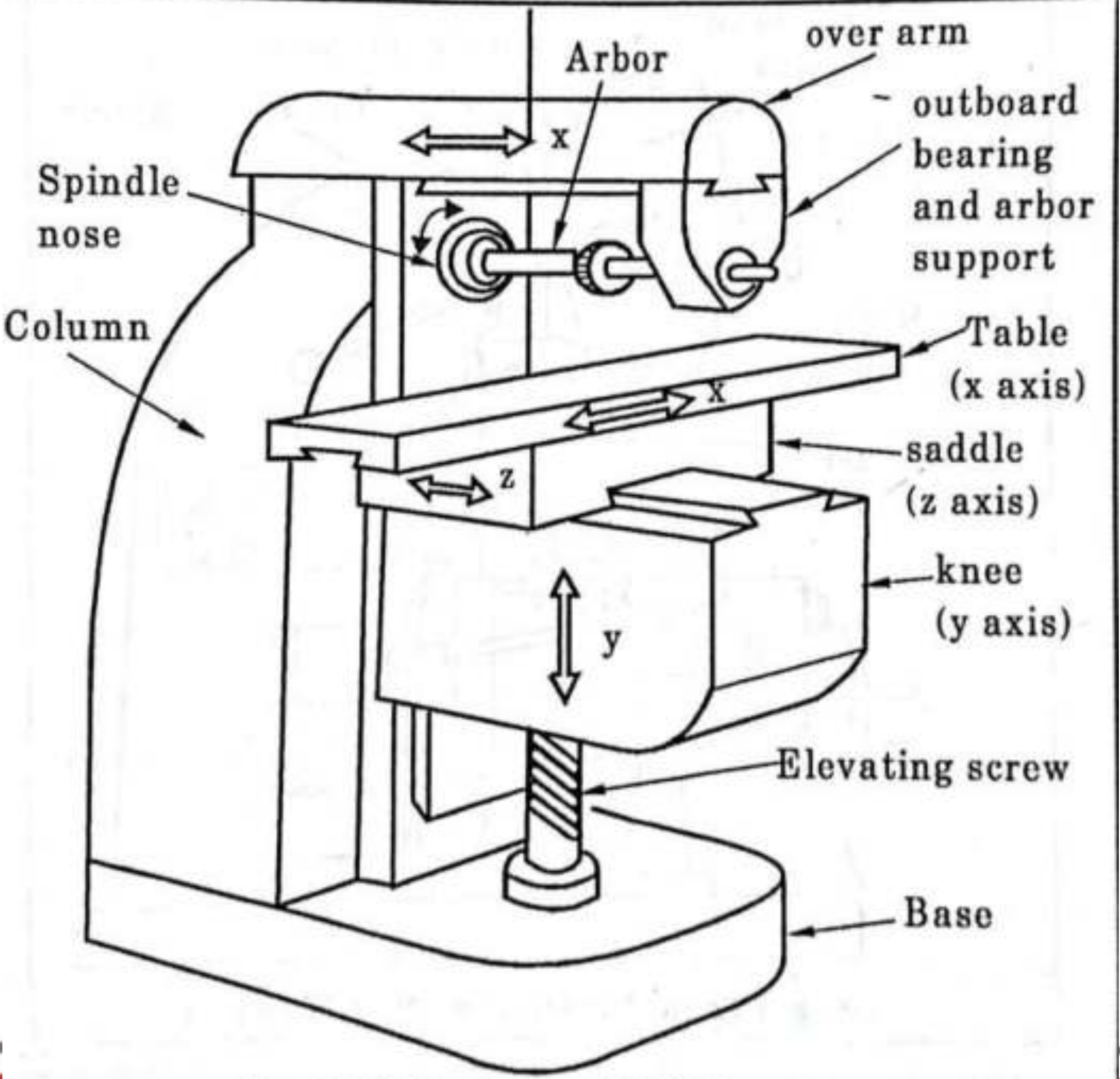


Fig 6.71 Horizontal Milling Machine

Size of a milling machine

- The size of a milling machine is specified as follows

1. The size of the table (length and width)
2. The maximum lengths of longitudinal, cross and vertical travel of the table.
3. Number of spindle speeds, number of feeds
4. Spindle nose taper
5. Power required
6. Net weight of the machine
7. The floor space required
8. Type of the machine

Column and knee type milling machine

- The column of a column and knee type milling machine is mounted vertically upon the base.
- Knee is mounted on the accurately machined guide ways of the column.
- It is designed to move up and down accurately. Saddle and table are mounted on the knee.
- There are different types of column and knee type machines.

a) Plain milling machine

- It is rigid and sturdy. Heavy workpieces are mounted and machined on the machine.
- The work mounted on the table is moved vertically, longitudinally and crosswise against the rotating cutter.
- The table cannot be rotated. It is also called as horizontal milling machine because the cutter rotates in horizontal plane.

b) Universal milling machine

- The table of a universal milling machine can be swivelled by 45º on either side and so helical milling works can be performed.
- It is named so because it can be adapted for a very wide range of milling operations.
- Various milling attachments like index head, vertical milling head, slot milling head and rotary table can be mounted.
- It can machine drills, reamers, gears, milling cutters with a very high degree of accuracy and so it finds an important place in a workshop.

c) Omniversal milling machine

- In addition to the table movements obtained in a universal milling machine, the knee can be tilted to a required angle.
- It is useful for machining helical grooves, reamer and bevel gears. It is mostly used in tool room work.

d) Vertical milling machine

- A spindle of a vertical milling machine is positioned at right angles to the table.
- The cutter is moved vertically or at an angle by swivelling the vertical head of the machine.
- The machine is adapted for machining slots and flat surfaces by moving the table.
- By mounting end mills and face milling cutters on the spindle, vertical milling and internal milling are preformed

Main Parts of Column and knee type milling machine

Base

- It is made of cast iron and supports all the other parts of the machine tool. A vertical column is mounted upon the base. In some machines, the base serves as a reservoir for cutting fluid.

Column

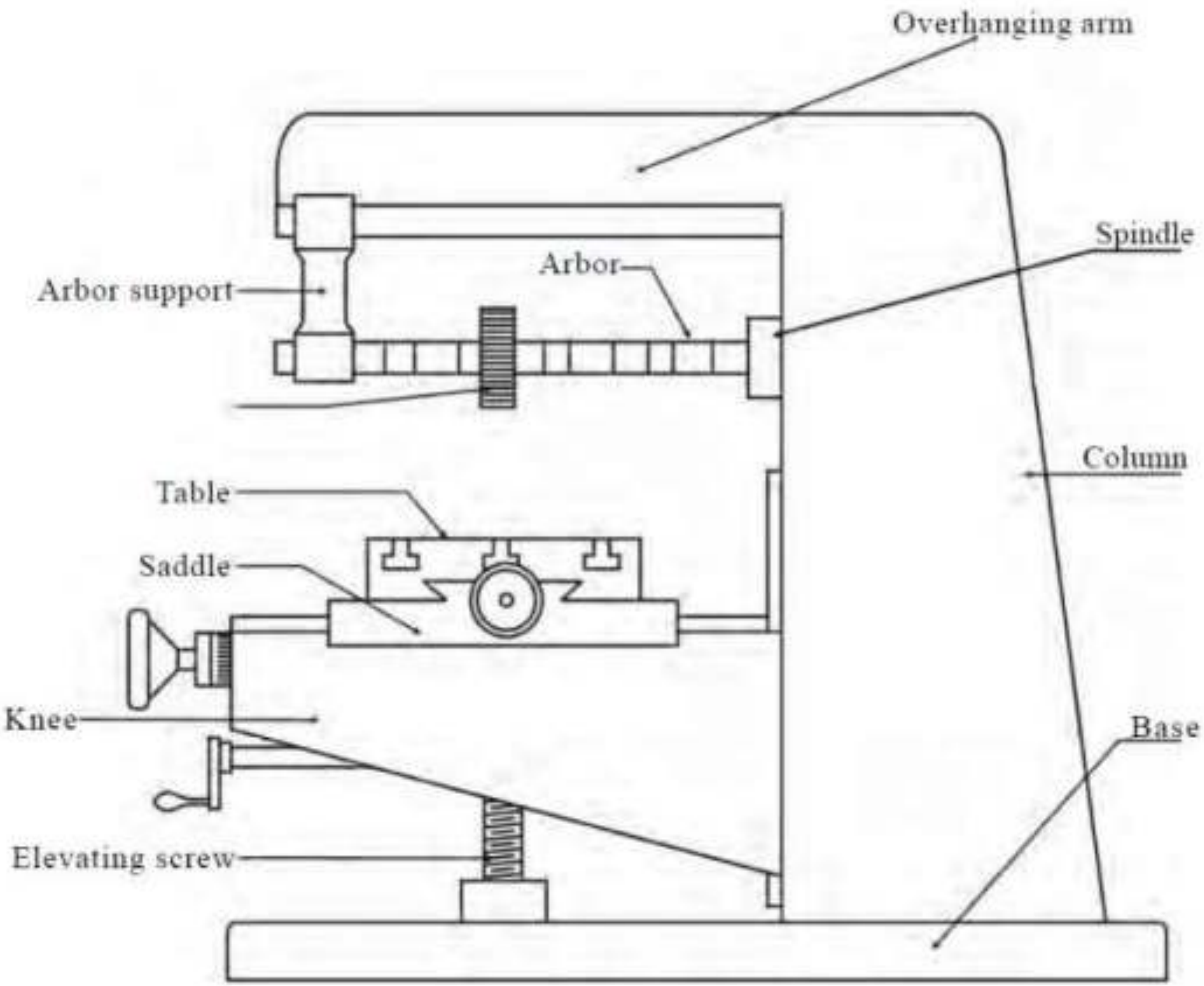
- It is mounted upon the base and is box shaped. It houses the mechanism for providing drive for the spindle. The front vertical face of the column is machined accurately to form dovetail guide ways for the knee to move up and down. The top of the column holds an overhanging arm.

Knee

- It slides up and down on the guide ways of the column. An elevating screw mounted on the base obtains this movement. Saddle is mounted upon the knee and moves in a cross direction.

Saddle

- It is mounted on the guide ways of the knee and moves towards or away from the face of the column. This movement can be obtained either by power or by hand. The top of the saddle has guide ways for the table movement.



Horizontal milling machine

Table

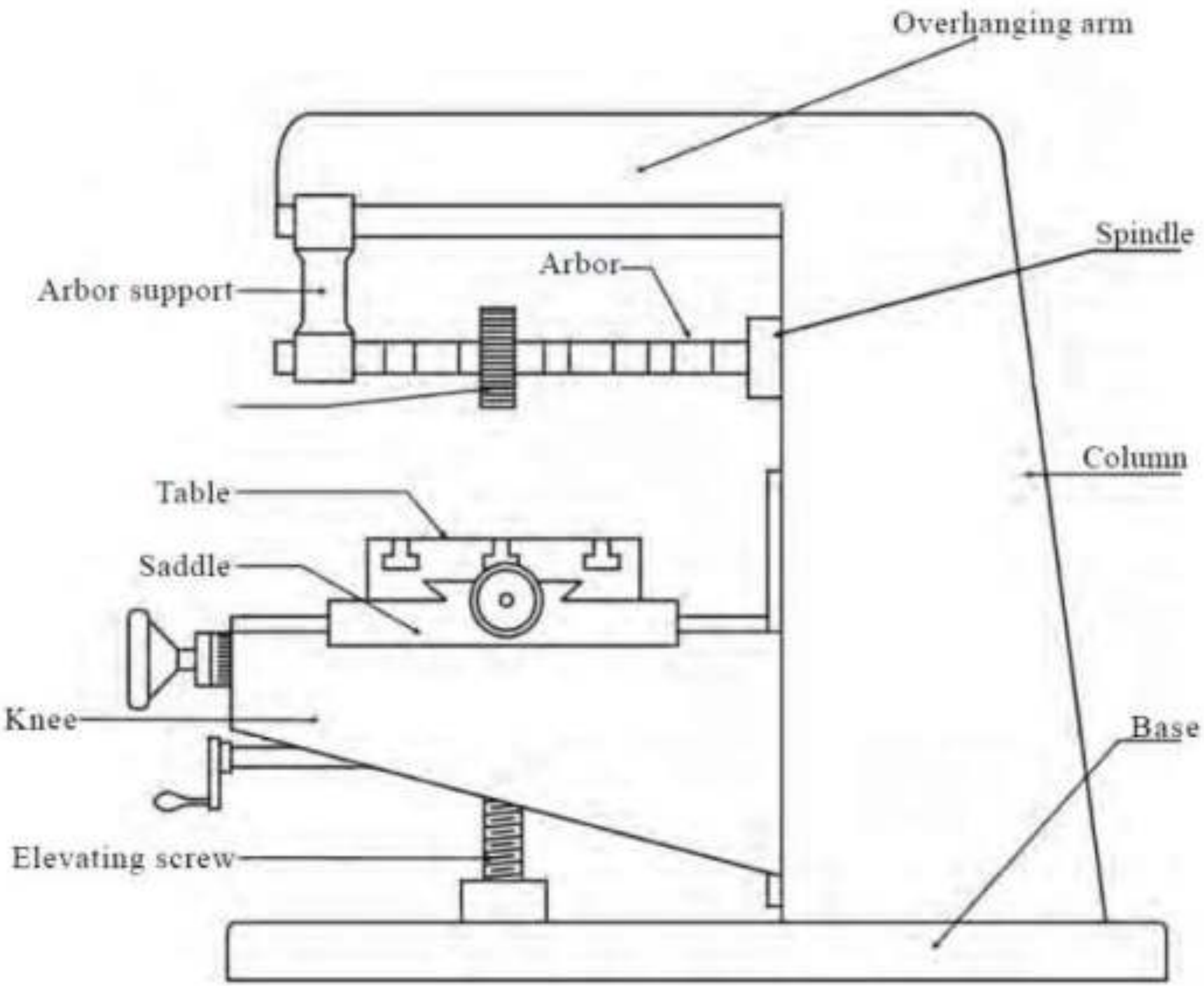
The table is moved longitudinally either by power or manually on the guide ways of the saddle. The trip dogs placed on it control the movement of the table. The table of a universal milling machine can be swivelled horizontally to perform helical works. The top surface of the table has got 'T' – slots on which the workpieces or other work holding devices are mounted.

Spindle

It is located in the upper part of the column. It receives power from the motor through belt, gears and clutches. The front end of the spindle has got a taper hole into which the cutters are held with different cutter holding devices.

Overhanging arm

It supports the arbour from the top of the column. The arbour is supported by the bearing fitted within the arbour support. It is also useful while using some special attachments.



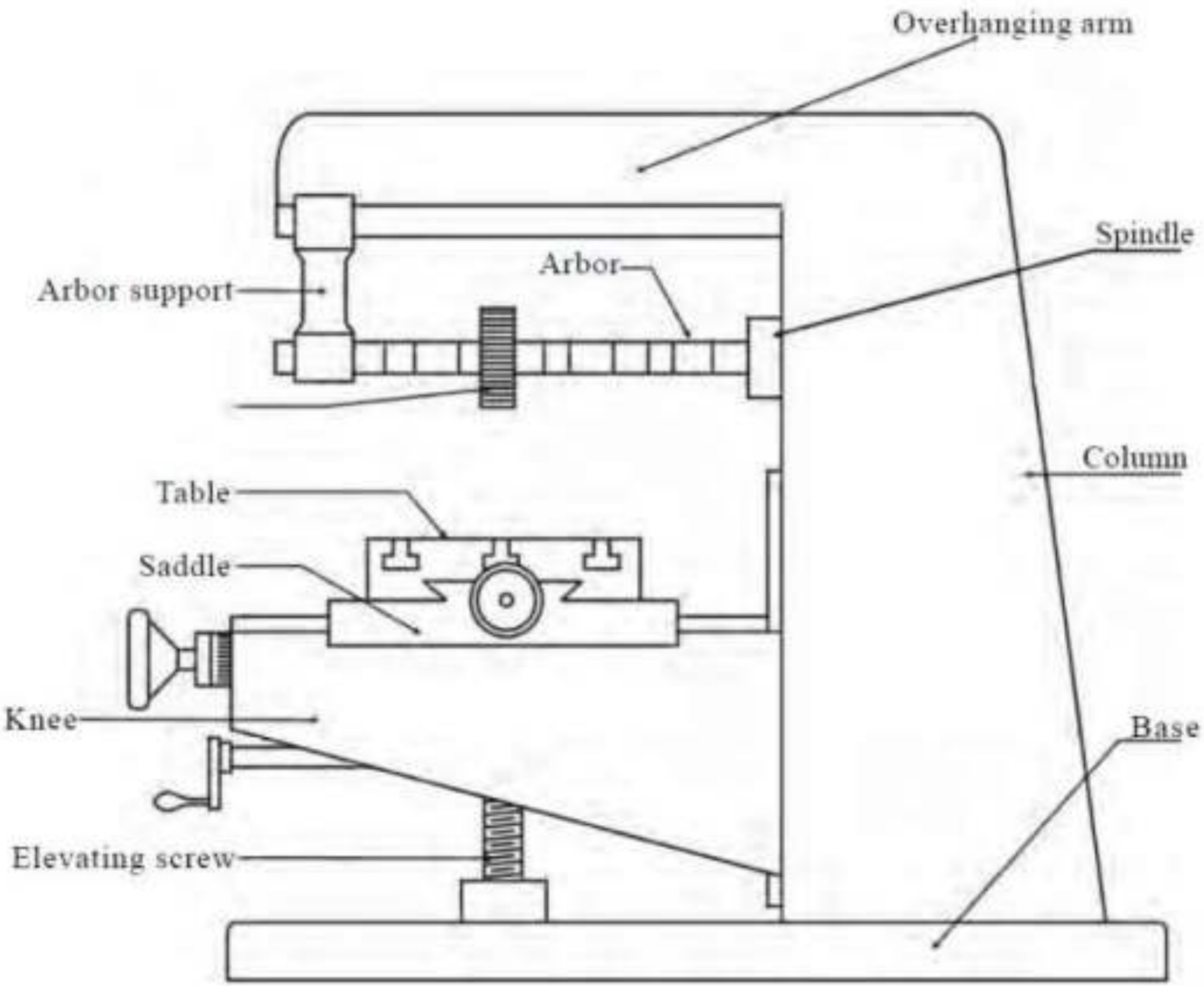
Horizontal milling machine

Front brace

It is an extra support fitted between the knee and the overhanging arm. It is slotted to allow the knee to be adjusted vertically.

Arbor

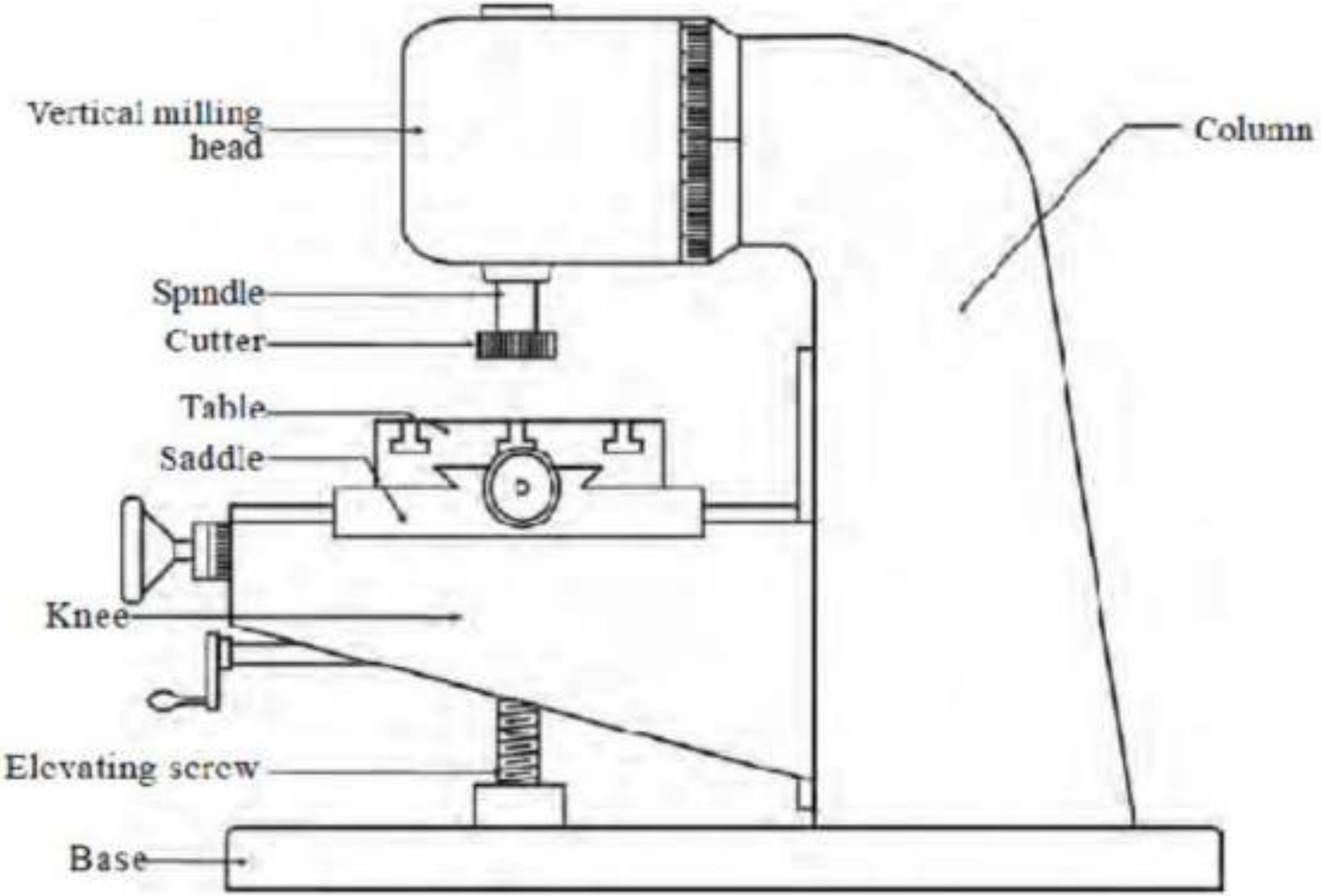
It supports the different types of cutters used in the machine. It is drawn into the taper hole of the spindle by a draw bolt. One or more cutters are mounted on the arbor by placing spacing collars between them. The arbor is supported by an arbor support. The arbor is provided with a Morse taper or self-releasing taper.



Horizontal milling machine

Vertical milling machine

- It is very similar to a horizontal milling machine in construction as it has the same parts of base, column, knee, saddle and table.
- The spindle of the machine is positioned vertically.
- The cutters are mounted on the spindle.
- The spindle is rotated by the power obtained from the mechanism placed inside the column.
- Angular surfaces are machined by swivelling the spindle head.



Vertical milling machine

Work holding devices

- For effective machining operations, the workpieces need to be properly and securely held on the machine table.
- The following are the usual methods of holding work on the table :

1. Vises :

i. Plain vise

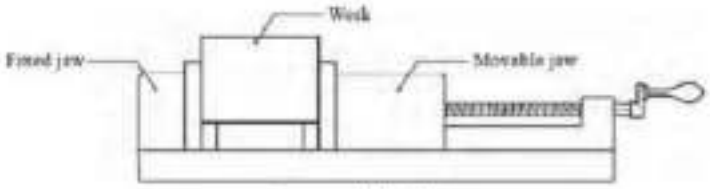
ii. Swivel Vise

iii. Universal Vise

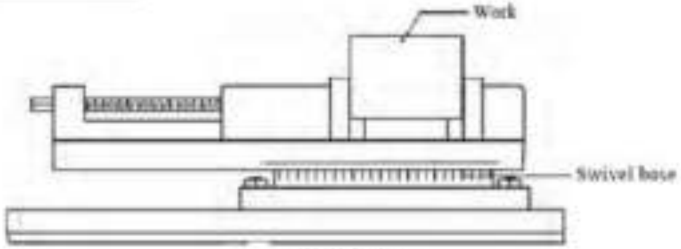
2. V- Block

3. Clamps, T bolts

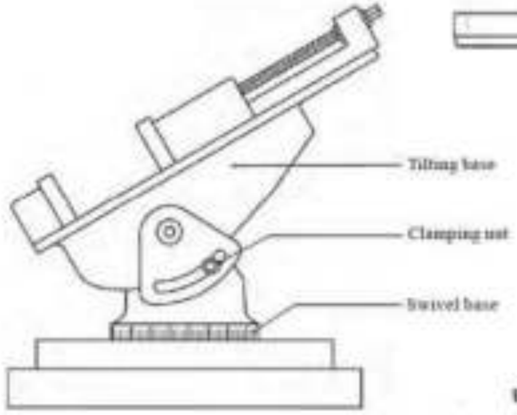
4. Angle Plate



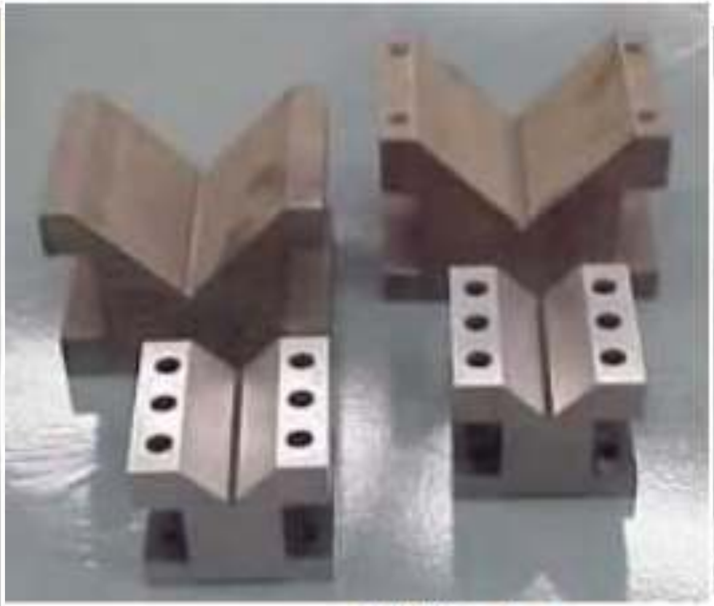
Plain vise



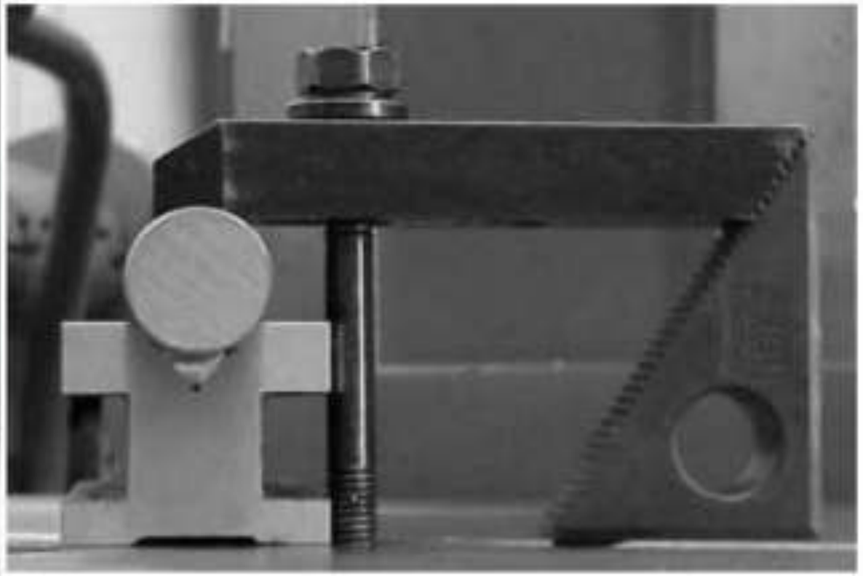
Swivel vise



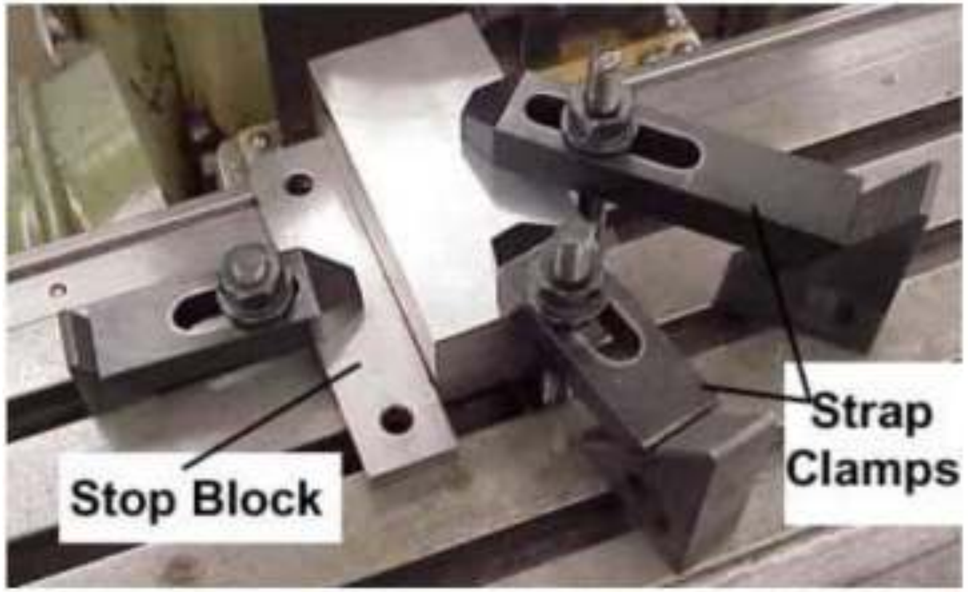
Universal vise



V-Blocks



Angle Plates



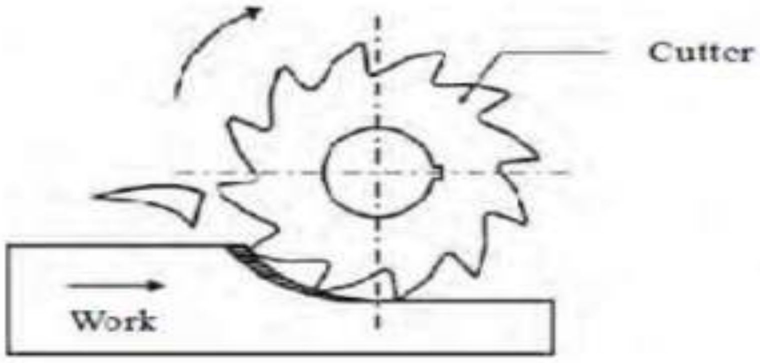
Milling Operation - Peripheral milling

The machining is performed by the cutting edges on the periphery of the milling cutter. It is classified under two headings

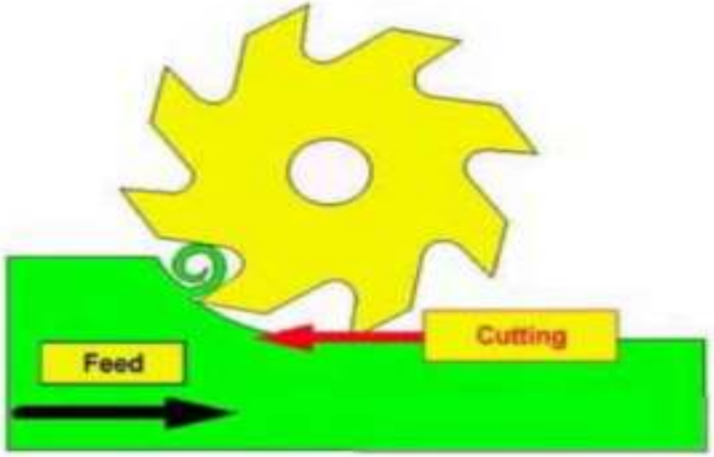
1. Up milling
2. Down milling

Up milling

- In this method, the workpiece mounted on the table is fed against the direction of rotation of the milling cutter.
- The cutting force is minimum during the beginning of the cut and maximum at the end of cut.
- The thickness of chip is more at the end of the cut. As the cutting force is directed upwards, it tends to lift the workpiece from the fixtures.
- A difficulty is felt in pouring coolant on the cutting edge. Due to these reasons the quality of the surface obtained by this method is wavy. This processes being safer is commonly used and sometimes called conventional milling.



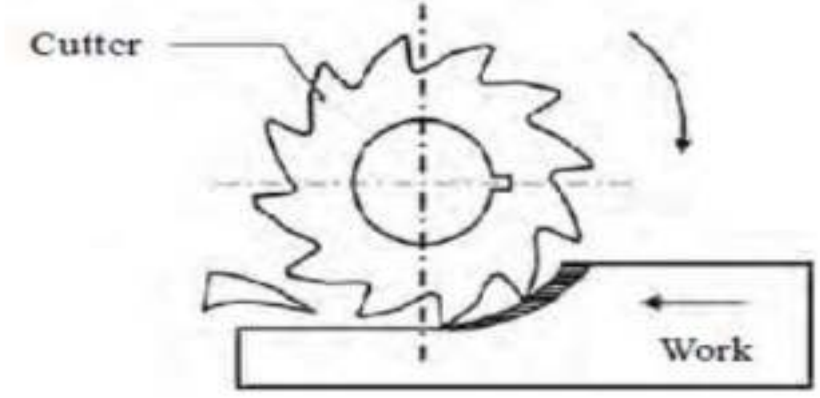
Upmilling



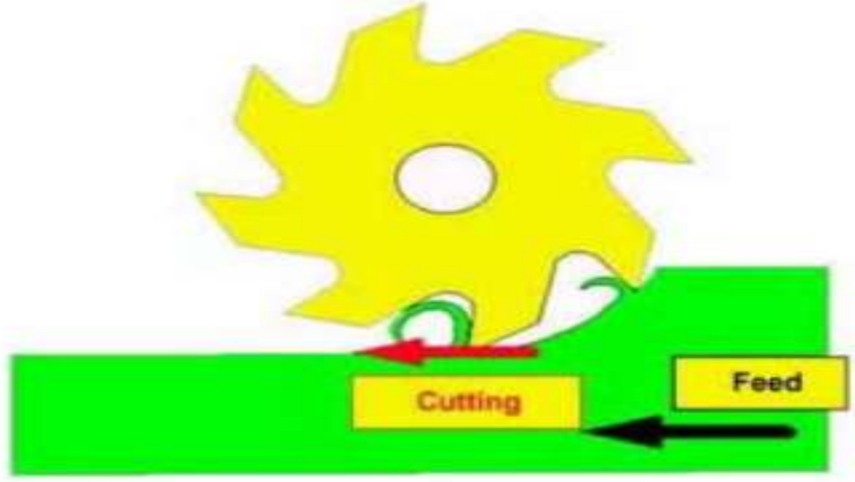
Up Cut Milling

Down milling

- The workpiece mounted on the table is moved in the same direction as that of the rotation of the milling cutter.
- The cutting force is maximum at the beginning and minimum at the end of cut. The chip thickness is more at the beginning of the cut.
- The workpiece is not disturbed because of the bite of the cutter on the work. The coolant directly reaches to the cutting point.
- So the quality of surface finish obtained is high. Because of the backlash error between the feed screw of the table and the nut, vibration is setup on the workpiece.



Downmilling



Down Cut Milling

Standard Milling Cutters

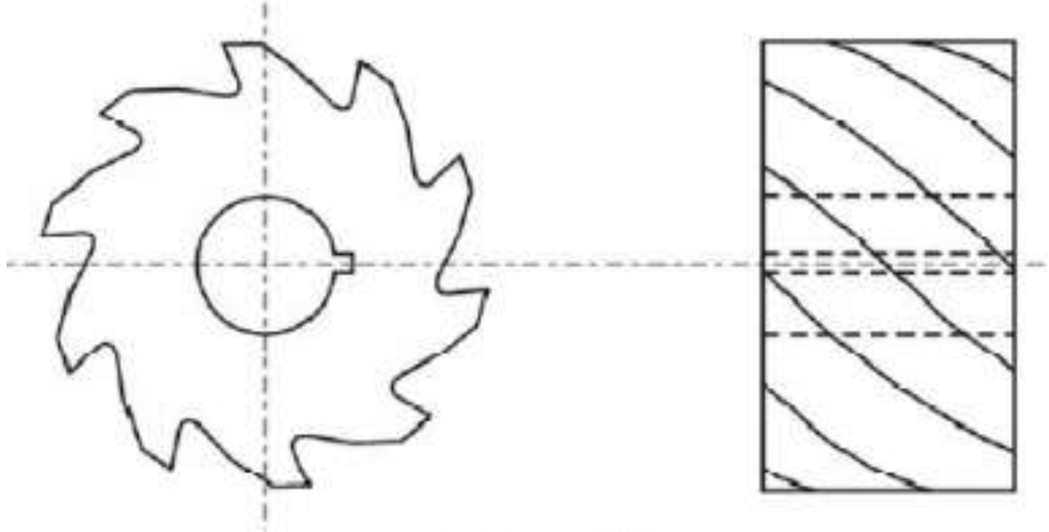
There are different types of milling cutters used in a milling machine.
A suitable milling cutter is selected according to the need.
They are

1. Plain milling cutter
2. Side milling cutter
3. Metal slitting saw
4. Angle milling cutter
5. End milling cutter
6. ‘T’ – Slot milling cutter
7. Fly cutter
8. Formed cutter

Plain Milling Cutter

Plain milling cutter

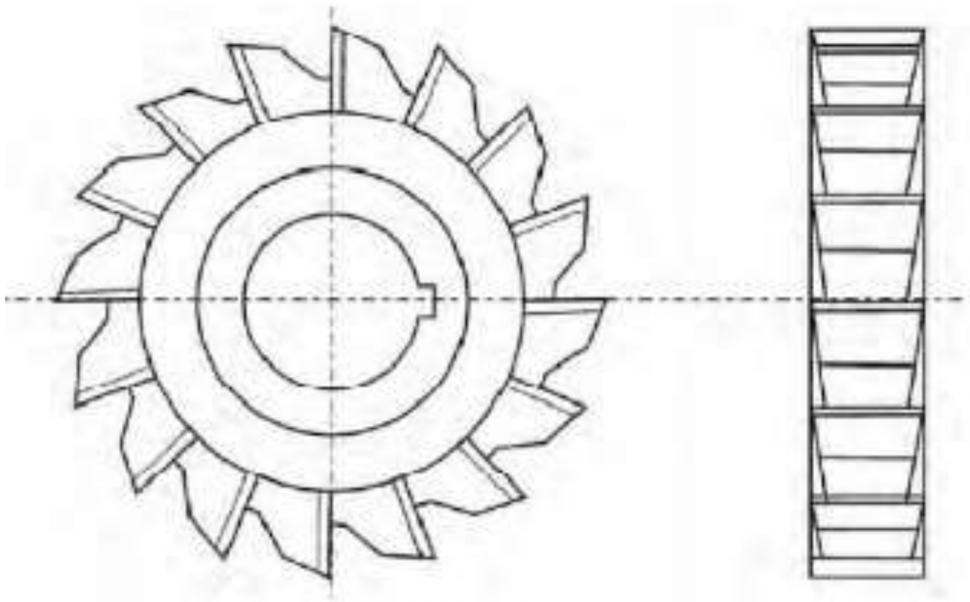
Side and face milling cutter



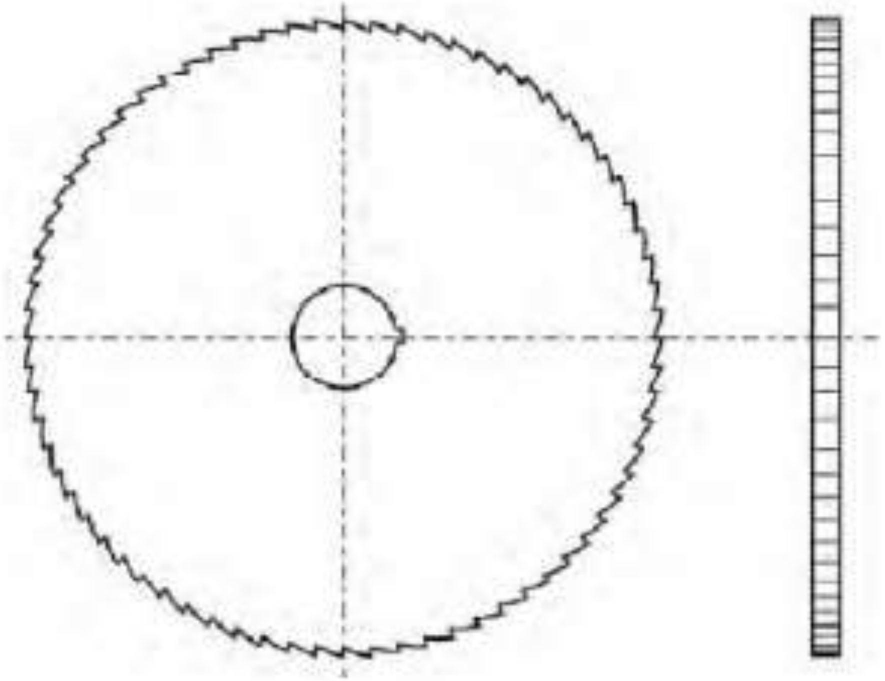
Plain milling cutter

Side milling cutter

Metal slitting saw



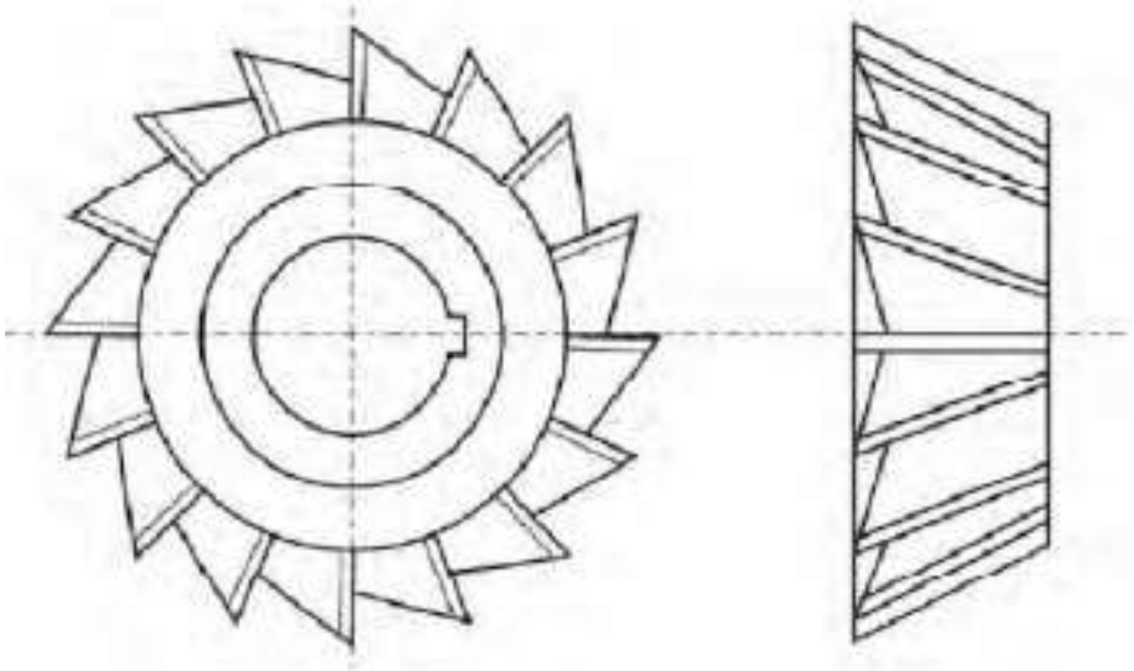
Side milling cutter



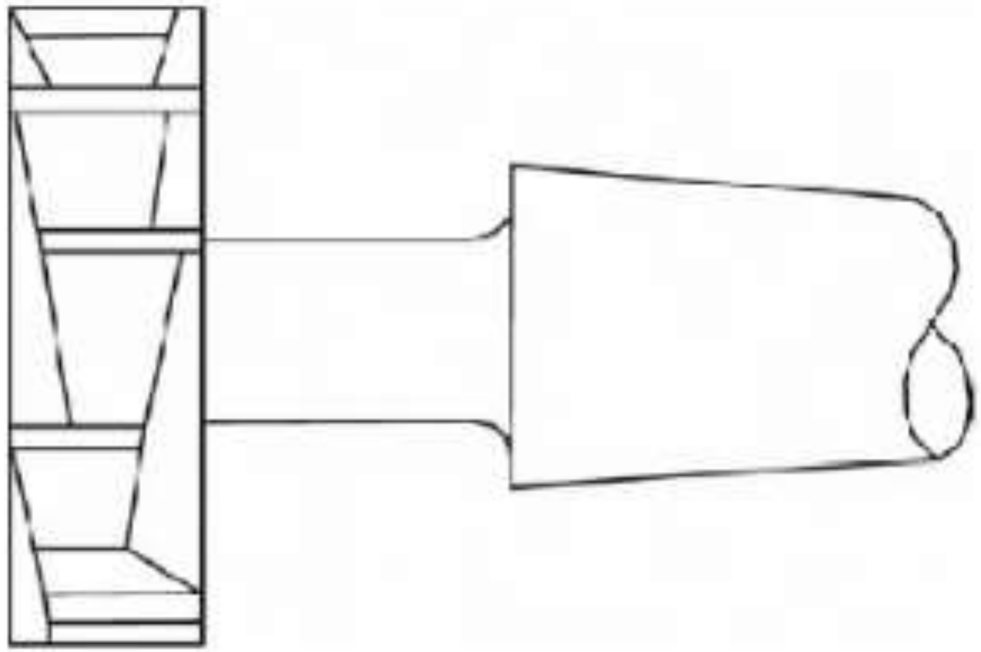
Metal slitting saw

Angle milling cutter

'T' – Slot milling cutter

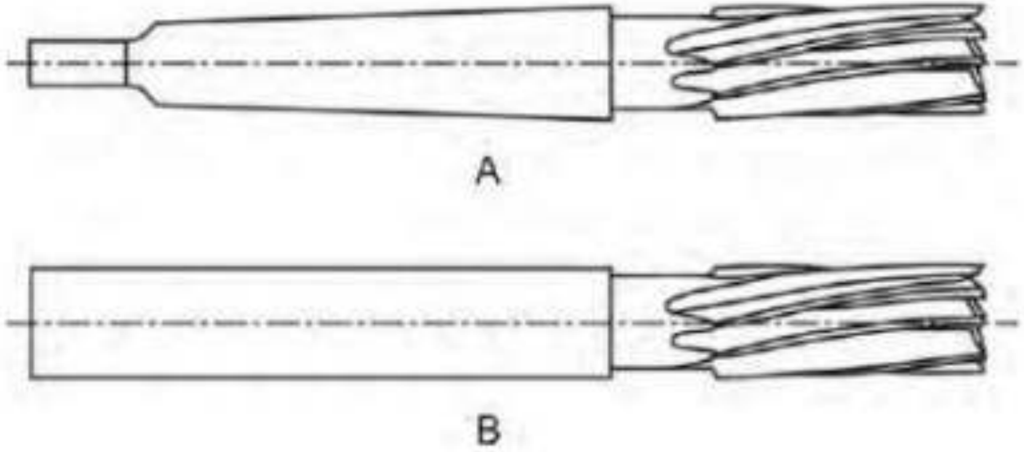


Angle milling cutter (Single)



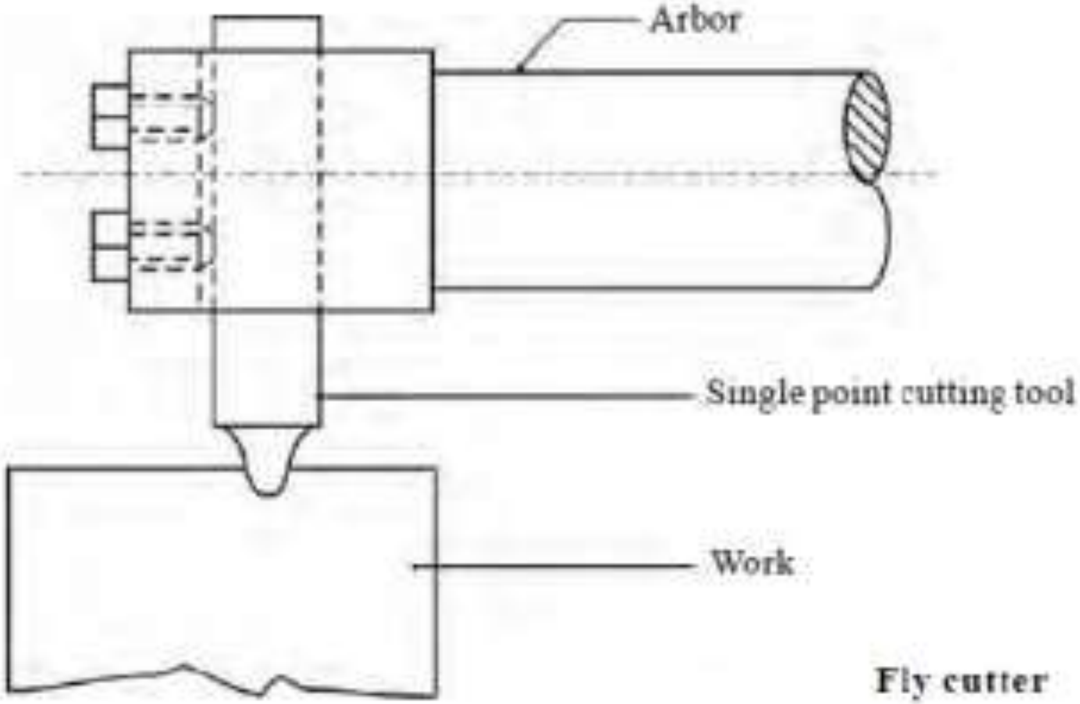
T' slot milling cutter

End milling cutter



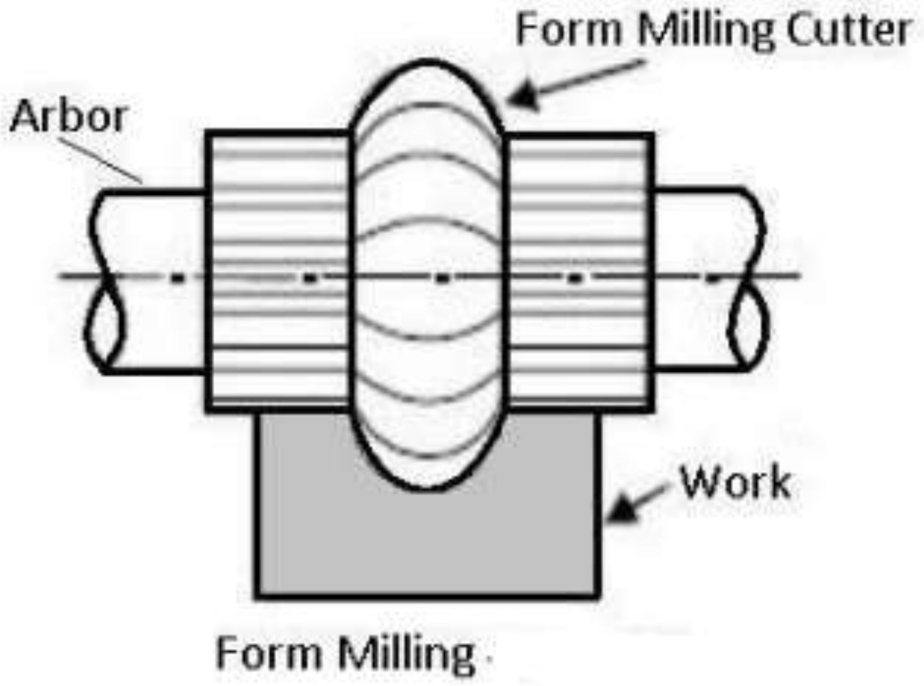
End milling cutters
A - Taper shank B - Straight shank

Fly cutter



Fly cutter

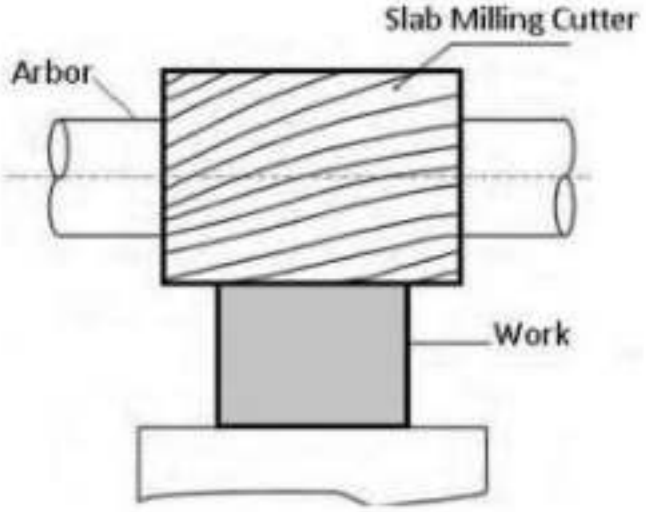
Formed cutter



Types of Milling Machine Operations

Plain Milling

- The plain milling is the most common types of milling machine operations.
- Plain milling is performed to produce a plain, flat, horizontal surface parallel to the axis of rotation of a plain milling cutter.
- The operation is also known as slab milling.

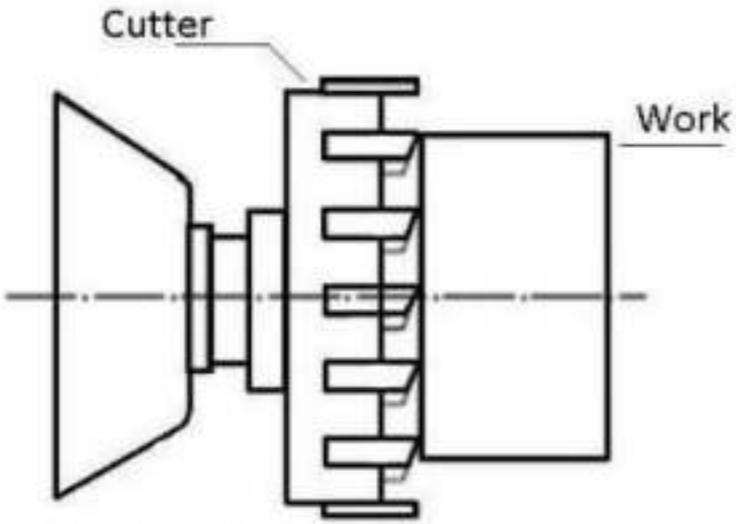


Plain Milling Operation

Types of Milling Machine Operations

Face Milling

- The face milling is the simplest milling machine operations.
- This operation is performed by a face milling cutter rotated about an axis perpendicular to the work surface.
- The operation is carried in plain milling, and the cutter is mounted on a stub arbor to design a flat surface.
- The depth of cut is adjusted by rotating the crossfeed screw of the table.



Face Milling Operation

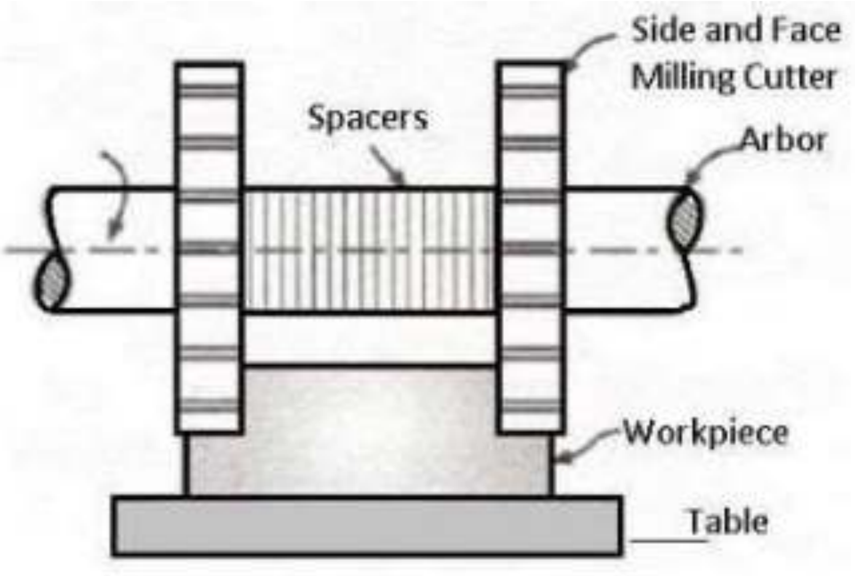
Types of Milling Machine Operations

Side Milling

- The side milling is the operation of producing a flat vertical surface on the side of a workpiece by using a side milling cutter.
- The depth of cut is set by rotating the vertical feed screw of the table.

Straddle Milling

- The straddle milling is the operation of producing a flat vertical surface on both sides of a workpiece by using two side milling cutters mounted on the same arbor.
- Distance between the two cutters is adjusted by using suitable spacing collars.
- The straddle milling is commonly used to design a square or hexagonal surfaces.

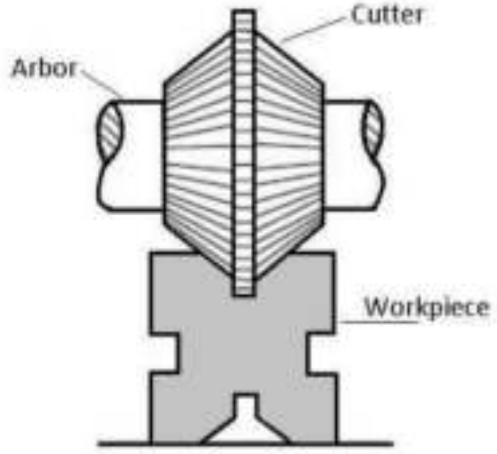


Straddle Milling Operation

Types of Milling Machine Operations

Angular Milling

- The angular milling is the operation of producing an angular surface on a workpiece other than at right angles of the axis of the milling machine spindle.
- The angular groove may be single or double angle and may be of varying included angle according to the type and contour of the angular cutter used.
- One simple example of angular milling is the production of V-blocks.

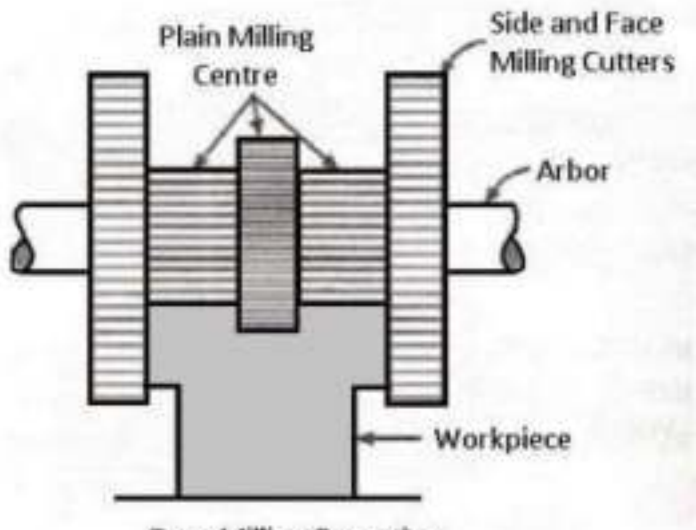


Angular Milling

Types of Milling Machine Operations

Gang Milling

- The gang milling is the operation of machining several surfaces of a workpiece simultaneously by feeding the table against a number of cutters having the same or different diameters mounted on the arbor of the machine.
- The method saves much of machining time and is widely used in repetitive work.
- Cutting speed of a gang of cutters is calculated from the cutter of the largest diameter

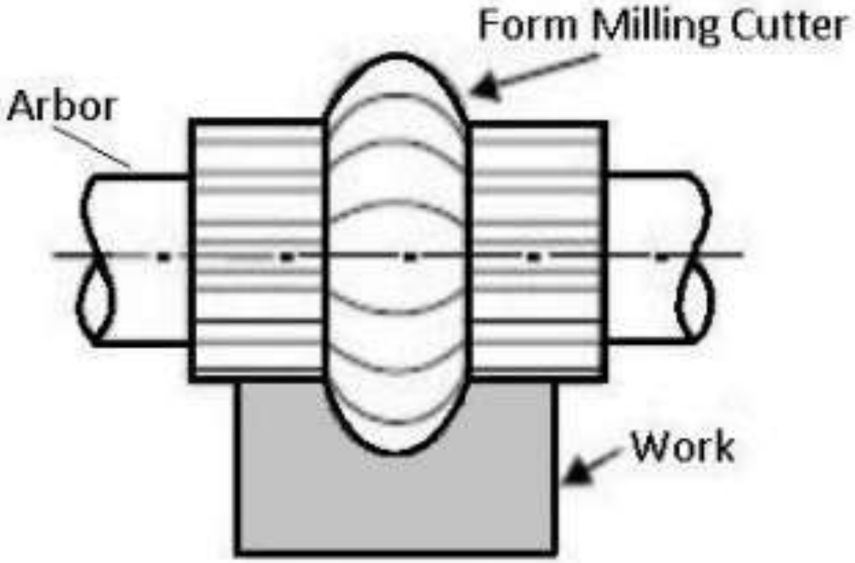


Gang Milling Operation

Types of Milling Machine Operations

Form Milling

- The form milling is the operation of producing the irregular contour by using form cutters.
- The irregular shape may be convex, concave, or of any other shape. After machining, the formed surface is inspected by a template gauge.
- Cutting rate for form milling is 20% to 30% less than that of the plain milling.

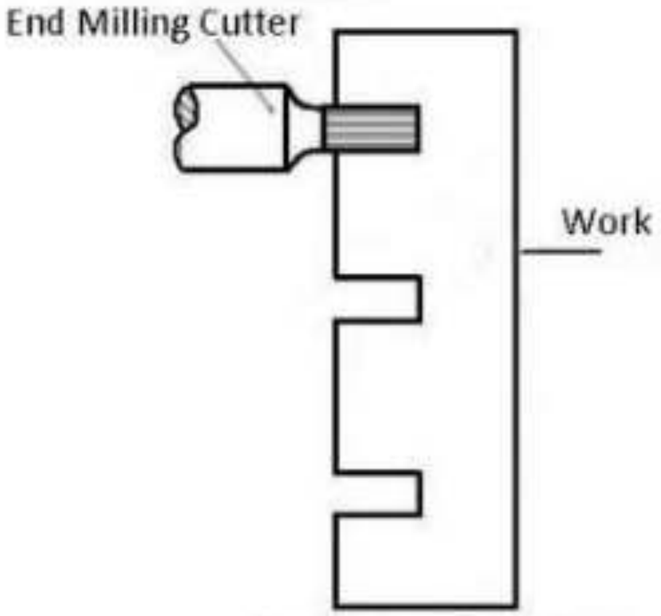


Form Milling Operation

Types of Milling Machine Operations

End Milling

- The end milling is the operation of producing a flat surface which may be vertical, horizontal or at an angle in reference to the table surface.
- The cutter used is an end mill. The end milling cutters are also used for the production of slots, grooves or keyways.
- A vertical milling machine is more suitable for end milling operation.

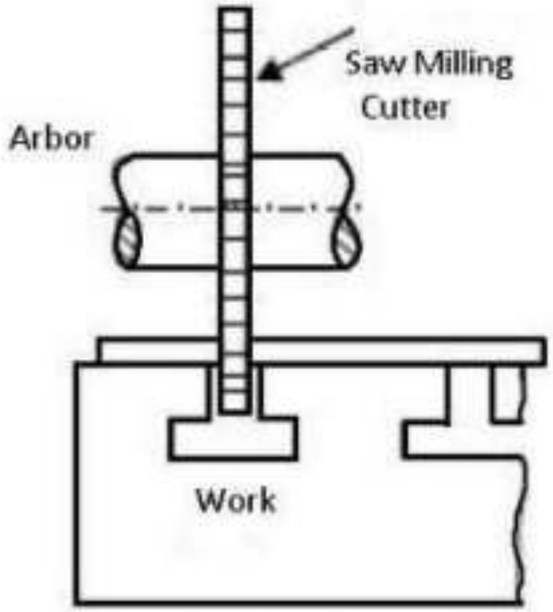


End Milling Operation

Types of Milling Machine Operations

Saw Milling

- Saw-milling is the operation of producing narrow slots or grooves on a workpiece by using a saw-milling cutter.
- The saw-milling also performed for complete parting-off operation.
- The cutter and the workpiece are set in a manner so that the cutter is directly placed over one of the T-slots of the table.

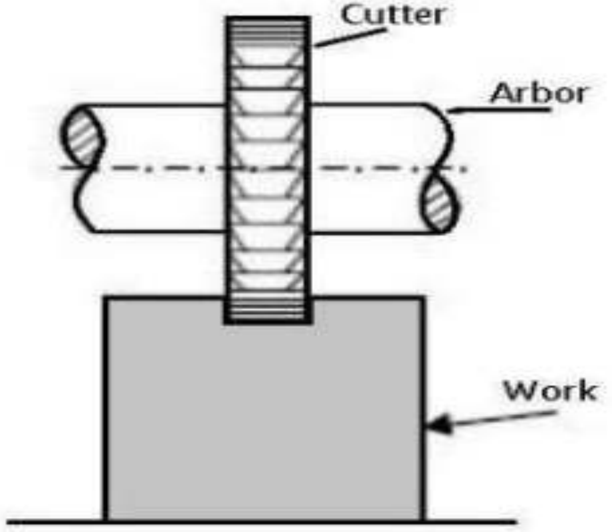


Saw Milling Opeartion

Types of Milling Machine Operations

Milling Keyways, Grooves and Slots

- The operation of producing of keyways, grooves and slots of varying shapes and sizes can be performed in a milling machine.
- It is done by using a plain milling cutter, a metal slitting saw, an end mill or by a side milling cutter.
- The open slots can be cut by a plain milling cutter, a metal slitting saw, or by a side milling cutter. The closed slots are produced by using endmills.

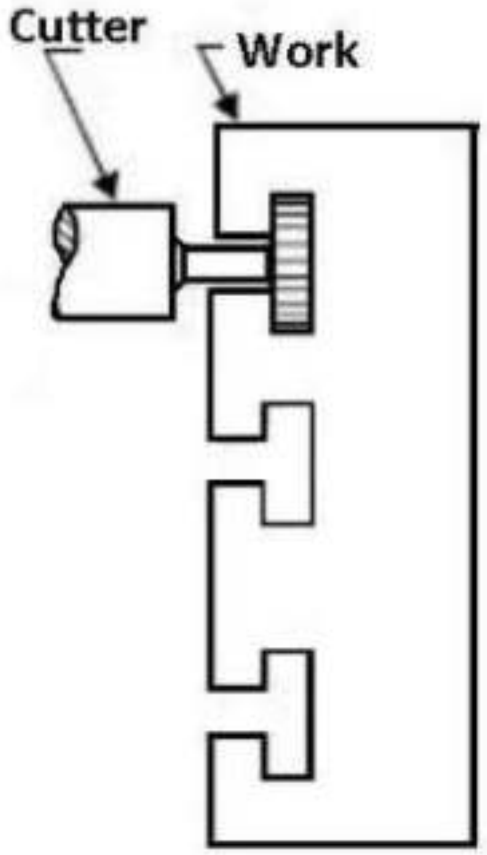


Keyway Milling Operation

Types of Milling Machine Operations

Milling Keyways, Grooves and Slots

- A dovetail slot or T-slot is manufactured by using special types of cutters designed to give the required shape on the workpiece.
- The second slot is cut at right angles to the first slot by feeding the work past the cutter.
- A woodruff key is designed by using a woodruff key slot cutter.
- Standard keyways are cut on the shaft by using side milling cutters or end mills.
- The cutter is set exactly at the centre line of the workpiece and then the cut is taken.

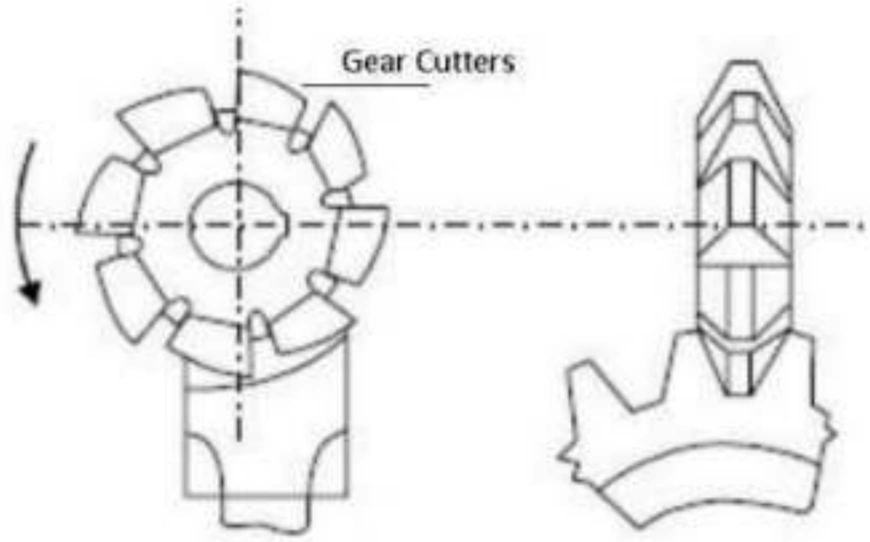


T-Slot Milling Operation

Types of Milling Machine Operations

Gear Cutting

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

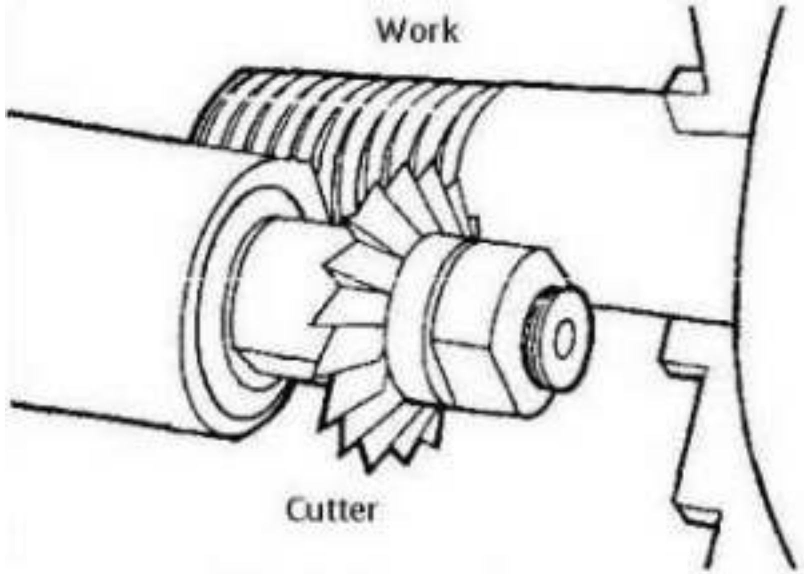


Gear Cutting Milling Operation

Types of Milling Machine Operations

Helical Milling

- The helical milling is the operation of producing helical flutes or grooves around the periphery of a cylindrical or conical workpiece.
- The operation is performed by rotating the table to the required helix angle. And then by rotating and feeding the workpiece against rotary cutting edges of a milling cutter.
- Production of the helical milling cutter, helical gears, cutting helical grooves or flutes on a drill blank or a reamer.



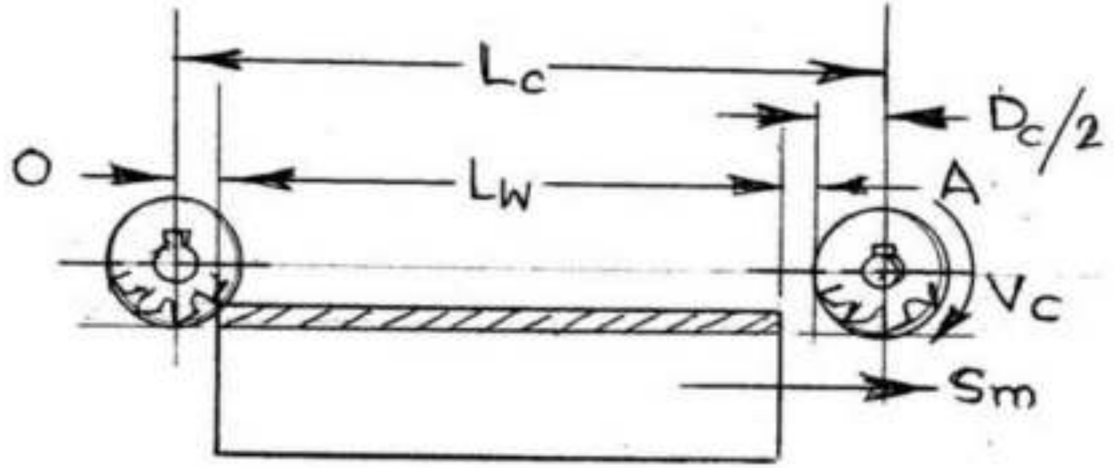
Helical Milling Operation

Machining time in Milling operations

There are different types of milling operations done by different types of milling cutters;

- Plain milling by slab milling cutter mounted on arbor
- End milling by solid but small end mill cutters being mounted in the spindle through collet
- Face milling by large face milling cutters being directly fitted in the spindle.

Fig. shows the scheme of plain milling by a plain or slab milling cutter and indicates how the machining time is to be calculated.



Plain milling operation.

Machining time in Milling operations

The machining time, TC for plain milling a flat surface can be determined as,

$TC = L_C / s_m$ (for job width < cutter length)

L_C = total length of travel of the job

$= L_W + A + O + D_C/2$

Lw = length of the workpiece

A, O = approach and over run (5 to 10 mm)

D_C= diameter of the cutter, mm

S_m= table feed, mm/min

$= s_o Z_C N$

where,

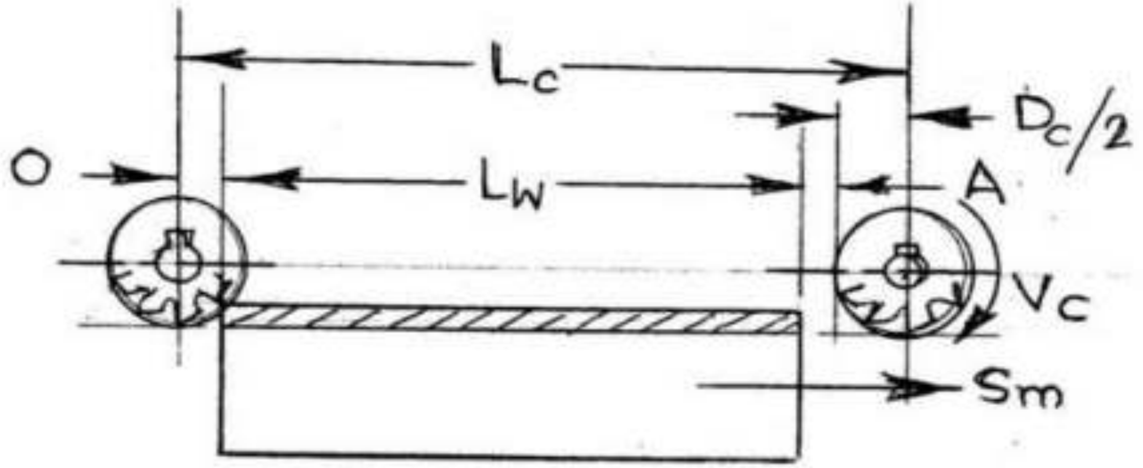
s_o = feed per tooth, mm/tooth

Z_C= number of teeth of the cutter

N = cutter speed, rpm.

Again, N has to be determined from V_C

$$V_C = \frac{\pi\, D_C\, N}{1000}$$



Plain milling operation.

Determine TC for plain milling a rectangular surface of length 100 mm and width 50 mm by a helical fluted plain HSS milling cutter of diameter 60 mm, length 75 mm and 6 teeth. Assume A = O = 5 mm, VC = 40 m/min and so = 0.1 mm/tooth?

Solution:

$$T_C = \frac{L_C}{s_m} \text{ min}$$

$$L_C = L_w + A + O + \frac{D_C}{2} = 100 + 5 + 5 + 30 = 140\,mm$$

$$s_m = s_o Z_C N = 0.1x6xN$$

where, $$N = \frac{1000V_C}{\pi D_C} = \frac{1000x40}{\pi x60} \cong 200\ rpm$$

$$s_m = 0.2x6x200 = 120\ mm/\text{min}$$

So, $$T_C = \frac{L_C}{s_m}$$

$$= \frac{140}{120} = 1.17 \text{ min.}$$

GRINDING MACHINE

Introduction

- Grinding is a metal cutting operation like any other process of machining removing metal in comparatively smaller volume.
- The cutting tool used is an abrasive wheel having many numbers of cutting edges.
- The machine on which grinding the operation is performed is called a grinding machine.
- Grinding is done to obtain very high dimensional accuracy and better appearance.

Types of grinding machines

- According to the accuracy of the work to be done on a grinding machine, they are classified as

1. Rough grinding machines
2. Precision grinding machines

Precision grinding machines

- Precision grinders are used to finish parts to very accurate dimensions. The main types of precision grinders are:

1. Cylindrical grinding machines
2. Internal grinding machines
3. Surface grinding machines
4. Tool and cutter grinding machines
5. Special grinding machines

Cylindrical Grinding Machine

- Cylindrical grinders are generally used to grind external surfaces like cylinders, taper cylinders, faces and shoulders of work. There are two types of cylindrical grinding machines and they are

1. External cylindrical grinding machines
2. Internal cylindrical grinding machines

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1. External cylindrical grinding machines
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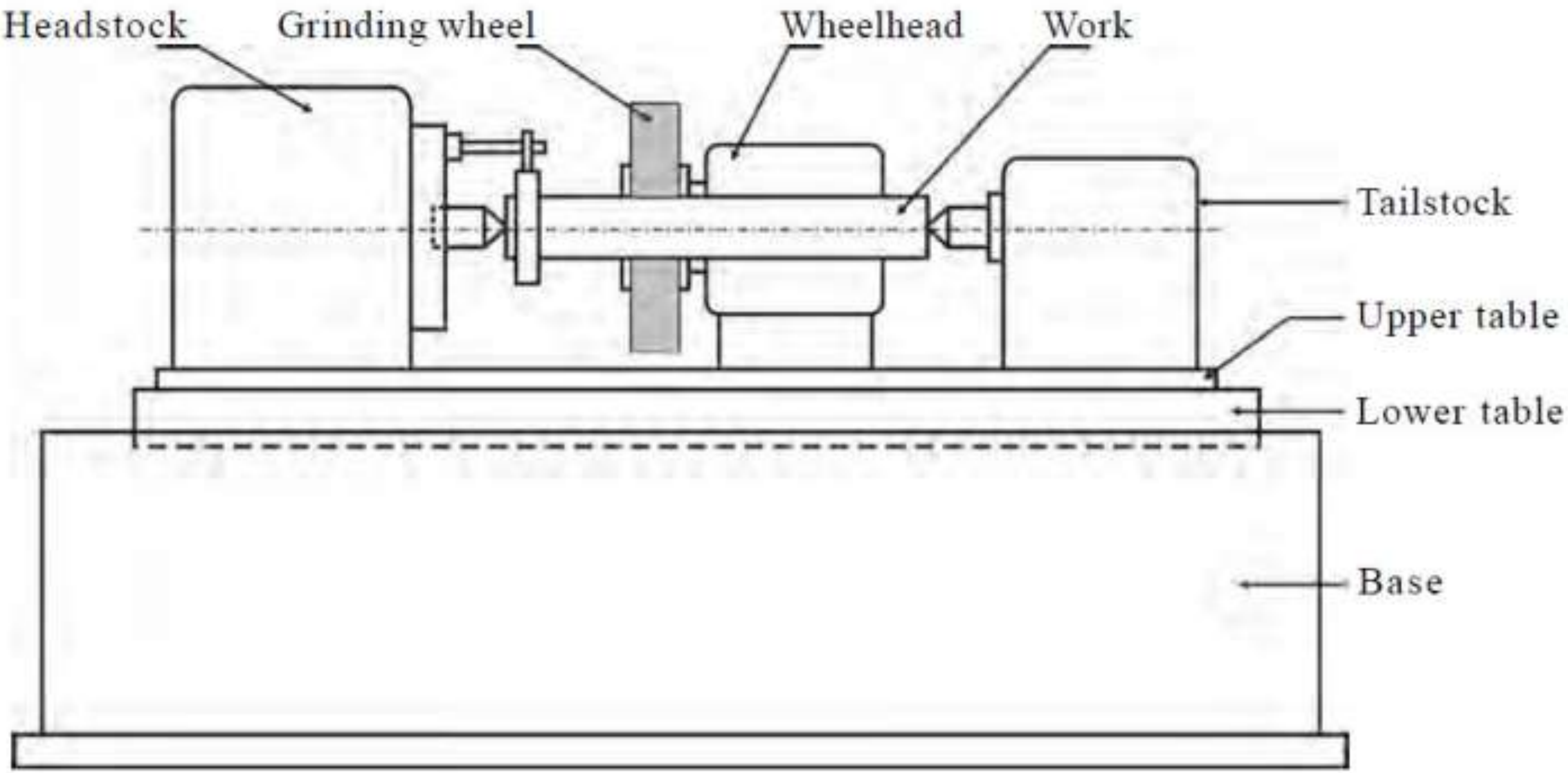
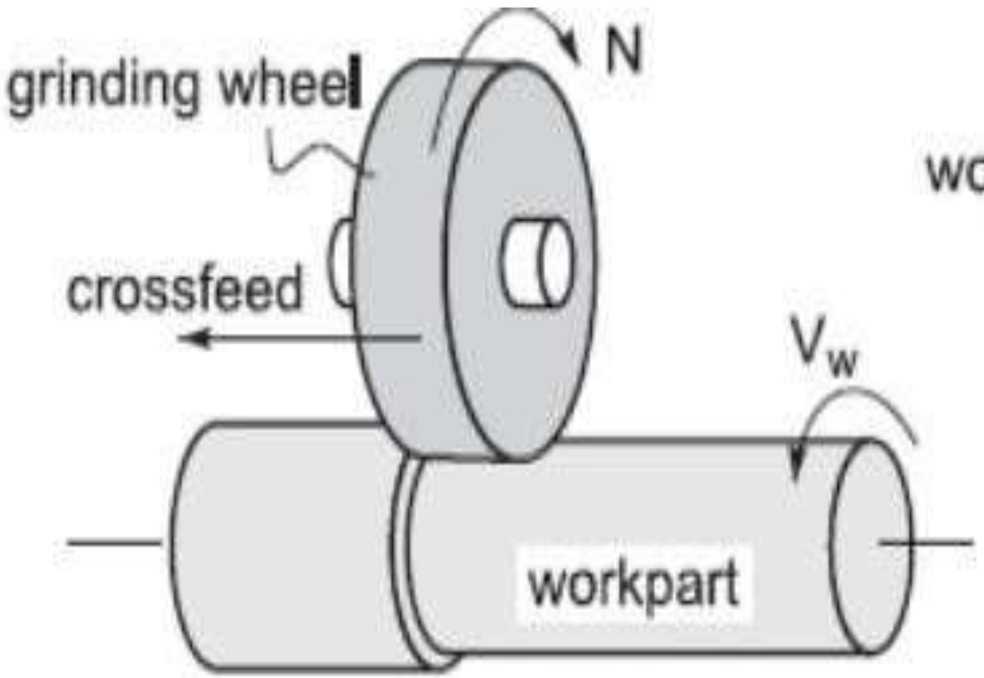
Cylindrical Grinding Machine

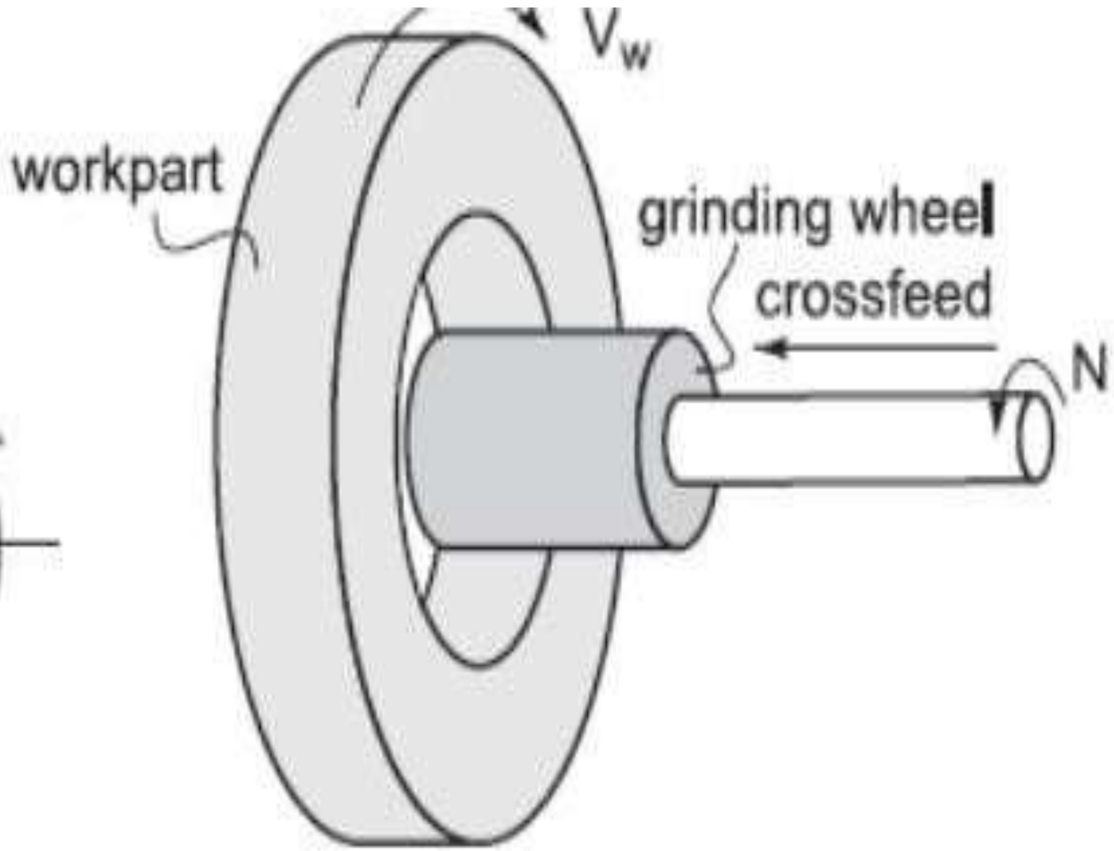


Cylindrical grinding machine

Cylindrical Grinding

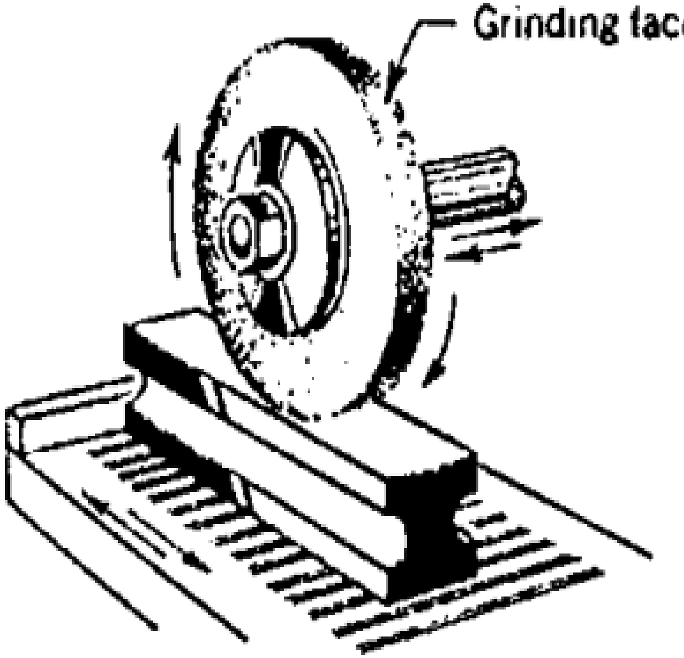
- Cylindrical grinding is performed by mounting and rotating the work between centres in a cylindrical grinding machine.
- The work is fed longitudinally against the rotating grinding wheel to perform grinding.
- The upper table of the grinding machine is set at 0° during the operation.
- This machine is used primarily for grinding cylindrical surfaces, although tapered and simple format surfaces may also be ground.
- The depth of cut is controlled by feeding the wheel into the work.
- Roughing cuts around 0.002 in(0.05 mm) per pass may be made but for finishing this should be reduce to about 0.0002 in (0.005 mm) per pass or less.


grinding wheel
N
crossfeed
V_w
workpart

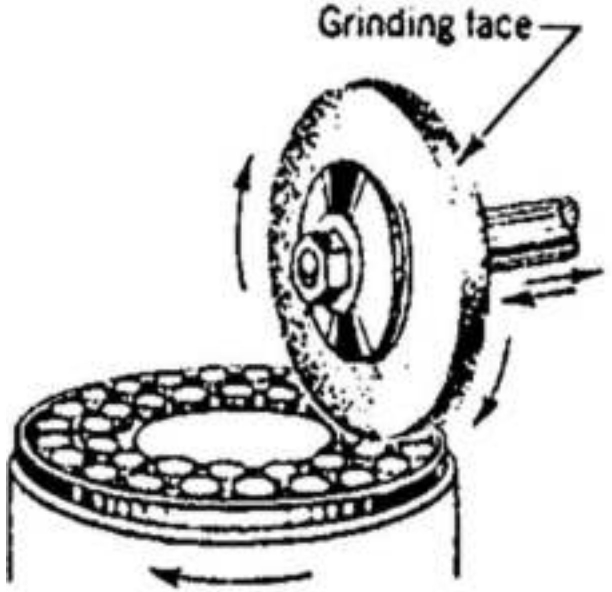

V_w
workpart
grinding wheel
crossfeed
N

Surface Grinding Machines

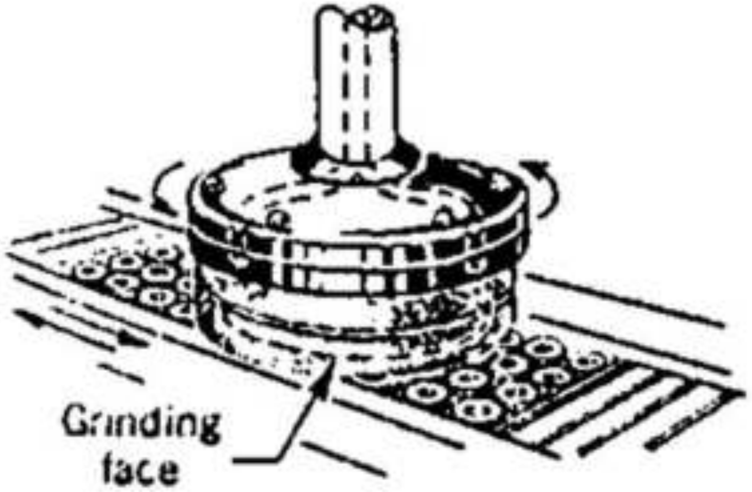
- Grinding flat or plane surfaces is known as surfaces grinding. Two general types of machines have been developed for this purpose; those of the planer type with a reciprocating table and those having a rotating worktable.
- Each machine has the possible variation of a horizontal or vertical positioned grinding wheel spindle. The four possibilities of construction are illustrated below figure.



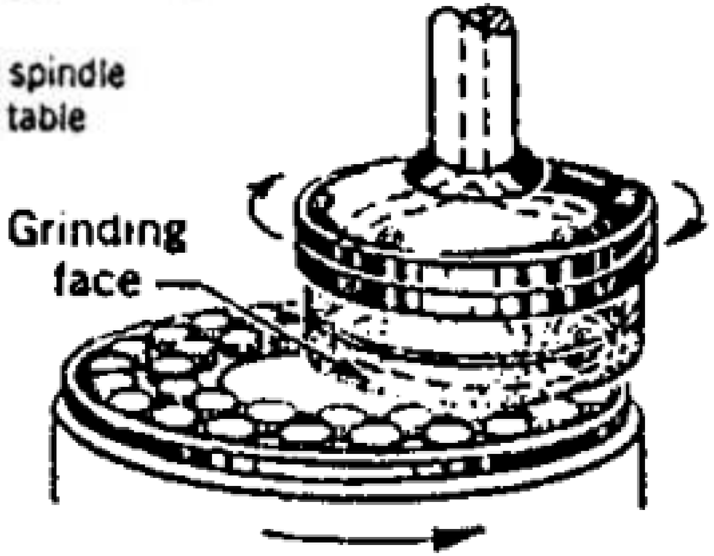
Horizontal spindle reciprocating table



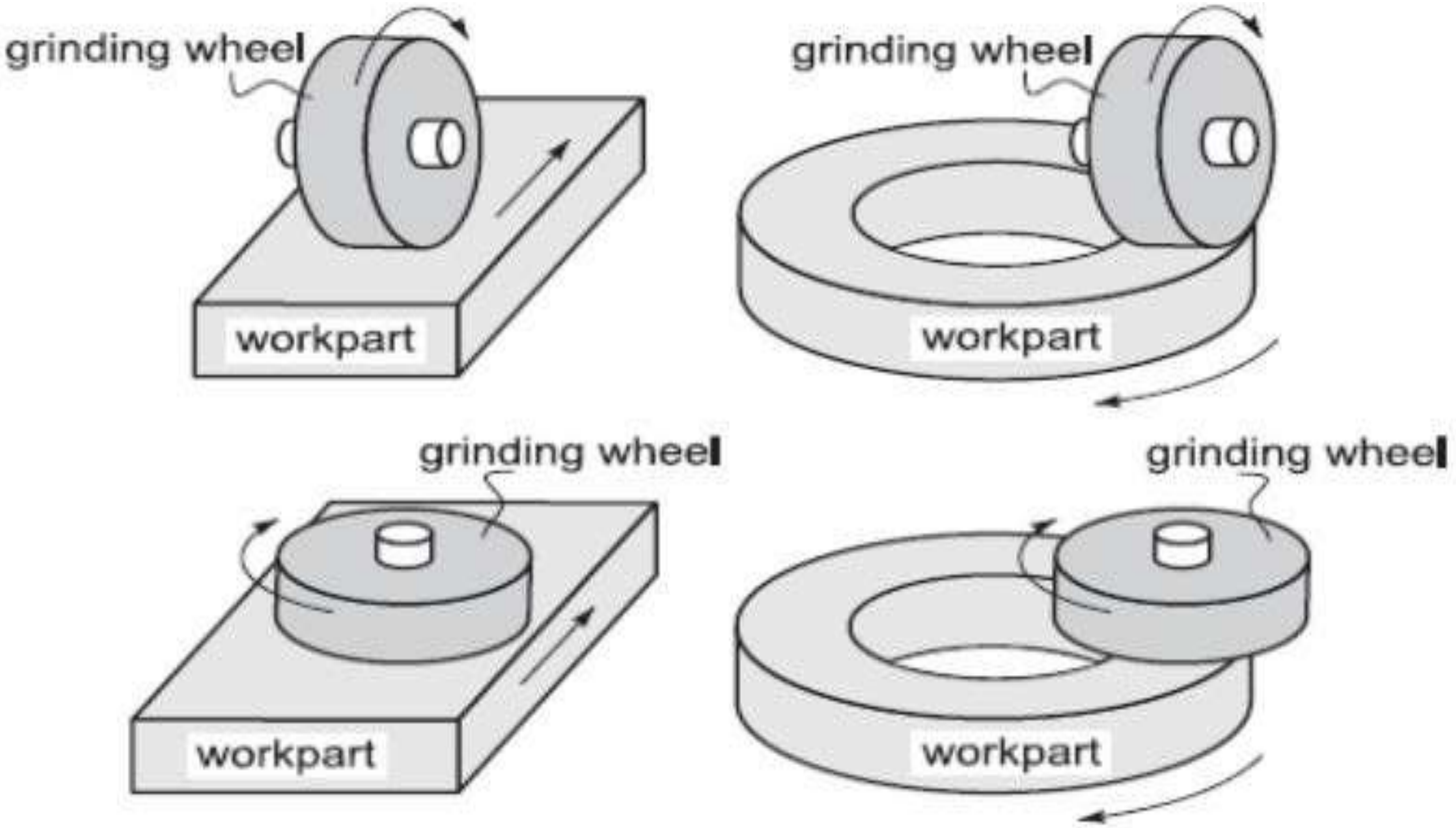
Horizontal spindle rotating table



Vertical spindle reciprocating table



Vertical spindle rotating table


grinding wheel
workpart
grinding wheel
workpart
grinding wheel
workpart
grinding wheel
workpart

Surface grinding machines

- Surface grinding machines are employed to finish plain or flat surfaces horizontally, vertically or at any angle.
- There are four different types of surface grinders. They are:

1. Horizontal spindle and reciprocating table type
2. Horizontal spindle and rotary table type
3. Vertical spindle and reciprocating table type
4. Vertical spindle and rotary table type

Horizontal spindle surface grinding machine

- The majority of surface grinders are of horizontal spindle type.
- In the horizontal type of the machine, grinding is performed by the abrasives on the periphery of the wheel.
- Though the area of contact between the wheel and the work is small, the speed is uniform over the grinding surface and the surface finish is good.
- The grinding wheel is mounted on a horizontal spindle and the table is reciprocated to perform grinding operation.

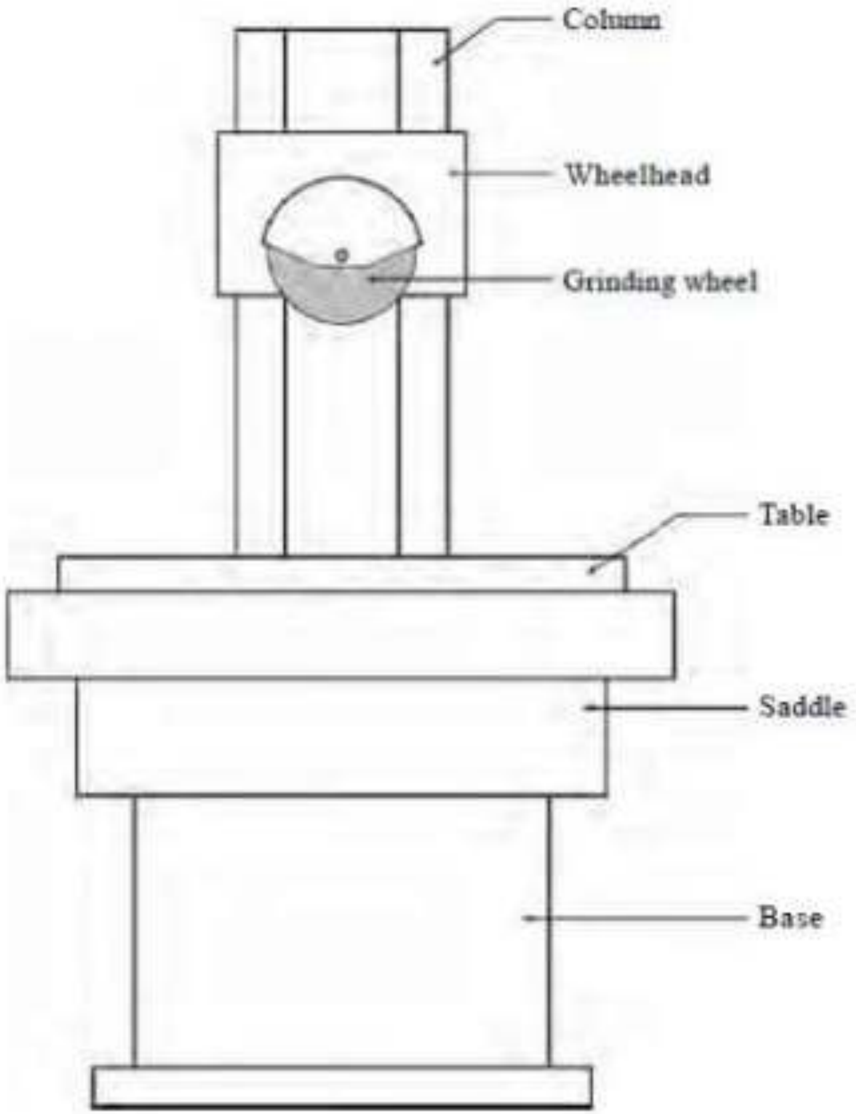


Fig Horizontal spindle surface grinder

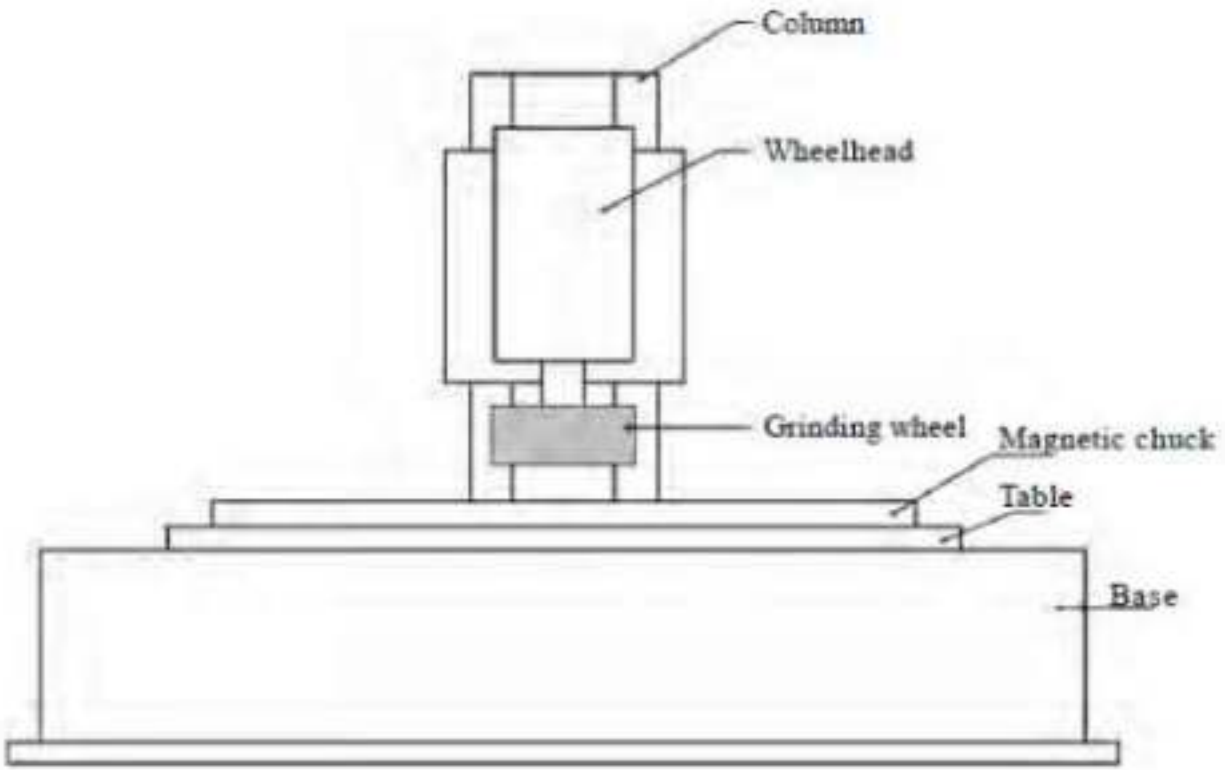


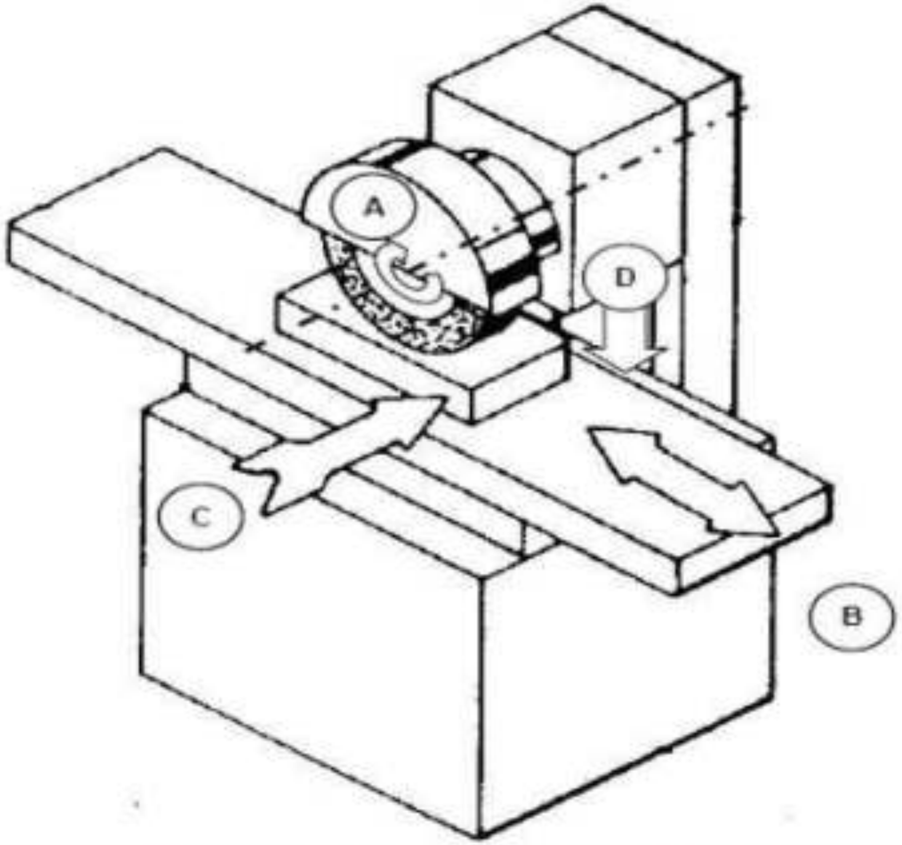
Fig Vertical spindle surface grinder

Vertical spindle surface grinding machine

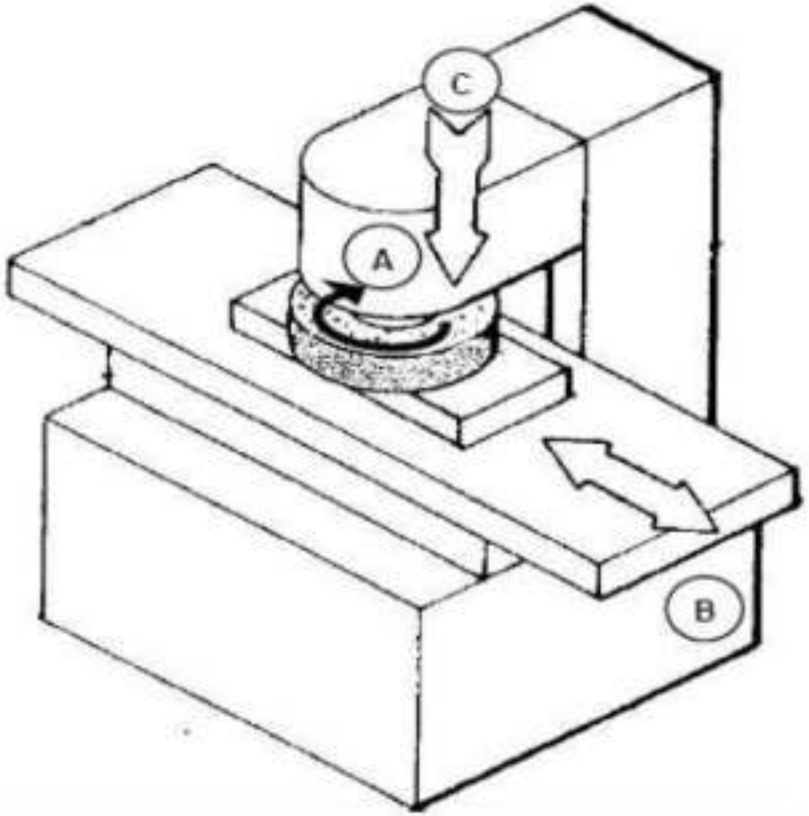
- The face or sides of the wheel are used for grinding in the vertical type surface grinders.
- The area of contact is large and stock can be removed quickly.
- But a criss-cross pattern of grinding scratches is left on the work surface.
- Considering the quality of surface finish obtained, the horizontal spindle type machines are widely used.

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.

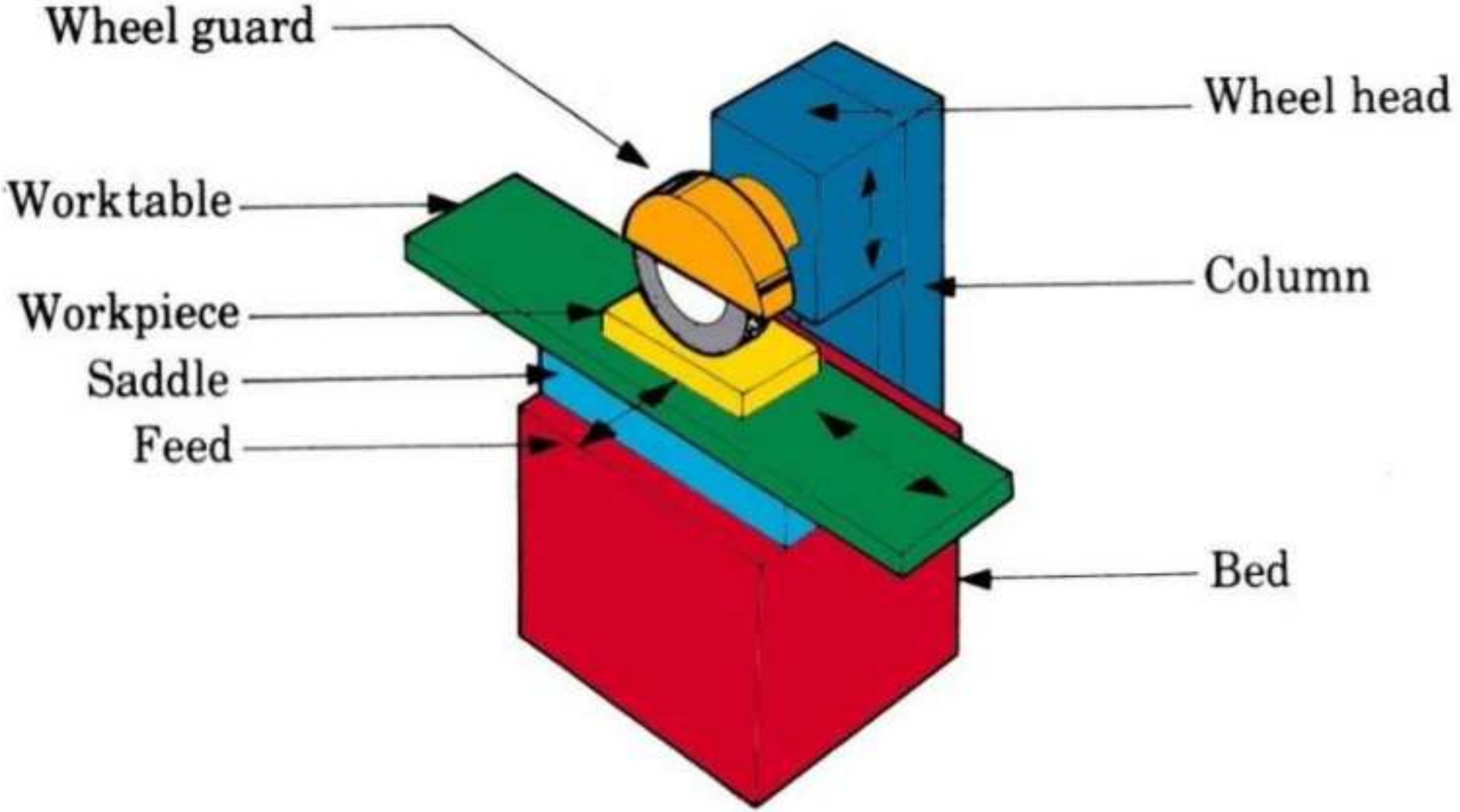


Horizontal Grinding Machine



Vertical Grinding Machine

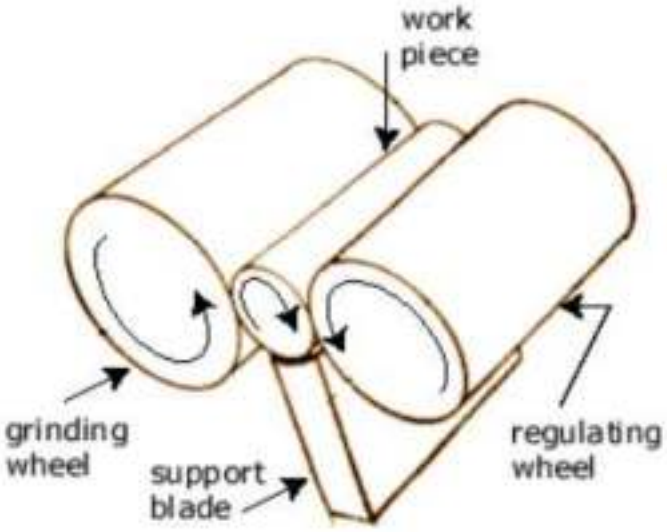
Surface grinding machine

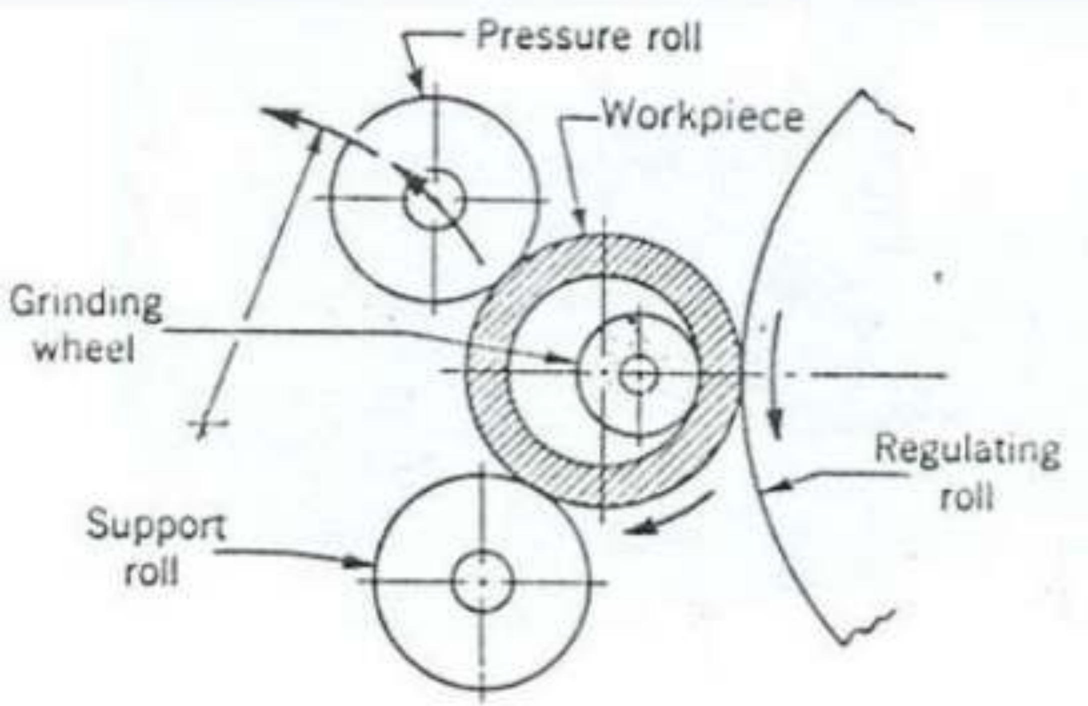


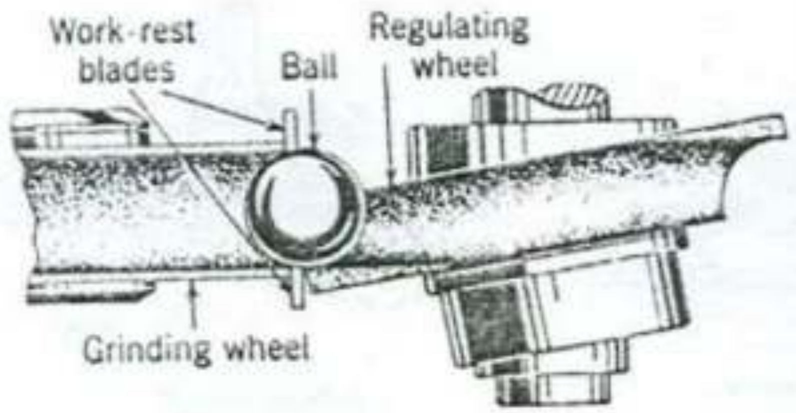
Centerless grinders

- Centerless grinders are designed so that they support and feed the work by using two wheels and a work rest as illustrated in figure.
- The large wheel is the grinding wheel and the smaller one the pressure or regulating wheel.
- The regulating wheel is a rubber-bonded abrasive having the frictional characteristics to rotate the work at is own rotational speed.
- The speed of this wheel, which may be controlled, varies from 50 to 200 ft/min (0.25-1.02 m/s).
- Both wheels are rotating the same direction.
- The rest assists in supporting the work while it is being ground, being extended on both sides to direct the work travel to and from the wheels.
- The axial movement of the work past the grinding wheel is obtained by tilting the wheel at a slight angle from horizontal. An angular adjustment of 0 ° to 10° is provided in the machine for this purpose.

Centerless grinders







Grinding wheel

- A grinding wheel is a multi-tooth cutter made up of many hard particles known as abrasives having sharp edges.
- The abrasive grains are mixed with a suitable bond, which acts as a matrix to manufacture grinding wheels.

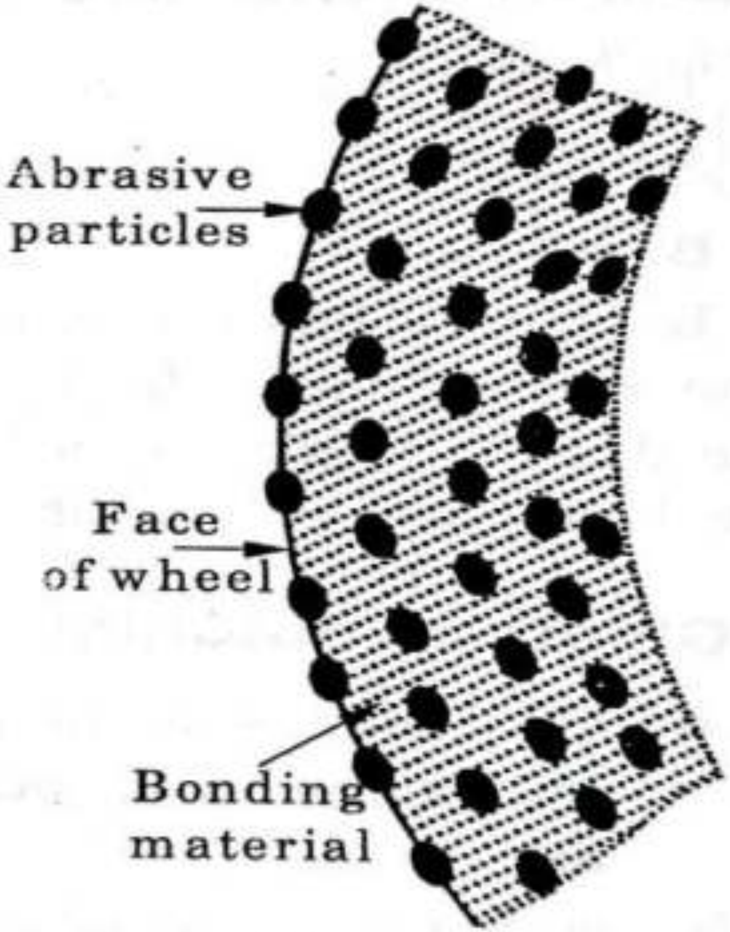
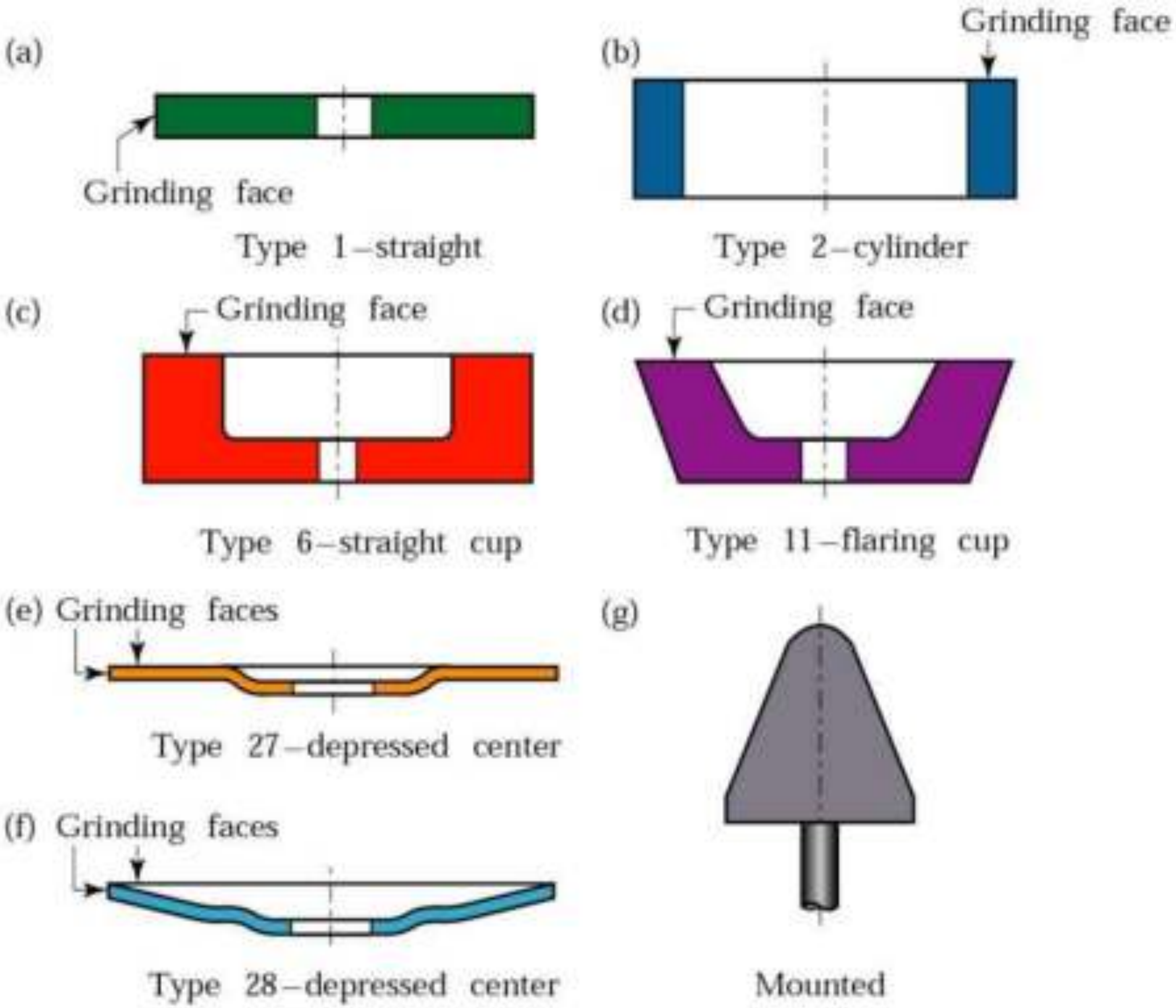


Fig. 6.83. Showing edge of abrasive grains.

According to construction, grinding wheels are classified under three categories.

1. Solid grinding wheels
2. Segmented grinding wheels
3. Mounted grinding wheels



(a)
Grinding face
Type 1–straight
(b)
Grinding face
Type 2–cylinder
(c)
Grinding face
Type 6–straight cup
(d)
Grinding face
Type 11–flaring cup
(e) Grinding faces
Type 27–depressed center
(f) Grinding faces
Type 28–depressed center
(g)
Mounted

Abrasives

- Abrasives are used for grinding and polishing operations.
- It should have uniform physical properties of hardness, toughness and resistance to fracture.

- Abrasive may be classified into two principal groups.

1. Natural abrasives
2. Artificial abrasives

Natural abrasives

- The natural abrasives are obtained from the Earth's crust. They include sandstone, emery, corundum and diamond.
- Sandstone is used as abrasive to grind softer materials only.
- Emery is natural alumina.
- It contains aluminium oxide and iron oxide. Corundum is also a natural aluminium oxide.
- It contains greater percentage of aluminium oxide than emery.
- Both emery and corundum have a greater hardness and abrasive action than sandstone.
- Diamond is the hardest available natural abrasive.
- It is used in making grinding wheels to grind cemented carbide tools.

Artificial abrasives

- Artificial abrasives are of two types.

1. Silicon carbide abrasives
2. Aluminium oxide abrasives

Silicon carbide

- Silicon carbide is manufactured from 56% silica, 34% powdered coke, 2% salt and 8 % sawdust in a long rectangular electric furnace of the resistance type that is built of loose brick work.
- There are two types of silicon carbide abrasives - green grit and black grit. Silicon carbide is next to diamond in the order of hardness.
- But it is not tough enough as aluminium oxide.
- It is used for grinding materials of low tensile strength such as cemented carbides, ceramic materials, grey brass, bronze, copper, aluminium, vulcanized rubber etc.
- This is manufactured under trade names of carborundum. It is denoted by the letter 'S'.

Aluminium oxide

- Aluminium oxide is manufactured by heating mineral bauxite, silica, iron oxide, titanium oxide, etc., mixed with ground coke and iron borings in arc type electric furnace.
- Aluminium oxide is tough and not easily fractured, so it is better adapted to grinding materials of high tensile strength such as most steels, carbon steels, high speed steels, and tough bronzes.
- This is denoted by the letter 'A'.

Types of bonds

- A bond is an adhesive substance that is employed to hold abrasive grains together in the form of grinding wheels.
- There are several types of bonds.
- Different grinding wheels are manufactured by mixing hard abrasives with suitable bonds.
- The table containing the types of wheels manufactured using different types of bonds and their symbols is given below

Type of bond	Symbol	Grinding wheel
1. Vitrified	V	Vitrified wheel
2. Silicate	S	Silicate wheel
3. Shellac	E	Elastic wheel
4. Resinoid	B	Resinoid wheel
5. Rubber	R	Vulcanised wheel
6. Oxychloride	O	Oxychloride wheel

Grain size, Grade and Structure

Grain size (Grit)

- The grinding wheel is made up of thousands of abrasive grains.
- The grain size or grit number indicates the size of the abrasive grains used in making a wheel, or the size of the cutting teeth.
- Grain size is denoted by a number indicating the number of meshes per linear inch of the screen through which the grains pass when they are graded.
- There are four different groups of the grain size namely coarse, medium, fine and very fine.
- If the grit number is large, the size of the abrasive is fine and a small grit number indicates a large grain of abrasive.

Grain size

Coarse	:	10,	12,	14,	16,	20,	24	
Medium	:	30,	36,	46,	54,	60		
Fine	:	80,	100,	120,	150,	180		
Very fine	:	220,	240,	280,	320,	400,	500,	600

Grain size, Grade and Structure

Grade

- The grade of a grinding wheel refers to the hardness with which the wheel holds the abrasive grains in place.
- It does not refer to the hardness of the abrasive grains. The grade is indicated by a letter of the English alphabet.
- The term ‘soft’ or ‘hard’ refers to the resistance a bond offers to disruption of the abrasives.
- A wheel from which the abrasive grains can easily be dislodged is called soft whereas the one, which holds the grains more securely, is called hard.
- The grade of the bond can be classified in three categories

Grade

Soft	:	A	B	C	D	E	F	G	H		
Medium	:	I	J	K	L	M	N	O	P		
Hard	:	Q	R	S	T	U	V	W	X	Y	Z

Grain size, Grade and Structure

Structure

- The relative spacing occupied by the abrasives and the bond is referred to as structure. It is denoted by the number and size of void spaces between grains. It may be 'dense' or 'open'.
- Open structured wheels are used to grind soft and ductile materials. Dense wheels are useful in grinding brittle materials.

Dense	:	1	2	3	4	5	6	7	8
Open	:	9	10	11	12	13	14	15 or higher	

Standard marking system of grinding wheels

- The Indian standard marking system for grinding wheels has been prepared with a view of establishing a uniform system of marking of grinding wheels to designate their various characteristics.

Prefix	Manufacturer's abrasive type symbol
First element (letter)	Type of abrasive
Second element (number)	Size of abrasive Third element (letter)
Grade of bond Fourth element (number)	Structure of the grinding wheel
Fifth element (letter)	Type of bond
Suffix	Manufacturer's symbol

Grinding Wheel Markings

The meaning of the given marking on a grinding wheel

w A 54 M 7 V 20

w	-	Manufacturer's abrasive type symbol	
A	-	Type of abrasive	- Aluminium oxide
54	-	Size of abrasive	- Medium
M	-	Grade of bond	- Medium
7	-	Structure of the grinding wheel	- Dense
V	-	Type of bond	- Vitrified
20	-	Manufacturer's symbol	

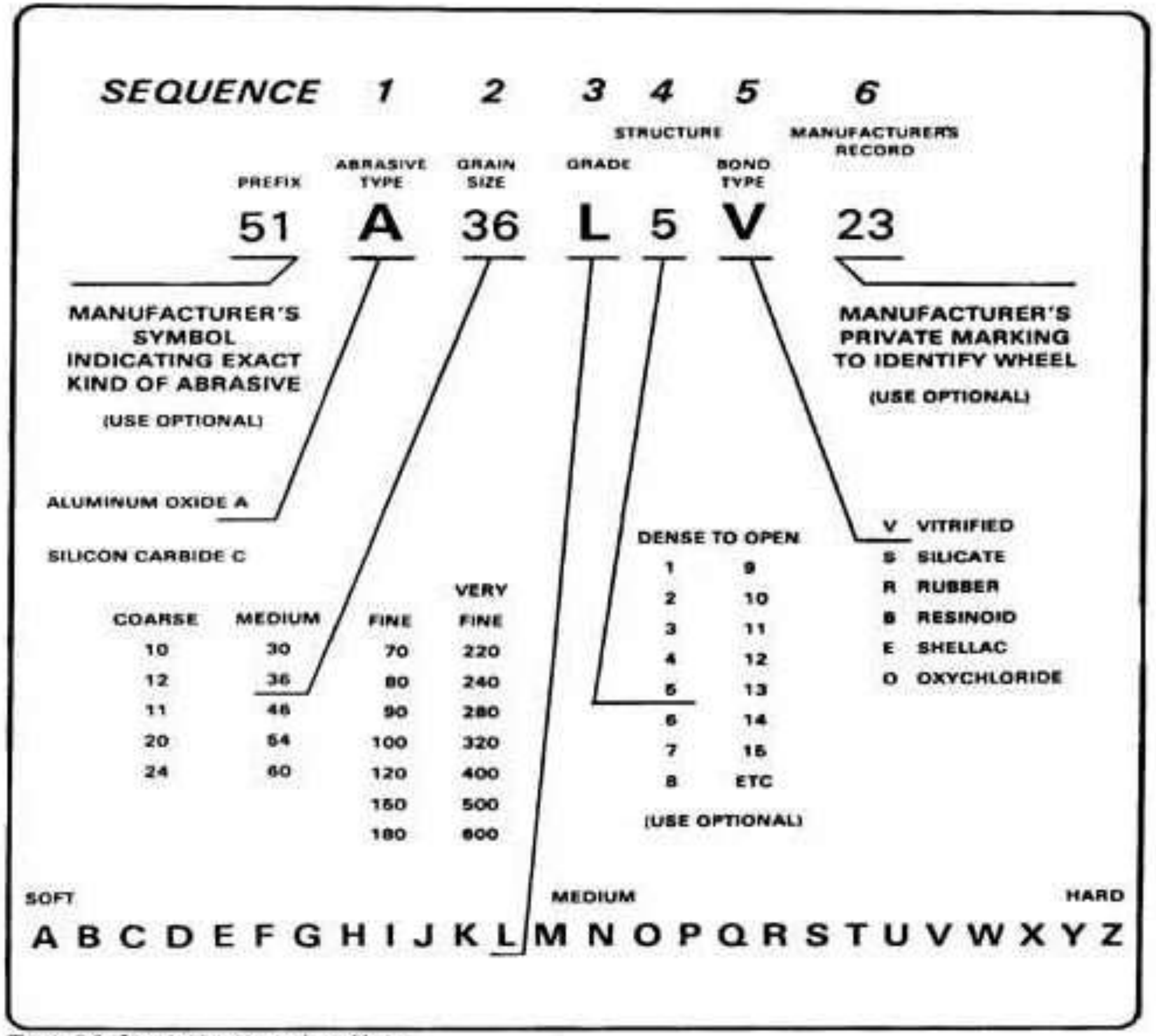


Figure 5-9. Standard system of markings.

Types of Grinding wheels

Cup wheel

- A cup wheel as pictured to the right is predominantly used in Tool and Cutter grinders where orientation of the wheel and a slim profile are required.
- These wheels are used (and dressed) on the side face and have the advantage of producing a truly flat surface on the side of lathe tools.
- They are used in jig grinders to produce flat surfaces or counter bores.

Types of Grinding wheels

Straight wheel

- These are by far the most common style of wheel and can be found on bench or pedestal grinders.
- They are used on the periphery only and therefore produce a slightly concave surface (hollow ground) on the part.
- This can be used to advantage on many tools such a chisels.

Types of Grinding wheels

Cylinder wheel

- Cylinder wheels provide a long, wide surface with no center mounting support (hollow). They can be very large, up to 12" in width.
- They are used only in vertical or horizontal spindle grinders.

Tapered wheel

- A straight wheel that tapers outward towards the center of the wheel.
- This arrangement is stronger than straight wheels and can accept higher lateral loads.

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Types of Grinding wheels

Straight cup

- Straight cup wheels are an alternative to cup wheels in tool and cutter grinders, where having an additional radial grinding surface is beneficial.

Dish cup

A very shallow cup-style grinding wheel. The thinness allows grinding in slots and crevaces.

It is used primarily in cutter grinding and jig grinding.

Types of Grinding wheels

Saucer wheel

A special grinding profile that is used to grind milling cutters and twist drills. It is most common in non-machining areas, as saw filers use saucer wheels in the maintenance of saw blades.

Diamond wheel

Diamond wheels are grinding wheels with industrial diamonds bonded to the
periphery.

They are used for grinding extremely hard materials such as carbide tips, gemstones or concrete. The saw pictured to the right is a slitting saw and is designed for slicing hard materials, typically gemstones.

Types of Grinding wheels

Diamond Mandrels

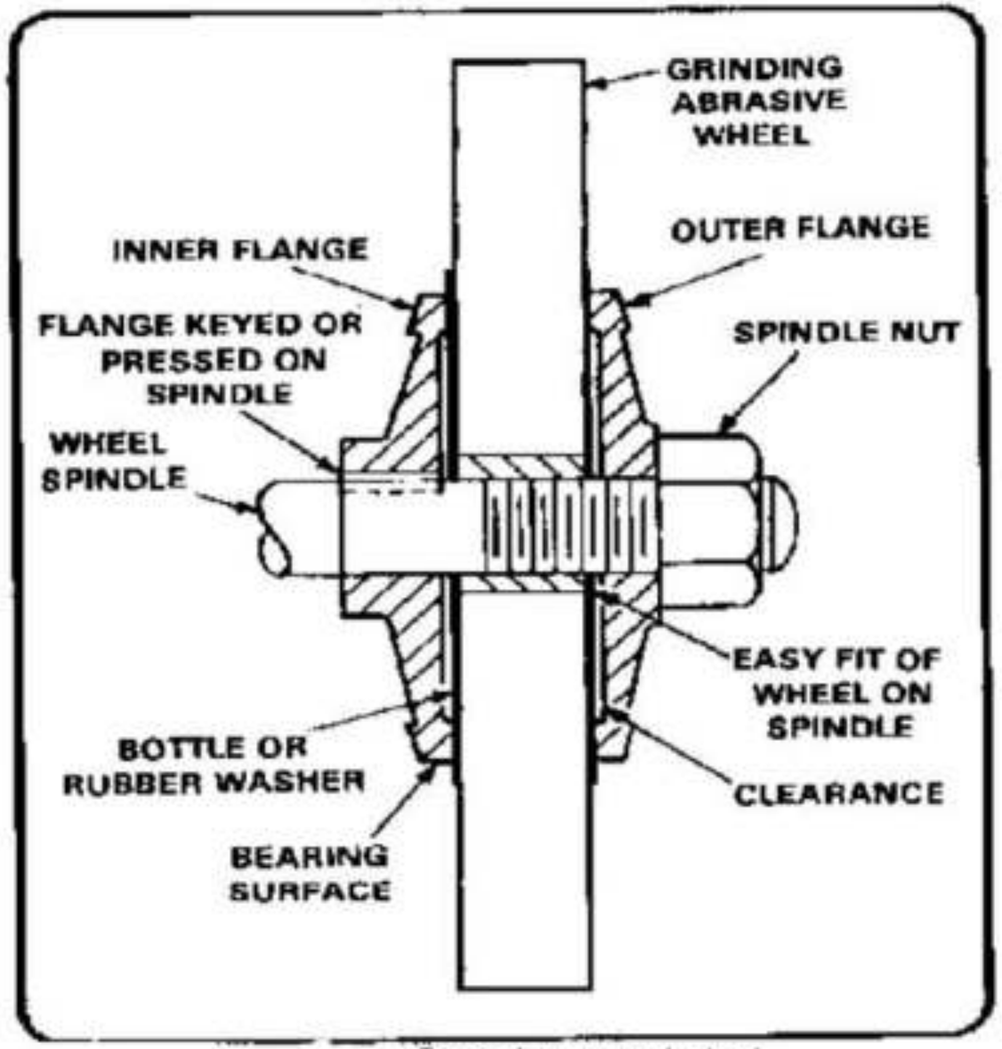
Diamond mandrels are very similar to their counterpart, a diamond wheel. They are tiny diamond rasps for use in a jig grinder doing profiling work in hard material.

Types of Grinding wheels

Cut off wheels

- Cut off or parting wheels are self-sharpening wheels that are thin in width and often have radial fibres reinforcing them.
- They are often used in the construction industry for cutting reinforcement steel (rebar), protruding bolts or anything that needs quick removal or trimming.
- You would recognise an angle grinder and the discs they use.

Correctly Mounted Wheel



. Correctly mounted wheel.

Defects And Remedies In Grinding

- Major and inevitable defects in grinding are glazing of grinding wheels.
- After the continuous use grinding wheel becomes dull or glazed.
- Glazing of the wheel is a condition in which the face or cutting edge acquires a glass like appearance.
- That is, the cutting points of the abrasives have become dull and worn down to bond.
- Glazing makes the grinding face of the wheel smoother and that stops the process of grinding.
- Sometimes grinding wheel is left 'loaded'. In this situation its cutting face is found being adhering with chips of metal.
- The opening and pores of the wheel face are found filled with workpiece material particals, preventing the grinding action.
- Loading takes place while grinding workpiece of softer material.

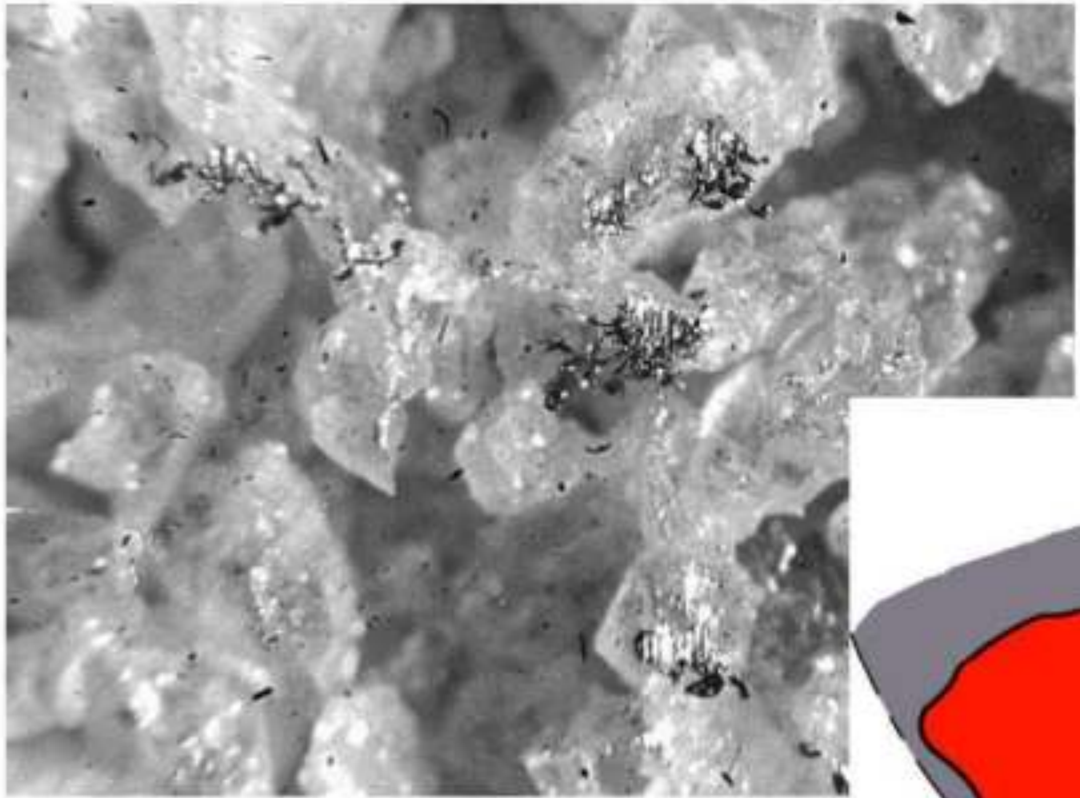
Dressing

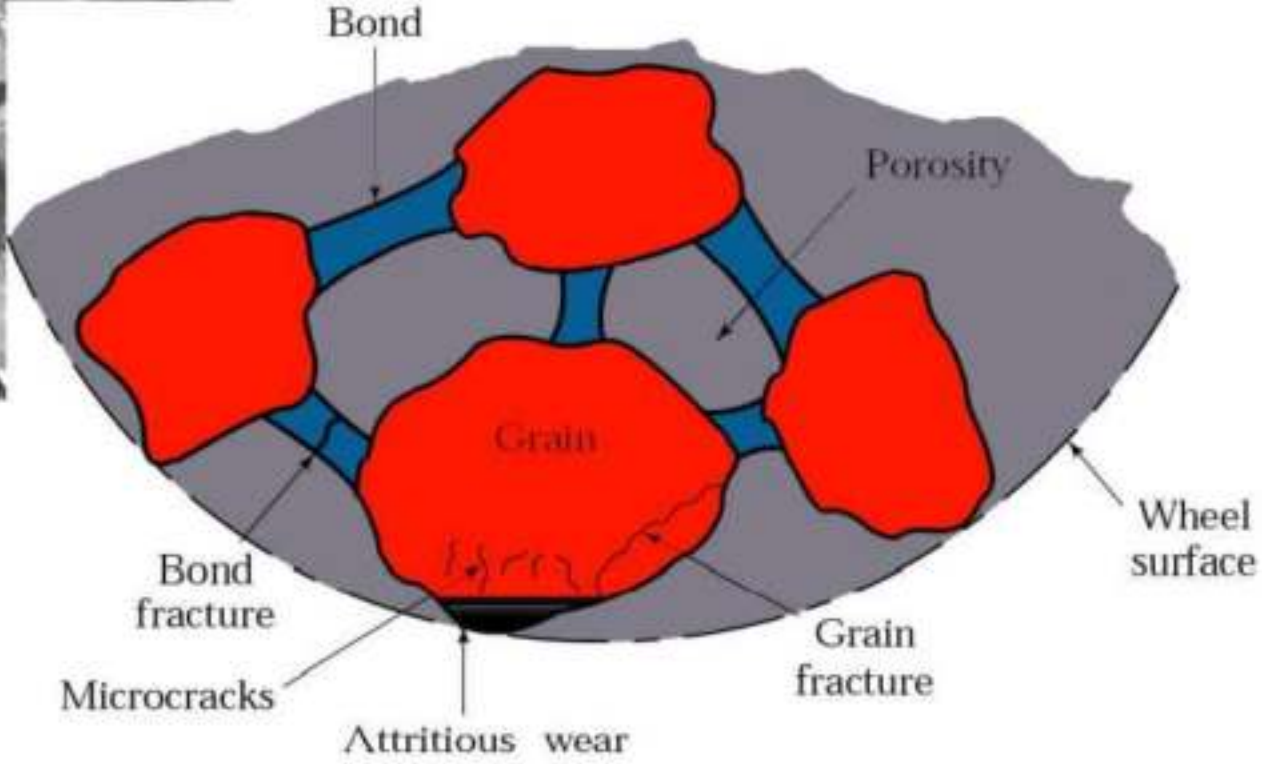
- The remedies of glazing and loading is dressing of grinding wheels.
- Dressing removes the loading and breaks away the glazed surface so that sharp abrasive particles can be formed again ready for grinding.
- Different type of dressing operations are done on a grinding wheel.
- One of them is the dressing with the help of star dresser.
- It consists of a number of hardened steel wheels with sharp points on their periphery.
- The total is held against the face of revolving wheel and moved across the face to dress the whole surface.
- Another type of wheel dresser consists of a steel tube filled with a bonded abrasive.
- The end of the tube is held against the wheel and moved across the face.

Truing

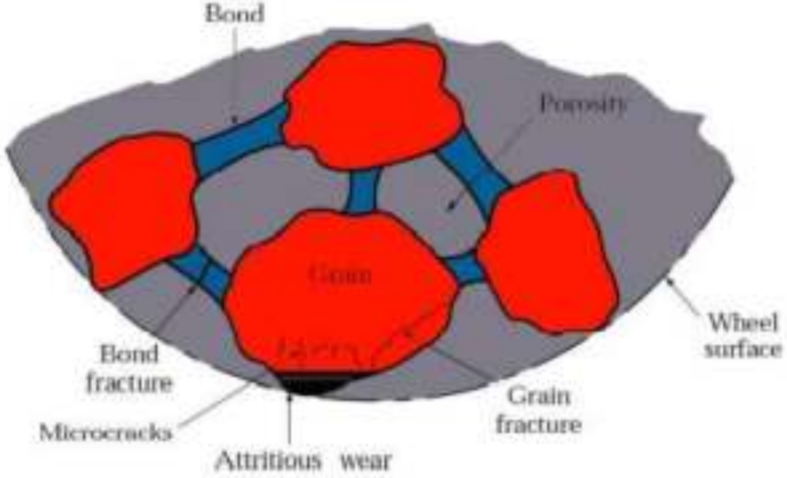
- Truing is the process of restoring the shape of grinding wheel when it becomes worn and break away at different points.
- Truing makes the wheel true and concentric with the bore.

Grinding Wheel Surface

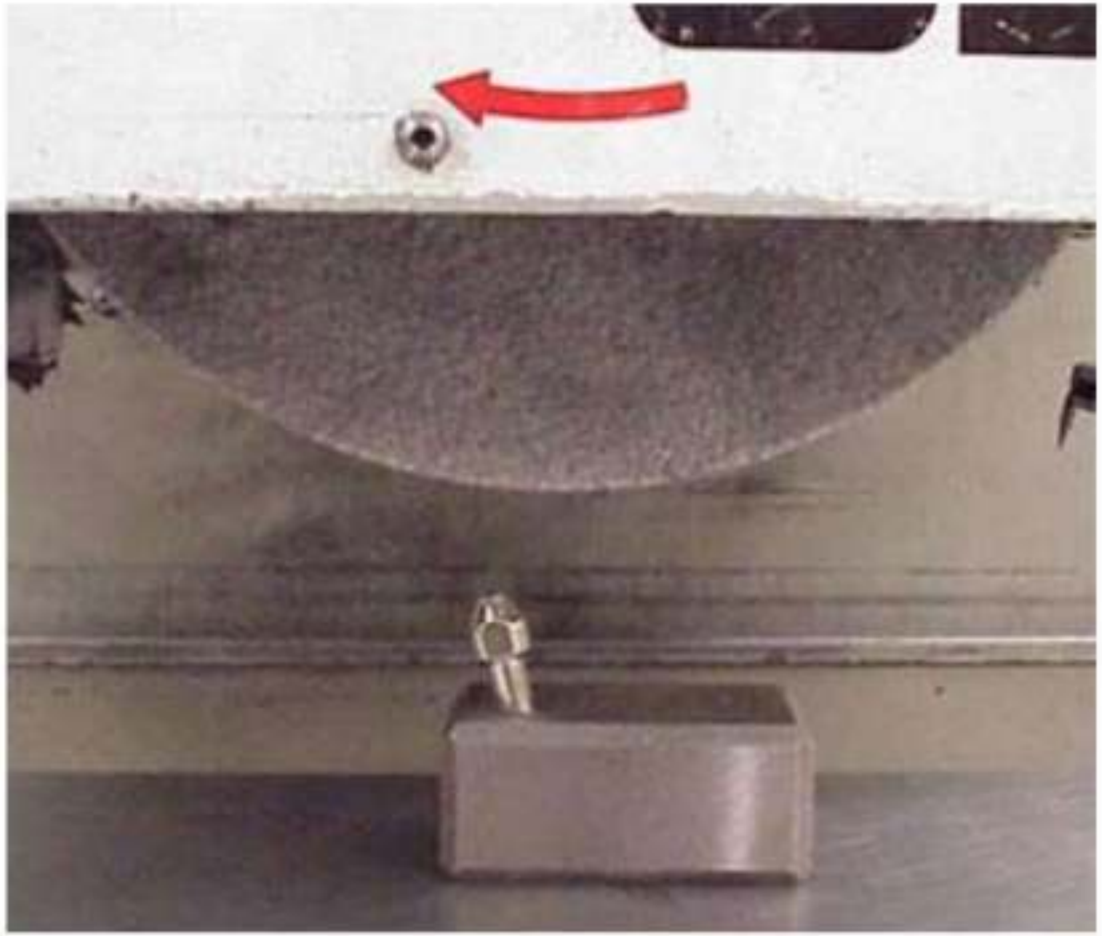




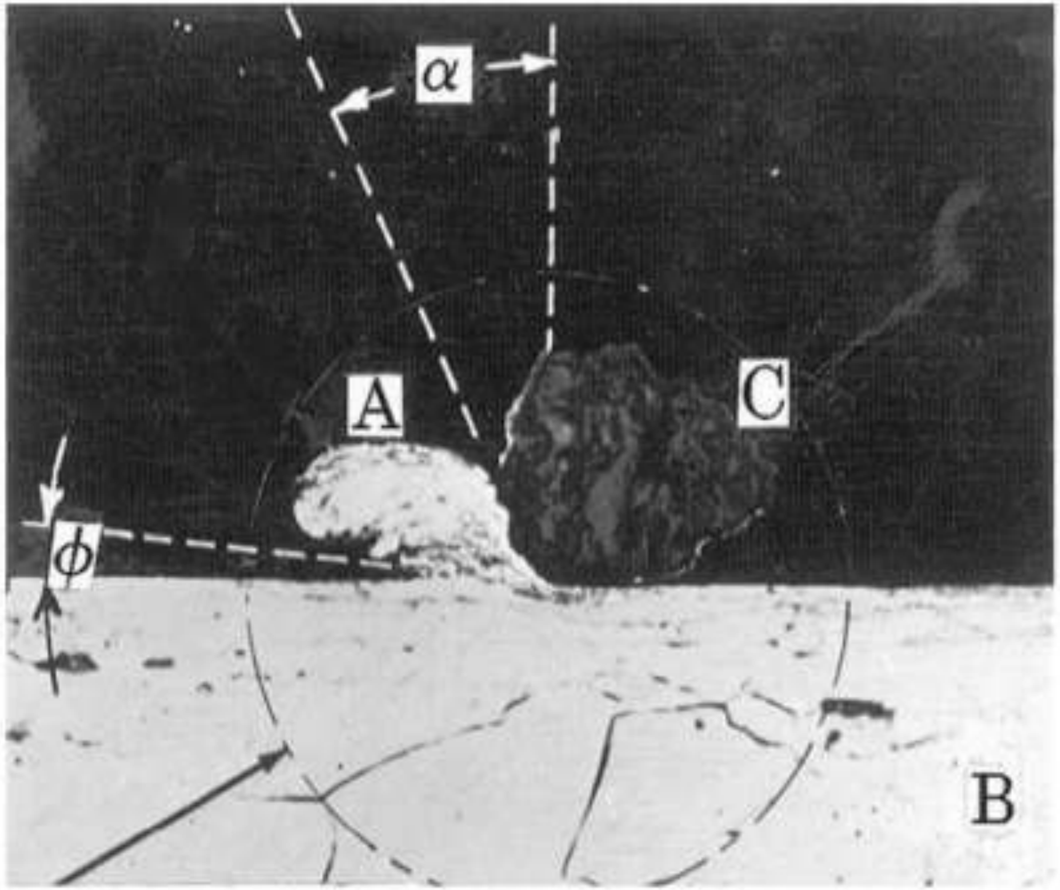
Grind Wheel Dressing

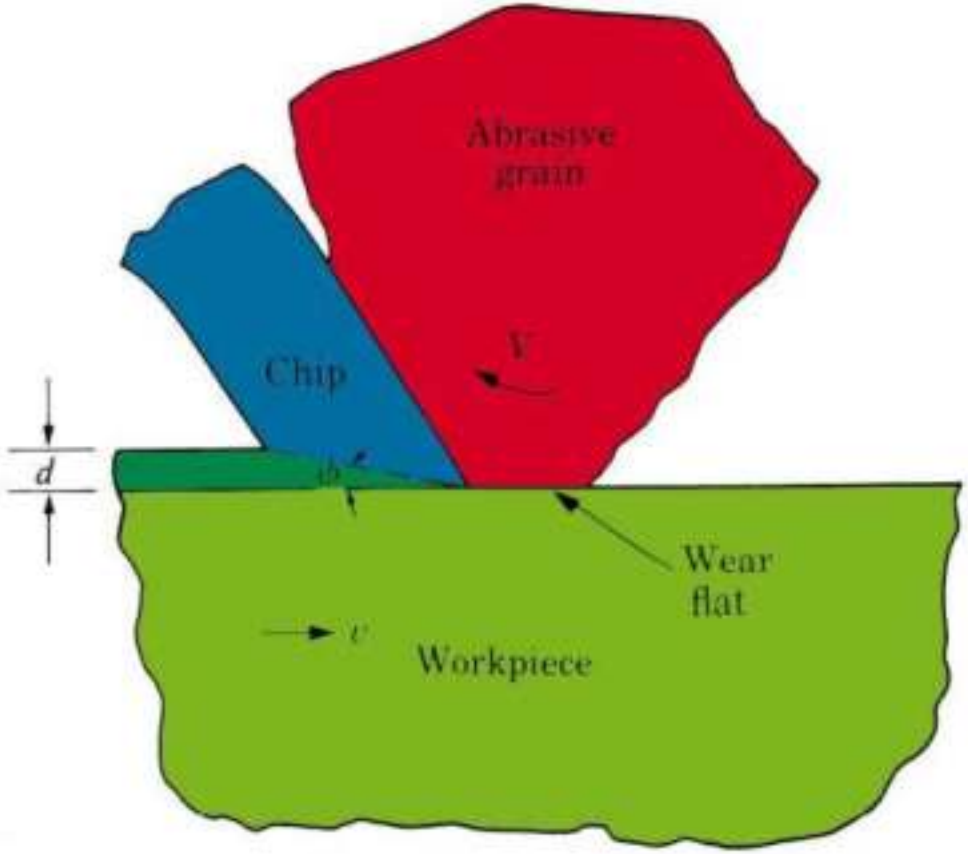


Grind Wheel Dressing



Grinding Chips





Balancing Of Grinding Wheel

- Due to continuous used a grinding wheel may become out of balance. It con not be balanced either by truing or dressing.
- Here it is important to explain the meaning of a balanced wheel.
- It is the coincidence of centre of mass of wheel with it axis of rotation.
- Wheels which are out of balance produce poor quality of surface and put undue strains on the grinding machine.
- Balancing of wheel is normally done at the time of its mounting on the grinding machine with the help of moving weights around a recessed flange.

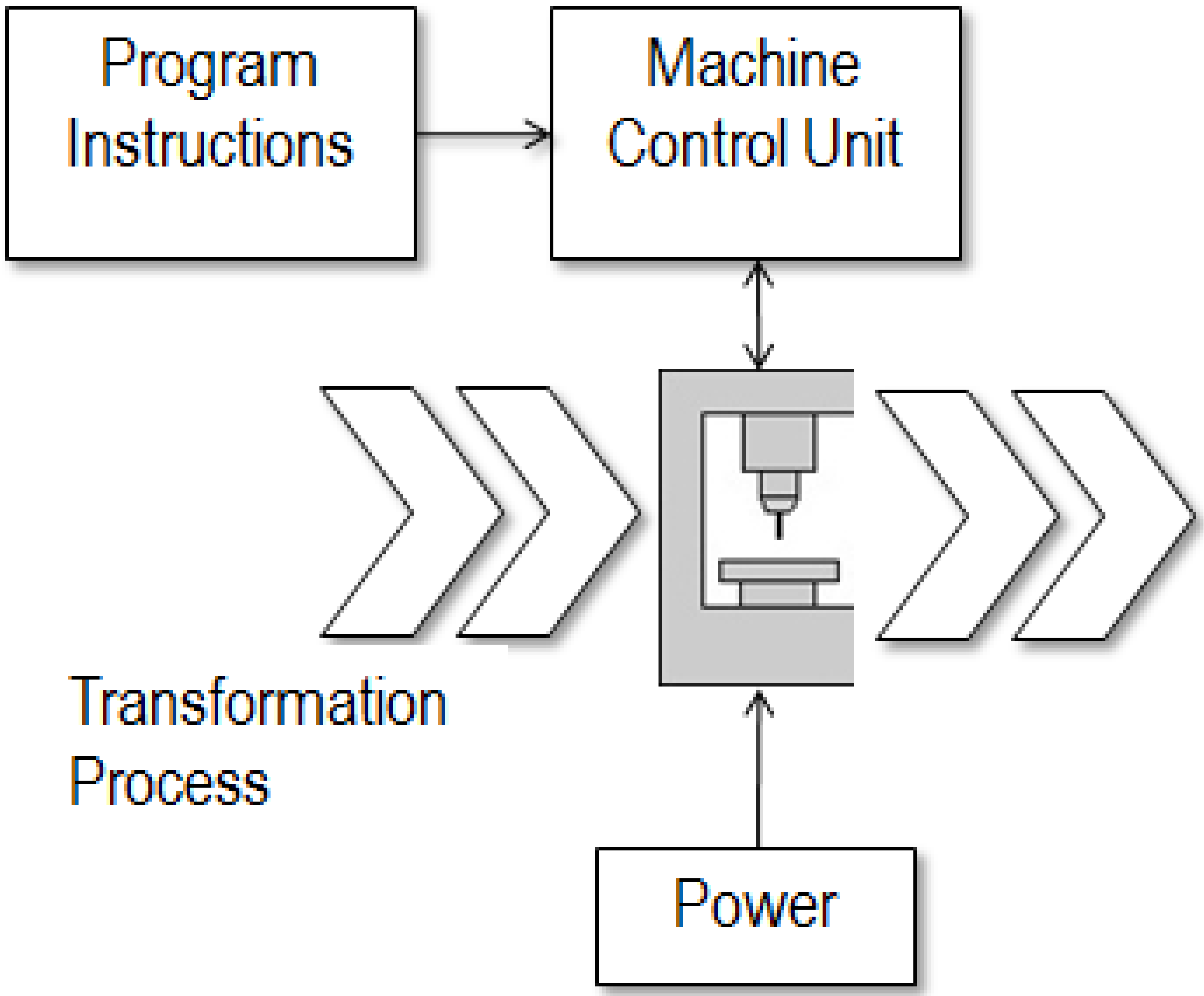
NUMERICAL CONTROL

DEFINITION

Programmable automation in which the mechanical actions of a ‘machine tool’ are controlled by a program containing coded alphanumeric data that represents relative positions between a work head (e.g., cutting tool) and a work part

THREE BASIC COMPONENTS OF NC

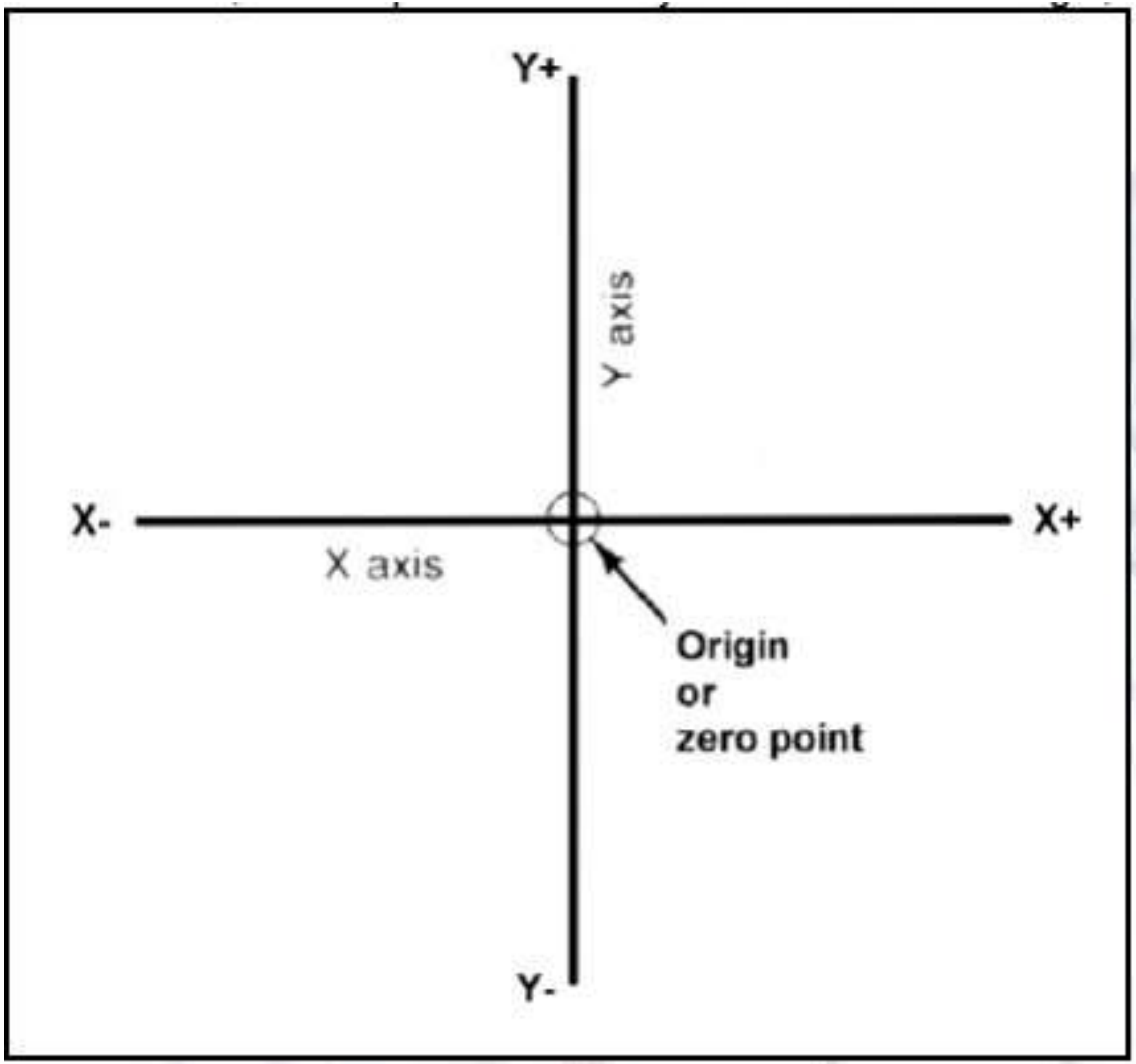
1. INPUT MEDIUM
2. MACHINE CONTROL UNIT
3. MACHINE TOOL

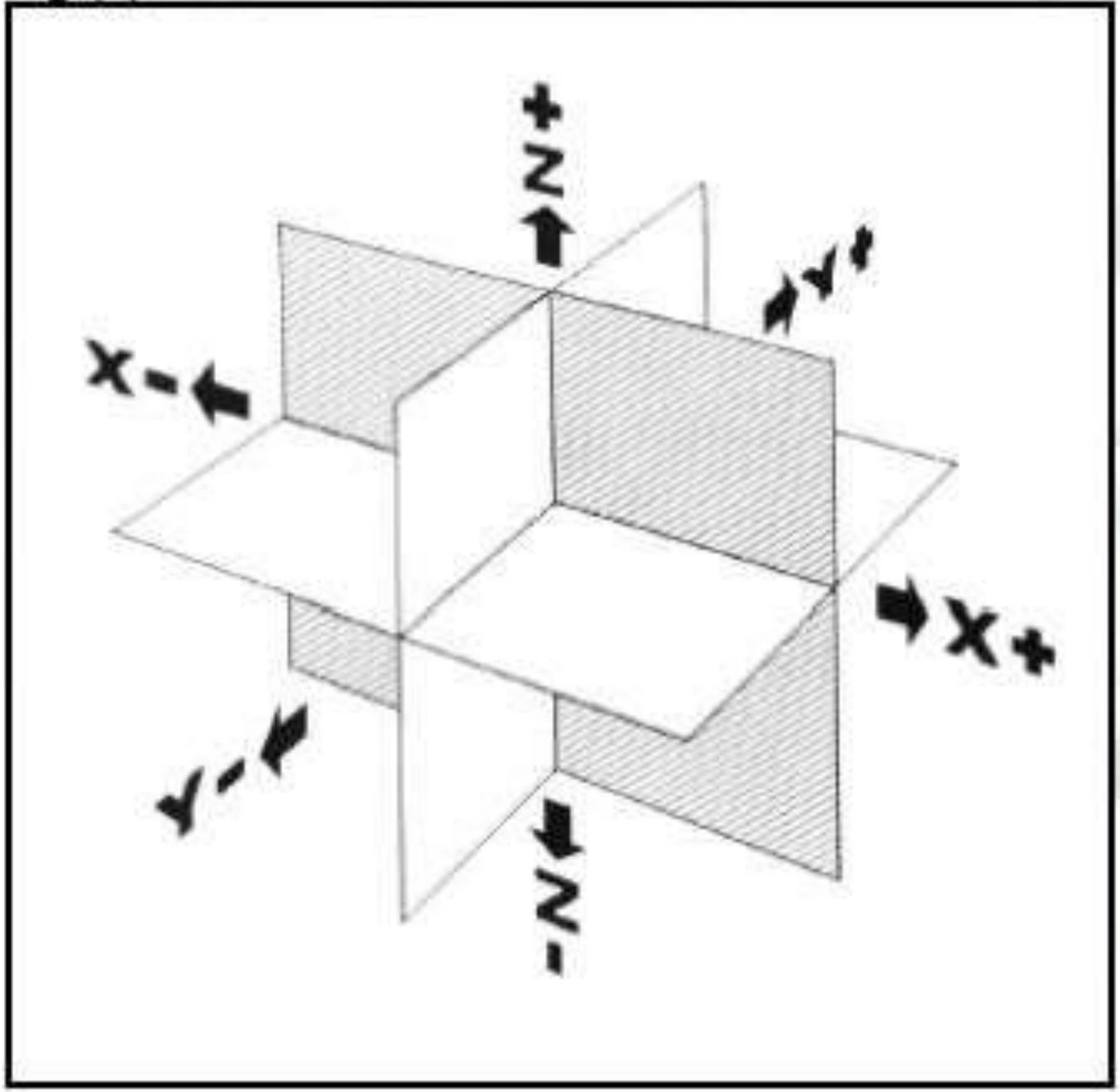


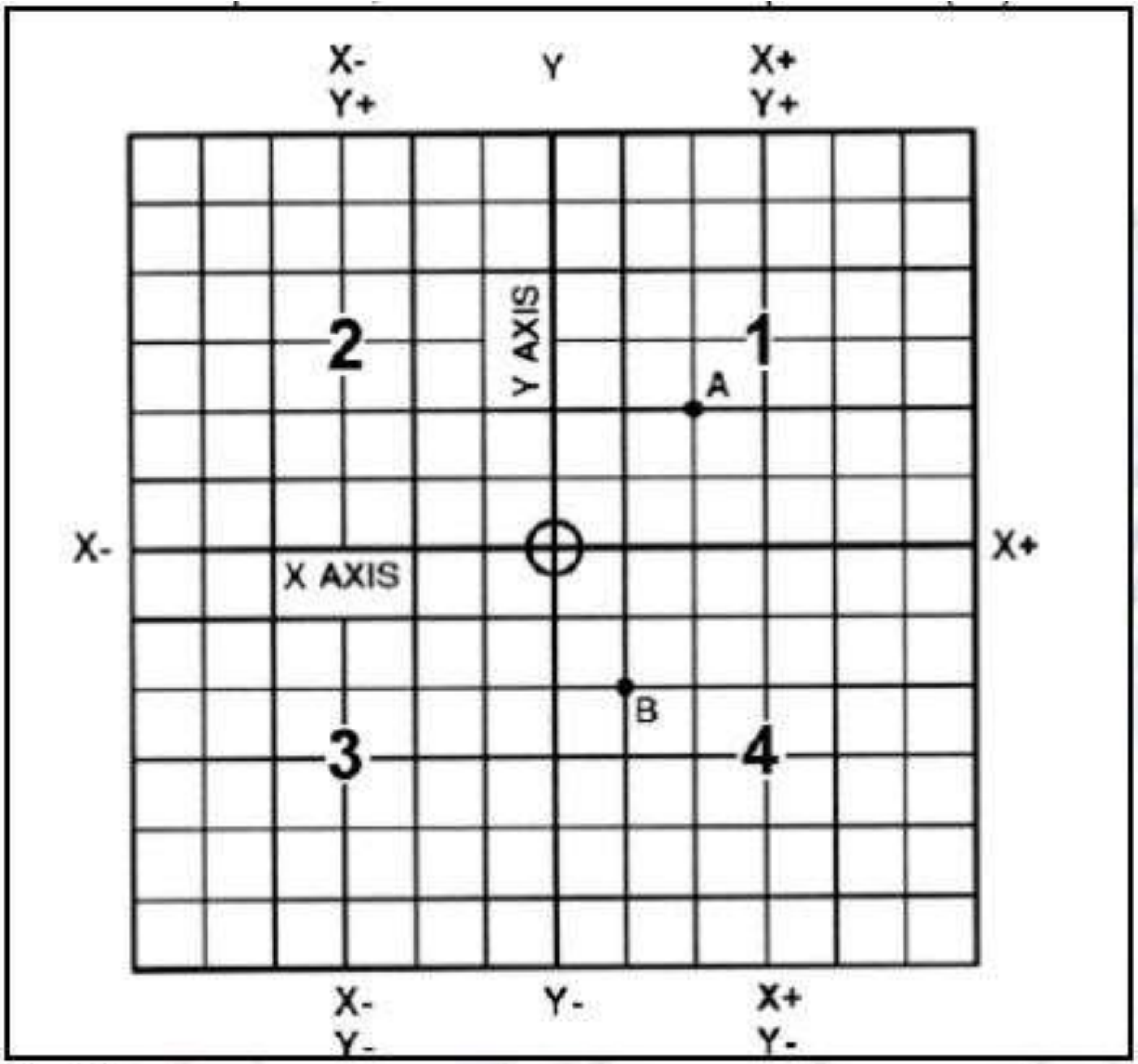
Program Instructions
Machine Control Unit
Transformation Process
Power

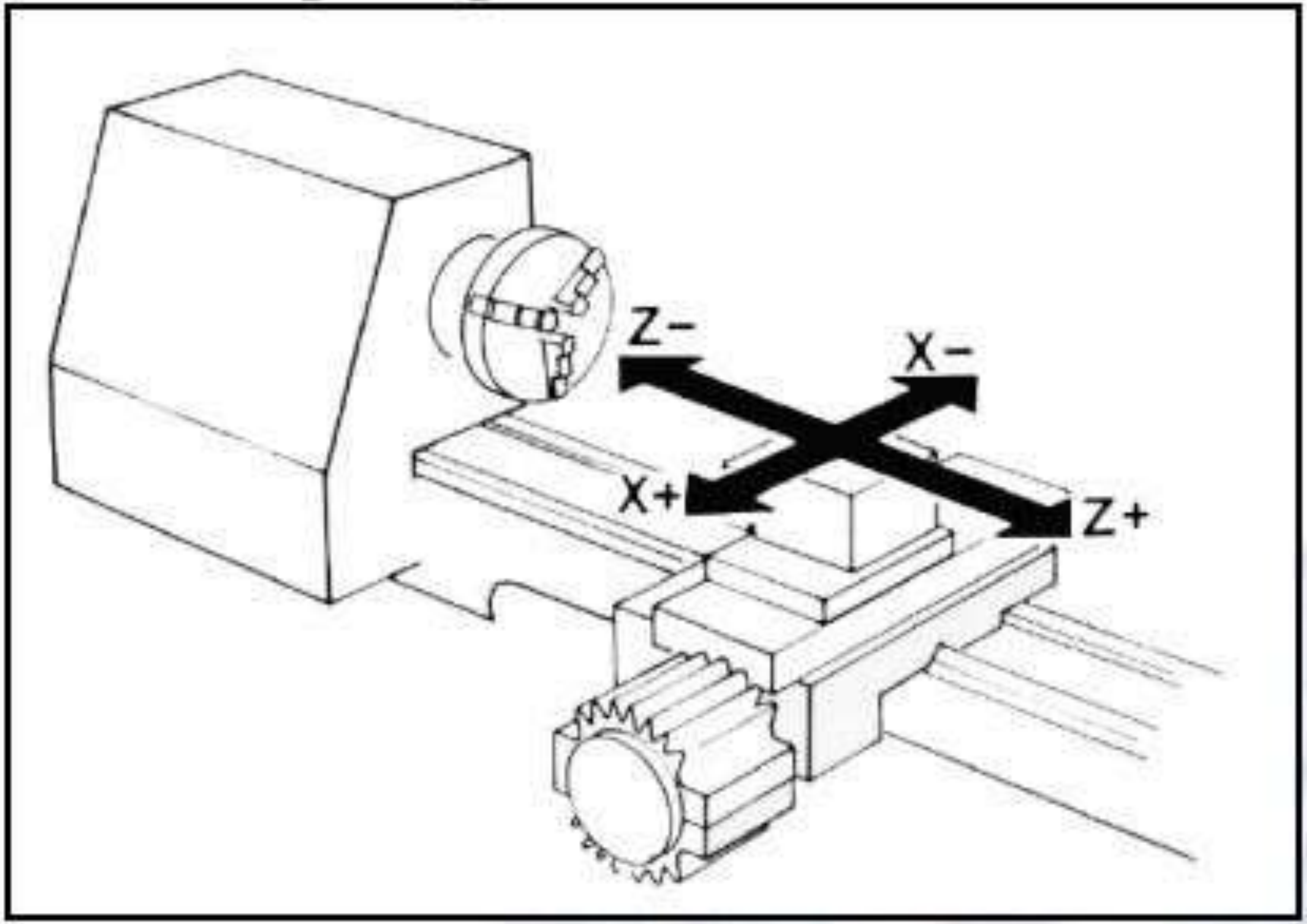
Principle

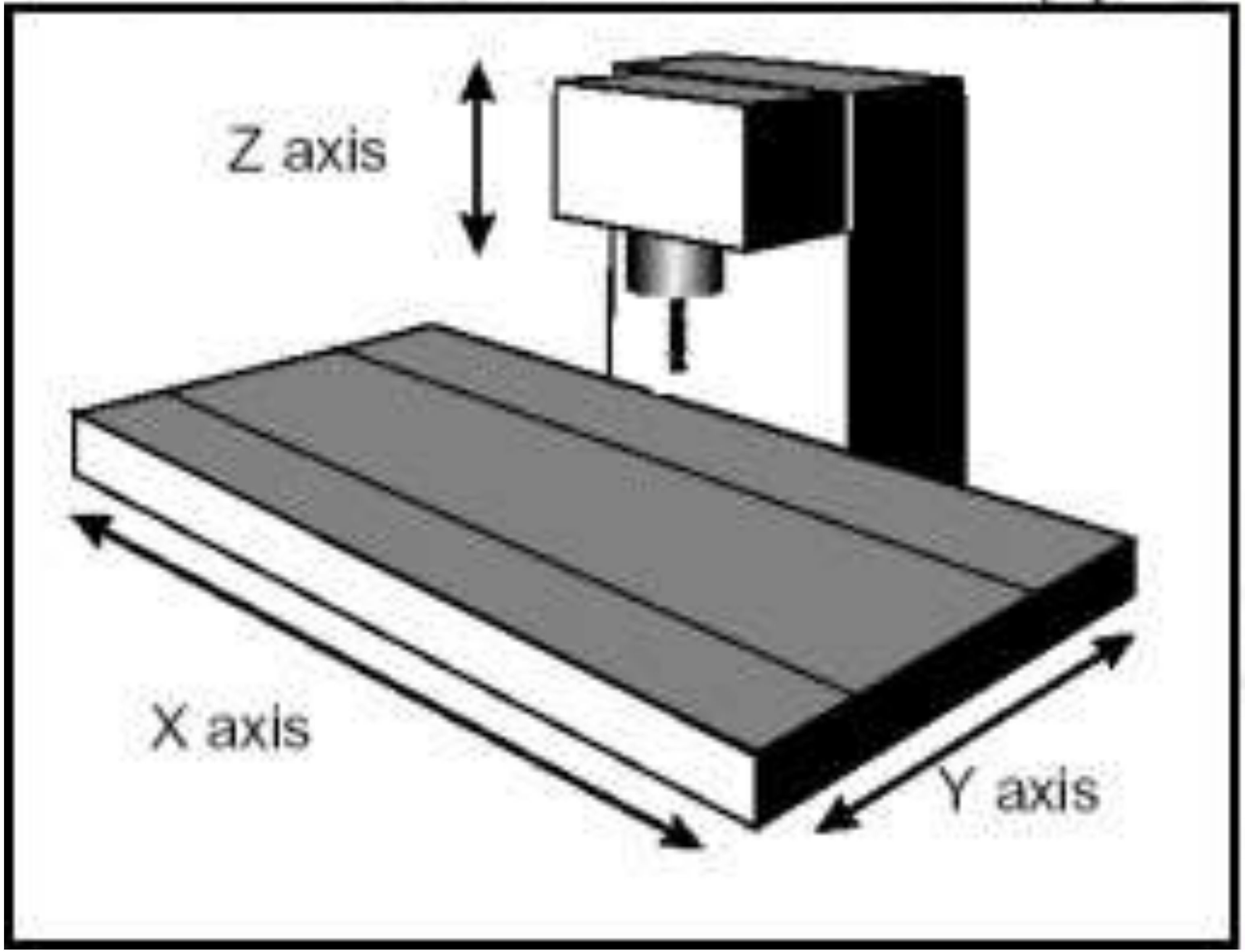
A system in which actions are controlled by direct insertion of numerical data.

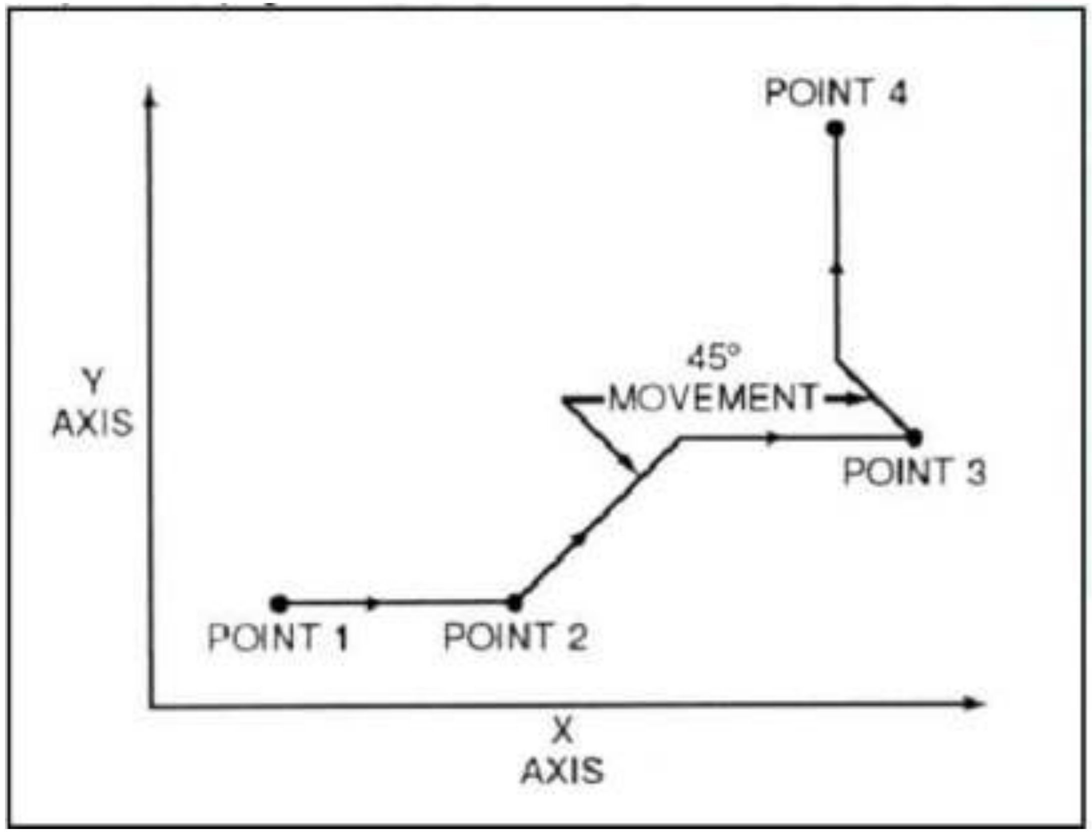

Y+
Y axis
X-
X axis
X+
Origin
or
zero point
Y-


Z+
X-
Y+
X+
Y-
Z-


X-
Y+
Y
X+
Y+
2
Y AXIS
1
A
X-
X AXIS
X+
B
3
4
X-
Y-
Y-
X+
Y-


Z–
X–
X+
Z+

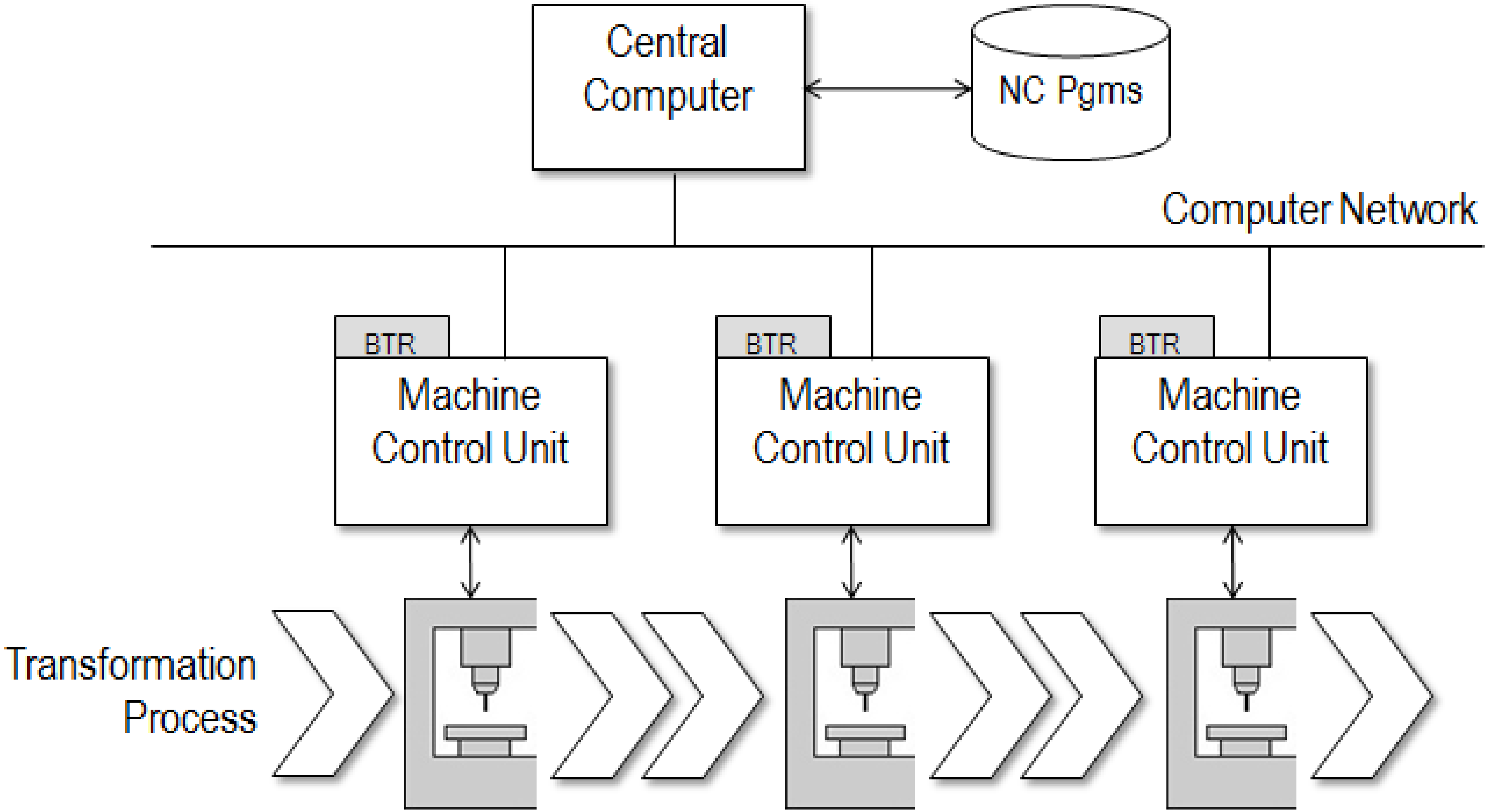

Z axis
X axis
Y axis


POINT 4
Y
AXIS
45°
MOVEMENT
POINT 3
POINT 1
POINT 2
X
AXIS

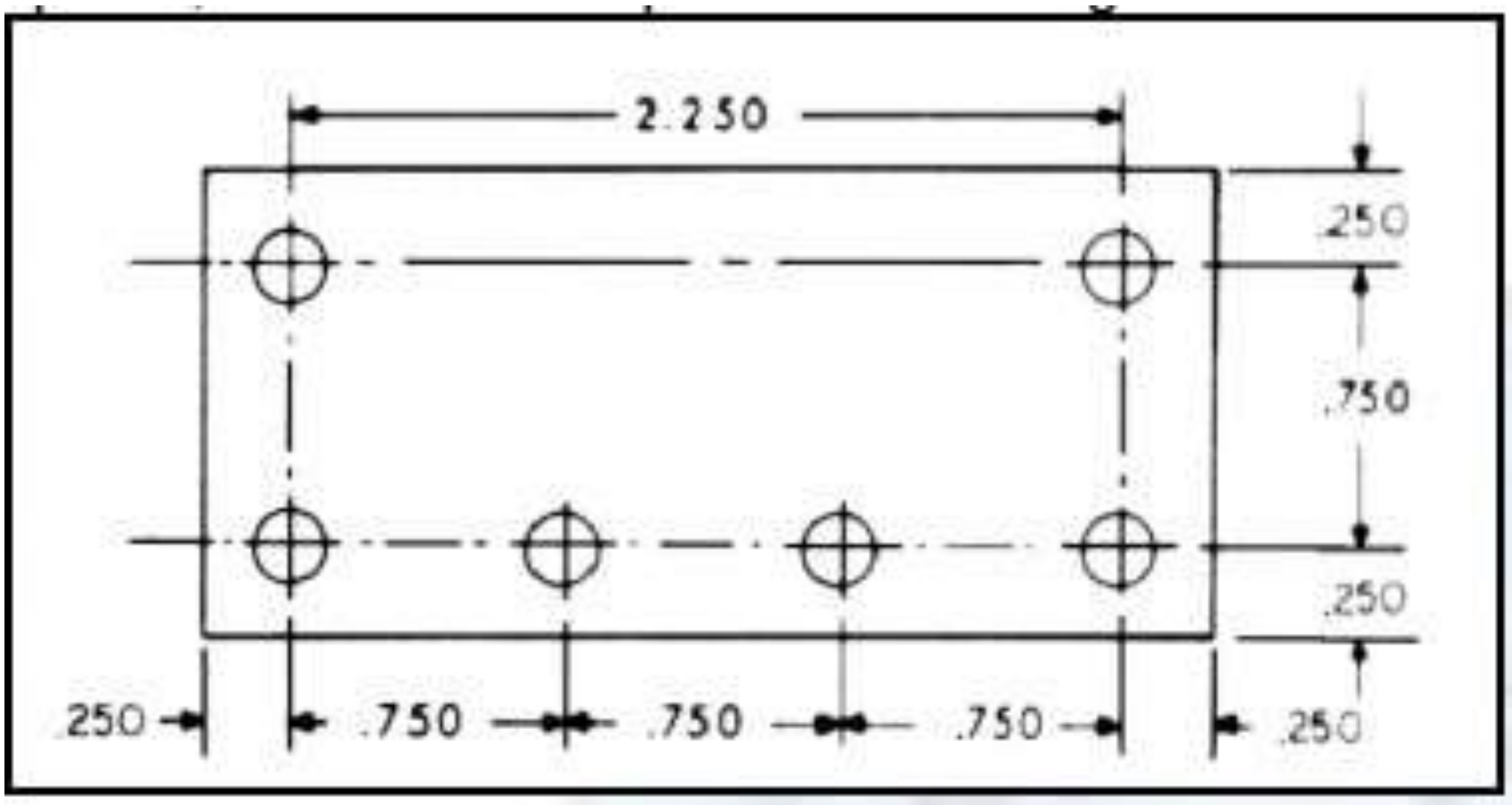
COMPUTER NUMERICAL CONTROL (CNC)

- Storage of more than one part program
- Various forms of program input
- Program editing at the machine tool
- Fixed cycles and programming subroutines
- Interpolation
- Acceleration and deceleration computations
- Communications interface
- Diagnostics

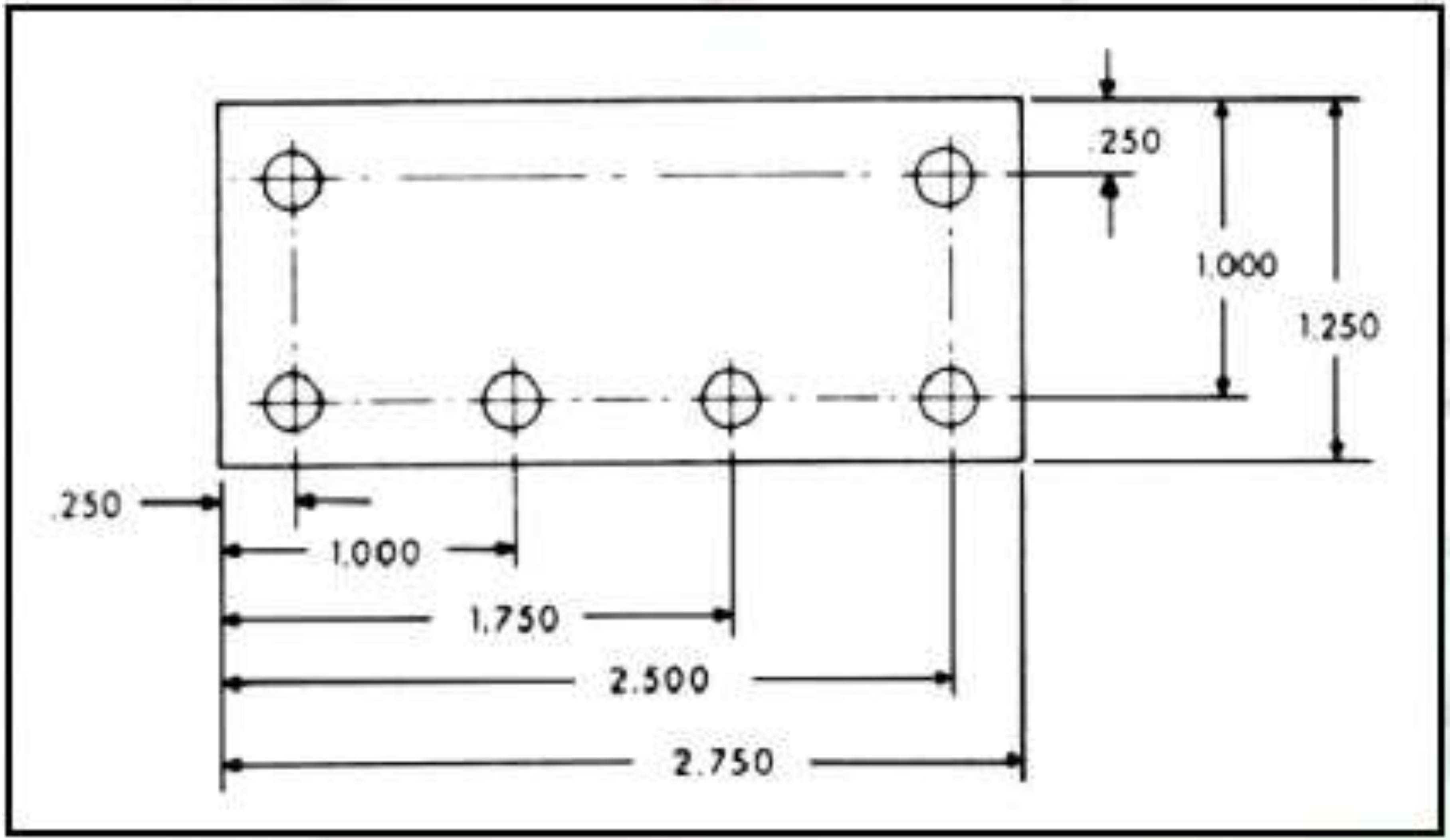
DIRECT NUMERICAL CONTROL (DNC)



REFERENCE POSTIONING SYSTEMS



INCREMENTAL



ABSOLUTE

Degree of Motion Control

Point-to-Point (PTP)

> Good for holes & slots

> Position tool over point.

Contouring

> Complex curved surfaces

> Computers needed for complex calculations

>Motion control to motors: varying voltages to DC servo motors.

Motion Control Systems

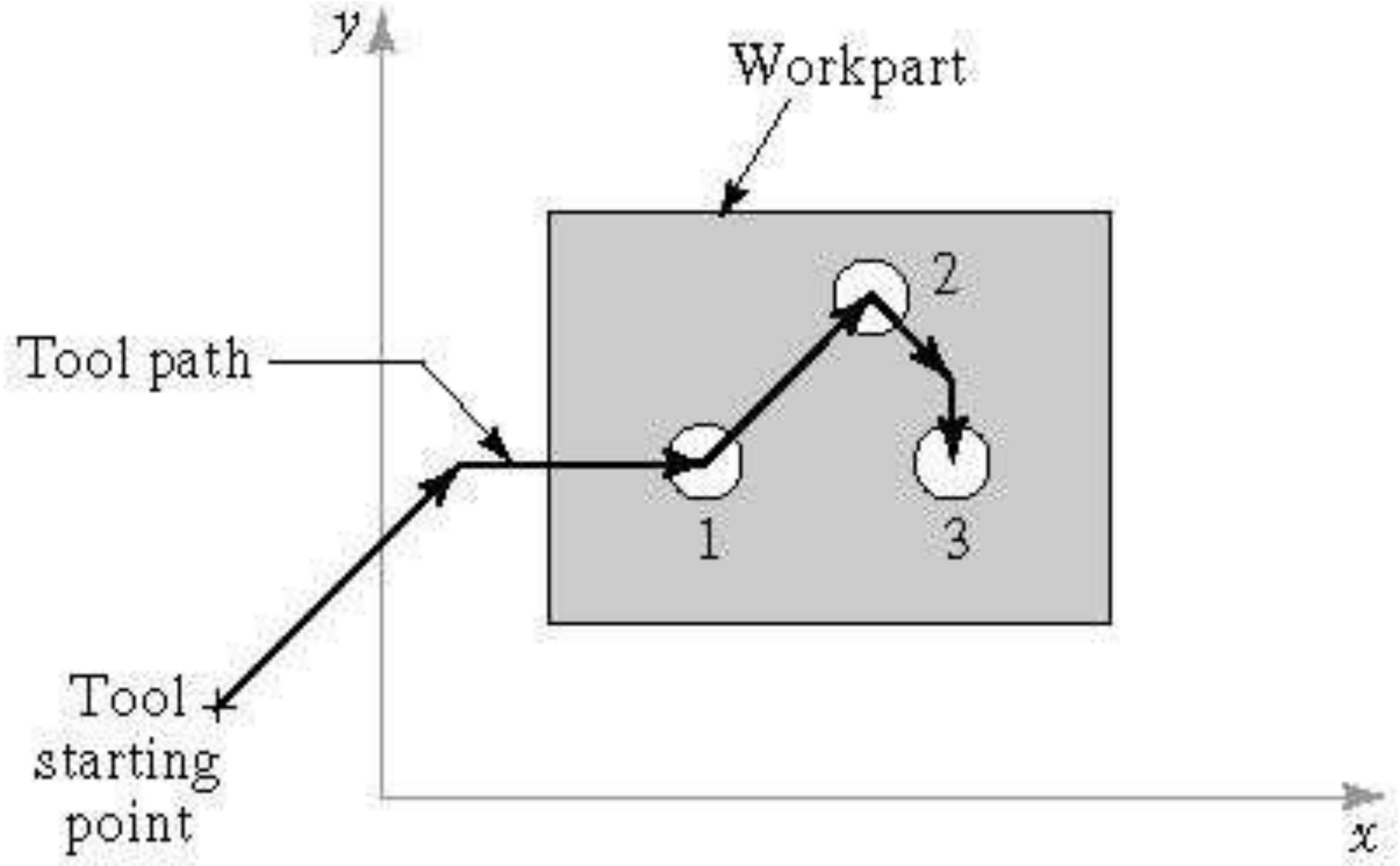
Point-to-Point systems

- Also called position systems
- System moves to a location and performs an operation at that location (e.g., drilling)
- Also applicable in robotics

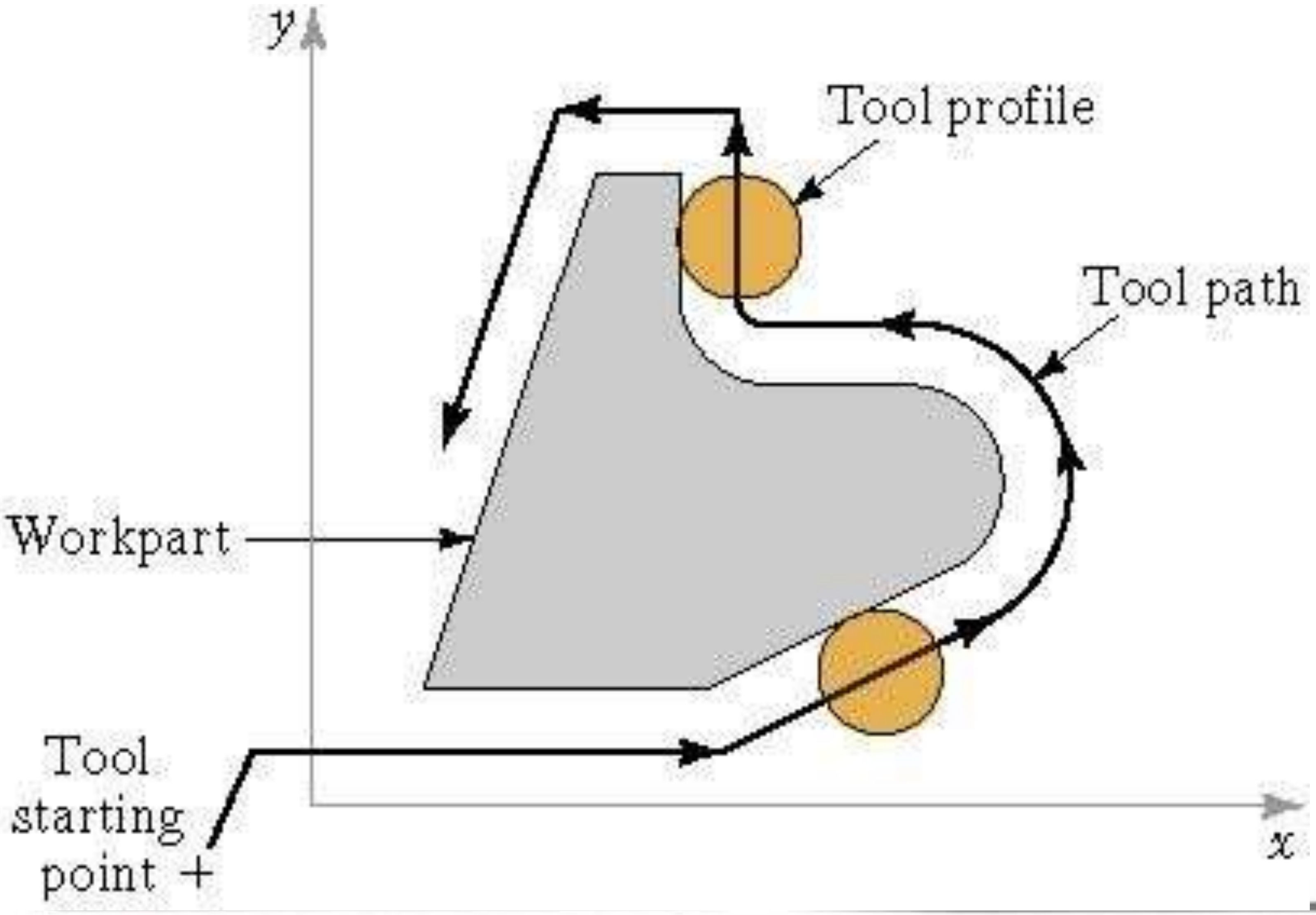
Continuous path systems

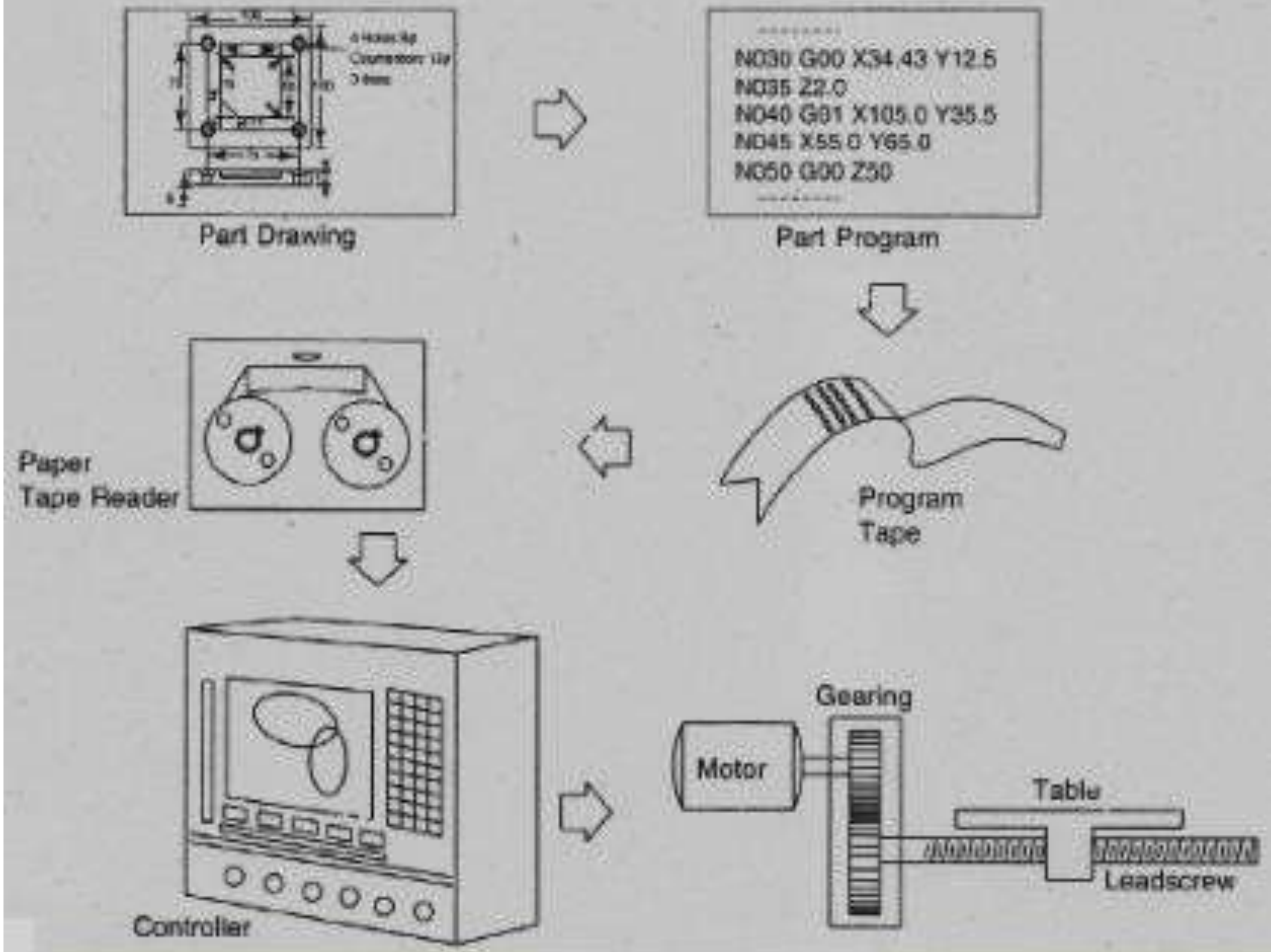
- Also called contouring systems in machining
- System performs an operation during movement (e.g., milling and turning)

PTP

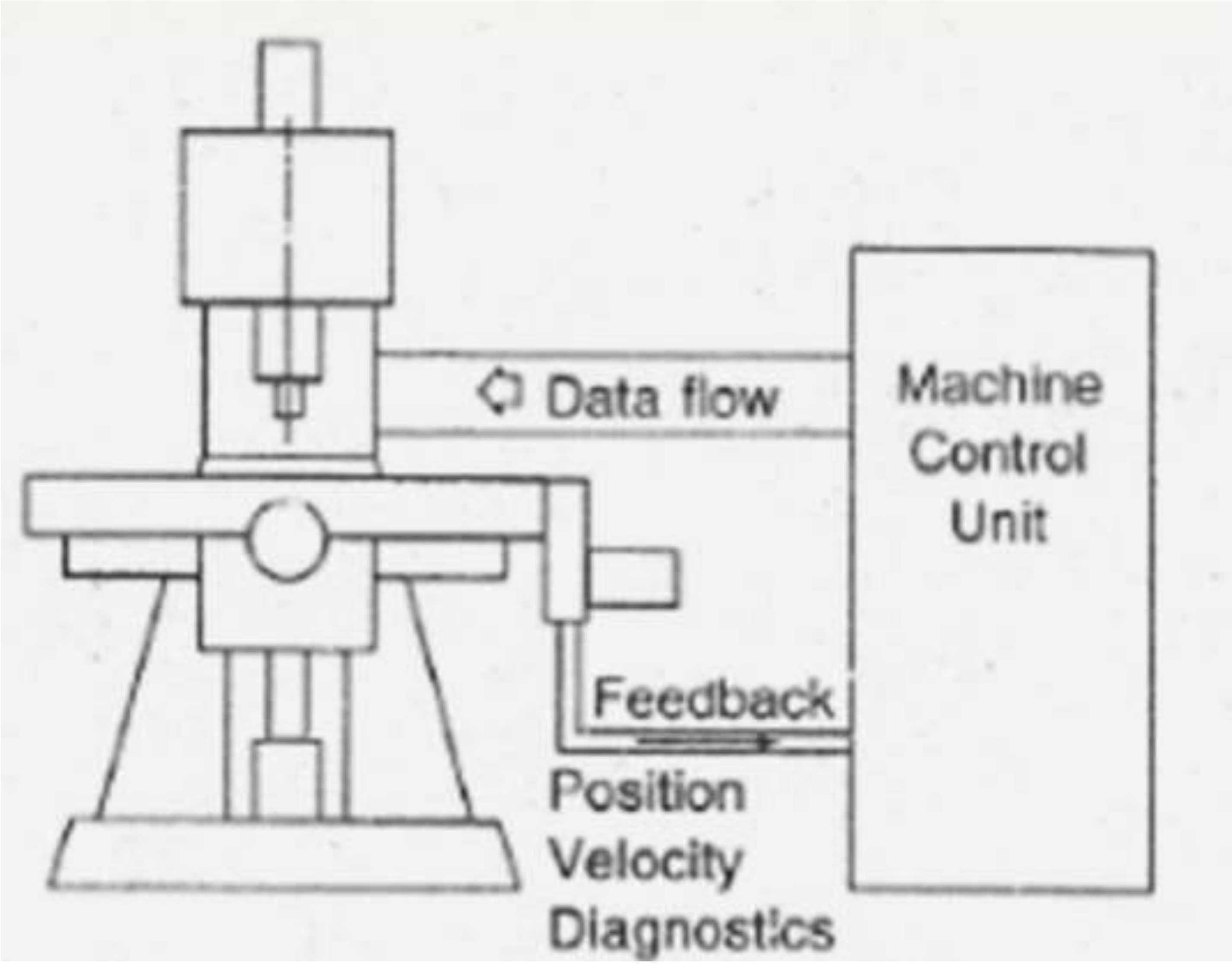


CONTOURING





N030 G00 X34.43 Y12.5
N035 Z2.0
N040 G01 X105.0 Y35.5
N045 X55.0 Y65.0
N050 G00 Z50
Part Drawing
Part Program
Paper
Tape Reader
Program
Tape
Controller
Gearing
Motor
Table
Leadscrew


Data flow
Machine
Control
Unit
Feedback
Position
Velocity
Diagnostics

Advantages of NC

Flexibility

Capability for Complex

Work-pieces

Manage Large Work-pieces

Reduced Jig & Fixture Cost

Higher Quality

Direct Numerical Control

Advantages:

> Library of programs
> Instant modifications
> Links with CAD
>Increase Information Response
> Instant Reports

Computer Numerical Control

(CNC)

Advantages:

> CRT allows review/editing
> Pre-check/simulation
> Interface allows more capability
> Accurate positioning
> More functions

Thank You

COMPUTER NUMERICAL CONTROL

Module 4

Dr. Roja A R
Assistant Professor
Mechanical Engineering

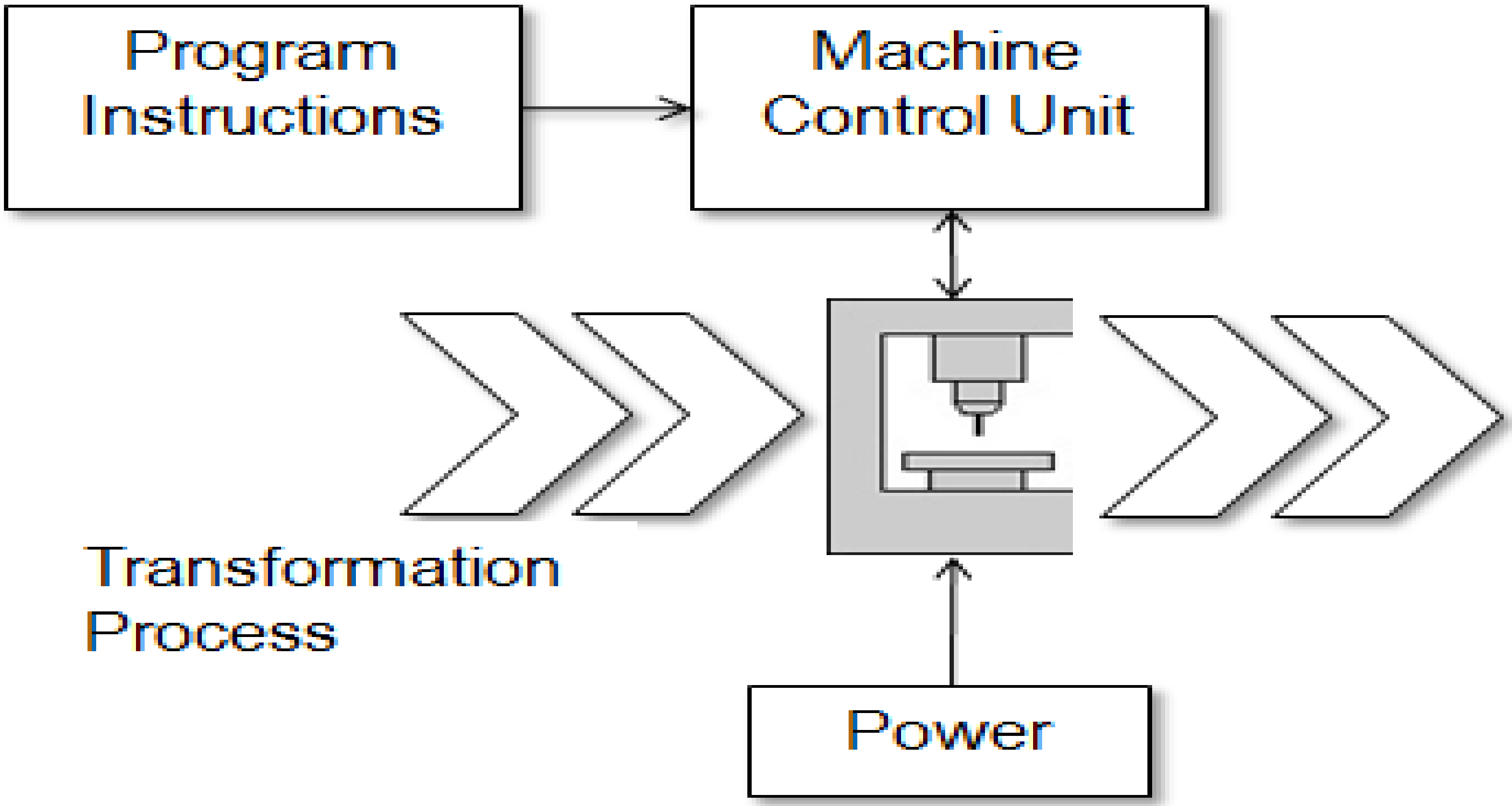
DEFINITION

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tool are controlled by means of a prepared program containing coded alphanumeric data.

CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off.

THREE BASIC COMPONENTS OF CNC

1. INPUT MEDIUM (Part Programme)
2. MACHINE CONTROL UNIT (MCU)
3. MACHINE TOOL (lathe, drill press, milling machine etc)


Program
Instructions
Machine
Control Unit
Transformation
Process
Power

THREE BASIC COMPONENTS OF CNC

The part program is a detailed set of commands to be followed by the machine tool.

Each command specifies a position in the Cartesian coordinate system (x,y,z) or motion (workpiece travel or cutting tool travel), machining parameters and on/off function.

Part programmers should be well versed with machine tools, machining processes, effects of process variables, and limitations of CNC controls.

The part program is written manually or by using computerassisted language such as APT (Automated Programming Tool).

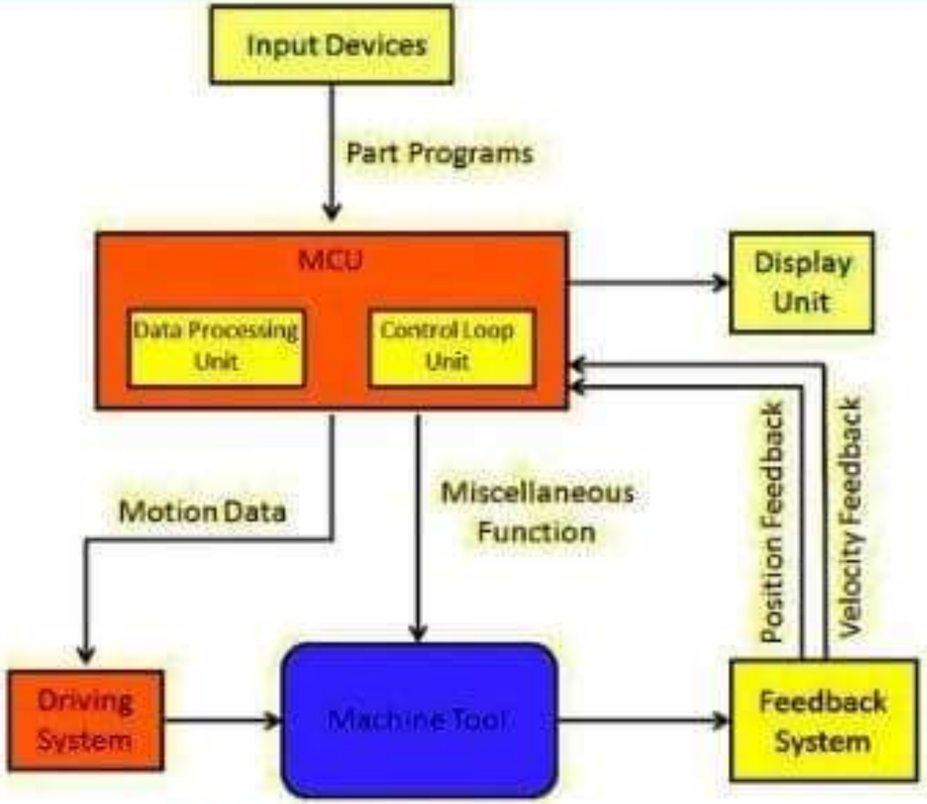
The machine control unit (MCU) is a microcomputer that stores the program and executes the commands into actions by the machine tool. The MCU consists of two main units: the data processing unit (DPU) and the control loops unit (CLU).

The DPU software includes control system software, calculation algorithms, translation software that converts the part program into a usable format for the MCU, interpolation algorithm to achieve smooth motion of the cutter, editing of part program (in case of errors and changes).

The DPU processes the data from the part program and provides it to the CLU which operates the drives attached to the machine leadscrews and receives feedback signals on the actual position and velocity of each one of the axes.

A driver (dc motor) and a feedback device are attached to the leadscrew. The CLU consists of the circuits for position and velocity control loops, deceleration and backlash take up, function controls such as spindle on/off

What Is a CNC Machine? | CNC Block Diagram | Parts of CNC Machine

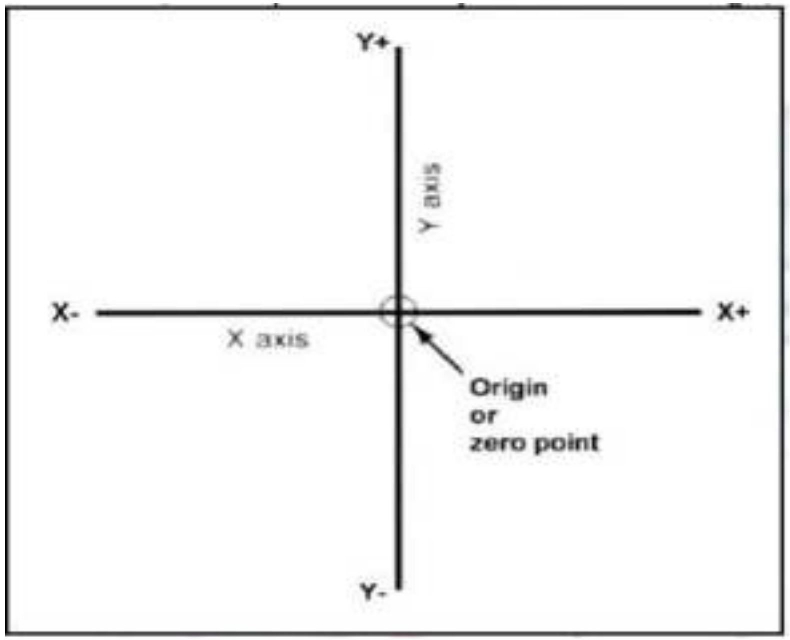


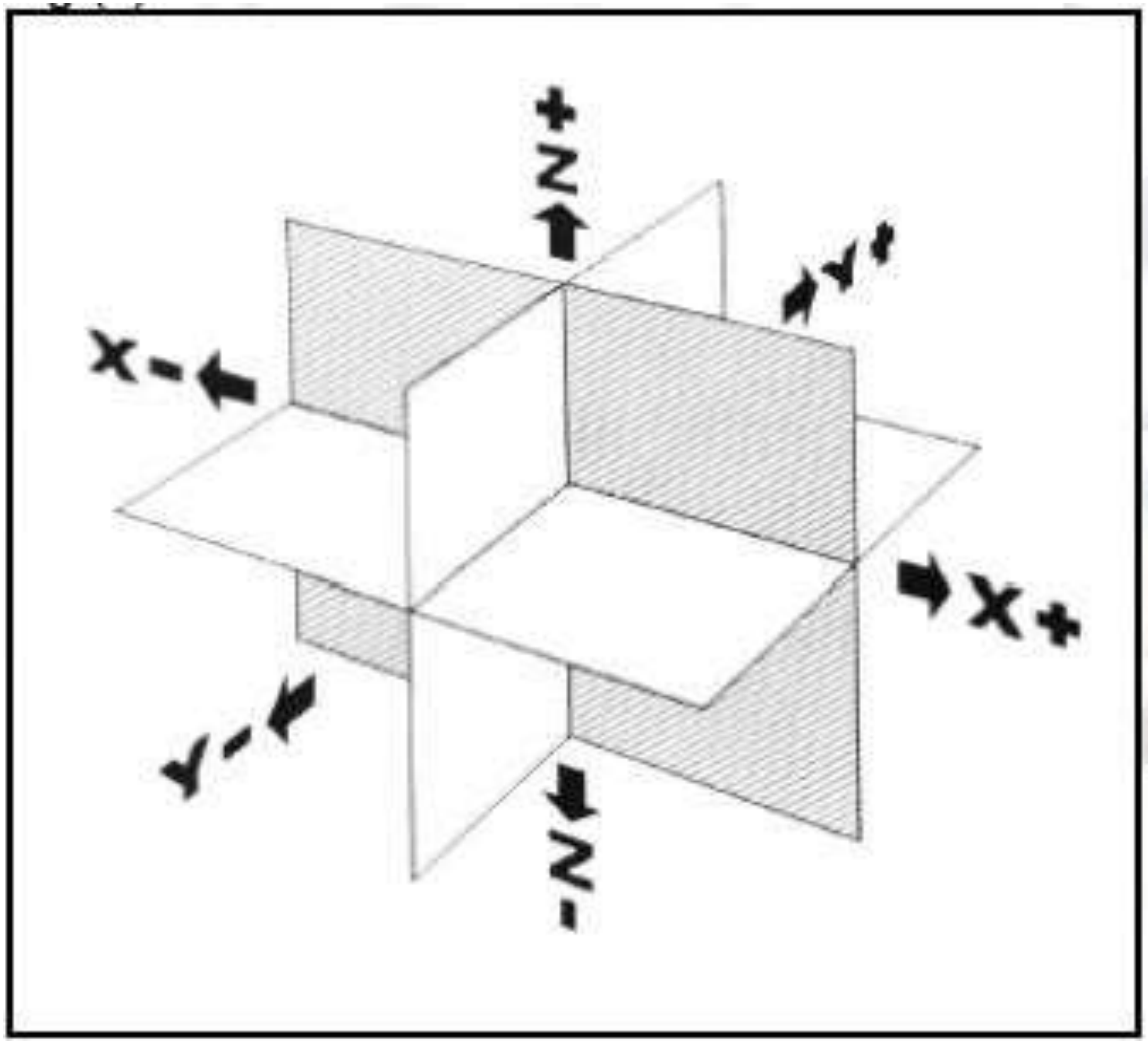
CNC Block Diagram

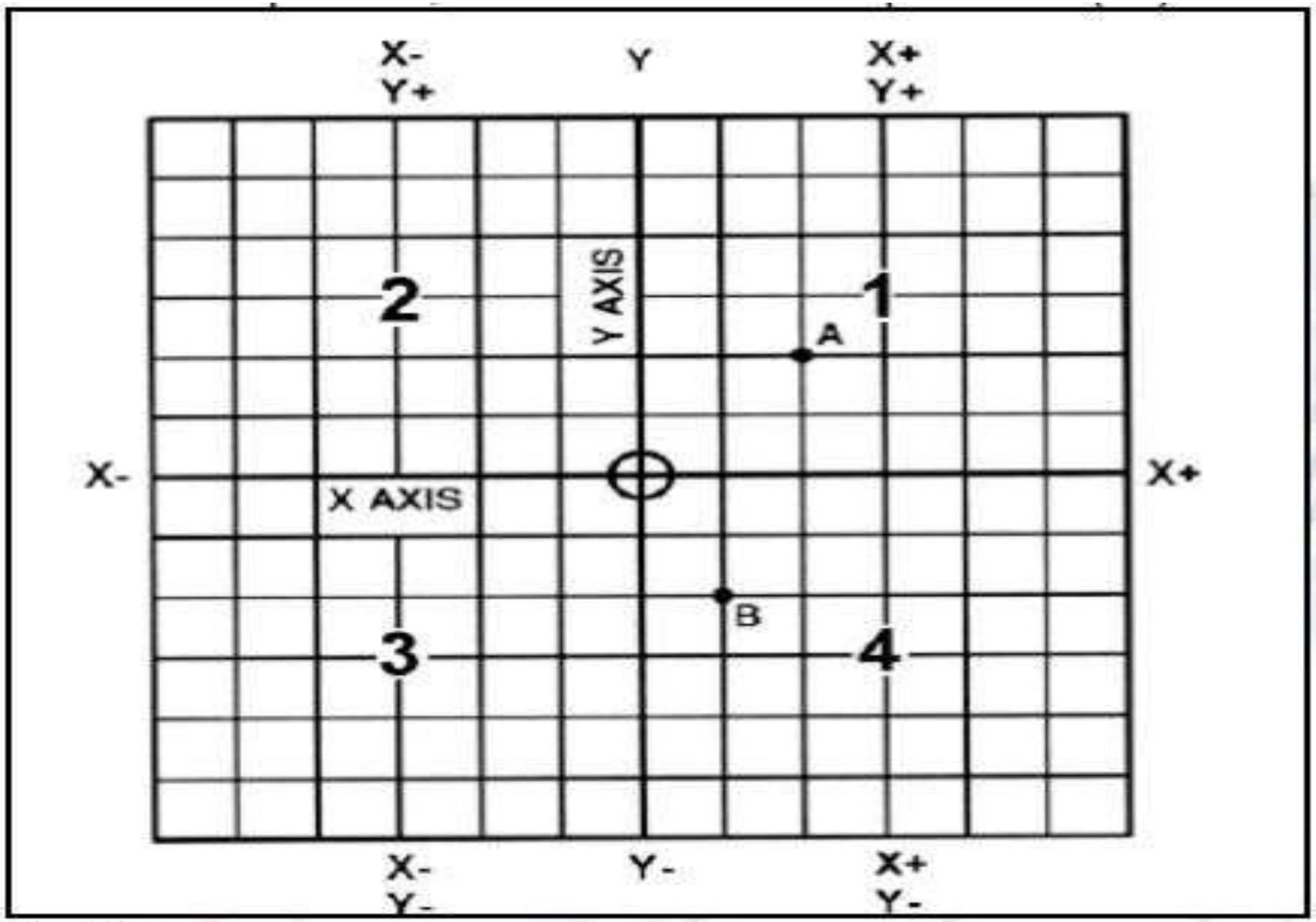
CNC Machine

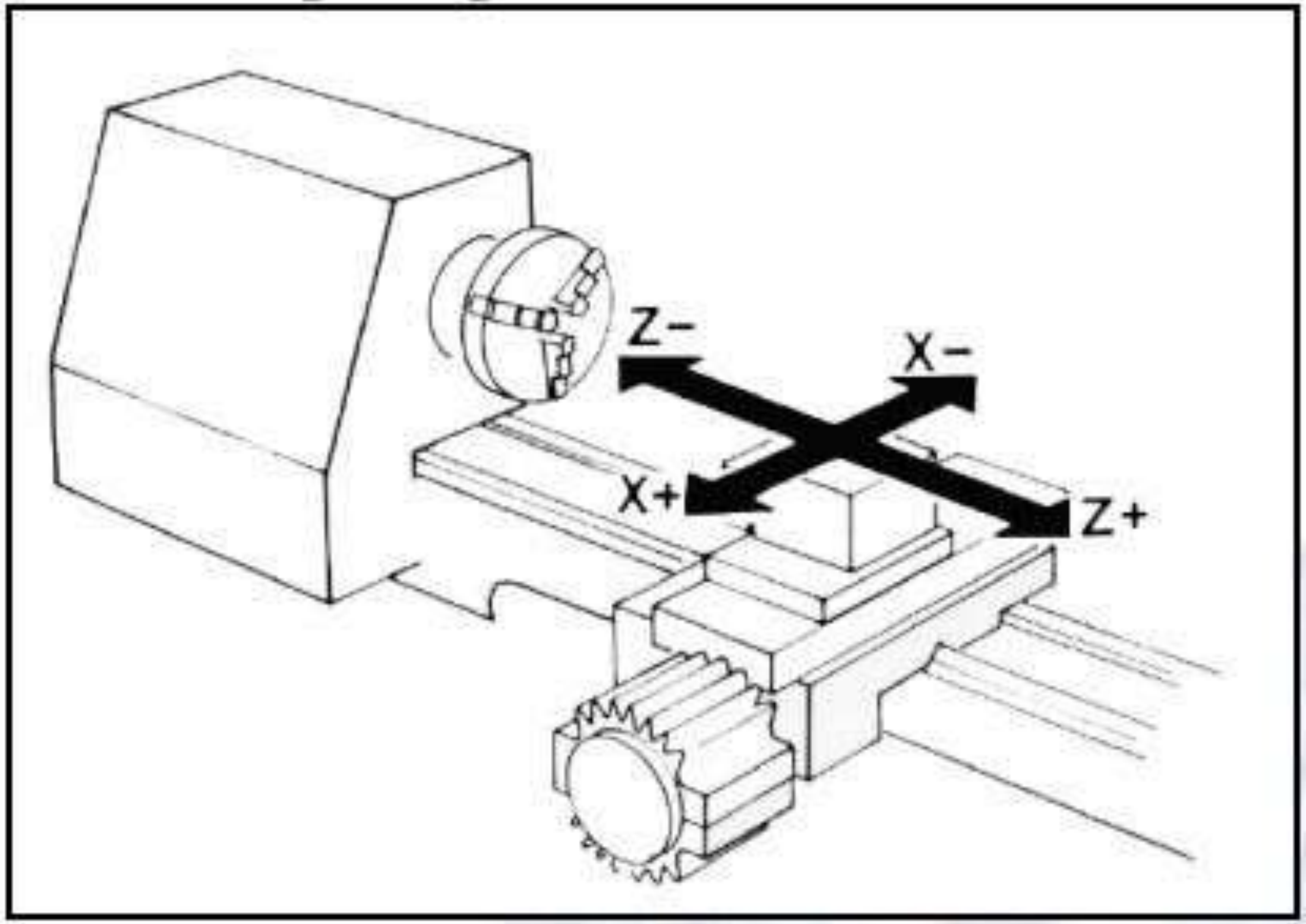
PRINCIPLE

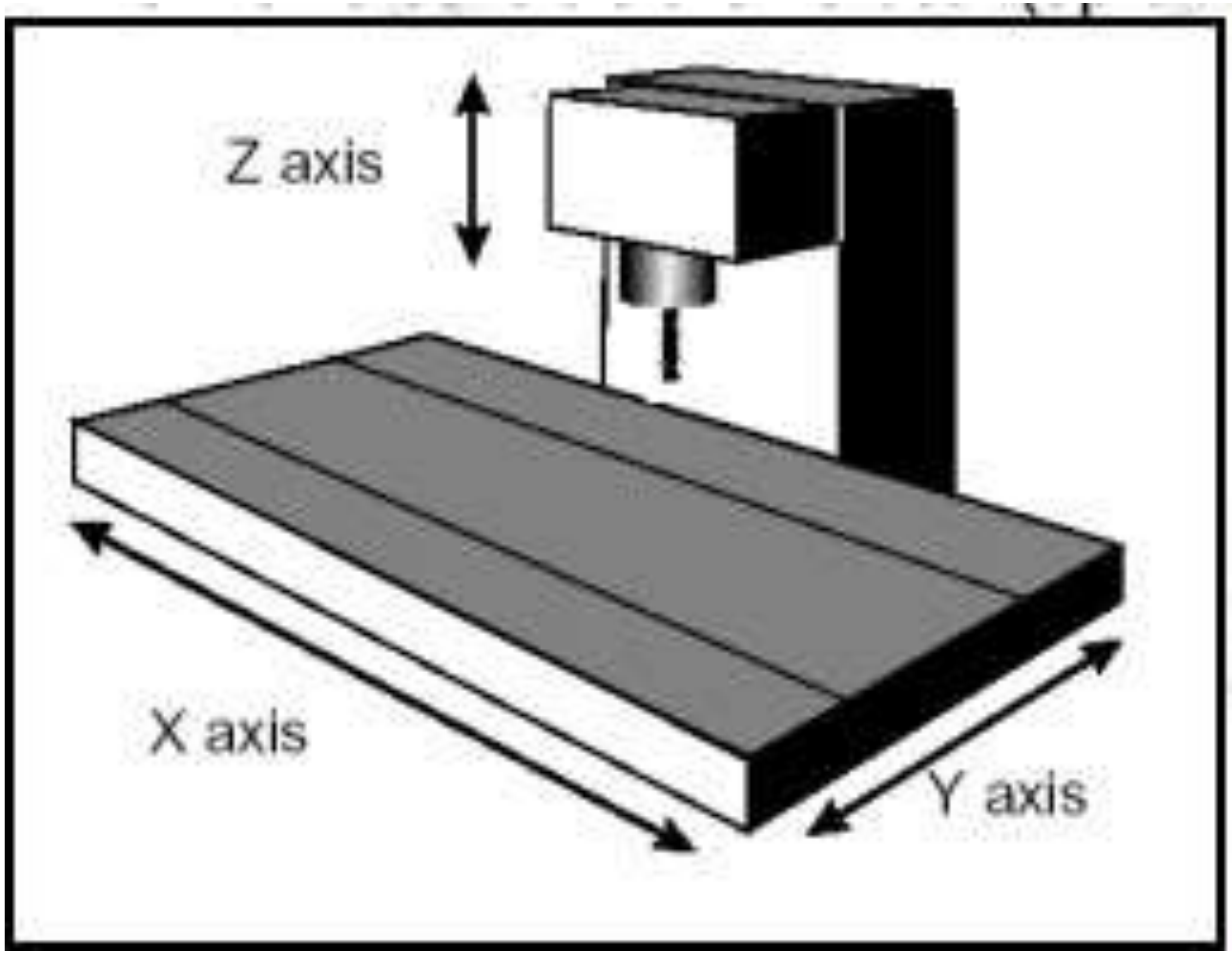
A system in which actions are controlled by direct insertion of numerical data.

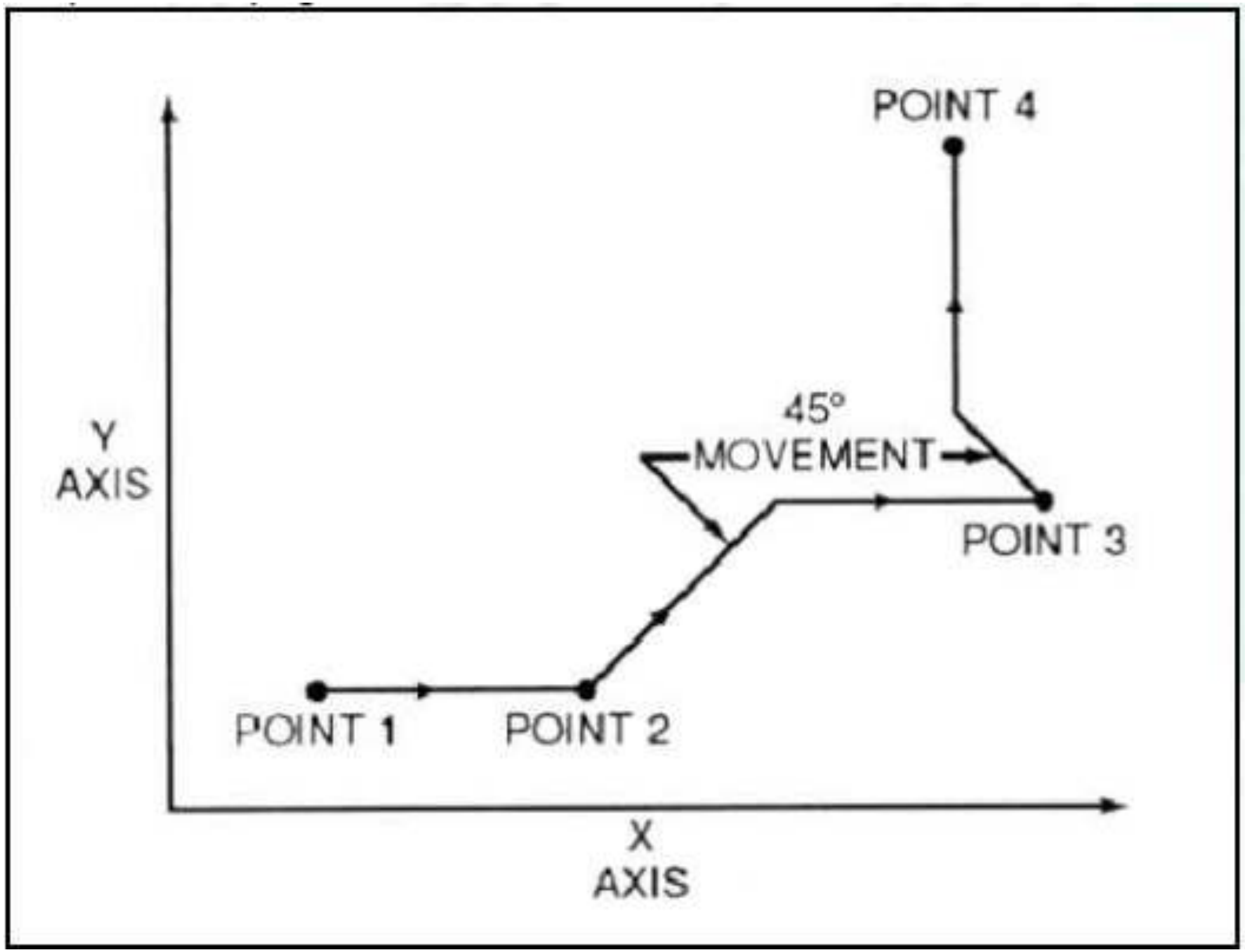



Z+
Y+
X-
X+
Y-
Z-


X-
Y+
Y
X+
Y+
2
1
Y AXIS
A
X-
X AXIS
X+
B
3
4
X-
Y-
Y-
X+
Y-


Z–
X–
X+
Z+


Z axis
X axis
Y axis


POINT 4
45°
MOVEMENT
Y
AXIS
POINT 3
POINT 1
POINT 2
X
AXIS

COMPUTER NUMERICAL CONTROL (CNC)

- Storage of more than one part program
- Various forms of program input
- Program editing at the machine tool
- Fixed cycles and programming subroutines
- Interpolation
- Acceleration and deceleration computations
- Communications interface
- Diagnostics

NC POSITION MOVEMENT

- **Incremental**

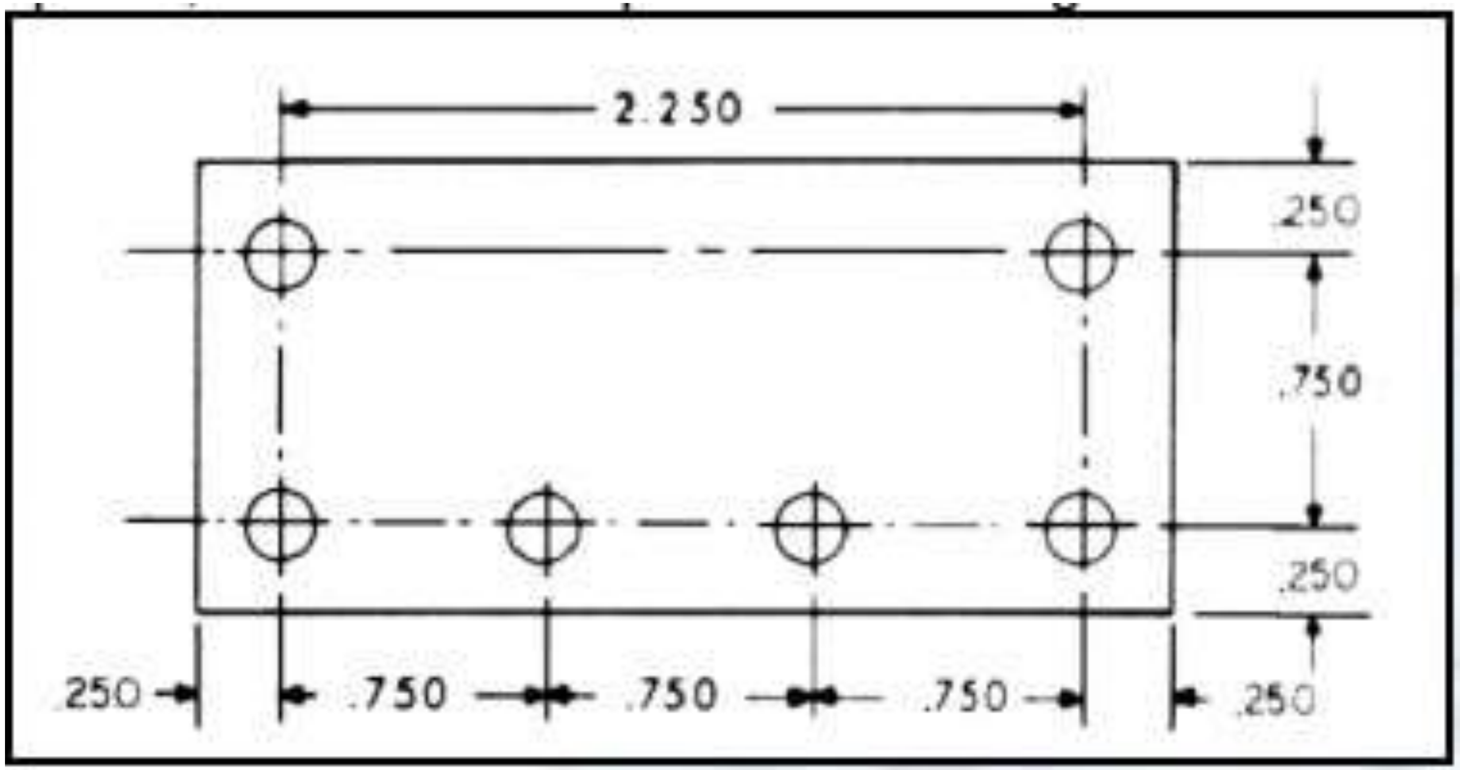
> Taking the “Last” position as the zero position.

- **Absolute**

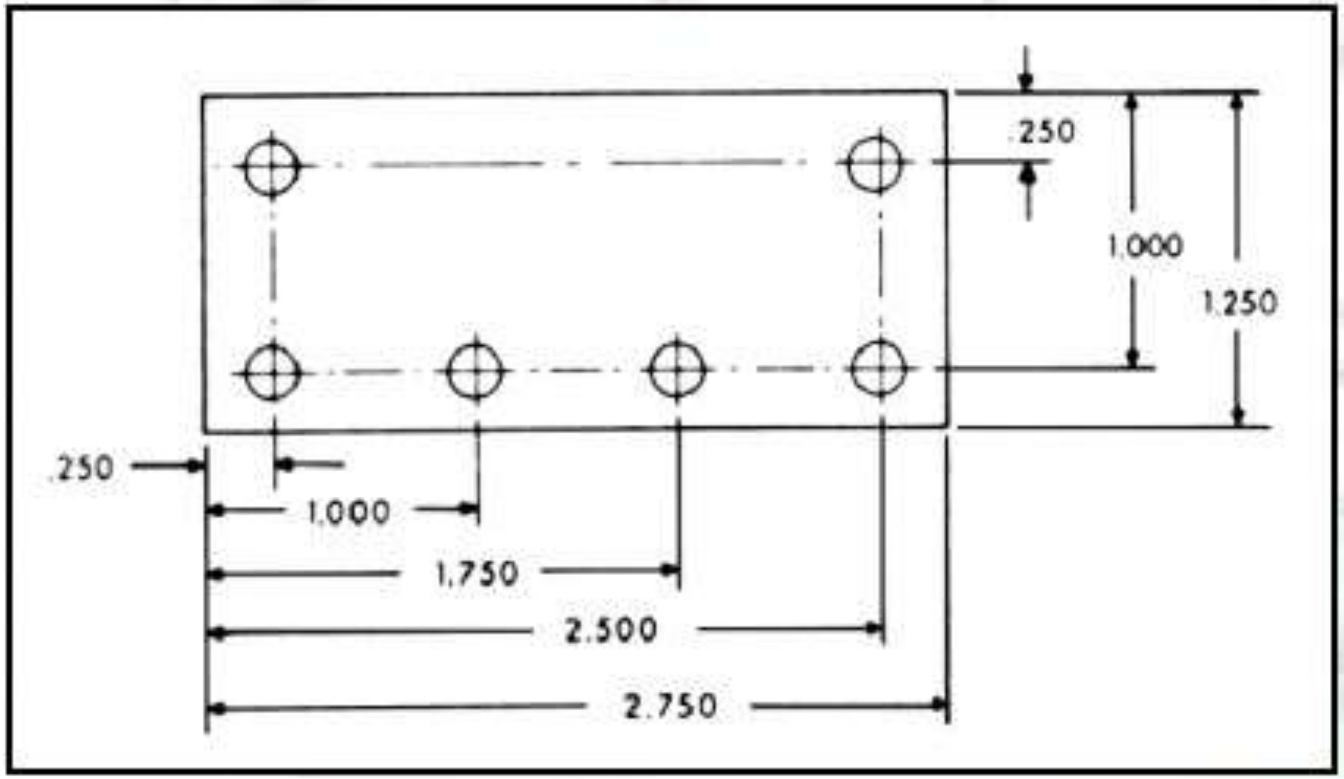
>Locations on Part –Fixed Reference Frame with

- Home position for reference.

REFERENCE POSTIONING SYSTEMS (INCREMENTAL)



REFERENCE POSTIONING SYSTEMS (ABSOLUTE)



Degree of Motion Control

- **Point-to-Point (PTP)**

> Good for holes & slots
> Position tool over point.

- **Contouring**

> Complex curved surfaces
> Computers needed for complex calculations
> Motion control to motors: varying voltages to DC servo motors.

Motion Control Systems

Point-to-Point systems

- Also called position systems
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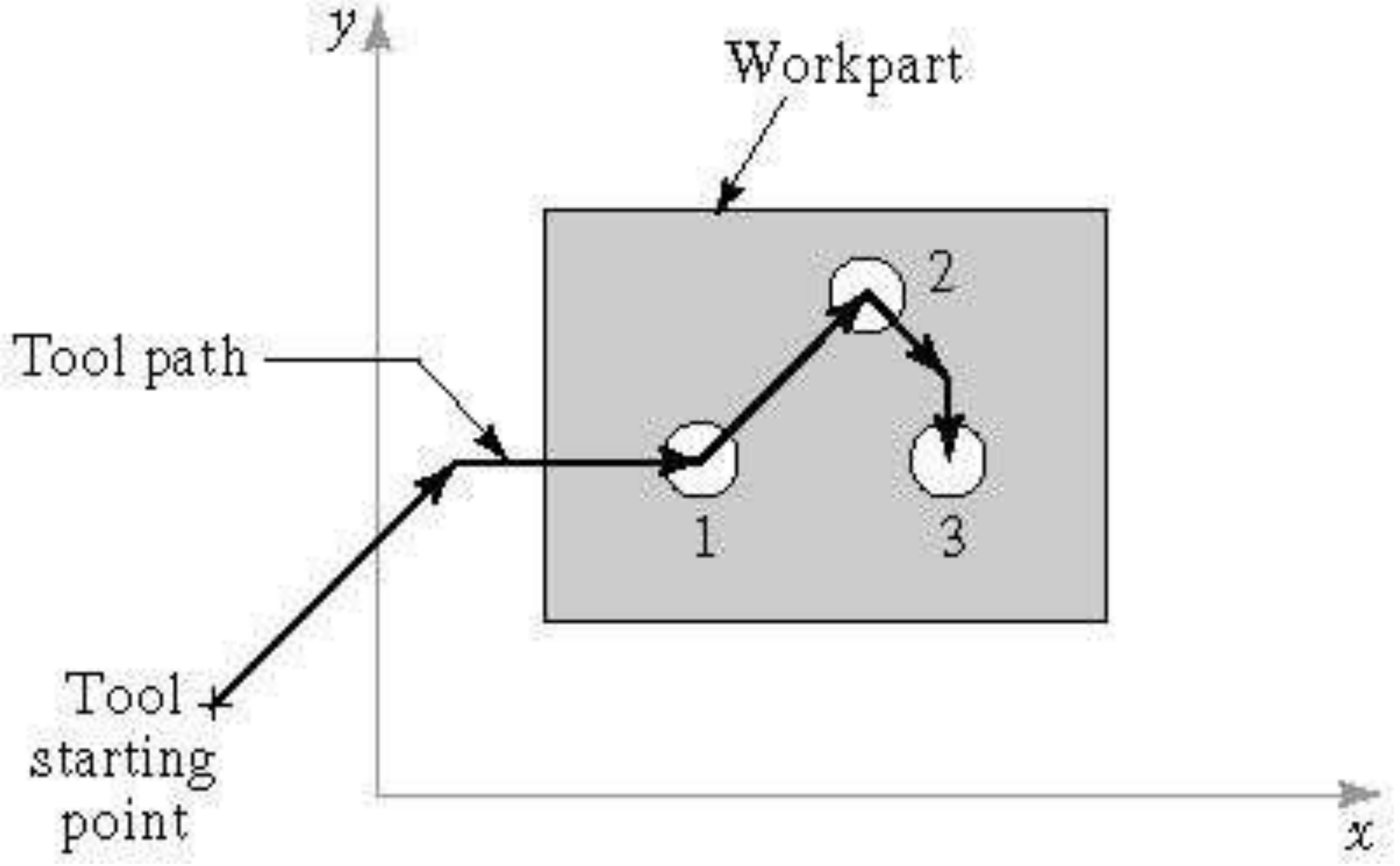
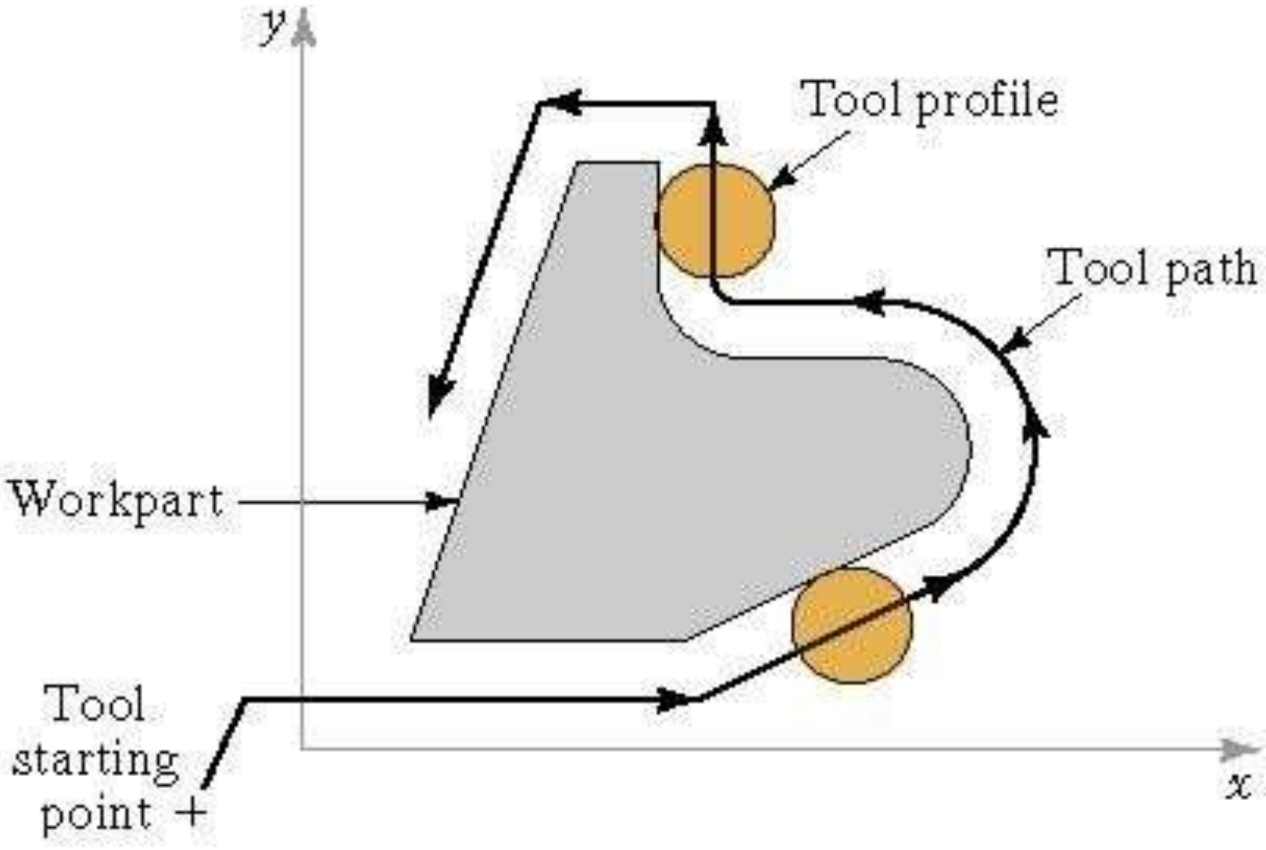
Continuous path systems

- Also called contouring systems in machining
- System performs an operation during movement (e.g., milling and turning)

Point-to-Point systems

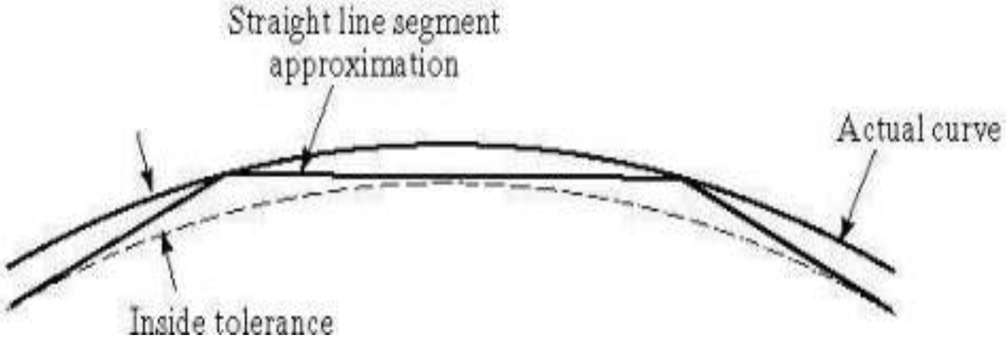


Continuous path systems

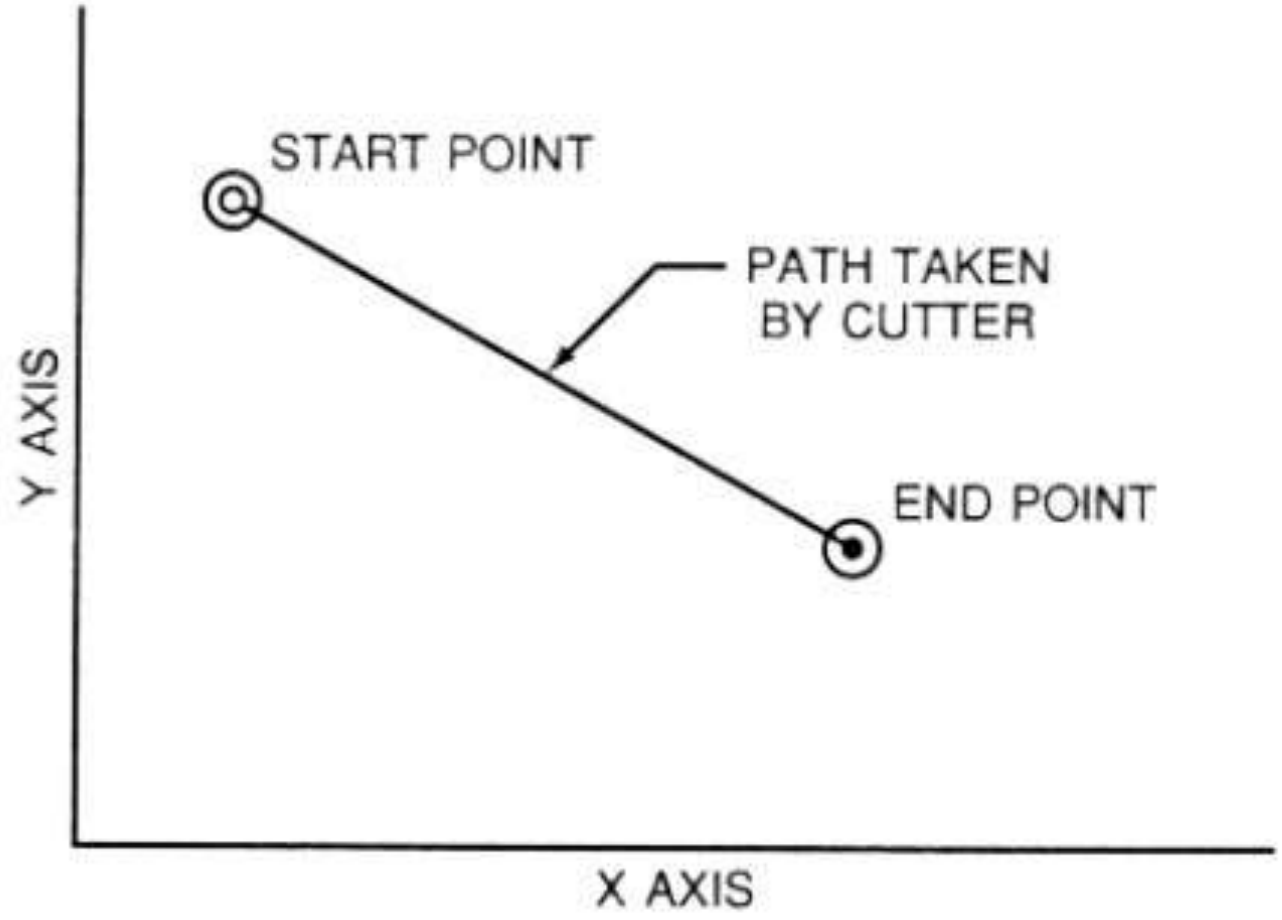


Interpolation Methods

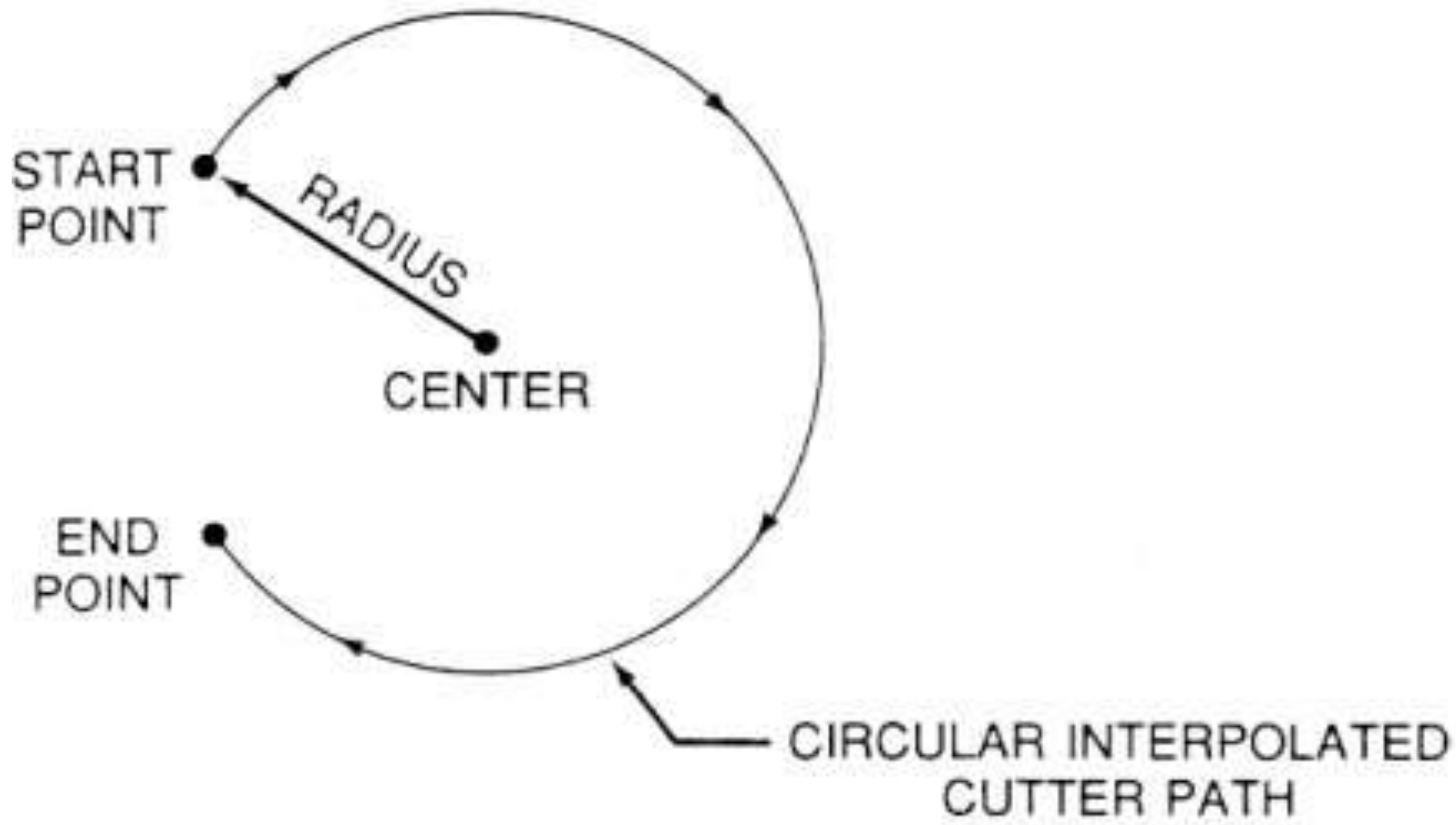
1. **Linear interpolation**
   - Straight line between two points in space
2. **Circular interpolation**
   - Circular arc defined by starting point, end point, center or radius, and direction
3. **Helical interpolation**
   - Circular plus linear motion
4. **Parabolic and cubic interpolation**
   - Free form curves using higher order equatio



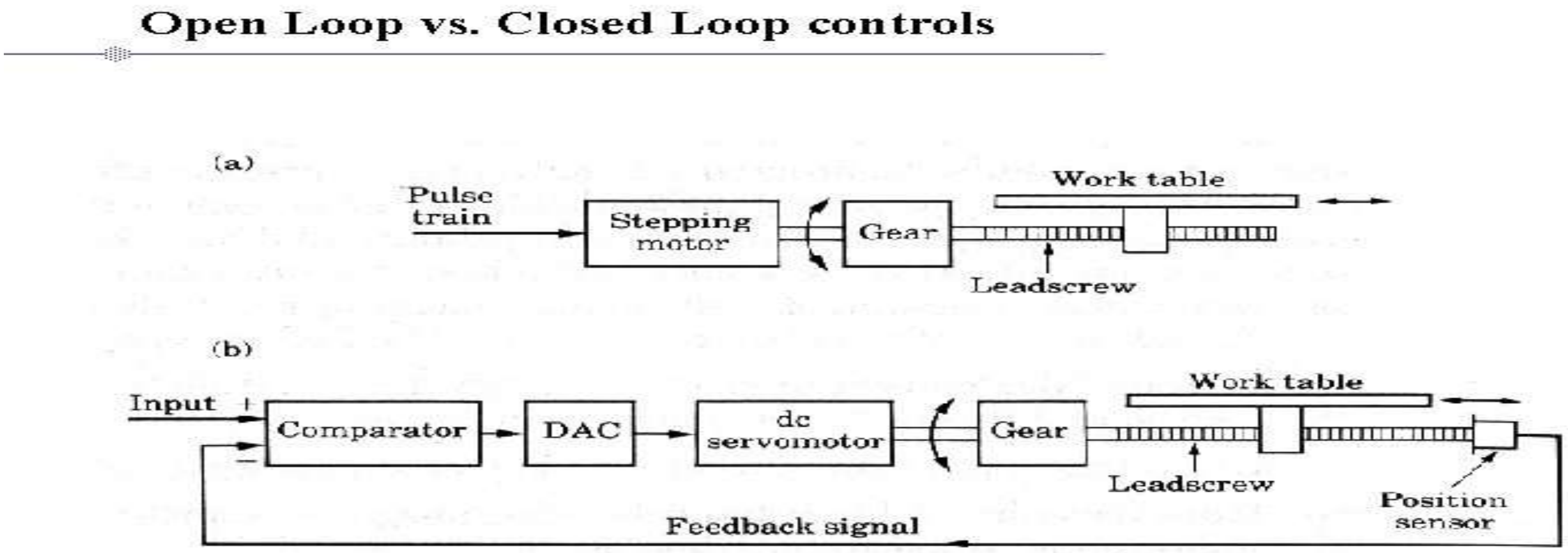
Linear Interpolation



CIRCULAR INTERPOLATION



Open and Closed Loop Controls



Open loop

- An open-loop NC system is one that does not use feedback signals to indicate the table position to the controller unit. Open-loop NC systems typically make use of stepping motors.
- The stepping motor is a motor that is driven and controlled by an electrical pulse train generated by the MCU (or other digital device). Each pulse drives the stepping motor by a fraction of one revolution, called the step angle.

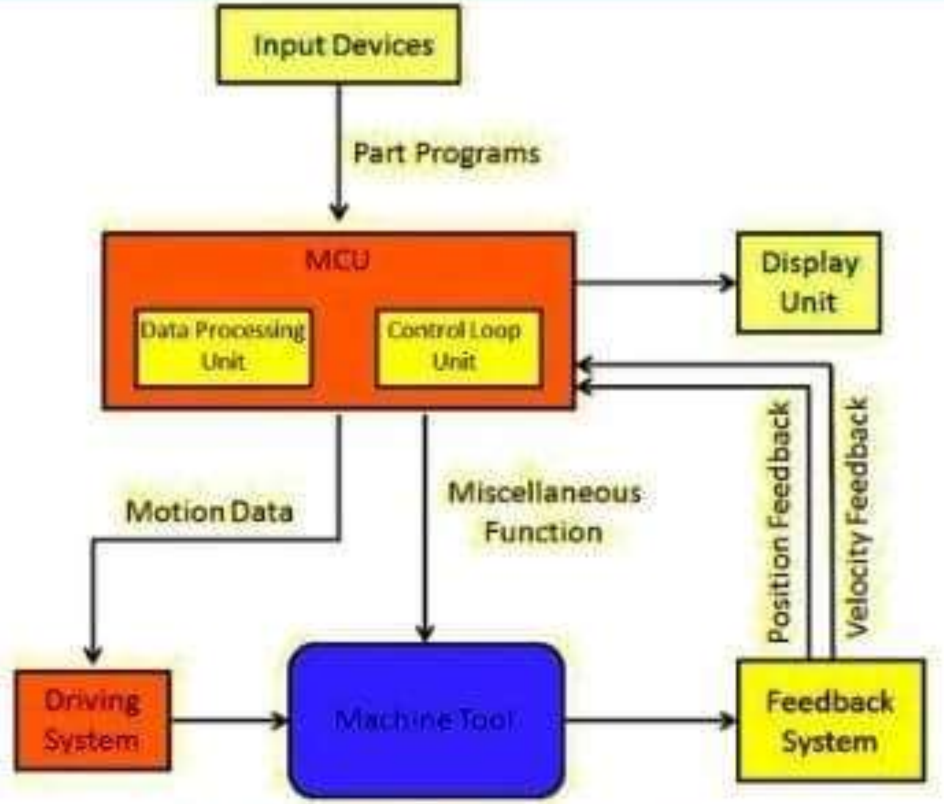
Open loop

- By controlling the number and rate of pulses to the motor, the position of the table is controlled without the need for feedback sensors.
- One of the disadvantages of the stepping motor as the drive unit for an NC system is the possible loss of one or more pulses when the motor is operating under load. This results in a loss in accuracy of the table position.
- Accordingly, stepping motors are used on NC systems in which the load is relatively small. Point-to-point drilling and most of the non machining applications of NC are cases where stepping motors can be used to good advantage.

Closed loop

- A closed loop system uses position sensors attached to the machine tool table to measure its position relative to the input value for the axis. Any difference between the input value and the measured value is used to drive the system toward a zero difference.
- The function of the feedback loop in a numerical control system is to assure that the table and work part have been properly located with respect to the tool.
- Closed-loop NC systems generally use dc servomotors or hydraulic actuators, although hydraulic actuators are becoming less common in machine tool drive systems. Various feedback sensor devices are used in NC.
- One common type is the optical encoder, which is also used as a component for position feedback in an industrial robot.

What Is a CNC Machine? | CNC Block Diagram | Parts of CNC Machine



CNC Block Diagram

CNC Machine

Parts of CNC Machine:

- The main parts of CNC machine are, and The following represent the various CNC machine parts:-

#1. Input Device
These are the device that is used to input part programs in a CNC machine. There are three commonly used input devices, & these are punch tape readers, magnetic tape readers, and computers via RS-232-C communication.

#2. Machine Control Unit (MCU)

- This is the heart of the CNC machine. It performs all the controls functions of the CNC machine, the various tasks performed by the MCU are It reads the coded instructions givens in it. It decodes the coded instruction. This axis applies interpolation (linear, spherical, and helical) to generate motion commands.
- It feeds the axis speed order to the amplifier circuit to drive the spindle mechanism. It receives feedback signals of position and speed for each drive axis. It implements auxiliary control functions such as coolant or spindle on / off and tool change.

#3. Machine Tools

- A CNC machine tool always has a slidings table & a spindle to control position and speed. The machine tables are controlled in the X and Y-axis direction, & the spindle is controlled in the Z-axis direction.

#4. Driving System

- The driving system of the CNC machine consists of an amplifier circuit, drive motors, and ball lead screws. The MCU feeds the signals (i.e., position and speed) of each axis into the amplifier circuit.
- The control signals are then amplified (amplified) to activate the drive motors. And actuated drive motors rotate the ball lead screw to position the machine table.

#5. Feedback System

- The system consists of transducers that act as sensors. It is also called a measurement system. It consists of position and motion transducers that continuously monitor the position and speed of the cutting tool located at any given moment.
- The MCU receives signals from these transducers, and it uses the difference between reference signals and response signals to generate control signals to correct position and motion errors.

#6. Display Unit

- A monitor is used to display programs, commands, and other useful data of the CNC machine.

#7. Bed

- On CNC machines, these parts bear all the weight of the machine; this means that all other components are mounted on it. The bed component is made of hardened materials such as cast iron because the tool turret passes over them in CNC lathe machines.

#8. Headstock

- The headstock is one of the mains components of the CNC lathe machines due to the fact that the workpieces are fixed to it. The CNC lathe features motors to help drive the main axle.

- **#9. Tailstock**
- This lathe provides additional grip to the workpiece when performing operations such as noodling, threading, turning, part of a CNC machine. Support is provided on the end surfaces of the workpiece.
- **#10. Tailstock Quill**
- The tailstock quill helps to centralize the workpieces between the headstock and the tailstock.
- **#11. Footswitch or Pedal**
- The pedal is used to open & close the chuck while trying to hold the component, such as the tailstock quill is moved to the forward and reversed positions.

- **#12. Chuck**
- The chuck is mounted on the main axle, which gives the tool space to fix.
- **#13. Control Panel**
- Control panels are also one of the important parts of CNC machines that are used to set or feed programs for the operation to be performed on the workpieces. It is also called the brains of the CNC machine.

Advantages of CNC Machine:

- It can generate parts with the highest accuracy and precision than any other manual machine.
- It can be run for 24 hours.
- The parts produced by it have the same accuracy. There is no variation in manufactured parts.
- It does not require a highly-skilled operator to operate. A semi-skilled operator can also work more accurately and accurately.
- Operators can easily make changes and corrections and reduce delay times.
- It has the ability to design complex designs with high accuracy in the shortest possible time.
- Modern design software allows the designers to emulate the creators of his idea. And it eliminates the need to creates prototypes or models and saves time and money.
- Fewer workers are required to operate CNC and save labor costs.

Disadvantages of CNC Machine:

Despite having so many advantages, it also has some disadvantages. And these are:

- The cost of these machines is very high as compared to manually operated machines.
- The machine requires high skilled operator
- Maintenances costs are significantly higher in the case of CNC.

NC PART PROGRAMMING

- **Bit** - 0 or 1 = absence or presence of hole in the tape
- **Character** - row of bits across the tape
- **Word** - sequence of characters (e.g., y-axis position)
- **Block** - collection of words to form one complete instruction
- **Part program** - sequence of instructions (blocks)

Block Format

- Organization of words with in a block in NC part program.
- Also knownas tape formatbecause the original formats were designed for punched tape.

Word address format -

- used on all modern CNC controllers.
- Uses a letter prefix to identify each type of word Spaces to separate words within the block.
- Allows any order of words in a block.
- Words can be omitted if their values do not change from the previous block.

- N - sequence number prefix
- G - preparatory words

Example: G00 = PTP rapid traverse move

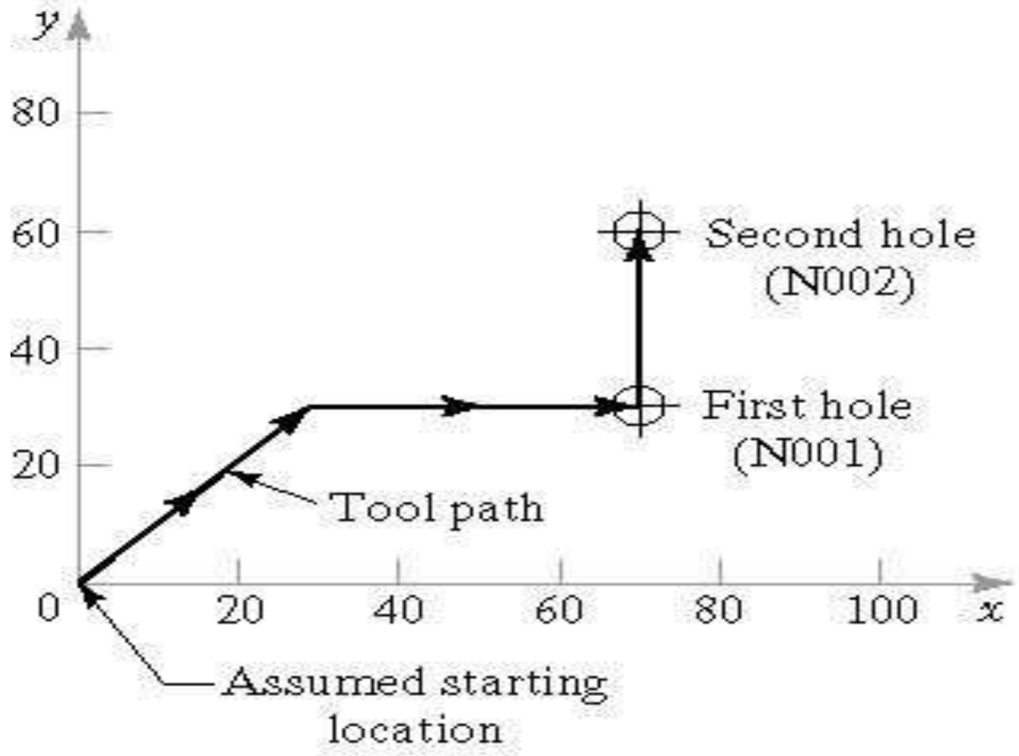
X, Y, Z - prefixes for x, y, and z-axes

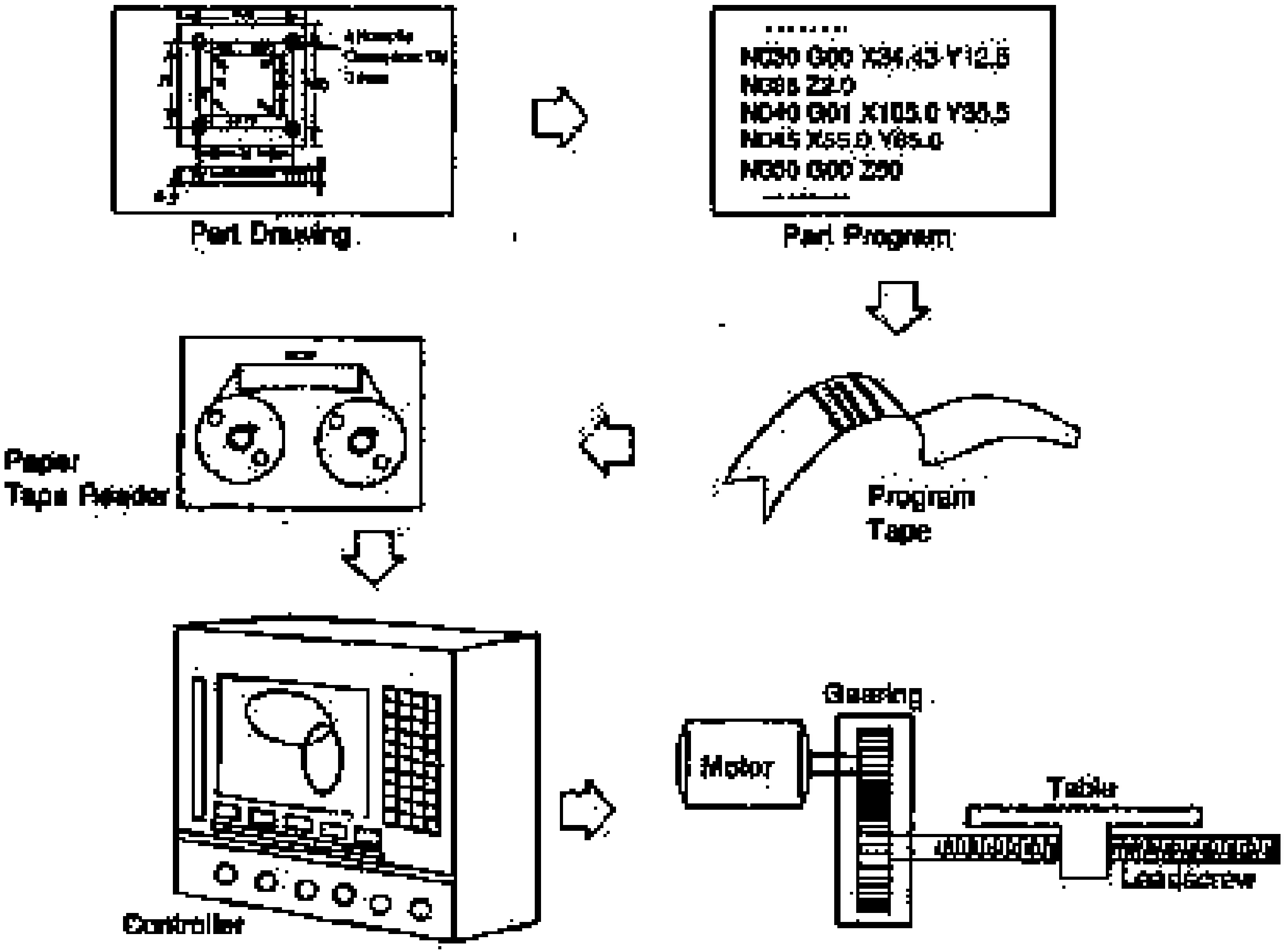
- F - feed rate prefix
- S - spindle speed
- T - tool selection
- M - miscellaneous command

Example: M07 = turn cutting fluid on

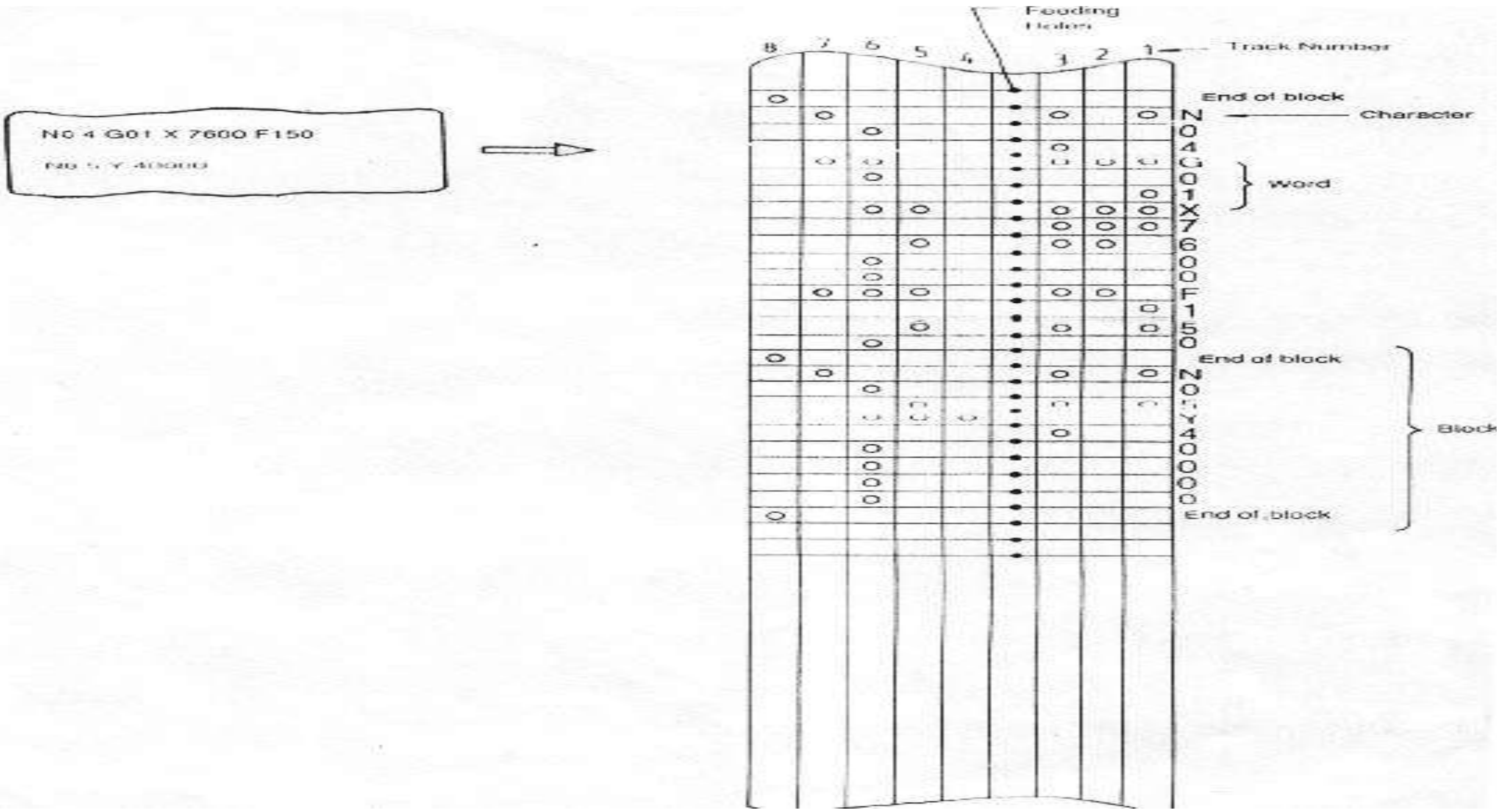
Example: Word Address Format

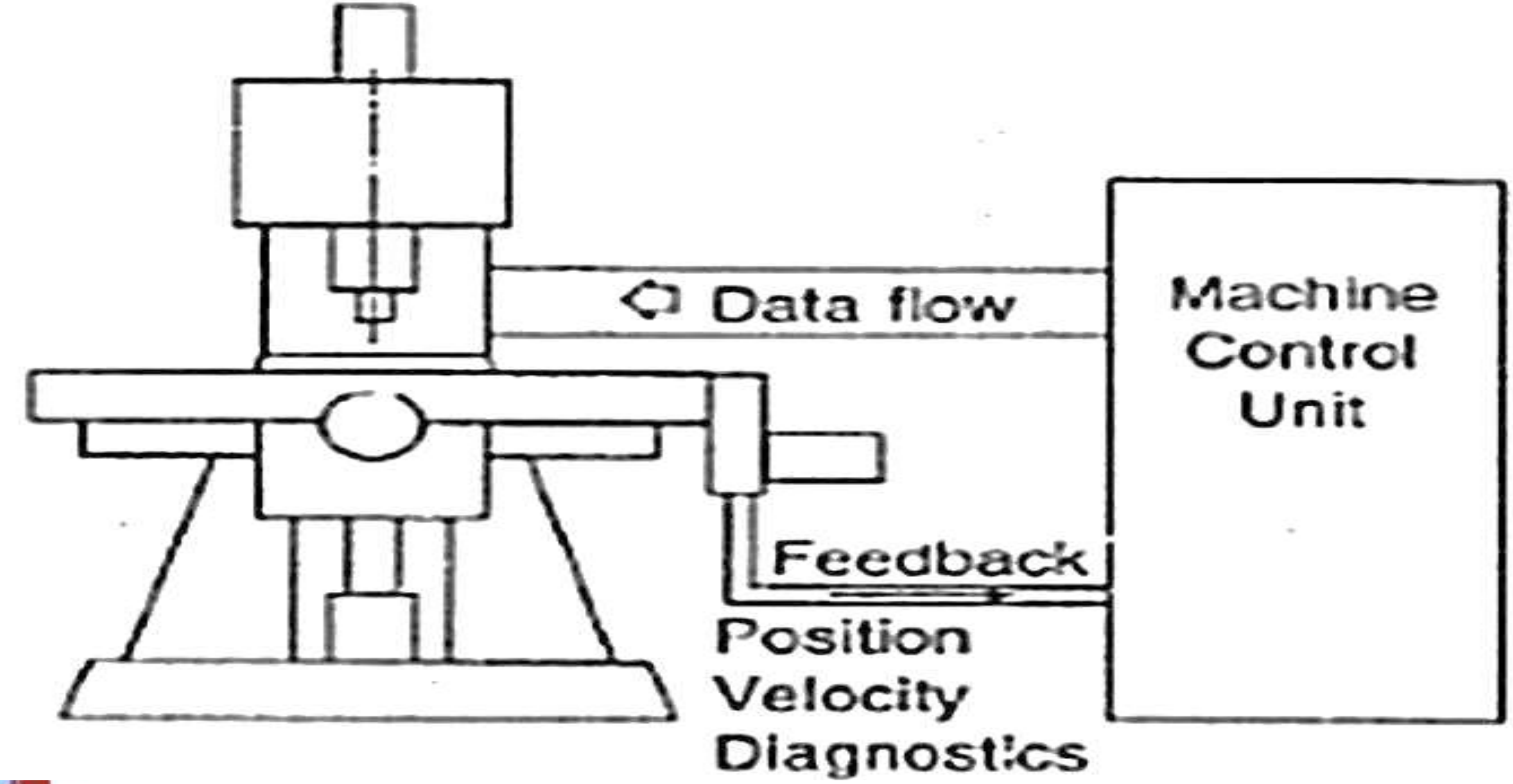
- N001 G00 X 7000 Y 3000 M03
- N002 Y 6000





N030 G00 X34.43 Y12.5
N035 Z2.0
N040 G01 X105.0 Y35.5
N045 X55.0 Y85.0
N050 G00 Z50
Part Drawing
Part Program
Paper
Tape Reader
Program
Tape
Controller
Gearing
Motor
Table
Leadscrew


N0 4 G01 X 7600 F150
N0 5 Y 40000
Feeding Holes
8 7 6 5 4 3 2 1
Track Number
End of block
Character
Word
End of block
Block
End of block


Data flow
Machine
Control
Unit
Feedback
Position
Velocity
Diagnostics

Advantages of NC

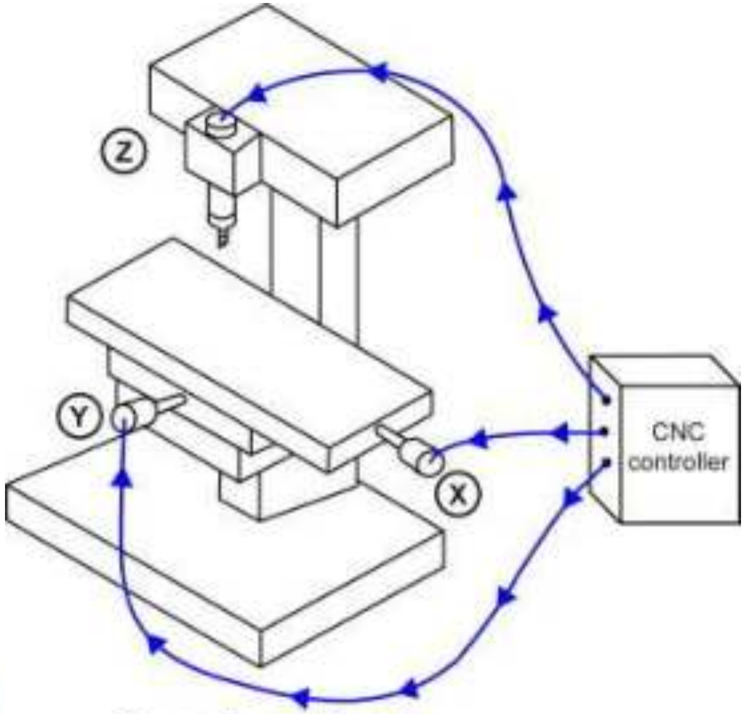
- Flexibility
- Capability for Complex
- Work-pieces
- Manage Large Work-pieces
- Reduced Jig & Fixture Cost
- Higher Quality

Computer Numerical Control (CNC)

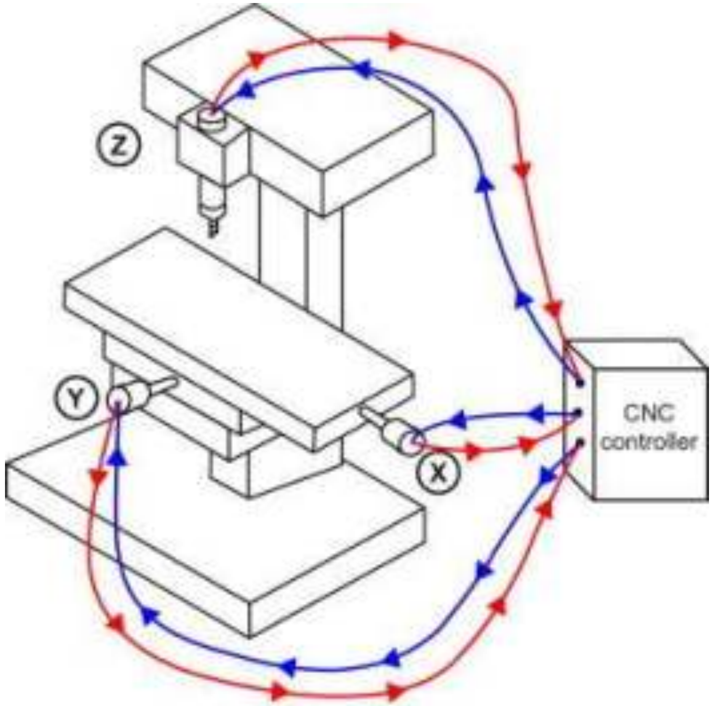
Advantages:

- CRT allows review/editing
- Pre check/simulation
- Interface allows more capability
- Accurate positioning
- More functions

Open Loop and Closed Loop CNC Machines

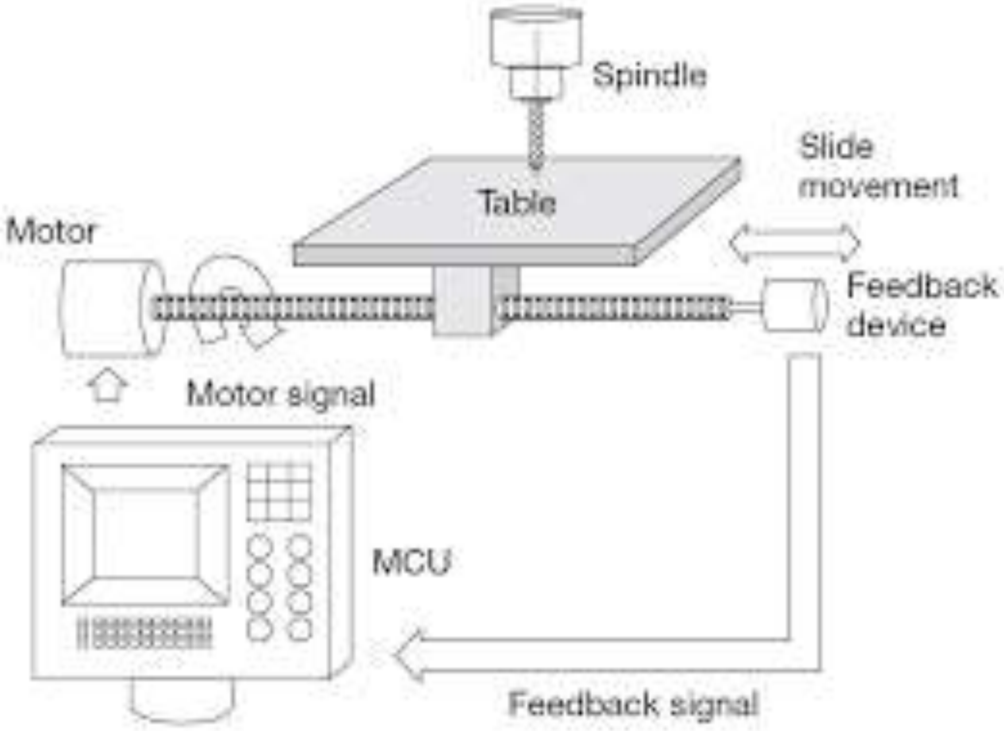


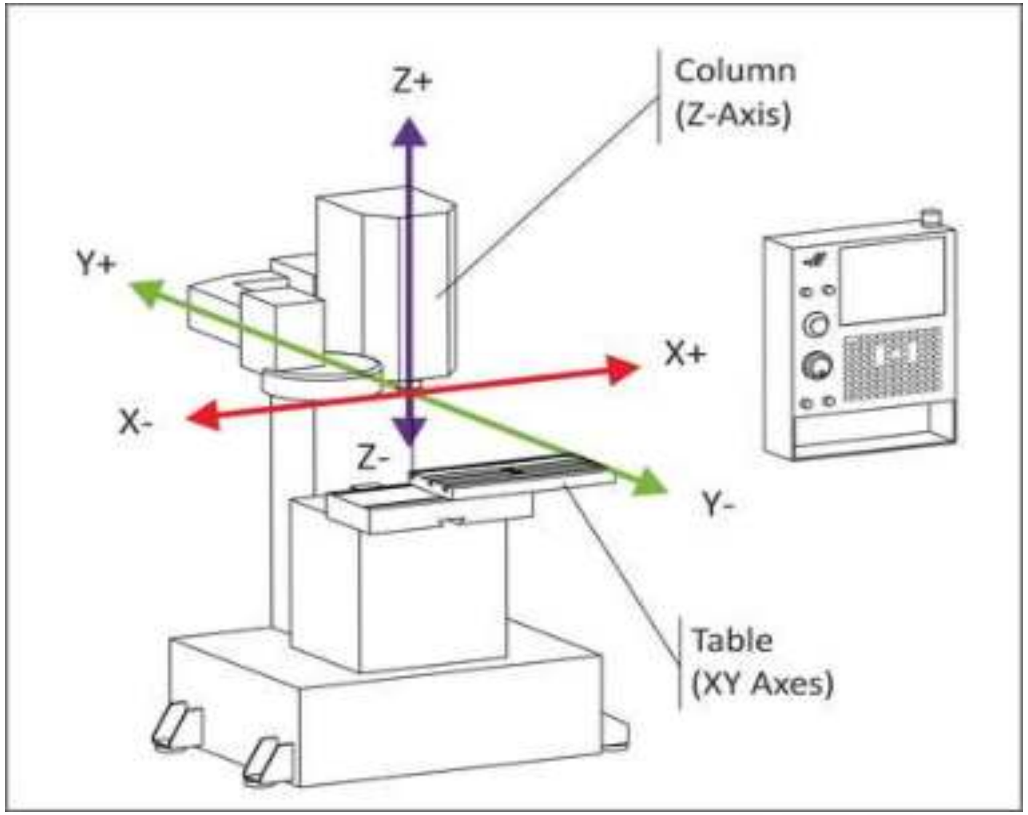
Open-Loop-System



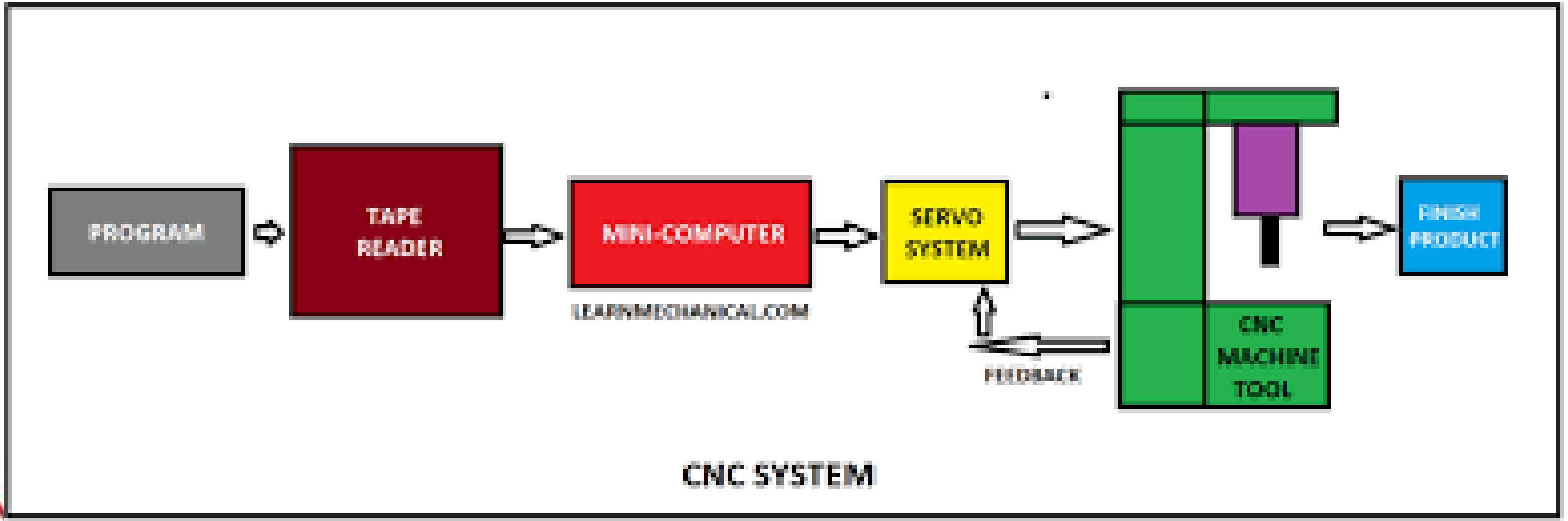
Closed-Loop-System

CNC Milling Block Diagram

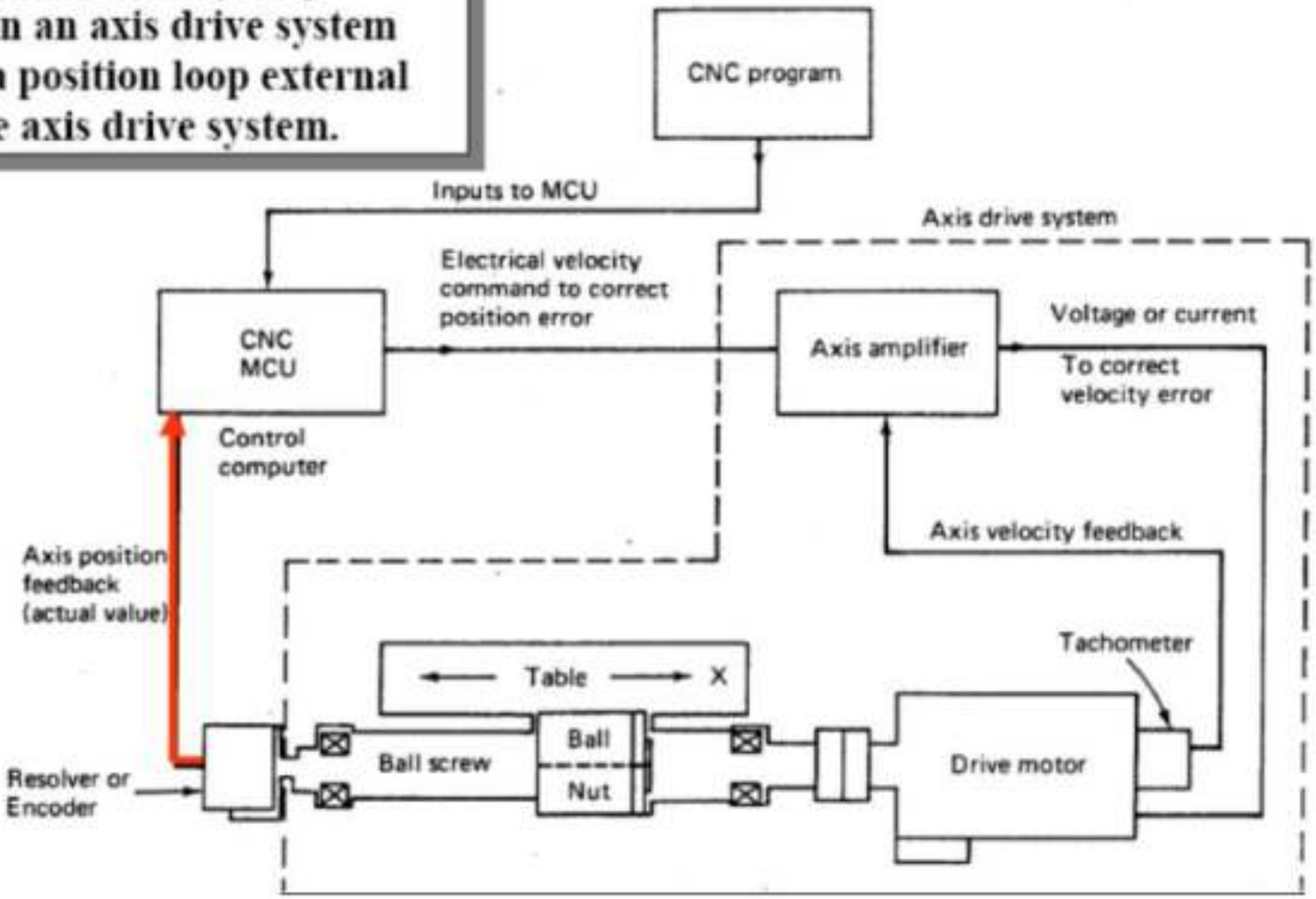




CNC Milling Block Diagram



A CNC control system includes a velocity loop within an axis drive system and a position loop external to the axis drive system.



Thank You

Non Conventional Machining

Module 5

Introduction

- Non-traditional Manufacturing Processes Is Defined As A Group Of Processes That Remove Excess Material By Various Techniques Involving Mechanical, Thermal, Electrical Or Chemical Energy Or Combinations Of These Energies
- Do Not Use A Sharp Cutting Tool As It Needs To Be Used For Traditional Manufacturing Processes.
- Extremely Hard And Brittle Materials Are Difficult To Machine By Traditional Machining Processes Such As Turning, Drilling, Shaping And Milling.
- Non-traditional Machining Processes, Also Called Advanced Manufacturing Processes, Are Employed Where Traditional Machining Processes Are Not Feasible, Satisfactory Or Economical

Use of Mechanical Energy

- Mechanical energy is used for removing material from workpiece.
- In this process, cutting tool with sharp edge is not used but material is removed by the abrasive action of high velocity of stream of hard, tiny abrasive particles.
- The particles are kept vibrating with very high velocity and ultra high frequency to remove the material.

USE Electrical Energy

- In this category of non-traditional machining electrical energy is used in the form of electrochemical energy or electro-heat energy to erode the material or to melt and vapourized it respectively.
- Electrochemical machining, electroplating or electro discharge machining are the examples work on this principle.

- **Use of Thermal Energy**
- According to this principle heat is generated by electrical energy.
- The generated thermal energy is focused to a very small portion of workpiece.
- This heat is utilized in melting and evaporating of metal. The example based o this principle is electric discharge machining.
- **Use of Chemical Energy**
- According to this principle of working chemicals are used to erode material from the workpiece. Selection of a chemical depends upon the workpiece material.
- Example of this type of machining is electrochemical machining.
- The same principle can also be applied in reversed way in the process of electrochemical plating.

Why Non Conventional Machining

- Very hard fragile materials difficult to clamp for traditional machining
- When the workpiece is too flexible or slender
- When the shape of the part is too complex

Non Conventional Machining Processes

1) Mechanical Processes

- Abrasive Jet Machining (AJM)
- Ultrasonic Machining (USM)
- Water Jet Machining (WJM)

2) Electrochemical Processes

- Electrochemical Machining (ECM)
- Electro Chemical Grinding (ECG)
- Electro Jet Drilling (EJD)

3) Electro-thermal Processes

- Electro-discharge Machining (EDM)
- Laser Jet Machining (LJM)
- Electron Beam Machining (EBM)

4) Chemical Processes

- Chemical Milling (CHM)
- Photochemical Milling (PCM)

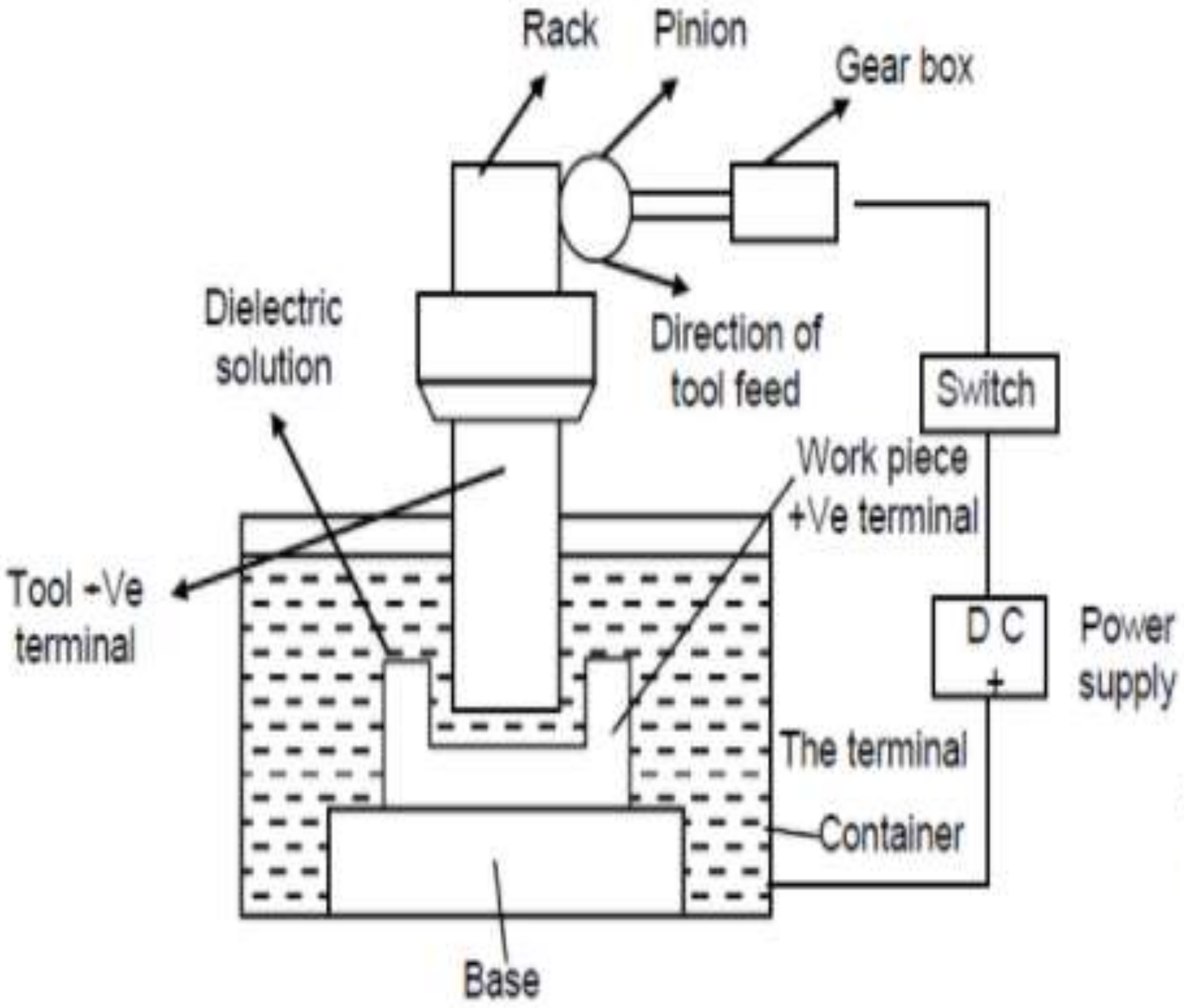
Electro-discharge Machining (EDM)

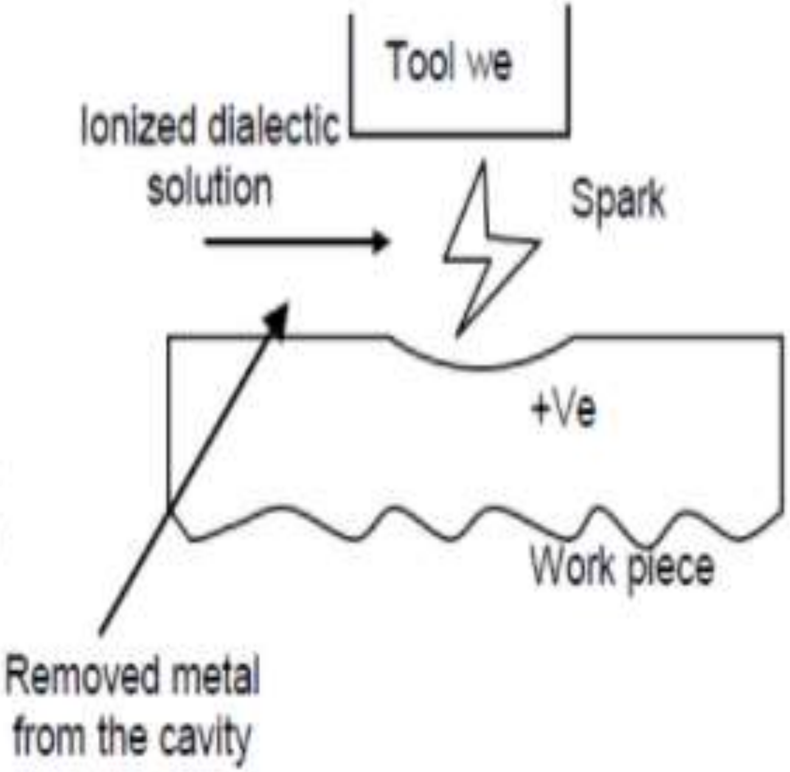
- It is an advanced machining process primarily used for hard and difficult metals which are difficult to machine with the traditional techniques.
- Only electrically conducting materials are machined by this process.
- The EDM process is best suited for making intricate cavities and contours which would be difficult to produce with normal machines like grinders, end-mills or other cutting tools.
- Metals such as hardened tool-steels, carbides, titanium, inconel and kovar are easily machined through EDM.

- EDM is A thermal process which makes use of spark discharges to erode the material from work piece surface.
- The cavity formed in EDM is A replica of the tool shape used as the erosions occur in the confined area. Since spark discharges occur in EDM, it is also called as "spark machining".
- The material removal takes place in EDM through A rapid series of electrical discharges. These discharges pass between the electrode and the work piece being machined.
- The fine chips of material removed from the work piece gets flushed away by the continuous flowing di-electric fluid.
- The repetitive discharge creates a set of successively deeper craters in the work piece until the final shape is produced.

EDM Principle

- The basic of EDM process is illustrated in schematic fig.
- In this process, the work piece and tool are submerged into a non-conducting, dielectric fluid which is separated by a small gap (for sparking).
- The dielectric fluid insulates the work piece from the tool and creates the resistance of electricity flow between the electrodes.
- The dielectric fluid may be typical hydrocarbon oil (kerosene oil) or de-ionized water.
- It also helps in cooling down the tool and workpiece, clears the inter-electrode gap (IEG), and concentrates the spark energy to a small cross sectional area under the electrode.





Metal removing process

- As the two electrodes come closer to one another, the electric field intensity increases beyond the strength of the dielectric enabling it to break and thereby allow the current to flow between the two electrodes.
- As a result of this effect, intense heat gets generated near the zone, which melts and evaporates the material in the sparking zone.
- As the flow of current is momentarily stopped, some fresh dielectric liquid particles come in position between the inter-electrode gap which restores the insulating properties of the dielectric.
- The solid particles (debris) are carried away by the flowing dielectric. Flushing refers to the addition of new liquid dielectric to the inter-electrode volume.
- A close view of the EDM process is shown in fig.
- The sparks occur at spots where the tool and the workpiece surfaces are the closest and since the spots change after each spark (because of the material removal after each spark), the spark travels all over the surfaces.
- This results in uniform removal of material, hence exact shape get reproduced on the workpiece surface.

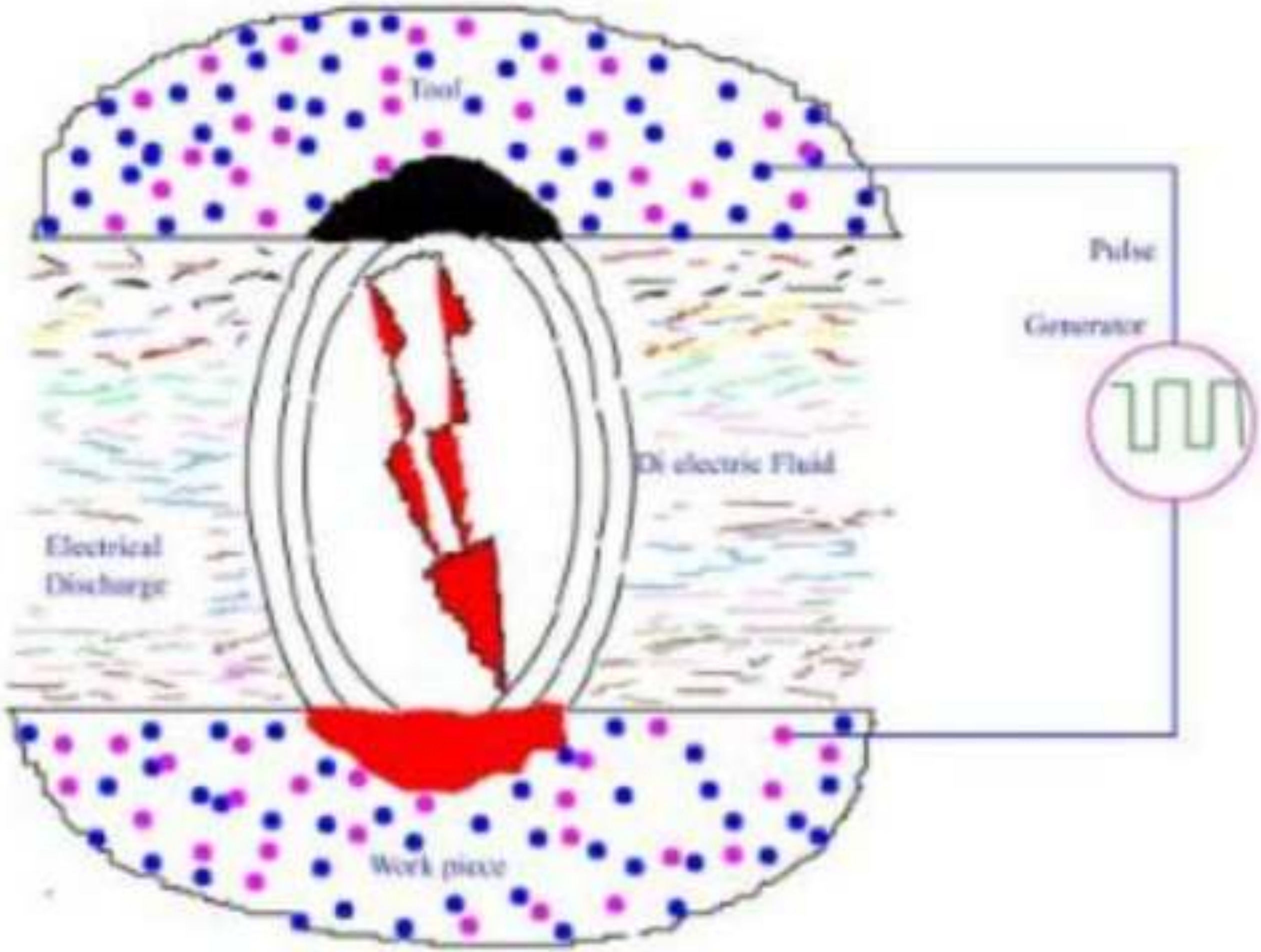


Figure Close View of ED Machining region

Advantages of EDM

- Any materials that are electrically conductive can be machined by EDM.
- Materials, regardless of their hardness, strength, toughness and microstructure can be easily machined / cut by edm process
- The tool (electrode) and workpiece are free from cutting forces
- Edge machining and sharp corners are possible in EDM process
- The tool making is easier as it can be made from softer and easily formable materials like copper, brass and graphite.
- The process produces good surface finish, accuracy and repeatability.
- Hardened work-pieces can also be machined since the deformation caused by it does not affect the final dimensions.
- EDM is a burr free process.
- Hard die materials with complicated shapes can be easily finished with good surface finish and accuracy through EDM process.
- Due to the presence of dielectric fluid, there is very little heating of the bulk material.

Limitations of EDM

Material removal rates are low, making the process economical only for very hard and difficult to machine materials.

- Re-cast layers and micro-cracks are inherent features of the EDM process, thereby making the surface quality poor.
- The EDM process is not suitable for non-conductors.
- Rapid electrode wear makes the process more costly.
- The surfaces produced by EDM generally have a matt type appearance, requiring further polishing to attain a glossy finish.

Applications of EDM

- Hardened steel dies, stamping tools, wire drawing and extrusion dies, header dies, forging dies, intricate mould cavities and such parts are made by the EDM process.
- The process is widely used for machining of exotic materials that are used in aerospace and automatic industries.
- EDM being a non-contact type of machining process, it is very well suited for making fragile parts which cannot take the stress of machining.
- The parts that fit such profiles include washing machine agitators; electronic components, printer parts and difficult to machine features such as the honeycomb shapes.
- Deep cavities, slots and ribs can be easily made by EDM as the cutting forces are less and longer electrodes can be used to make such collets, jet engine blade slots, mould cooling slots etc.
- Micro- EDM process can successfully produce micro-pins, micro-nozzles and micro-cavities.

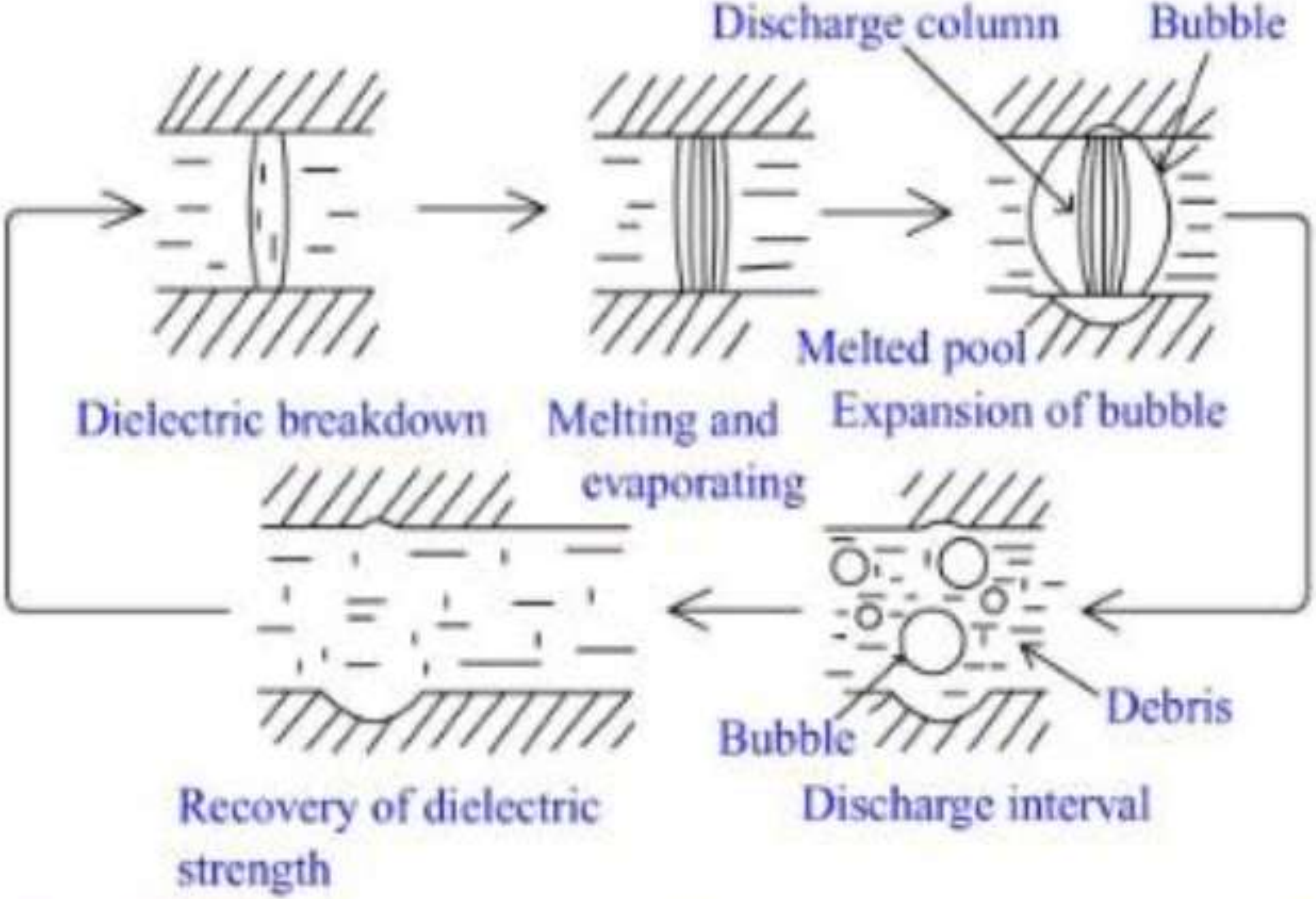
Mechanism of Material Removal in EDM

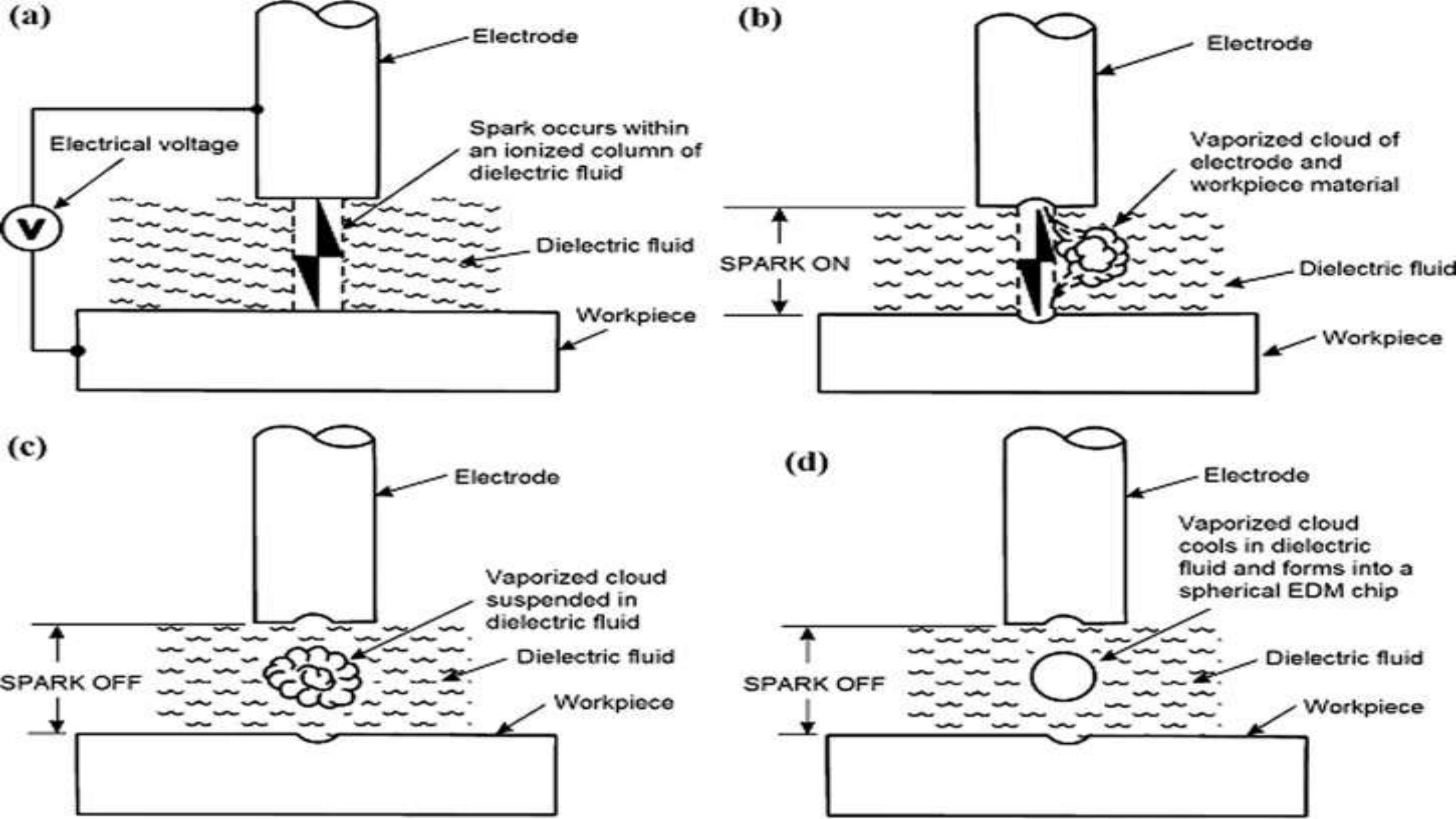
- In EDM, for a particular machining condition there are numerous phenomena involved, i.e., Heat conduction and radiation, phase changes, electrical forces, bubble formation and collapse, rapid solidification etc.
- Thermo-electric phenomenon is the most appropriate theory for the explanation of the electrical discharge machining process.
- The removal of material in EDM is associated with the erosive effects produced when discrete and spatial discharge occurs between the tool and workpiece electrodes.
- Short duration sparks are generated between these two electrodes.
- The generator releases electrical energy, which is responsible for melting a small quantity of material from both the electrodes. At the end of the pulse duration, a pause time begins.
- The forces that may be of electric, hydrodynamic and thermodynamic in nature remove the melted pools. The material removal process by a single spark is as follows:

- An intense electric field develops in the gap between electrode and workpiece.
- There are some contaminants inside the dielectric fluid which build a high-conductivity bridge between the electrode and workpiece.
- When the voltage increases, the bridge and dielectric fluid between the electrode and workpiece heat up. The dielectric is ionized to form a spark channel. The temperature and pressure rapidly increase and a spark is generated. A small amount of material is evaporated on the electrode and workpiece at the spark contact point.
- Bubbles rapidly expand and explode during sparking until the voltage is turned off. Next the heating channel collapses and the dielectric fluid enters into the gap in-order to flush away the molten metal particles.

The material removal rate depends on the following factors:

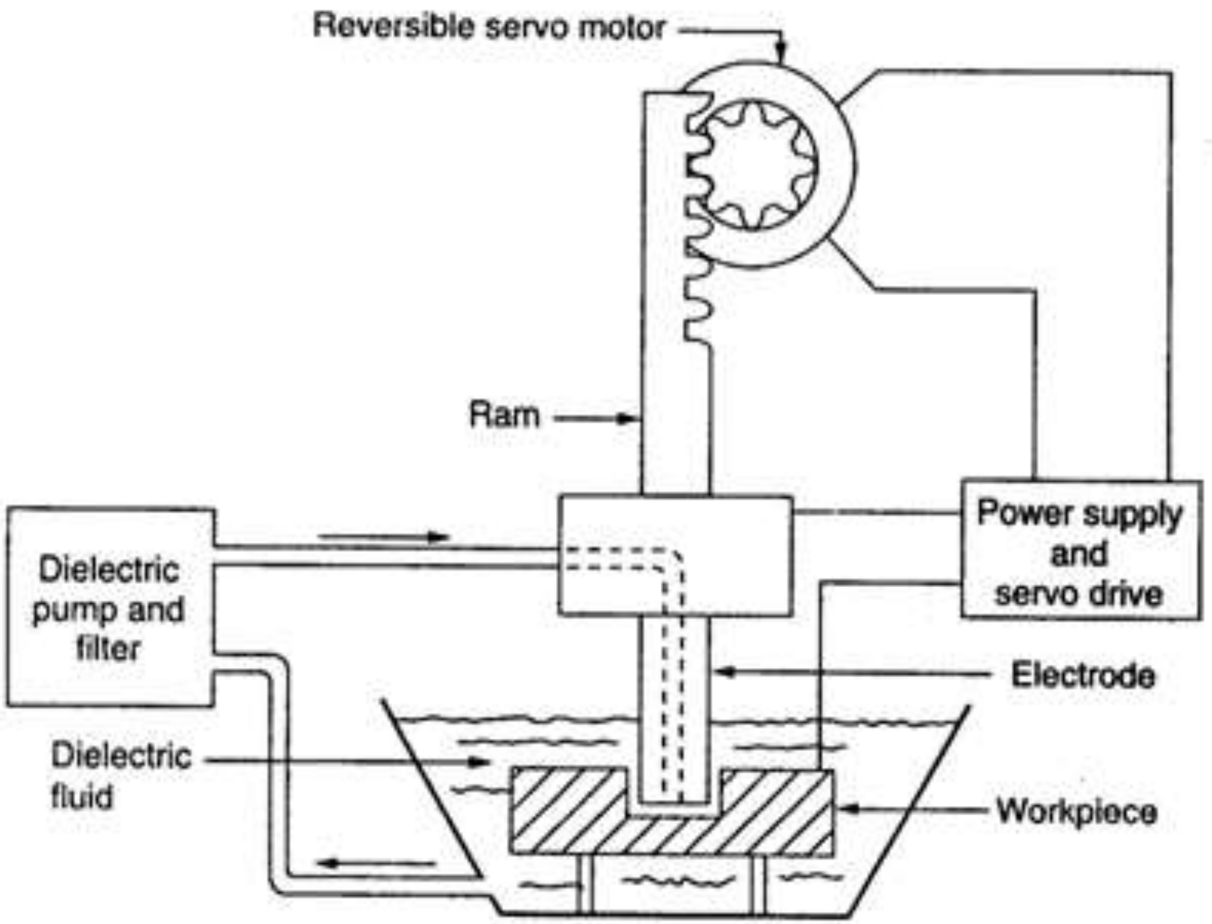
- Peak amperage or intensity of the spark
- Length of the ON time
- OFF time influences the speed and stability
- Duty cycle: percentage of on-time relative to total cycle time
- Gap distance: smaller the gap better is the accuracy and slower is the material removal rate.
- The material removal phenomena in edm are shown schematically in the fig.


Discharge column
Bubble
Dielectric breakdown
Melting and evaporating
Melted pool
Expansion of bubble
Recovery of dielectric strength
Bubble
Debris
Discharge interval

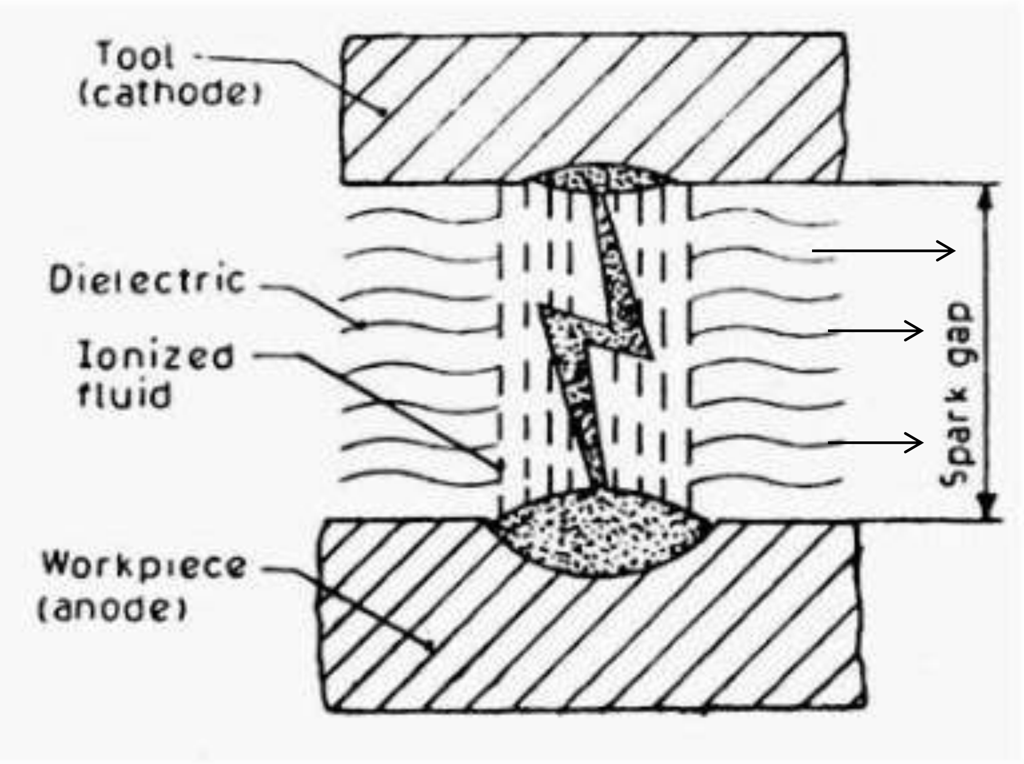


(a)
Electrode
Electrical voltage
V
Spark occurs within an ionized column of dielectric fluid
Dielectric fluid
Workpiece
(b)
Electrode
Vaporized cloud of electrode and workpiece material
SPARK ON
Dielectric fluid
Workpiece
(c)
Electrode
Vaporized cloud suspended in dielectric fluid
Dielectric fluid
SPARK OFF
Workpiece
(d)
Electrode
Vaporized cloud cools in dielectric fluid and forms into a spherical EDM chip
Dielectric fluid
SPARK OFF
Workpiece

Electric Discharge Machining (EDM) - Setup



EDM – Spark generation



EDM – Working principle

- Electrical Discharge Machining (**EDM**) is a controlled process that is used to remove metal with the help of an intensified electric spark.
- Spark is generated when the tool and work piece with high potential difference is separated by a spark gap.
- In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape.

Dielectric fluid

- Dielectric fluids should have

1. Adequate viscosity
2. High flash point
3. High corrosion resistance
4. Good electrical discharge efficiency
5. Low cost and ease of availability

Eg: Hydro carbon oil, Kerosene, Tri ethylene glycol…

Recast layer

- The sparks produced during the EDM process melt the metal's surface, which then undergo ultra rapid quenching.
- The layer formed on the work piece surface after solidification is called recast layer

Pulse Characteristics

- Energy of a pulse:

$$\mathbf{E = VIT}$$

Where, V = Voltage, I = Current, T = Time.

- Energy of pulse with ON/OFF times:

$$\mathbf{E = V_p I_p ((t_{on}/(t_{on} + t_{off}))}$$

Where, V_p & I_p are Voltage and Current of a single pulse, t_{on} = Pulse ON time, t_{off} = Pulse OFF time.

Material Removal Rate (MRR)

$$MRR = \alpha \, \mathbf{V_p I_p \left((t_{on} / (t_{on} + t_{off}) \right)}$$

- Where, α = Material removal constant of the work piece.

Process Parameters of EDM

- Electrode/ Work piece based parameters

1. Diameter of electrode
   - (As diameter of tool increases, peak temperature attained reduces)
2. Material Hardness
   - (As work piece material hardness increases, MRR reduces)
3. Melting point
   - (As melting point of specimen increases, MRR reduces)
4. Thermal diffusivity
   - (As thermal diffusivity of work piece increases, heat energy utilized for ablation reduces which reduces MRR)

Process Parameters of EDM

- Dielectric fluid & flushing based parameters:

1. Specific resistance of the fluid
2. Pressure of fluid
3. Contamination
4. Flow rate
5. Supply method

    i) Internal type (Recommended)

    ii) External type

Process Parameters of EDM

- Processing / Machining Parameters:

1. Voltage applied
2. Polarity
3. T_{on} & T_{off}
4. Spark gap
5. Electrode rotation

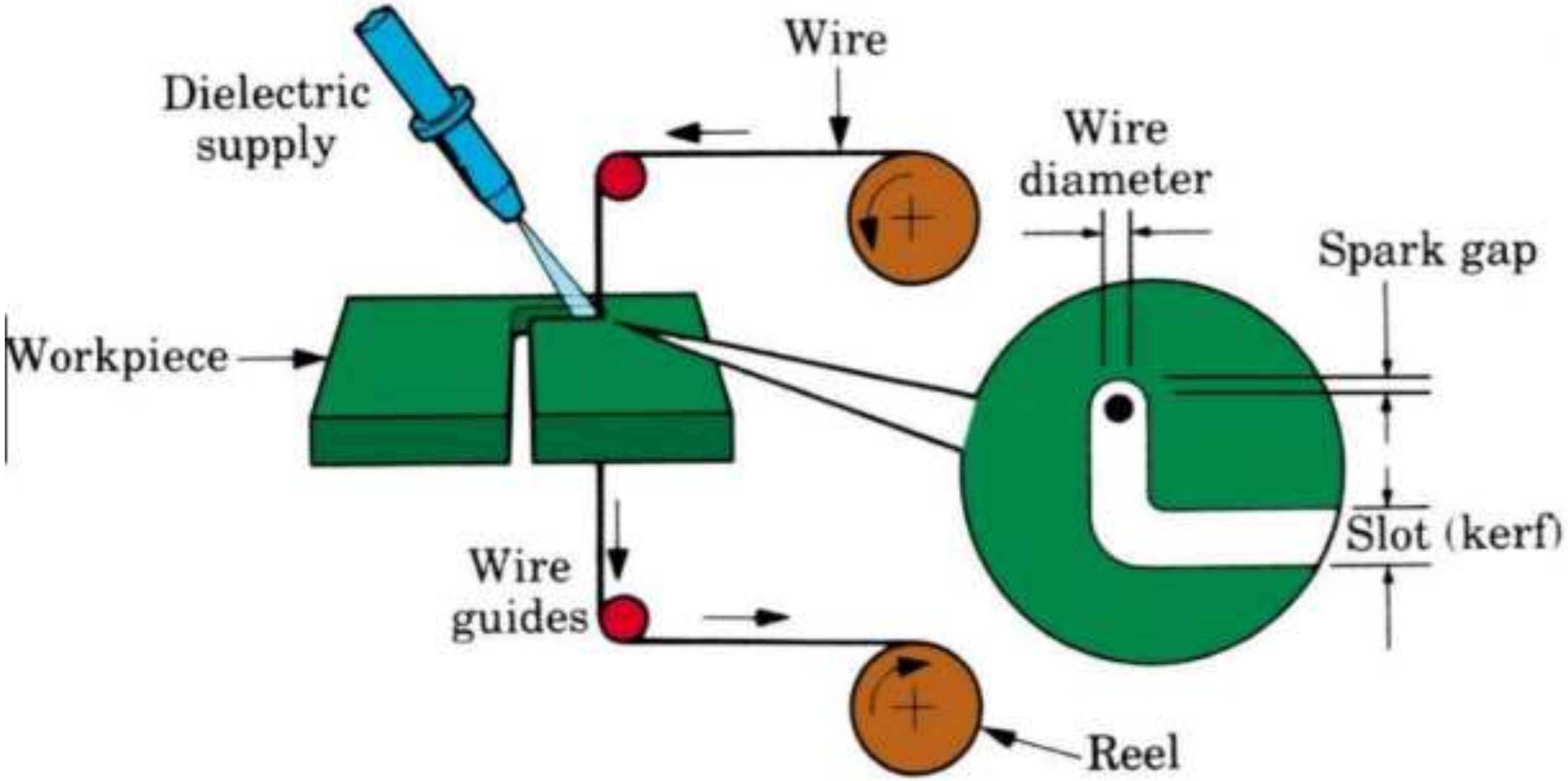
Influence of process parameters

- Negative polarity to work piece increases accuracy & reduces hole over size (HOS)
- HOS increases with increase in voltage.
- Electrode rotation (Max. speed 50 rpm) improves debris removal & accuracy.
- Horizontal spindle configuration improves debris removal.
- Planetary motion of the electrode improves accuracy as it provides extra space for the removal of air bubbles & debris.
- The maximum machined depth is attained when the gap control speed is 0.01 - 0.02 mm/sec.

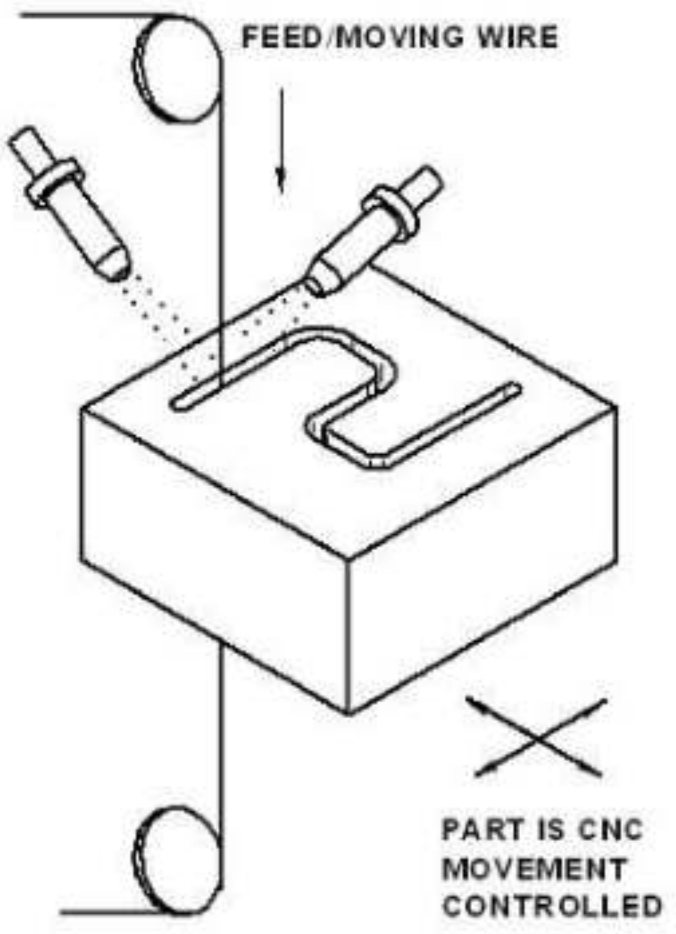
Heat Affected Zone (HAZ) in EDM

- Compared to other non conventional process, EDM produces less damage & HAZ.
- The HAZ of EDM comprises of region of low hardness.
- Grain size & structure of material around the machined spot hardly changes.

Wire EDM


Dielectric supply
Wire
Wire diameter
Spark gap
Workpiece
Slot (kerf)
Wire guides
Reel

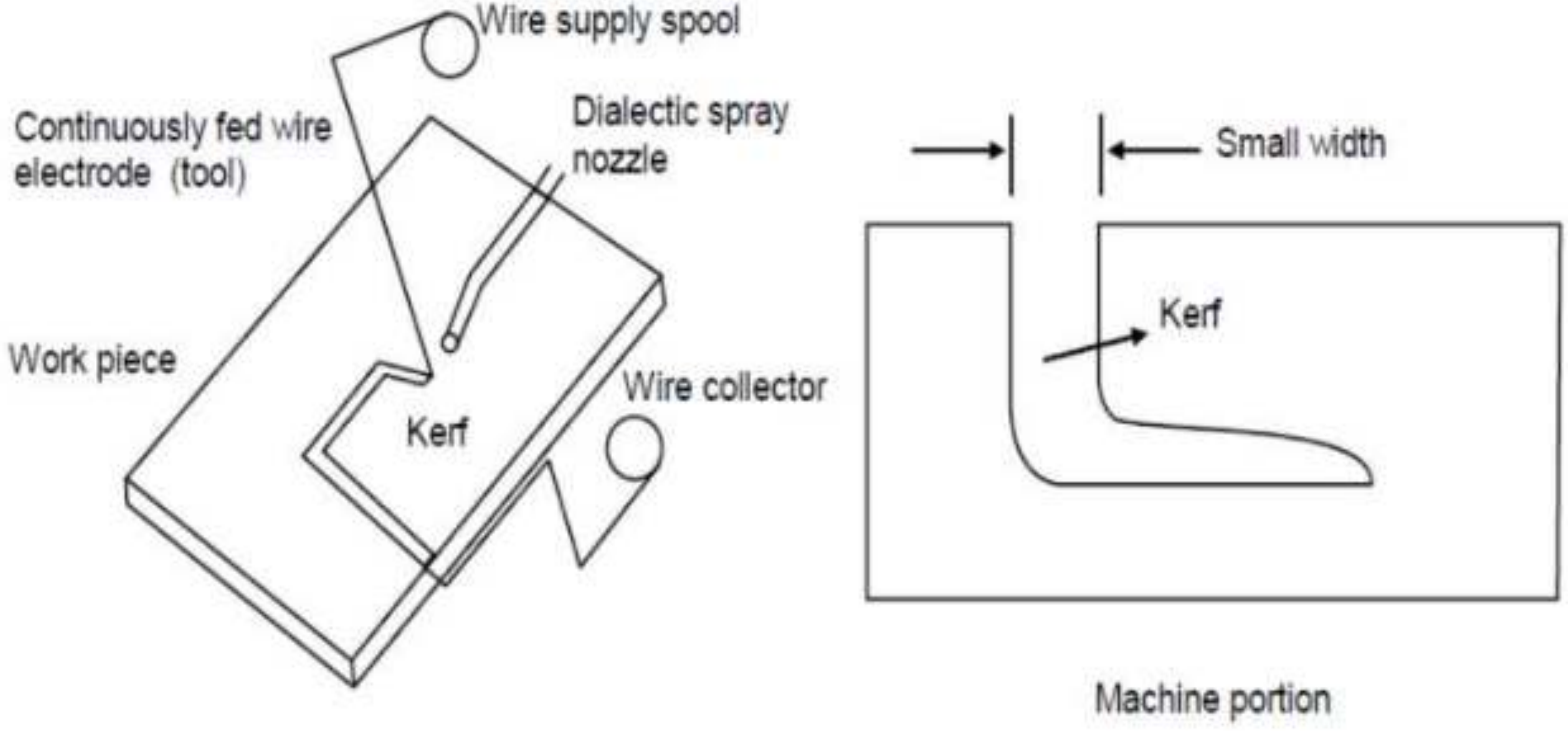
Wire EDM



Applications of EDM

- EDM is used **for making die** for wire drawing, extrusion, heading, forging etc. from **hardened steel** and **stamping tool** with intricate cavities.
- In machining of **exotic materials** that are used in aerospace and automatic industries.
- For making **fragile parts** which cannot take the stress of machining.
- **Deep cavities**, **slots** and **ribs** can be easily made by EDM for collets, jet engine blade slots,
- Micro-EDM process can successfully produce **micro-pins, micro-nozzles and micro-cavities**.

Wire Cut Electric Discharge Machining (WCEDM)



Wire Cut Electric Discharge Machining (WCEDM)

- This is a special type of electric discharge machining that uses a small diameter wire as a cutting tool on the work.
- Working principle of wire cut electric discharge machining is same as that of electric discharge machining.
- The tool used in WCEDM process is a small diameter wire as the electrode to cut narrow kerf in the workpiece.
- During the process of cutting the wire is continuously advanced between a supply spoil and wire collector.
- This continuous feeding of wire makes the machined geometry insensitive to distortion of tool due to its erosion.
- Material of wire can be brass, copper, tungsten or any other suitable material to make EDM tool.
- Normally, wire diameter ranges from 0.076 to 0.30 mm depending upon the width of kerf.

- Two type of movements are generally given to the total (wire).
- One is continuous feed from wire supply spoal to wire collector.
- Other is movement of the whole wire feeding system, and wire along the kerf to be cut into the workpiece.
- Both movements are accomplished with ultra accuracy and pre-determined speed with the help of numerical control mechanism.
- Dielectric fluid and spray mechanism:-
- Like EDM process dielectric fluid is continuously sprayed to the machining zone. This fluid is applied by nozzles directed at the tool work interface or workpiece is submerged in the dielectric fluid container.
- Rest of the process details in case of WCEDM process are same as that in case of EDM process.

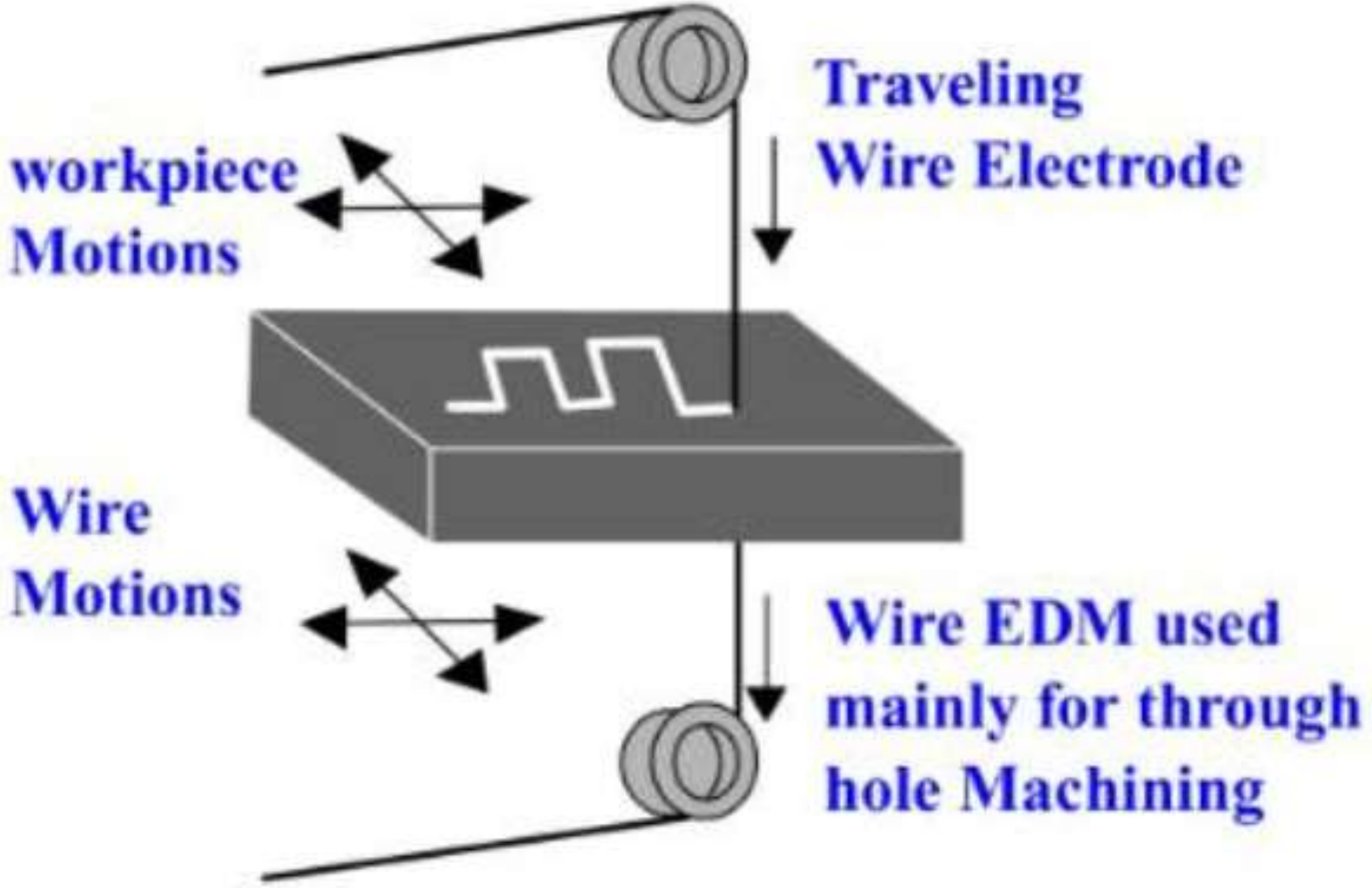
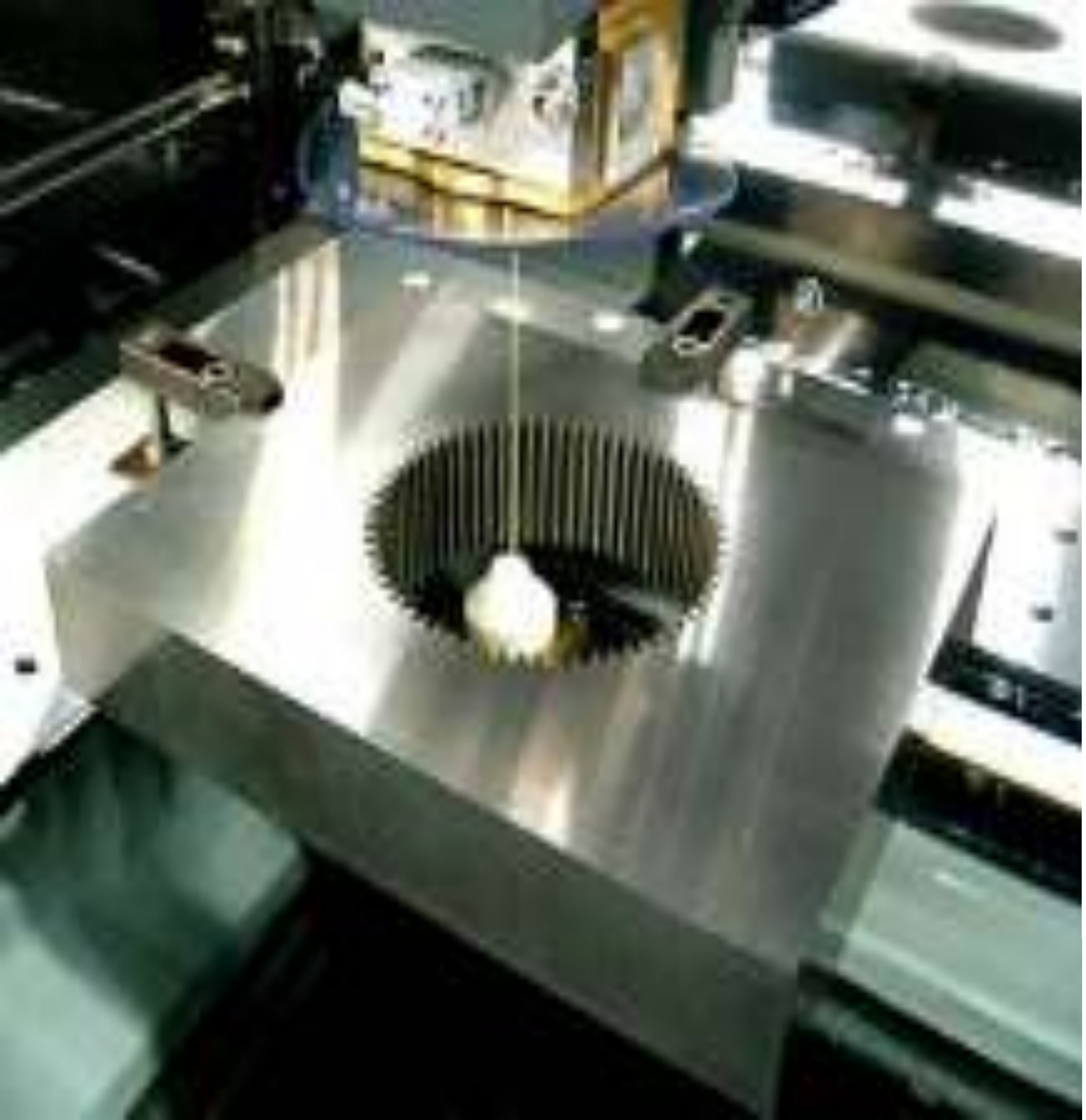
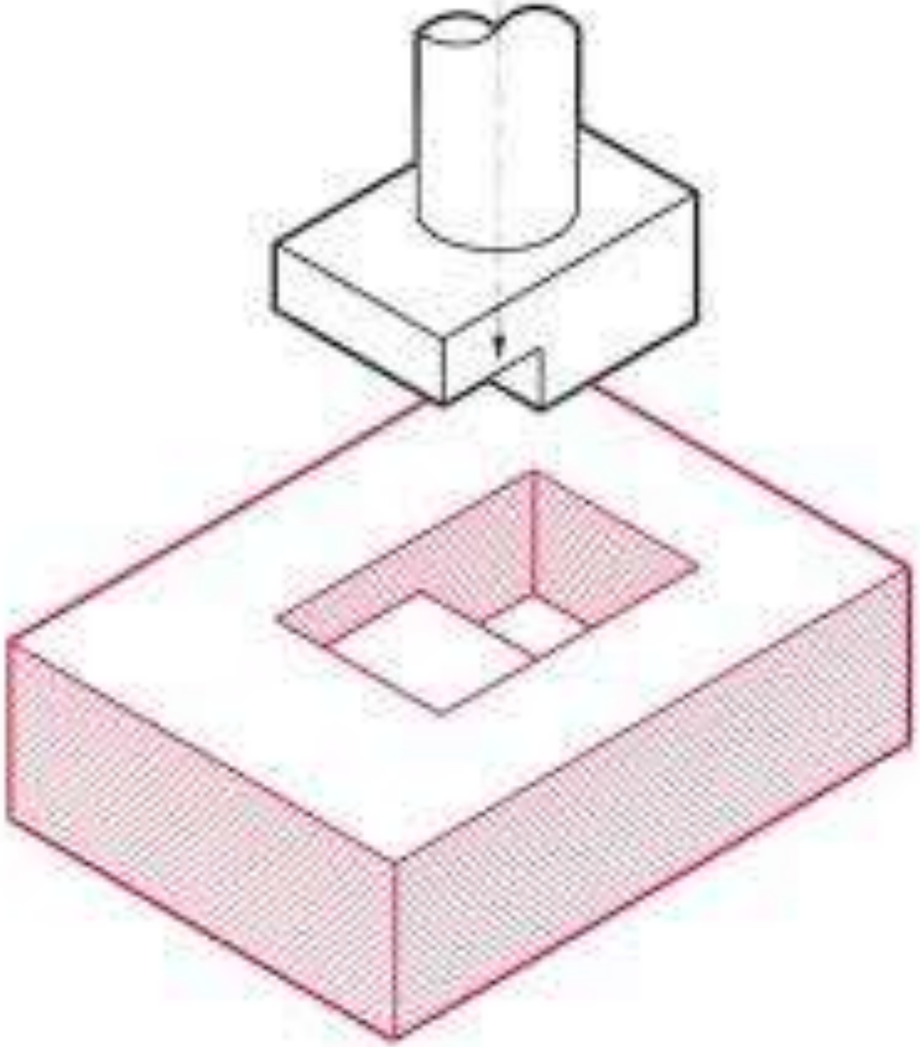


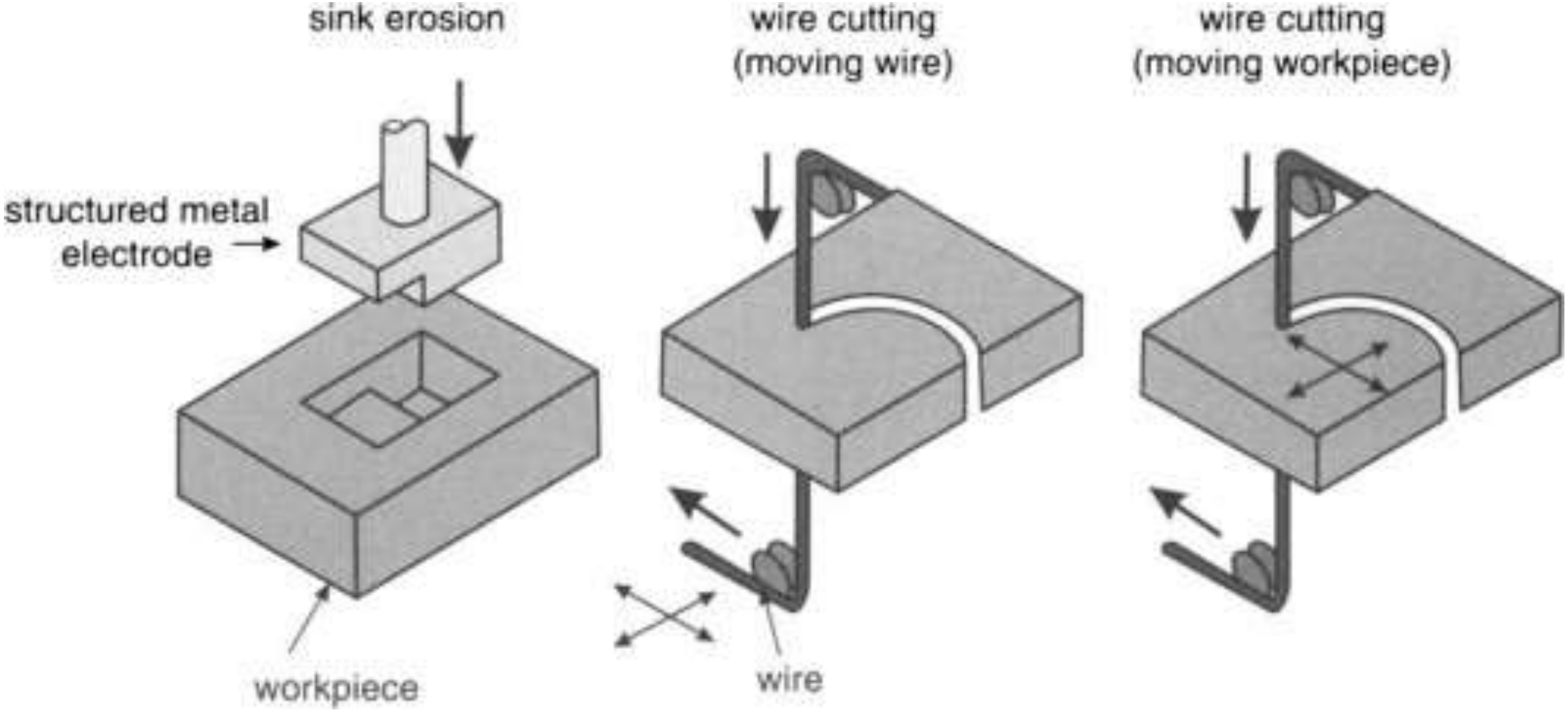
Fig. Schematic of Wire-Cut EDM Process

Applications of Wire-Cut EDM

The process is used in the following areas:

- Aerospace, medical, electronics and semiconductor applications
- Tool & die making industries.
- For cutting the hard extrusion dies
- In making fixtures, gauges & cams
- Cutting of gears, strippers, punches and dies
- manufacturing hard electrodes.
- Manufacturing micro-tooling for micro-edm, micro-usm and such other micro-machining applications


sink erosion
wire cutting
(moving wire)
wire cutting
(moving workpiece)
structured metal
electrode
workpiece
wire

Water Jet Machining

Water Jet Machining

- Water jet machining (WJM) is an advanced manufacturing, non-conventional machining process wherein a high-velocity jet of water strikes the workpiece and causes its machining by erosion of the workpiece material.
- In the WJM process, the pressure of the water coming out of the nozzle is in the range of 60,000 psi or 4136.85 bar.
- This means that the pressure is almost 4000 times the normal atmospheric pressure (1 bar).
- The simple water jet machining process is unable to machine hard materials. It can only be used for softer materials like rubber, ABS, leather, wood, plastics, etc.
- So in order to machine hard materials like aluminum, steels, granite, cast iron, etc abrasive particles are mixed with the jet of water to increase the machining capability of the water jet machining process.
- This process is similar to Ultrasonic machining and Abrasive jet machining which cause the machining of the workpiece by mechanical means. This machining process is paired a with CNC machine for precise and automated control.

Working principle of WJM

- The water jet machining process works on the principle that when a high-velocity jet of water strikes the workpiece, machining of the workpiece takes place by erosion of the workpiece material.

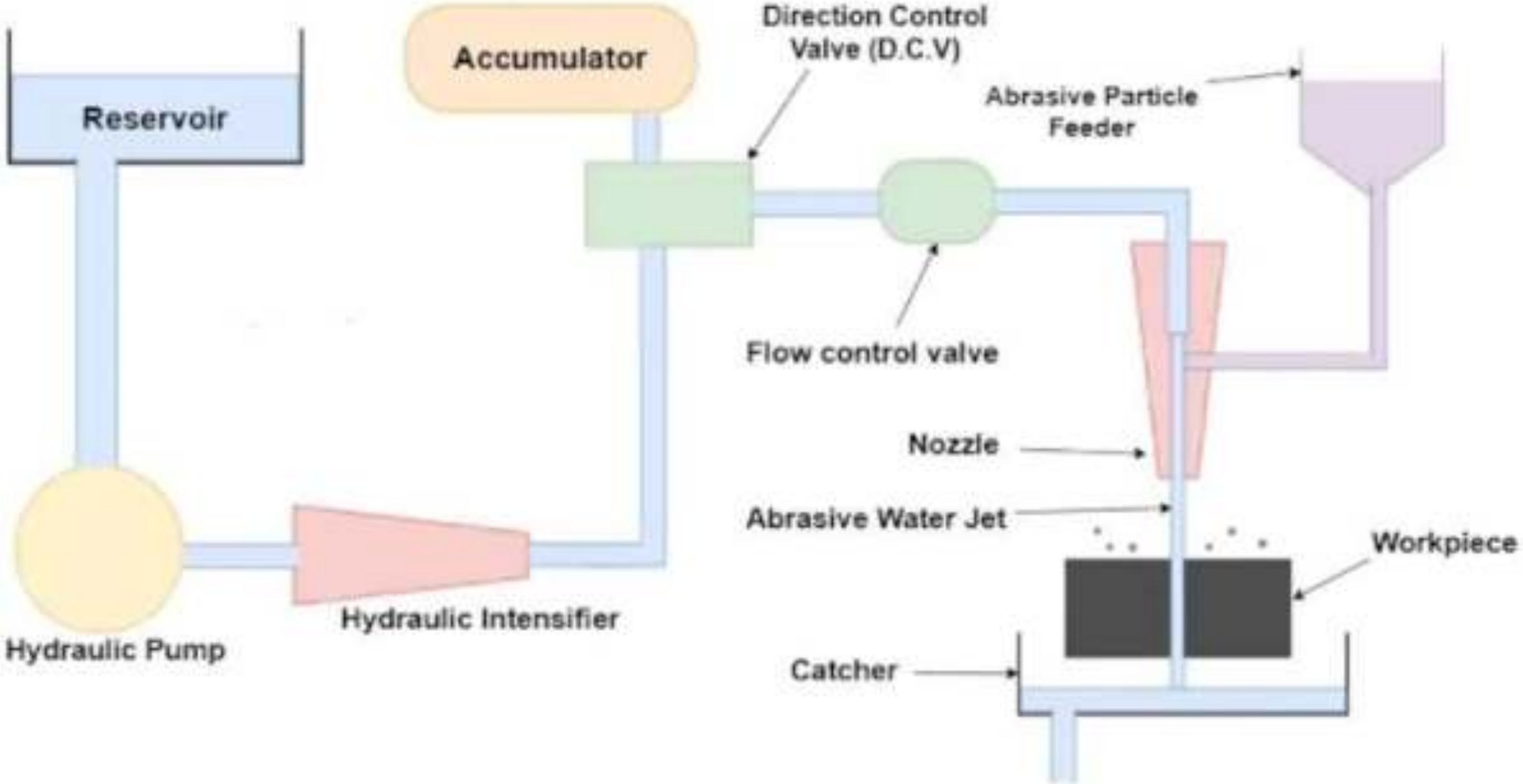
- The construction and working of the simple water jet machine are almost similar to its abrasive counterpart. So, let us look at the construction and working of the abrasive jet machine.

Construction of Water jet machine

The following are the main parts of the water jet machining process:

- Water reservoir
- Hydraulic pump
- Hydraulic intensifier
- Accumulator
- Direction control valve
- Flow control valve
- Mixing chamber
- Nozzle
- Abrasive particle feeder
- Catcher

Construction of Water jet machine



Water reservoir

- The water reservoir is used to store the water to be used in the water jet machining process.

Hydraulic pump

- A pump is responsible for the circulation of water and is used to raise the pressure of the water from atmospheric pressure to around 5 bar before being sent to the hydraulic intensifier.

Hydraulic intensifier

- This is the device responsible for creating the enormous amount of pressure that can cut through metals.
- The hydraulic intensifier receives the pressurized water from the pump at around 5 bar and increases it to around 4000 bar or roughly 60,000 psi.

Accumulator

- The high-pressure water is stored in the accumulator and supplies to the nozzle when required. The accumulator also prevents fluctuation of water supply during the process.
- The accumulator of the water jet machining relies on the property of "**compressibility of water**" so that a uniform discharge pressure is maintained.

Direction Control valve

- As the name suggests, the direction control valve is used to control the direction of water and hence control the water jet machining process.

Flow control valve

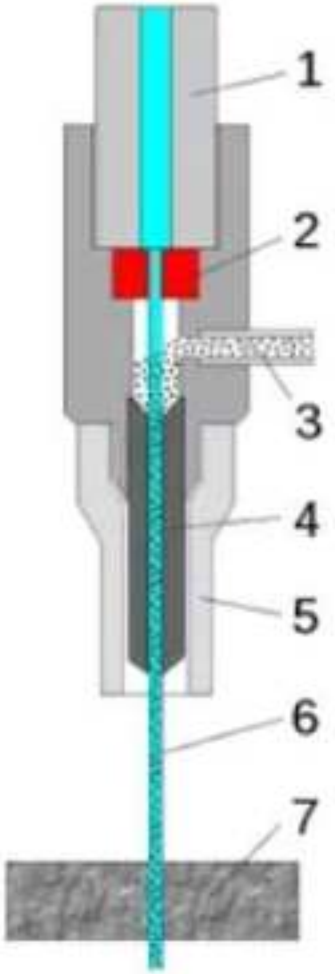
- After the direction control valve, the flow control valve is placed and is used to control the flow or speed of the water coming out of the nozzle.

Mixing chamber

- It is the place where the abrasive particles are mixed with the stream of water.

Nozzle

- The nozzle is a device of reducing cross-section whose function is to increase the kinetic energy of the water by converting the pressure energy in it into kinetic energy.
- The nozzle increases the speed of water to supersonic speeds. Hard materials like diamond or tungsten carbide in order to prevent the erosion of the nozzle itself by the jet of water.



1: HIGH-PRESSURE WATER JET.

2: HARD MATERIAL (RUBY OR DIAMOND).

3: ABRASIVE PARTICLE (GARNET).

4: MIXING TUBE.

5: GUARD.

6: CUTTING WATER JET.

7: WORKPIECE

- This is a detailed figure of the nozzle that shows the mixing of the abrasive particles with the water jet. Here, the parts shown in the figure are:

Abrasive particle feeder

- It is a hopper from where the abrasive particles are fed into. The abrasive particle feeder provides a continuous flow of abrasive particles to the stream of water.
- Materials like silicon carbide, sand, aluminum oxide, etc are used as abrasives in water jet machining.

Catcher

- The jet of water after being used is collected by the catcher, from where it can be reused again after proper filtration and treatment.

Working of Water jet machining

- The hydraulic pump receives water from the reservoir at atmospheric pressure and increases it to about 4-5 bar.
- This water is then sent to the hydraulic intensifier which greatly increases the water pressure up to 4000 bar.
- The pressurized water is then sent to the accumulator whereas a part of it is supplied to the nozzle via the control valves.
- The accumulator stores the water and supplies it when needed.
- The flow control valve is used to control the amount of water reaching the nozzle.

- This water is then passed through the nozzle and the mixing chamber where a supersonic jet of water along with abrasive particles is created.
- This jet of water then strikes the workpiece and due to the abrasive action and high-speed jet, the workpiece is machined.
- The water is then collected by the catcher from where it can be reused again or disposed of safely.   This is how the water jet machining process works.

Materials that can be machined using Water jet machining

- Aluminum
- Steels
- Cast Iron
- Concrete
- Stones
- Granite
- Metal alloys

- WOOD
- LEATHER
- CERAMICS
- PLASTICS
- RUBBER
- GLASS
- COMPOSITES ETC.

Applications of Water Jet machining

- Water jet machining is used in manufacturing aerospace components.
- Manufacturing of engine components.
- It is used to machine thick sheets of steel, aluminum, etc.
- It is used for drilling and cutting operations.
- Materials that are hard to machine using conventional processes.

Advantages of Water Jet machining

- High precision can be achieved in water jet machining.
- There is no need for coolant while machining.
- Complex shapes and cuts can be produced.
- A good surface finish can be obtained.
- Machined parts are dust-free as they are washed by the water jet.
- It is eco-friendly as no harmful by-products are produced.

Disadvantages of Water Jet machining

- Very thick materials cannot be machined using water jet machining.
- High initial investment is required.
- The time required is much more when compared to traditional processes.

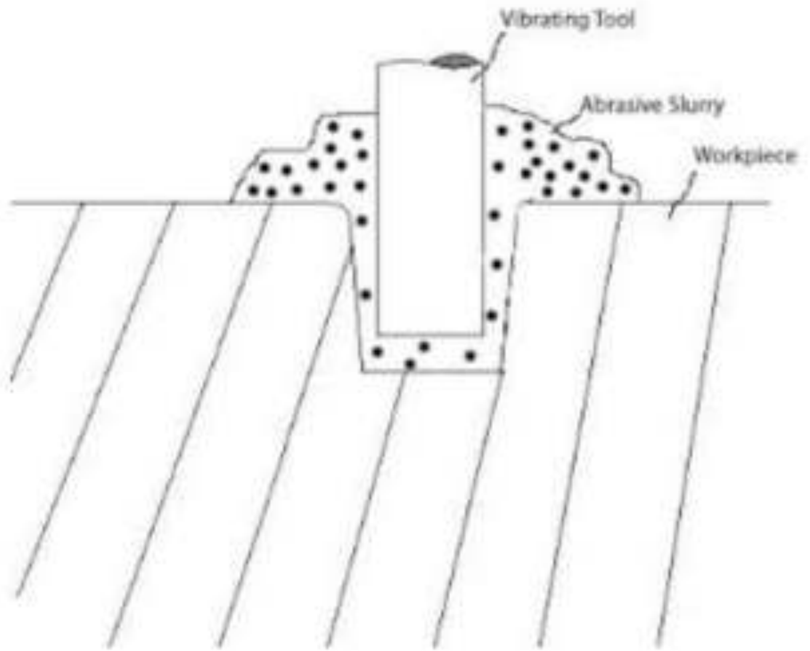
Ultrasonic Machining (USM)

Ultrasonic Machining (USM)

- Ultrasonic machining (USM) also called as ultrasonic vibration machining is a machining process in which material is removed from the surface of a part by low amplitude and high frequency vibration of a tool against surface of material in the presence of abrasive particles.
- The motion of the tool takes place vertically or orthogonal to the surface of the part. The tool travel with an amplitude of 0.05 mm to 0.125 mm (0.002 in to 0.005 in).
- The slurry is formed by mixing fine abrasive grains in the water. This slurry is made to flow across the w/p and the tip of the tool during machining process. The abrasive gain particles in the slurry helps in the removal of the material form the surface of the w/p. The grain sizes of the abrasive material are typically ranges from 100 to 1000. The smaller grains (i.e. higher number of grain) results in smooth surface finishes.
- This machining process is usually used to machine brittle materials and materials that have high hardness.

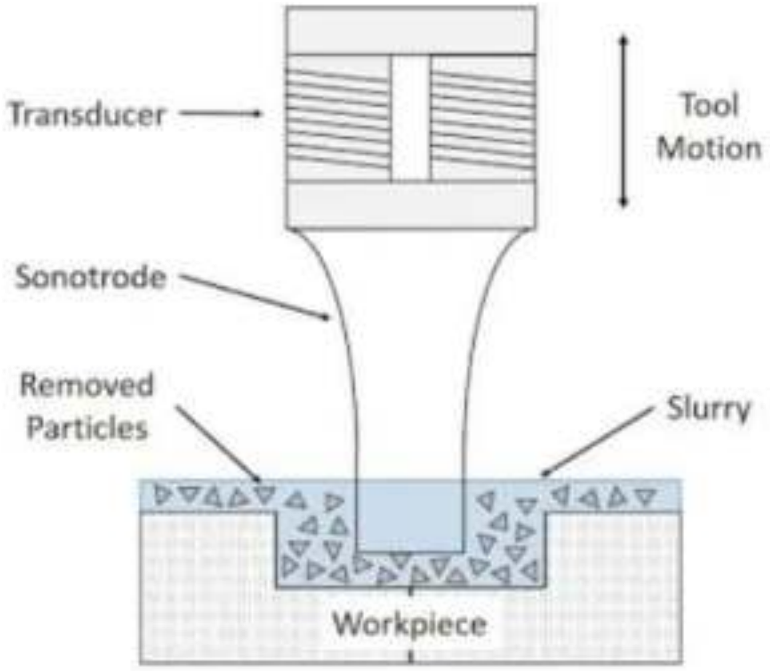
Working Principle of Ultrasonic Machining

- An electric current at high frequency (in the ultrasonic range i.E. 18 khz to 40 khz) is used to generate mechanical vibration of low amplitude and high frequency. The mechanical vibration generated is used for machining the surface of a part in the presence of abrasive grain particles in the form of slurry. The slurry flows across the tool and workpiece. When the tool presses against the w/p, the slurry containing abrasive particle chips off the materials from the surface.



Main parts

- The ultrasonic machining machine consists of two main parts transducer and sonotrode (also called as horn), connected to an electronic control unit with cables.



1. Transducer:

- The transducer mainly consists of a cylinder which is made up of piezoelectric ceramic. It converts electrical energy into mechanical vibration. Transducer then vibrates sonotrode at low amplitude and high frequency.

2. Sonotrode:

- It is made of low carbon steel. One end of it is connected with the transducer and other end contains tool. The sonotrode vibrates at low amplitude and high frequency and removes material from the w/p by abrasion where it contacts it.

3. Control Unit:

- The control unit consists of an electronic oscillator which produces an alternating current at high frequency. The frequency produced is usually in between 18 khz to 40 khz in ultrasonic range.

Working Of Ultrasonic Machining Process

- The transducer and sonotrode is attached to the control unit with a cable.
- The control unit has an electronic oscillator that produces an alternating current with high ultrasonic frequency ranges in between 18 khz to 40 khz.
- This high frequency alternating current is supplied to the transducer. The transducer converts this alternating current into mechanical vibration and transmits this mechanical vibration to the sonotrode attached to it.
- The sonotrode is vibrated by the transducer with low amplitude and high frequency. When this vibrating sonotrode strikes the surface of the w/p, it removes the material form it. The slurry flows in between the tool and workpiece and helps in the removal of the material from the surface.
- The slurry used in the ultrasonic machining contains 20 % to 60% of water by volume, aluminum oxide, boron carbide and silicon carbide particles.
- This is how ultrasonic machining works.

Advantages

- This machining method is capable of machining brittle and hard material with high precision.
- It can machine fragile materials such glass and non-conductive metals which are not machined by non-traditional methods such as electrochemical machining or electrical discharge machining.
- It is capable of producing high tolerance parts.
- There is no distortion produced in the worked material. And this is because, no heat is generated by the sonotrode against the w/p.
- There is no change observed in the physical properties of the material.
- The machined parts produced require fewer finishing process because of absence of burrs in the process.

Disadvantages

- The metal removal is slow due to micro chipping or erosion mechanism.
- The wear of sonotrode tip occurs more quickly.
- The machining of deep holes is not easy by this method because of the inability of abrasive slurry to flow at the bottom of the hole (except rotary ultrasonic machining).
- Ultrasonic vibration machining can be used only to machine materials that have hardness value atleast 45 hrc (hrc: rockwell scale to measure hardness of a material).

Application

- It is commonly used to machine brittle and hard materials. Glass, carbides, ceramics, precious stones and hardened steels are the most common materials machined by USM.
- It is very precise machining method and used in the creation of micro-electrochemical system components like micro-structured glass wafers.

Thank YOU