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PRODUCTION TECHNOLOGY MATERIAL

MATERIAL BY KUNALSINH KATHIA
M.E MACHINE DESIGN (HJDITER)

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Cutting Fluids & Tool Wear

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Basic methods of controlling cutting temperature

- It is already realized that the cutting temperature, particularly when it is quite high, is very detrimental for both cutting tools and the machined jobs and hence need to be controlled, i.e., reduced as far as possible without sacrificing productivity and product quality.
- The methods generally employed for controlling machining temperature and its detrimental effects are :
- **Proper selection of cutting tools; material and geometry .**
- **Proper selection of cutting velocity and feed .**
- **Proper selection and application of cutting fluid .**

Selection of material and geometry of cutting tool for reducing cutting temperature and its effects

- Cutting tool material may play significant role on reduction of cutting temperature depending upon the work material.
- PVD or CVD coating of HSS and carbide tools enables reduce cutting temperature by reducing friction at the chip-tool and work-tool interfaces.
- In high speed machining of steels lesser heat and cutting temperature develop if machined by CBN tools which produce lesser cutting forces by retaining its sharp geometry for its extreme hardness and high chemical stability.
- The cutting tool temperature of ceramic tools decrease further if the thermal conductivity of such tools is enhanced (by adding thermally conductive materials like metals, carbides, etc in Al_2O_3)

Selection of material and geometry of cutting tool for reducing cutting temperature and its effects

- Cutting temperature can be sizably controlled also by proper selection of the tool geometry in the following ways.
- large positive tool–rake helps in reducing heat and temperature
- generation by reducing the cutting forces, but too much increase in rake mechanically and thermally weakens the cutting edges.
- compound r10:40:03 AMake, preferably with chip–breaker, also enables reduce heat and temperature through reduction in cutting forces and friction
- even for same amount of heat generation, the cutting temperature decreases with the decrease in the principal cutting edge angle, φ as

$$\theta_C \; \alpha \; [V_C^{0.5} (s_o \sin\phi)^{0.25}]$$

- nose radiusing of single point tools not only improves surface finish but also helps in reducing cutting temperature to some extent.

Selection of material and geometry of cutting tool for reducing cutting temperature and its effects

- Selection of cutting velocity and feed:
- Cutting temperature can also be controlled to some extent, even without sacrificing MRR, by proper or optimum selection of the cutting velocity and feed within their feasible ranges.
- The rate of heat generation and hence cutting temperature are governed by the amount of cutting power consumption, Pc where;

$$P_C = P_Z . V_C = t s_o \tau_s f V_C$$

- So apparently, increase in both so and Vc raise heat generation proportionately.
- But increase in VC, though further enhances heat generation by faster rubbing action, substantially reduces cutting forces, hence heat generation by reducing τs and also the form factor f. The overall relative effects of variation of Vc and soon cutting temperature will depend upon other machining conditions. Hence, depending upon the situation, the cutting temperature can be controlled significantly by optimum combination of Vc and so for a given MRR.

Selection of material and geometry of cutting tool for reducing cutting temperature and its effects

- Control of cutting temperature by application of cutting fluid:
- Cutting fluid, if employed, 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 .

Purposes of application of cutting fluid in machining and grinding.

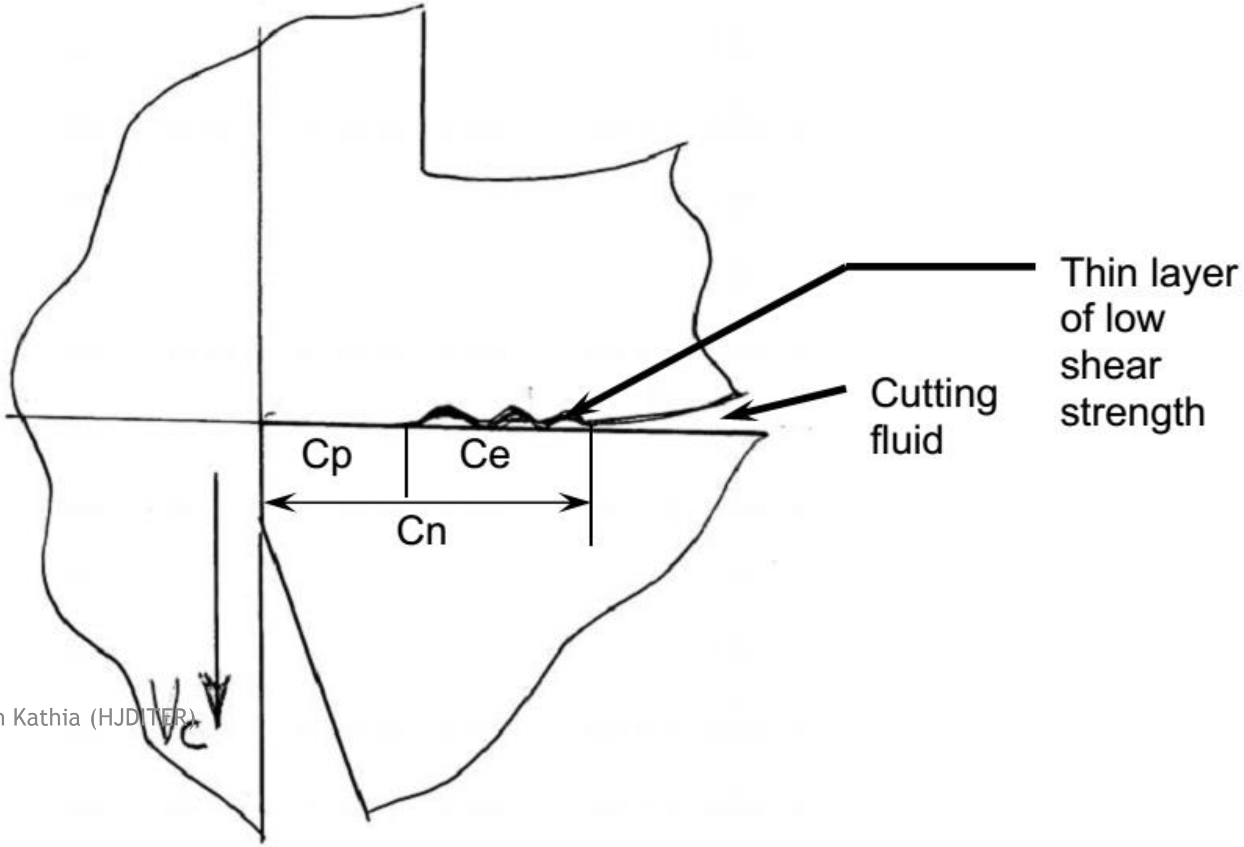
- The basic purposes of cutting fluid application are :
- • Cooling of the job and the tool to reduce the detrimental effects of cutting temperature on the job and the tool
- • Lubrication at the chip–tool interface and the tool flanks to reduce cutting forces and friction and thus the amount of heat generation.
- • 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
- • 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, H_2S, N_xO_y present in the atmosphere.
- However, 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

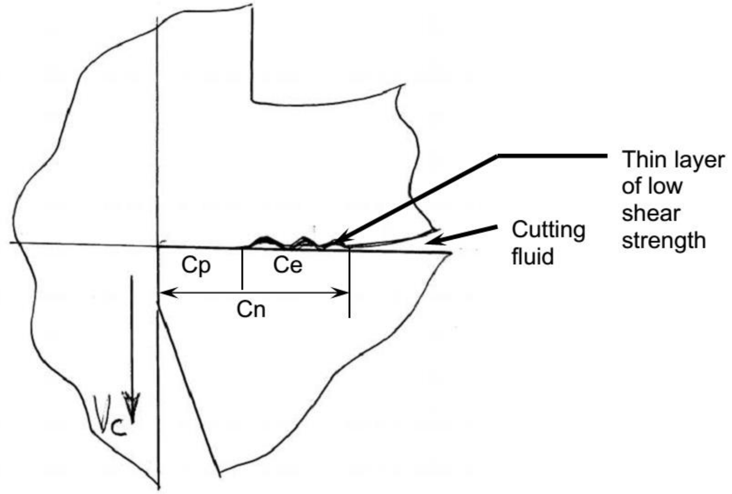
- To enable the cutting fluid fulfil its functional requirements without harming the Machine – Fixture – Tool – Work (M-F-T-W) system and the operators, the cutting fluid should possess the following properties:
- o **For cooling :**
- • high specific heat, thermal conductivity and film coefficient for heat transfer
- • spreading and wetting ability
- o **For lubrication :**
- • high lubricity without gumming and foaming
- • wetting and spreading
- • high film boiling point
- • friction reduction at extreme pressure (EP) and temperature
- o **Chemical stability, non-corrosive to the materials of the M-F-T-W system**
- o **less volatile and high flash point**
- o **high resistance to bacterial growth**
- o **odorless and also preferably colorless**
- o **non toxic in both liquid and gaseous stage**
- o **easily available and low cost.**

Principles of cutting fluid action

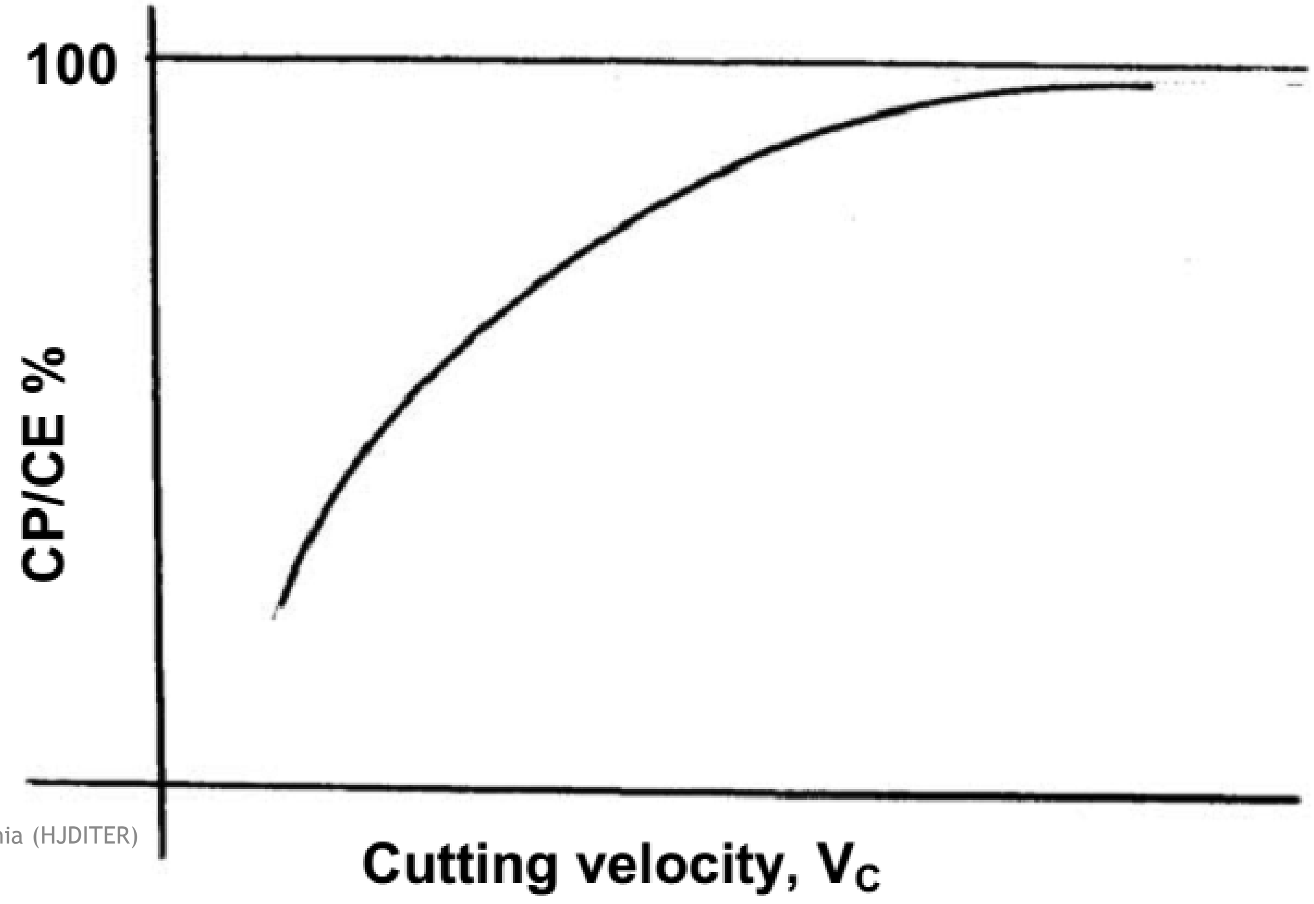
- The chip-tool contact zone is usually comprised of two parts; plastic or bulk contact zone and elastic contact zone as indicated in Fig.



- The cutting fluid cannot penetrate or reach the plastic contact zone but enters in the elastic contact zone by capillary effect.
- With the increase in cutting velocity, the fraction of plastic contact zone gradually increases and covers almost the entire chip-tool contact zone as indicated in Fig.(next slide)
- Therefore, at high speed machining, the cutting fluid becomes unable to lubricate and cools the tool and the job only by bulk external cooling

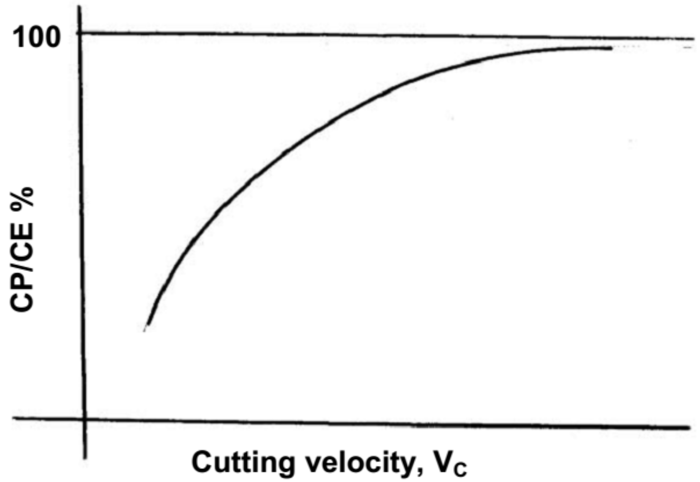


Plastic and elastic contact zone with increase in cutting velocity



Cont…..

- The chemicals like chloride, phosphate or sulphide present in the cutting fluid chemically reacts with the work material at the chip undersurface under high pressure and temperature and forms a thin layer of the reaction product.
- The low shear strength of that reaction layer helps in reducing friction.
- To form such solid lubricating layer under high pressure and temperature some extreme pressure additive (EPA) is deliberately added in reasonable amount in the mineral oil or soluble oil.
- For extreme pressure, chloride, phosphate or sulphide type EPA is used depending upon the working temperature.



Types of cutting fluids and their application

- The cutting fluids, which are commonly used, are:
  - Air blast or compressed air only.
  - Water.
  - Soluble oil
  - Cutting oils
  - Chemical fluids
  - Solid or semi-solid lubricant
  - Cryogenic cutting fluid

Air blast or compressed air only:

- Machining of some materials like grey cast iron become inconvenient or difficult if any cutting fluid is employed in liquid form.
- In such case only air blast is recommended for cooling and cleaning .

Water

- For its good wetting and spreading properties and very high specific heat.
- water is considered as the best coolant and hence employed where cooling is most urgent.

Soluble oil

- Water acts as the best coolant but does not lubricate.
- Besides, use of only water may impair the machine-fixture-tool-work system by rusting.
- So oil containing some emulsifying agent and additive, together called cutting compound, is mixed with water in a suitable ratio (1 ~ 2 in 20 ~ 50).
- This milk like white emulsion, called soluble oil, is very common and widely used in machining and grinding.

Cutting oils

- Cutting oils are generally compounds of mineral oil to which are added desired type and amount of vegetable, animal or marine oils for improving spreading, wetting and lubricating properties.
- As and when required some EP additive is also mixed to reduce friction and adhesion formation in heavy cuts.

Chemical fluids

- These are occasionally used fluids which are water based where some organic and or inorganic materials are dissolved in water to enable desired cutting fluid action.
- There are two types of such cutting fluid;
  - Chemically inactive type – high cooling, anti-rusting and wetting but less lubricating
  - Active (surface) type – moderate cooling and lubricating.

Solid or semi-solid lubricant

- Paste, waxes, soaps, graphite, Moly-di-sulphide (MoS_2) may also often be used,
- either applied directly to the work piece or as an extra agent in the tool to reduce friction and thus cutting forces, temperature and tool wear.

Cryogenic cutting fluid

- Extremely cold (cryogenic) fluids (often in the form of gases) like liquid CO_2 or N_2 are used in some special cases for effective cooling without creating much environmental pollution and health hazards.

Methods of application of cutting fluid

- The effectiveness and expense of cutting fluid application significantly depend also on how it is applied in respect of flow rate and direction of application.
- In machining, depending upon the requirement and facilities available, cutting fluids are generally employed in the following ways (flow).

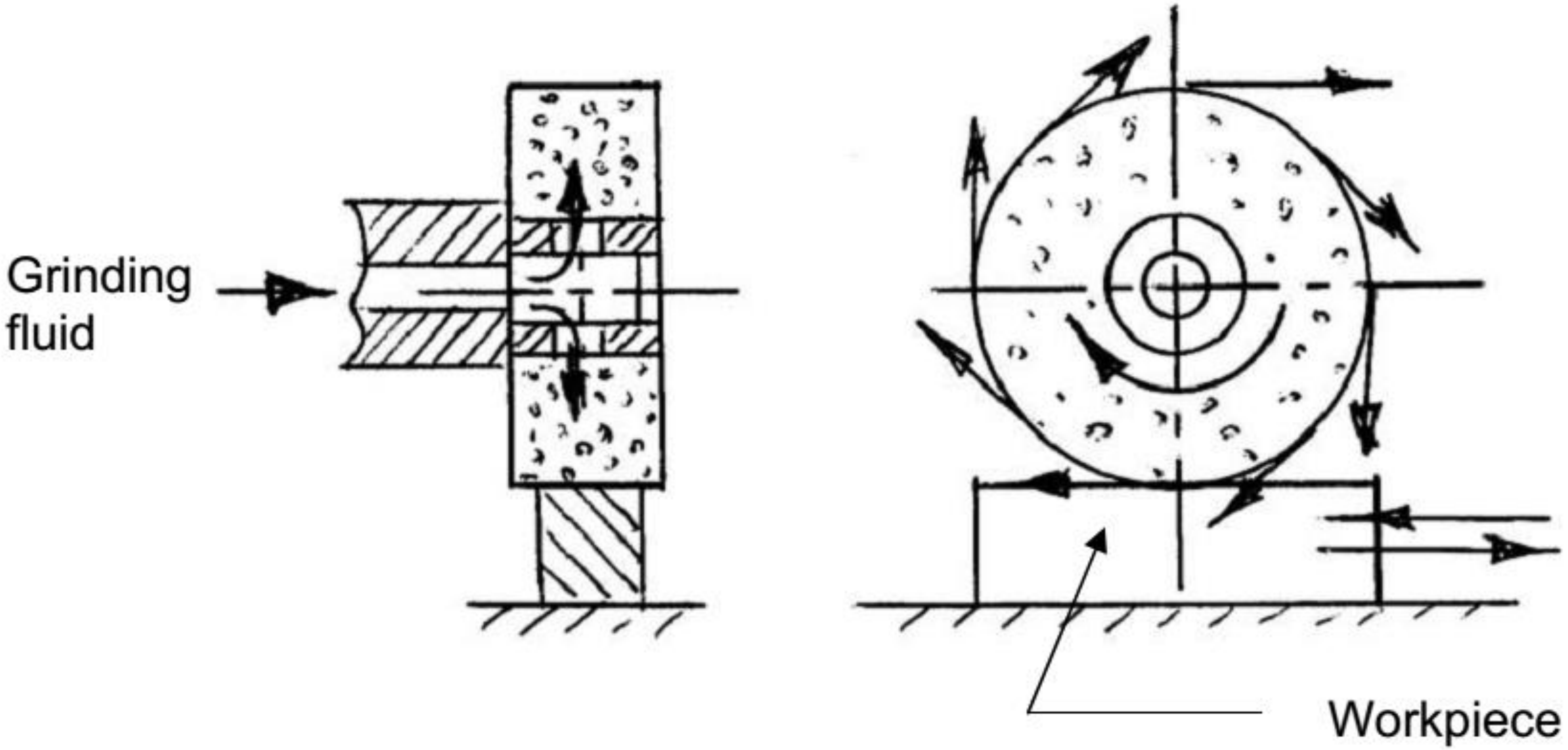
Methods of application of cutting fluid

- Drop-by-drop under gravity
- Flood under gravity
- In the form of liquid jet(s)
- Mist (atomized oil) with compressed air
- Z-Z method – centrifugal through the grinding wheels (pores) as indicated in Fig.

Z-Z method

- The direction of application also significantly governs the effectiveness of the
- cutting fluid in respect of reaching near the chip-tool and work-tool interfaces.
- Depending upon the requirement and accessibility the cutting fluid is applied from top or side(s).
- in operations like deep hole drilling the pressurized fluid is often sent through the axial or inner spiral hole(s) of the drill.
- For effective cooling and lubrication in high speed machining of ductile metals having wide and plastic chip-tool contact, cutting fluid may be pushed at high pressure to the chip-tool interface through hole(s) in the cutting tool.

Z-Z method



Cutting tool failure & tool life

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Failure of cutting tools

- Smooth, safe and economic machining necessitate
  - prevention of premature and catastrophic failure of the cutting tools
  - reduction of rate of wear of tool to prolong its life
- To accomplish the a foresaid objectives one should first know why and how the cutting tools fail.
- Cutting tools generally fail by :
- Mechanical breakage due to excessive forces and shocks. Such kind of tool failure is random and catastrophic in nature and hence are extremely detrimental.
- Quick dulling by plastic deformation due to intensive stresses and temperature. This type of failure also occurs rapidly and are quite detrimental and unwanted
- Gradual wear of the cutting tool at its flanks and rake surface.

- The first two modes of tool failure are veryharmful 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.
- The cutting tool is withdrawn immediately after it fails or, if possible, just before it totally fails.
- For that one must understand that the tool has failed or is going to fail shortly.

Conditions

- It is understood or considered that the tool has failed or about to fail by one or more of the following conditions :
- (a) In R&D laboratories
- • total breakage of the tool or tool tip(s)
- • massive fracture at the cutting edge(s)
- • excessive increase in cutting forces and/or vibration
- • average wear (flank or crater) reaches its specified limit(s)
- (b) In machining industries
- • excessive (beyond limit) current or power consumption
- • excessive vibration and/or abnormal sound (chatter)
- • total breakage of the tool
- • dimensional deviation beyond tolerance
- • rapid worsening of surface finish
- • adverse chip formation.

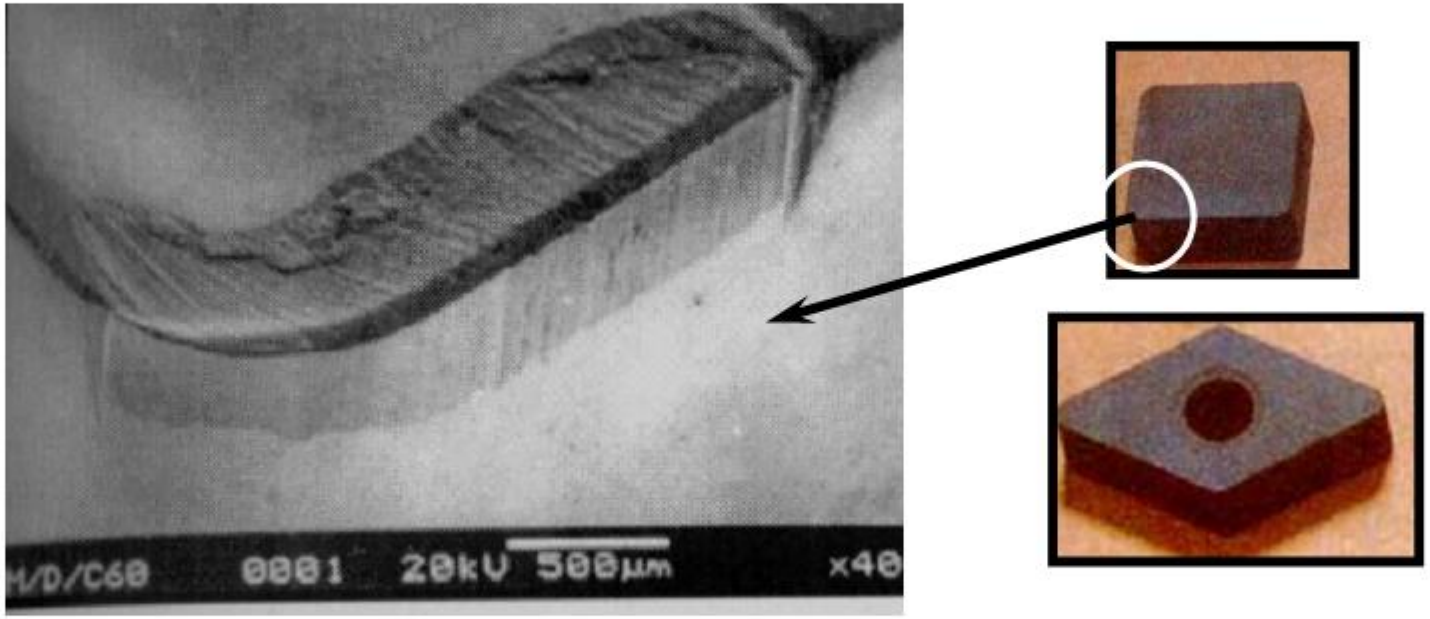
Mechanisms and pattern (geometry) of cutting tool wear

- For the purpose of controlling tool wear one must understand the various mechanisms of wear, that the cutting tool undergoes under different conditions.
- The common mechanisms of cutting tool wear are :
- i) Mechanical wear
- • thermally insensitive type; like abrasion, chipping and delamination
- • thermally sensitive type; like adhesion, fracturing, flaking etc.
- ii) Thermochemical wear
- • macro-diffusion by mass dissolution
- • micro-diffusion by atomic migration
- iii) Chemical wear
- iv) Galvanic wear

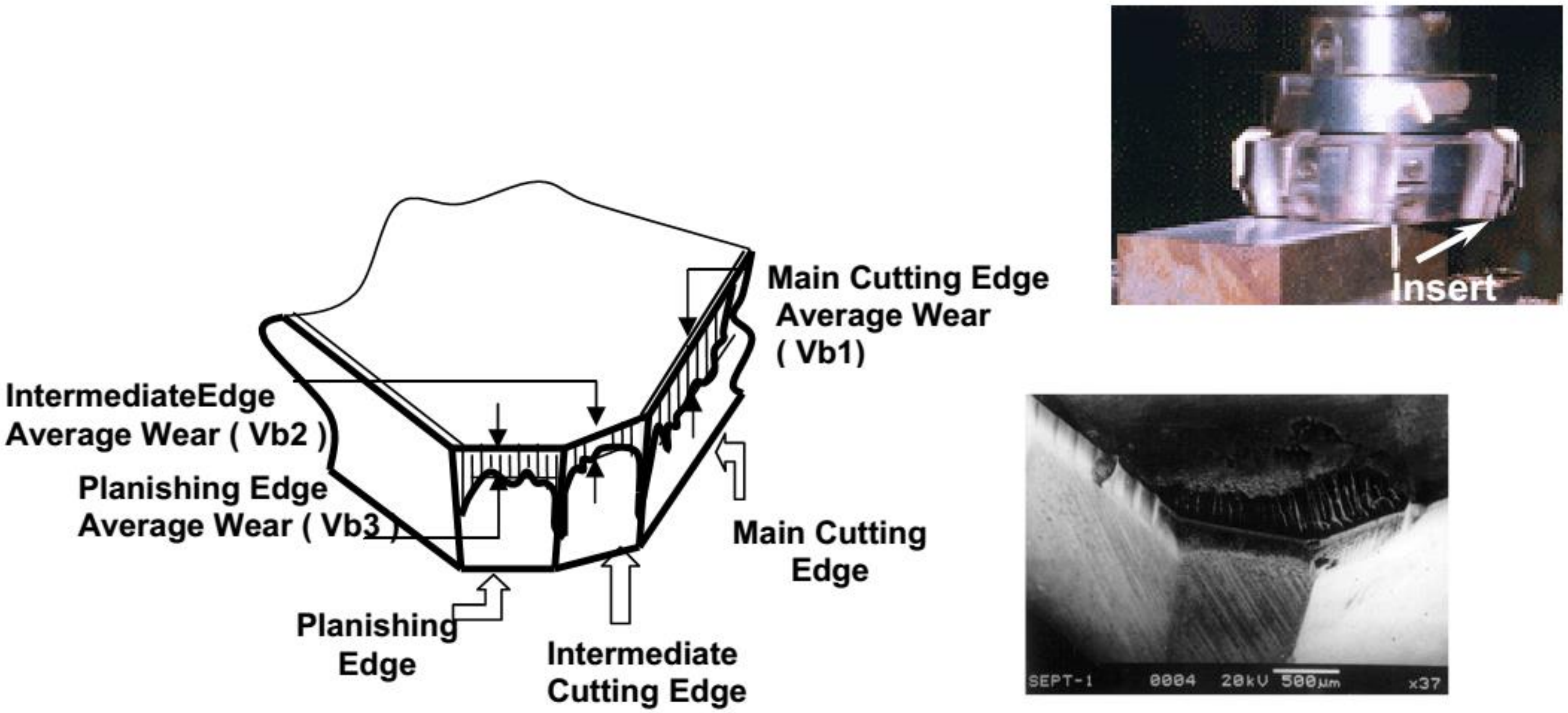
- In diffusion wear the material from the tool at its rubbing surfaces, particularly at the rake surface gradually diffuses into the flowing chips either in bulk or atom by atom when the tool material has chemical affinity or solid solubility towards the work material.
- The rate of such tool wear increases with the increase in temperature at the cutting zone.
- Diffusion wear becomes predominant when the cutting temperature becomes very high due to high cutting velocity and high strength of the work material.
- Chemical wear, leading to damages like grooving wear may occur if the tool material is not enough chemically stable against the work material and/or the atmospheric gases.

- Galvanic wear, based on electrochemical dissolution, seldom occurs when both the work tool materials are electrically conductive, cutting zone temperature is high and the cutting fluid acts as an electrolyte.

Photographic view of the wear pattern of a turning tool insert



Schematic (a) and actual view (b) of wear pattern of face milling insert



(a) (b)

- In addition to ultimate failure of the tool, the following effects are also caused by the growing tool-wear :
- • increase in cutting forces and power consumption mainly due to the principal flank wear
- • increase in dimensional deviation and surface roughness mainly due to wear of the tool-tips and auxiliary flank wear (Vs)
- • odd sound and vibration
- • worsening surface integrity
- • mechanically weakening of the tool tip.

Tool Life

- Tool life generally indicates, the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed.
- Tool life is defined in two ways :
- (a) In R & D : Actual machining time (period) by which a fresh cutting tool (or point) satisfactorily works after which it needs replacement or reconditioning. The modern tools hardly fail prematurely or abruptly by mechanical breakage or rapid plastic deformation. Those fail mostly by wearing process which systematically grows slowly with machining time. In that case, tool life means the span of actual machining time by which a fresh tool can work before attaining the specified limit of tool wear. Mostly tool life is decided by the machining time till flank wear.
- (b) In industries or shop floor : The length of time of satisfactory service or amount of acceptable output provided by a fresh tool prior to it is required to replace or recondition.

Assessment of tool life

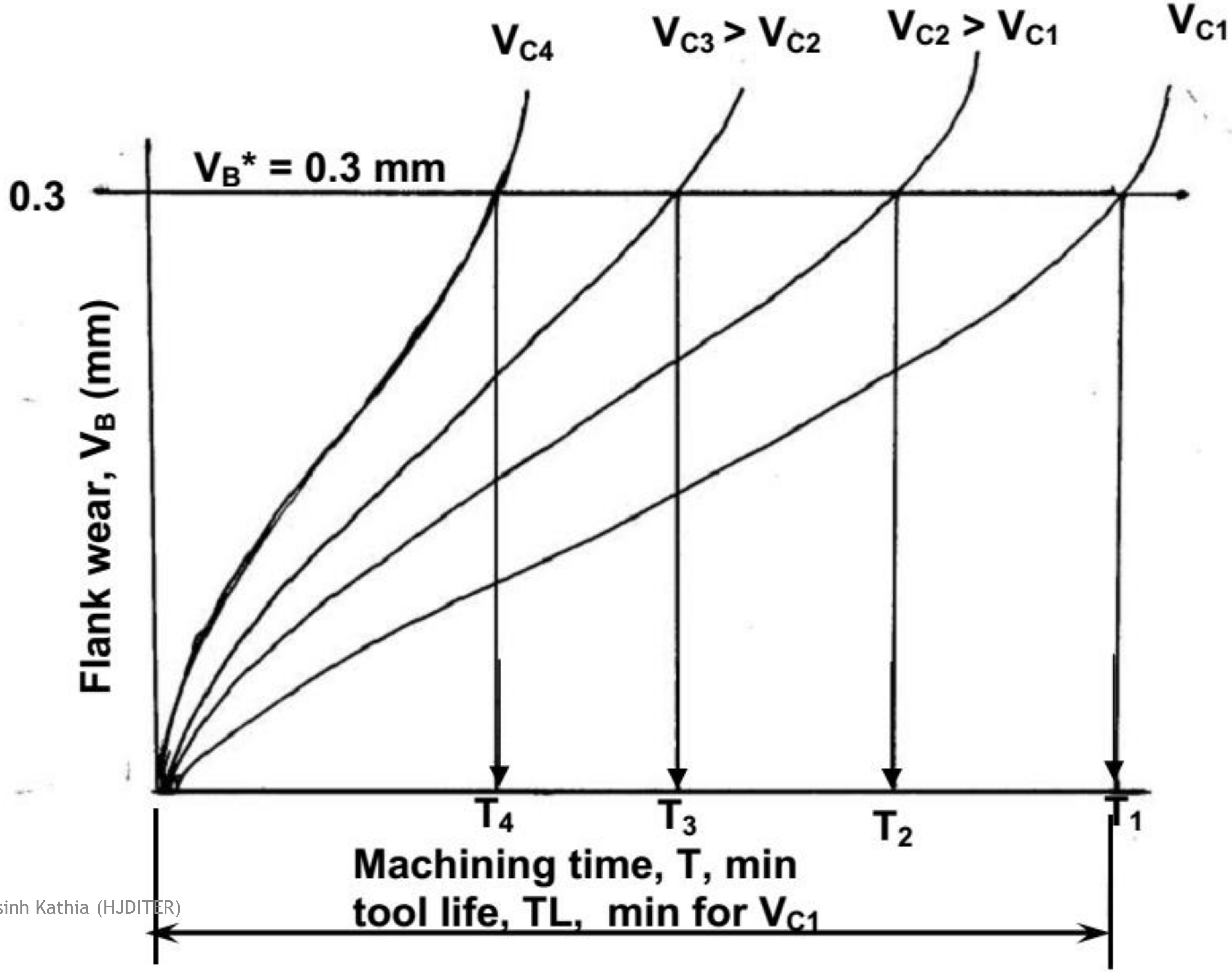
- For R & D purposes, tool life is always assessed or expressed by span of machining time in minutes, whereas, in industries besides machining time in minutes some other means are also used to assess tool life, depending upon the situation, such as …..
- • no. of pieces of work machined
- • total volume of material removed
- • total length of cut.

Measurement of tool wear

- i) by loss of tool material in volume orweight, in one life time – this method is crude and is generally applicable for critical tools like grinding wheels.
- ii) by grooving and indentation method – in this approximate method wear depth is measured indirectly by the difference in length of the groove or the indentation outside and inside the worn area
- iii) using optical microscope fitted with micrometer – very common and effective method
- iv) using scanning electron microscope (SEM) – used generally, for detailed study; both qualitative and quantitative .

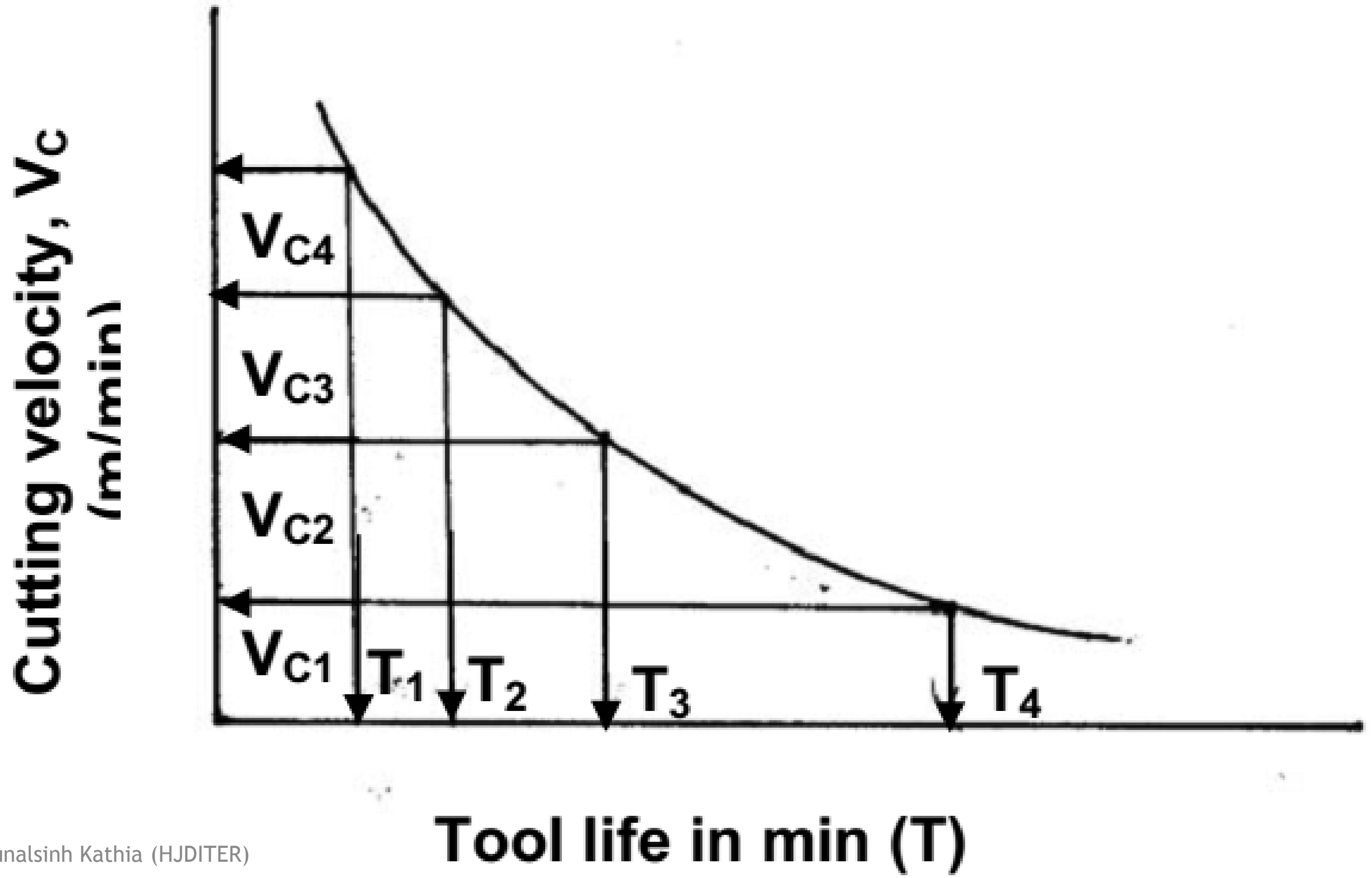
Taylor’s tool life equation.

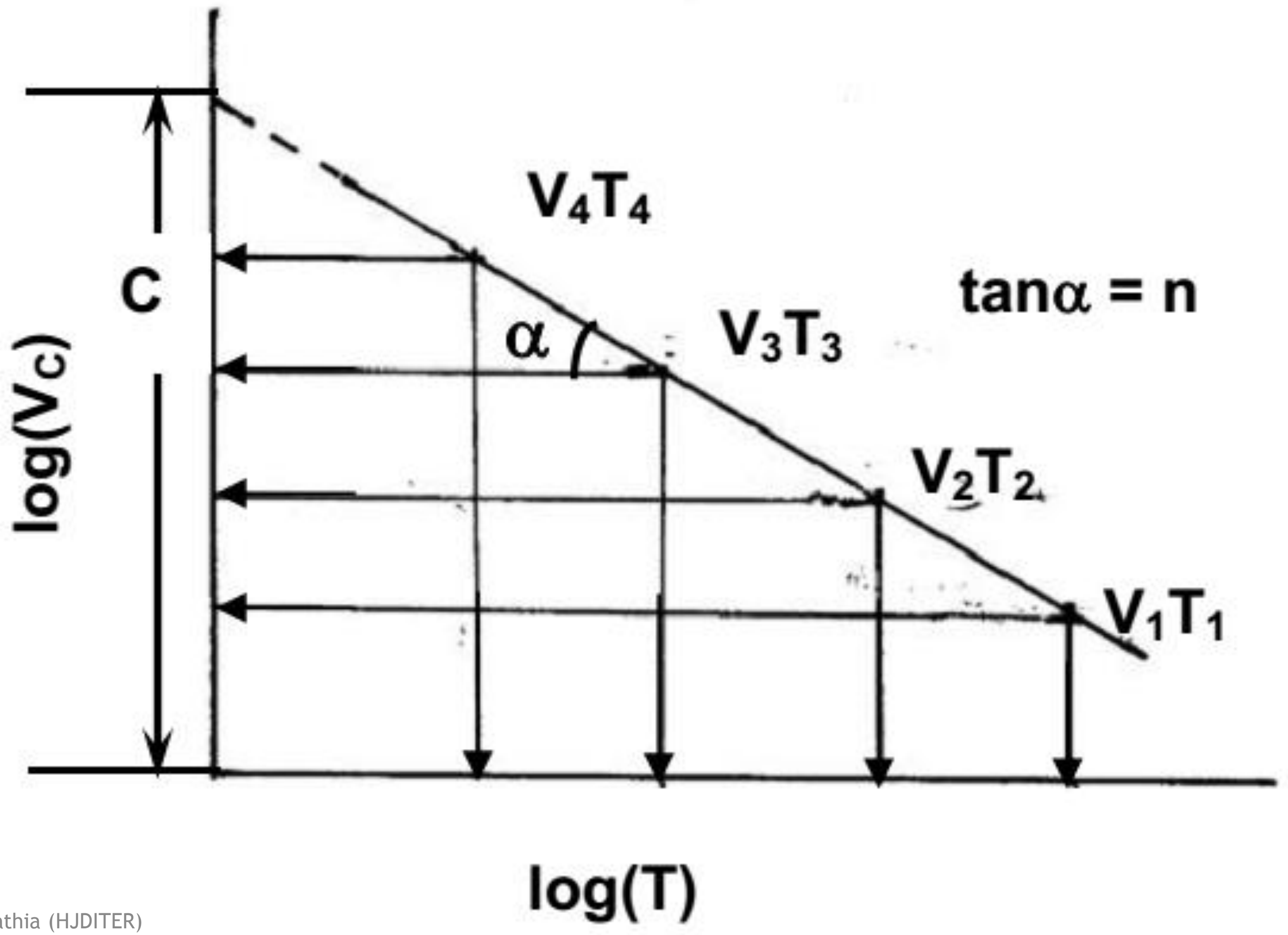
- Wear and hence tool life of any tool for any work material is governed mainly by the level of the machining parameters i.e., cutting velocity, (VC), feed, (so) and depth of cut (t).
- Cutting velocity affects maximum and depth of cut minimum.



Vc4
Vc3 > Vc2
Vc2 > Vc1
Vc1
VB* = 0.3 mm
0.3
Flank wear, VB (mm)
T4
T3
T2
T1
Machining time, T, min
tool life, TL, min for Vc1

- The usual pattern of growth of cutting tool wear (mainly VB), principle of assessing tool life and its dependence on cutting velocity are schematically shown in Fig.
- The tool life obviously decreases with the increase in cutting velocity keeping other conditions unaltered as indicated in Fig.
- If the tool lives, T1, T2, T3, T4etc are plotted against the corresponding cutting velocities, V1, V2, V3, V4etc as shown in Fig. 3.2.4, a smooth curve like a rectangular hyperbola is found to appear.
- When F. W. Taylor plotted the same figure taking both V and T in log-scale, a more distinct linear relationship appeared as schematically shown in Fig.


Cutting velocity, V_C
(m/min)
V_{C4}
V_{C3}
V_{C2}
V_{C1}
T_1
T_2
T_3
T_4
Tool life in min (T)



C
log(V_C)
V_4T_4
V_3T_3
V_2T_2
V_1T_1
α
tanα = n
log(T)

- 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 undertaken (i.e., 0.3 mm, 0.4 mm, 0.6 mm etc.)

Cutting tool geometry

Production Technology

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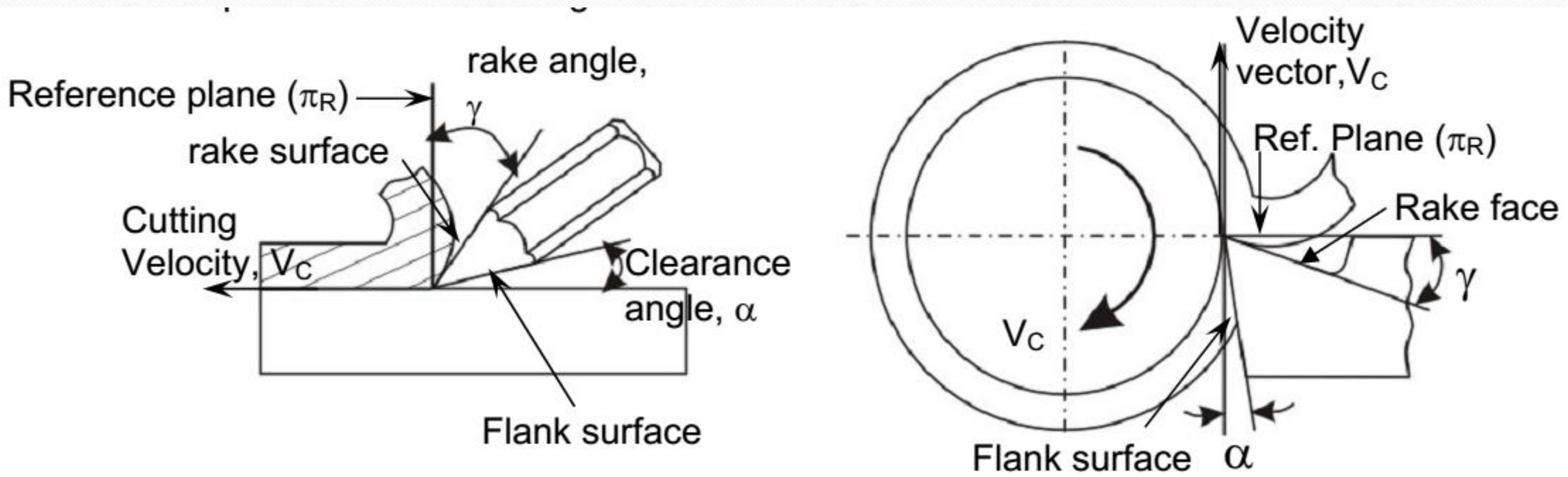
Geometry of single point turning tools

- Both material and geometry of the cutting tools play very important roles on their performances in achieving effectiveness, efficiency and overall economy of machining.
- 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 than two): e.g., milling cutters, broaching tools, hobs, gear shaping cutters etc.

Concept of rake and clearance angles of cutting tools

- The word tool geometry is basically referred to some specific angles or slope of the salient faces and edges of the tools at their cutting point.
- Rake angle and clearance angle are the most significant for all the cutting tools.
- The concept of rake angle and clearance angle will be clear from some simple operations shown in Fig.

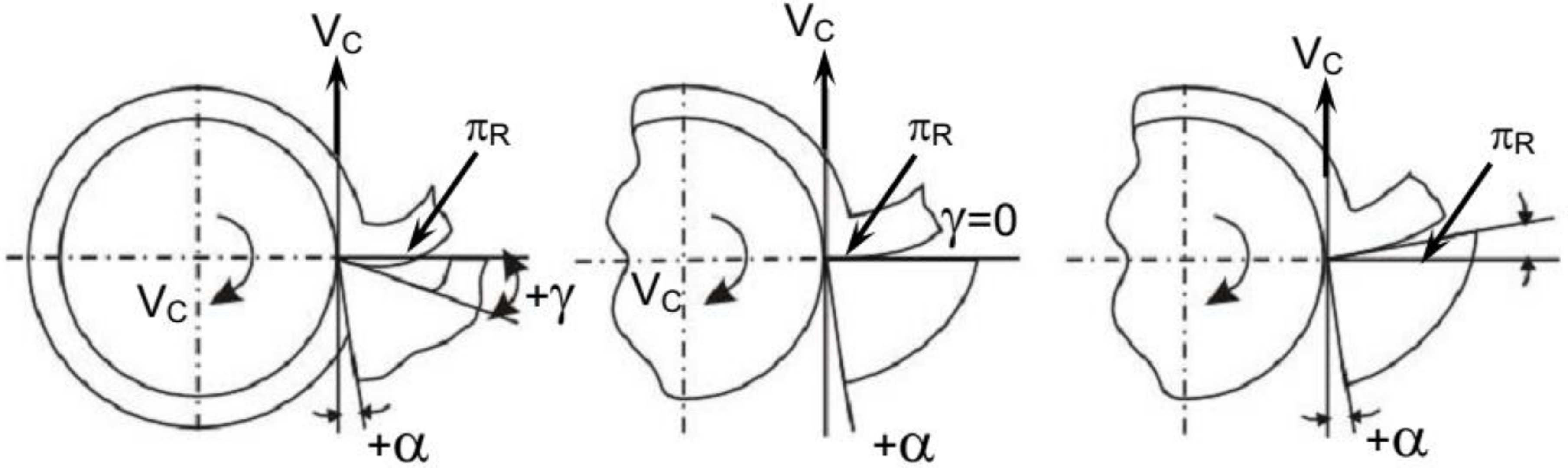


rake angle,
Reference plane (π_R)
γ
rake surface
Cutting
Velocity, V_C
Clearance
angle, α
Flank surface
Velocity
vector, V_C
Ref. Plane (π_R)
Rake face
γ
V_C
Flank surface
α

DEFINATION

- Rake angle (γ): Angle of inclination of rake surface from reference plane
- clearance angle (α): Angle of inclination of clearance or flank surface from the finished surface
- Rake angle is provided for ease of chip flow and overall machining.
- Rake angle may be positive, or negative or even zero as shown in Fig..

RAKE +Ve & -Ve



(a) positive rake (b) zero rake (c) negative rake

ADVANTAGE

- Relative advantages of such rake angles are:
- • Positive rake – helps reduce cutting force and thus cutting power requirement.
- • Negative rake – to increase edge-strength and life of the tool
- • Zero rake – to simplify design and manufacture of the form tools.
- 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 (3o~ 15o) depending upon tool-work materials and type of the machining operations like turning, drilling, boring etc.)

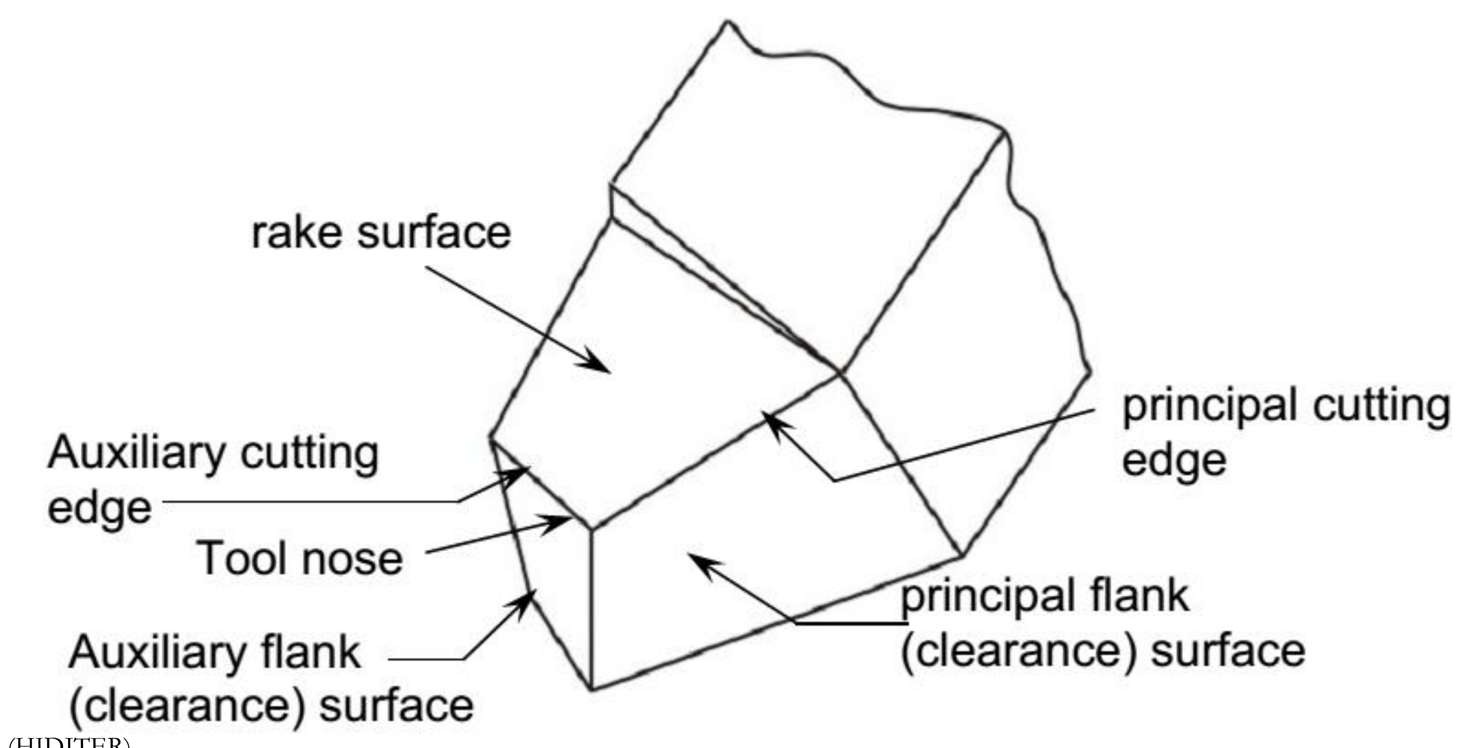
Systems of description of tool geometry

- • Tool-in-Hand System – where only the salient features of the cutting tool point are identified or visualized .
- There is no quantitative information, i.e., value of the angles.
- Machine Reference System – ASA system
- Tool Reference Systems
  - Orthogonal Rake System – ORS
  - Normal Rake System – NRS
- Work Reference System – WRS

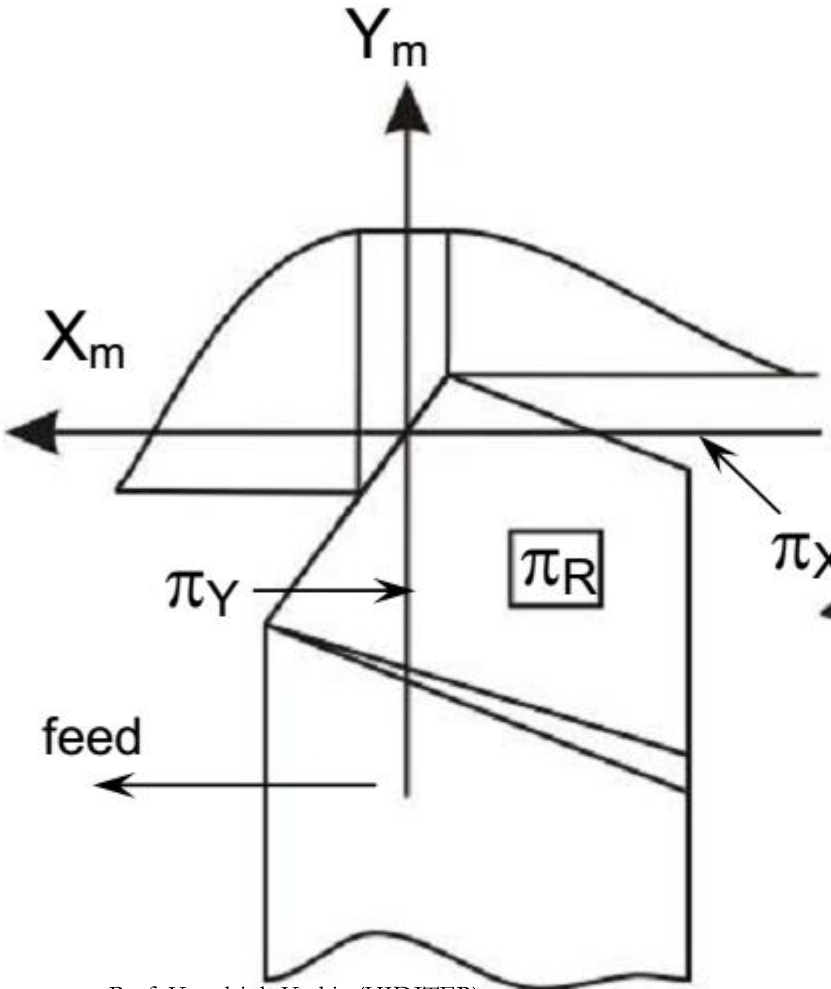
Machine Reference System

- This system is also called ASA system; ASA stands for American Standards Association.
- Geometry of a cutting tool refers mainly to its several angles or slope of its salient working surfaces and cutting edges.
- Those angles are expressed w.r.t. some planes of reference.
- In Machine Reference System (ASA), the three planes of reference and the coordinates are chosen based on the configuration and axes of the machine tool concerned.
- The planes and axes used for expressing tool geometry in ASA system for turning operation are shown in Fig

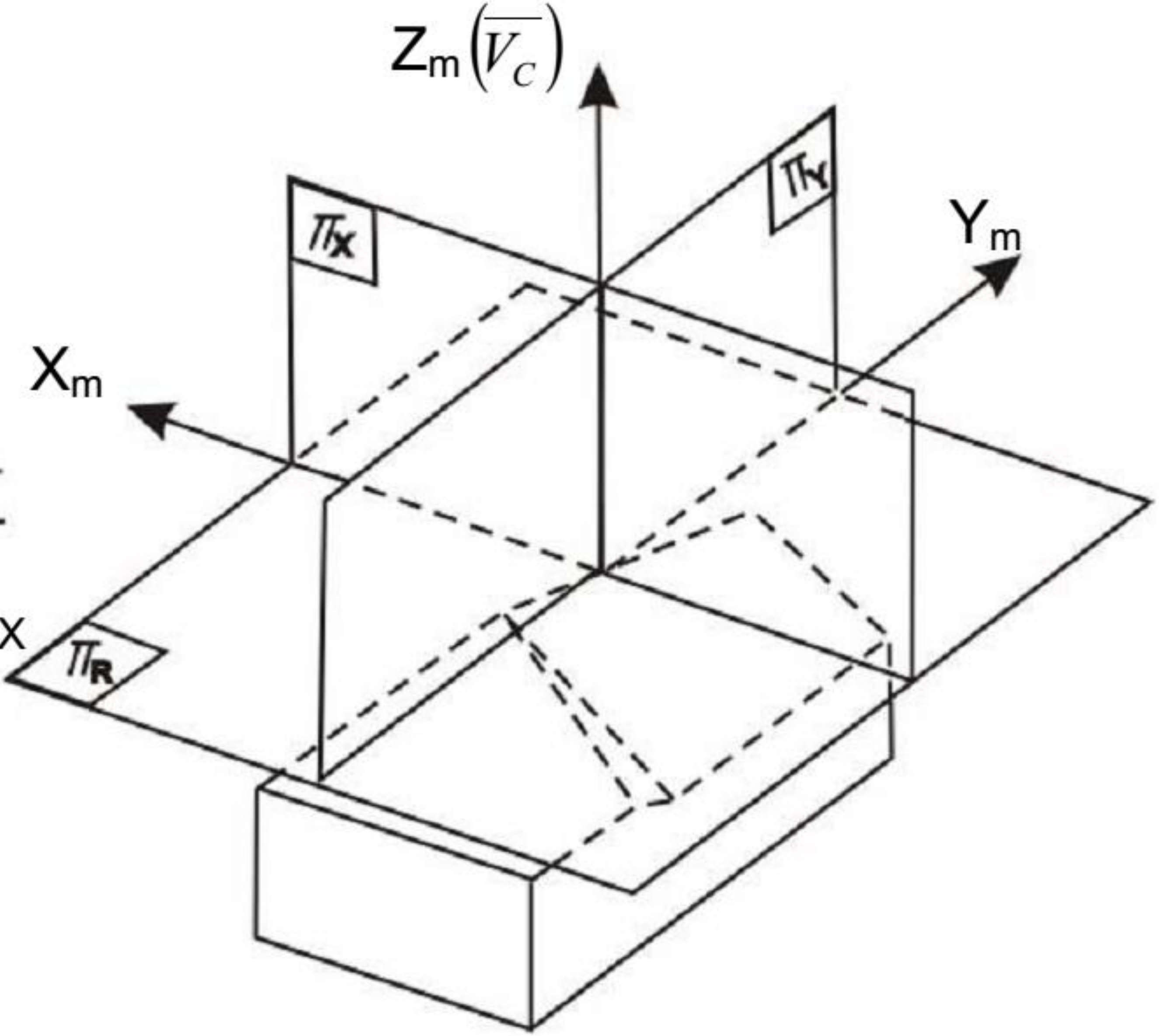
Basic features of single point tool (turning) in Tool-in-hand system



Planes and axes of reference in ASA system



Y m
X m
π R
π Y
π X
feed



Z m ($\overline{V_C}$)
Y m
X m
π X
π Y
π R

Denotations

- **πR- πX- πY and Xm– Ym- Zm**
- where,
- **πR**= Reference plane; plane perpendicular to the velocity vector
- **πX** = Machine longitudinal plane; plane perpendicular to πR and taken
- in the direction of assumed longitudinal feed
- **πY**= Machine Transverse plane; plane perpendicular to both πR and πX

Denotations

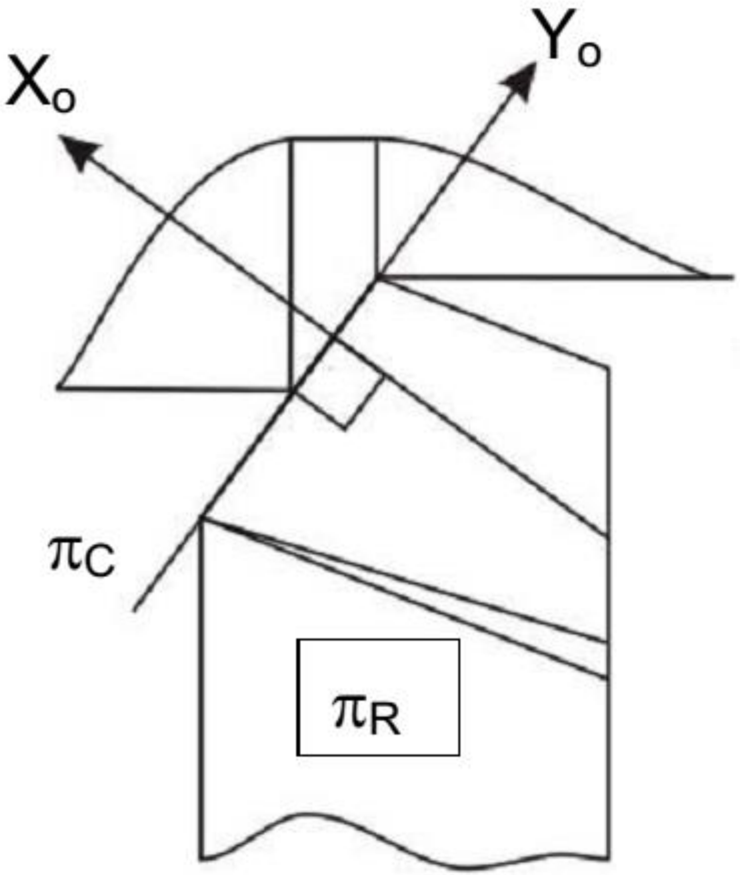
- The axes Xm, Ym and Zm are in the direction of longitudinal feed, cross feed
- and cutting velocity (vector) respectively. The main geometrical features and
- angles of single point tools in ASA systems and their definitions will be clear from Fig

Tool Reference Systems

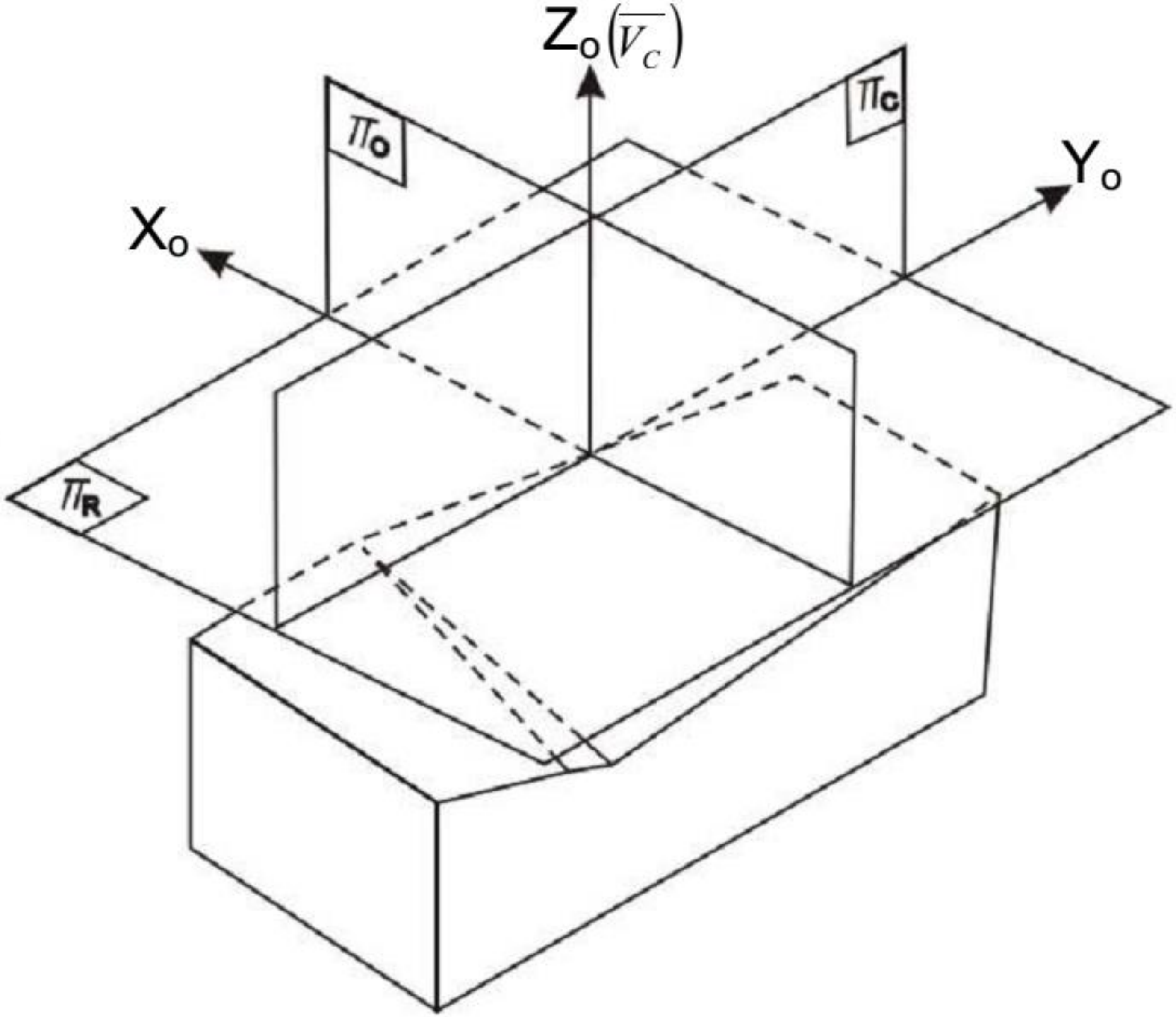
- **Orthogonal Rake System – ORS**

- This system is also known as ISO – old.
- The planes of reference and the co-ordinate axes used for expressing the tool angles in ORS are:
- πR- πC- πO and Xo- Yo- Zo
- which are taken in respect of the tool configuration as indicated in Fig

Planes and axes of reference in ORS



Xo
Yo
πC
πR



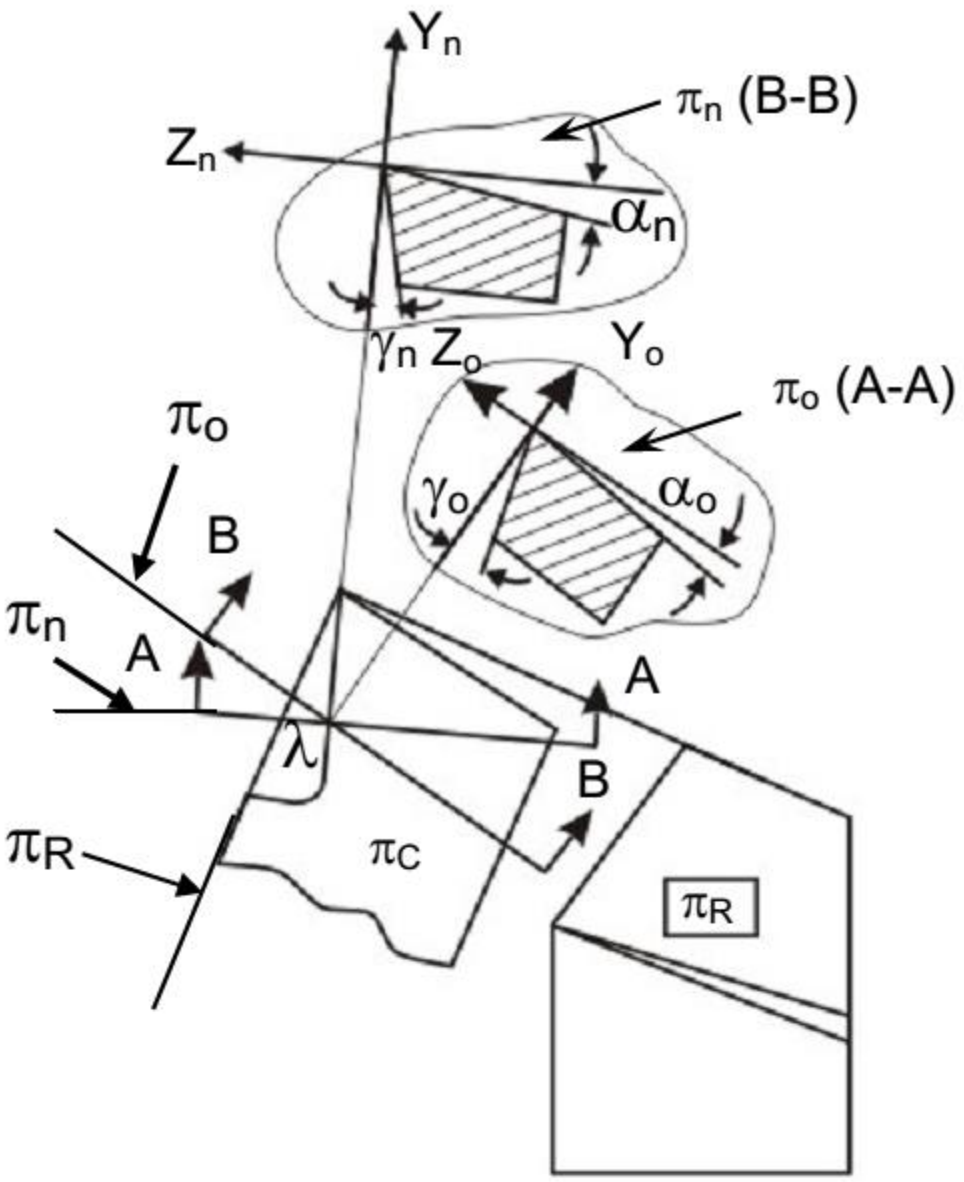
Zo
Xo
Yo
πo
πc
πR

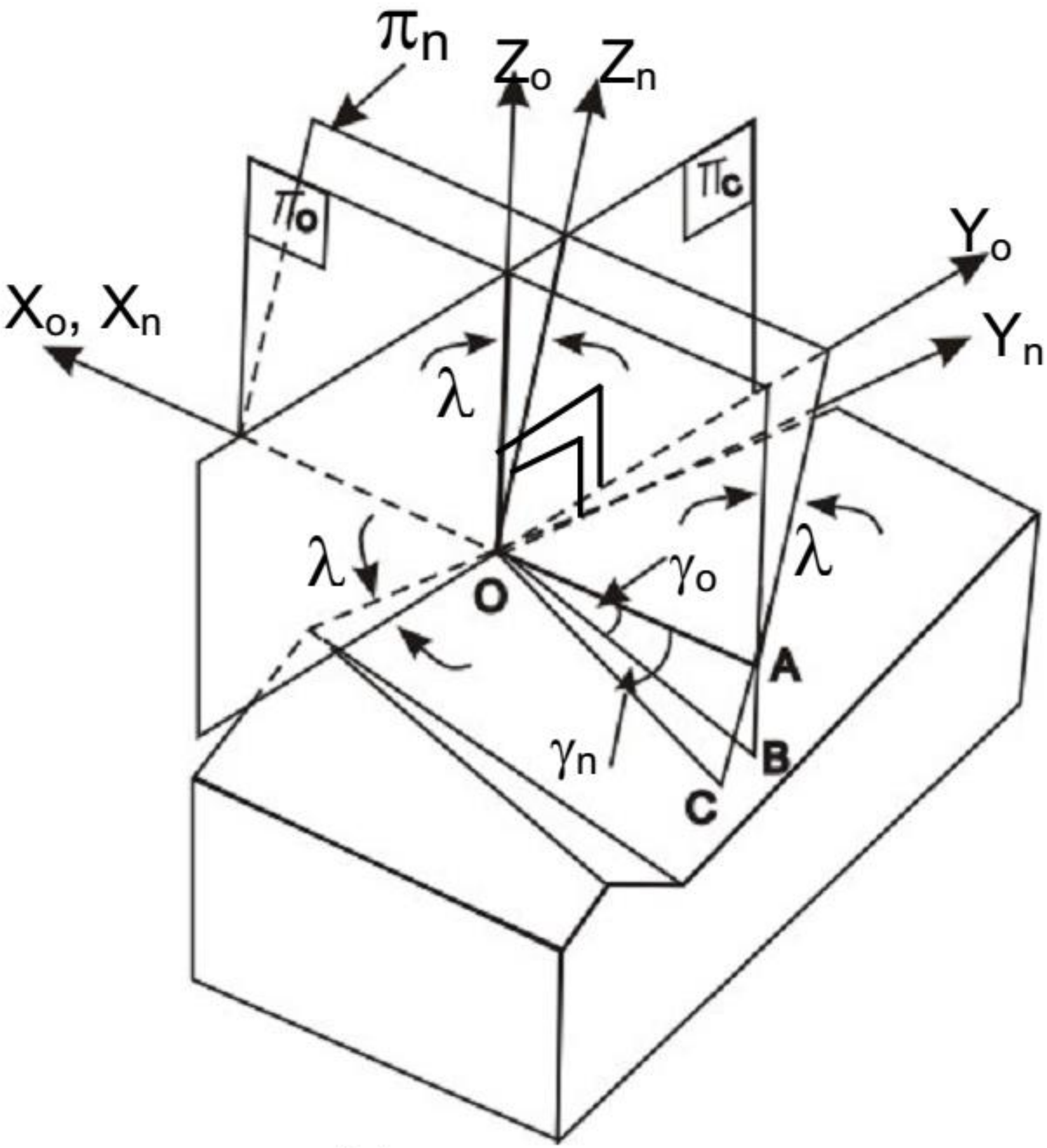
Normal Rake System – NRS

- This system is also known as ISO – new.
- ASA system has limited advantage and use like convenience of inspection.
- But ORS is advantageously used for analysis and research in machining and tool performance.
- But ORS does not reveal the true picture of the tool geometry when the cutting edges are inclined from the reference plane, i.e., $\lambda \neq 0$.
- Besides, sharpening or re sharpening, if necessary, of the tool by grinding in ORS requires some additional calculations for correction of angles.

Normal Rake System – NRS

- These two limitations of ORS are overcome by using NRS for description and use of tool geometry.
- The basic difference between ORS and NRS is the fact that in ORS, rake and clearance angles are visualized in the orthogonal plane, πo, whereas in NRS those angles are visualized in another plane called Normal plane, πN.
- The orthogonal plane, $\pi o$is simply normal to $\pi R$and πC irrespective of the inclination of the cutting edges, i.e., λ, but πN(and $\pi N'$ for auxiliary cutting edge) is always normal to the cutting edge.
- The differences between ORS and NRS have been depicted in Fig.





(a)

Differences of NRS from ORS w.r.t. cutting tool geometry.

Designation of tool geometry

- Designation (signature) of tool geometry in …….
- ASA System –
- **γy, γx, αy, αx, φe, φs, r (inch)**
- • ORS System –
- **λ, γo, αo, $\alpha o'$, $\varphi 1$, φ, r (mm)**
- • NRS System –
- **λ, γn, αn, $\alpha n'$, $\varphi 1$, φ, r (mm)**

Cutting tool materials

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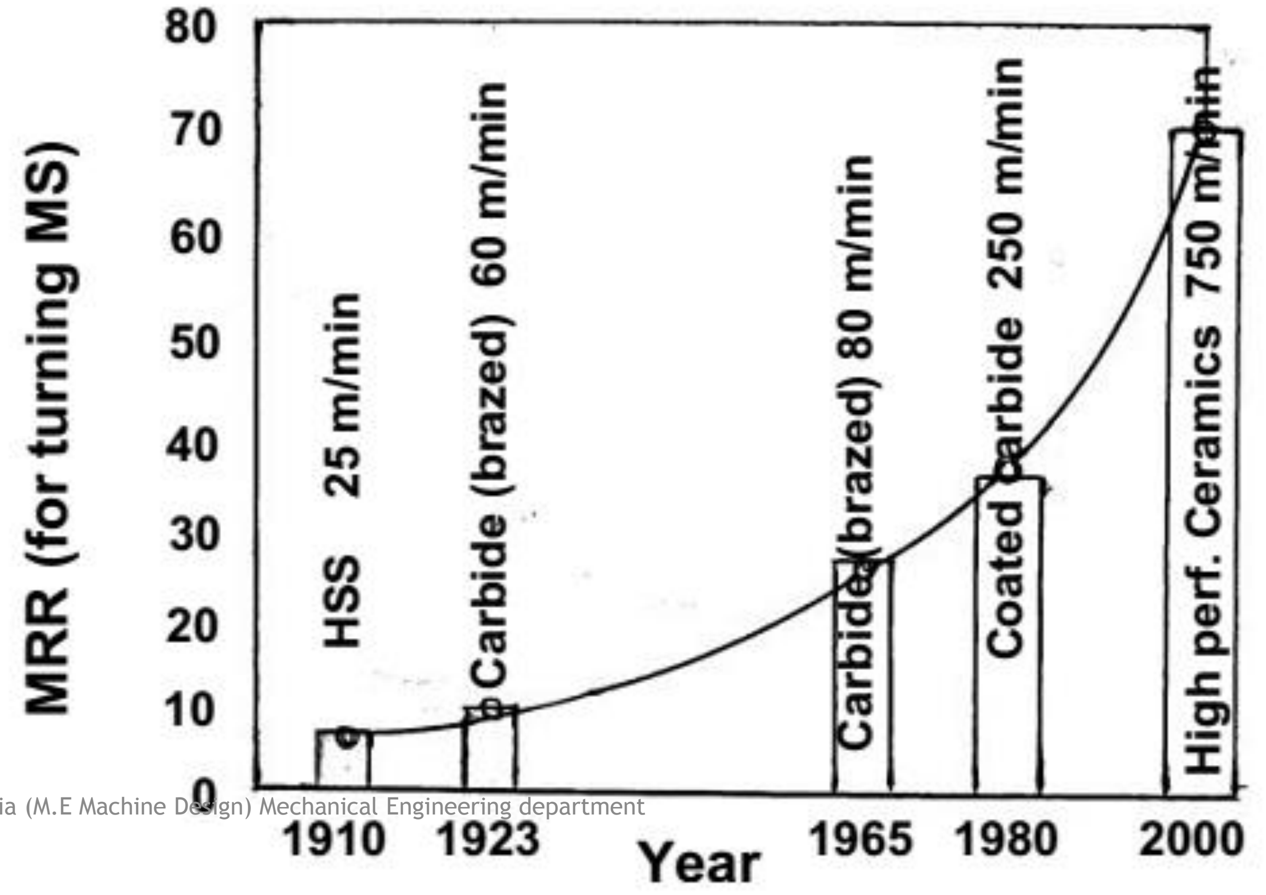
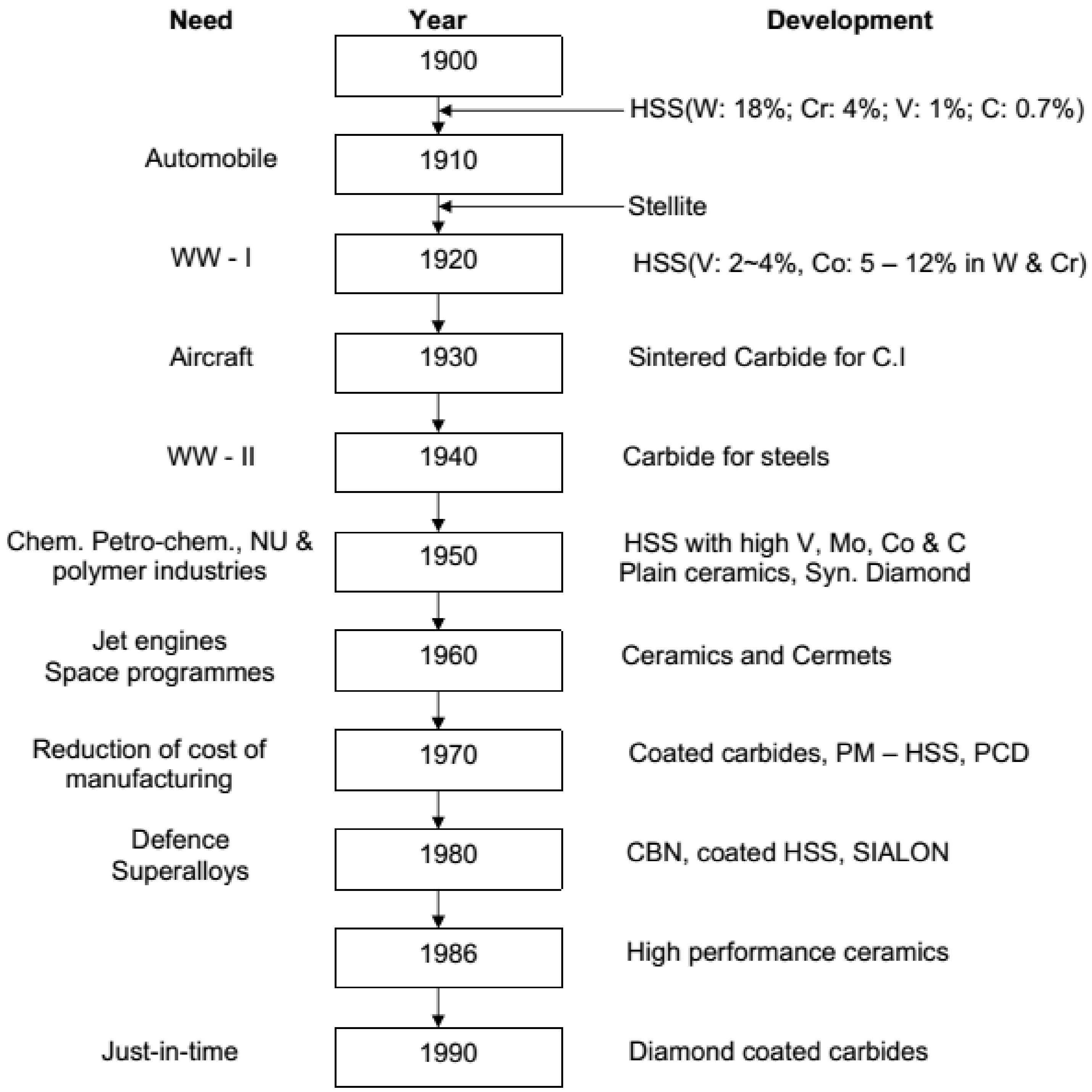
Needs And Chronological Development of Cutting Tool Materials

- With the progress of the industrial world it has been needed to continuously develop and improve the cutting tool materials and geometry;
- to meet the growing demands for high productivity, quality and economy of machining
- to enable effective and efficient machining of the exotic materials that are coming up with the rapid and vast progress of science and technology
- for precision and ultra-precision machining
- for micro and even nano machining demanded by the day and future.
- It is already stated that the capability and overall performance of the cutting tools depend upon,
  - the cutting tool materials
  - the cutting tool geometry
  - proper selection and use of those tools
  - the machining conditions and the environments
- Out of which the tool material plays the most vital role.

The relative contribution of the cutting tool materials on productivity, for instance, can be roughly assessed.



The chronological development of cutting tool materials is briefly indicated



Characteristics And Applications Of The Primary Cutting Tool Materials HSS (High speed steel)

- Advent of HSS in around 1905 made a break through at that time in the history of cutting tool materials though got later superseded by many other novel tool materials like cemented carbides and ceramics which could machine much faster than the HSS tools.
- The basic composition of HSS is 18% W, 4% Cr, 1%V, 0.7% C and rest Fe.
- Such HSS tool could machine (turn) mild steel jobs at speed only upto 20 ~ 30m/min (which was quite substantial those days) .

HSS is still used as cutting tool material where…..

- the tool geometry and mechanics of chip formation are complex,
- such as helical twist drills, reamers, gear shaping cutters, hobs, form tools, broaches etc.
- • brittle tools like carbides, ceramics etc. are not suitable under shock loading
- • the small scale industries cannot afford costlier tools
- • the old or low powered small machine tools cannot accept high speed and feed.
- • The tool is to be used number of times by re-sharpening.

HSS Nowadays improved with following…..

- • Refinement of microstructure
- • Addition of large amount of cobalt and Vanadium to increase hot hardness and wear resistance respectively
- • Manufacture by powder metallurgical process
- • Surface coating with heat and wear resistive materials like TiC, TiN, etc by Chemical Vapour Deposition (CVD) or Physical Vapour Deposition (PVD)

The commonly used grades of HSS

Type	C	W	Mo	Cr	V	Co	R_C
T – 1	0.70	18		4	1		
T – 4	0.75	18		4	1	5	
T – 6	0.80	20		4	2	12	
M – 2	0.80	6	5	4	2		64.7
M – 4	1.30	6	5	4	4		
M – 15	1.55	6	3	5	5	5	
M – 42	1.08	1.5	9.5	4	1.1	8	62.4

What these addition makes

- Addition of large amount of Co and V, refinement of microstructure and coating increased strength and wear resistance and thus enhanced productivity and life of the HSS tools remarkably

Stellite

- This is a cast alloy of Co (40 to 50%), Cr (27 to 32%), W (14 to 19%) and C (2%).
- Stellite is quite tough and more heat and wear resistive than the basic HSS (18 – 4 – 1) But such stellite as cutting tool material became obsolete for its poor grind ability and specially after the arrival of cemented carbides.

Sintered Tungsten carbides

- The advent of sintered carbides made another breakthrough in the history of cutting tool materials.
  - Straight or single carbide
  - Composite carbides
  - Mixed carbides

Straight or single carbide

- First the straight or single carbide tools or inserts were powder metallurgically produced by mixing, compacting and sintering 90 to 95% WC powder with cobalt.
- The hot, hard and wear resistant WC grains are held by the binder Co which provides the necessary strength and toughness.
- Such tools are suitable for machining grey cast iron, brass, bronze etc.
- which produce short discontinuous chips and at cutting velocities two to three times of that possible for HSS tools.

Composite carbides

- The single carbide is not suitable for machining steels because of rapid growth of wear, particularly crater wear, by diffusion of Co and carbon from the tool to the chip under the high stress and temperature bulk (plastic) contact between the continuous chip and the tool surfaces.
- For machining steels successfully, another type called composite carbide have been developed by adding (8 to 20%) a gamma phase to WC and Co mix.
- The gamma phase is a mix of TiC, TiN, TaC, NiC etc. which are more diffusion resistant than WC due to their more stability and less wettability by steel.

Mixed carbides

- Titanium carbide (TiC) is not only more stable but also much harder than WC.
- So for machining ferritic steels causing intensive diffusion and adhesion wear a large quantity (5 to 25%) of TiC is added with WC and Co to produce another grade called Mixed carbide. But increase in TiC content reduces the toughness of the tools.
- Therefore, for finishing with light cut but high speed, the harder grades containing upto 25% TiC are used and for heavy roughing work at lower speeds lesser amount (5 to 10%) of TiC is suitable.

Gradation of cemented carbides and their applications

ISO Code	Colour Code	Application
P	[blue box]	For machining long chip forming common materials like plain carbon and low alloy steels
M	[yellow box]	For machining long or short chip forming ferrous materials like Stainless steel
K	[red box]	For machining short chipping, ferrous and non-ferrous material and non-metals like Cast Iron, Brass etc.

Groups

- K-group is suitable for machining short chip producing ferrous and nonferrous metals and also some non metals.
- P-group is suitably used for machining long chipping ferrous metals i.e.plain carbon and low alloy steels.
- M-group is generally recommended for machining more difficult-to machine materials like strain hardening austenitic steel and manganese steel etc.

P-GROUP

ISO Application group	Material	Process
P01	Steel, Steel castings	Precision and finish machining, high speed
P10	Steel, steel castings	Turning, threading and milling high speed, small chips
P20	Steel, steel castings, malleable cast iron	Turning, milling, medium speed with small chip section
P30	Steel, steel castings, malleable cast iron forming long chips	Turning, milling, low cutting speed, large chip section
P40	Steel and steel casting with sand inclusions	Turning, planning, low cutting speed, large chip section
P50	Steel and steel castings of medium or low tensile strength	Operations requiring high toughness turning, planning, shaping at low cutting speeds

K-GROUP

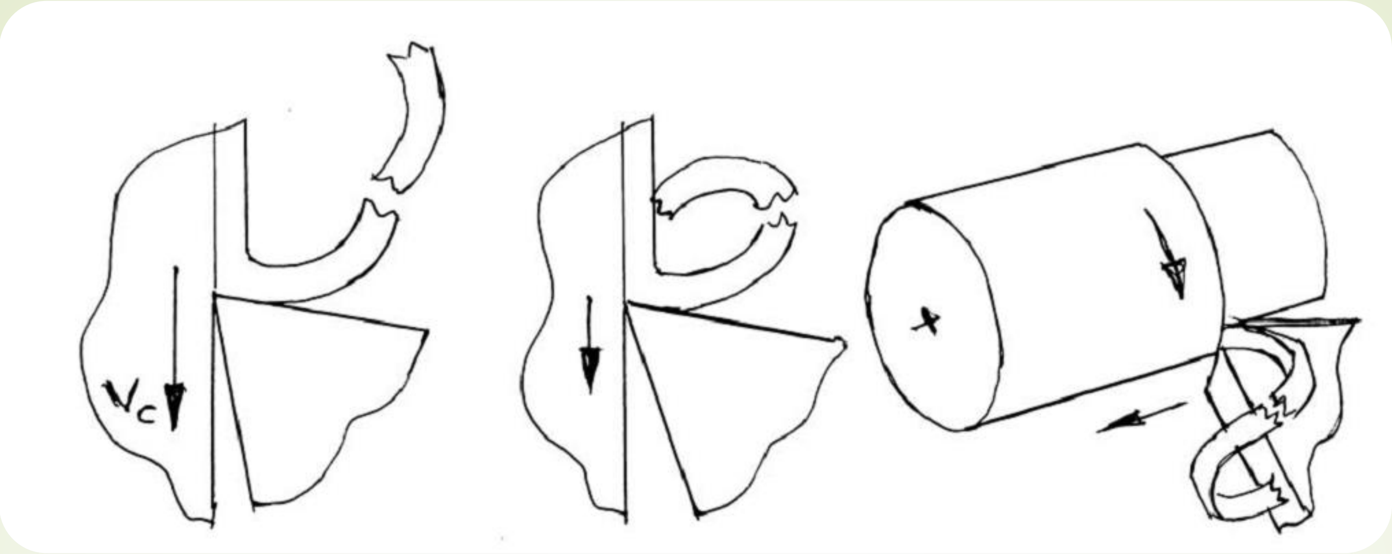
K01	Hard grey C.I., chilled casting, Al. alloys with high silicon	Turning, precision turning and boring, milling, scraping
K10	Grey C.I. hardness > 220 HB. Malleable C.I., Al. alloys containing Si	Turning, milling, boring, reaming, broaching, scraping
K20	Grey C.I. hardness up to 220 HB	Turning, milling, broaching, requiring high toughness
K30	Soft grey C.I. Low tensile strength steel	Turning, reaming under favourable conditions
K40	Soft non-ferrous metals	Turning milling etc.

M-GROUP

M10	Steel, steel castings, manganese steel, grey C.I.	Turning at medium or high cutting speed, medium chip section
M20	Steel casting, austentic steel, manganese steel, spherodized C.I., Malleable C.I.	Turning, milling, medium cutting speed and medium chip section
M30	Steel, austenitic steel, spherodized C.I. heat resisting alloys	Turning, milling, planning, medium cutting speed, medium or large chip section
M40	Free cutting steel, low tensile strength steel, brass and light alloy	Turning, profile turning, specially in automatic machines.

NOTICABLE THING

- The smaller number refers to the operations which need more wear resistance and the larger numbers to those requiring higher toughness for the tool.



Mechanics of Chip Removal

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Mechanism of chip formation in machining

- Machining is a semi-finishing or finishing process essentially done to impart required or stipulated dimensional and form accuracy and surface finish to
- enable the product to fulfill its basic functional requirements
- provide better or improved performance
- • render long service life.

- **Machining is a process of gradual removal of excess material from the preformed blanks in the form of chips.**

What chip indicates?

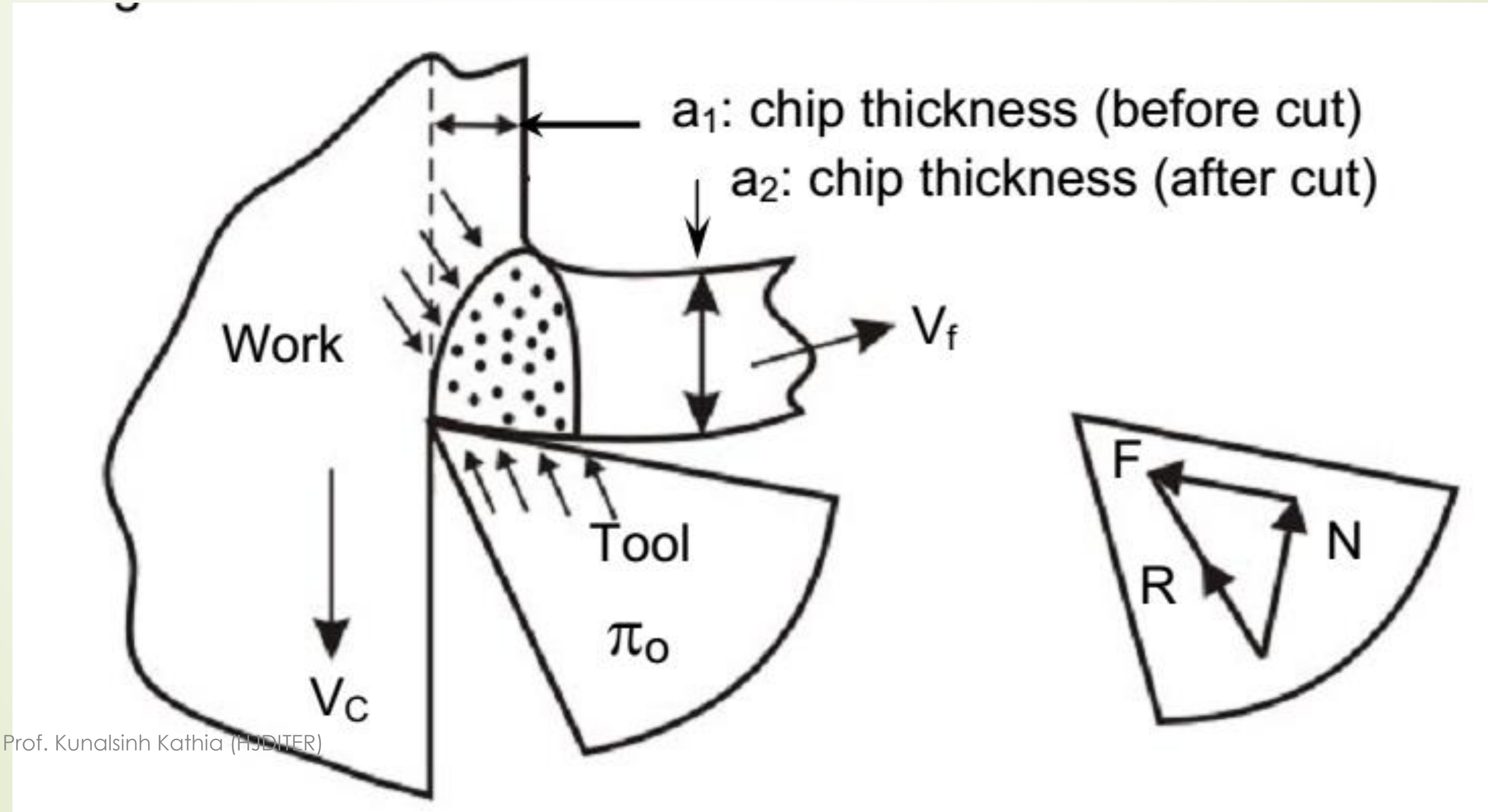
- Nature and behavior of the work material under machining condition
- Specific energy requirement (amount of energy required to remove unit volume of work material) in machining work
- Nature and degree of interaction at the chip-tool interfaces.

The form of machined chips depend mainly upon....

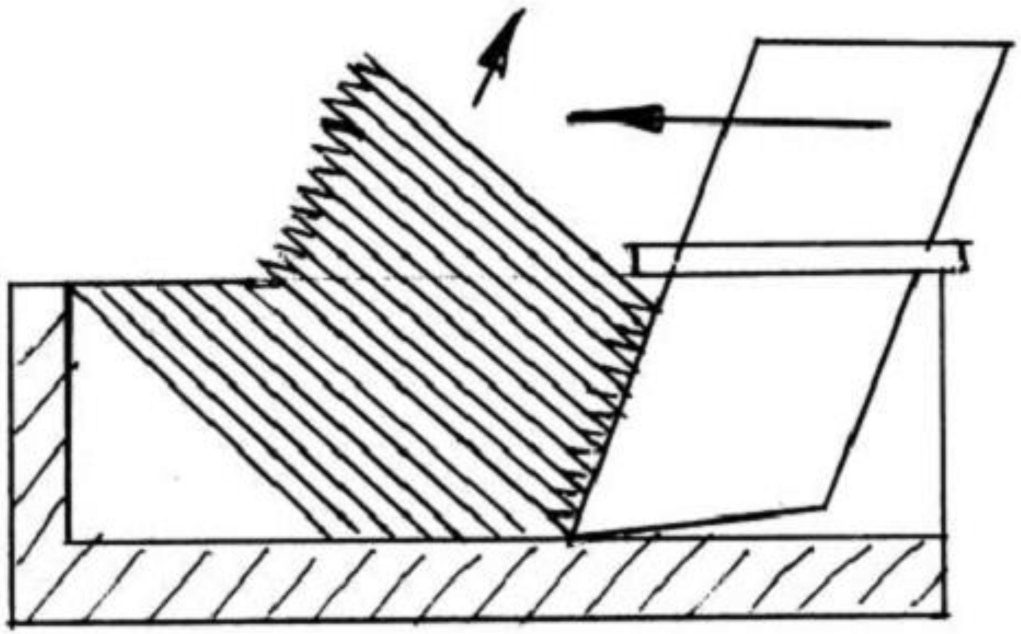
- Work material
- Material and geometry of the cutting tool
- Levels of cutting velocity and feed and also to some extent on depth of
- cut ...
- Machining environment or cutting fluid that affects temperature and
- friction at the chip-tool and work-tool interfaces.

Mechanism of chip formation in machining ductile materials

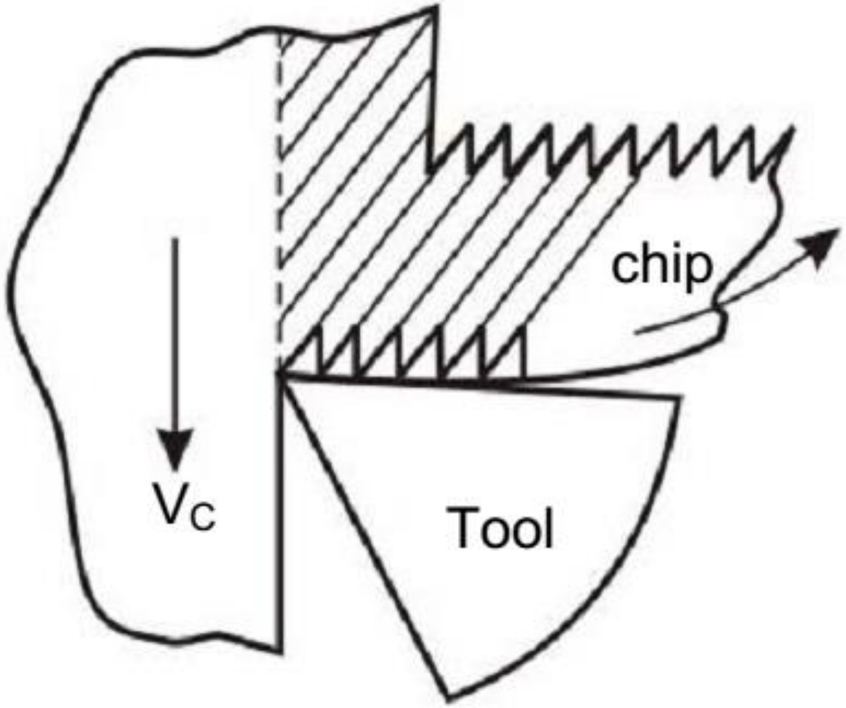
- **During continuous machining the uncut layer of the work material just ahead of the cutting tool (edge) is subjected to almost all sided compression as indicated in Fig.**



- The force exerted by the tool on the chipa rises out of the normal force, N and frictional force, F as indicated in Fig
- 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 and 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 Piispannen [1] using a card analogy as shown in Fig



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

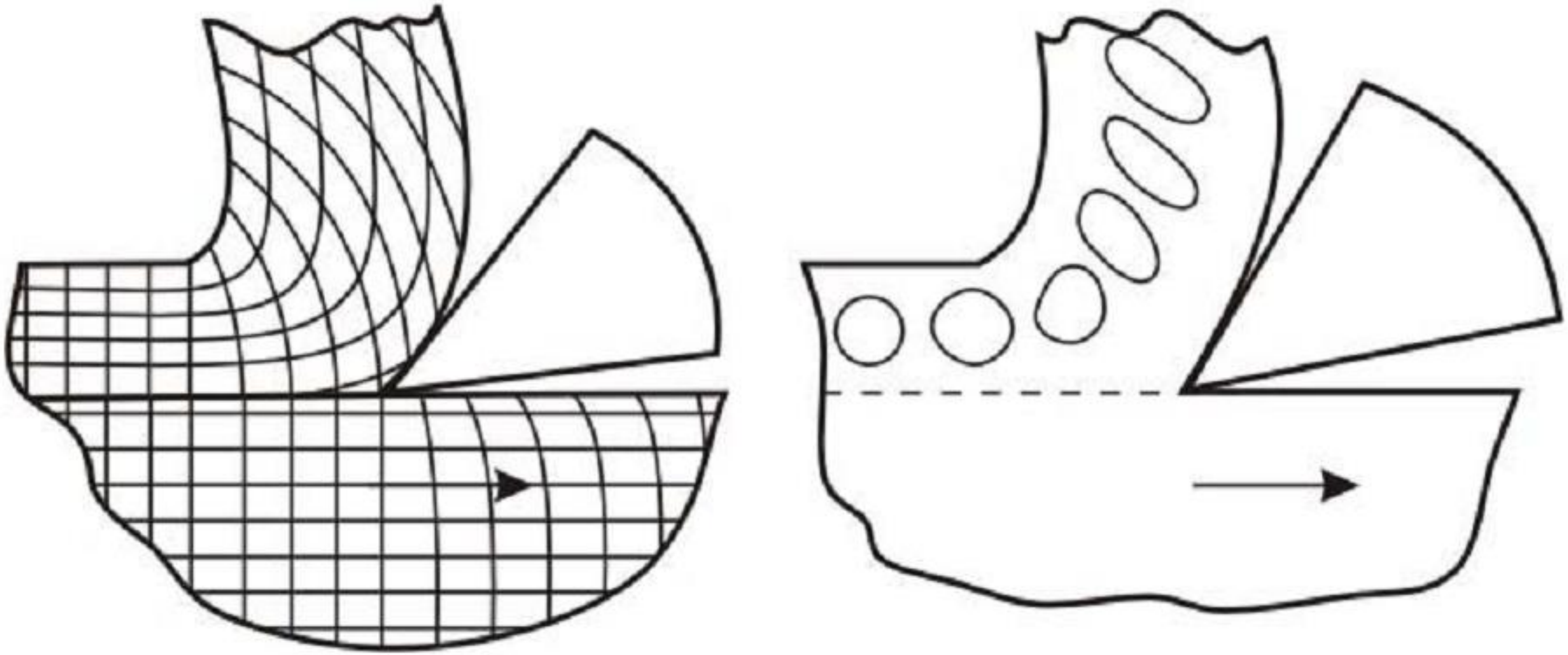


(b) Chip formation by shear in lamella.

- In actual machining chips also, such serrations are visible at their upper surface as indicated in Fig.
- The lower surface becomes smooth due to further plastic deformation due to intensive rubbing with the tool at high pressure and temperature.
- The pattern of shear deformation by lamellar sliding, indicated in the model, can also be seen in actual chips by proper mounting, etching and polishing the side surface of the machining chip and observing under microscope.

Experimental methods

- The overall deformation process causing chip formation is quite complex and hence needs thorough experimental studies for clear understanding the phenomena and its dependence on the affecting parameters.
- The feasible and popular experimental methods for this purpose are:
- Study of deformation of rectangular or circular grids marked on the side surface



(a) rectangular grids

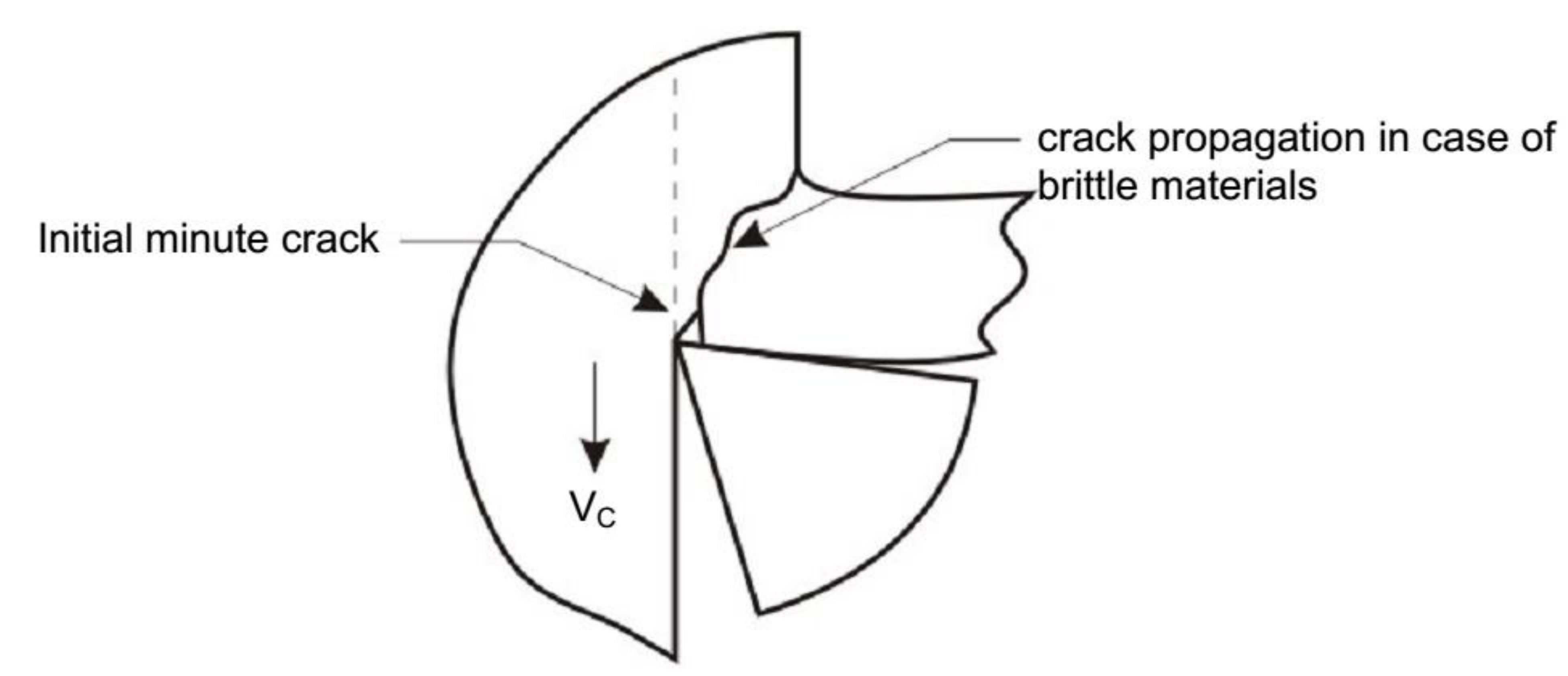
(b) circular grids

- It has been established by several analytical and experimental methods including circular grid deformation that though the chips are initially compressed ahead of the tool tip, the final deformation is accomplished mostly by shear in machining ductile materials. However, machining of ductile materials generally produces flat, curved or coiled continuous chips.

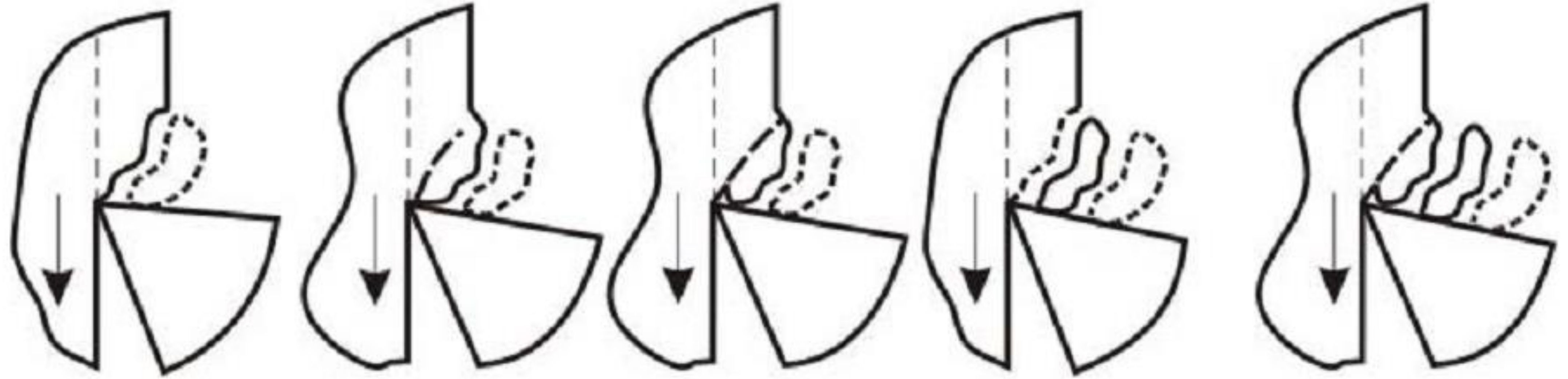
Mechanism of chip formation in machining brittle materials

- The basic two mechanisms involved in chip formation are
- • Yielding – generally for ductile materials
- • Brittle fracture – generally for brittle materials
- 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.

Development and propagation of crack causing chip separation



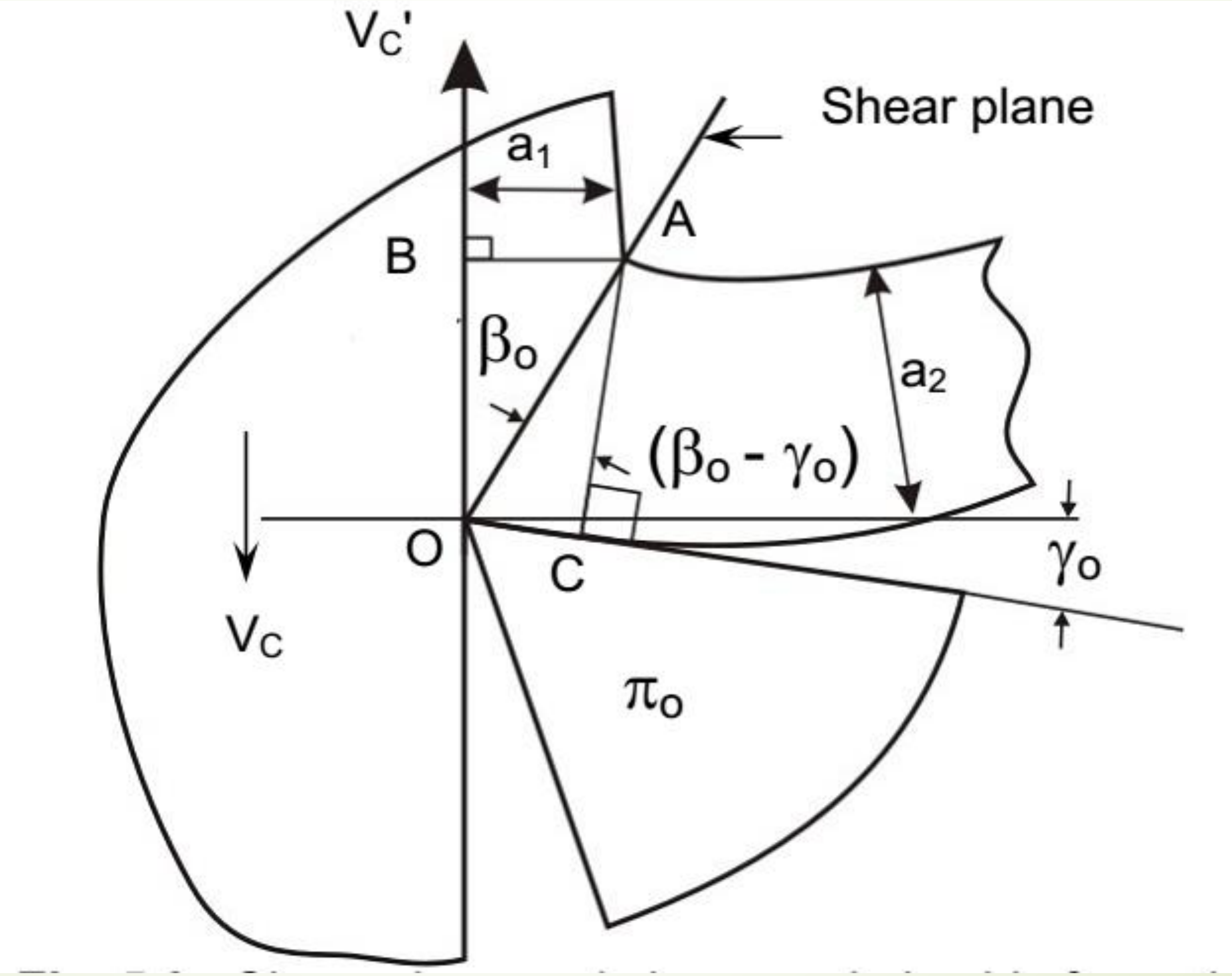
- Machining of brittle material produces discontinuous chips and mostly of irregular size and shape. The process of forming such chips is schematically shown in Fig



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

Chip thickness ratio

- **Shear angle :**It has been observed that during machining, particularly ductile materials, the chip sharply changes its direction of flow (relative to the tool) from the direction of the cutting velocity, VC to that along the tool rake surface after thickening by shear deformation or slip or lamellar sliding along a plane. This plane is called shear plane and is schematically shown in Fig.
- **Shear plane** : Shear plane is the plane of separation of work material layer in the form of chip from the parent body due to shear along that plane.
- **Shear angle** : Angle of inclination of the shear plane from the direction of cutting velocity


Vc'
Shear plane
a1
A
B
βo
a2
(βo - γo)
O
C
γo
Vc
πo

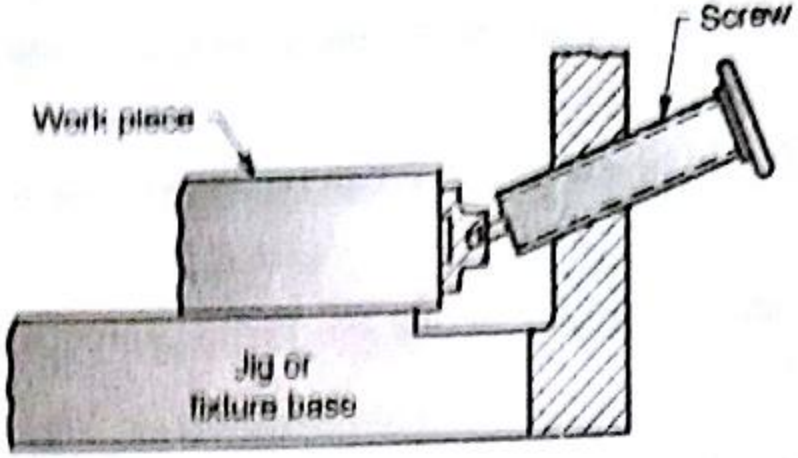
JIGS & FIXTURES CLAMPING DEVICES

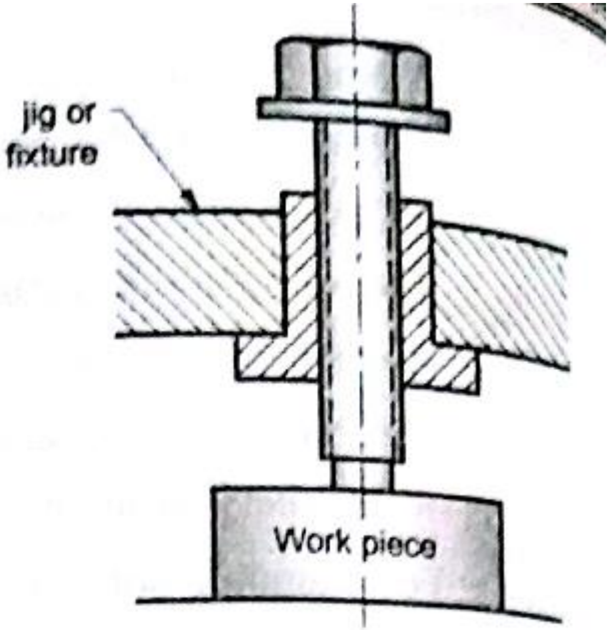
Production Technology
Mr. Kunalsinh Kathia
Mechanical Engineering Department

CLAMPING DEVICES

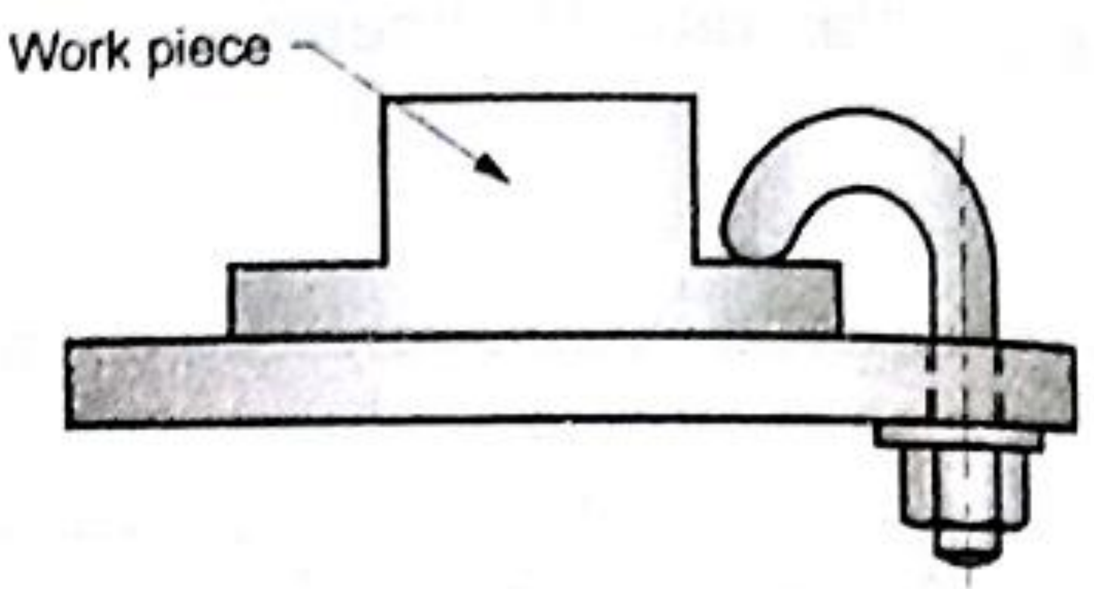
1. Screw clamps
2. Hook bolt clamps
3. Lever type clamps
4. Wedge clamps
5. Quick action clamps
6. Power clamps

SCREW CLAMPS





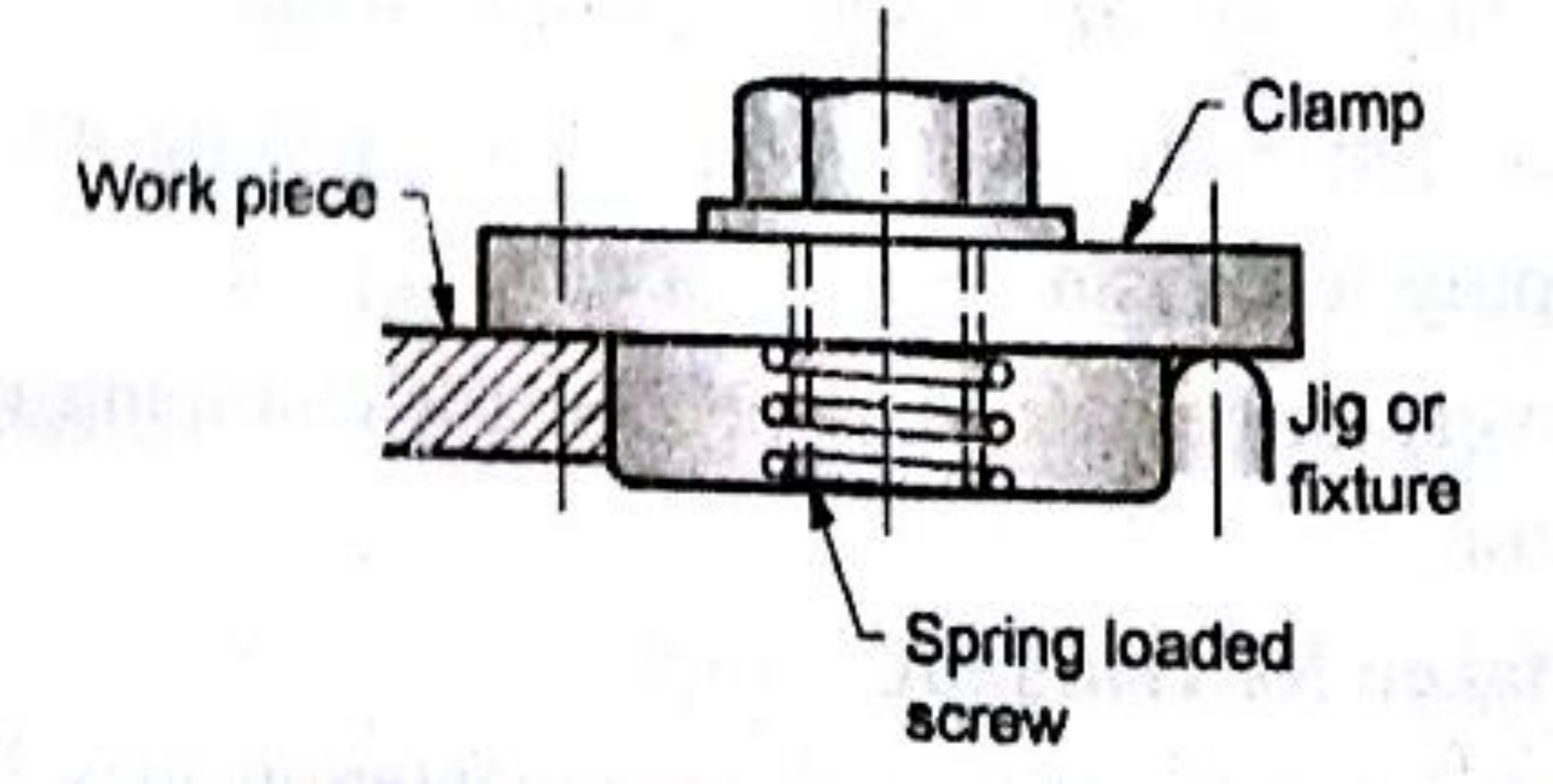
HOOK BOLT CLAMP



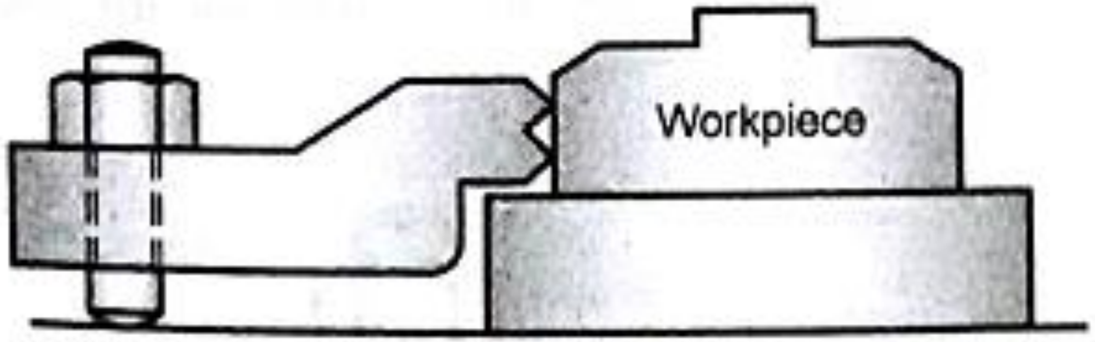
LEVER TYPE CLAMP

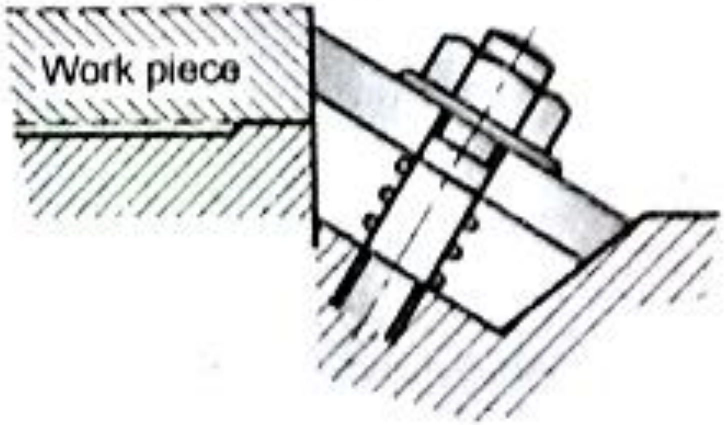
1. Simple Bridge type clamp
2. Edge clamp
3. Heel Clamp
4. Latch Clamp
5. Hinged Clamp

SAMPLE BRIDGE TYPE CLAMP

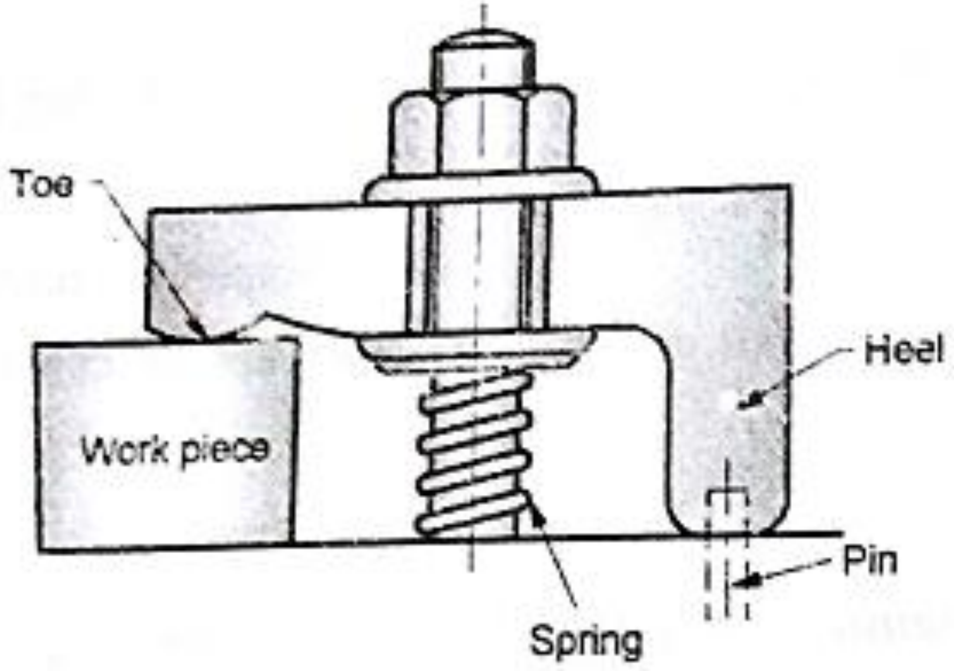


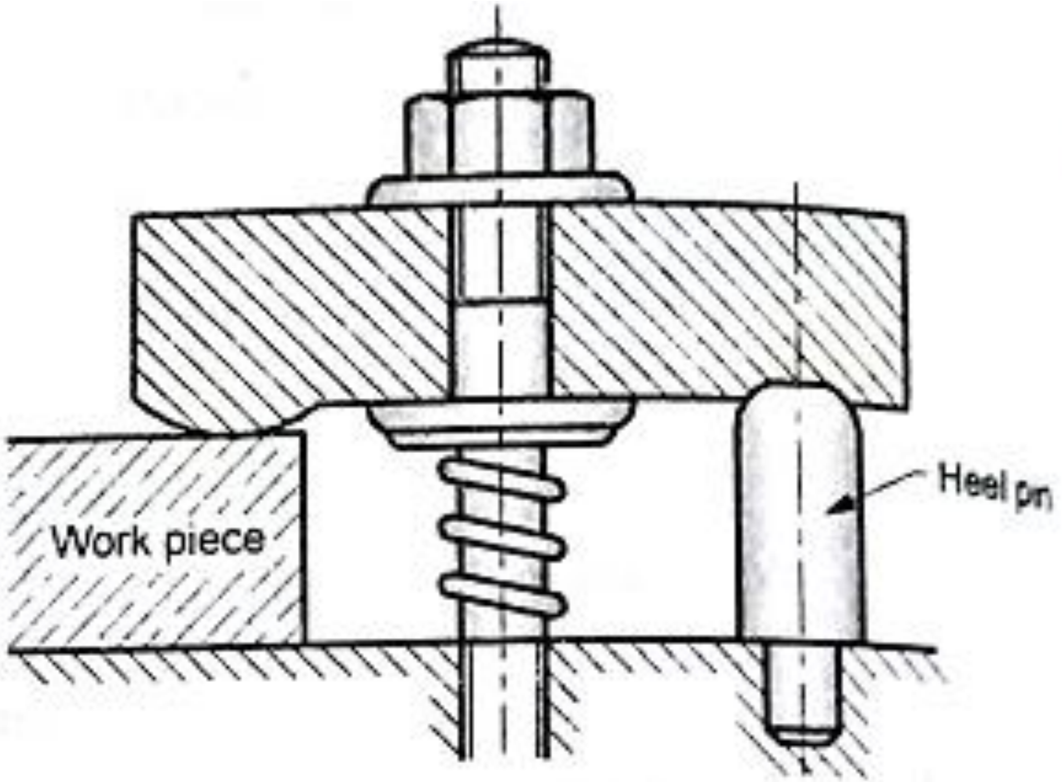
EDGE CLAMP



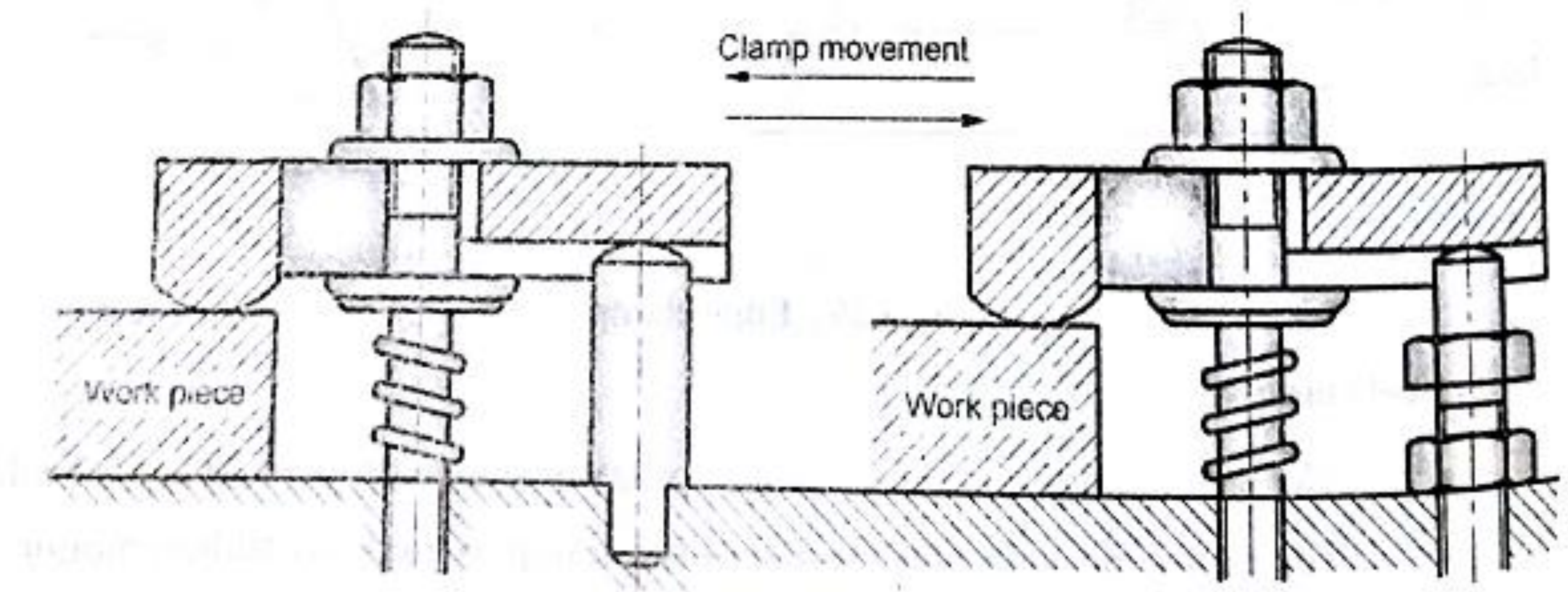


HEEL CLAMP



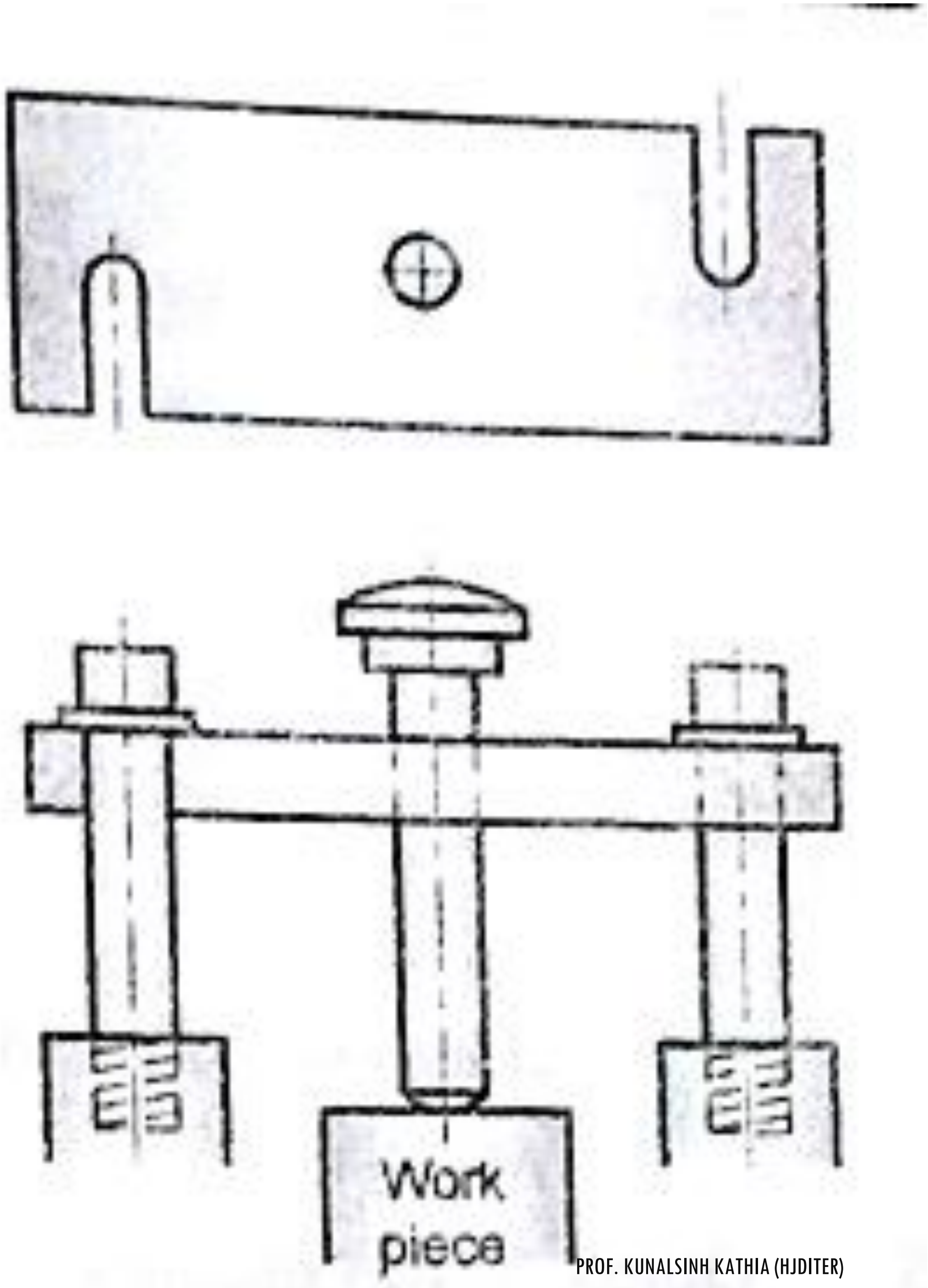


SLIDING HEEL CLAMP

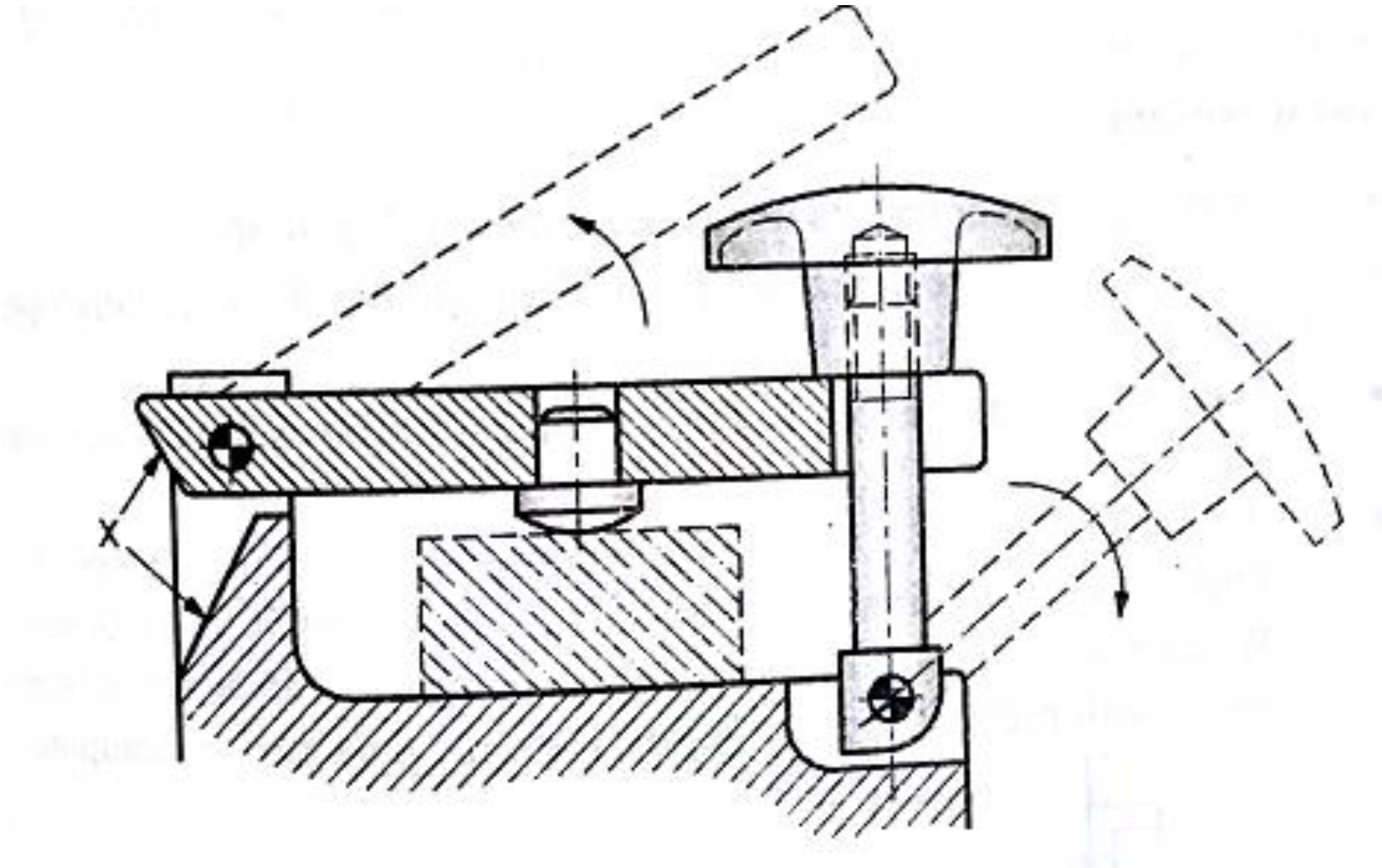


LATCH CLAMP

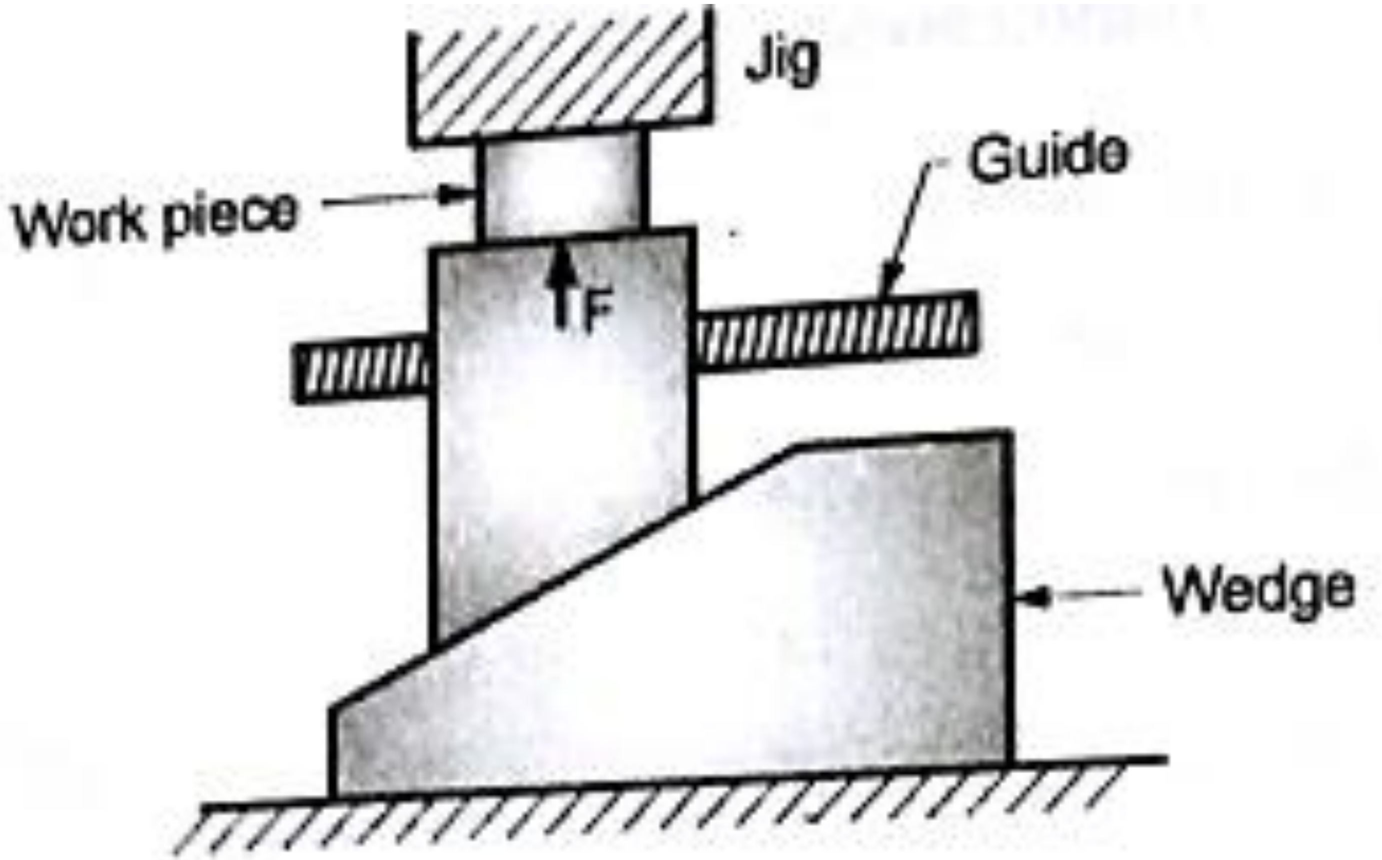
Swinging latch clamp:



HINGED CLAMP



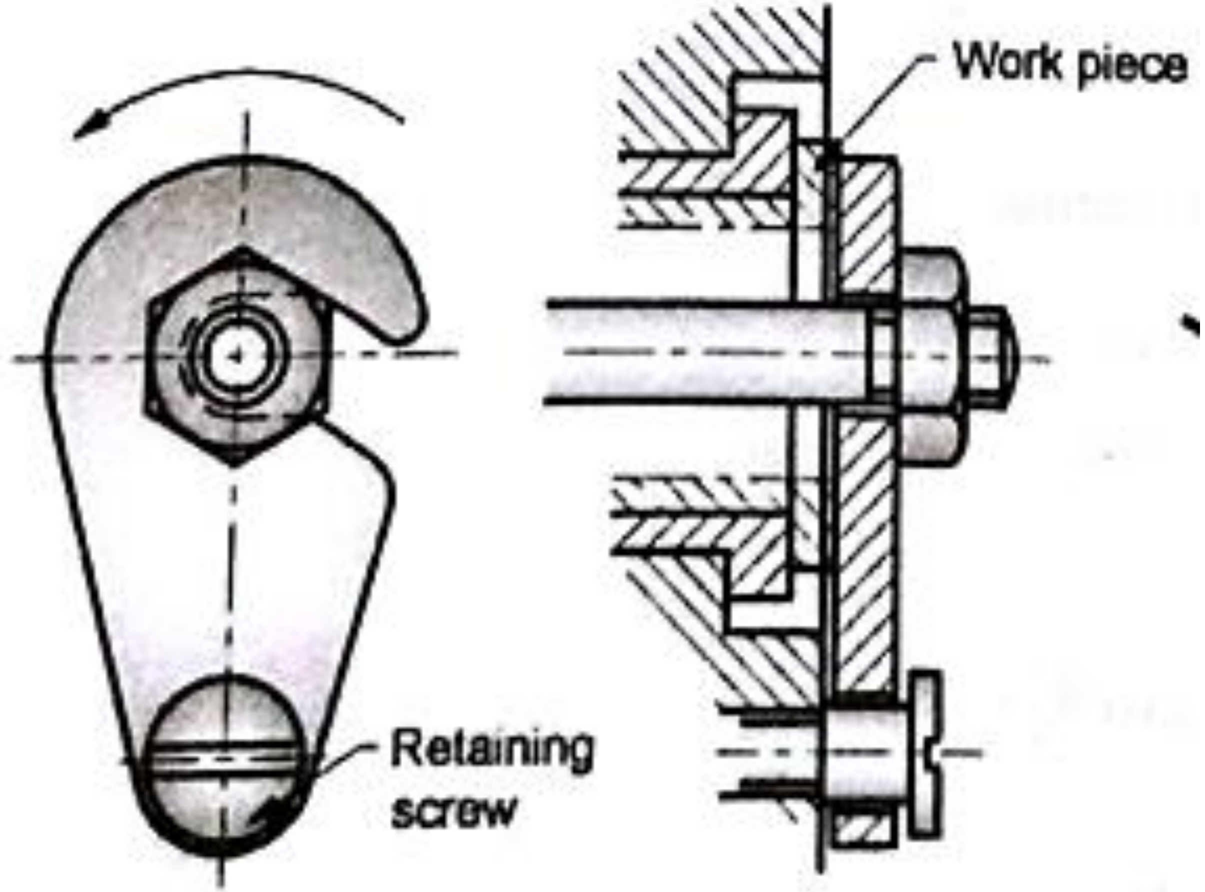
WEDGE CLAMP



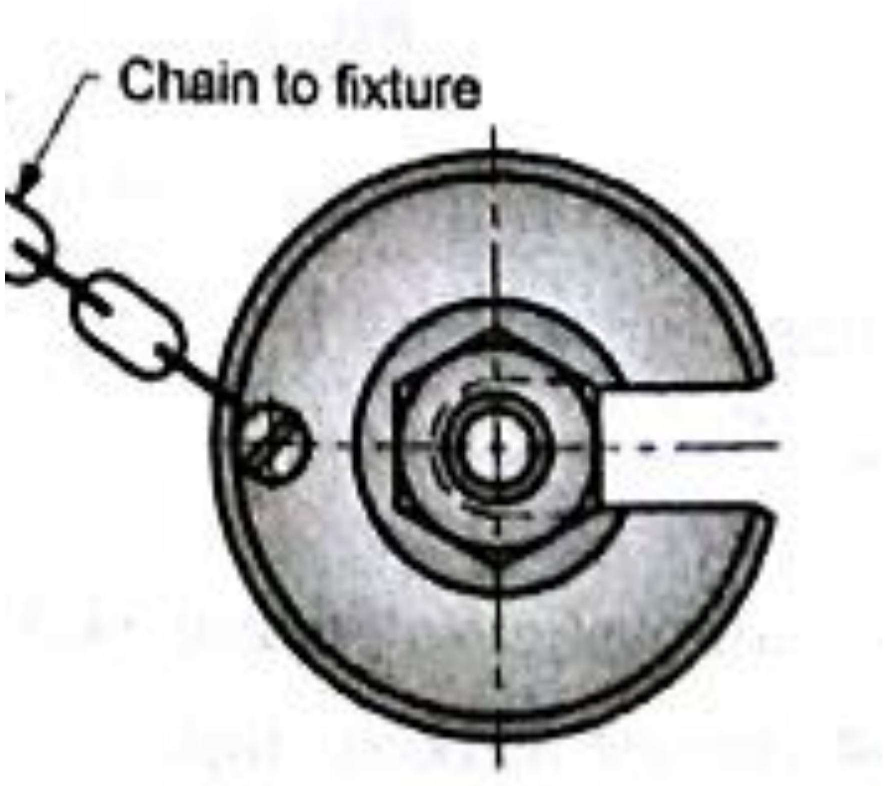
QUICK ACTION CLAMPS

1. Swing washers and C washer clamps
2. Quick action nuts
3. Cam operated clamps
4. Toggle operated clamp
5. Bayonet clamp

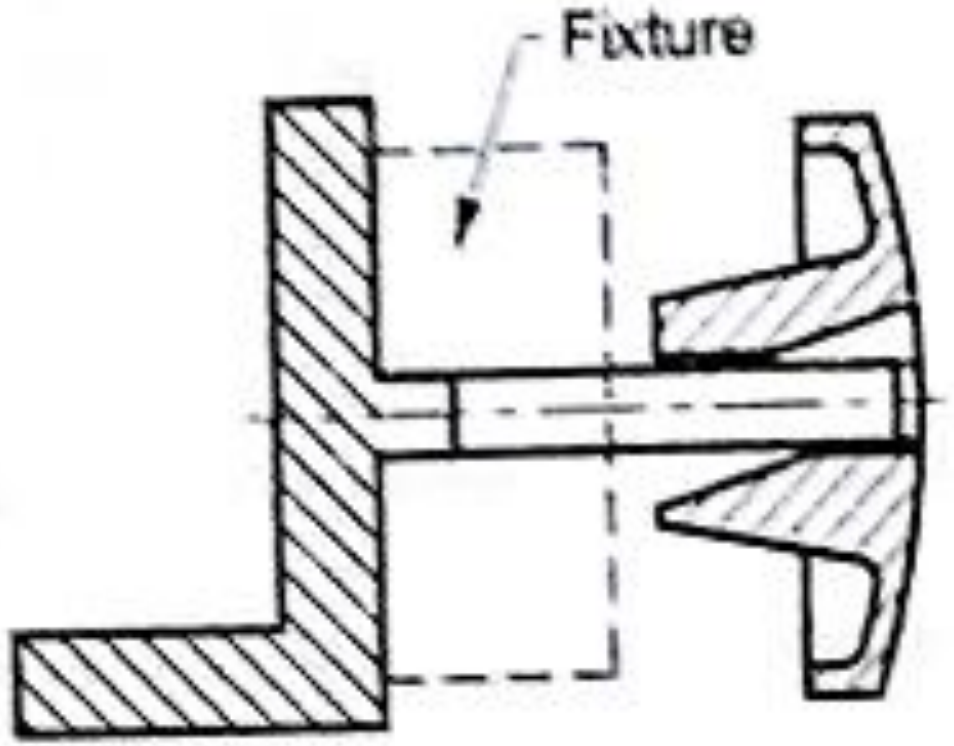
SWING WASHER CLAMP



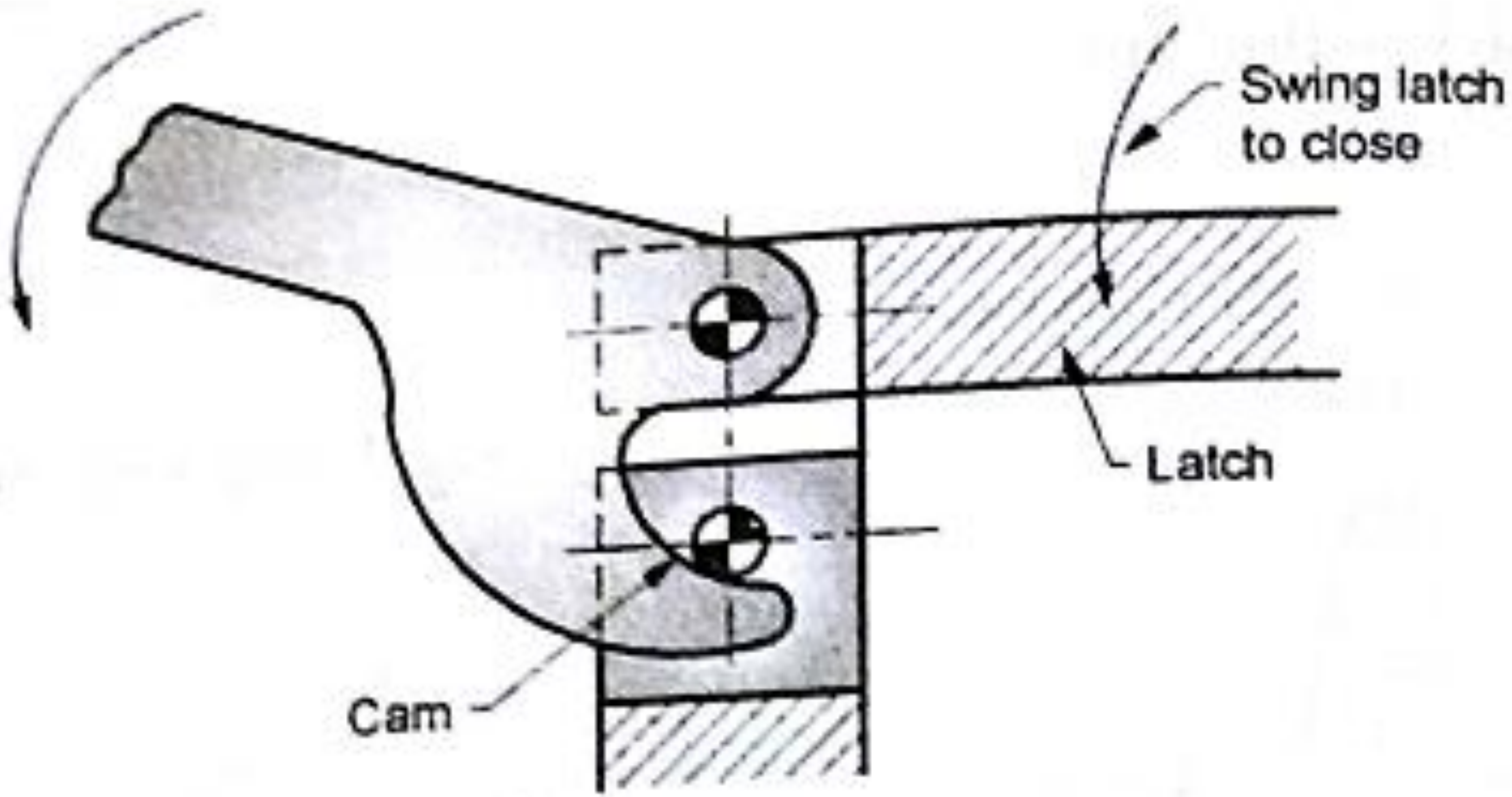
C WASHER CLAMP



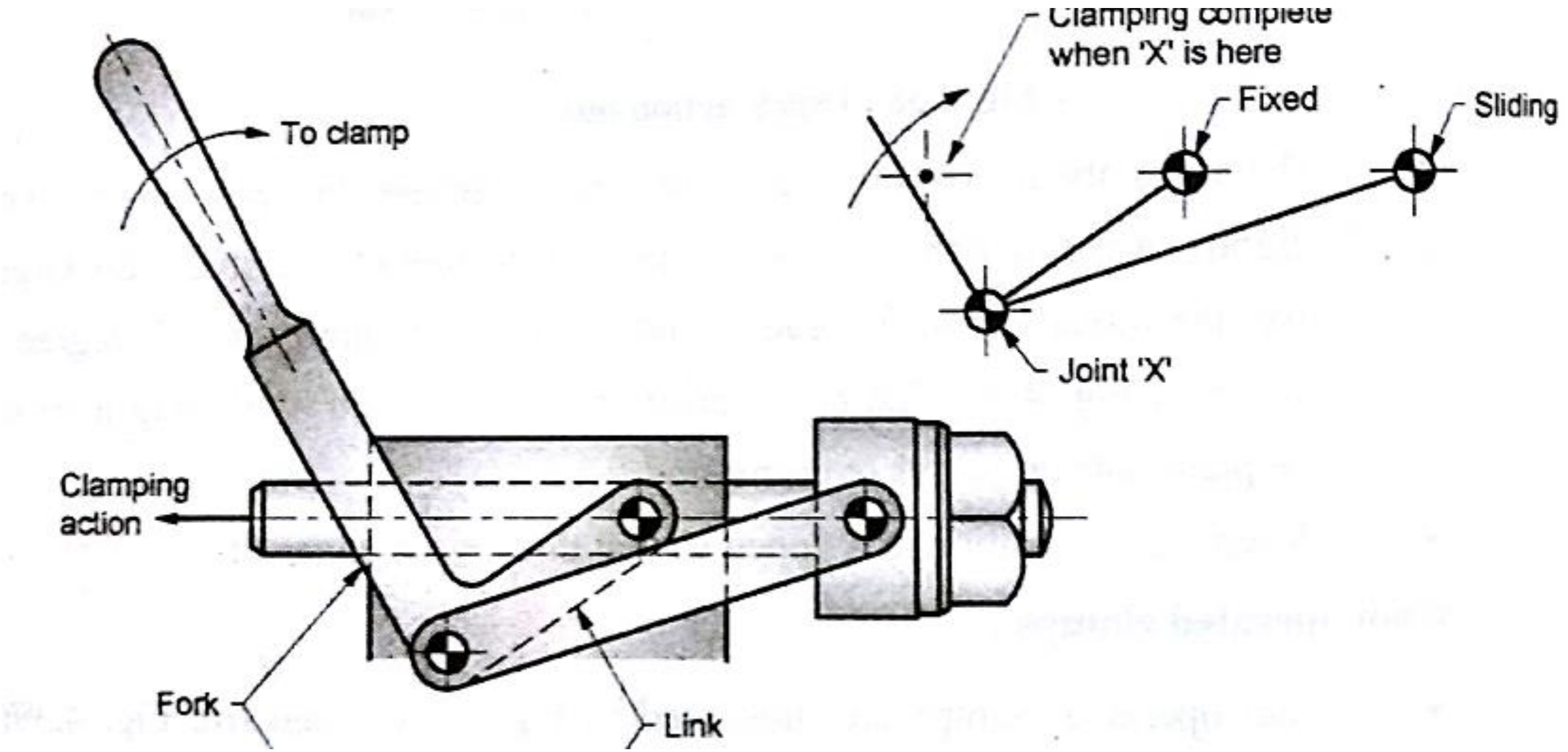
QUICK ACTION NUT



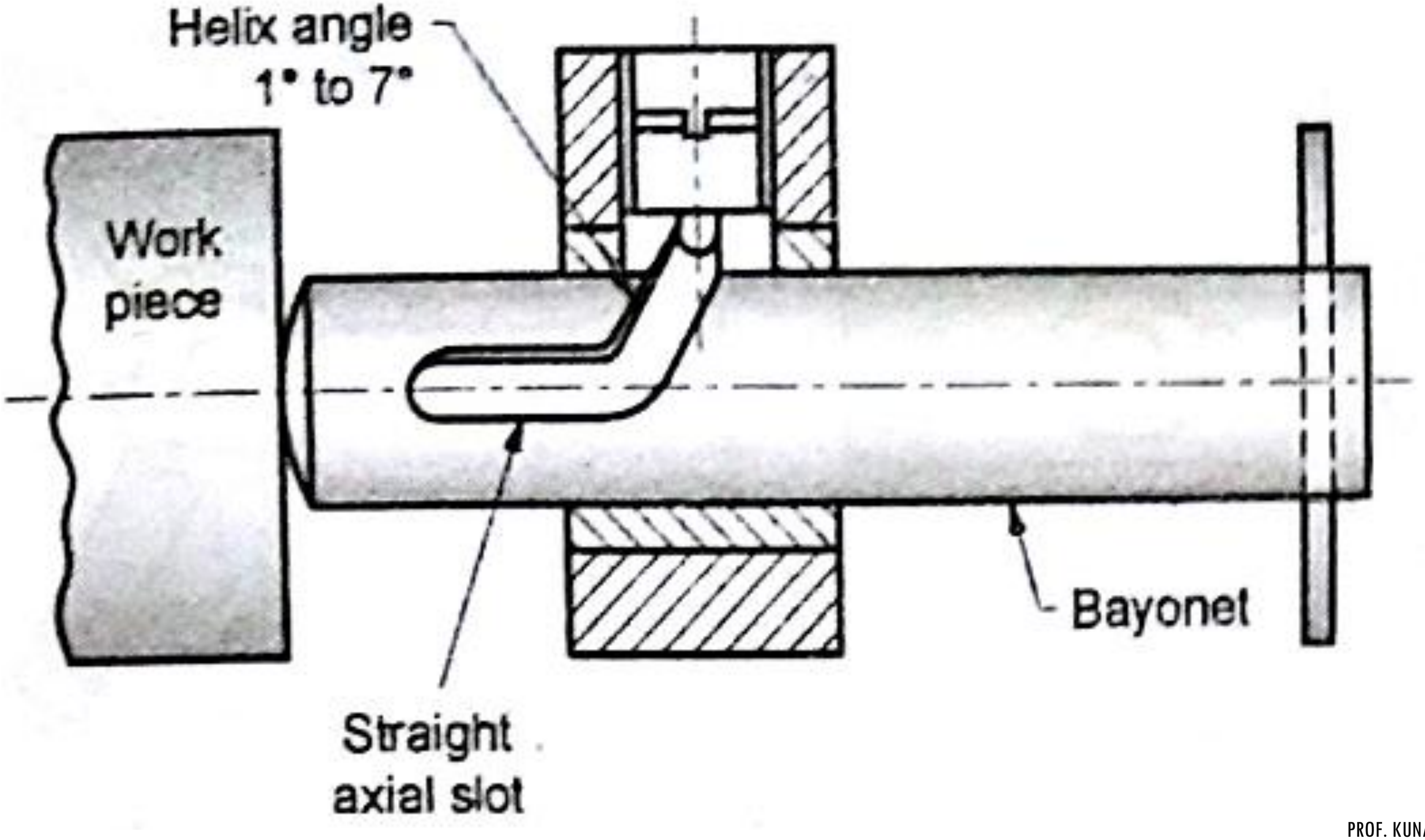
CAM OPERATED CLAMP



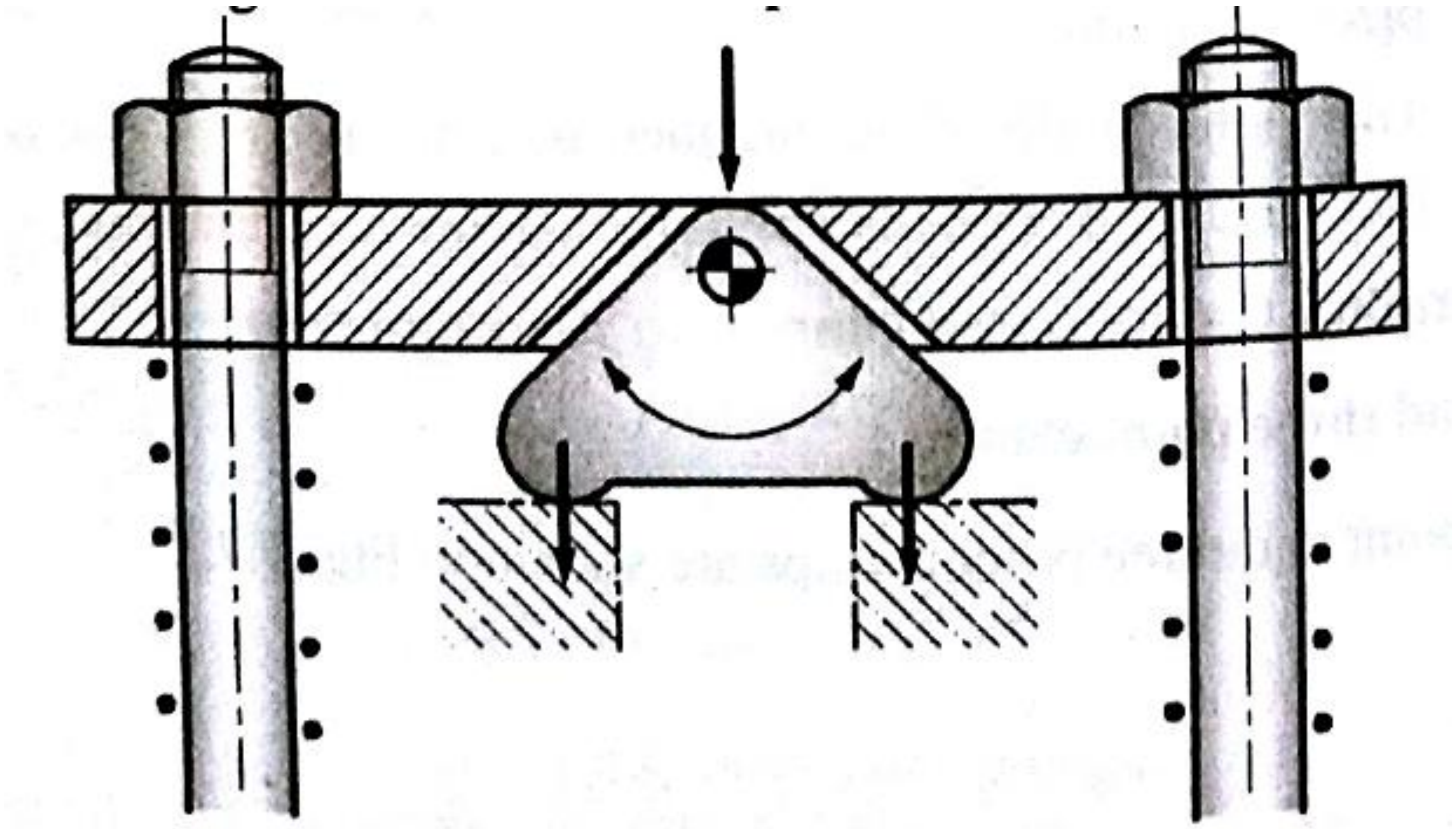
TOGGLE OPERATED CLAMP



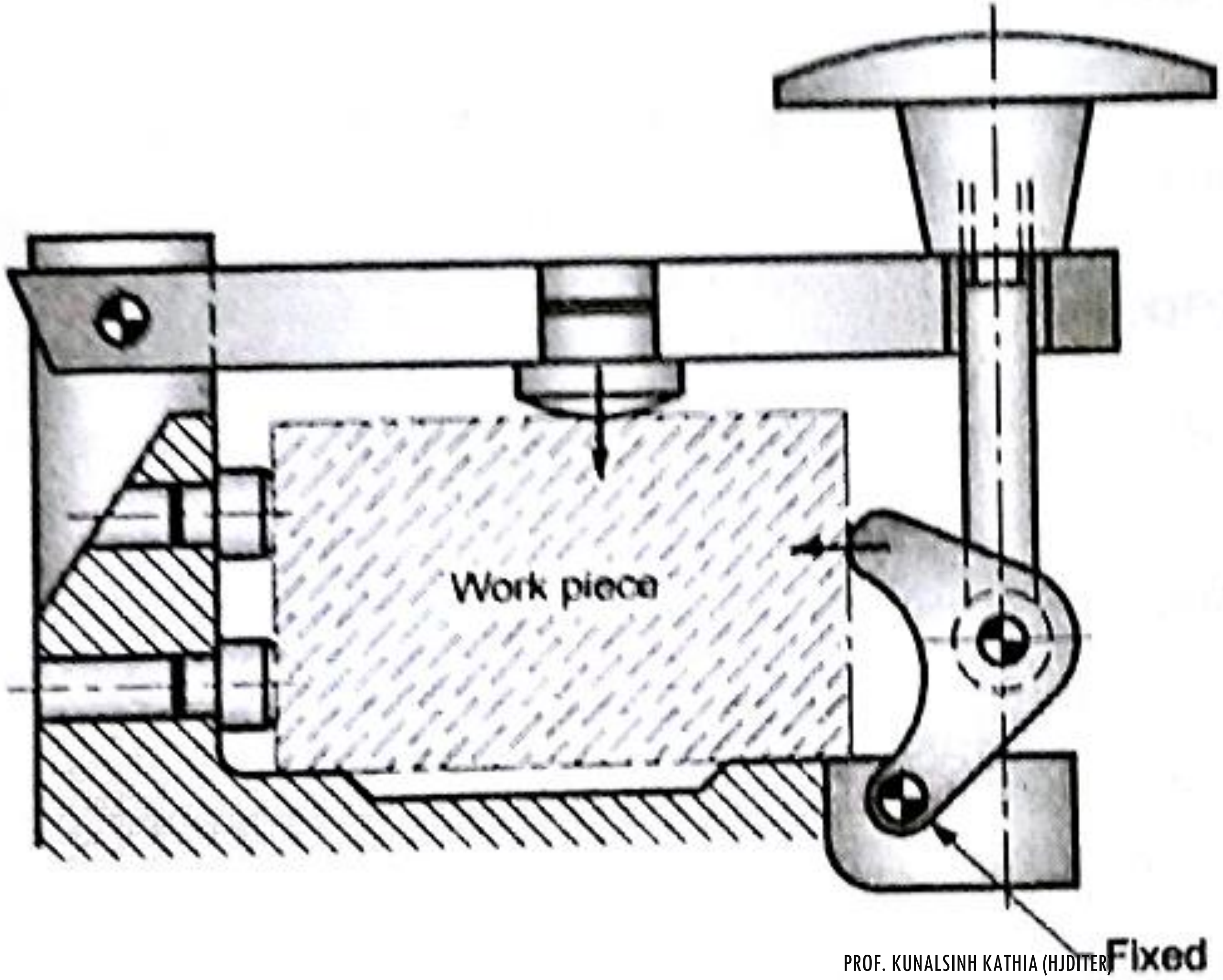
BAYONET CLAMP



EQUALISING CLAMP



TWO WAY CLAMP



POWER CLAMPING

The mechanical clamping methods described so far suffer from the following disadvantages.

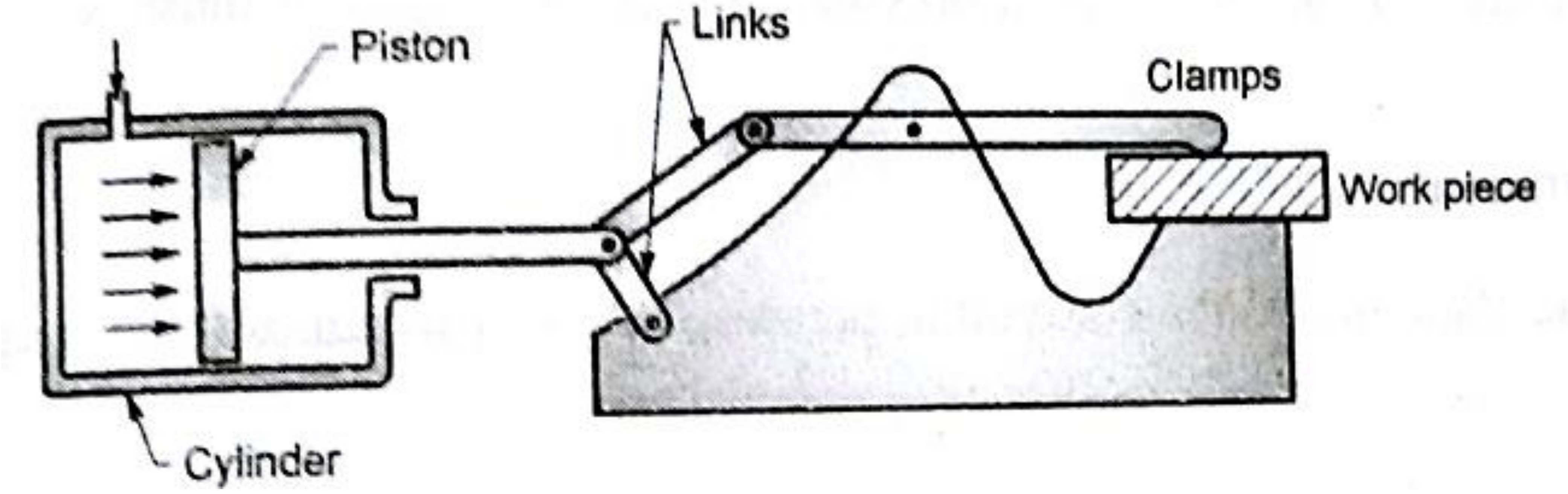
(1) The clamping pressure available is limited.

(2) The time required for clamping is long.

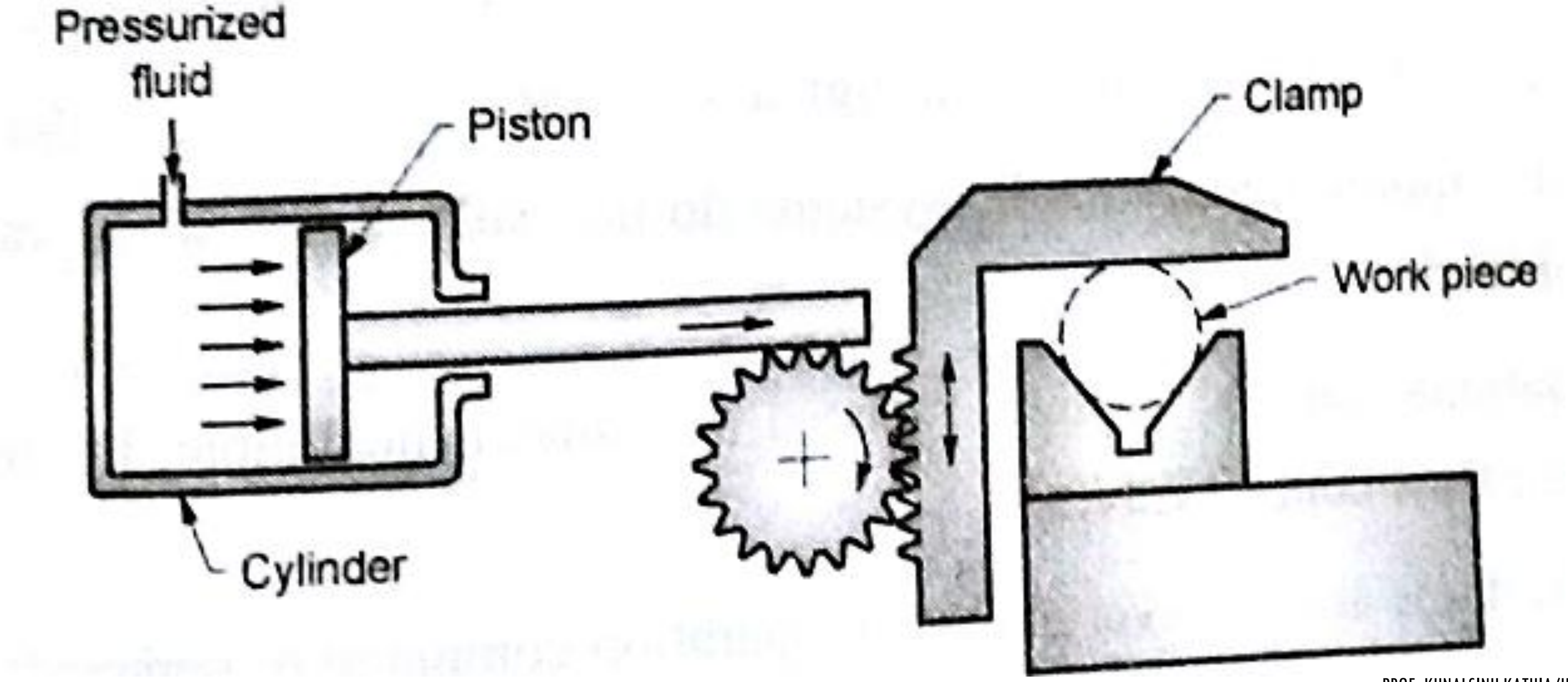
(3) Clamping pressure varies from one component to another.

(4) Operator fatigue is inevitable.

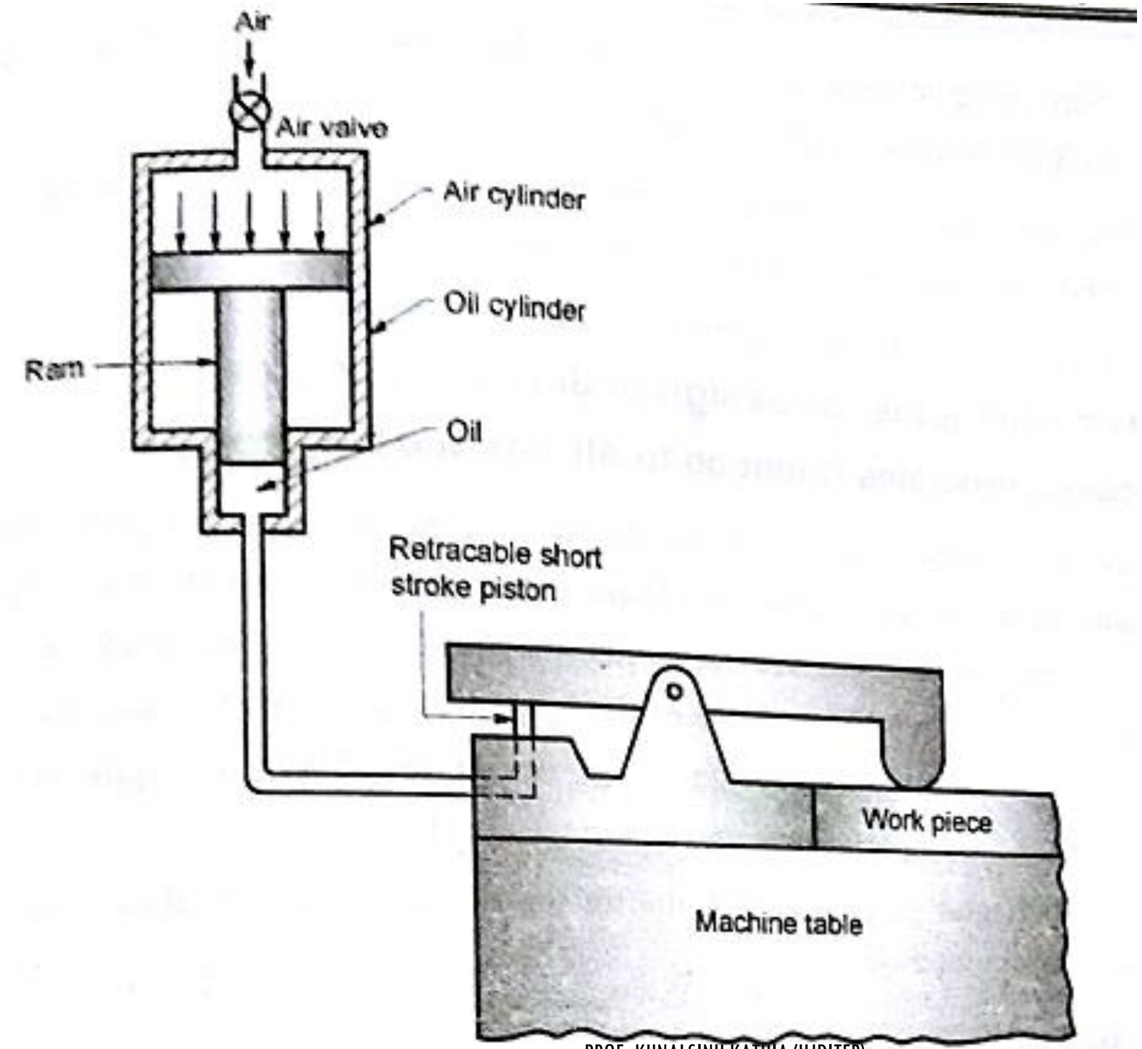
FLUID POWER CLAMP



FLUID POWER CLAMPING (RACK & PINION)



AIR TO HYDRAULIC BOOSTER

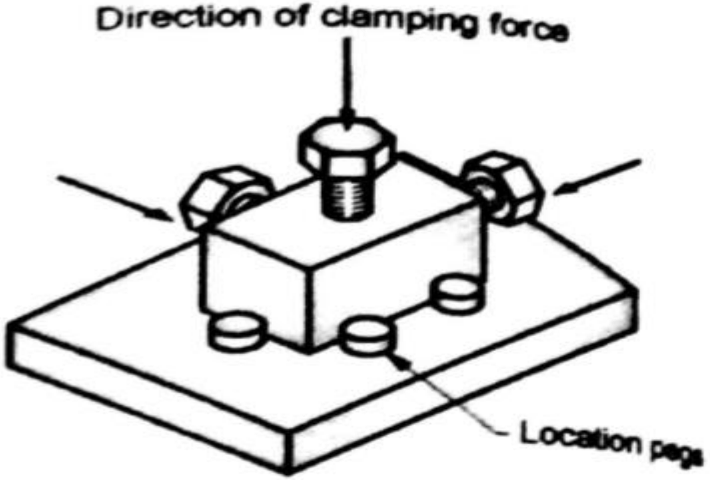


JIGS & FIXTURES

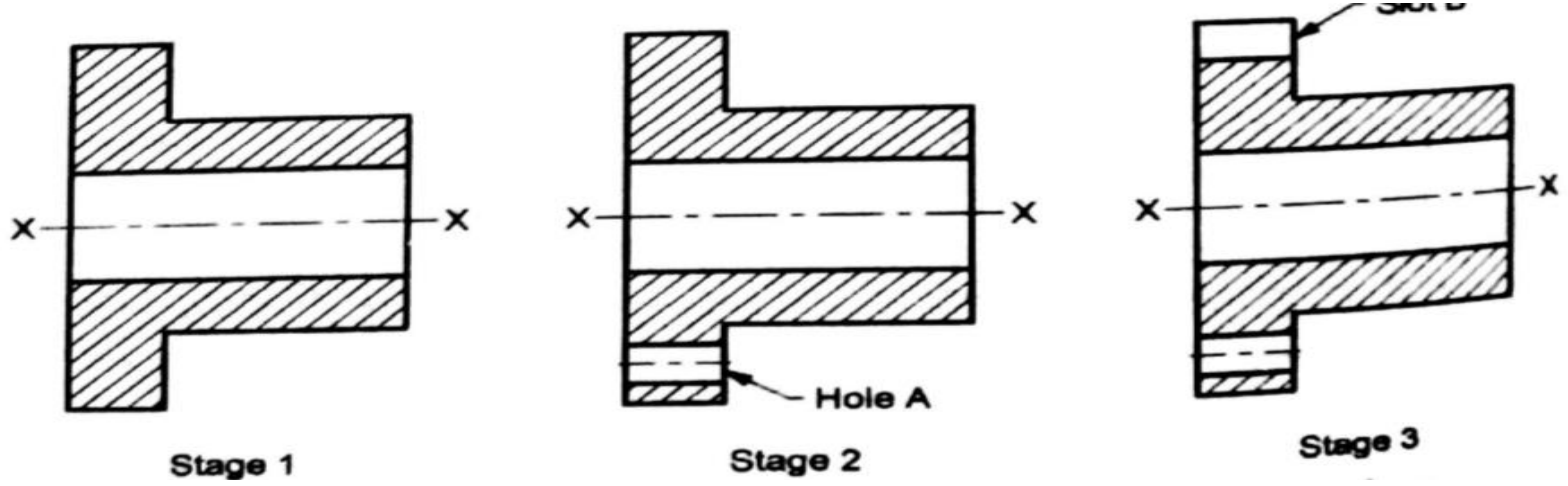
Production technology

Prof. Kunalsinh kathia
Mechanical engineering department

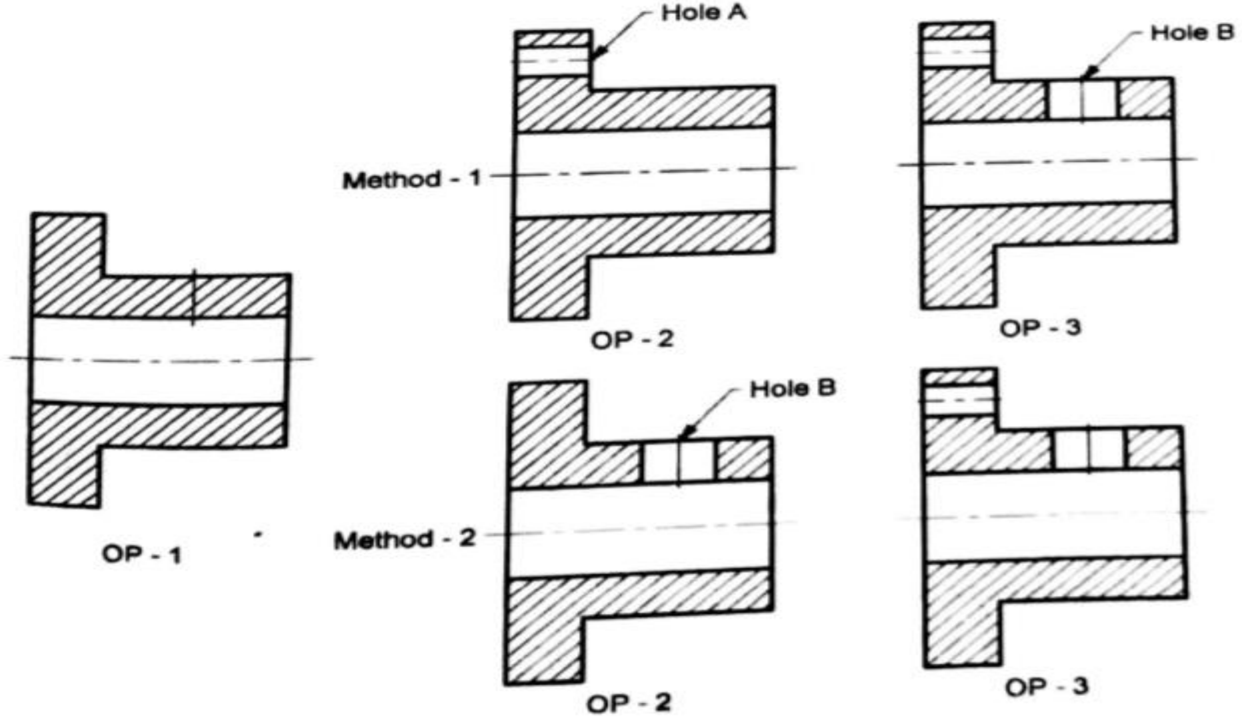
6 degree of freedom



3 stages in machining of cylindrical workpeice



2 stages of machining



Pads pin and buttons

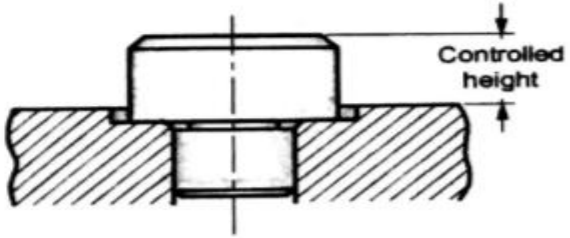


Fig. 4.7 : Location pad

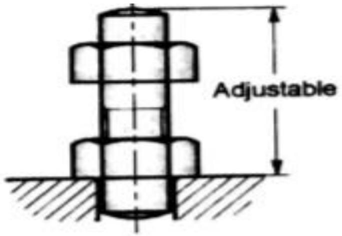


Fig. 4.8 : Adjustable pin (pad)

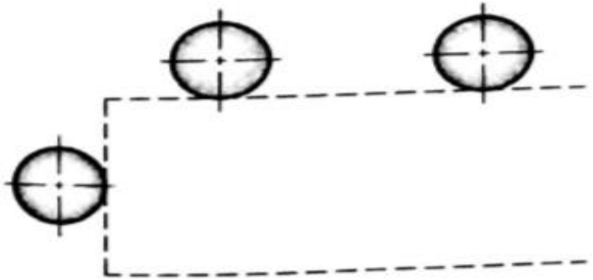


Fig. 4.9 : Pins used to locate a rectangular work piece

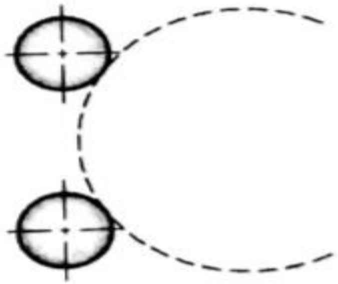
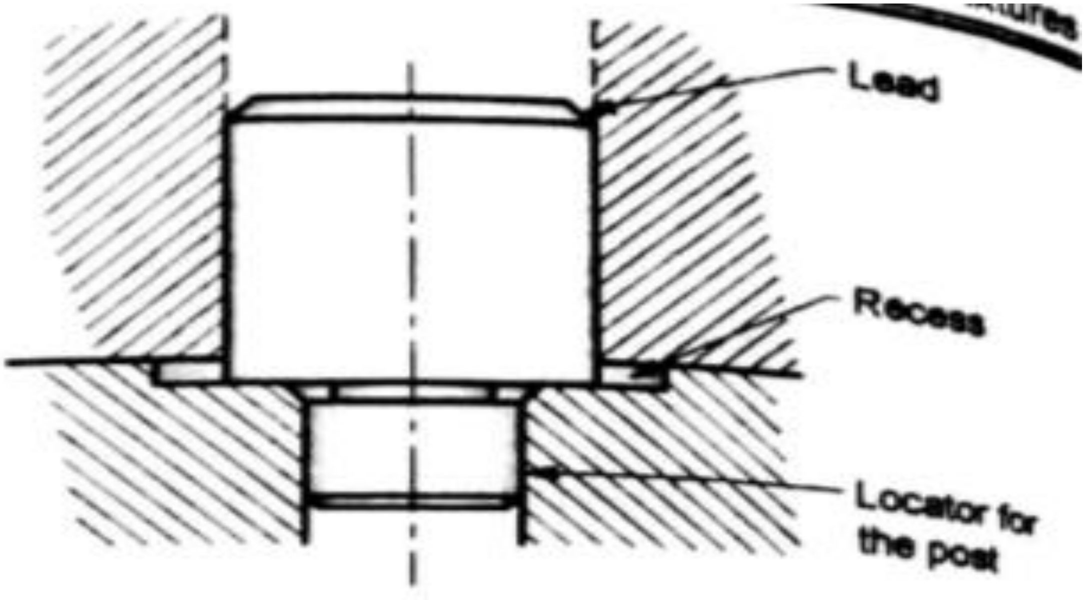


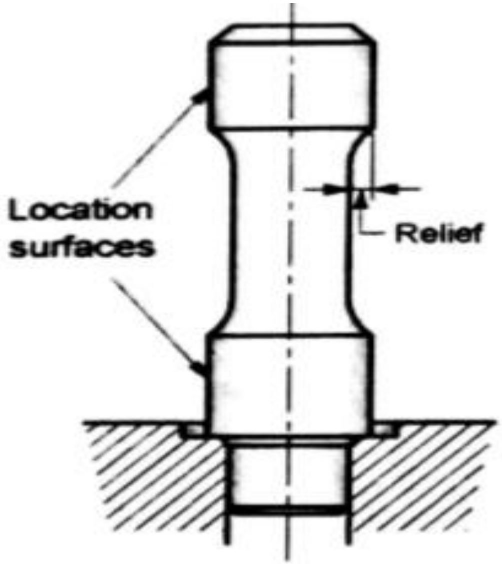
Fig. 4.10 : Pins used to locate cylindrical work piece

Cylindrical locators

Short cylindrical locator



Cylindrical locators



g. 4.12 : Long location post with central portion relieved

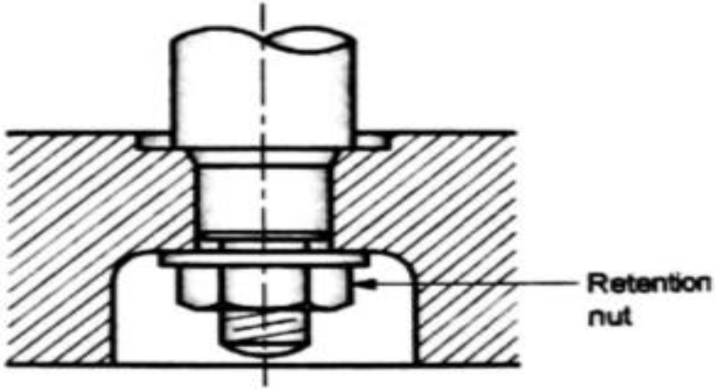
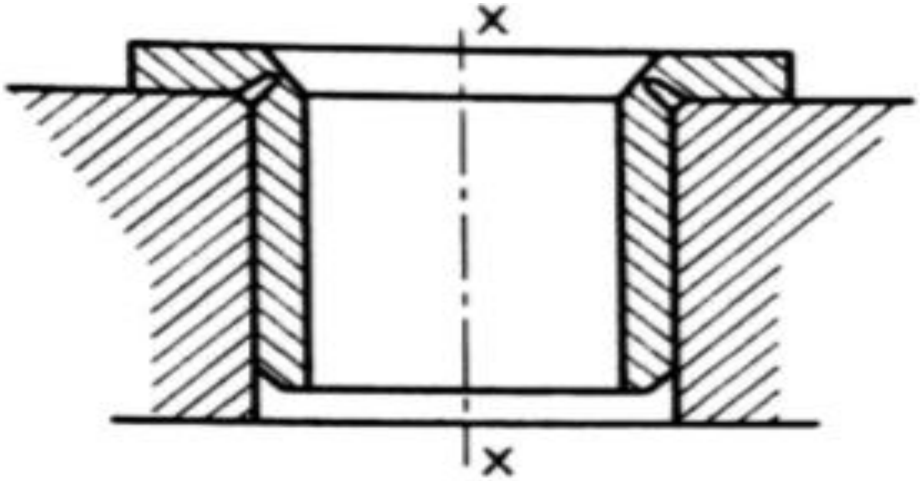


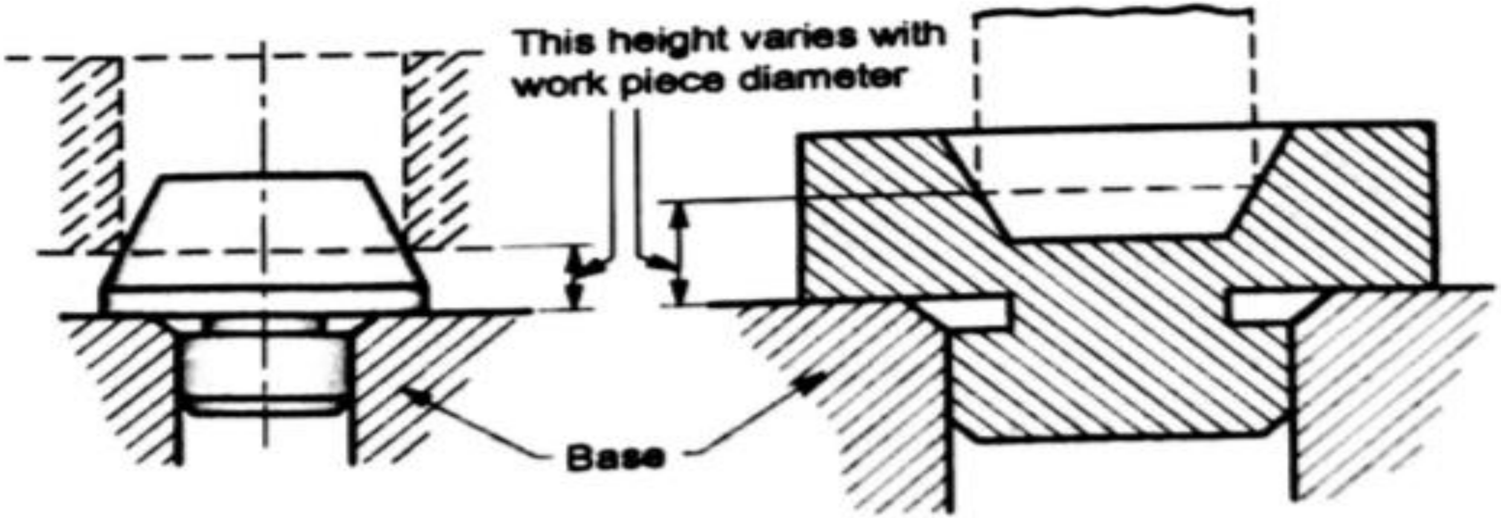
Fig. 4.13 : Locator retention by the use of a nut

Location pot

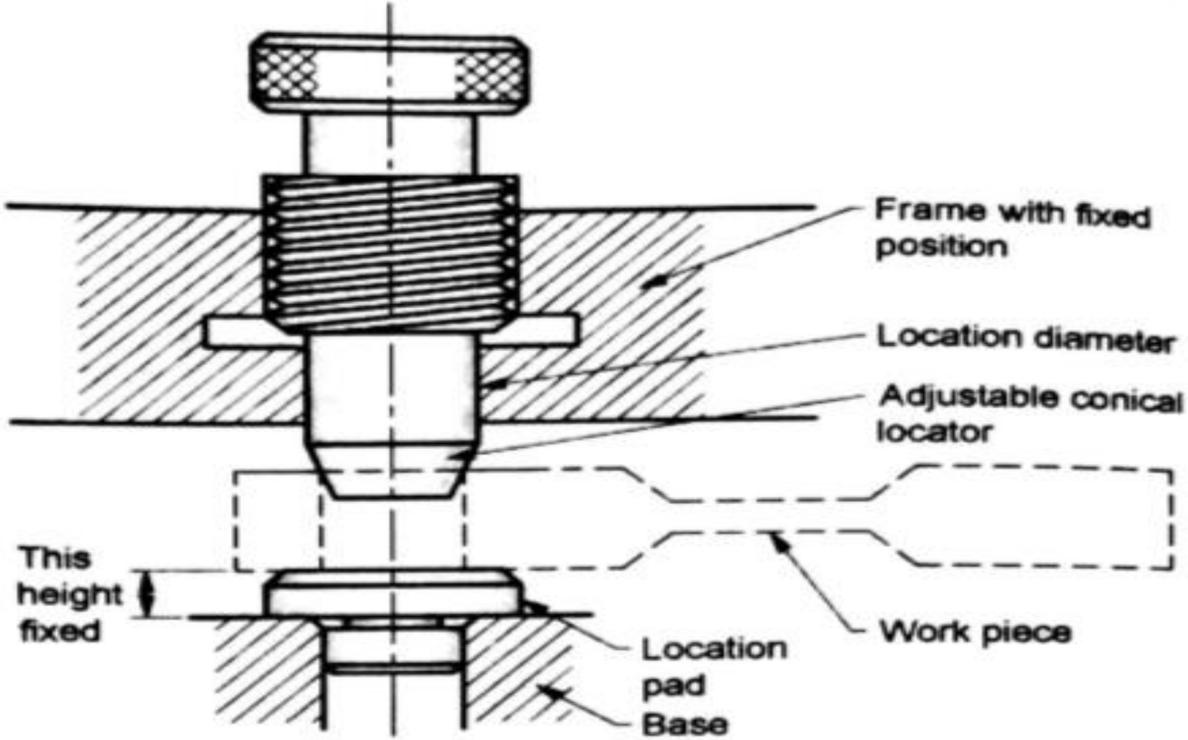


Conical locators

Fixed conical post and pot locators



Adjustable conical locators



Drill Bushes & Jigs

Prof. Kunalsinh Kathia

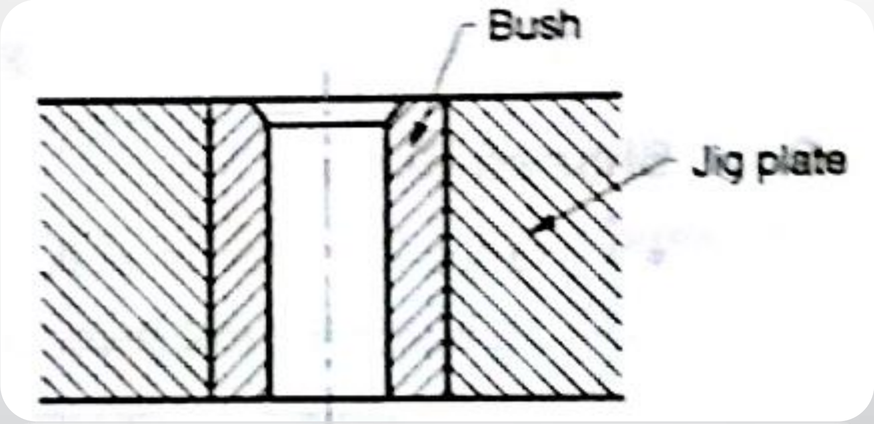
Mechanical Engineering Department

HJD INSTITUTE KERA

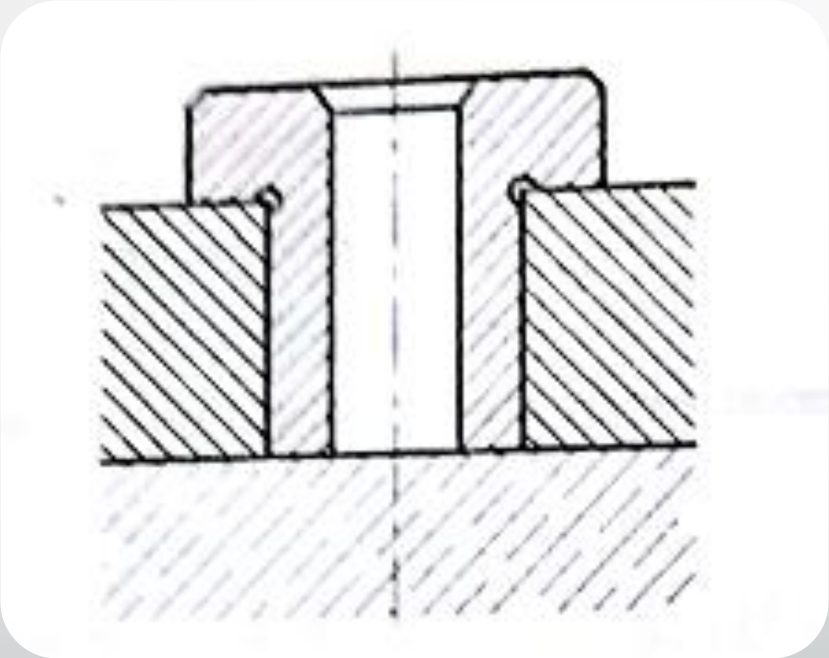
Types of Bush

- Headless plain bush
- Headed bush
- Shaped bush
- Extended bush
- Long bush in two sections
- Renewable bush
- Slip Bush
- Bushes with flats
- Bushes with light clamping
- Bushes to control hole depth

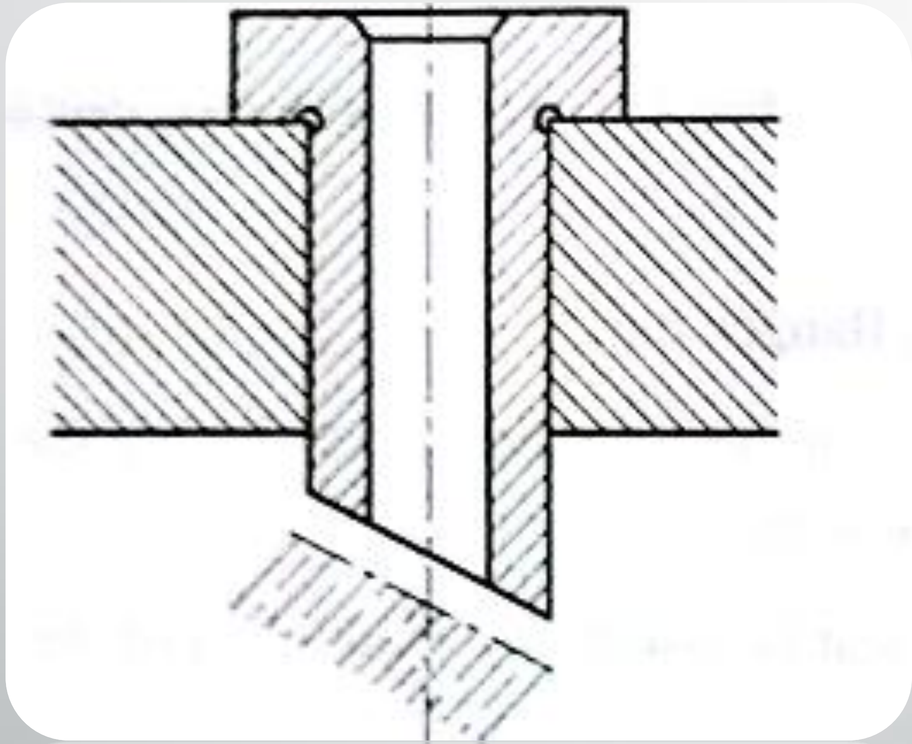
Headless plain bush

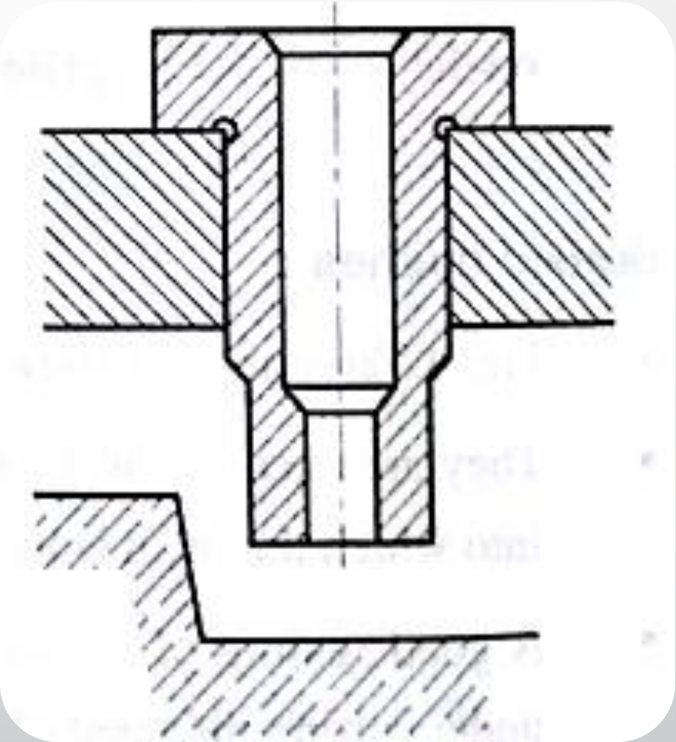


Headed Bush

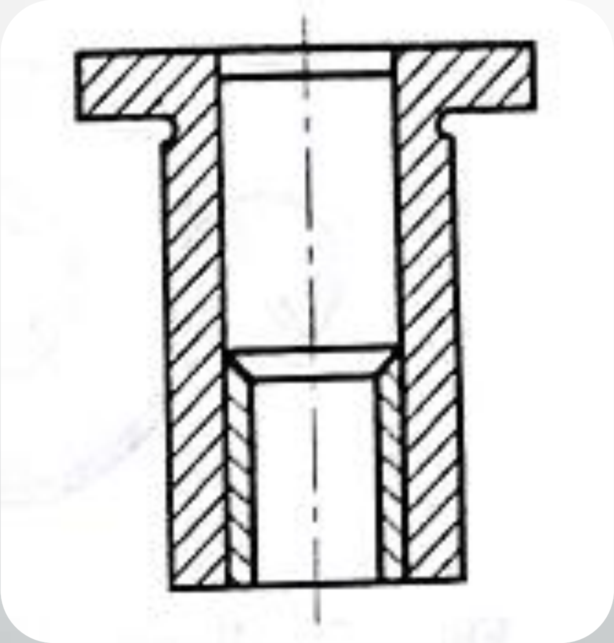


Shape drill bush & Extended type

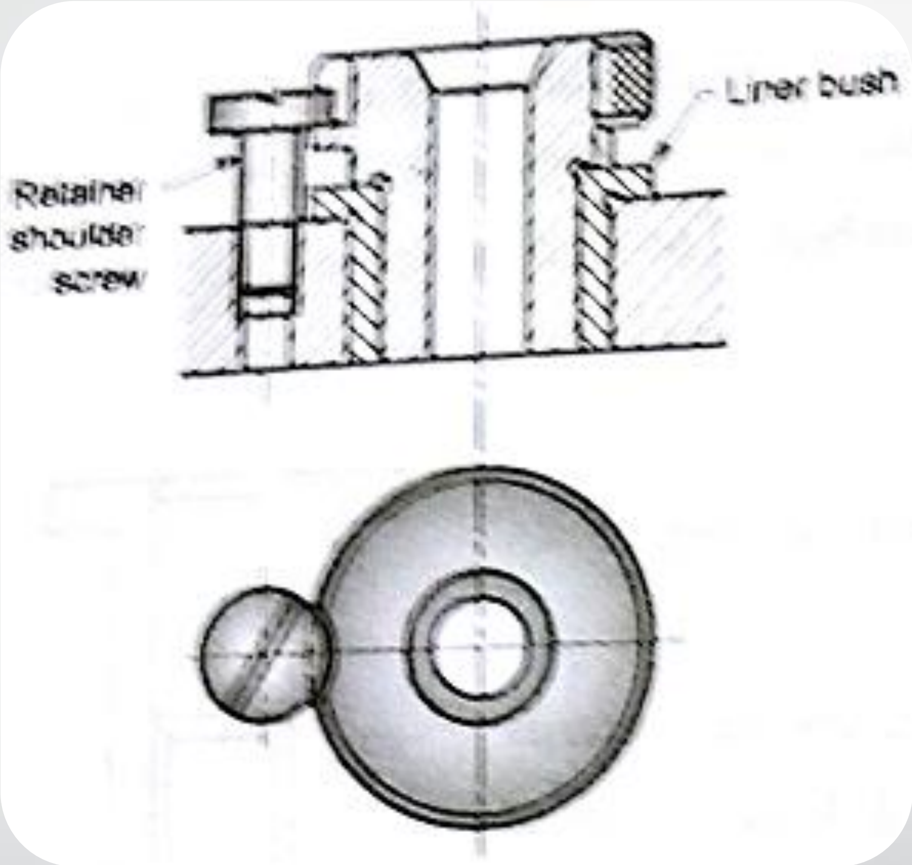




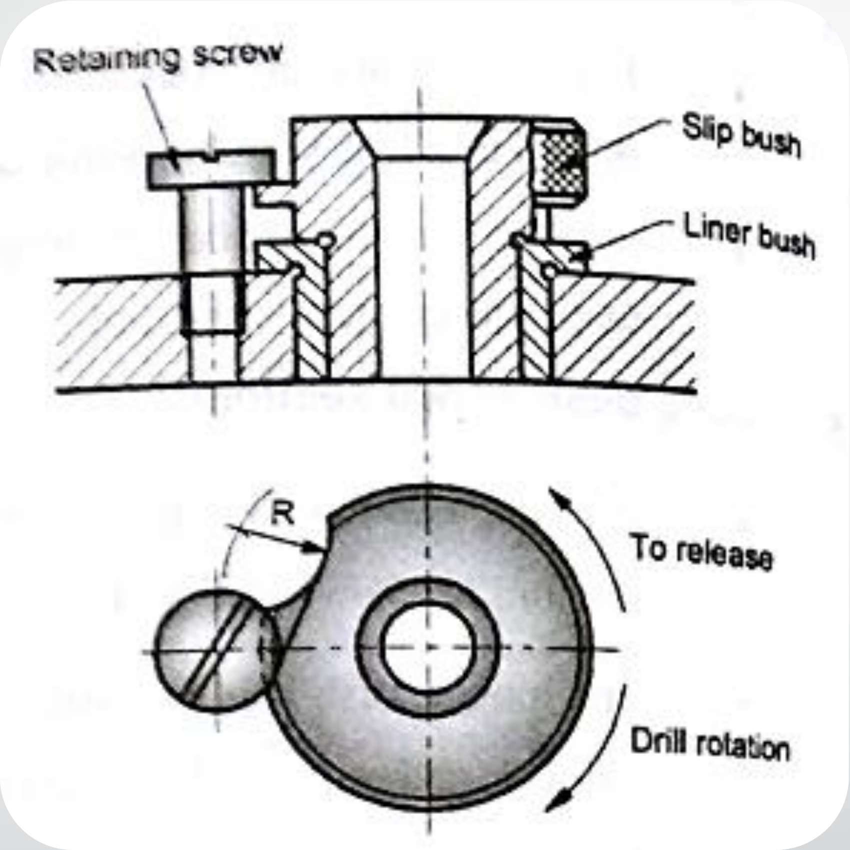
Long bush in two sections



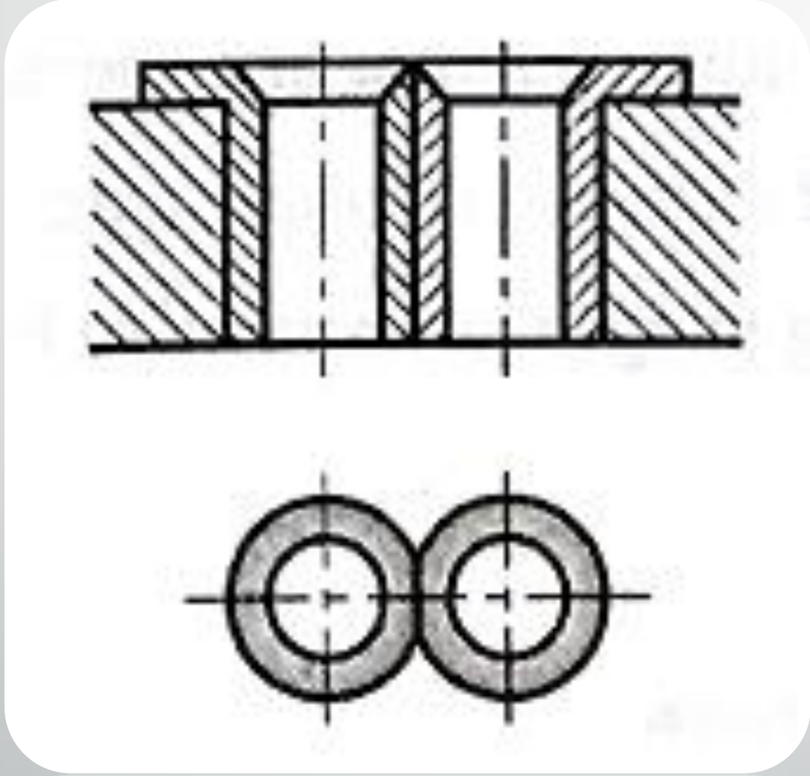
Renewable type bush

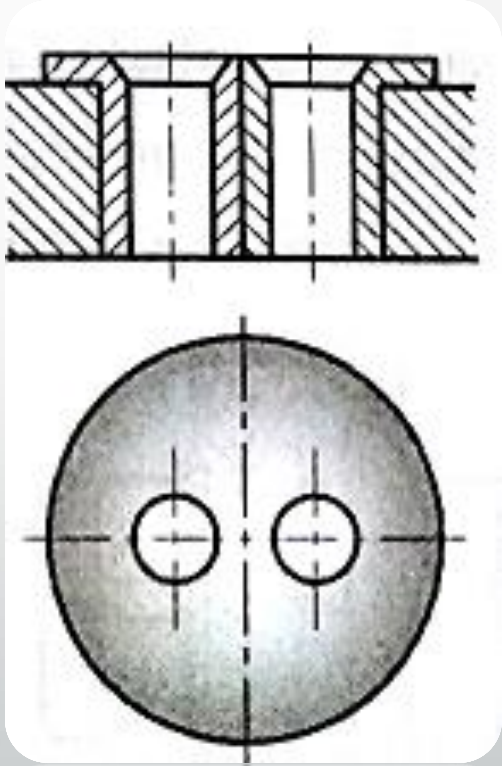


Slip type bush

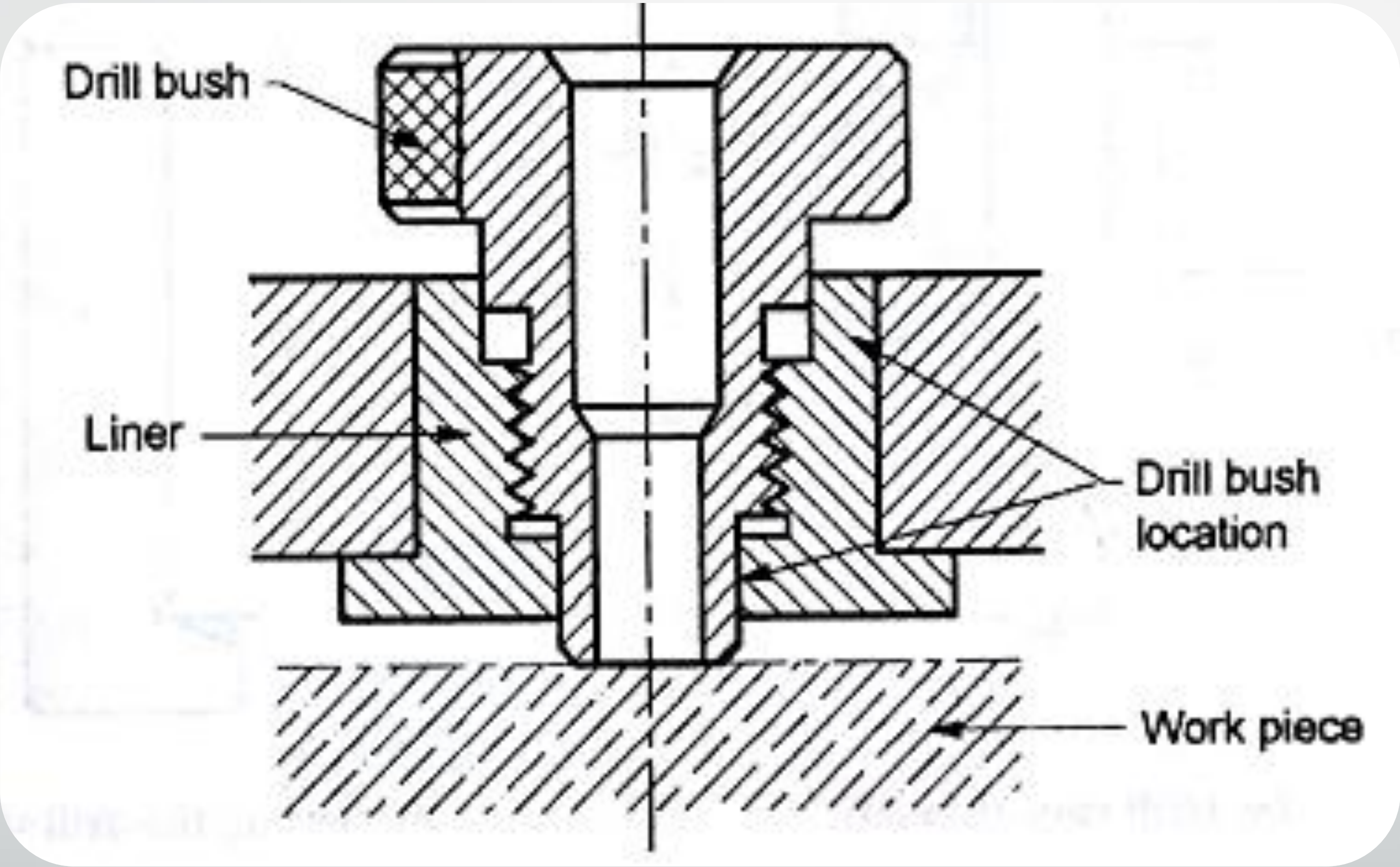


Bushes with flats

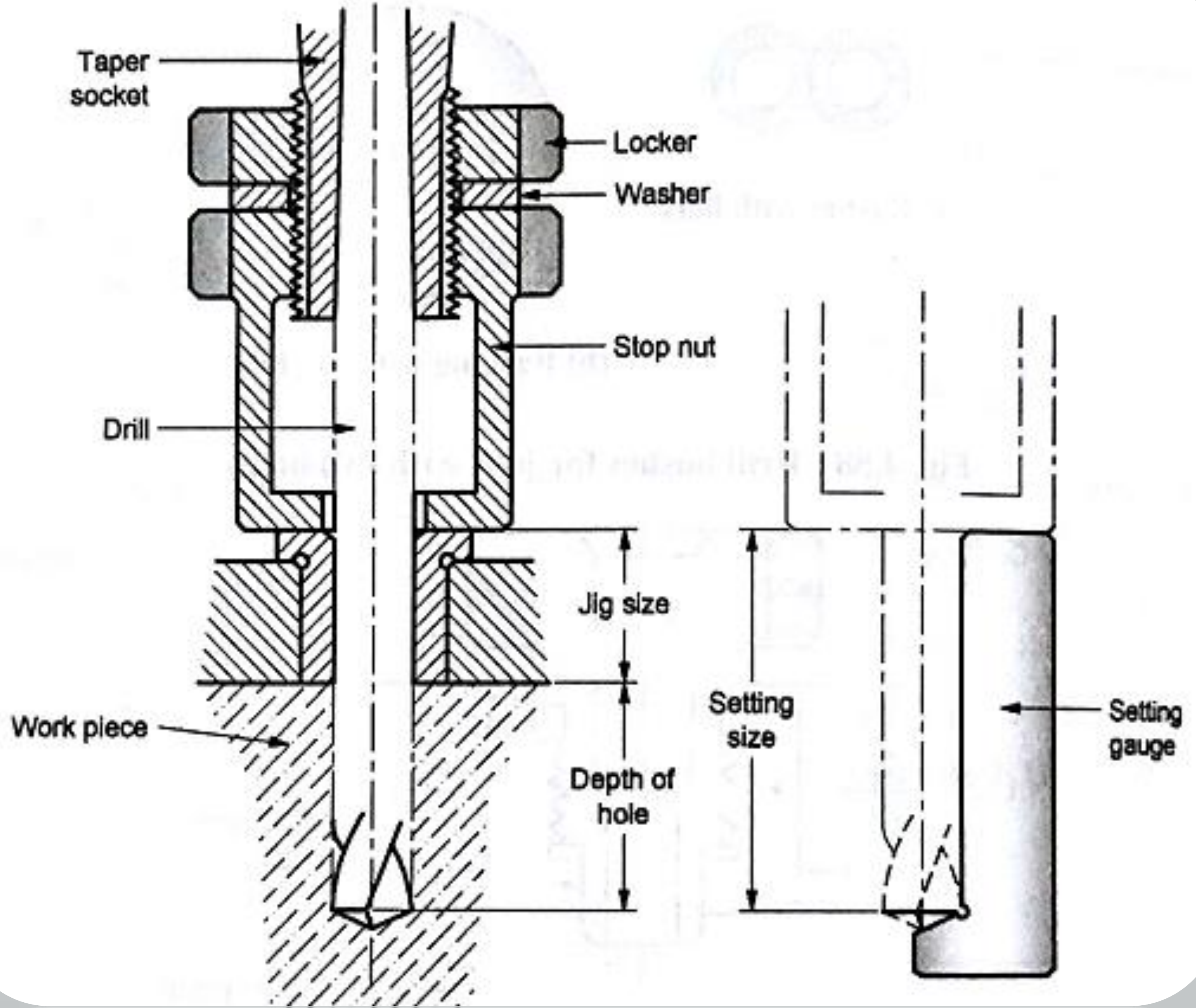




Drill bushes for light clamping



Drill bush to control hole depth



Drill Jigs

1. Template jig
2. Plate jig
3. Channel jig
4. Diameter jig
5. Solid jig
6. Post jig
7. Angular post jig
8. Turn over jig
9. Box jig
10. Latch or head type jig
11. Sandwich jig
12. Indexing jig

Template jig

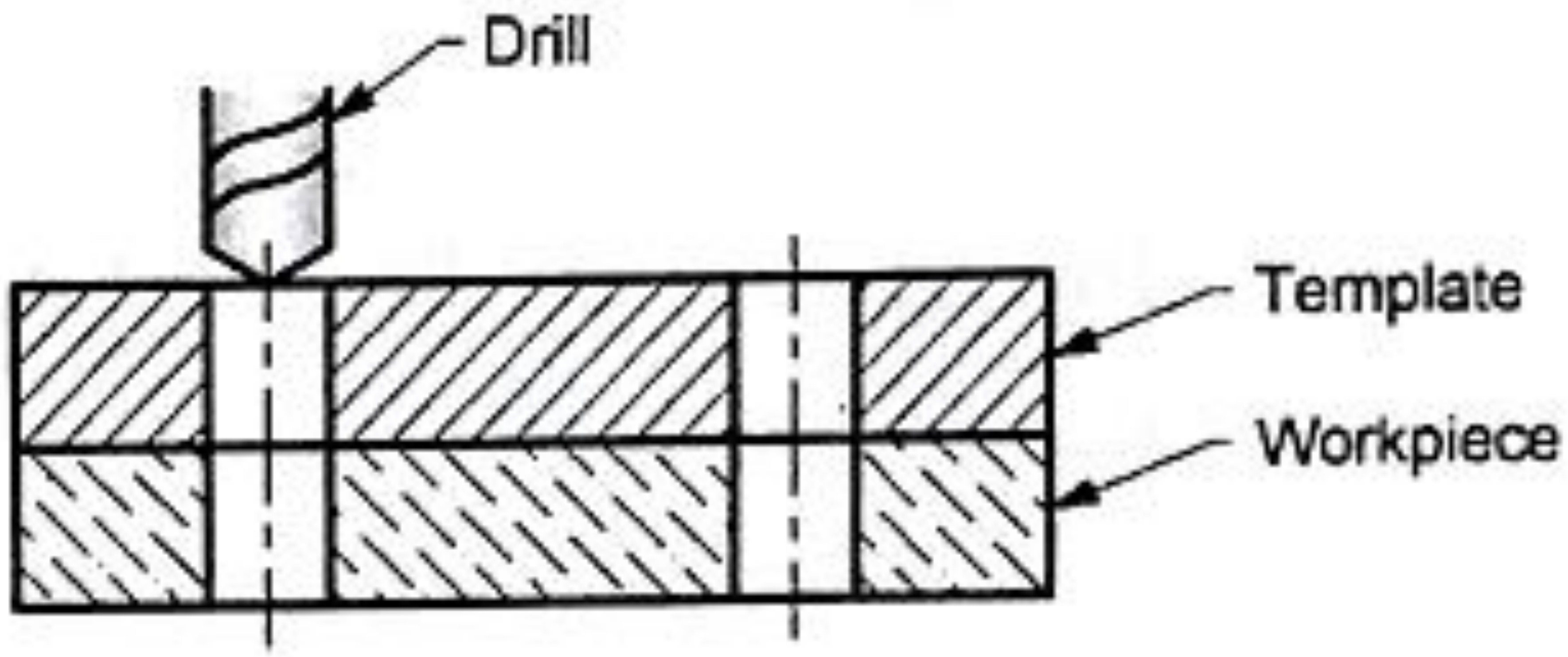
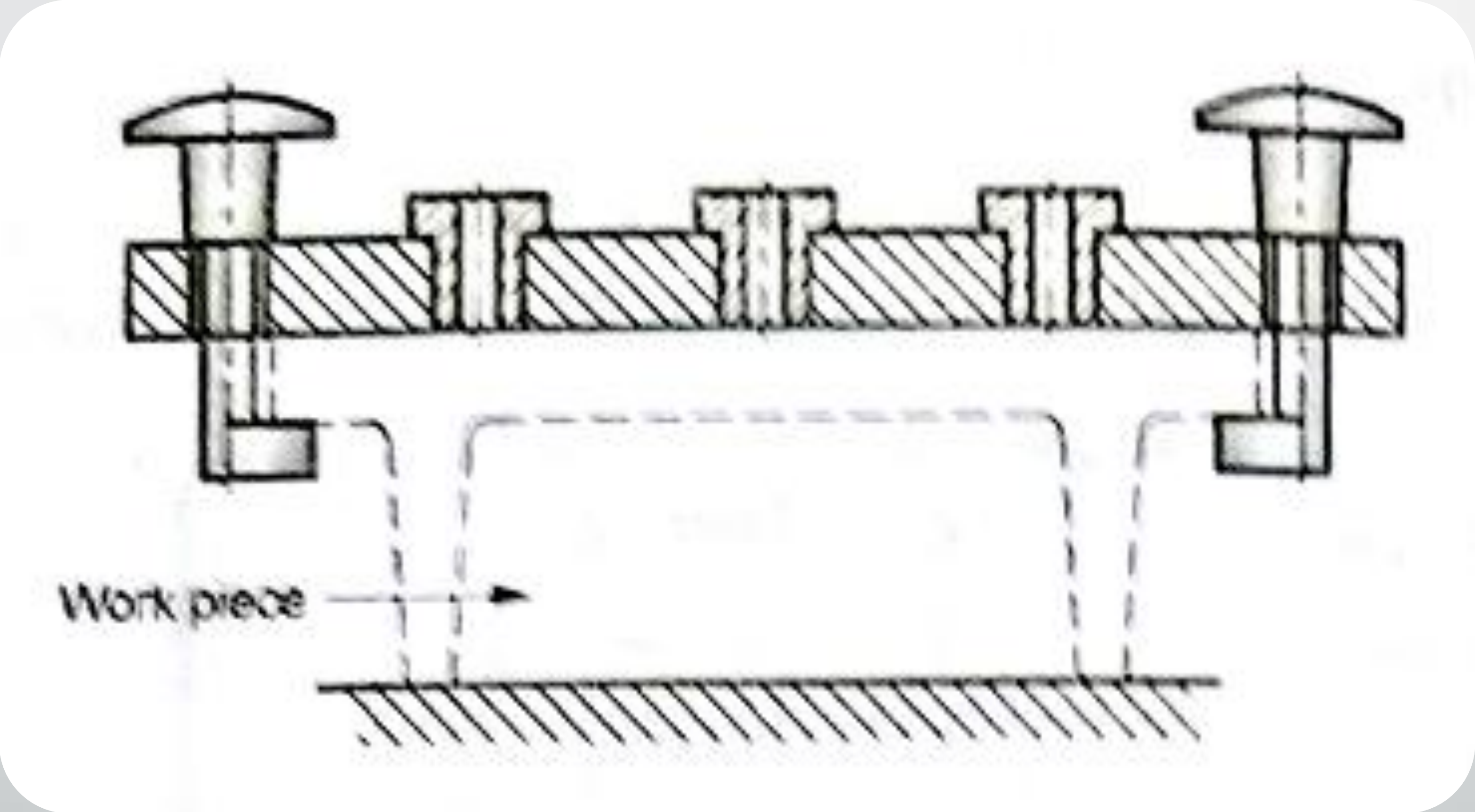
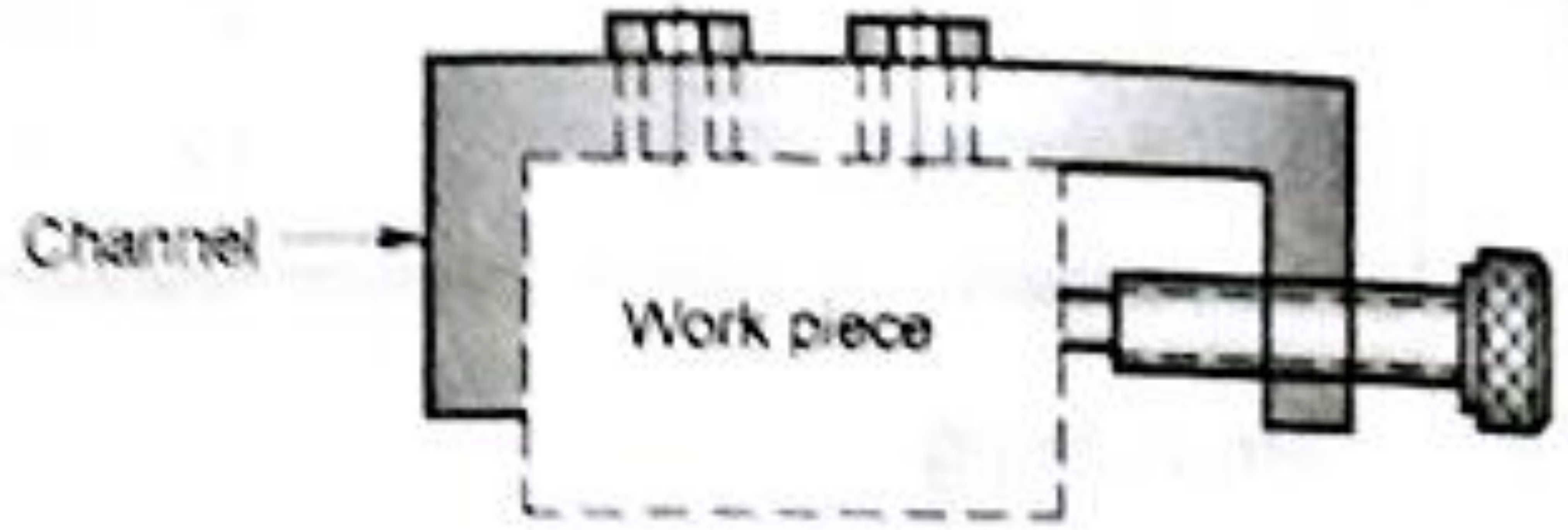


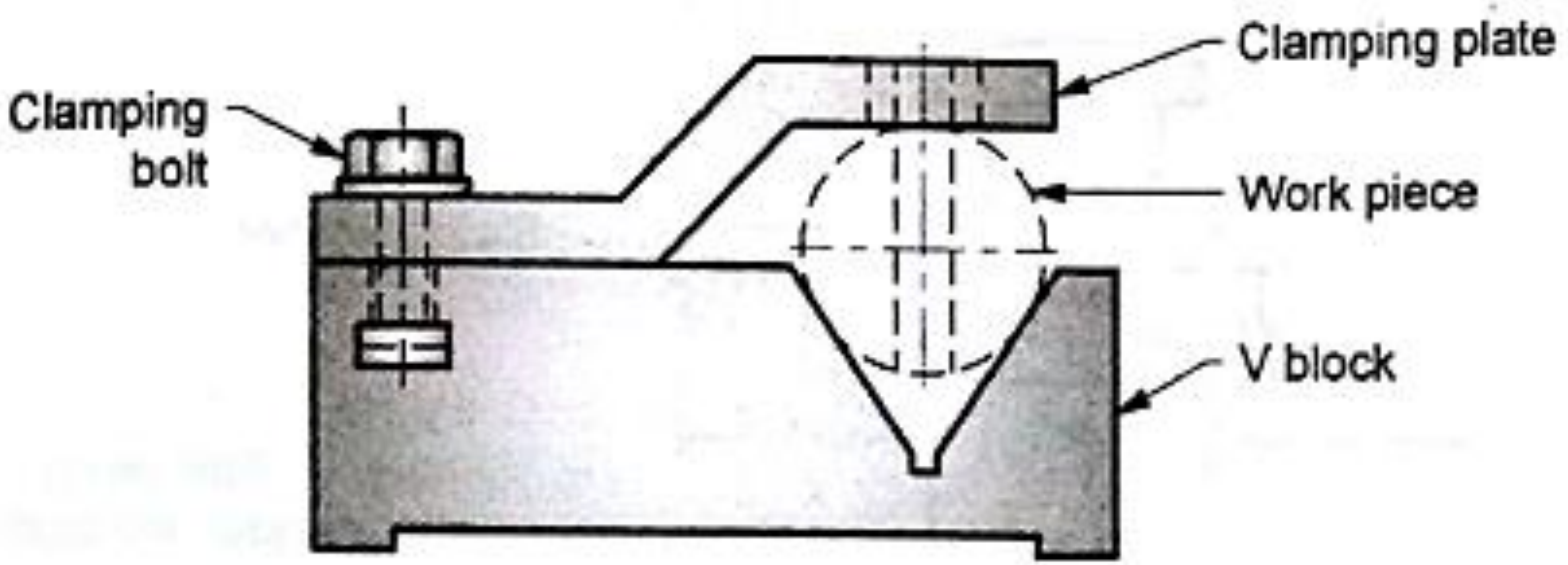
Plate jig



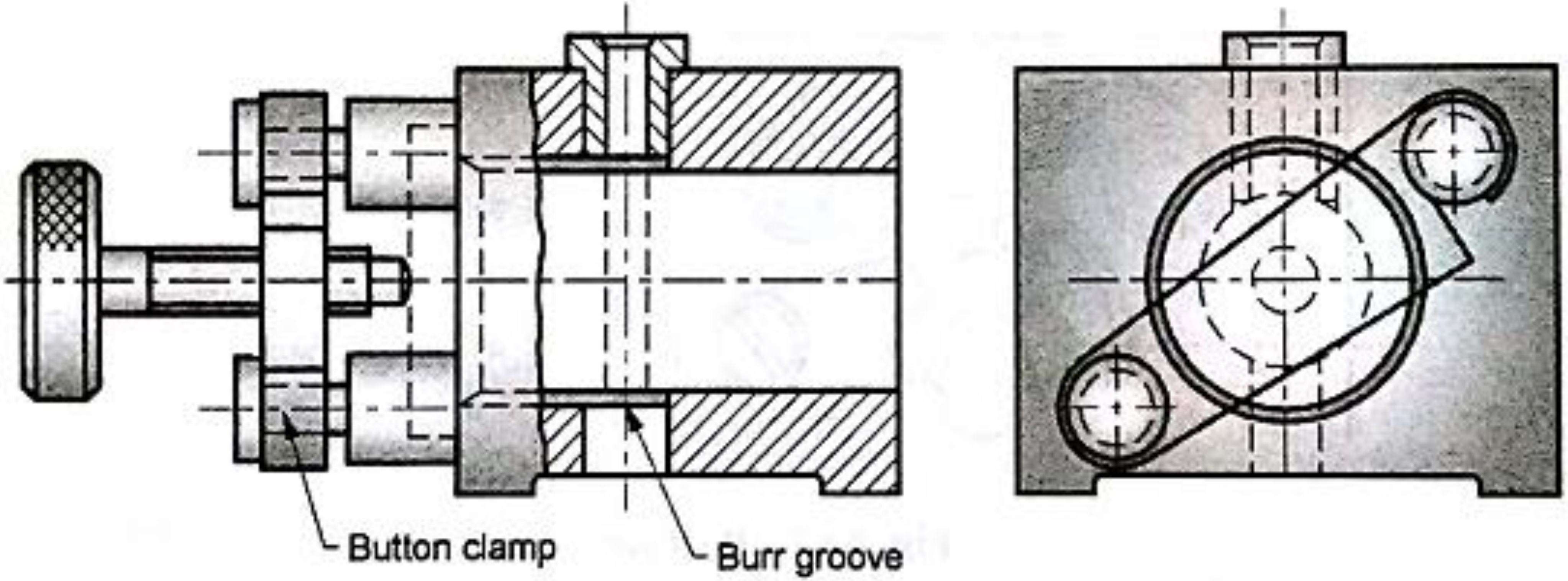
Channel Jig



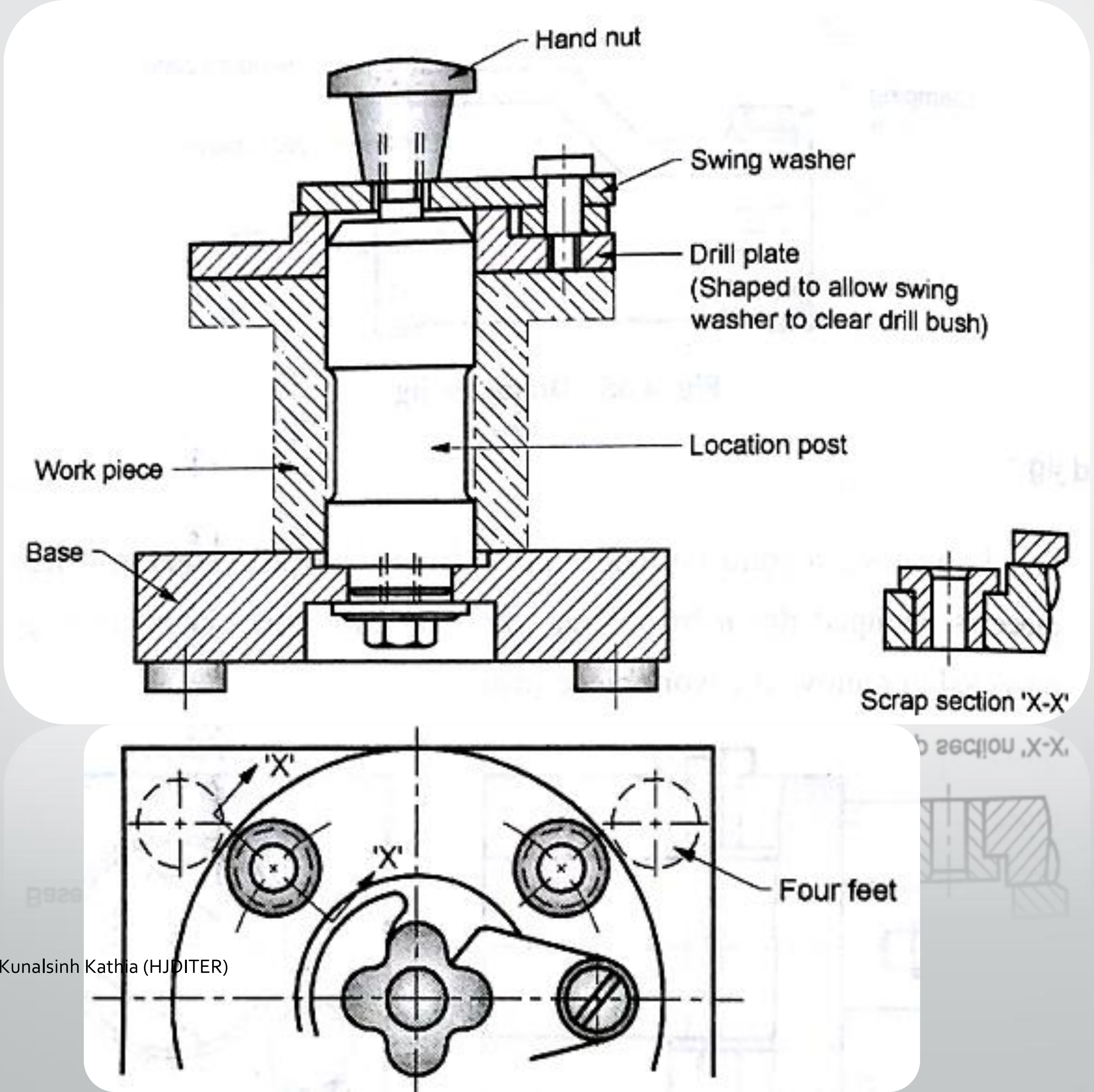
Diameter Jig



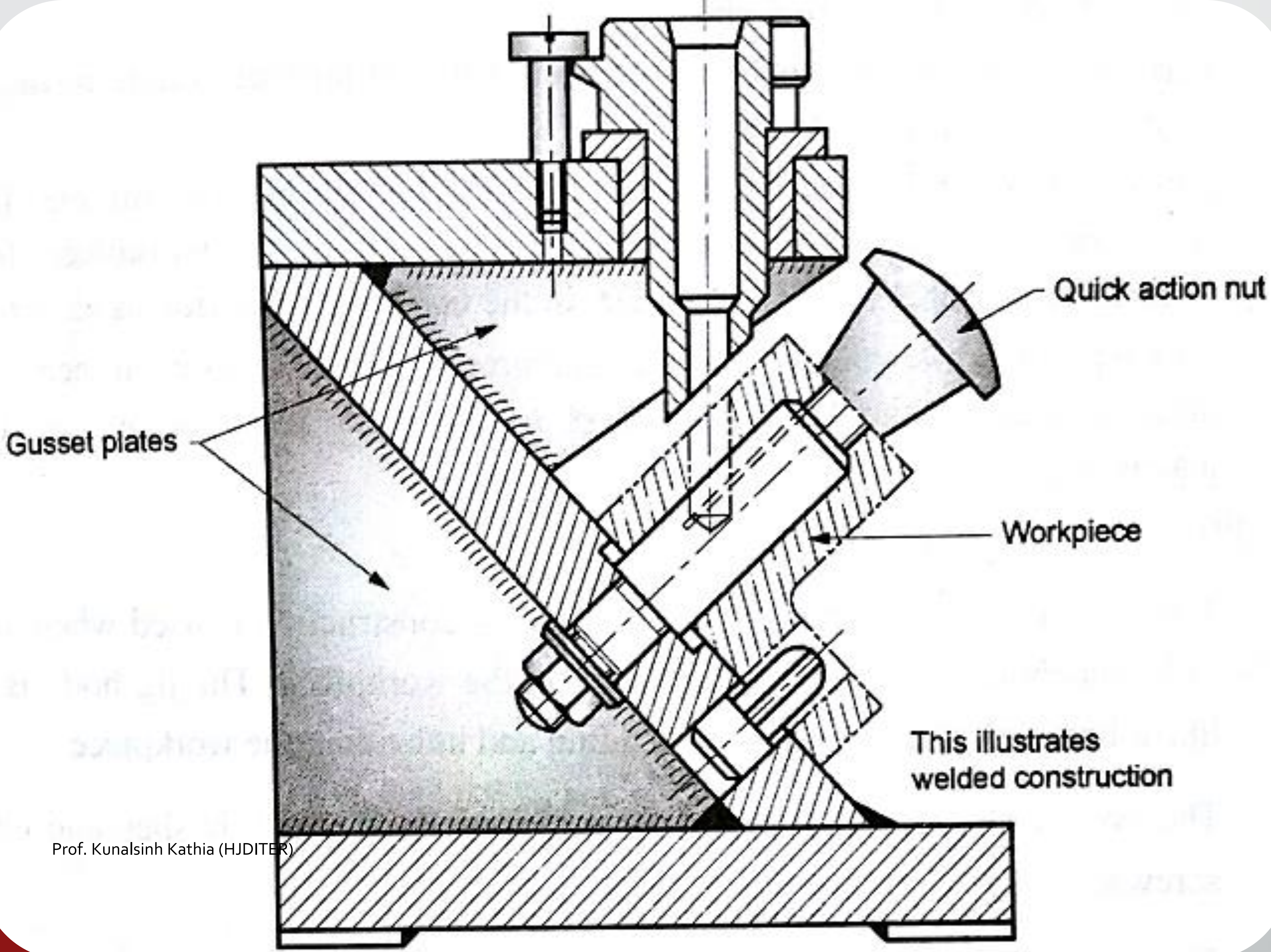
Solid Jig



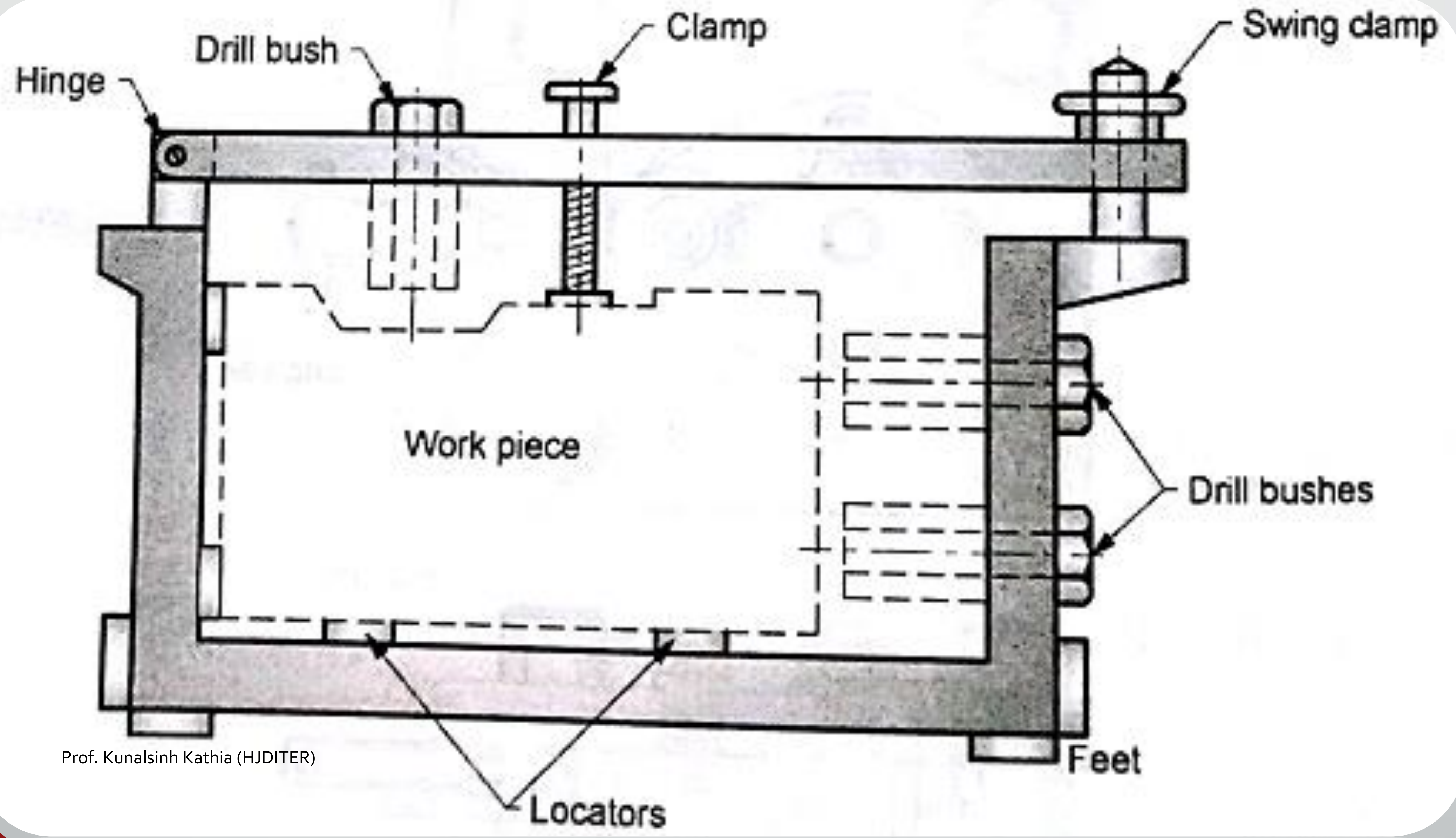
Post Jig


Hand nut
Swing washer
Drill plate
(Shaped to allow swing
washer to clear drill bush)
Location post
Work piece
Base
Scrap section 'X-X'
'X'
'X'
Four feet

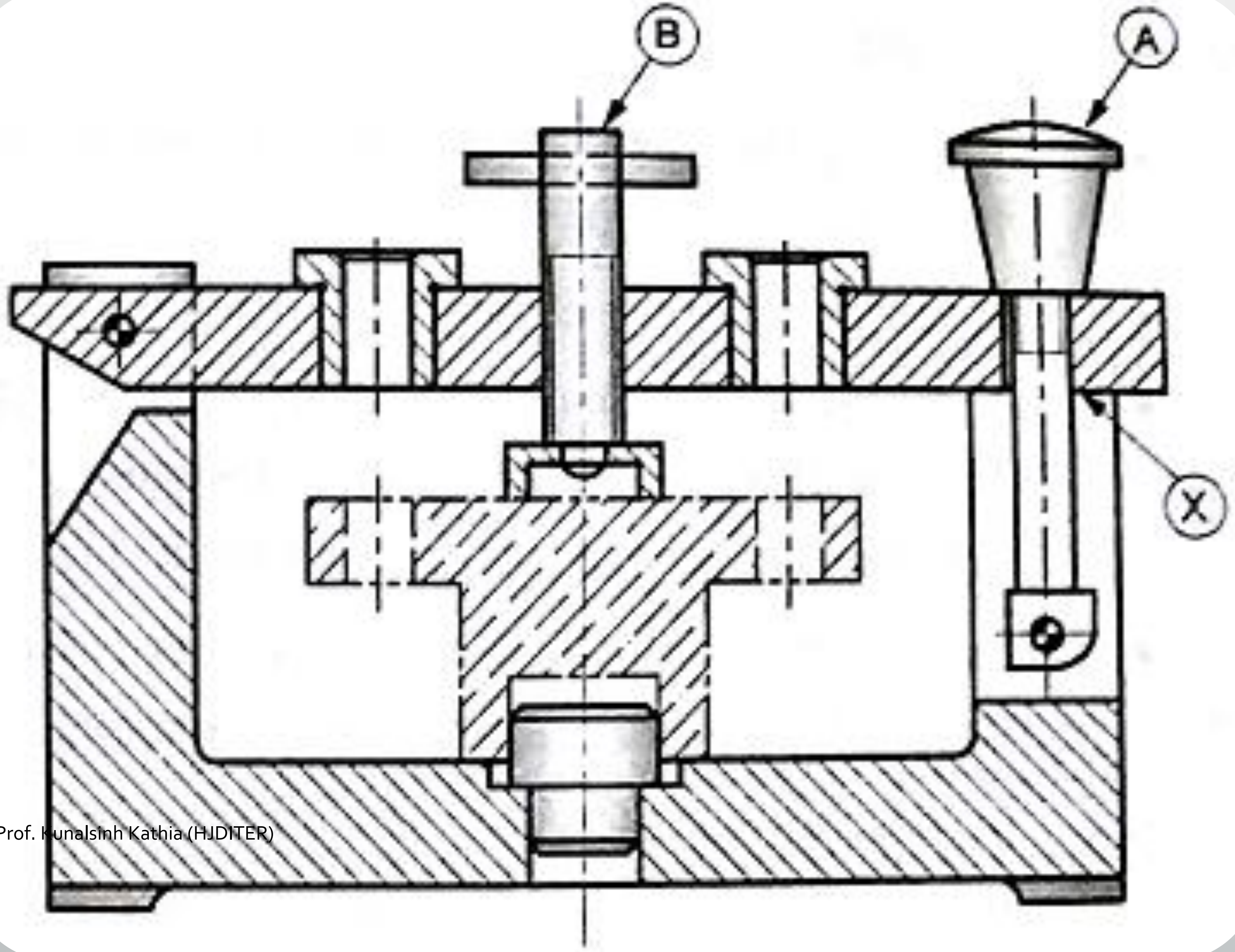
Angular post jig



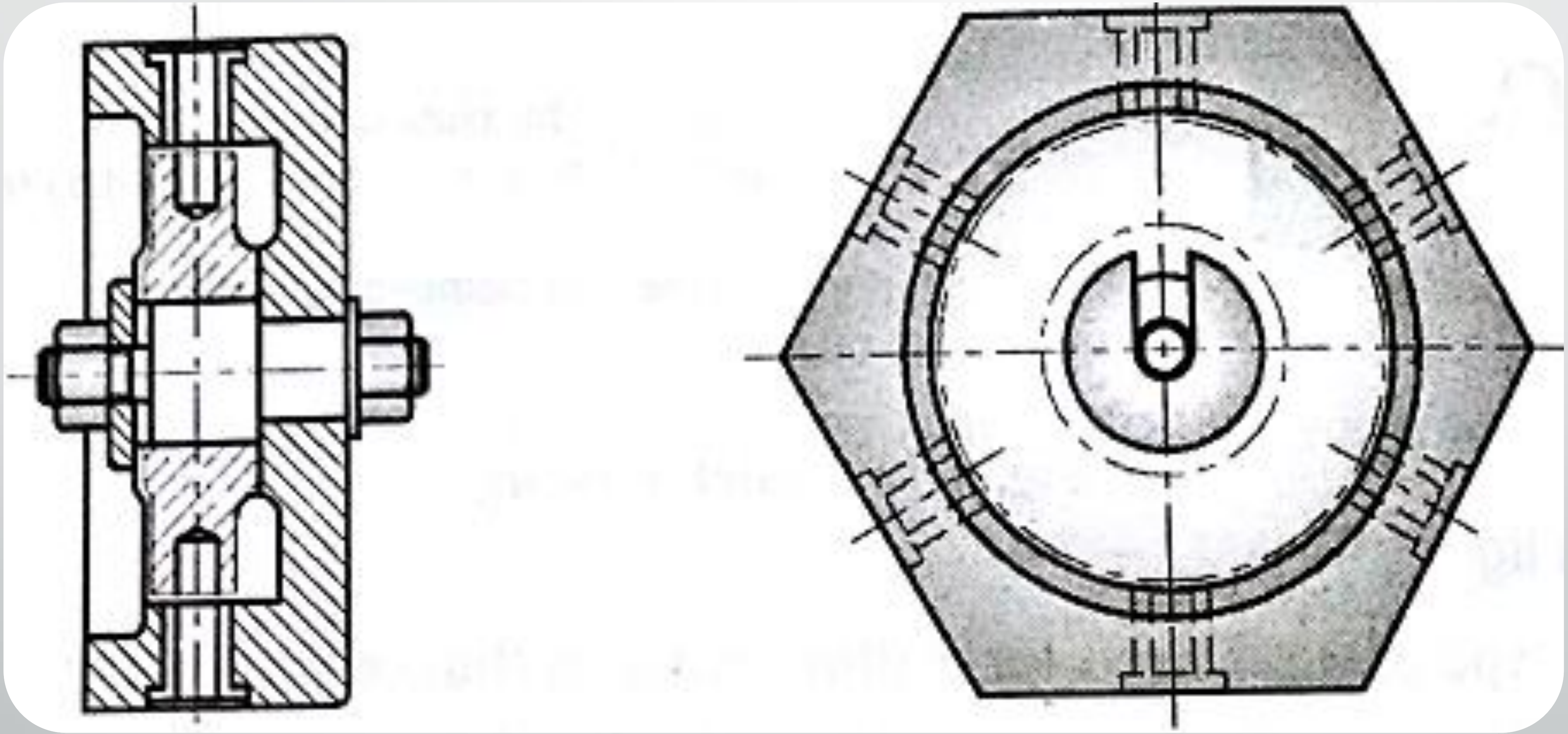
Box jig


Hinge
Drill bush
Clamp
Swing clamp
Work piece
Drill bushes
Feet
Locators

Latch type jig



Indexing jig



Presses (Punch & Die)

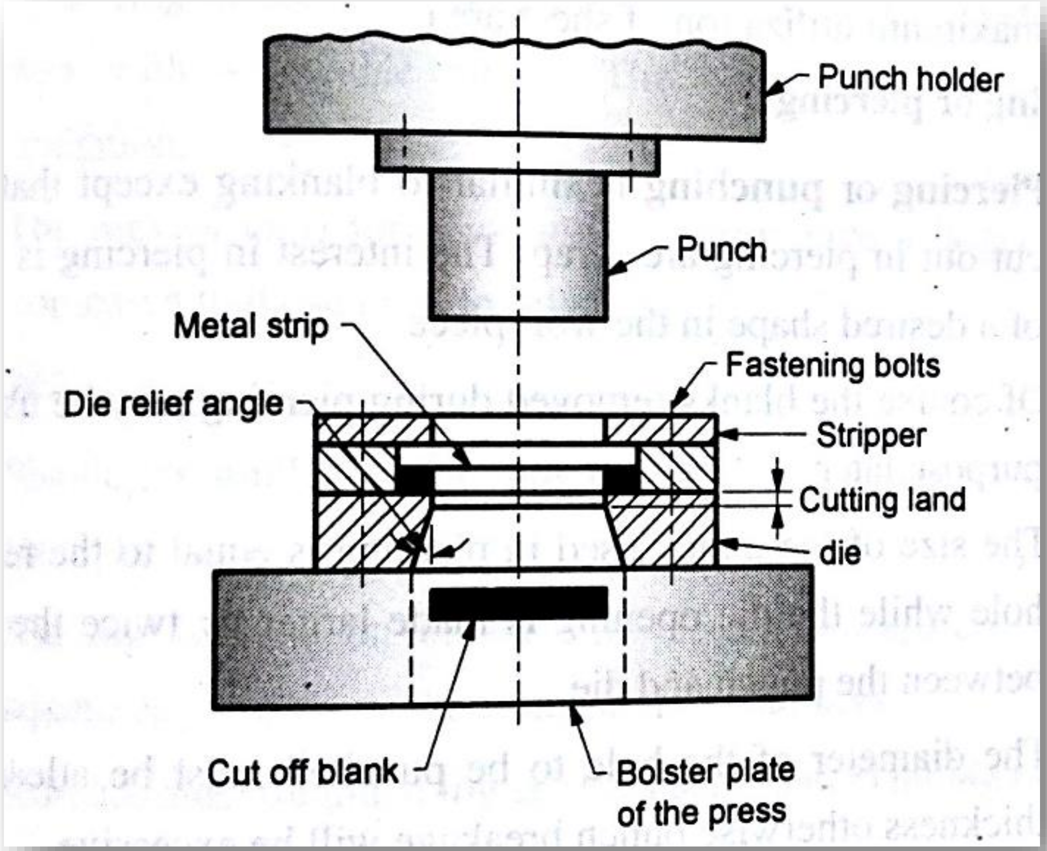
PROF. KUNALSINH KATHIA

PRODUCTION TECHNOLOGY

Common cutting operations

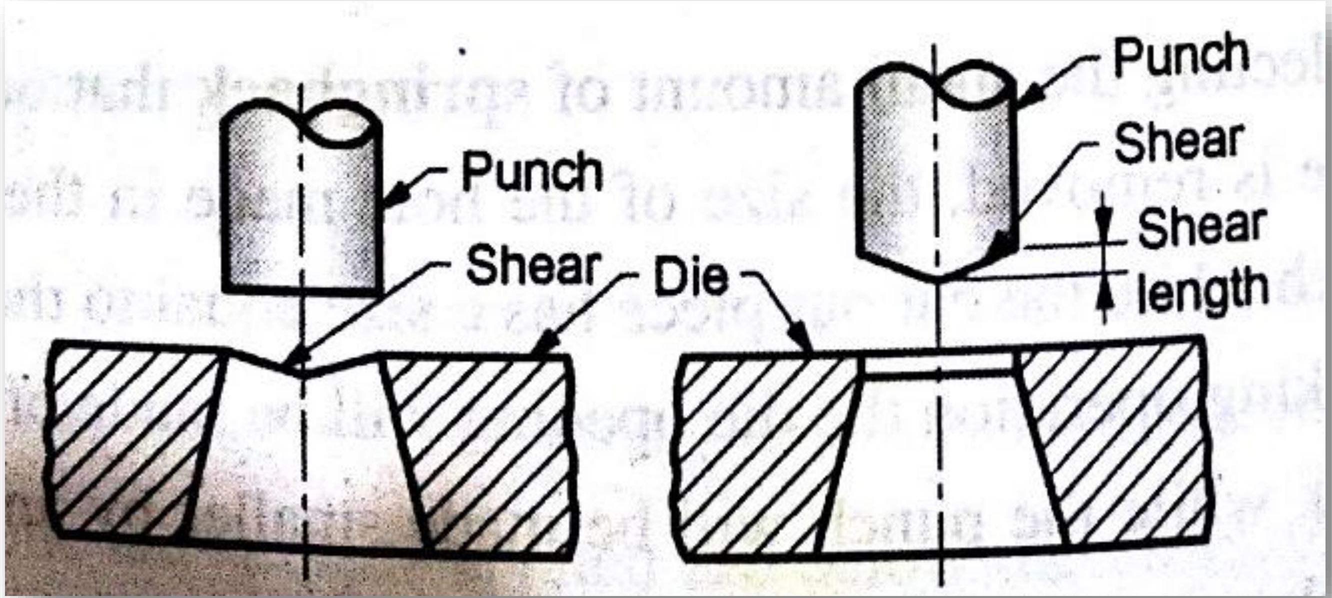
- Blanking
- Punching or piercing
- Trimming
- Shaving
- Notching
- Lancing
- Nibbling
- Perforating
- Parting
- Shearing

Blanking



Punch holder
Punch
Metal strip
Fastening bolts
Die relief angle
Stripper
Cutting land
die
Cut off blank
Bolster plate
of the press

Punching or Piercing



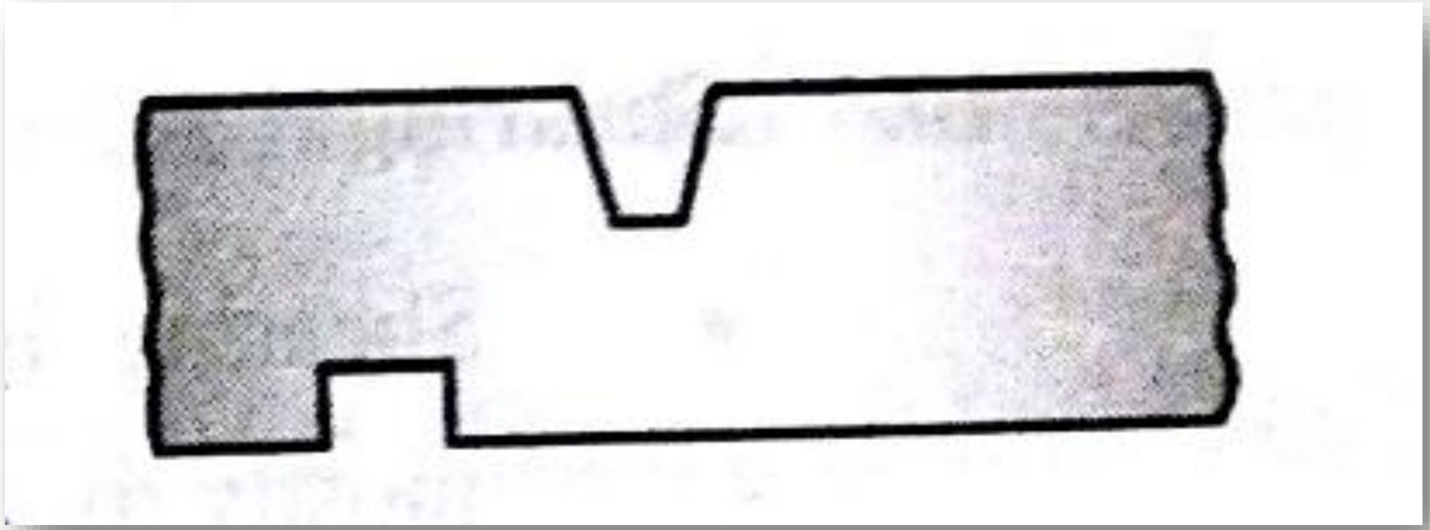
Trimming

Is process to remove excessive material.

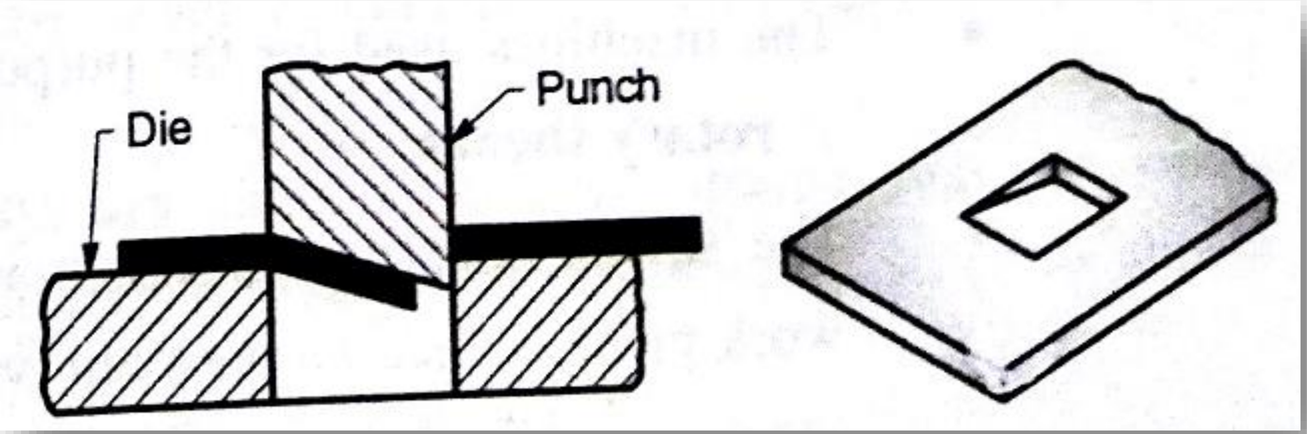
Shaving

- Shaving is similar to trimming except that the amount of metal removed is much less around 10% of the metal thickness.
- Shaving is done on blanked or pierced workpieces to obtain smooth, square edges with closer dimensional tolerances.
- Shaving dies use much lower clearances than blanking or punching dies.

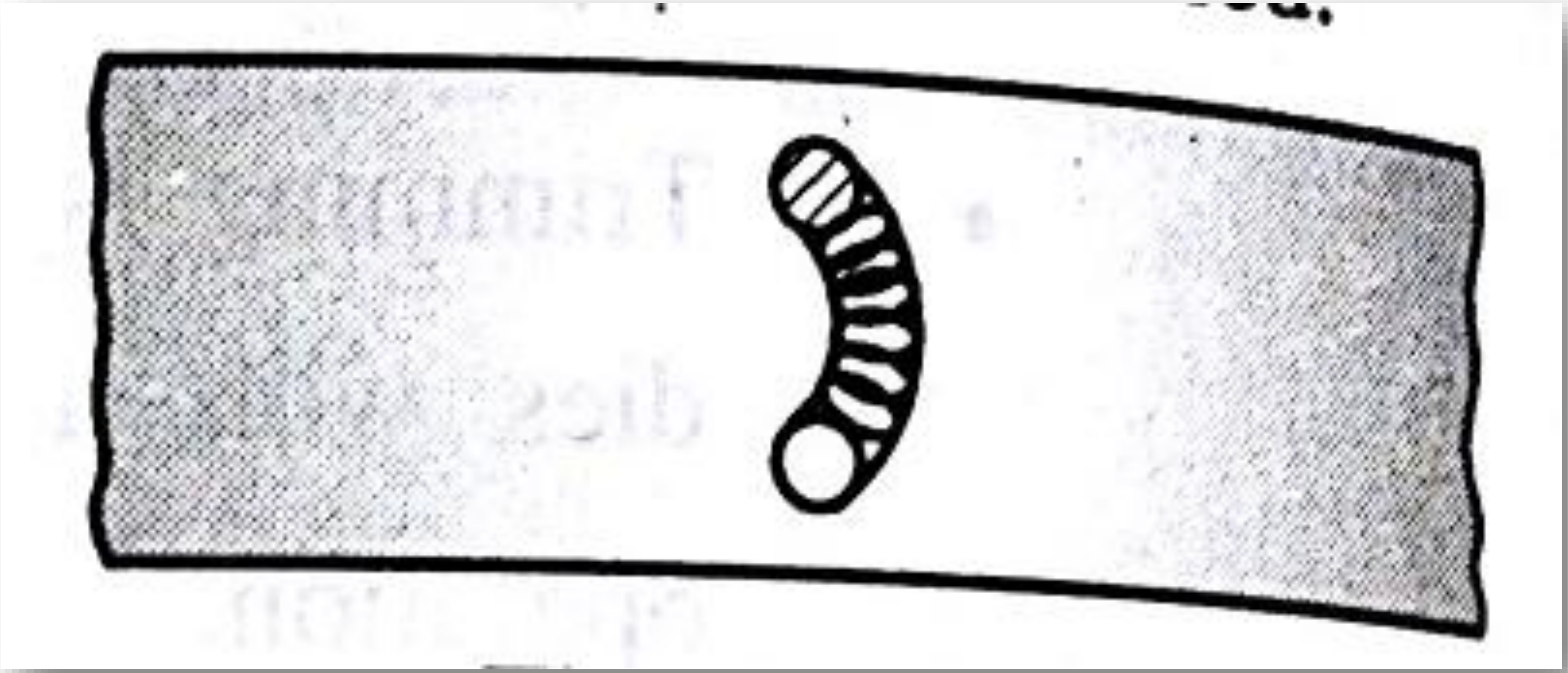
Notching



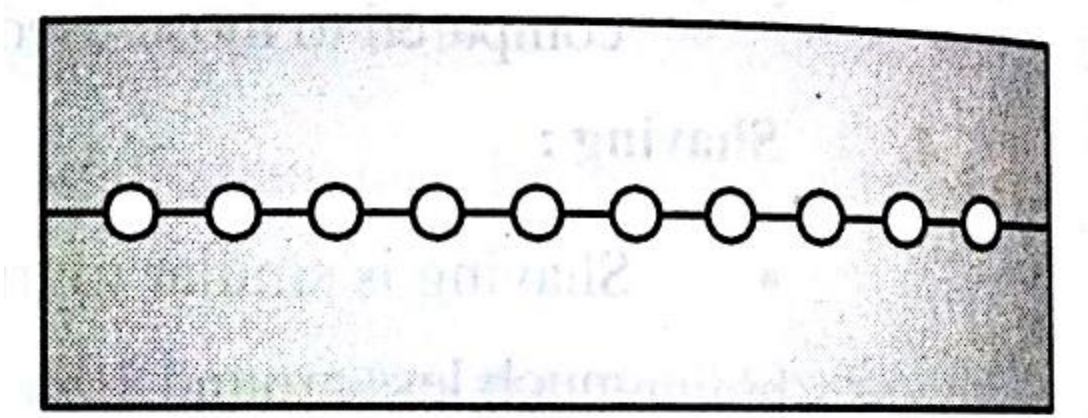
Lancing



Nibbing



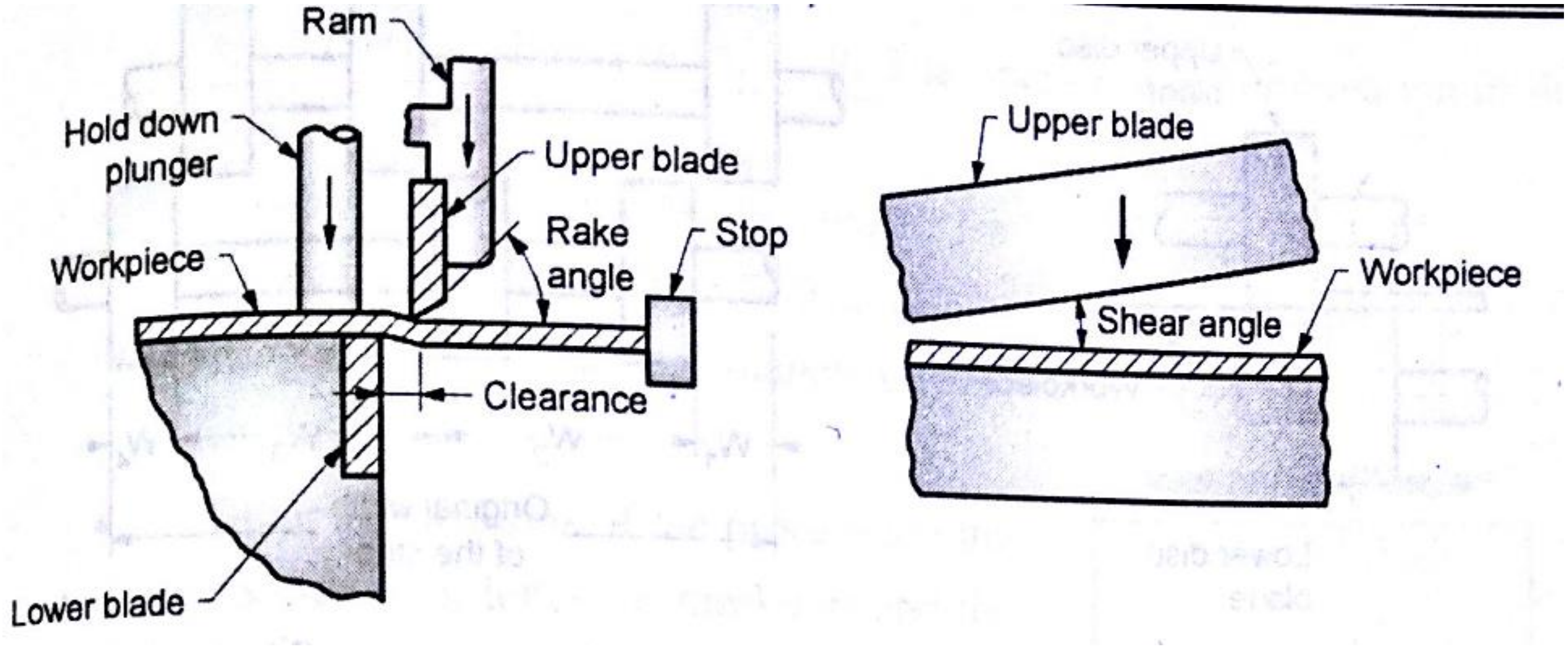
Perforating



Parting

Parting is the operation in which metal is cut simultaneously along two parallel lines or contours in such a say that the side thrust is neutralised.

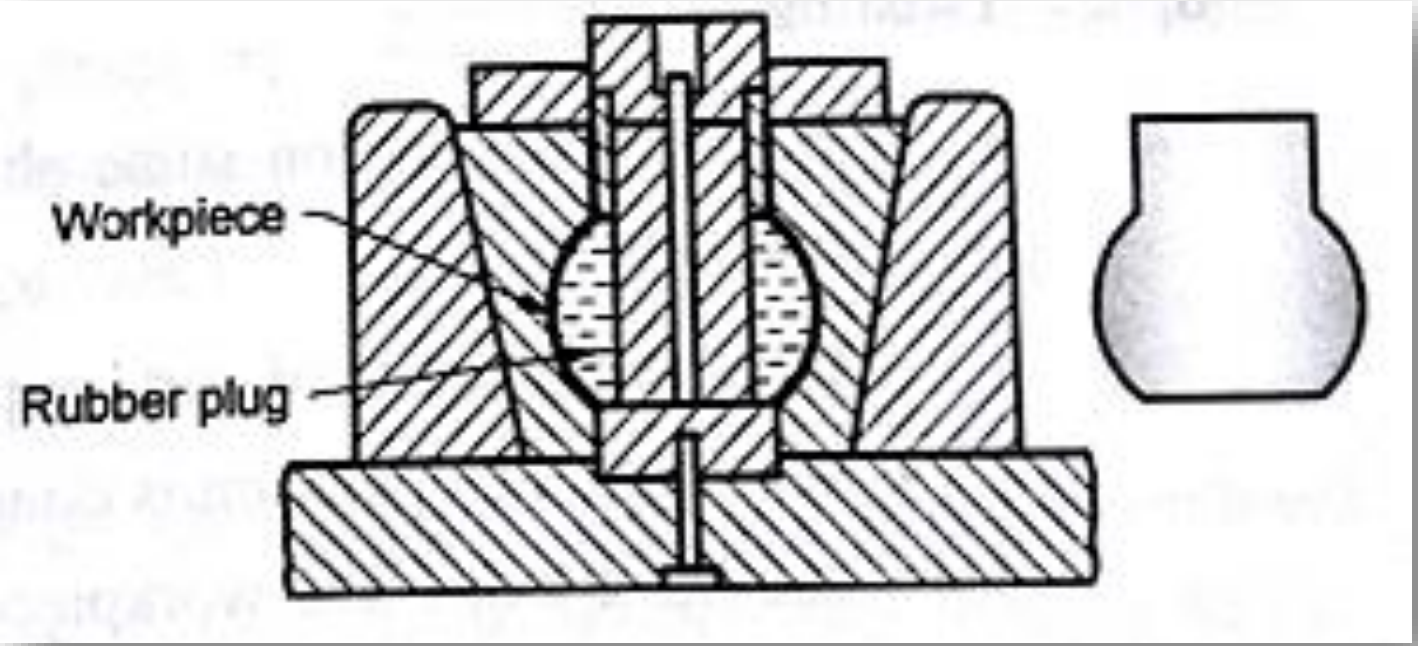
Shearing


Ram
Hold down
plunger
Upper blade
Rake
angle
Stop
Workpiece
Clearance
Lower blade
Upper blade
Workpiece
Shear angle

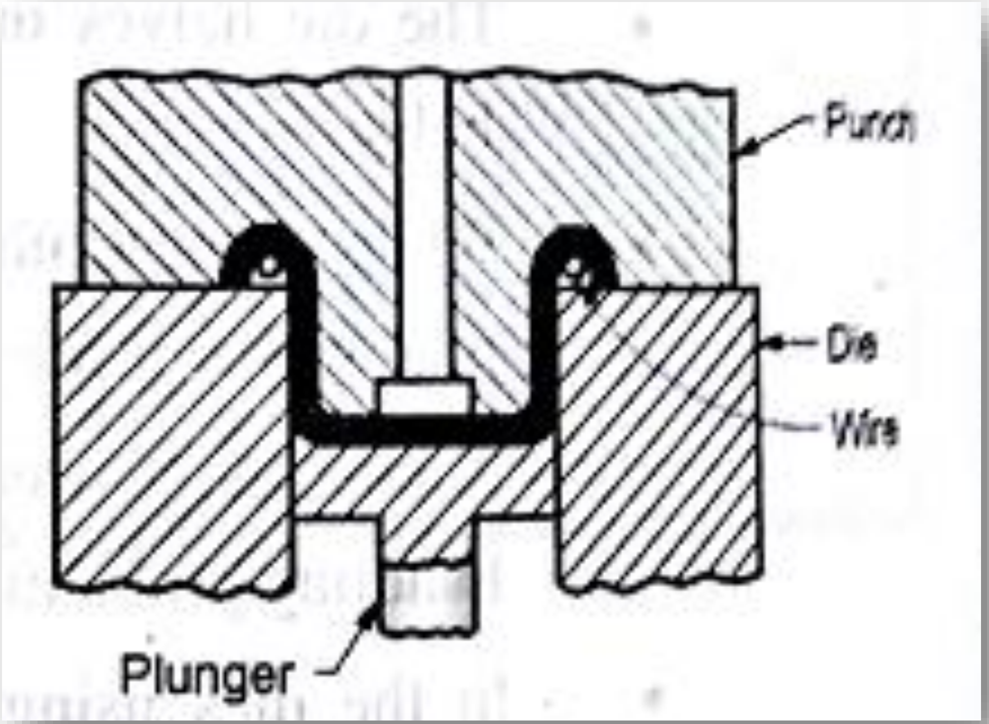
Forming operations

1. Bending
2. Drawing
3. Rigid die operations like buldging, curling,coining etc
4. Flexible die operation like Rubber pad forming, marforming, hydroforming

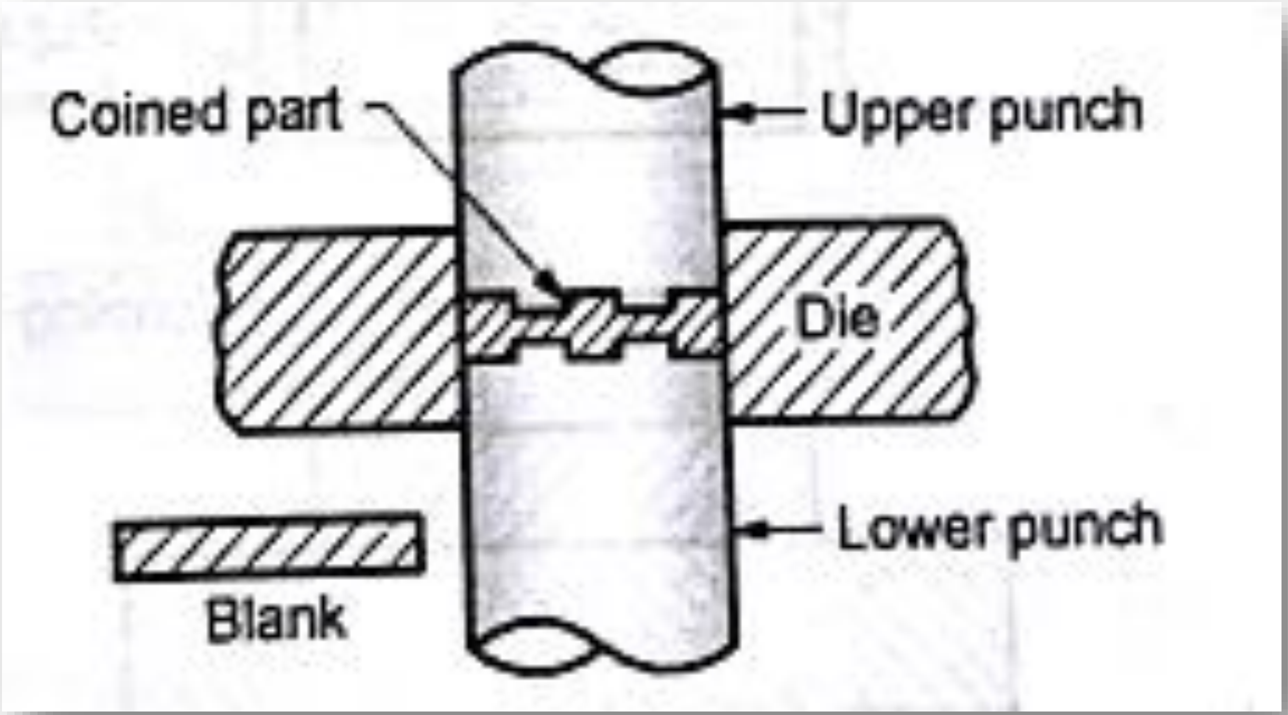
Bulging



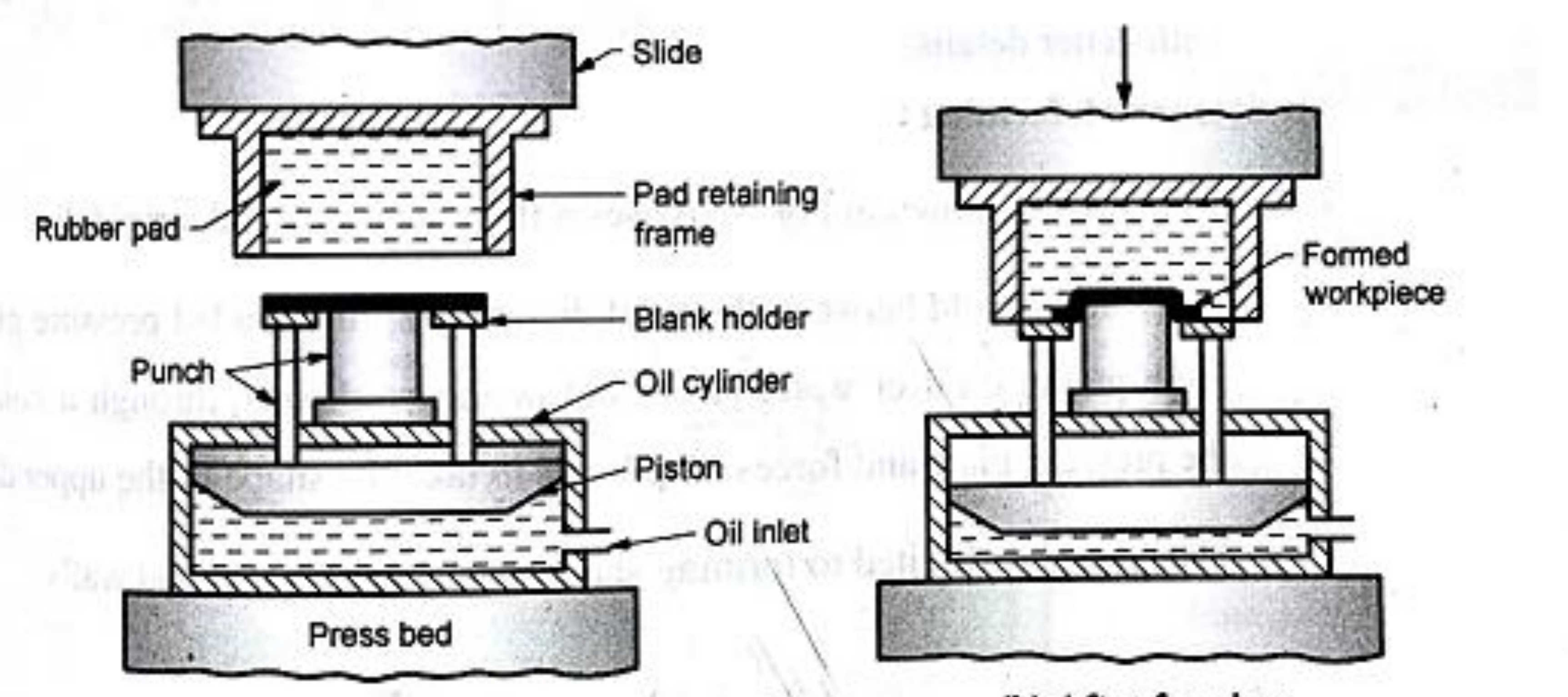
Curling



Coining



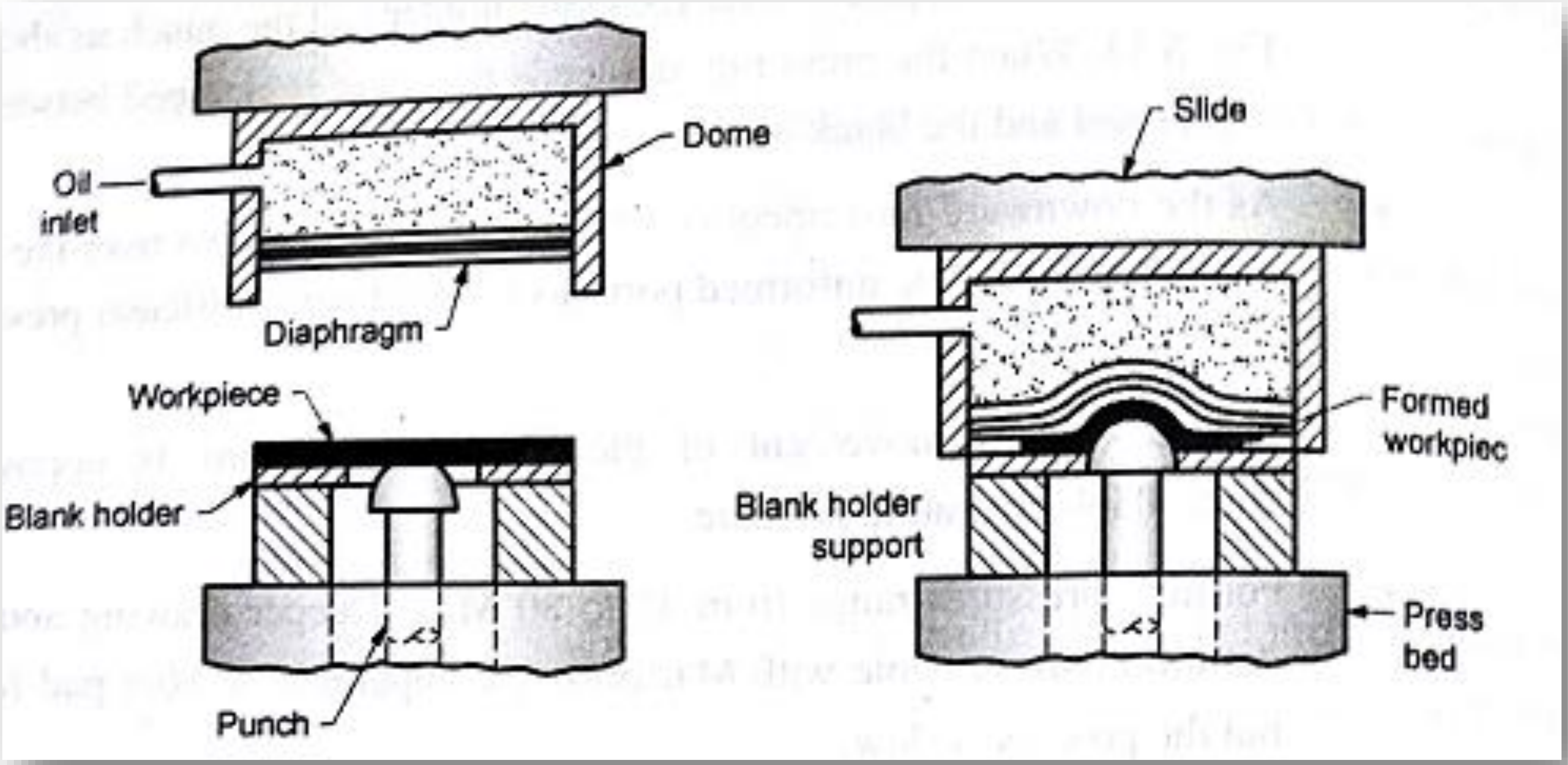
Marforming



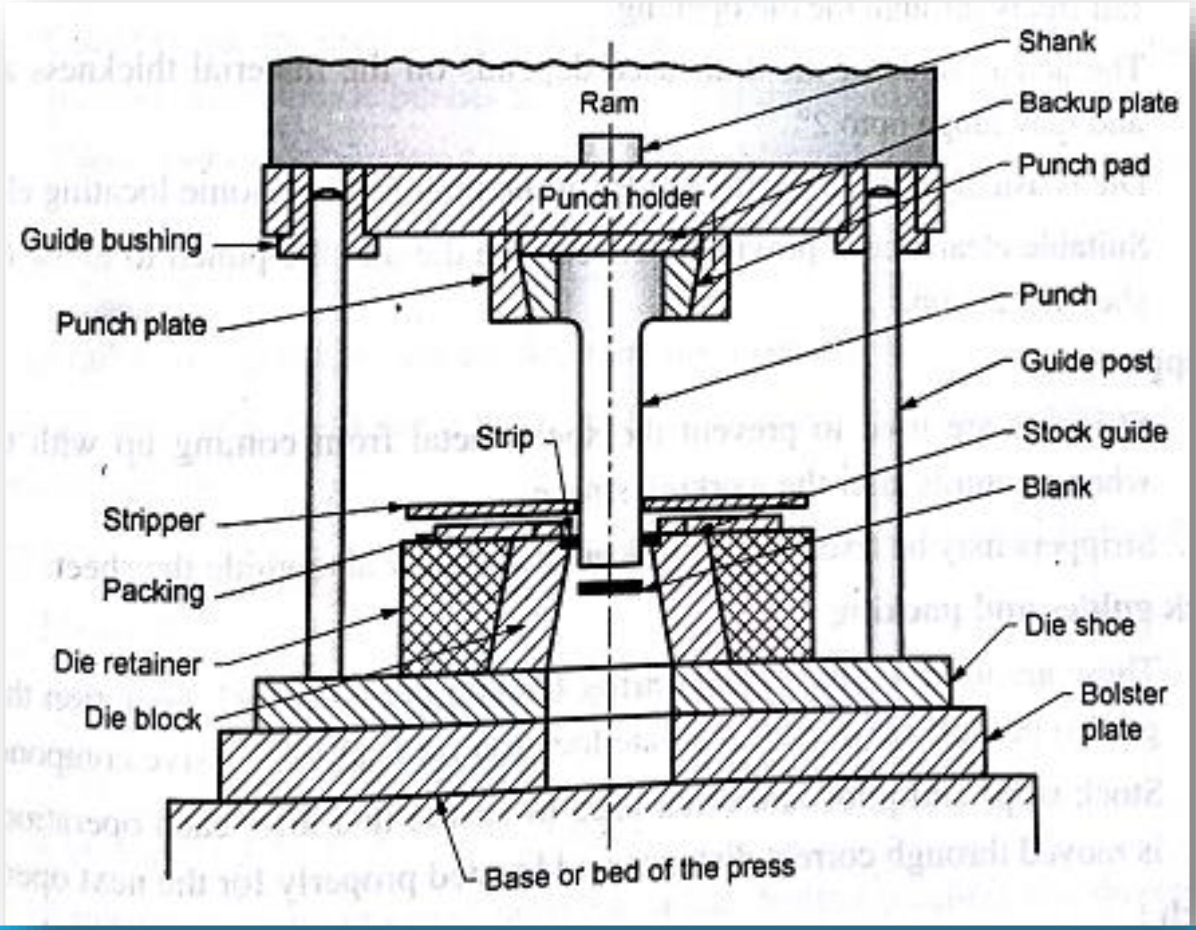
(a) Before forming

(b) After forming

Hydroforming



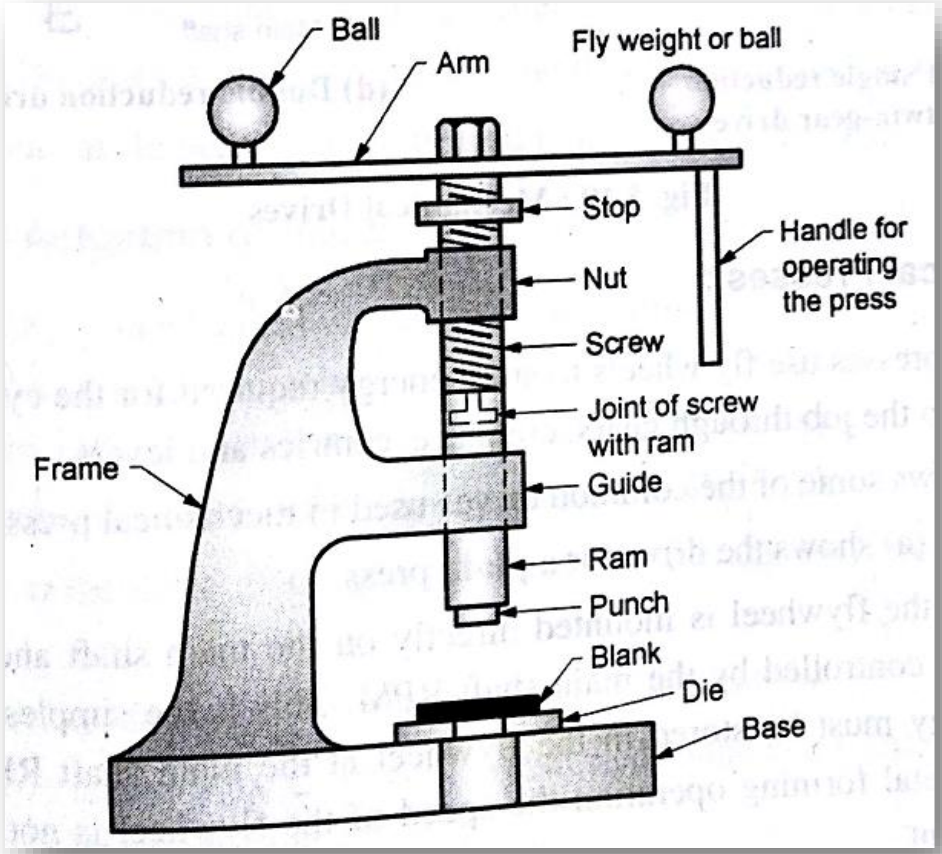
Press working terminogly.



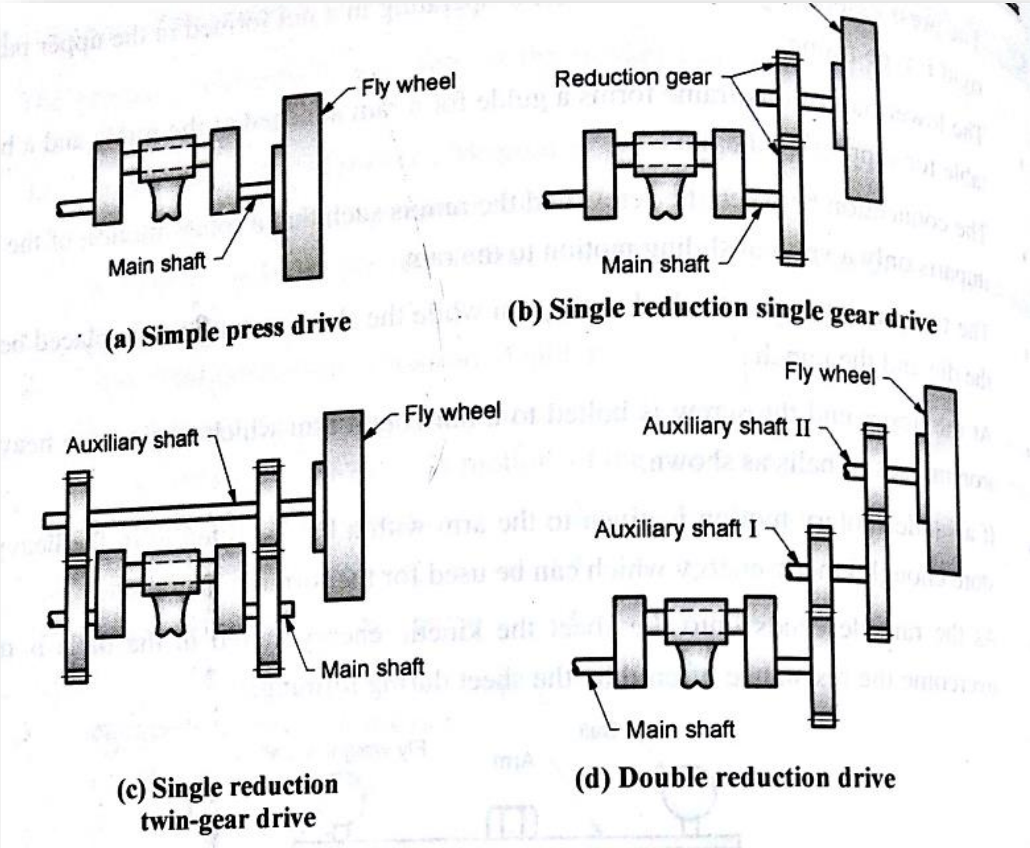
Types of presses

1. Based on source of power
    1. Manual
    2. Powerd
2. Based on method of actuation of slides
    1. Crank operated
    2. Cam
    3. Electric
    4. Screw
    5. Rack and pinion
    6. Knuckle joint
    7. Toggle joint
3. Based on number of slides
    1. Single action press
    2. Double action press
    3. Triple action press
4. Based on type of frame used
    1. C frame
    2. Gap bed press
    3. Adjustable bed press
    4. Horn press
    5. Straight side press
    6. Arch press
    7. Tie rod type
    8. Piller type

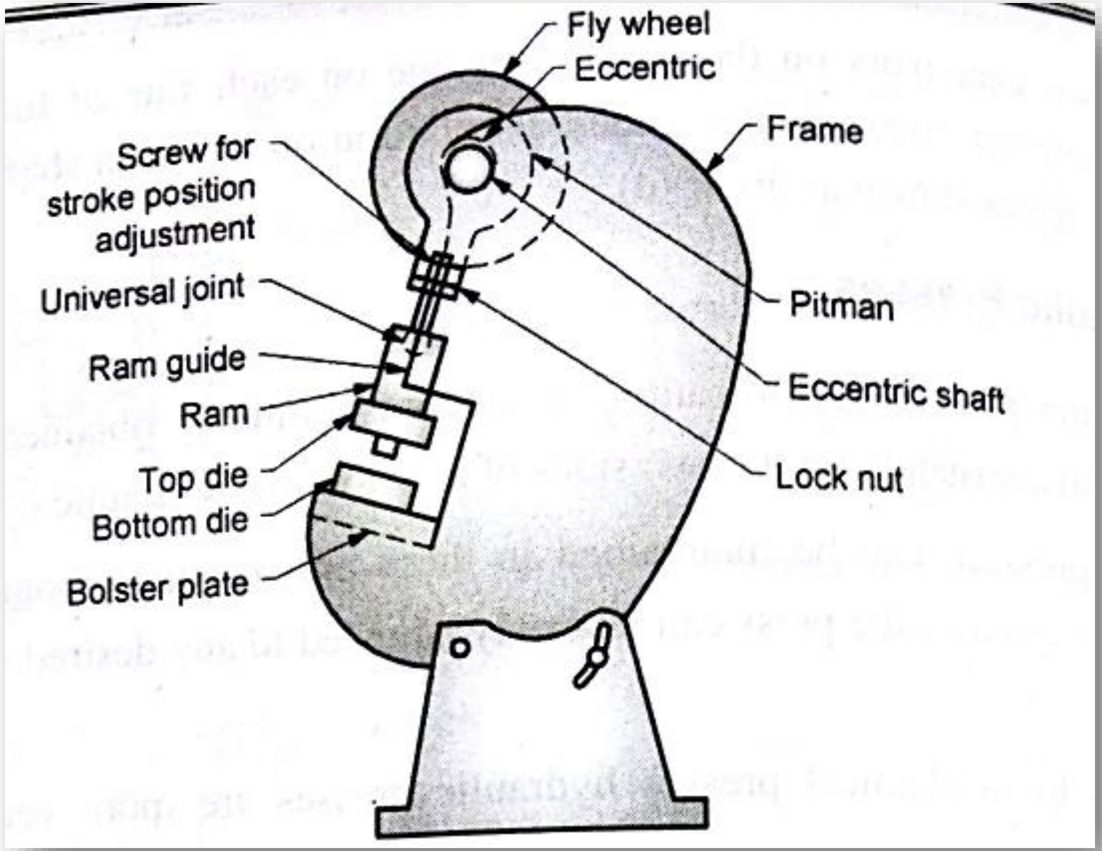
Fly press


Ball
Arm
Fly weight or ball
Stop
Handle for operating the press
Nut
Screw
Joint of screw with ram
Frame
Guide
Ram
Punch
Blank
Die
Base

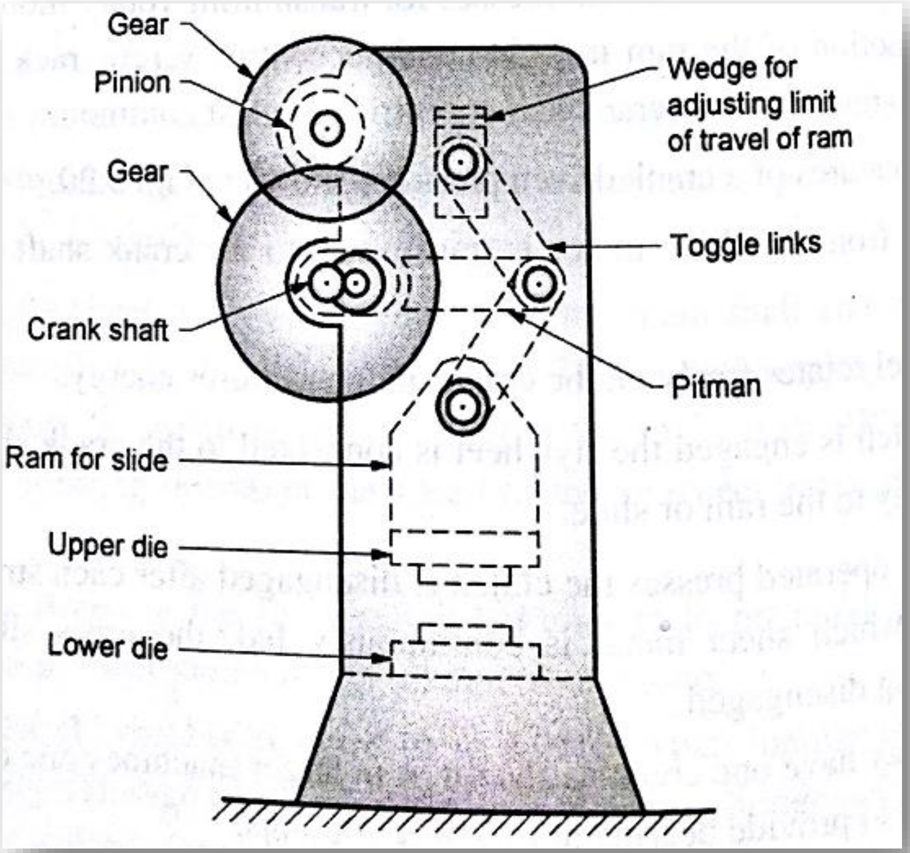
Mechanical Press



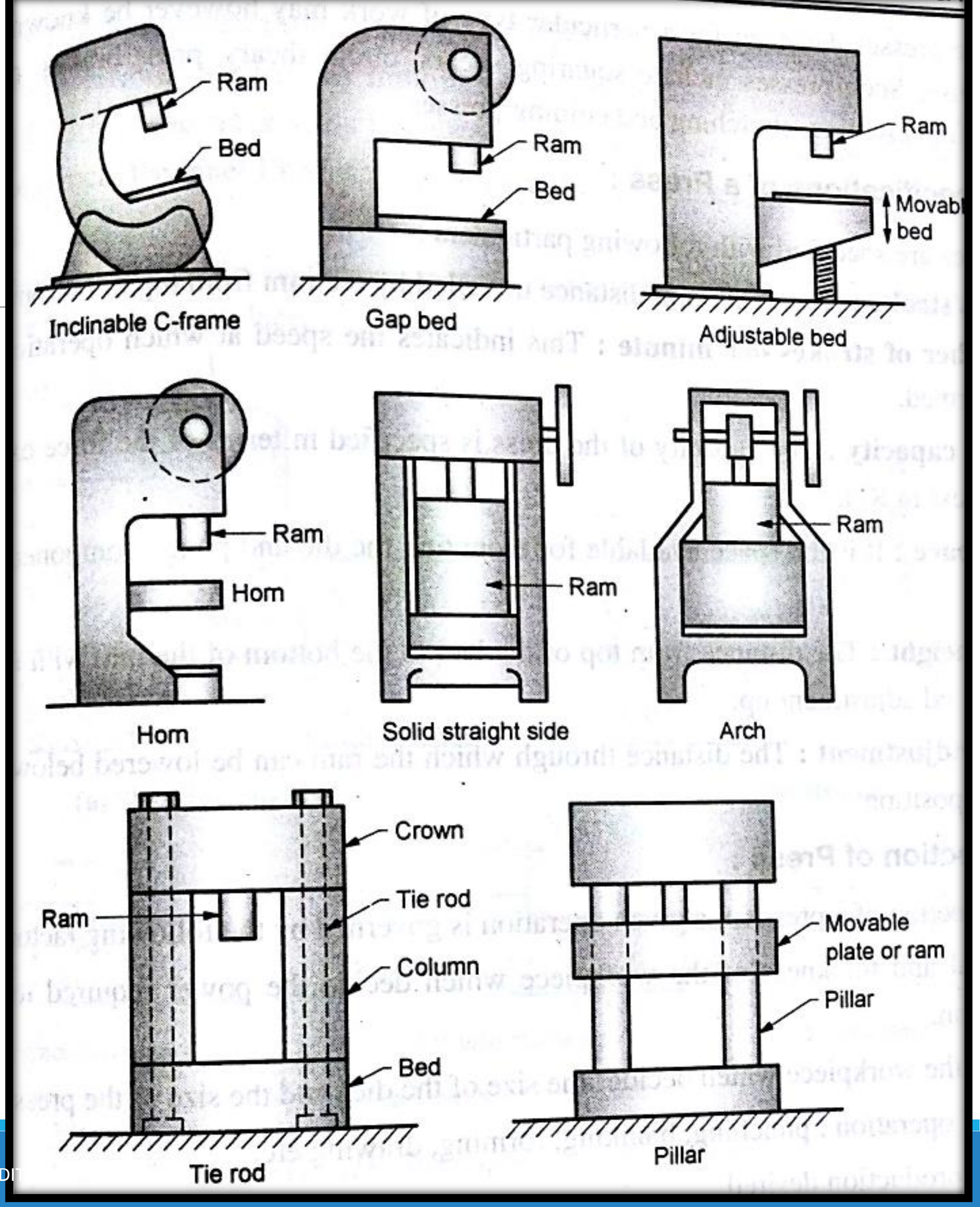
Crank operated press



Knuckle joint press



Based on type frame



AJM
Production technology
Prof. Kunalsinh Kathia
HJD INSTITUTE

DEFINATION:-

- In Abrasive Jet Machining (AJM), abrasive particles are made to impinge on the work material at a high velocity. The jet of abrasive particles is carried by carrier gas or air.
- The high velocity stream of abrasive is generated by converting the pressure energy of the carrier gas or air to its kinetic energy and hence high velocity jet.

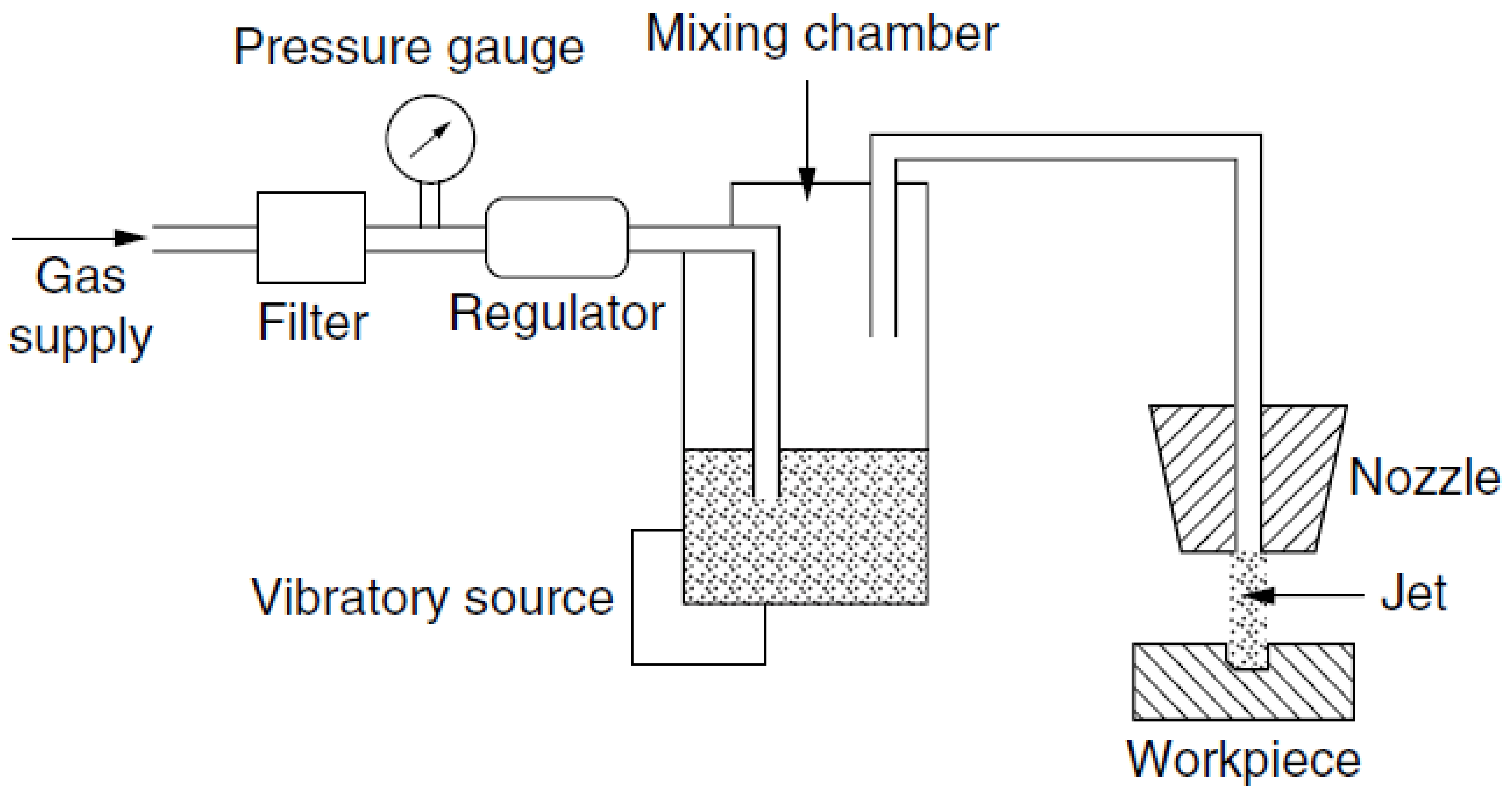
Introduction

- A stream of abrasive grains (Al_2O_3 or SiC) is carried by high pressure gas or air (compressed).
- Impinges on the work surface at very high velocity through a nozzle of 0.3 to 0.5 mm diameter.
- Sand Blasting (SB) - a similar process
- The major differences between are SB and AJM

  (i) smaller diameter abrasives

  (ii) a more finely controlled delivery system
- Material removal – by mechanical abrasion action of the high velocity abrasive particles.
- Best suited for hole drilling in superhard materials.
- Typically used to cut, clean, peen, deburr, deflash and etch glass, ceramics and other hard materials.

Machining System



Machining System – Contd.

- A gas (Nitrogen, CO_2 or air) is supplied at 2 – 8 kg/cm^2
- Oxygen should never be used. (because, it causes violent chemical action with the workpiece chips or abrasive particles).
- Gas passes through a mixing chamber after filtration and regulation.
- In the mixing chamber, abrasive particles (10 – 40 μm) are present and vibrated at 50 Hz.
- Amplitude of vibration – to control the feed rate of abrasives.
- (Gas + abrasives) - passed through a 0.45 mm diameter tungsten carbide nozzle at a speed of 150 – 300 m/s.
- The nozzle is directed over the area to be machined.

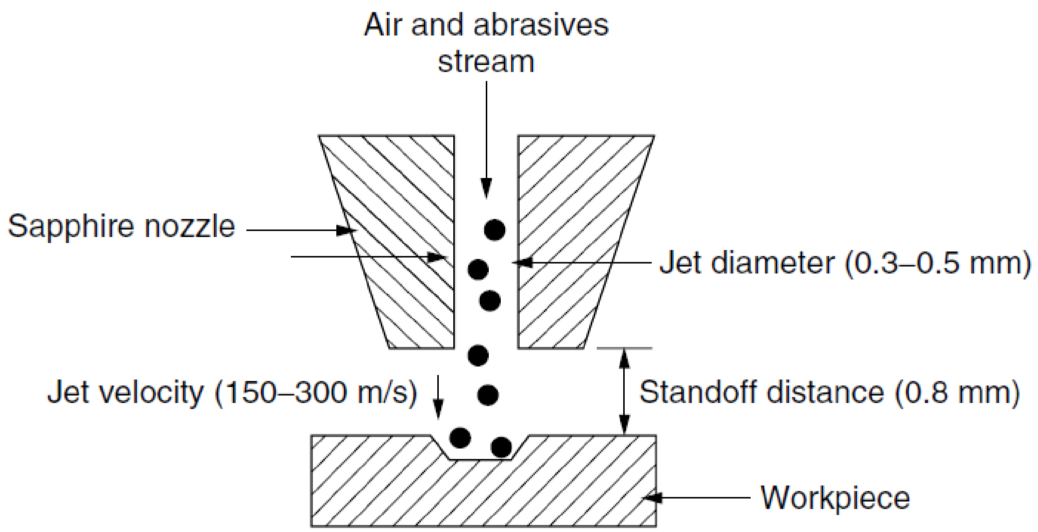
Machining System – Contd.

- Aluminum oxide (Al_2O_3) and silicon carbide (SiC) powders are used for heavy cleaning, cutting and deburring.
- Magnesium carbonate is recommended for use in light cleaning and etching.
- Sodium bicarbonate – fine cleaning and cutting of soft materials.
- Commercial grade powders are not suitable – b’cos their sizes are not well classified. Also, they may contain silica which can cause a health hazard.
- Abrasive powders are not reused. B’cos, contaminations and worn grits will reduce the machining rate (MRR).
- The nozzle stand off distance is 0.81 mm.

Machining System – Contd.

- Relative motion between nozzle and workpiece – can be manual
- Or automatically controlled using cam drives, tracer mechanisms or using computer controlled according to the cut geometry required.
- Masks of copper, glass or rubber – can be used to concentrate the jet stream of abrasives to a confined area on the workpiece.
- Intricate and precise shapes can be produced using masks with corresponding contours.
- Dust removal or collecting equipment must be incorporated to protect the environment.

Material Removal



- **The abrasive particles from the nozzle follow parallel paths for a short distance**
- **Then the abrasive jet flares outward like a narrow cone.**
- **When the sharp-edged abrasive particles of Al_2O_3 or SiC hit a brittle and fragile material at high speed, tiny brittle fractures are created from which small particles dislodge.**
- **The dislodged particles are carried away by the air or gas.**

Material Removal Rate

- **Material or Volumetric Removal Rate (MRR or VRR) is given by the formula**

$$= KN{d_a}^3 v^{3/2} \left(\frac{\rho_a}{12 H_w} \right)^{3/4}$$

where K = constant
N = number of abrasive particles impacting/unit area
d_a = mean diameter of abrasive particles, μm
ρ_a = density of abrasive particles, kg/mm^3
H_w = hardness number of the work material
v = speed of abrasive particles, m/s

Process Parameters

- **MRR, machining accuracy, surface roughness and nozzle wear are influenced by**
  - **Size and distance of the nozzle.**
  - **Composition, strength, size, and shape of abrasives**
  - **Flow rate**
  - **Composition, pressure, and velocity of the carrier gas.**
- **MRR is mainly dependent on the flow rate and size of abrasives.**
- **Larger grain sizes produce greater removal rates.**
- **At a particular pressure, the VRR increases with the abrasive flow rate up to an optimum value and then decreases with any further increase in flow rate. (Why?)**
- **The mass flow rate of the gas decreases with an increase in the abrasive flow rate**
- **Hence the mixing ratio increases and causes a decrease in the removal rate because of the decreasing energy available for material removal.**

Process Parameters – Contd.

- **Typical MRR is 16.4 mm^3/min when cutting glass.**
- **Cutting rates for metals vary from 1.6 to 4.1 mm^3/min.**
- **For harder ceramics, cutting rates are about 50 percent higher than those for glass – 24.6 mm^3/min.**
- **The minimum width of cut can be 0.13 mm.**
- **Tolerances are typically within ± 0.05 mm by using good fixation and motion control.**
- **Finished surface has a random or matte texture.**
- **Attainable surface roughness - 0.2 to 1.5 µm using 10 and 50 µm particles, respectively.**
- **Taper is present in deep cuts.**
- **High nozzle pressures result in a greater removal rate, but the nozzle life is decreased.**

Process Characteristics

Abrasives	
Type	Al_2O_3 or SiC (used once)
Size	Around 25 µm
Flow rate	3–20 g/min
Medium	
Type	Air or CO_2
Velocity	150–300 m/s
Pressure	2–8 kg/cm^2
Flow rate	28 L/min
Nozzle	
Material	Tungsten carbide or sapphire
Shape	Circular, 0.3–0.5 mm diameter
	Rectangular (0.08 × 0.51 mm to 6.61 × 0.51 mm)
Tip distance	0.25–15 mm
Life	WC (12–30 h), sapphire (300 h)
Operating angle	Vertical to 60° off vertical
Area	0.05–0.2 mm^2
Tolerance	±0.05 mm
Surface roughness	0.15–0.2 µm (10-µm particles)
	0.4–0.8 µm (25-µm particles)
	1.0–1.5 µm (20-µm particles)

Comparison to Other Machining Processes

1. Comparison with EDM Key Wire EDM strengths

i) Extremely precise parts are possible [±0.0001" (±0.025mm)]

ii) Very thick parts [over 12" (30 cm)] can be made

iii) Intentional taper can be put into a part for die clearance and other uses

Key Precision Abrasive jet strengths

iv) Five to ten times faster in parts less than 1" (2.5 cm) thick [but, at ±0.003" (±0.1 mm), less precise as well

vi) No Heat Affected Zone (HAZ), so no need for secondary operations to remove the HAZ or additional heat-treating to compensate for it

vii) Works well in non-conductive materials (such as glass, stone, plastic) as well as conductive materials

viii) Can pierce material directly without the need for a pre-drilled starter hole

ix) Can produce large parts at reasonable costs

x) Simple and rapid programming and set-up with minimal fixturing

Applications

- **Drilling holes, cutting slots, cleaning hard surfaces, deburring, polishing, and radiusing.**
- **Deburring of cross holes, slots, and threads in small precision parts that require a burr-free finish, such as hydraulic valves, aircraft fuel systems, and medical appliances.**
- **Machining intricate shapes or holes in sensitive, brittle, thin, or difficult-to-machine materials.**
- **Insulation stripping and wire cleaning without affecting the conductor.**
- **Micro-deburring of hypodermic needles.**
- **Frosting glass and trimming of circuit boards, hybrid circuit resistors, capacitors, silicon, and gallium.**
- **Removal of films and delicate cleaning of irregular surfaces because the abrasive stream is able to follow contours.**

Advantages

- **Because AJM is a cool machining process, it is best suited for machining brittle and heat-sensitive materials like glass, quartz, sapphire, and ceramics.**
- **The process is used for machining superalloys and refractory materials.**
- **It is not reactive with any workpiece material.**
- **No tool changes are required.**
- **Intricate parts of sharp corners can be machined.**
- **The machined materials do not experience hardening.**
- **No initial hole is required for starting the operation as required by wire EDM.**
- **Material utilization is high.**
- **It can machine thin materials.**

Limitations

- **The removal rate is slow.**
- **Stray cutting can't be avoided (low accuracy of ± 0.1 mm).**
- **The tapering effect may occur especially when drilling in metals.**
- **The abrasive may get impeded in the work surface.**
- **Suitable dust-collecting systems should be provided.**
- **Soft materials can't be machined by the process.**
- **Silica dust may be a health hazard.**
- **Ordinary shop air should be filtered to remove moisture and oil.**

USM

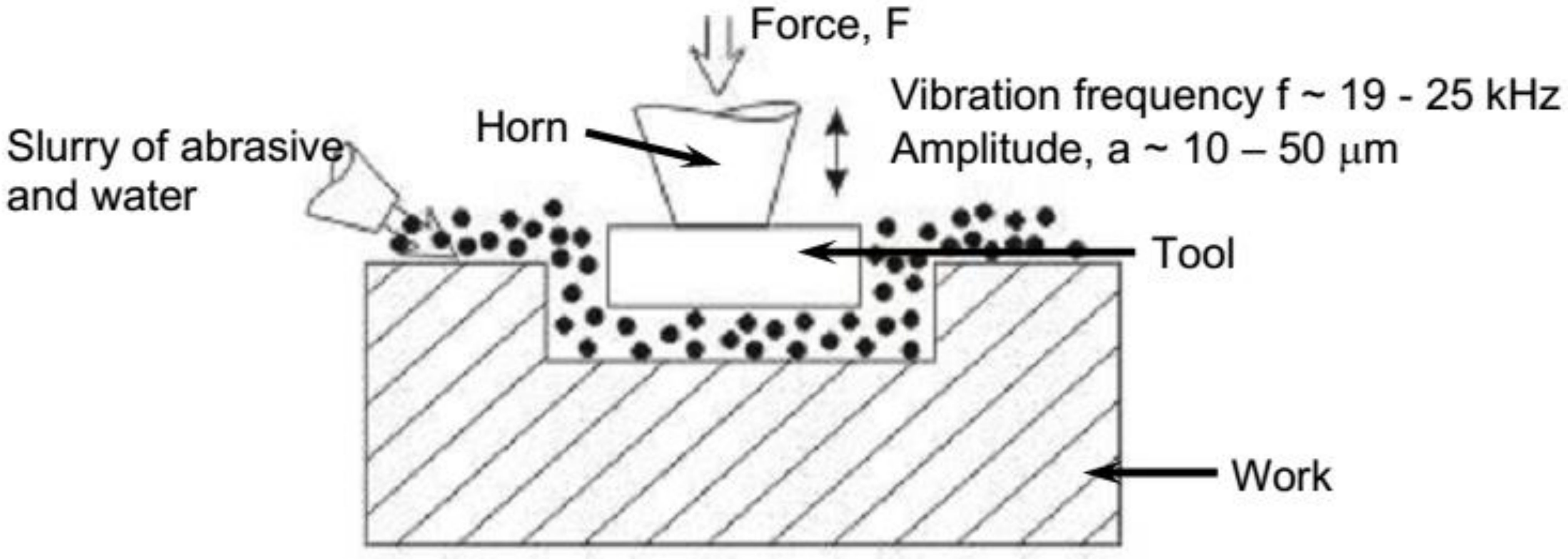
PRODUCTION TECHNOLOGY

PROF. KUNALSINH KATHIA

HJD INSTITUTE KERA

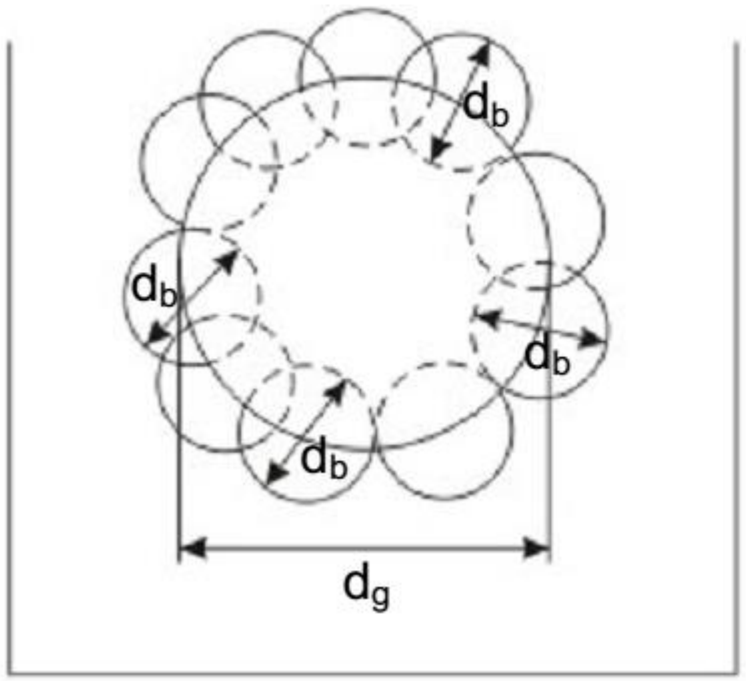
INTRODUCTION

USM PROCESS FUNDAMENTALS



MECHANISMS OF MATERIAL REMOVAL

SCHEMETIC REPRESENTATION OF ABRASIVE GRIT

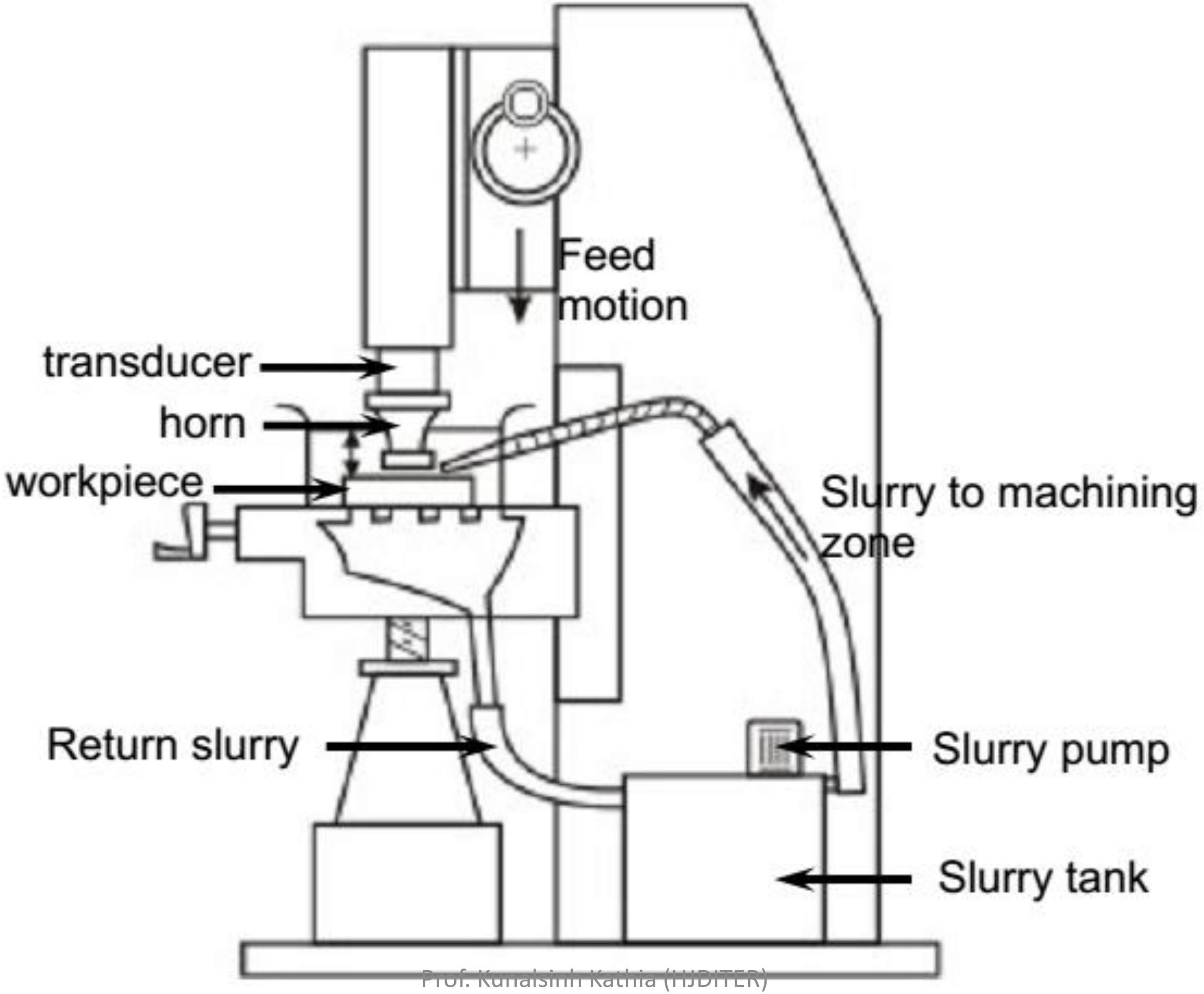


PROCESS PARAMETERS

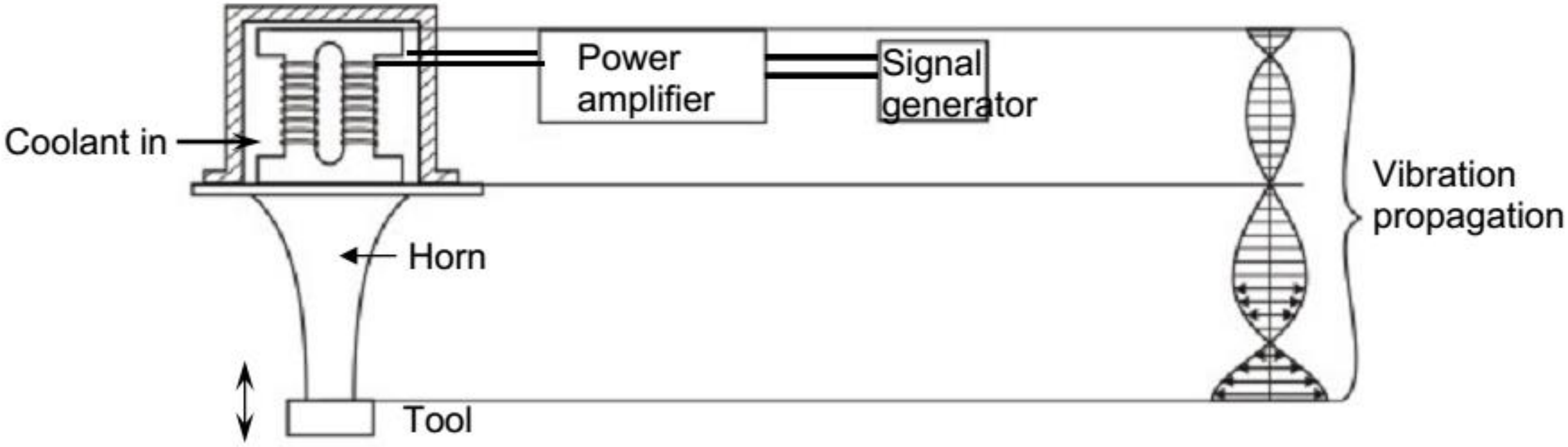
- Amplitude of vibration (a_o) – 15 – 50 μm
- Frequency of vibration (f) – 19 – 25 kHz
- Feed force (F) – related to tool dimensions
- Feed pressure (p)
- Abrasive size – 15 μm – 150 μm
- Abrasive material – Al_2O_3
  - SiC
  - B_4C
  - Boronsilicarbide
  - Diamond
- Flow strength of work material
- Flow strength of the tool material
- Contact area of the tool – A
- Volume concentration of abrasive in water slurry – C

USM MACHINE

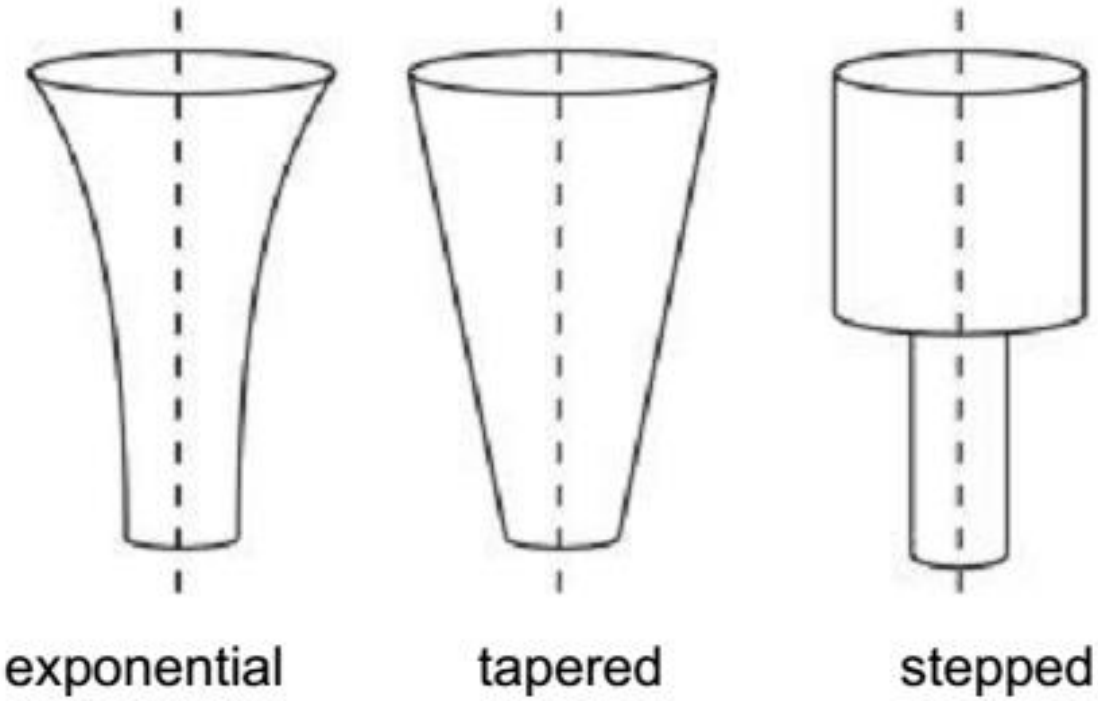
SCHEMETIC VIEW OF USM



WORKING OF HORN IN USM



TYPES OF HORN USED IN USM



APPLICATIONS

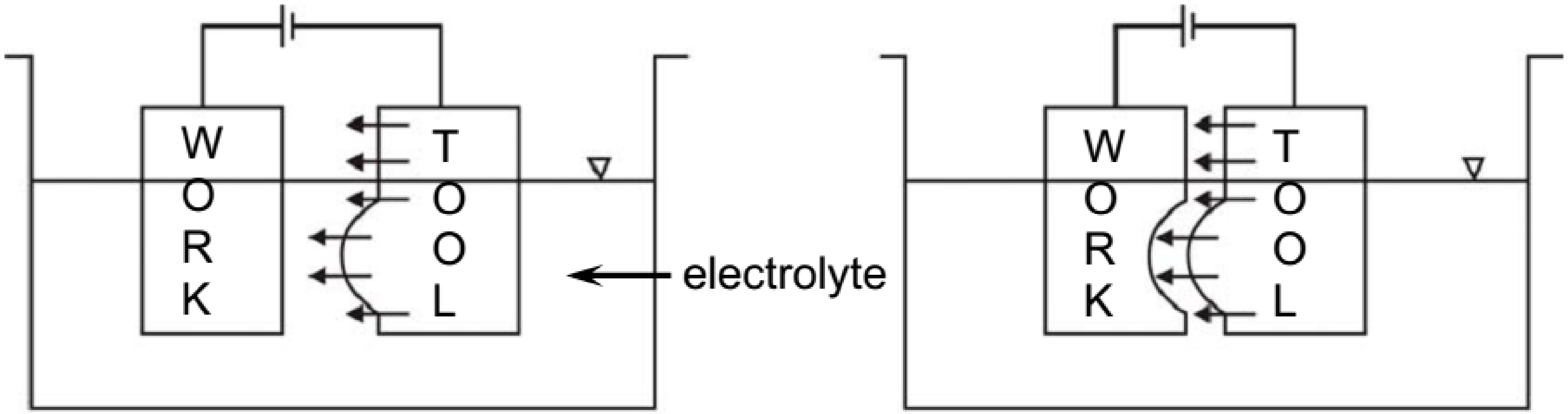
ECM

PRODUCTION TECHNOLOGY

MR.KUNALSINH R. KATHIA

MECHANICAL ENGINEERING DEPARTMENT

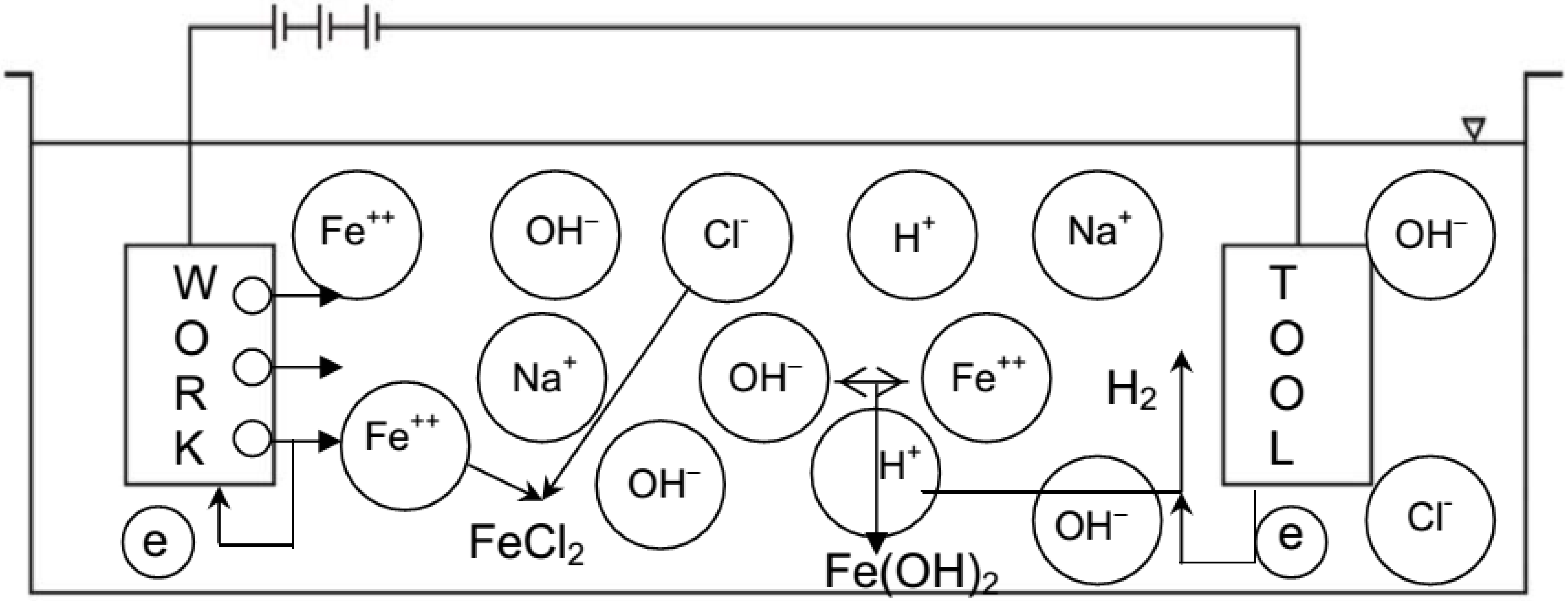
INTRODUCTION



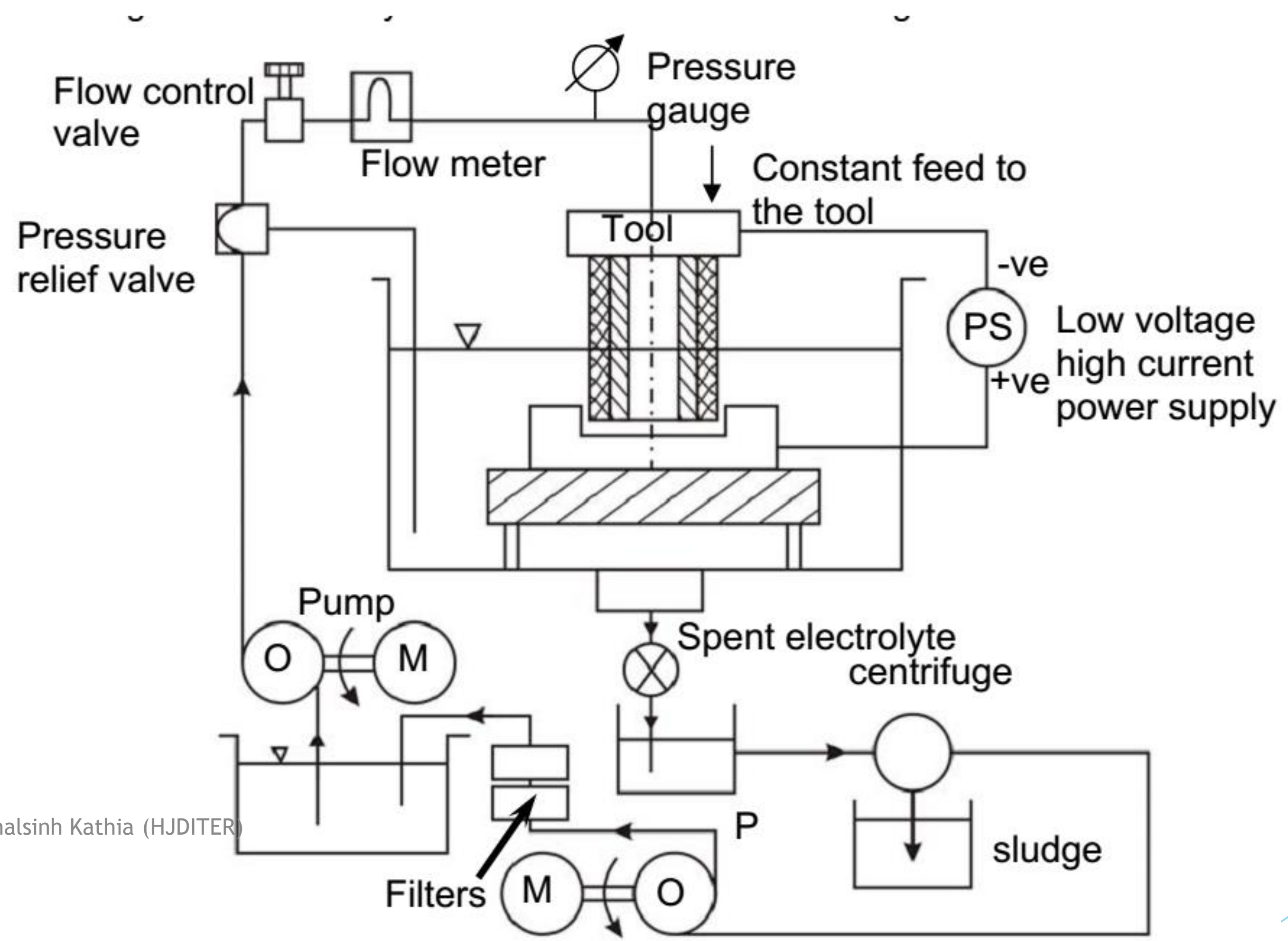
Initial stage of ECM

Steady state of ECM

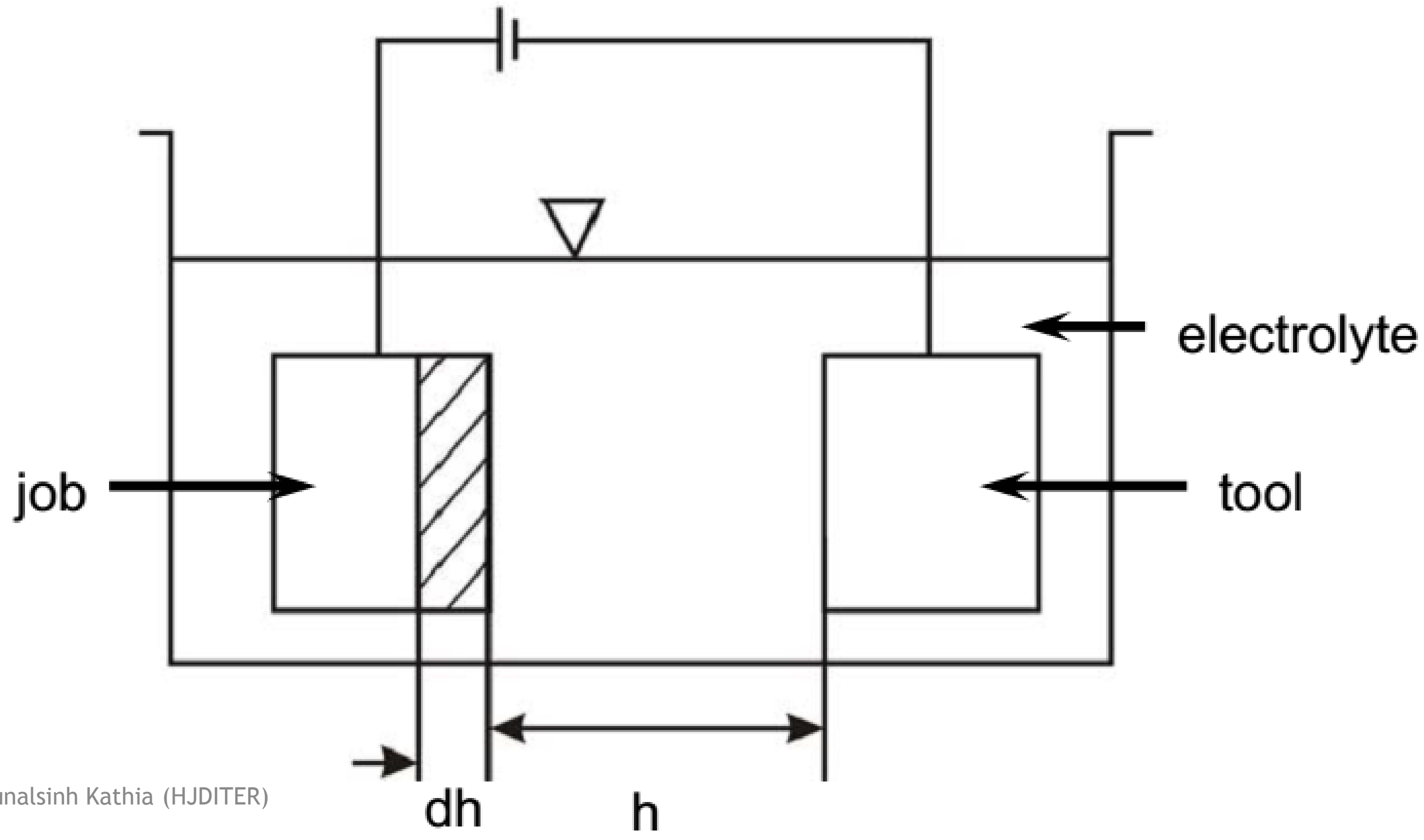
Process



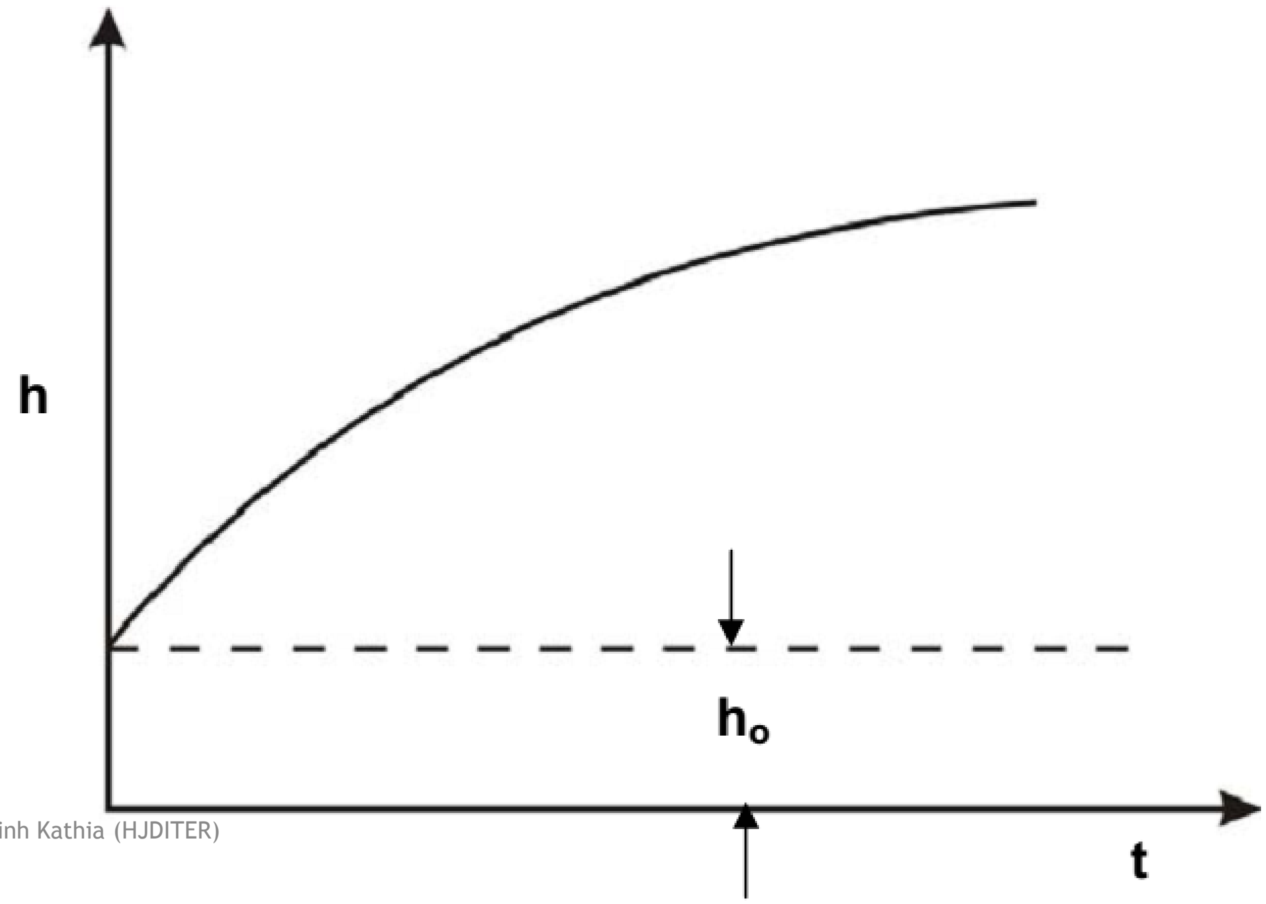
Equipment


Flow control valve
Flow meter
Pressure gauge
Constant feed to the tool
Tool
Pressure relief valve
-ve
PS
+ve
Low voltage high current power supply
Pump
O
M
Spent electrolyte
centrifuge
P
sludge
Filters
M
O

No feed to tool condition



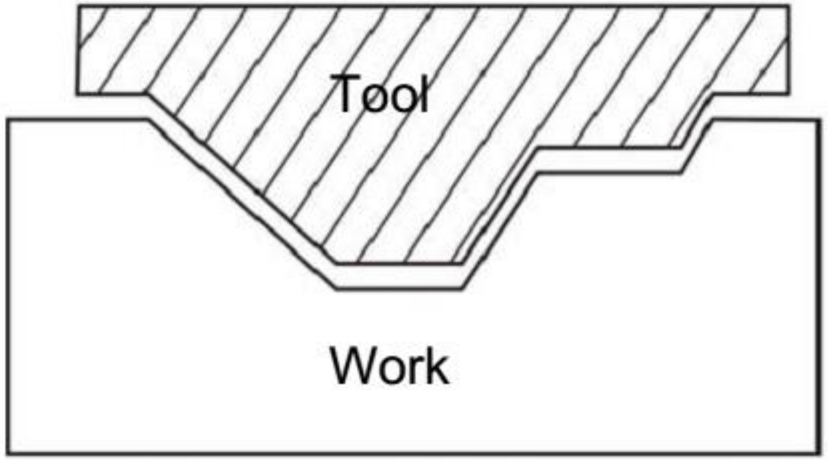
Variation of tool-workpiece gap under zero feed condition



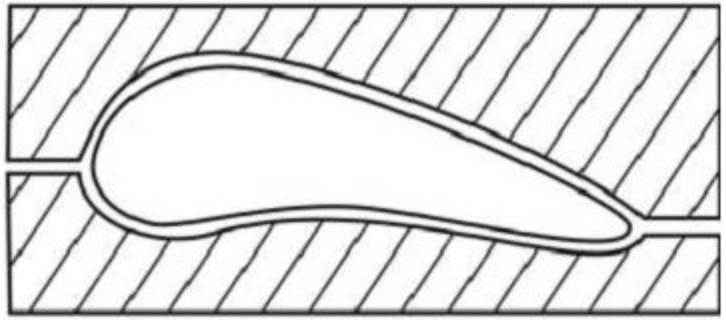
Applications

Ecm is used for

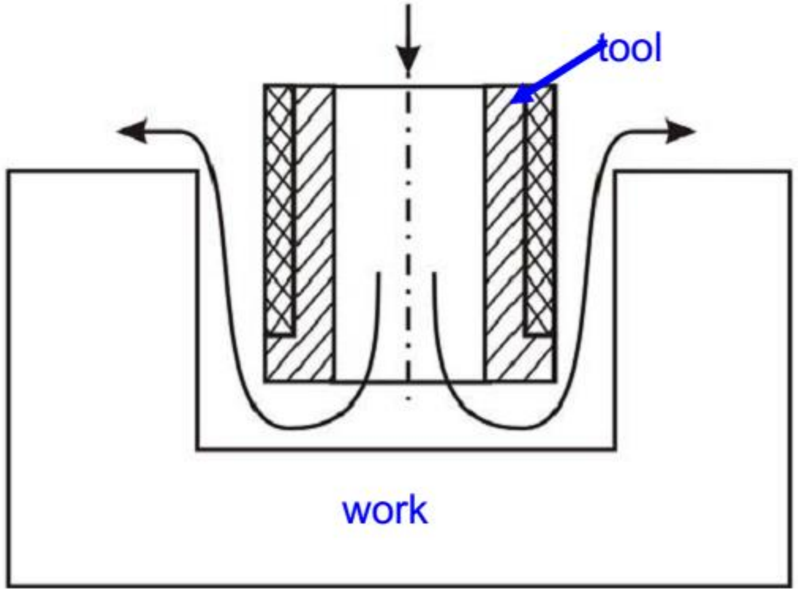
- •Die sinking
- • Profiling and contouring
- •Trepanning
- •Grinding
- •Drilling
- •Micro-machining



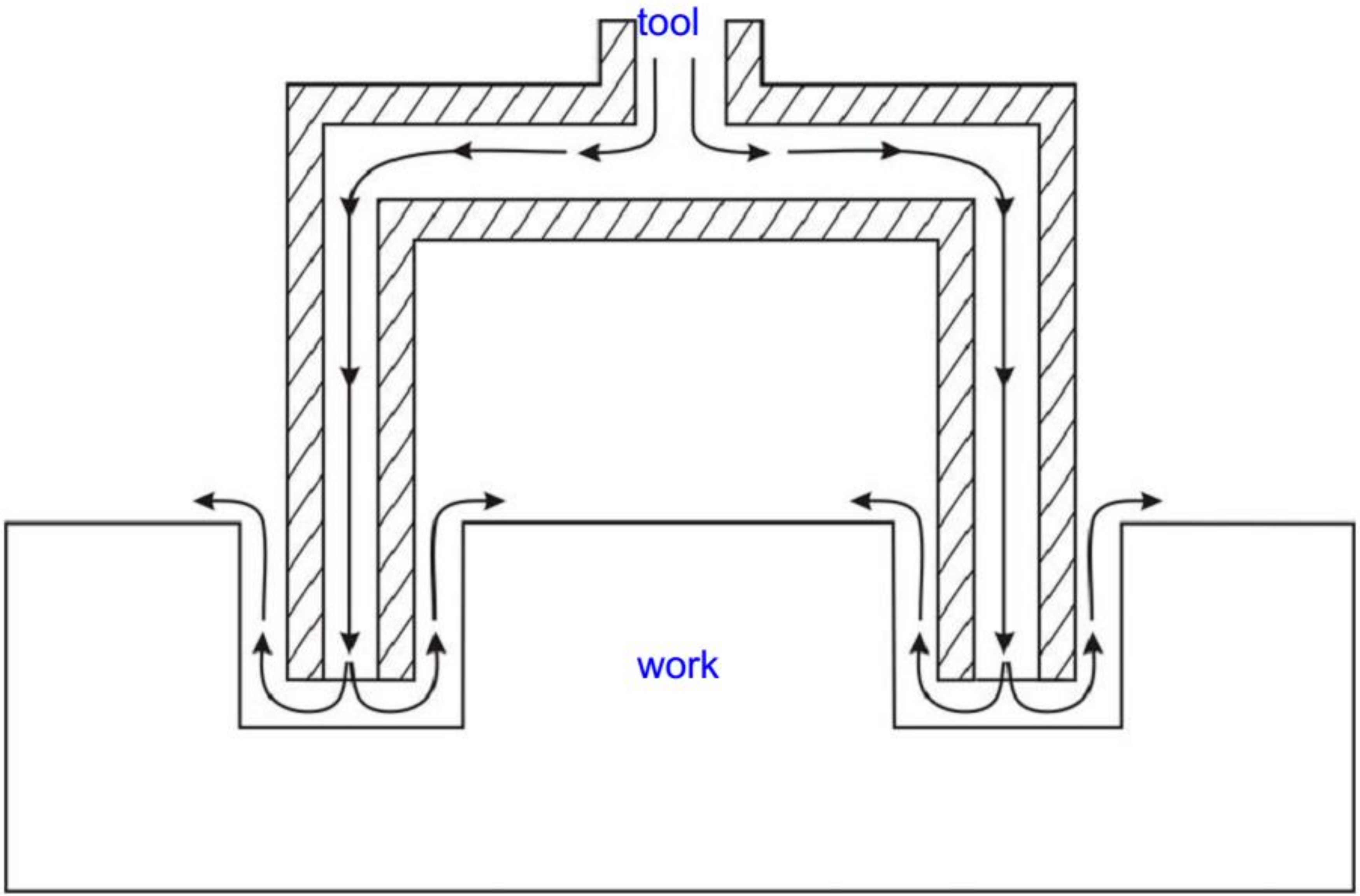
Die sinking



3D profiling



(drilling)



trepanning

Process Parameters

Power Supply	
Type	direct current
Voltage	2 to 35 V
Current	50 to 40,000 A
Current density	0.1 A/mm^2 to 5 A/mm^2
Electrolyte	
Material	NaCl and $NaNO_3$
Temperature	20°C – 50°C
Flow rate	20 lpm per 100 A current
Pressure	0.5 to 20 bar
Dilution	100 g/l to 500 g/l
Working gap	0.1 mm to 2 mm
Overcut	0.2 mm to 3 mm
Feed rate	0.5 mm/min to 15 mm/min
Electrode material	Copper, brass, bronze
Surface roughness, R_a	0.2 to 1.5 μm

EDM

NON CONVENTIONAL MACHINING

PROF.KUNALSINH R. KATHIA
MECHANICAL ENGINEERING DEPARTMENT

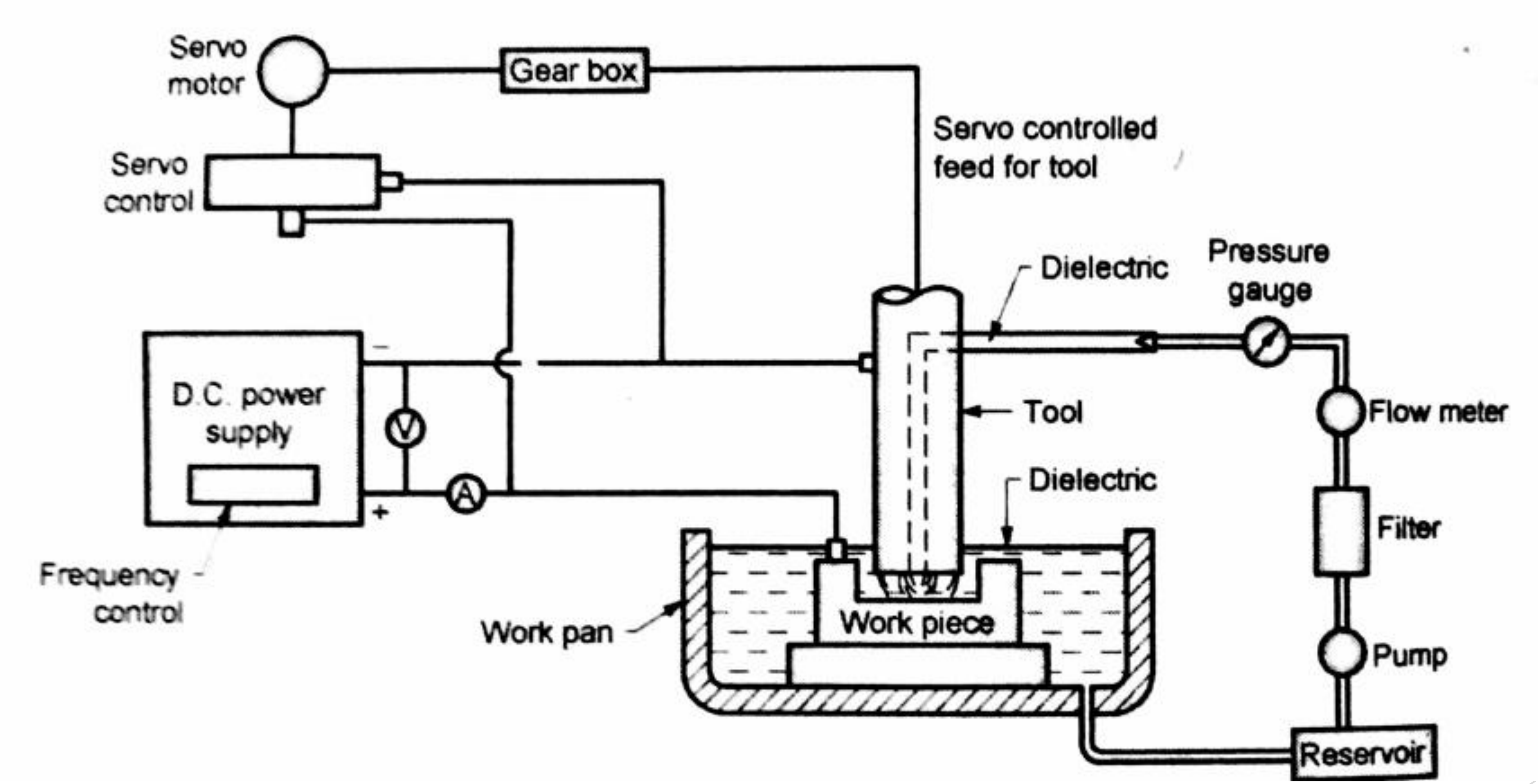
Introduction

▶Electro Discharge Machining (EDM) is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark.

▶EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys.

▶EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.

Process



Servo motor
Gear box
Servo control
Servo controlled feed for tool
Dielectric
Pressure gauge
D.C. power supply
V
A
Tool
Flow meter
Dielectric
Filter
Frequency control
Work pan
Work piece
Pump
Reservoir

Process

- In EDM, a potential difference is applied between the tool and workpiece. Both the tool and the work material are to be conductors of electricity.
- The tool and the work material are immersed in a dielectric medium. Generally kerosene or deionized water is used as the dielectric medium.
- A gap is maintained between the tool and the workpiece.
- Depending upon the applied potential difference and the gap between the tool and workpiece, an electric field would be established.
- Generally the tool is connected to the negative terminal of the generator and the workpiece is connected to positive terminal.
- As the electric field is established between the tool and the job, the free electrons on the tool are subjected to electrostatic forces.
- If the work function or the bonding energy of the electrons is less, electrons would be emitted from the tool (assuming it to be connected to the negative terminal). Such emission of electrons are called or termed as cold emission.

Process-2

- ▶The “cold emitted” electrons are then accelerated towards the job through the dielectric medium.
- ▶As they gain velocity and energy, and start moving towards the job, there would be collisions between the electrons and dielectric molecules.
- ▶Such collision may result in ionization of the dielectric molecule depending upon the work function or ionization energy of the
- ▶dielectric molecule and the energy of the electron.
- ▶Thus, as the electrons get accelerated, more positive ions and electrons would get generated due to collisions.
- ▶This cyclic process would increase the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap. The concentration would be so high that the matter existing in that channel could be characterized as “plasma”.
- ▶The electrical resistance of such plasma channel would be very less. Thus all of a sudden, a large number of electrons will flow from the tool to the job and ions from the job to the tool.
- ▶This is called avalanche motion of electrons.

Process-2

▶The high speed electrons then impinge on the job and ions on the tool.
▶The kinetic energy of the electrons and ions on impact with the surface of the job and tool respectively would be converted into thermal energy or heat flux.
▶Such intense localized heat flux leads to extreme instantaneous confined rise in temperature which would be in excess of 10,000oC.

Process-2

- Such localized extreme rise in temperature leads to material removal. Material removal occurs due to instant vaporization of the material as well as due to melting.
- The molten metal is not removed completely but only partially. As the potential difference is withdrawn as shown in Fig. 1, the plasma channel is no longer sustained. As the plasma channel collapse, it generates pressure or shock waves, which evacuates the molten material forming a crater of removed material around the site of the spark.
- Thus to summarise, the material removal in EDM mainly occurs due to formation of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference.
- Generally the work piece is made positive and the tool negative. Hence, the electrons strike the job leading to crater formation due to high temperature and melting and material removal.
- Similarly, the positive ions impinge on the tool leading to tool wear. In EDM, the generator is used to apply voltage pulses between the tool and the job.
- A constant voltage is not applied. Only sparking is desired in EDM rather than

Characteristics of EDM

- (a) The process can be used to machine any work material if it is electrically conductive
- (b) Material removal depends on mainly thermal properties of the work material rather than its strength, hardness etc. .
- (c) In EDM there is a physical tool and geometry of the tool is the positive impression of the hole or geometric feature machined
- (d) The tool has to be electrically conductive as well. The tool wear once again depends on the thermal properties of the tool material
- (e) Though the local temperature rise is rather high, still due to very small pulse on time, there is not enough time for the heat to diffuse and thus almost no increase in bulk temperature takes place. Thus the heat affected zone is limited to 2 – 4 μm of the spark crater.
- (f) However rapid heating and cooling and local high temperature leads to surface hardening which may be desirable in some applications
- (g) Though there is a possibility of taper cut and overcut in EDM, they can be controlled and compensated.

Dielectric

- In EDM, as has been discussed earlier, material removal mainly occurs due to thermal evaporation and melting. As thermal processing is required to be carried out in absence of oxygen so that the process can be controlled and oxidation avoided.
- Oxidation often leads to poor surface conductivity (electrical) of the work piece hindering further machining.
- Hence, dielectric fluid should provide an oxygen free machining environment. Further it should have enough strong dielectric resistance so that it does not breakdown electrically too easily but at the same time ionize when electrons collide with its molecule. Moreover, during sparking it should be thermally resistant as well.

Dielectric

- Generally kerosene and deionized water is used as dielectric fluid in EDM.
- Tap water cannot be used as it ionizes too early and thus breakdown due to presence of salts
- as impurities occur. Dielectric medium is generally flushed around the spark zone.
- It is also applied through the tool to achieve efficient removal of molten material.

Seat No.: _____ Enrolment No.______

GUJARAT TECHNOLOGICAL UNIVERSITY

BE SEM-VIII Examination May 2012

Subject code: 181903

Subject Name: Production Technology

Date: 14/05/2012 **Time: 10.30 am – 01.00 pm**

Total Marks: 70

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** The following observations were made during orthogonal turning of a mild steel tubing of 60 mm diameter on a lathe. **07**

(1) Cutting speed ……..………24 m/min
(2) Tool rake angle ……….......32º
(3) Feed rate …………………..0.12 mm/rev
(4) Tangential cutting force……3000N
(5) Feed force…………………..1200N
(6) Length of continuous chip in one revolution…96 mm

Determine:

(i) Co-efficient of friction
(ii) Shear plane angle
(iii) Velocity of chip tool face
(iv) Chip thickness

(b) Compare hobbing and shaping as production methods of spur gear in large quantities with neat sketch giving expected degree of accuracy and surface finish. **07**

Q.2 **(a)** Describe Ultrasonic Machining (USM) process with neat sketch. Discuss how the following factors effects the material removal rate of USM. **07**

(i) Grain Size (iv) Feed force
(ii) Frequency (v) Hardness ratio
(iii) Amplitude (vi) Abrasive concentration

(b) List the various types of locating devices used for both Jigs and Fixture and Explain any three of them with neat sketch. **07**

OR

(b) Draw neat schematic diagram of a sectioned view of a blanking die and punch assembly and label on it. Explain the function of (i) Die Block (ii) Punch (iii) Knock out. **07**

Q.3 **(a)** Draw neat sketch of chip formation in metal cutting and derive following relation for the shear angle (Ø) **07**

$$\phi = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

Where r = chip thickness ratio, α = tool rake angle

(b) Discuss following thread manufacturing methods with neat sketch (i) Chasing (ii) Rolling (iii) Tapping **07**

OR

Q.3 **(a)** Draw neat sketch of single point cutting tool with label of six major angles and other terminology of it. Discuss essential characteristic and function of cutting fluids. **07**

(b) Enlist different types of gears and draw gear tooth terminology. With appropriate example discuss plain indexing and compound indexing methods of manufacturing a gear on milling machine. **07**

Q.4 **(a)** Calculate the different seeds available on spindle of a lathe and show them on 1 x 2 x 3 (cross) and 1 x 2 x 3 (open) ray diagram using following data: **07**

(1) Max spindle speed RPM = 166
(2) Min spindle speed RPM = 30
(3) No of spindle speed = 6

(b) Describe principle of Electrical Discharge Machining (EDM) with figure and state its advantages, limitation and application. **07**

OR

Q.4 **(a)** Explain single spindle automates and transfer machines with suitable example. **07**

(b) How are unconventional machining methods classified? Compare LBM and EBM process with different factors which consider for classification of unconventional machining. **07**

Q.5 **(a)** Distinguish between a Jig and Fixture. Sketch different drill bushes useful in drill jigs. **07**

(b) Determine the material utilization factor for producing 60 mm equilateral triangle blank from a 4 mm thick. Assume bridge allowance is 1.5T and the blanks are arranged in straight line as showing in figure 1. a = b **07**

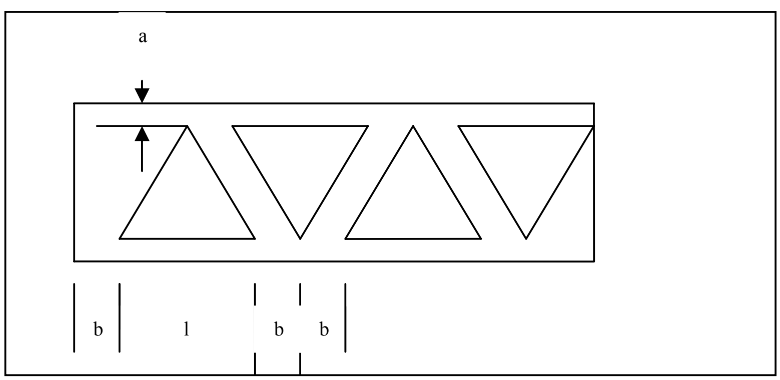


Figure 1.

OR

Q.5 **(a)** Draw and discuss following clamping devices **07**

(i) Hinged Clamp
(ii) Quick Action Nut
(iii) Hydraulic Clamp

(b) Differentiate Between **07**

(i) Capstan and Turret lathes
(ii) Piercing and Blanking operation

****

Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VIII • EXAMINATION – SUMMER 2013

Subject Code: 181903 **Date: 15/05/2013**

Subject Name: Production Technology

Time: 10:30 am TO 01:00 pm **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** Define Non-conventional machining? Why do we need these processes? Give classification of the Non conventional processes? **07**

(b) Distinguish between jig and fixture. State advantages of jigs and fixtures. **07**

Q.2 **(a)** Write in detail the methods of reducing the cutting forces in press working. **07**

(b) Discuss the various types of pilots used in progressive die. **07**

OR

(b) Sketch and design a progressive die to make a steel washer 30 mm outside diameter with 15 mm hole. From 1.6 mm thick steel sheet. The ultimate shear strength of the material is 320 N/mm^2. Calculate, **07**

a. Maximum punch force necessary to blank and punch the washer if both punches operate at the same time.
b. Punch and die size for piercing and blanking operation

Q.3 **(a)** Write short note on ï ñLathe tool Dynamometerò. **07**

(b) In orthogonal cutting, if the feed is 1.25 mm/rev and chip thickness after cutting is 2mm, determine the following. **07**

1. Chip thickness ratio
2. Shear angle

The tool bit has a rake angle of 10º.

If shear strength = 600 N/mm^2

Width of cut = 10 mm

Cutting speed = 30 m/min

Co-efficient of friction = 0.9

Determine,

a. Shear force
b. Friction angle
c. Cutting force
d. Horse power at the cutting tool

OR

Q.3 **(a)** Draw Merchantô s force diagram. Derive the equations for frictional force, normal reaction, shear force and normal force. **07**

(b) The following equation for tool life has been obtained for H. S. S. tool. **07**

$$VT^{0.13} f^{0.6} d^{0.3} = C$$

A 60 minute tool life was obtained while cutting at V = 40 m/min, f = 0.25 mm/rev and d= 2 mm.

Calculate the effect on tool life if speed, feed and depth of cut are together increased by 25% and also if they are increased individually by 25%. Also give your comments.

Q.4	**(a)**	What is LASER? Explain LBM.	**07**
	(b)	Describe the degrees of freedom for workpiece located in space. Draw a simple sketch to show the 3-2-1 locating principle and explain.	**07**
		OR	
Q.4	**(a)**	List various clamping devices used in jigs and fixtures. Sketch any two clamping devices and explain its working.	**07**
	(b)	Write important functions of dielectric fluid and electrolyte. Also write various types of commonly used dielectric fluid and electrolyte.	**07**
Q.5	**(a)**	Explain with the help of sketch, principle, types, and applications of gear hobbing.	**07**
	(b)	Describe the essential parts of turret lathe. What is the field of application of turret lathe?	**07**
		OR	
Q.5	**(a)**	Write short note on Gear finishing process.	**07**
	(b)	Discuss the various types of multi spindle automats.	**07**

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Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE – SEMESTER–VIII • Remedial EXAMINATION – WINTER 2013

Subject Code: 181903 **Date: 17/09/2013**

Subject Name: Production Technology

Time: 03:00 pm – 05:30 pm **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1	**(a)**	Draw a neat sketch of a single point cutting tool indicating its complete geometry on it.	**07**
	(b)	Draw a merchant circle diagram and derive expressions to show relationship among the different forces acting on the cutting tool and different parameter involved in metal cutting.	**07**
Q.2	**(a)**	Classify the generating process for gear cutting ? Explain "Gear Hobbing" in detail.	**07**
	(b)	Describe each type of chip with the help of suitable sketch.	**07**
		OR	
	(b)	What is tool life? State factors influencing on it in detail.	**07**
Q.3	**(a)**	Explain with suitable diagram working of electro discharge machine. State its advantage, disadvantage and application.	**07**
	(b)	Explain Abrasive Jet machining with schematic diagram stating its advantages and limitation.	**07**
		OR	
Q.3	**(a)**	Explain principle of Ultrasonic machining with the help of neat diagram. State its advantages and application.	**07**
	(b)	With neat sketch, explain the process of Electro –chemical grinding. State its limitation.	**07**
Q.4	**(a)**	How the Presses are classified? Sketch and describe any one of it.	**07**
	(b)	What are automatic transfer machines? Write principle, advantages and disadvantages of it.	**07**
		OR	
Q.4	**(a)**	What is difference between a capstan and turret lathe? Describe in brief with the help of suitable sketch.	**07**
	(b)	Make a neat sketch of a die- set and describe its various details and accessories	**07**
Q.5	**(a)**	Enlist types of Jig. Explain construction and working of template jig.	**07**
	(b)	Explain "Principle of location" in detail.	**07**
		OR	
Q.5	**(a)**	Enlist types of Fixtures. Explain any two with sketch.	**07**
	(b)	Describe with neat sketch any three types of clamping device with their features and application.	**07**

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Seat No.: ________ Enrolment No.___________

GUJARAT TECHNOLOGICAL UNIVERSITY

BE - SEMESTER–VIII • EXAMINATION – SUMMER 2014

Subject Code: 181903 **Date: 03-06-2014**

Subject Name: Production Technology

Time: 10:30 am TO 01:00 pm **Total Marks: 70**

Instructions:

1. **Attempt all questions.**
2. **Make suitable assumptions wherever necessary.**
3. **Figures to the right indicate full marks.**

Q.1 **(a)** What are the main characteristics of cutting tool materials **03**

(b) Explain in brief Taylor's relationship for cutting speed-tool life. **04**

(c) During an orthogonal machining (turning) operation of C-40 steel, the following data were obtained. **07**

(1) Chip thickness = 0.45mm
(2) Width of cut = 2.5mm
(3) Feed = 0.25mm/rev
(4) Tangential cut force = 1130N
(5) Feed thrust force = 295N
(6) Cutting speed = 2.5m/s
(7) Rake angle = 10^o

Calculate (1) Force of shear at shear plane
(2) Kinetic co-efficient of friction.

Q.2 **(a)** Discuss various types of tool wears and their causes. **07**

(b) A 300mm dia. bar is turned at 45rev/min with depth of cut of 2mm and feed of 0.3mm/rev. The forces measured at the cutting tool point are **07**

Cutting force = 1850N
Feed force = 450N

Calculate (1) power consumption
(2) specific cutting energy

OR

(b) The following equation for tool life is given for a turning operation **07**

$$V\,T^{0.13}\,f^{0.77}\,d^{0.37} = C$$

A 60 min tool life was obtained while cutting at V = 30m/min, f = 0.3mm/rev and d = 2.5mm

Determine the changes in tool-life if the cutting speed, feed and depth of cut are increased by 20% individually and also taken together.

Q.3 **(a)** Classify various non-conventional machining processes. **07**

(b) Explain the working principle of EDM. What are the main process parameters . State advantages of EDM. **07**

OR

Q.3 **(a)** State various thread manufacturing methods. **03**

(b) Differentiate between gear forming and gear generating methods. **04**

(c) Explain gear finishing processes. **07**

Q.4 **(a)** What are the advantages of using jigs and fixtures. **03**

(b) Explain in brief Angle jig. **04**

(c) Explain basic design steps for cam for single spindle automat. **07**

OR

Q.4	**(a)**	Explain in brief hydraulic clamp.	**03**
Q.4	**(b)**	Explain in brief Indexing jig by taking suitable example.	**04**
	(c)	Differentiate between Capstan and turret lathe	**07**
Q.5	**(a)**	How cutting force is calculated for press work. What are the various methods for reducing force requirements.	**07**
	(b)	Explain in brief two pass layout in press work by taking suitable example.	**07**

OR

Q.5	**(a)**	Explain various methods of mounting of punches.	**07**
	(b)	Explain various machine tool structures, based on rigidity.	**07**

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