Course Title : MACHINE TOOLS

III B.Tech I Sem

Mechanical Engineering

(AY: 2023 – 2024)

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PROGRAM	:	**B.TECH (ME)**	**ACADEMIC YEAR**	:	**2023–24**
YEAR & SEMESTER	:	**III B. Tech – I Sem**	**COURSE TYPE**	:	**Core**
COURSE TITLE	:	**MACHINE TOOLS**	**COURSE CODE**	:	**20APC0327**
FACULTY NAME	:	**Dr. B. SUDHEER REDDY**	**DEPARTMENT**	:	**MECHANICAL ENGINEERING**
INSTRUCTION	:	**Le. 3 Tu. 1 Pr. -**	**CREDITS**	:	**3**
NUMBER. ON ROLL	:	**72**	**ASSESSMENT**	:	**30 (CIE) + 70 (SEE)**

Course Outcomes	
CO1	**To understand the basic concepts of the philosophy of metal cutting and the mechanism of chip formation**
CO2	**To understand the basic concepts horning.**
CO3	**To understand the basic principle of drilling, shaping and planning operation, parts of the drilling**
CO4	**To able to understand the principle of milling, grinding, Lapping, Honing and Broaching operation**
CO5	**To understand the design of Jigs and fixtures and uses, Classification of Jigs & Fixtures - Principles of location and clamping.**

UNIT I

Elementary treatment of metal cutting theory – Elements of cutting process – Geometry of single point tool and angles, chip formation and types of chips – built up edge and its effects, chip breakers. Mechanics of orthogonal cutting –Merchant's Force diagram, cutting forces – cutting speeds, feed, depth of cut, heat generation, tool life, coolants, machinability –economics of machining. cutting Tool materials and cutting fluids –types and characteristics.

UNIT II

Engine lathe – Principle of working- specification of lathe – types of lathes – work holders and tool holders – Taper turning, thread turning and attachments for Lathes. Turret and capstan lathes – collet chucks – other work holders – tool holding devices – box and tool layout. Principal features of automatic lathes – classification – Single spindle and multi-spindle automatic lathes– tool layout and cam design

UNIT III

Drilling and Boring Machines – Principles of working, specifications, types, operations performed – tool holding devices – twist drill – Boring tools – machining time calculation. Shaping, Slotting and Planning machines – Principles of working – Principal parts – specification, classification, Operations performed. Machining time calculations.

UNIT IV

Milling machine – Principles of working – specifications – classifications of milling machines – Principal features – machining operations, Types and geometry of milling cutters– methods of indexing – Accessories to milling machines. Grinding machine –Theory of grinding – classification– cylindrical and surface grinding machine – Tool and cutter grinding machine – special types of grinding machines – Grinding wheel: Different types of abrasives – bonds, specification and selection of a grinding wheel. Static and dynamic balancing of a wheel Truing and Dressing of wheels. Lapping, Honing and Broaching machines – comparison of grinding, lapping and honing. machining time calculations.

UNIT V

Principles of design of Jigs and fixtures and uses, 3-2-1 Classification of Jigs & Fixtures – Principles of location and clamping – Types of clamping & work holding devices, Typical examples of jigs and fixtures Unit built machine tools – multispindle heads. power units-principal of working types of UBMTS, characterization, applications.

Text Books:

1. Workshop Technology – Vol II, B.S.RaghuVamshi, Dhanpat Rai & Co, 10th edition, 2013
2. Production Technology by R.K. Jain and S.C. Gupta, Khanna Publishers, 17th edition, 2012

Reference Books:

1. Manufacturing Technology-Kalpakzian- Pearson
2. Metal cutting Principles by Milton C.Shaw, oxford Second Edn, 2nd edition, 2012
3. Production Technology by H.M.T. (Hindustan Machine Tools),TMH, 1st edition, 2001
4. Production Technology by K.L.Narayana, IK International Pub.
5. Machining and machine tools by AB. Chattopadyay, WileyEdn,2013
6. Unconventional Machining process by V.K.Jain, Allied Pub.
7. Manufacturing technology Vol II by P.N. Rao, Tata McGraw Hill, 4th edition, 2013

COs	PO No. and keyword	Competency Indicator	Performance Indicator
CO1	PO 5: Modern tool usage	5.2	5.2.2
CO2	PO 1: Engineering knowledge	1.2	1.2.2
CO3	PO 5: Modern tool usage	5.2	5.2.2
CO4	PO 5: Modern tool usage	5.2	5.2.2
CO5	PO 1: Engineering knowledge PO 7: Environment and sustainability	1.6 7.2	1.3.1 7.2.1

Unit – 1

Elementary treatment of Metal Cutting

Elementary treatment of metal cutting theory – Elements of cutting process – Geometry of single point tool and angles, chip formation and types of chips – built up edge and its effects, chip breakers. Mechanics of orthogonal cutting –Merchant's Force diagram, cutting forces – cutting speeds, feed, depth of cut, heat generation, tool life, coolants, machinability – economics of machining. cutting Tool materials and cutting fluids –types and characteristics.

Introduction to Metal Cutting

In an industry, metal components are made into different shapes and dimensions by using various metal working processes.

Metal working processes

Non-cutting shaping
Forging, rolling, pressing, etc.

Cutting shaping
turning, drilling, milling, etc.

Manufacturing a solid product of definite size and shape from a given material taken in three possible states:

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

Material Removal Processes – Metal Cutting Process

- A family of shaping operations, the common feature of which is removal of material from a starting work part so the remaining part has the desired geometry
- Traditional Process (Machining) – Material removal by a sharp cutting tool, e.g., turning, milling, drilling
- Nontraditional processes - Various energy forms other than sharp cutting tool to remove material. e.g., Laser and Electron Beam machining
- Abrasive processes – Material removal by hard, abrasive particles, e.g., grinding

Why Machining is Important

- Variety of work materials can be machined
  - Most frequently used to cut metals
- Variety of part shapes and special geometric features possible, such as:
  - Screw threads
  - Accurate round holes
  - Very straight edges and surfaces
- Good dimensional accuracy and surface finish

Disadvantages with Machining

- Wasteful of material
  - Chips generated in machining are wasted material, at least in the unit operation
- Time consuming
  - A machining operation generally takes more time to shape a given part than alternative shaping processes, such as casting, powder metallurgy, or forming

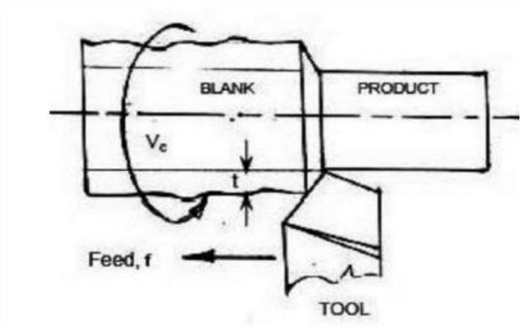
Machining

Machining is an **essential process of finishing** by which work pieces are produced ***to the desired dimensions and surface finish by gradually removing the excess material*** from the preformed blank in the form of chips with the help of cutting tool(s) moved past the work surface(s).

Principle of machining

A metal rod of irregular shape, size and surface is converted into a finished product of desired dimension and surface finish by machining by proper relative motions of the tool-work pair.

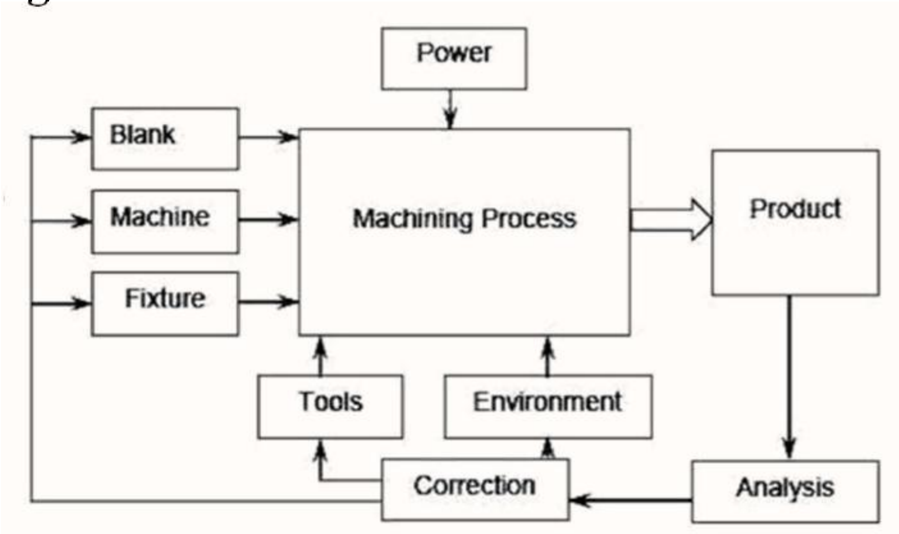
- Machining to high accuracy and finish essentially enables a product:
  - Fulfill its functional requirements.
  - Improve its performance.
  - Prolong its service.



Principle of machining (Turning)

Requirements of machining

- The blank and the cutting tool are properly mounted (in fixtures) and moved in a powerful device called machine tool enabling gradual removal of layer of material from the work surface resulting in its desired dimensions and surface finish.
- Additionally some environment called cutting fluid is generally used to ease machining by cooling and lubrication.



Definition of machine tool

A machine tool is a non-portable power operated and reasonably valued device or system of devices in which energy is expended to produce jobs of desired size, shape and surface finish by removing excess material from the preformed blanks in the form of chips with the help of cutting tools moved past the work surface(s).

Basic functions of machine tools

Machine tools basically produce geometrical surfaces like flat, cylindrical or any contour on the preformed blanks by machining work with the help of cutting tools.

The physical functions of a machine tool in machining are:

- Firmly holding the blank and the tool.
- Transmit motions to the tool and the blank.
- Provide power to the tool-work pair for the machining action.
- Control of the machining parameters, i.e., speed, feed and depth of cut.

Types of cutting tools (Based on metal cutting)

Single point
turning tools, shaping, planning and slotting tools and boring tools.

Multipoint
milling cutters, broaching tools, hobs, gear shaping cutters etc.

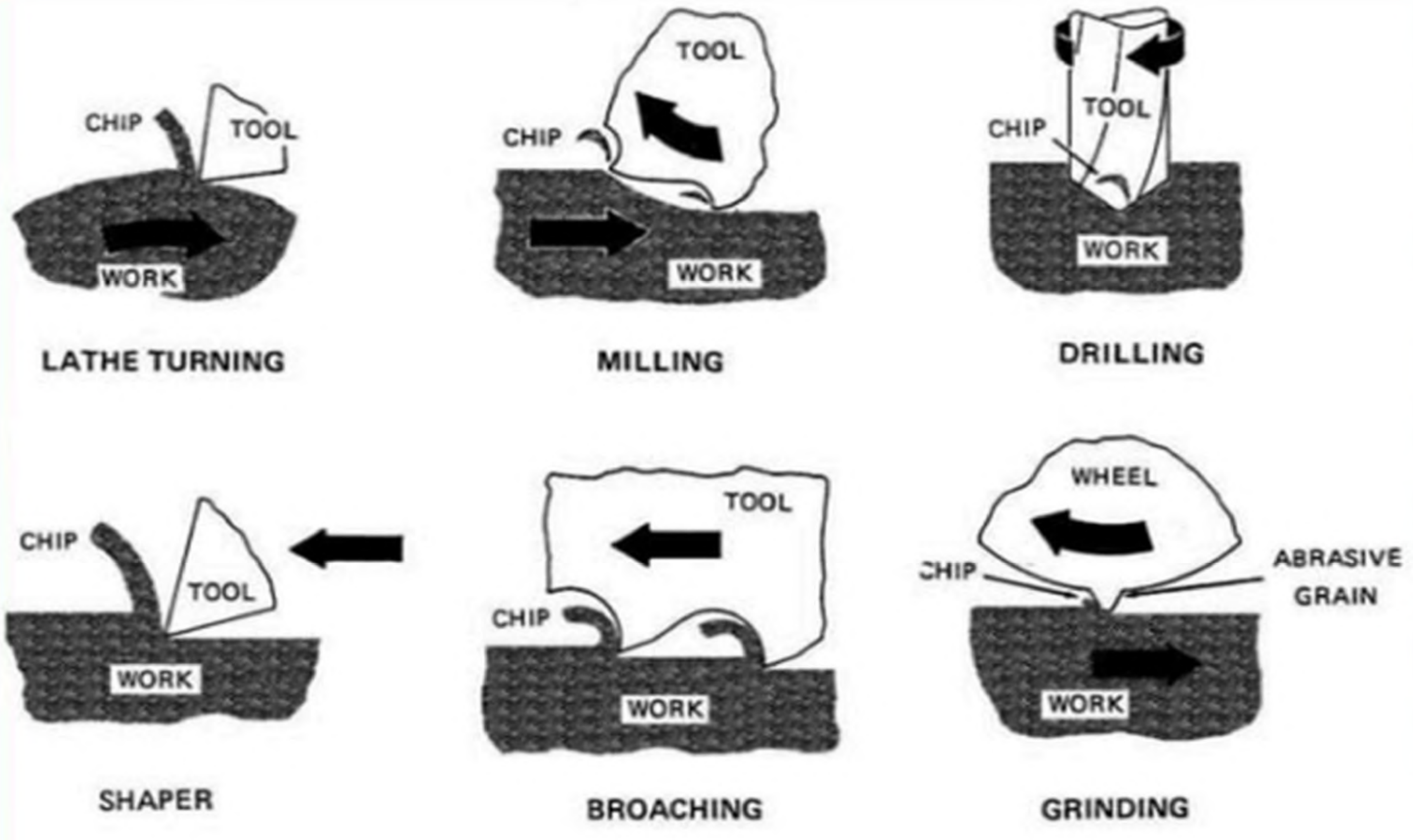
Types of cutting tools (A/c to motion of cutting)

Linear Motion
Lathe, broaching , shaping, Planning

Rotary Motion
milling, grinding, broaching, hobs, gear shaping etc.

Linear & Rotary Motion
Drilling, honing, boring etc.

Different types of material removal Operations

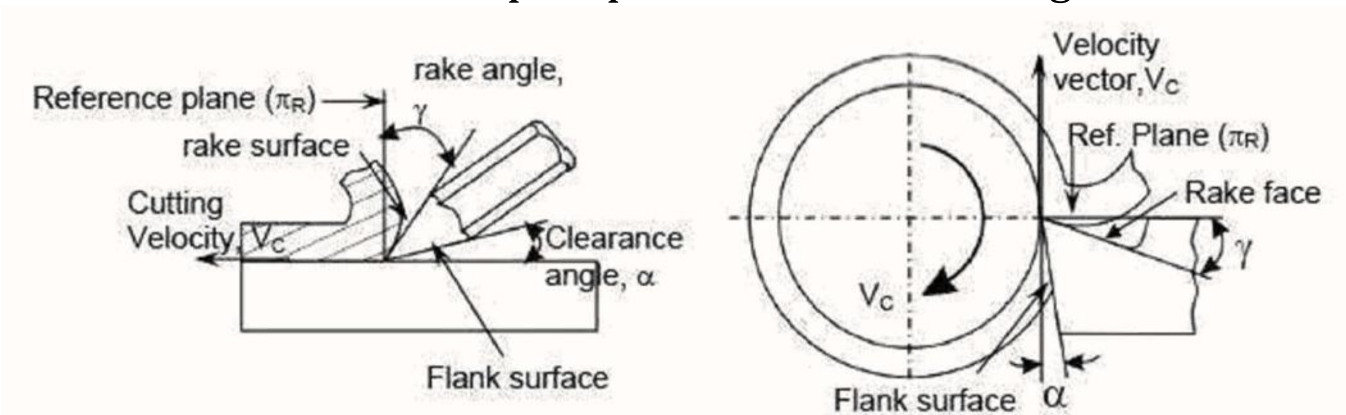


Geometry of single point cutting (turning) tools

Both material and geometry of the cutting tools play very important roles on their performances in achieving effectiveness, efficiency and overall economy of machining.

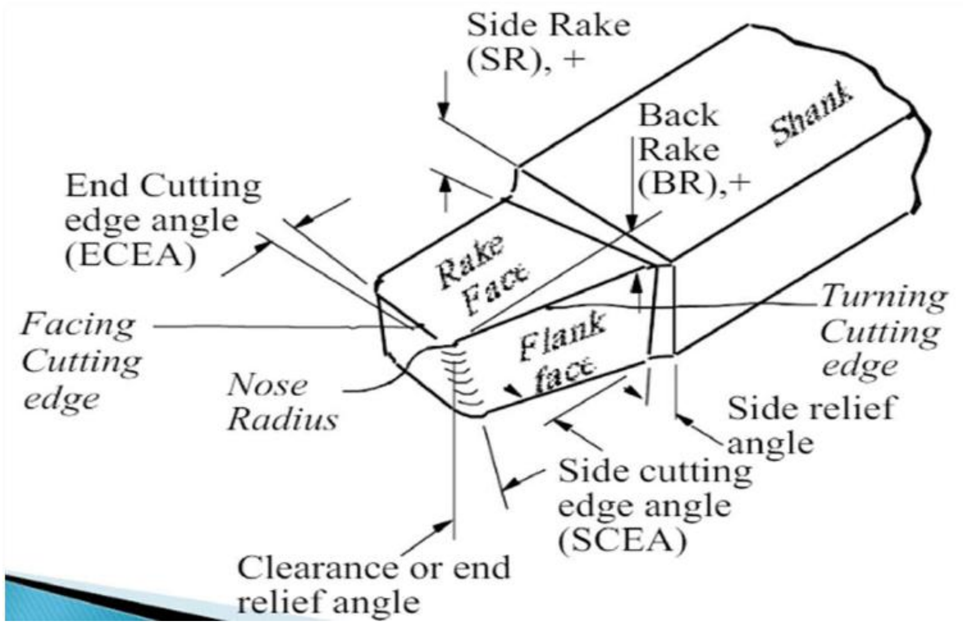
Concept of rake and clearance angles of cutting tools

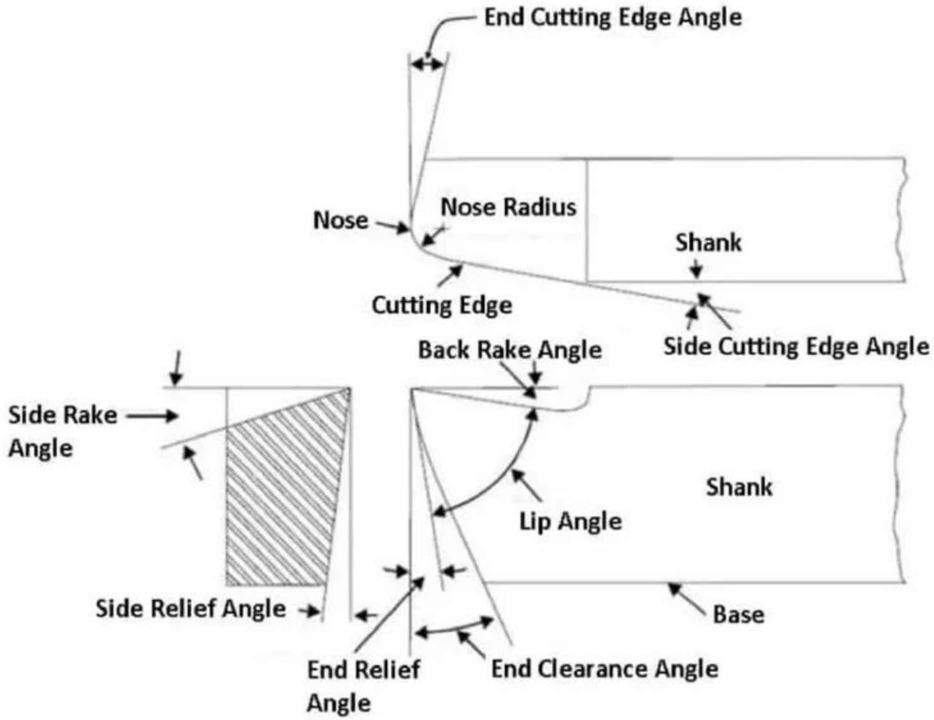
The word tool geometry is basically referred to some specific angles or slope of the salient faces and edges of the tools at their cutting point. Rake angle and clearance angle are the most significant for all the cutting tools. The concept of rake angle and clearance angle will be clear from some simple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



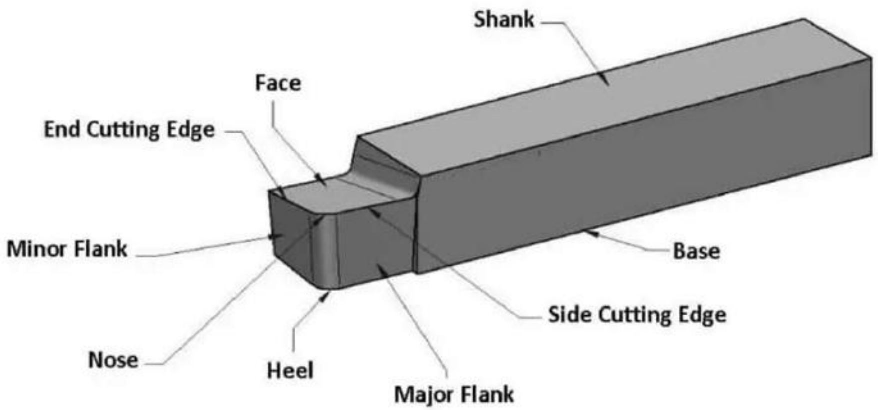
Rake and clearance angles of cutting tools

Single Point Cutting Tool Geometry or Nomenclature:





- Shank
- Flank
- Face
- Heel
- Nose
- Nose Radius
- Cutting Edges
- Side Cutting Edge Angle
- End Cutting Edge Angle
- Back Rake angle
- Side rake angle
- Side Relief Angle and
- Back Relief Angle

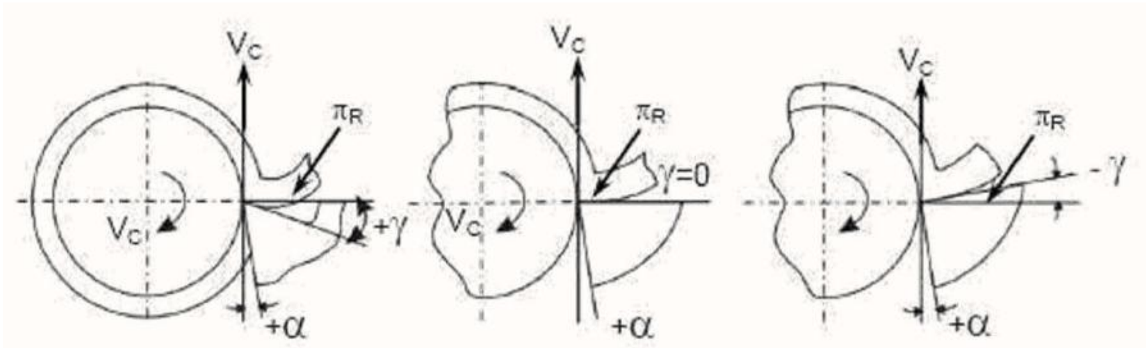


Tool signature for single point cutting tool

- Shank
  - It is the main body of the tool
- Flank
  - The surface of the tool adjacent to the cutting edge
- Face
  - The surface on which the chip slides
- Nose
  - It is the point where the side cutting edge and end cutting edge intersect
- Nose Radius
  - Strengthens finishing point of tool
- Cutting Edge
  - It is the edge on the face of the tool which removes the material from the work piece
- Side cutting edge angle
  - Angle between side cutting edge and the side of the tool shank

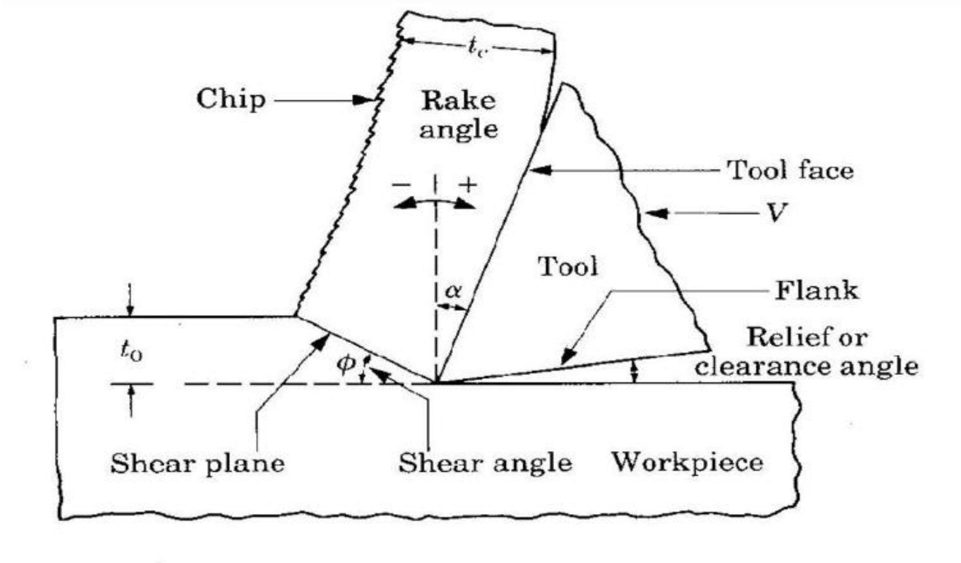
Rake angle (γ): Angle of inclination of rake surface from reference plane.
Clearance angle (α): Angle of inclination of clearance or flank surface from the finished surface.
Rake angle is provided for ease of chip flow and overall machining.
Rake angle may be positive, or negative or even zero as shown in Fig. (a, b and c).
Relative advantages of such rake angles are:
Positive rake - helps reduce cutting force and thus cutting power requirement.
Zero rake - to simplify design and manufacture of the form tools.
Negative rake - to increase edge-strength and life of the tool.
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.

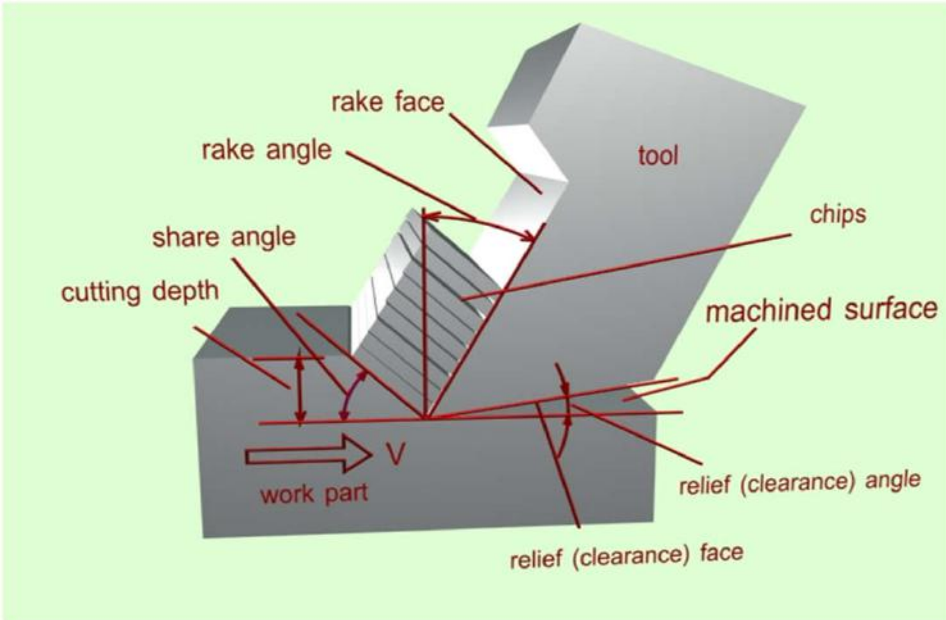
Hence, clearance angle is a must and must be positive (30 ~ 150) depending upon tool-work materials and type of the machining operations like turning, drilling, boring etc.



(a) Positive rake (b) Zero rake (c) Negative rake
Fig. Three possible types of rake angles

Single Point Cutting Tool Terminology-2D / 3D





- End cutting edge angle
  - Angle between end cutting edge and the line normal to the tool shank
- Side Relief angle
  - Angle between the portion of the side flank immediately below the side cutting edge and a line perpendicular to the base of the tool, measured at right angle to the side flank
- End Relief angle
  - Angle between the portion of the end flank immediately below the end cutting edge and a line perpendicular to the base of the tool, measured at right angle to the end flank
- Side Rake angle
  - Angle between the tool face and a line parallel to the base of the tool and measured in a plane perpendicular to the base and the side cutting edge
- Back Rake angle
  - Angle between the tool face and a line parallel to the base of the tool and measured in a plane perpendicular to the side cutting edge

Cutting Tool Materials

- Carbon steels, High-speed steels
- Cast carbides, Cemented carbides, Coated carbides
- Cermets, Ceramic Tools
- Polycrystalline Cubic Boron Nitride (PCBN)
- Polycrystalline Diamond (PCD)

Properties of Cutting Tool Materials

- Harder than work piece.
- High toughness
- High thermal shock resistance
- Low adhesion to work piece material
- Low diffusivity to work piece material

Theory of Metal Cutting

- Metal cutting or machining is the process of producing a work piece by removing unwanted material from a block of metal, in the form of chips.
- This process is most important since almost all the products get their final shape and size by metal removal, either directly or indirectly.

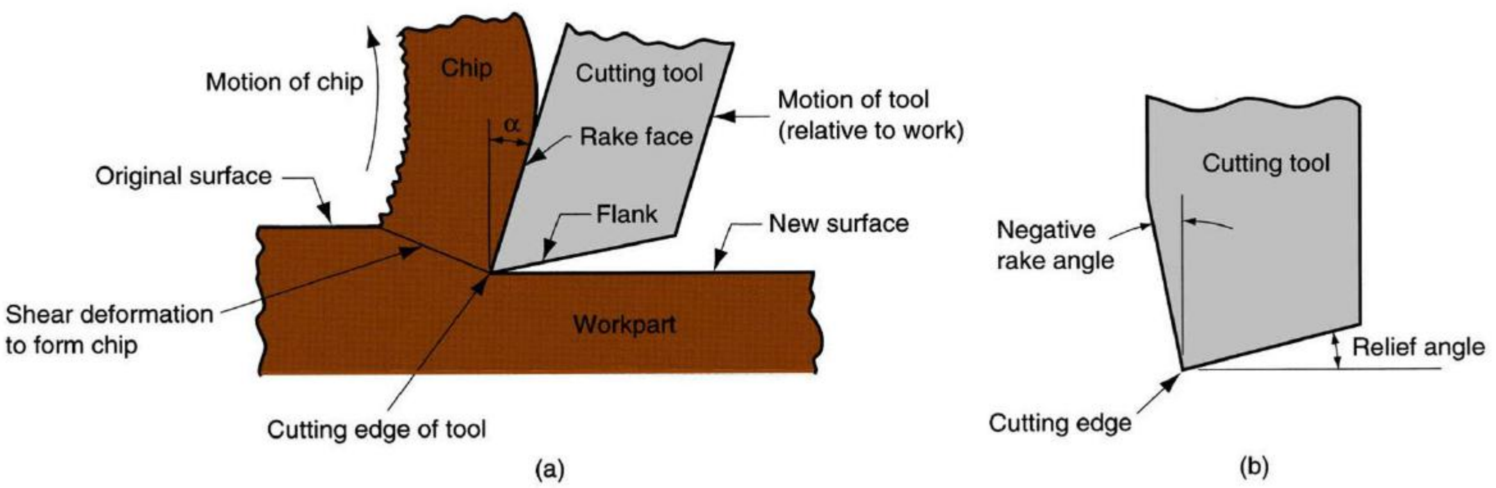
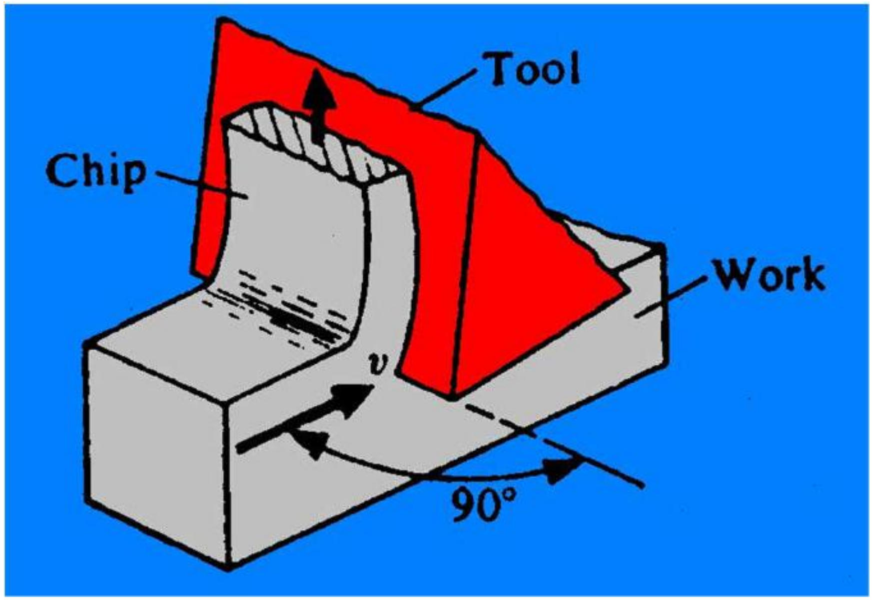
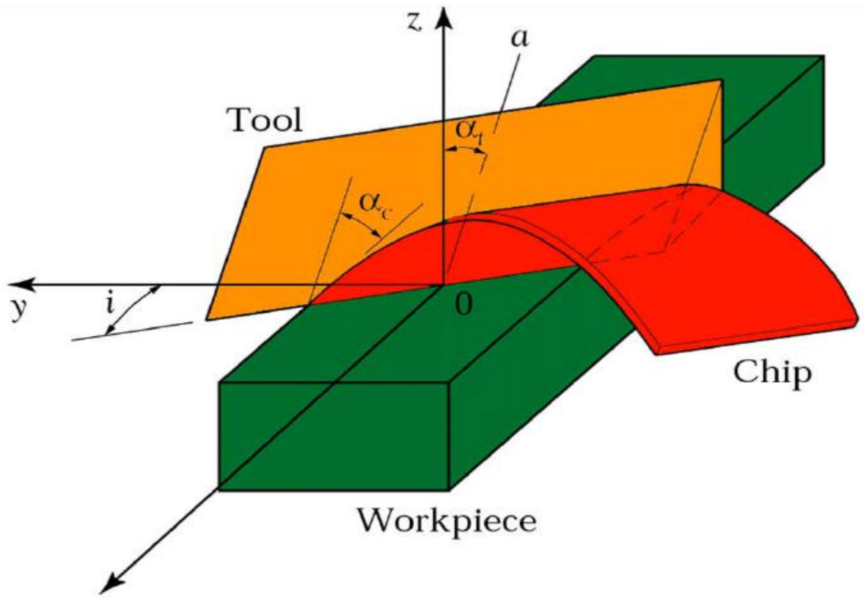


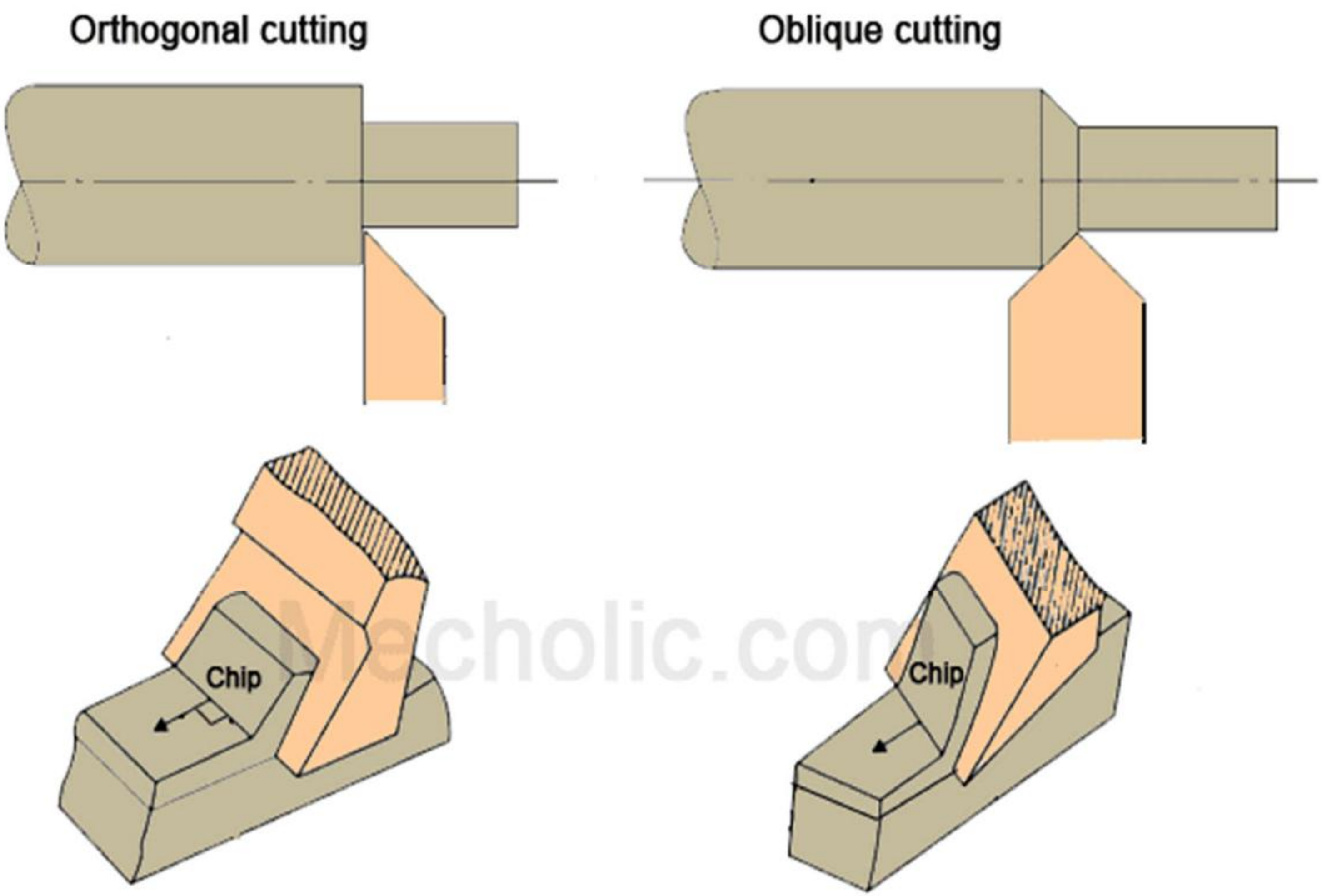
Figure (a) A cross-sectional view of the machining process, (b) tool with negative rake angle; compare with positive rake angle in (a).

Orthogonal and oblique cutting

- Orthogonal cutting
  - The cutting edge of the tool is straight and perpendicular to the direction of motion.
- Oblique cutting
  - The cutting edge of the tool is set at an angle to the direction of motion.



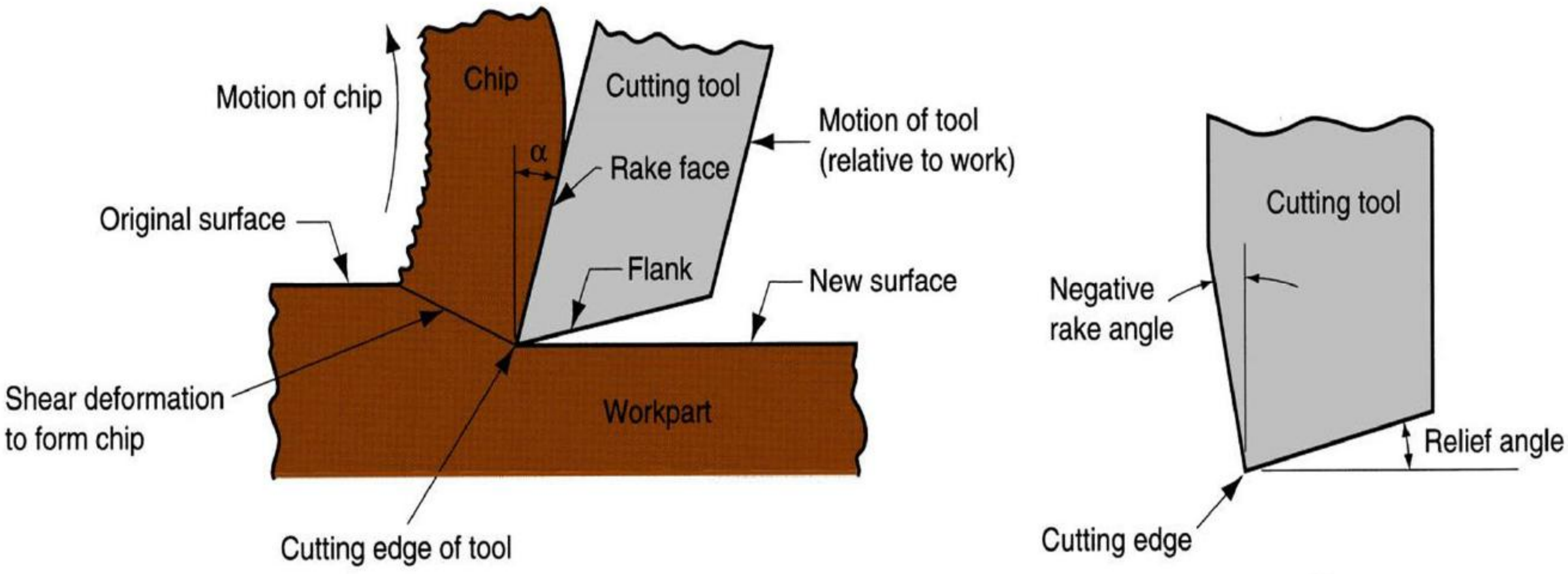



Orthogonal cutting
Oblique cutting
Chip
Chip
Mecholic.com

BASIS OF COMPARISON	ORTHOGONAL	OBLIQUE CUTTING
Description	In orthogonal cutting, the cutting edge of the tool makes right angle to the direction of feed motion.	Oblique cutting, the cutting edge of the tool is inclined to the direction of feed motion.
Components Of Force	There are only two components of force which are mutually perpendicular. The components include: cutting force and thrust force ; and can be represented by 2D coordinate system.	Three components of force are considered, that is thrust force, radial force and cutting force. These components cannot be represented by 2D coordinate system; they can only be represented by 3D coordinate system.
Tool Life	The tool that uses orthogonal type of cutting has a lesser cutting life compared to tools that use oblique cutting.	The tool that uses oblique type of cutting has a more cutting life compared to tools that use oblique cutting.
Heat Concentration At The Cutting Region	Has a high heat concentration at the cutting region.	Has a lesser concentration of heat at the cutting region.
Cutting Edge	The cutting edge is larger than the cutting width.	The cutting edge may or may not be larger than cutting width.
Chips Flow	The chips flow in the direction normal to the cutting edge.	The chips flow along the sideways.
Shear Force Per Unit Area	The Shear force that act per unit area is high, a factor which increases the heat developed per unit area.	The Shear force per unit is low, a factor which decreases heat developed per unit area hence increasing tool life.
Surface Finish	The surface finish obtained is very poor when compared to oblique cutting which gives a fairly good surface finish.	The surface finish obtained is a bit finer when compared to orthogonal cutting which gives a poor surface finish.
Use	Used in grooving, parting, slotting, pipe cutting etc..	Used almost in all industrial cutting, used in drilling, grinding, milling etc.

The Mechanism of Cutting

- Cutting action involves shear deformation of work material to form a chip. As chip is removed, new surface is exposed
- Orthogonal Cutting - assumes that the cutting edge of the tool is set in a position that is perpendicular to the direction of relative work or tool motion. This allows us to deal with forces that act only in one plane.



(a) A cross-sectional view of the machining process, (b) tool with negative rake angle; compare with positive rake angle in (a).

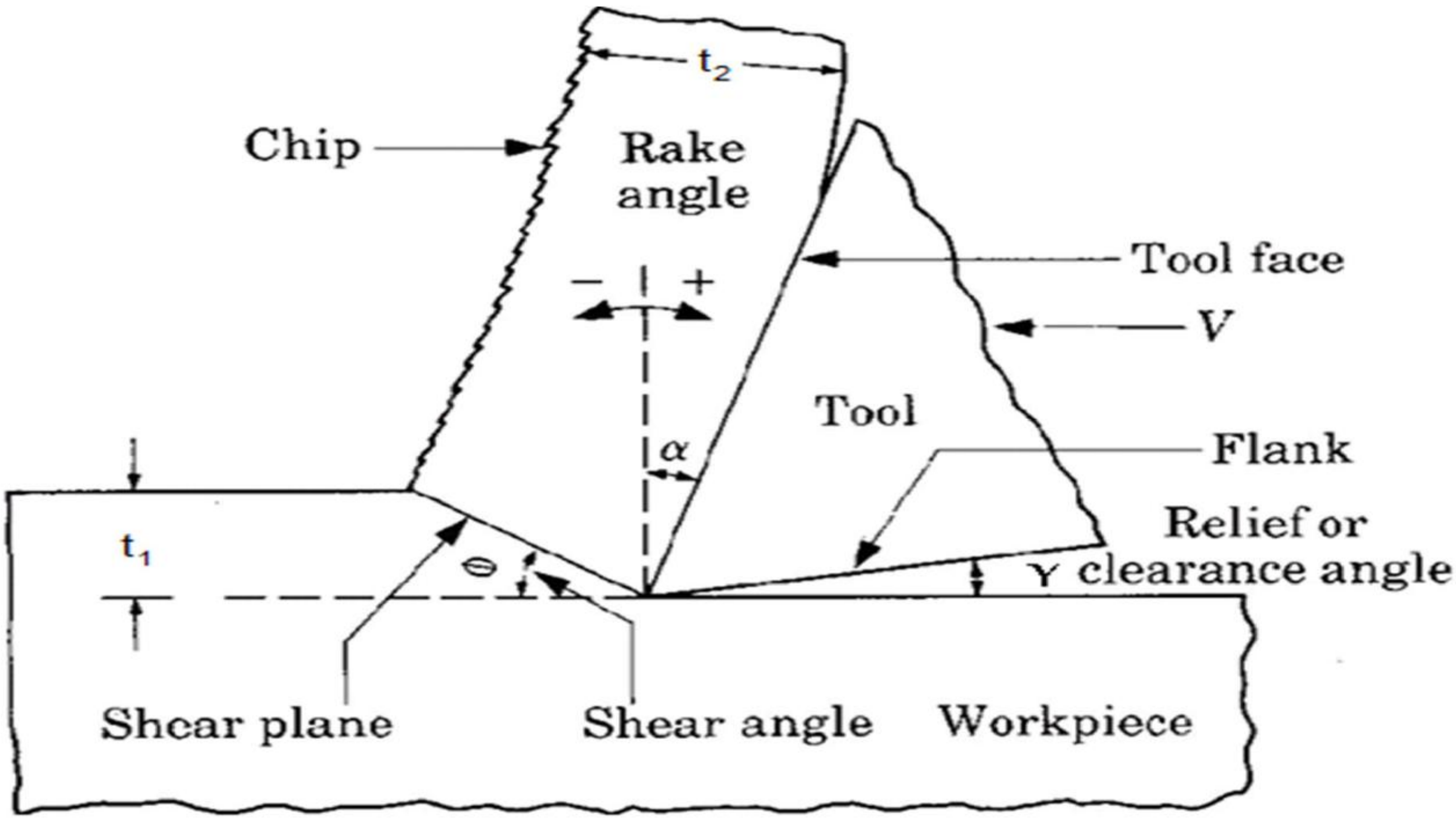
Mechanics of Orthogonal Cutting

Orthogonal Cutting

- Ideal Orthogonal Cutting is when the cutting edge of the tool is straight and perpendicular to the direction of motion.
- During machining, the material is removed in form of chips, which are generated by shear deformation along a plane called the shear plane.
- The surface the chip flows across is called the face or rake face.
- The surface that forms the other boundary of the wedge is called the flank.
- The rake angle is the angle between the tool face and a line perpendicular to the cutting point of the work piece surface.

Mechanics of Orthogonal Cutting

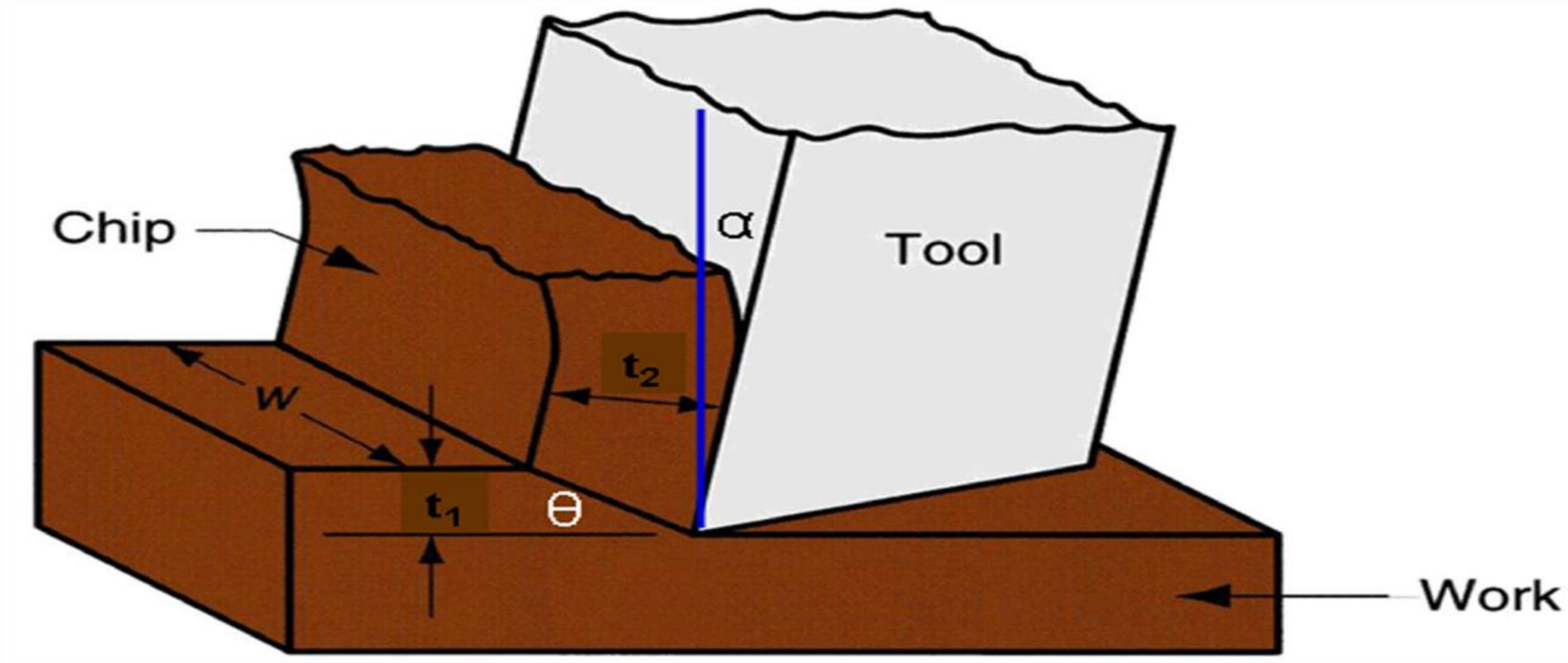
- The relief or clearance angle is the angle between the tool flank and the newly formed surface of the work piece angle.



Mechanics of Orthogonal Cutting

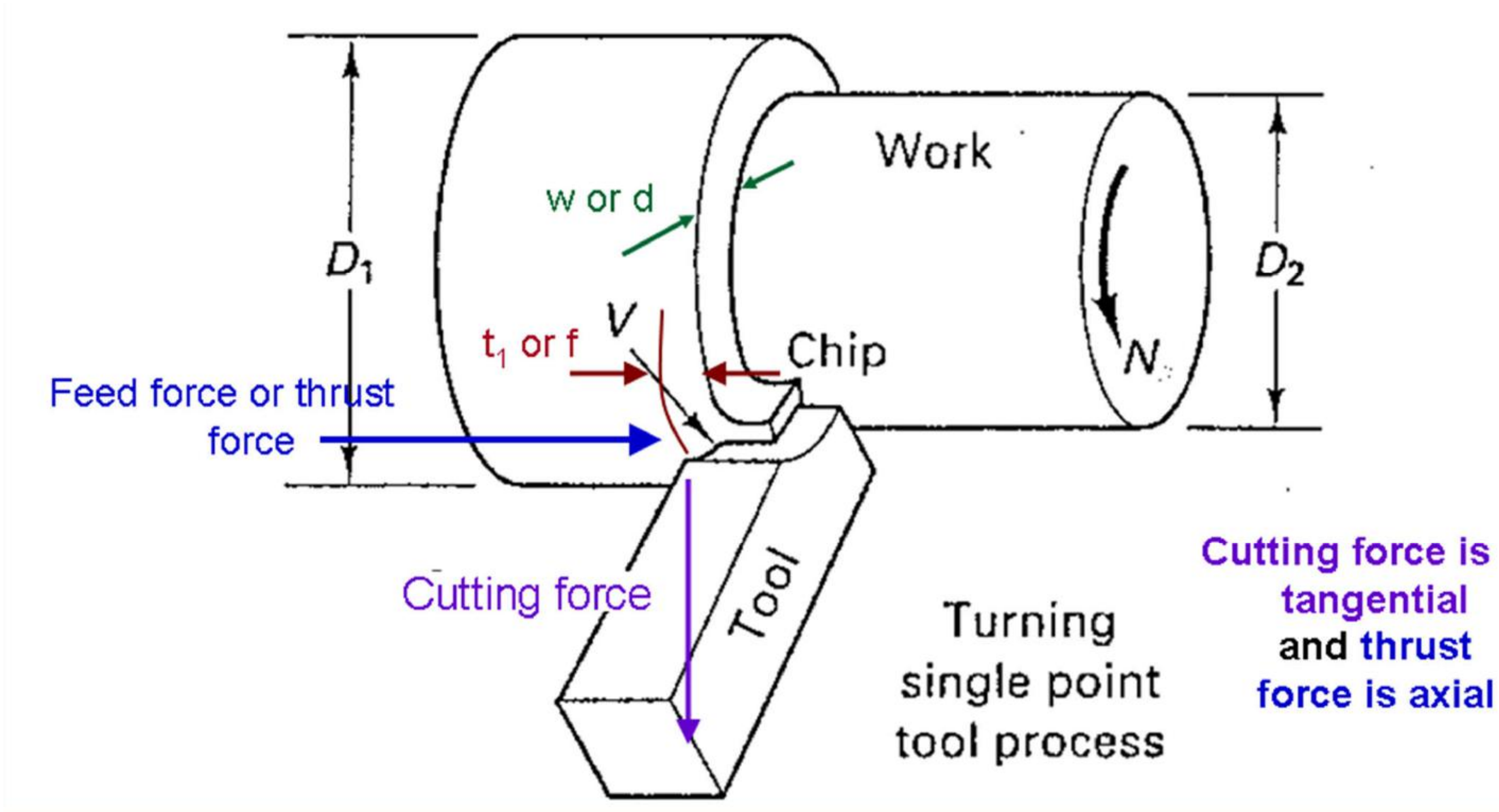
Orthogonal cutting model:

- t_1 = un deformed chip thickness
- t_2 = deformed chip thickness (usually $t_2 > t_1$)
- α = rake angle
- If we are using a lathe, t_1 is the feed per revolution.

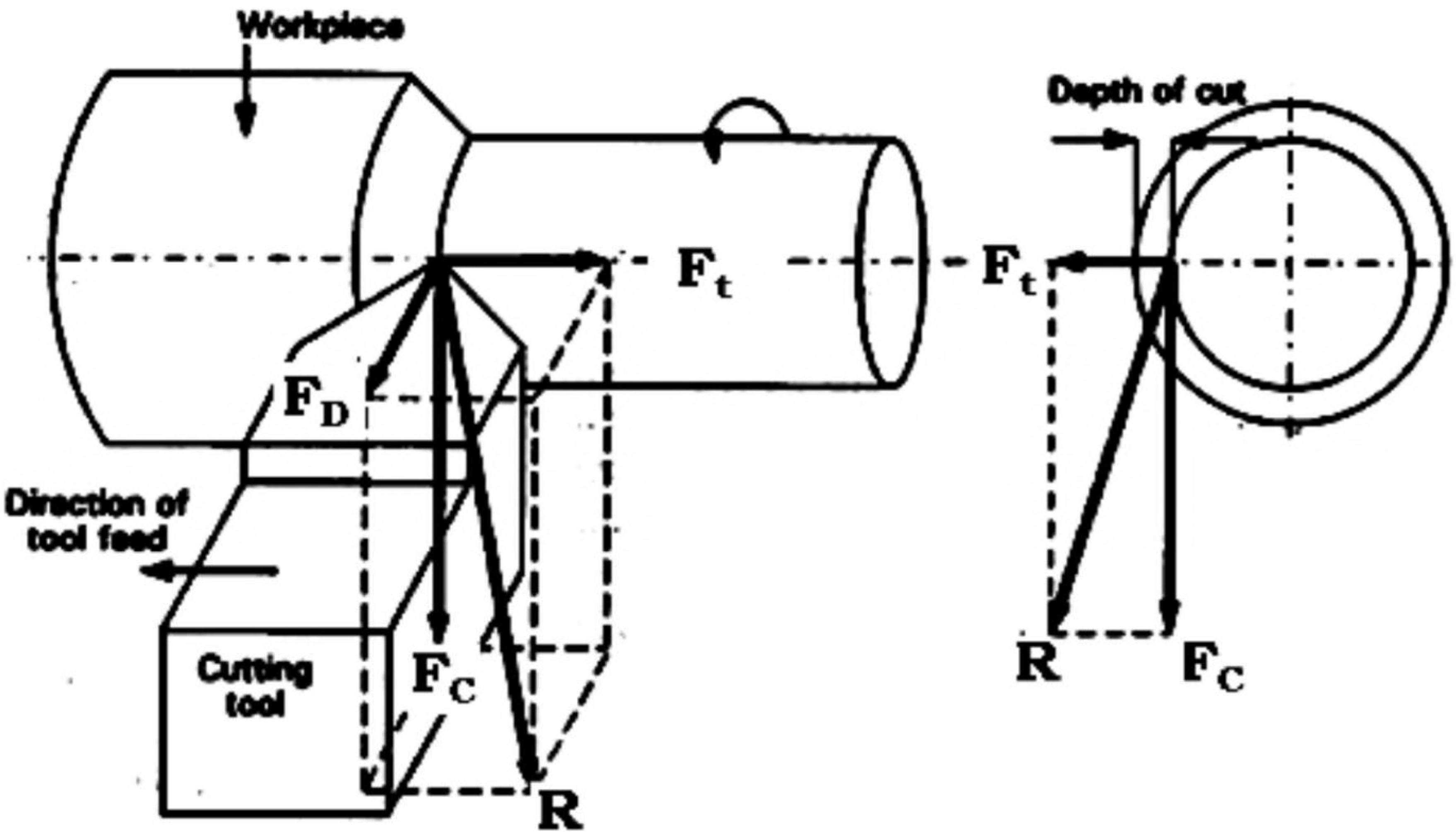


The Mechanism of Cutting

- In turning, w = depth of cut and t_1 = feed



The Mechanism of Cutting



Cutting force (Fc) is tangential and Thrust force is axial (Ft)

Cutting forces in a turning operation

Mechanics of Orthogonal Cutting

Chip thickness ratio (or) cutting ratio

$$\boxed{\text{Cutting ratio} = r = \frac{t_1}{t_2}}$$

where

- r = *chip thickness ratio or cutting ratio*;
- t_1 = thickness of the chip prior to chip formation;
- t_2 = chip thickness after separation

Which one is more correct?

- $r \geq 1$
- $r \leq 1$
- Chip thickness after cut always greater than before, so chip ratio always less than 1.0

Mechanics of Orthogonal Cutting

Shear Plane Angle

- Based on the geometric parameters of the orthogonal model, the shear plane angle *θ* can be determined as:

$$\boxed{\tan\theta = \frac{r\cos\alpha}{1 - r\sin\alpha}}$$

where

- *r = chip thickness ratio or cutting ratio*;
- α = Rake angle
- θ *= Shear angle*

Mechanics of Orthogonal Cutting

Shear Plane Angle Proof

$$t_1 = h\sin\theta, \qquad t_2 = h\cos(\theta - \alpha)$$

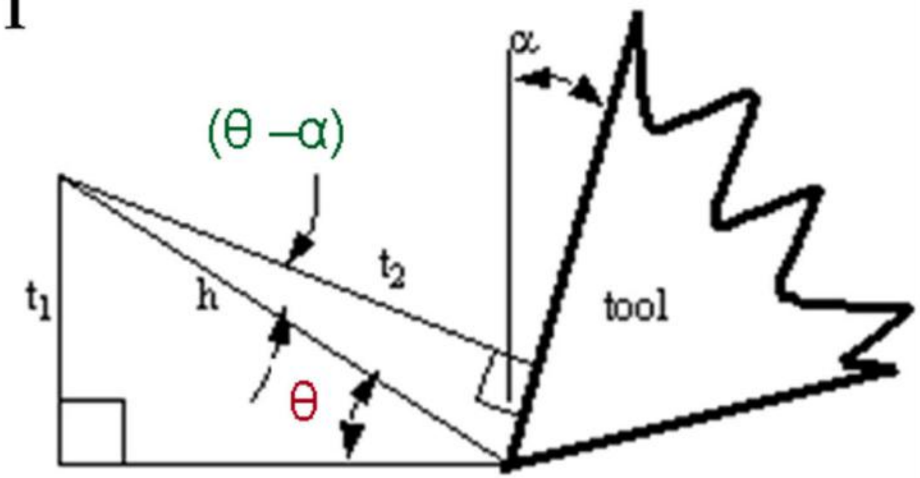
$$r = \frac{t_1}{t_2} = \frac{h\sin\theta}{h\cos(\theta-\alpha)} = \frac{\sin\theta}{\cos\theta\cos\alpha + \sin\theta\sin\alpha}$$

$$r\cos\theta\cos\alpha + r\sin\theta\sin\alpha = \sin\theta$$

$$\frac{r\cos\theta\cos\alpha}{\sin\theta} + \frac{r\sin\theta\sin\alpha}{\sin\theta} = 1$$

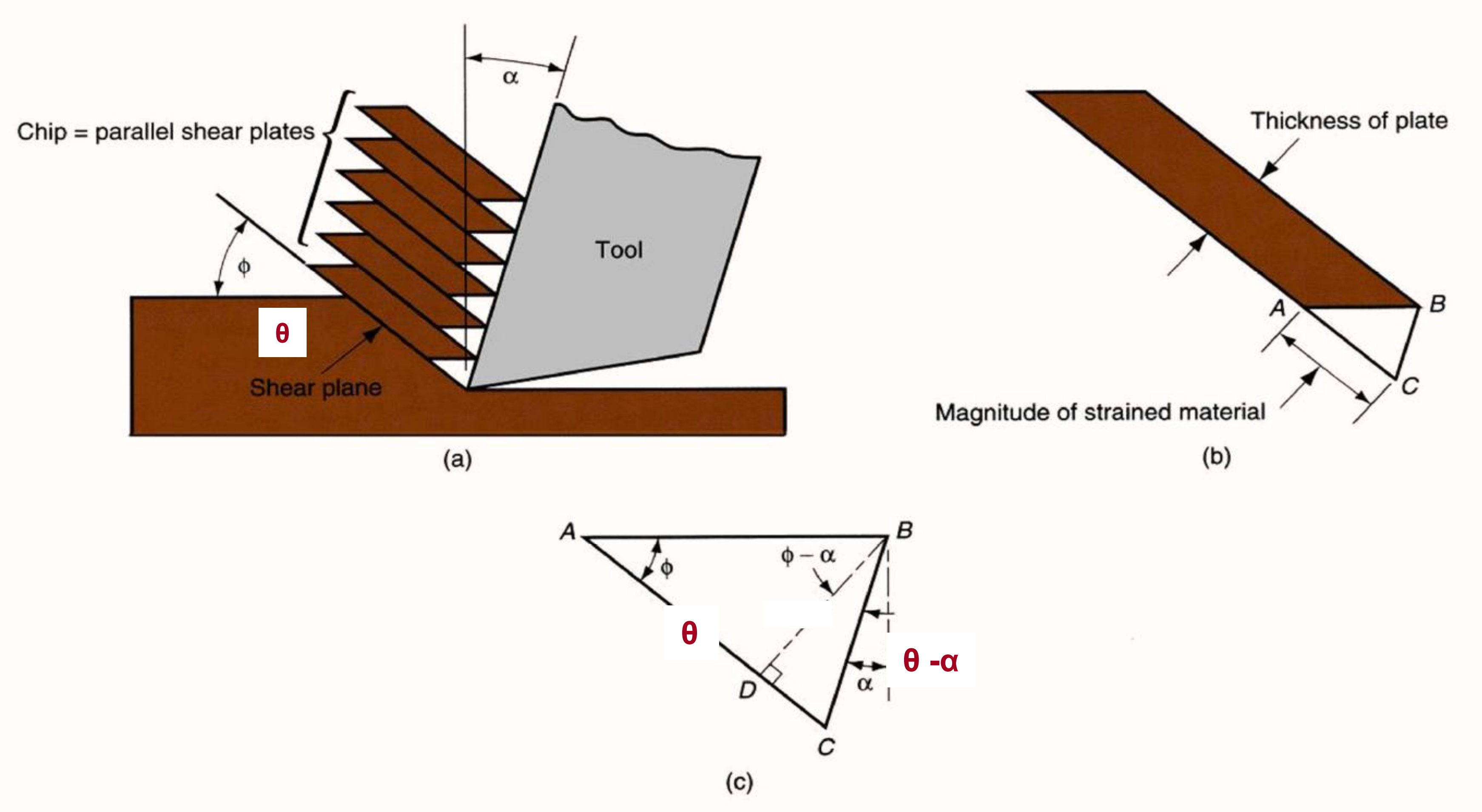
$$\frac{r\cos\alpha}{\tan\theta} + r\sin\alpha = 1$$

$$\boxed{\tan\theta = \frac{r\cos\alpha}{1 - r\sin\alpha}}$$



Mechanics of Orthogonal Cutting

Shear Strain in chip formation



(a) chip formation depicted as a series of parallel plates sliding relative to each other, (b) one of the plates isolated to show shear strain, and (c) shear strain triangle used to derive strain equation.

Mechanics of Orthogonal Cutting

Shear Strain in chip formation

- Shear strain in machining can be computed from the following equation, based on the preceding parallel plate model:
  - $\gamma = \tan(\theta - \alpha) + \cot\theta$

where

- γ = shear strain
- θ = shear angle
- α = rake angle of cutting tool

Mechanics of Orthogonal Cutting

Shear Strain Proof

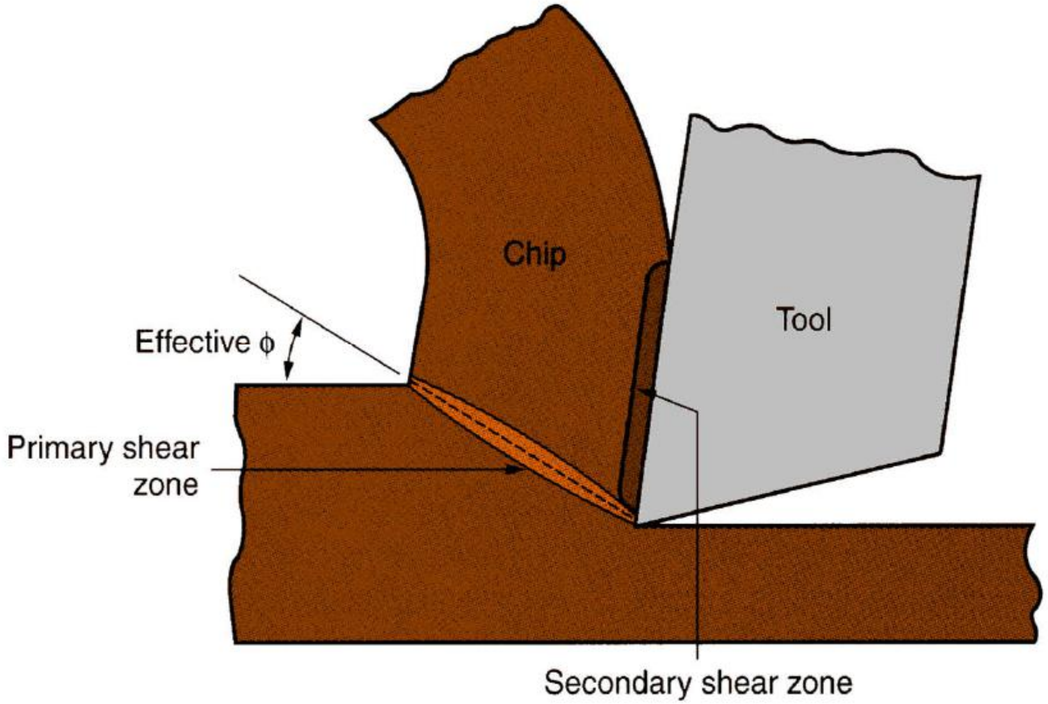
- From the shear strain triangle
  - γ = AC/DB= (AD+DC)/DB
  - γ = AD/DB + DC/DB
  - AD/DB = Cot θ
  - DC/DB = tan (θ - α)
  - Therefore γ = Cot θ + tan (θ - α)

    – $\gamma = \tan(\theta - \alpha) + \cot\theta$

Chip Formation

Chip formation

- Mechanics of metal cutting is greatly depend on the shape and size of the chips formed.



More realistic view of chip formation, showing shear zone rather than shear plane. Also shown is the secondary shear zone resulting from tool-chip friction.

Four Basic Type of Chips in Machining are

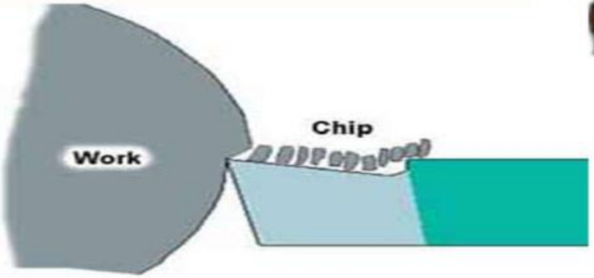
- Discontinuous chip
- Continuous chip
- Continuous chip with Built-up Edge (BUE)
- Serrated chip

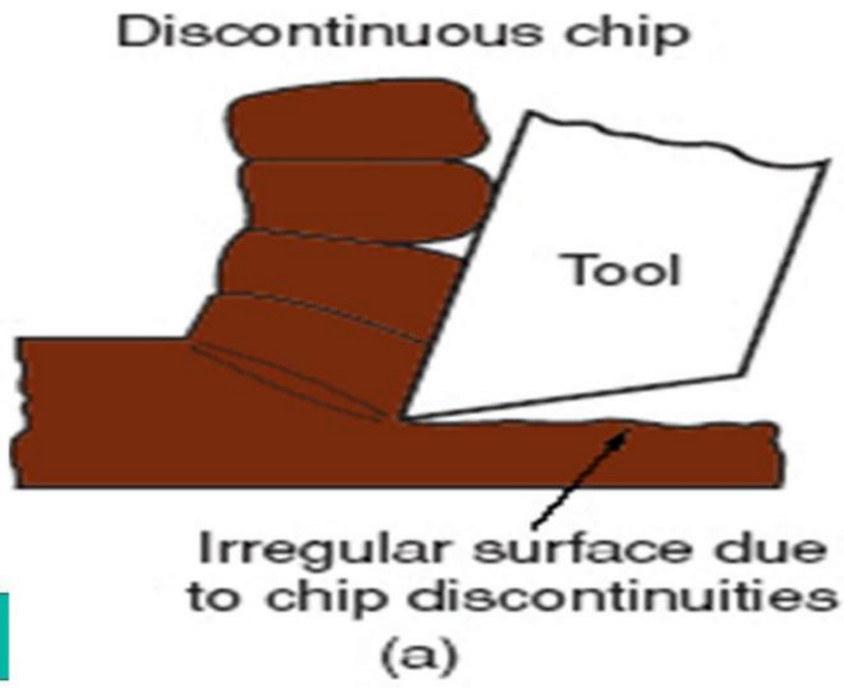
Discontinuous chip

- When brittle materials like cast iron are cut, the deformed material gets fractured very easily and thus the Chip produced is in the form of discontinuous segments

Reasons

- Brittle work materials
- Low cutting speeds
- Large feed and depth of cut
- High tool-chip friction



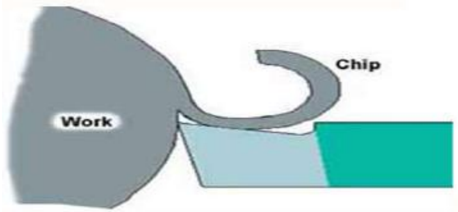


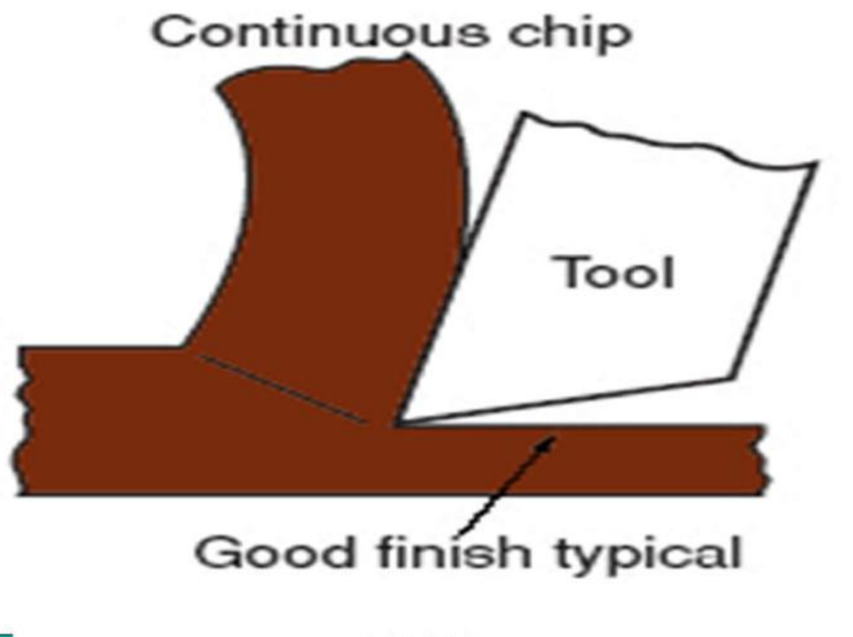
Continuous chip

- Continuous chips are normally produced when machining steel or ductile materials at high cutting speeds. The continuous chip which is like a ribbon flows along the rake face.

Reasons

- Ductile work materials
- High cutting speeds
- Small feeds and depths
- Sharp cutting edge
- Low tool-chip friction





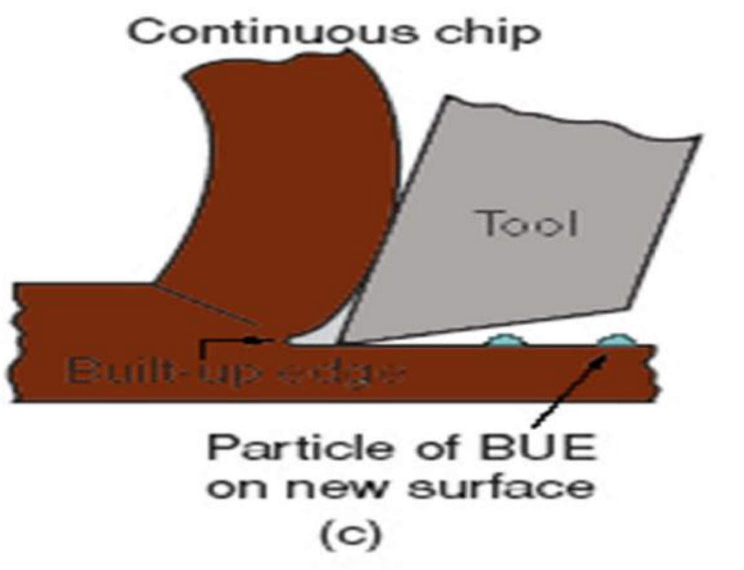
(b)

Continuous chip with Built-up Edge (BUE)

- When the friction between tool and chip is high while machining ductile materials, some particles of chip adhere to the tool rake face near the tool tip. When such sizeable material piles upon the rake face, it acts as a cutting edge in place of the actual cutting edge is termed as built up edge (BUE). By virtue of work hardening, BUE is harder than the parent work material

Reasons

- Ductile materials
- Low-to-medium cutting speeds
- Tool-chip friction causes portions of chip to adhere to rake face
- BUE forms, then breaks off, cyclically

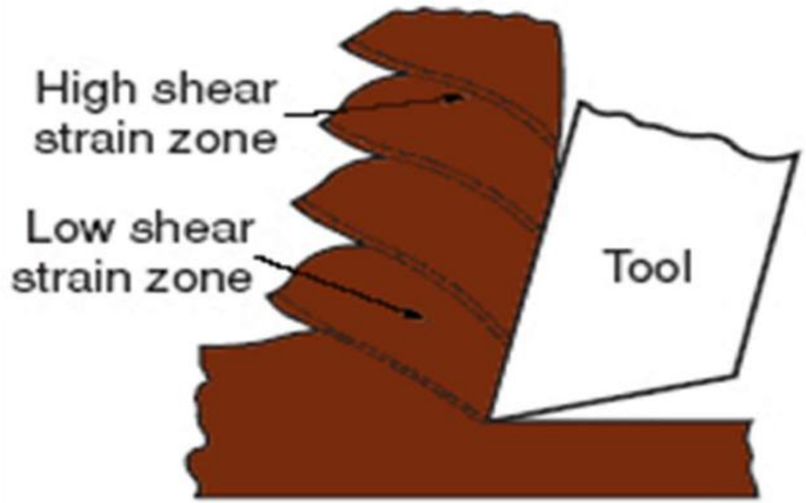


Serrated chip

- Semi Continuous (saw tooth appearance) chips produced when machining tool steels or Harden materials at high cutting speeds.

Reasons

- Ductile materials
- Low-to-medium cutting speeds
- Tool-chip friction causes portions of chip to adhere to rake face
- BUE forms, then breaks off, cyclically



(d)

Chip Breakers

- Long continuous chip are undesirable
- Chip breaker is a piece of metal clamped to the rake surface of the tool which bends the chip and breaks it
- Chips can also be broken by changing the tool geometry, thereby controlling the chip flow

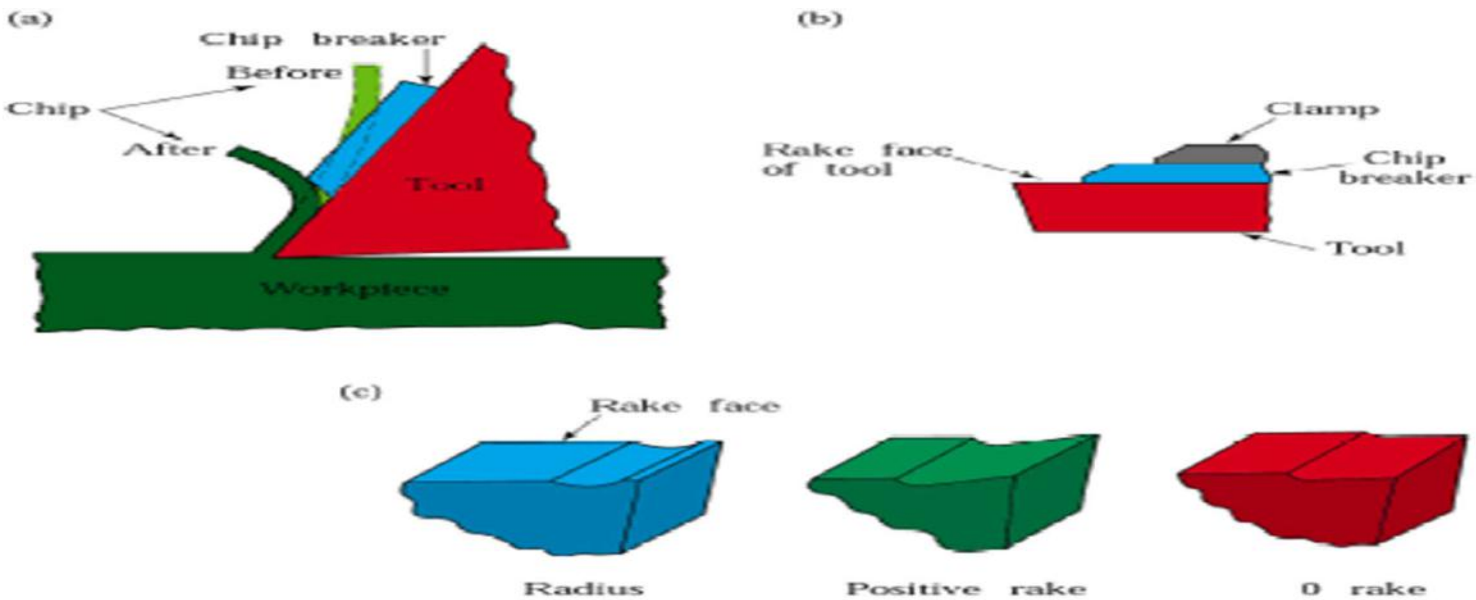
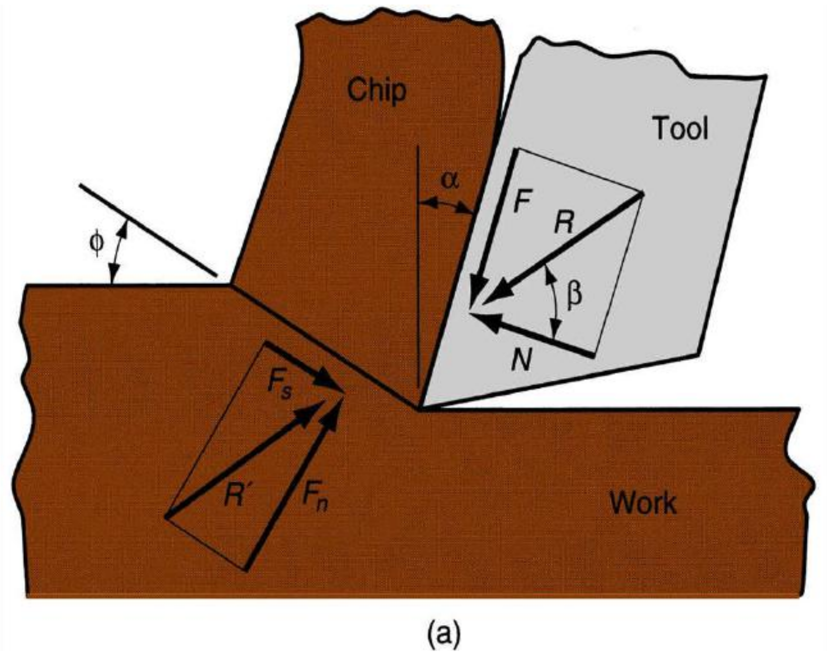


Fig. (a) Schematic illustration of the action of a chip breaker .(b) Chip breaker Clamped on the rake of a cutting tool. (c) Grooves in cutting tools acting as chip breakers

Force & Velocity Relationships and the Merchant Equation

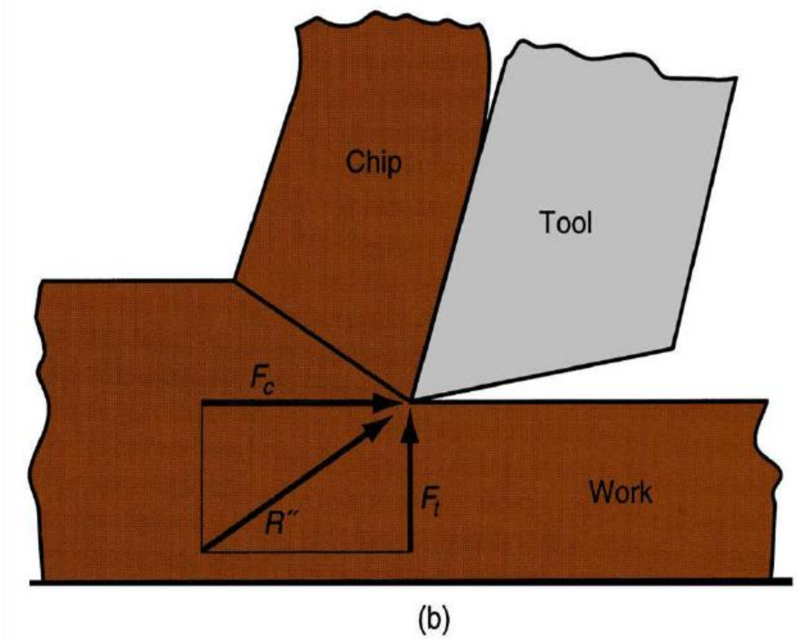
Forces Acting on Chip

- Friction force F and Normal force to friction N
- Shear force F_s and Normal force to shear F_n



Cutting Force and Thrust Force

- F, N, F_s and F_n cannot be measured directly, in order to measure these forces the forces acting on the tool to be measured initially
  - Cutting force F_c and Thrust force F_t



Forces in metal cutting: (a) forces acting on the chip in orthogonal cutting
(b) forces acting on the tool that can be measured

Resultant Forces

- Vector addition of F and N = resultant R
- Vector addition of F_s and F_n = resultant R'
- Forces acting on the chip must be in balance:
  - R' must be equal in magnitude to R
  - R' must be opposite in direction to R
  - R' must be collinear with R

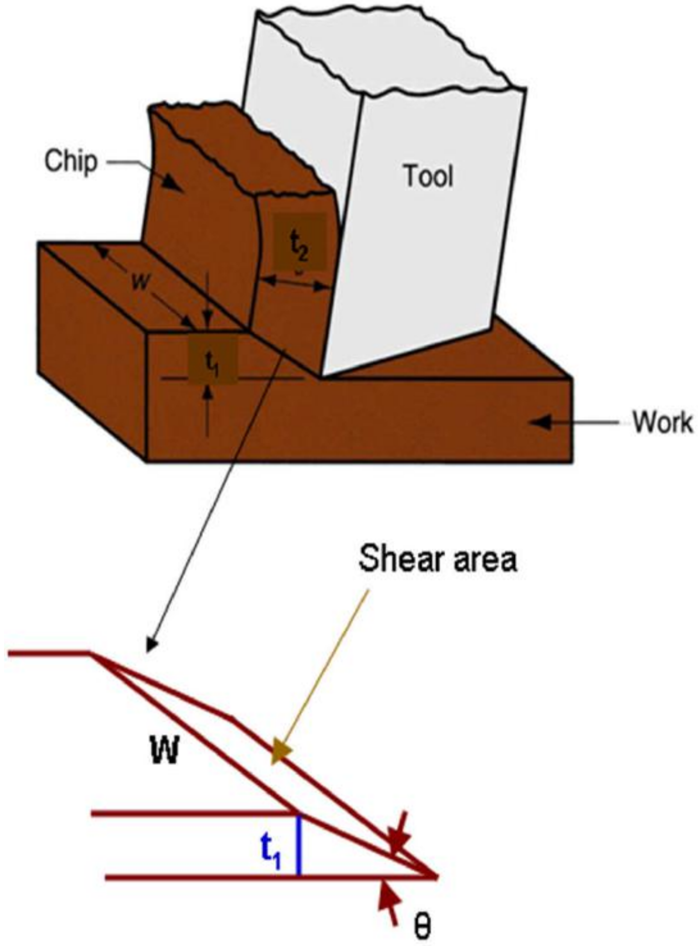
Shear Stress

- Shear stress acting along the shear plane

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

- where As = area of the shear plane

$$A_s = \frac{t_1 w}{\sin\theta}$$



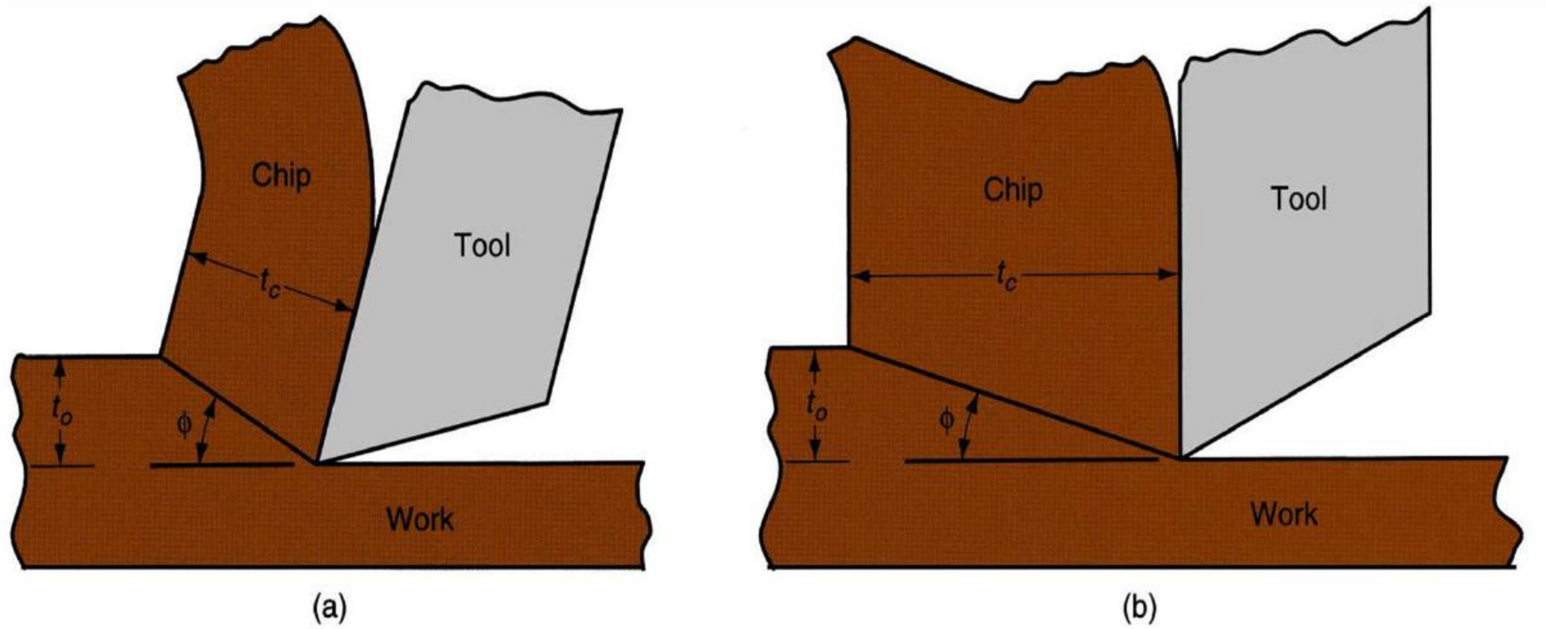
- Shear stress = shear strength of work material during cutting

Shear Stress- Effect of Higher Shear Plane Angle

Shear angle and its significance

Effect of Higher Shear Plane Angle

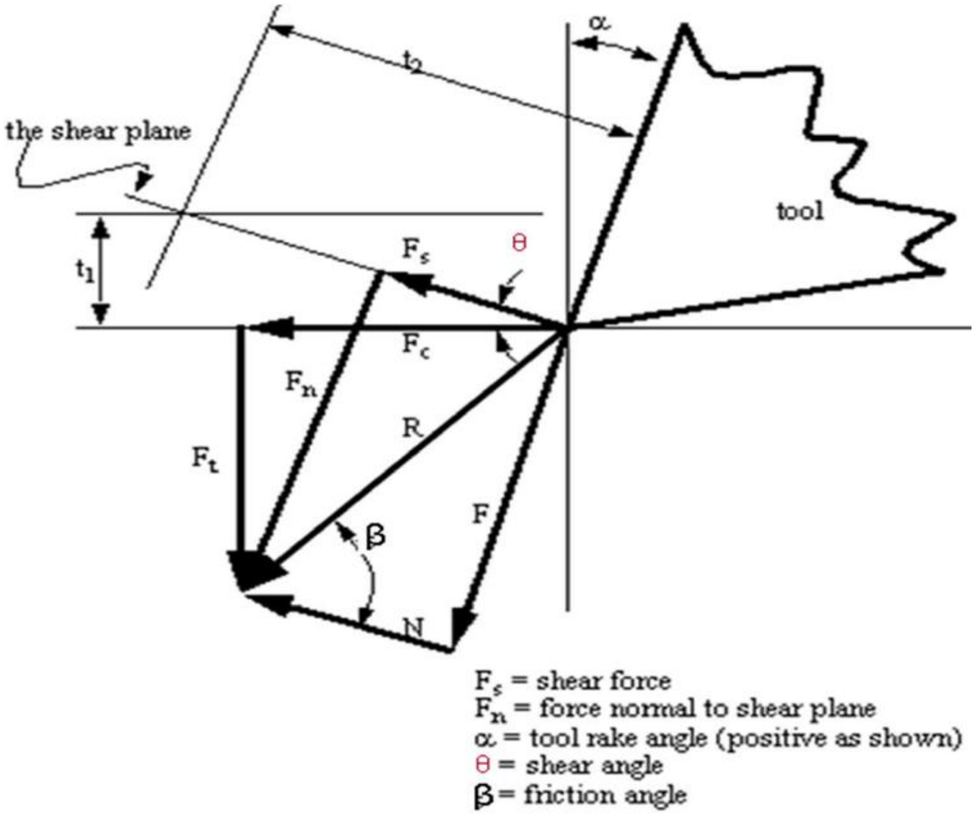
- Higher shear plane angle means smaller shear plane which means lower shear force, cutting forces, power, and temperature



Effect of shear plane angle ϕ : (a) higher θ with a resulting lower shear plane area; (b) smaller θ with a corresponding larger shear plane area. Note that the rake angle is larger in (a), which tends to increase shear angle according to the Merchant equation

Force Calculations

- The forces and angles involved in cutting are drawn here,
- Having seen the vector based determination of the cutting forces, we can now look at equivalent calculations:



$$\frac{F}{N} = \tan\beta = \mu$$

Where $\mu =$ The coefficient of friction

Force Calculations

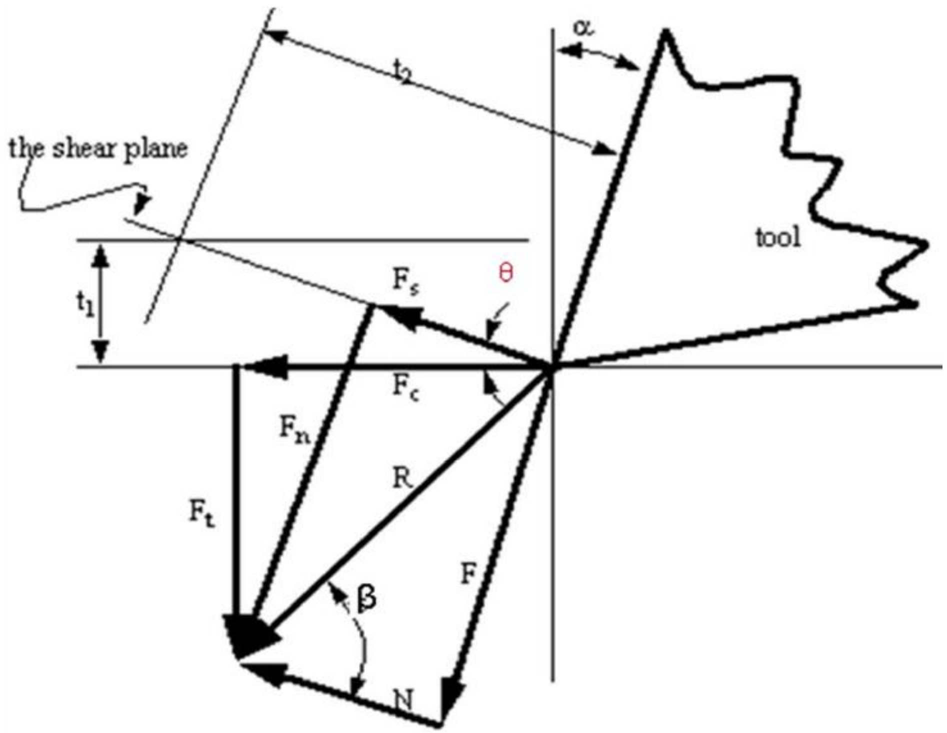
And, by trigonometry:

$$F = F_t \cos\alpha + F_c \sin\alpha,$$

$$F_s = F_c \cos\theta - F_t \sin\theta$$

$$N = F_c \cos\alpha - F_t \sin\alpha,$$

$$F_n = F_c \sin\theta + F_t \cos\theta$$



F_s = shear force
F_n = force normal to shear plane
α = tool rake angle (positive as shown)
θ = shear angle
β = friction angle

Where the Resultant force R is Given by

$$R = \sqrt{F_c^2 + F_t^2} = \sqrt{F_s^2 + F_n^2} = \sqrt{F^2 + N^2}$$

Force Calculations

- We can write the cutting and thrust forces in terms of the shear force:

$$R = \left(F_c^2 + F_t^2\right)^{1/2} = \left(F_s^2 + F_n^2\right)^{1/2} = \left(F^2 + N^2\right)^{1/2}$$

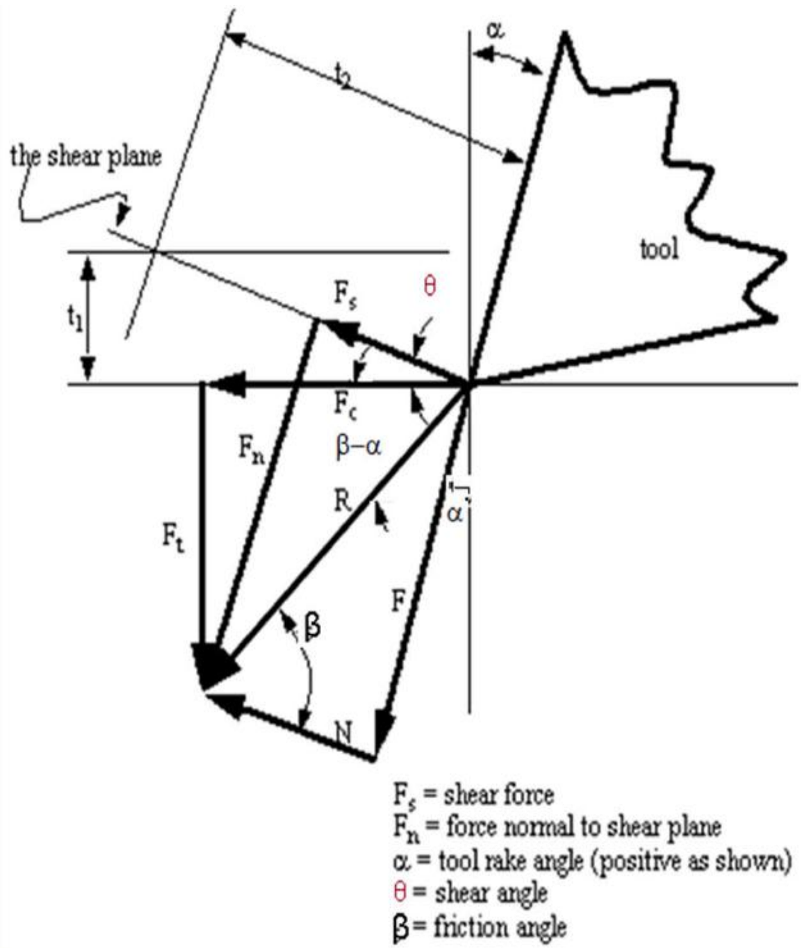
$$F_c = R\cos(\beta - \alpha)$$

$$F_t = R\sin(\beta - \alpha)$$

$$F_s = R\cos(\theta + \beta - \alpha)$$

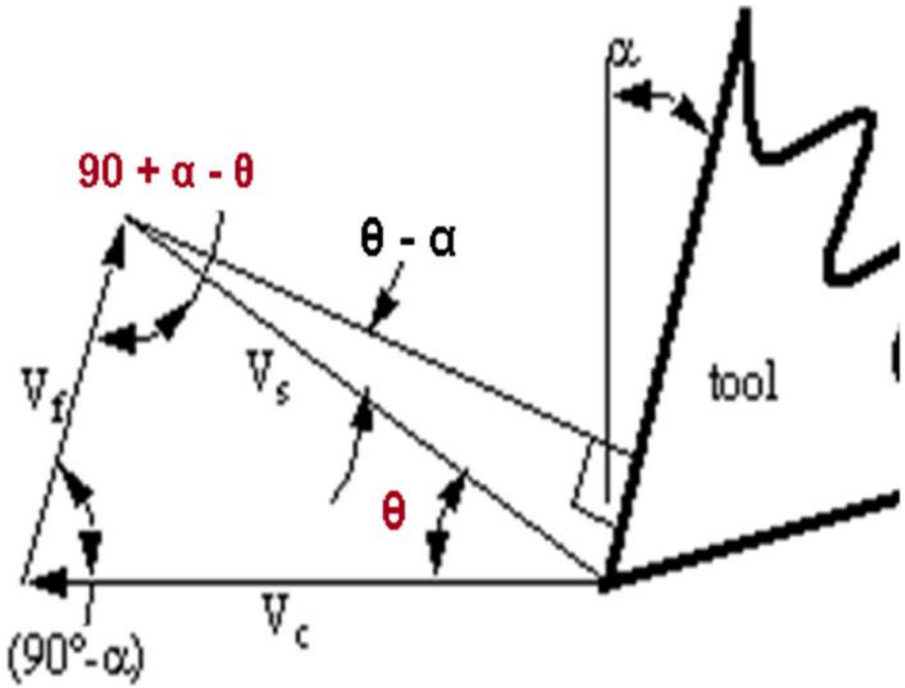
$$F_n = R\sin(\theta + \beta - \alpha)$$

$$\boxed{F_c = \frac{F_s\cos(\beta - \alpha)}{\cos(\theta + \beta - \alpha)} \qquad F_t = \frac{F_s\sin(\beta - \alpha)}{\cos(\theta + \beta - \alpha)}}$$



Velocity Calculations

- Having seen the vector based determination of the cutting forces, we can now look at equivalent calculations:
- V_c= Cutting velocity (ft/min) as set or measured on the machine
- V_s= Shearing velocity
- V_f= Frictional velocity



Using the sign rules:

$$\frac{V_s}{\sin(90^o - \alpha)} = \frac{V_c}{\sin(90^o + \alpha - \theta)}$$

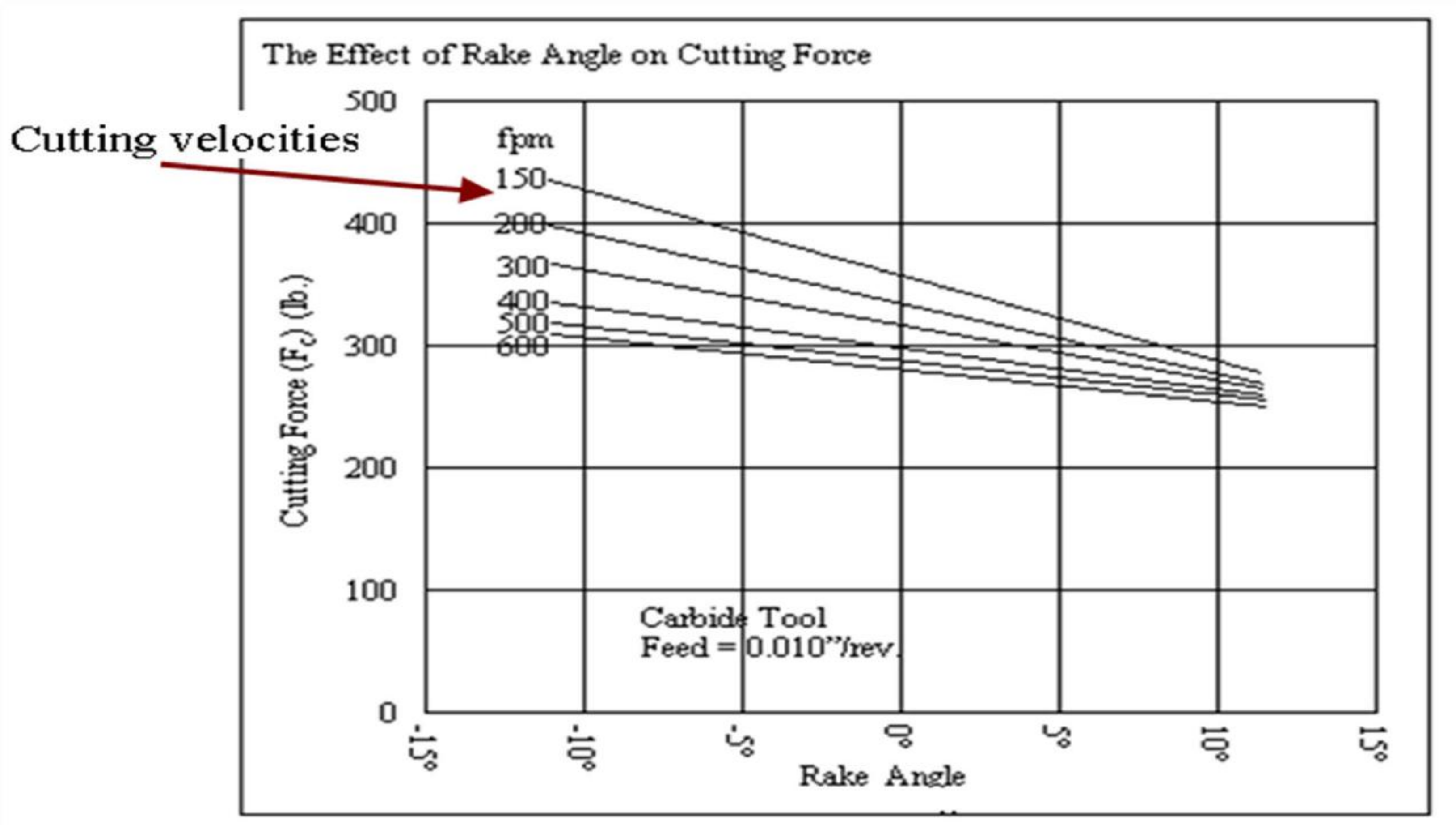
$$V_s = \frac{V_c \sin(90^o - \alpha)}{\sin(90^o + \alpha - \theta)} = \frac{V_c \cos\alpha}{\cos(\theta - \alpha)}$$

Also,

$$V_f = \frac{V_c \sin\theta}{\cos(\theta - \alpha)}$$

Cutting Force Vs Rake Angle α

- The effects of rake angle on cutting force are shown in the graph below,



The Merchant Equation

- To determine θ he assumed the minimum energy principle applied in metal cutting so that the deformation process adjusted itself to a minimum energy condition.

- Of all the possible angles at which shear deformation can occur, the work material will select a shear plane angle θ that minimizes energy, given by

$$\boxed{\theta = 45 + \frac{\alpha}{2} - \frac{\beta}{2}}$$

  – Derived by Eugene Merchant

What the Merchant Equation Tells Us

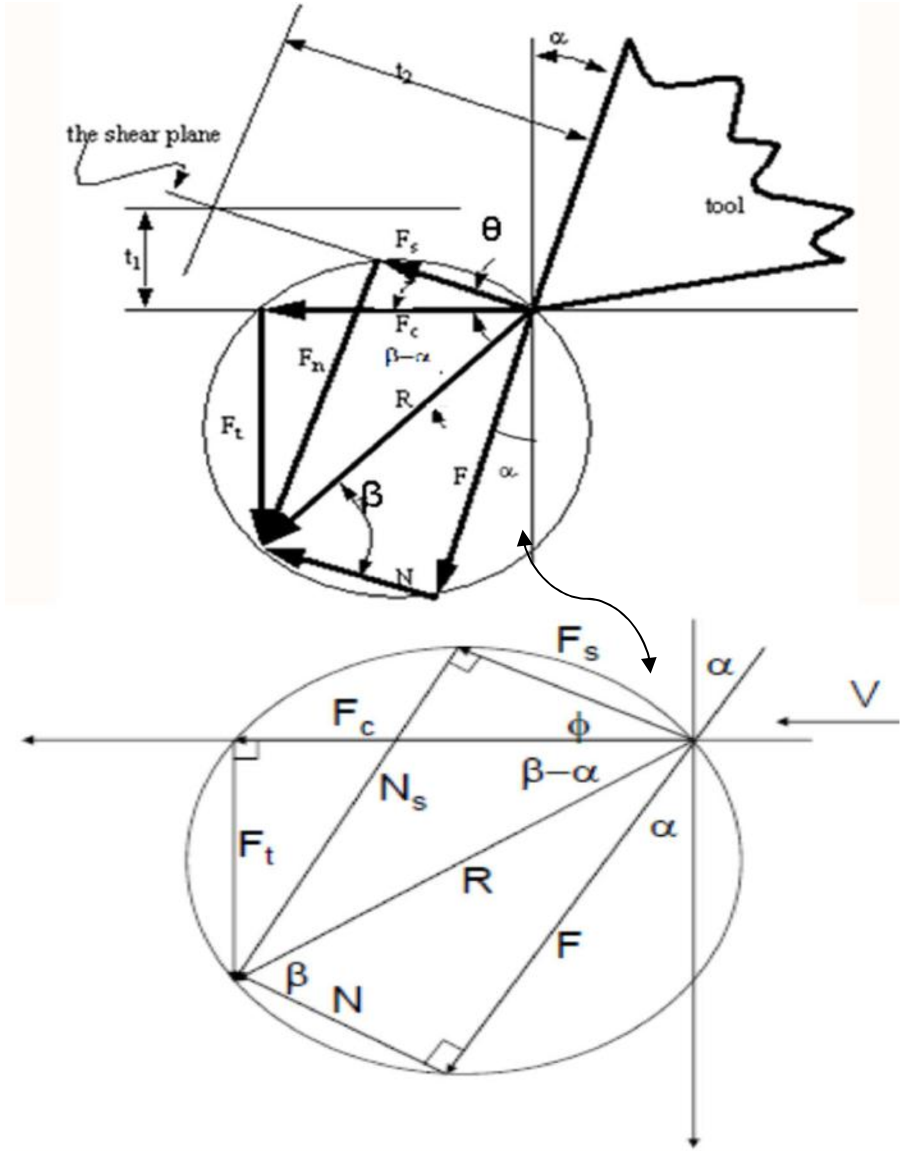
- To increase shear plane angle
  - Increase the rake angle (α)
  - Reduce the friction angle (β) or coefficient of friction

$$\boxed{\theta = 45 + \frac{\alpha}{2} - \frac{\beta}{2}}$$

Merchant's Force Circle

- Merchant's Force Circle is a method for calculating the various forces involved in the cutting process.

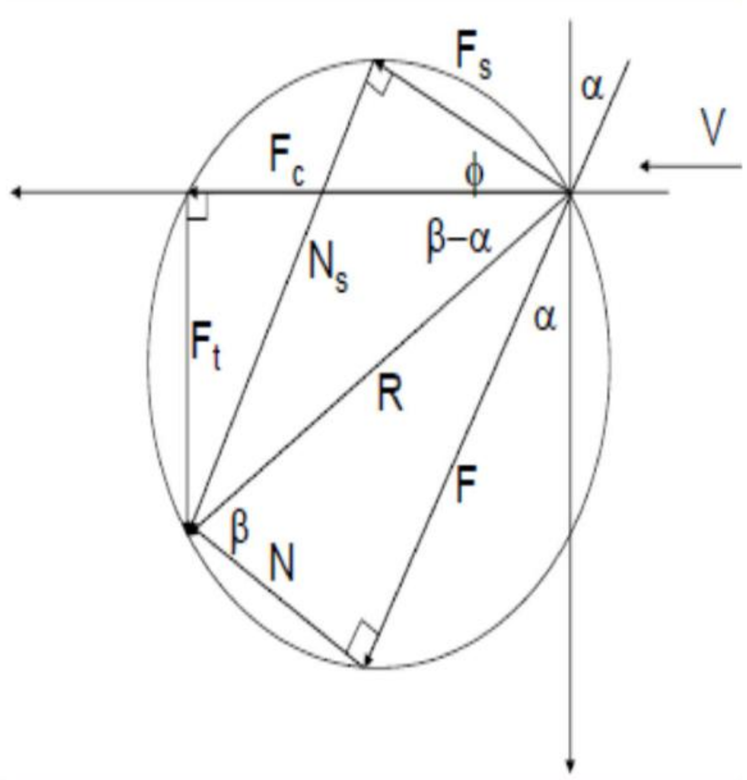
1. Set up x-y axis labeled with forces, and the origin in the centre of the page. The scale should be enough to include both the measured forces. The cutting force (F_c) is drawn horizontally, and the tangential force (F_t) is drawn vertically. (These forces will all be in the lower left hand quadrant).



Merchant's Force Circle

Merchant's Force Circle

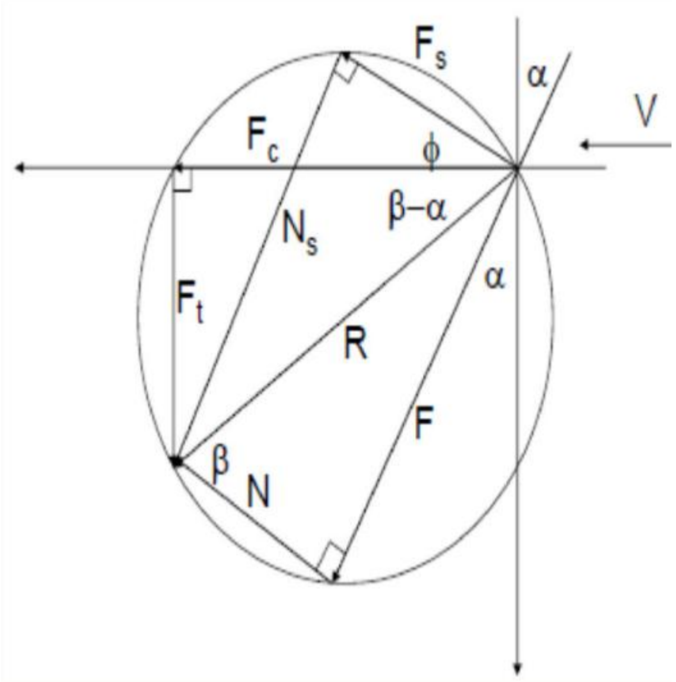
2. Draw in the resultant (R) of Fc and Ft.
3. Locate the centre of R, and draw a circle that encloses vector R. If done correctly, the heads and tails of all 3 vectors will lie on this circle.
4. Draw in the cutting tool in the upper right hand quadrant, taking care to draw the correct rake angle (α) from the vertical axis.
5. Extend the line that is the cutting face of the tool (at the same rake angle) through the circle. This now gives the friction vector (F).



Merchant's Force Circle

Merchant's Force Circle

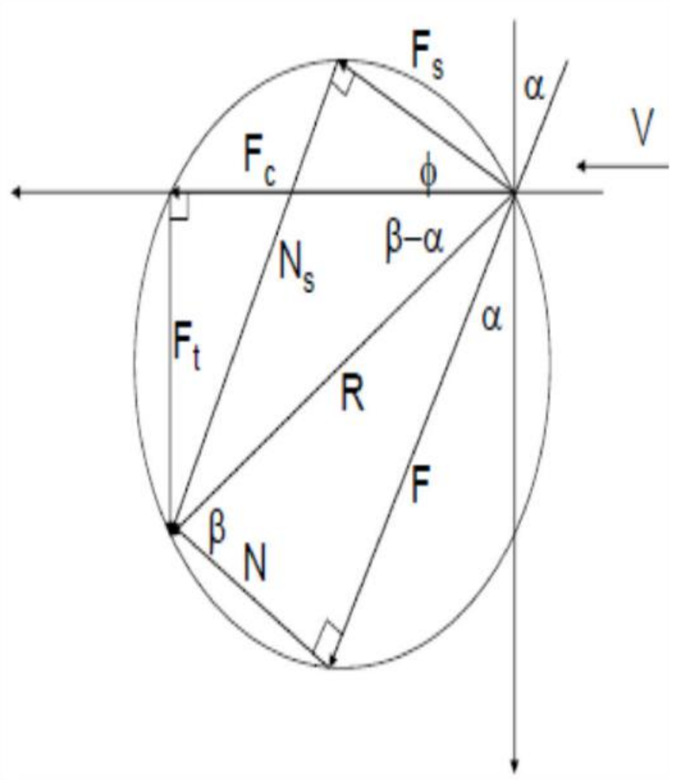
6. A line can now be drawn from the head of the friction vector, to the head of the resultant vector (R). This gives the normal vector (N). Also add a friction angle (β) between vectors R and N. As a side note recall that any vector can be broken down into components. Therefore, mathematically, R = Fc + Ft = F + N.
7. We next use the chip thickness, compared to the cut depth to find the shear force. To do this, the chip is drawn on before and after cut. Before drawing, select some magnification factor (e.g., 200 times) to multiply both values by. Draw a feed thickness line (t_1) parallel to the horizontal axis. Next draw a chip thickness line parallel to the tool cutting face.



Merchant's Force Circle

Merchant's Force Circle

8. Draw a vector from the origin (tool point) towards the intersection of the two chip lines, stopping at the circle. The result will be a shear force vector (Fs). Also measure the shear force angle between F_s and F_c.
9. Finally add the shear force normal (F_n) from the head of F_s to the head of R.
10. Use a scale and protractor to measure off all distances (forces) and angles.



Merchant's Force Circle

Power and Energy Relationships

- There are a number of reasons for wanting to calculate the power consumed in cutting. These numbers can tell us how fast we can cut, or how large the motor on a machine must be. Having both the forces and velocities found with the Merchant for Circle, we are able to calculate the power,
- The power to perform machining can be computed from:

$$Pc = Fc \cdot Vc \text{ in kw}$$

$$Pc = Fc \cdot Vc / 33{,}000 \text{ in HP}$$

where

- P_c = cutting power in KW
- F_c = cutting force in KN
- Vc = cutting speed in m/min

Power and Energy Relationships

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- F_c = cutting force in KN
- Vc = cutting speed in m/min

Power and Energy Relationships

- Gross power to operate the machine tool P_g or HP_g is given by

$$\boxed{P_g = \frac{P_c}{E}} \qquad \boxed{HP_g = \frac{HP_c}{E}}$$

where

- E = mechanical efficiency of machine tool
- Typical E for machine tools ~ 90%

- There are losses in the machine that must be considered when estimating the size of the electric motor required:

or

$$\boxed{P_g = \frac{P_c}{E} + P_t}$$

Where

- Pt = power required to run the machine at no-load conditions (hp or kW)

Power and Energy Relationships

- Useful to convert power into power per unit volume rate of metal cut (power to cut one cubic inch per minute)
- Called *unit power, P_u* or *unit horsepower, HP_u*

$$\boxed{P_U = \frac{P_c}{R_{MR}}} \quad \text{or} \quad \boxed{HP_U = \frac{HP_c}{R_{MR}}}$$

- where R_{MR} = material removal rate

Power and Energy Relationships

- Unit power is also known as the *specific energy U*

$$\boxed{U = P_u = \frac{P_c}{R_{MR}} = \frac{F_c \cdot V_c}{V_c \cdot t_1 \cdot w} = \frac{F_c}{t_1 \cdot w}}$$

- Units for specific energy are typically N-m/mm^3 or J/mm^3 (in-lb/in^3)
- Specific energy is in fact pressure and sometimes is called specific cutting pressure:

$$\boxed{U = \frac{F_c}{A}}$$

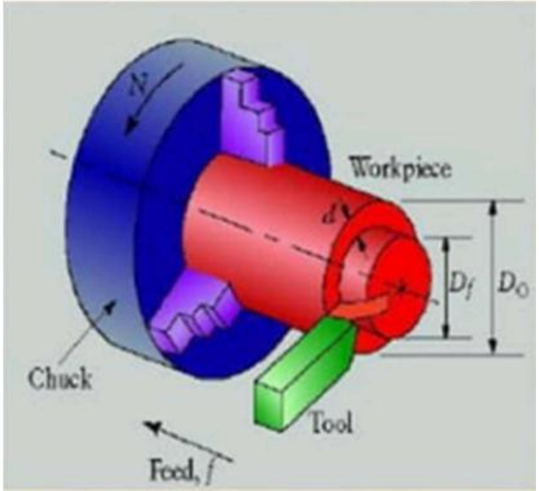
Cutting Temperature

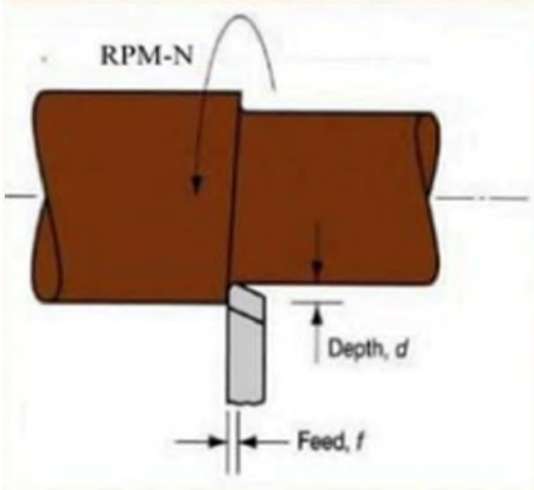
- Approximately 98% of the energy in machining is converted into heat
- This can cause temperatures to be very high at the tool-chip
- The remaining energy (about 2%) is retained as elastic energy in the chip

High cutting temperatures

- Reduce tool life
- Produce hot chips that pose safety hazards to the machine operator
- Can cause inaccuracies in part dimensions due to thermal expansion of work material

Cutting Parameters





Cutting input Parameters

- Cutting Speed
- Feed
- Depth of Cut

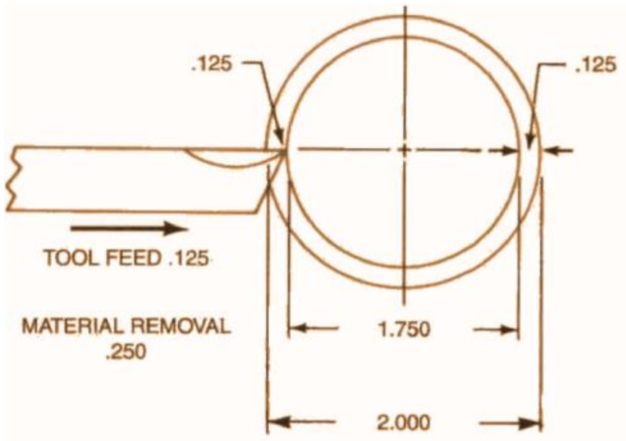
Cutting output Parameters

- Material removal rate
- Surface roughness
- Wear mechanisms

Speed is the relative movement between tool and w/p, which ***produces*** a *cut*

Feed is the relative movement between tool and w/p, which ***spreads*** the *cut*

Depth of cut parameter focuses on the tertiary cutting motion of the tool as the tool is pushed deeper into the workpiece to the specified depth.



The depth of cut will usually vary between 0.1 to 1.0 mm.

Cutting speed of a cutting tool can be defined as the rate at which its cutting edge passes over the surface of the workpiece in unit time.

It is normally expressed in terms of surface speed, referred to as speed(v) and expressed in meters per minute (m/min)

In turning, it is given by the surface speed of the workpiece
$V = r\omega = r \cdot (2\pi N)/60 = \pi DN/1000$ m/min   D in mm, N in rpm

D= Dia. of w/p
N=rpm of spindle

V=linear velocity
ω = angular velocity = rad/sec

Feed: The feed is the distance advanced by the tool into or along the workpiece each time the tool point passes a certain position in its travel over the surface.
In case of turning, feed is the distance that the tool advances in one revolution of the workpiece.

Feed **f** is usually expressed in mm/rev.
Feed in mm/min = Feed in mm/rev x N

Depth of cut : It is the distance through which the cutting tool is plunged into the workpiece surface.

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

The depth of cut ***d*** is expressed in mm.=(d1-d2)/2 for turning

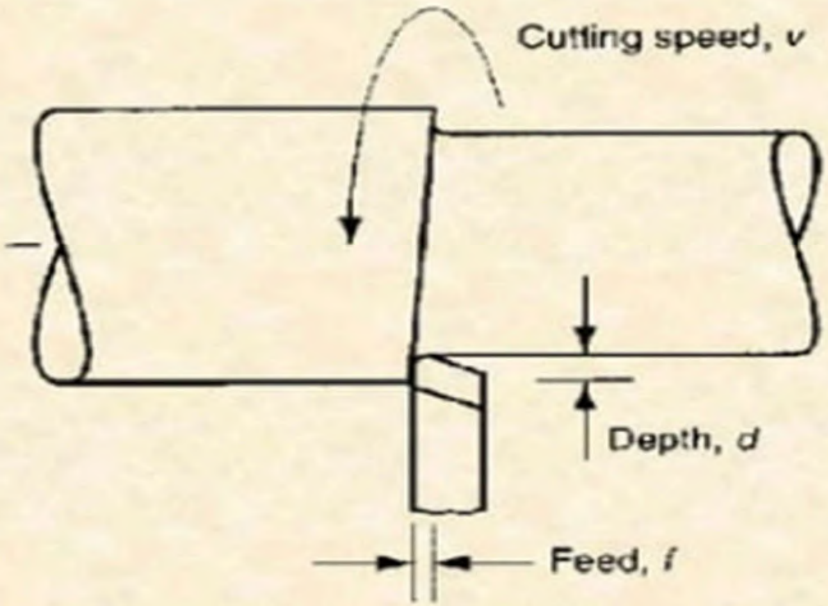
Material Removal Rate

➢Volume of material removed per unit time(1 min) or volume of material removed divided by the machining time

MRR= (Initial weight – Final weight)/Machining time $\quad v_R << v_F$

MRR= Volume removed/cutting time=mm³/min or mm³/sec

Power required = MRR x Specific cutting energy (Watts/mm³/sec)



$MRR = vfd$

m/min * mm/rev * mm

$Roughing(R)$

$f = 0.4 - 1.25 mm/rev$

$d = 2.5 - 20 mm$

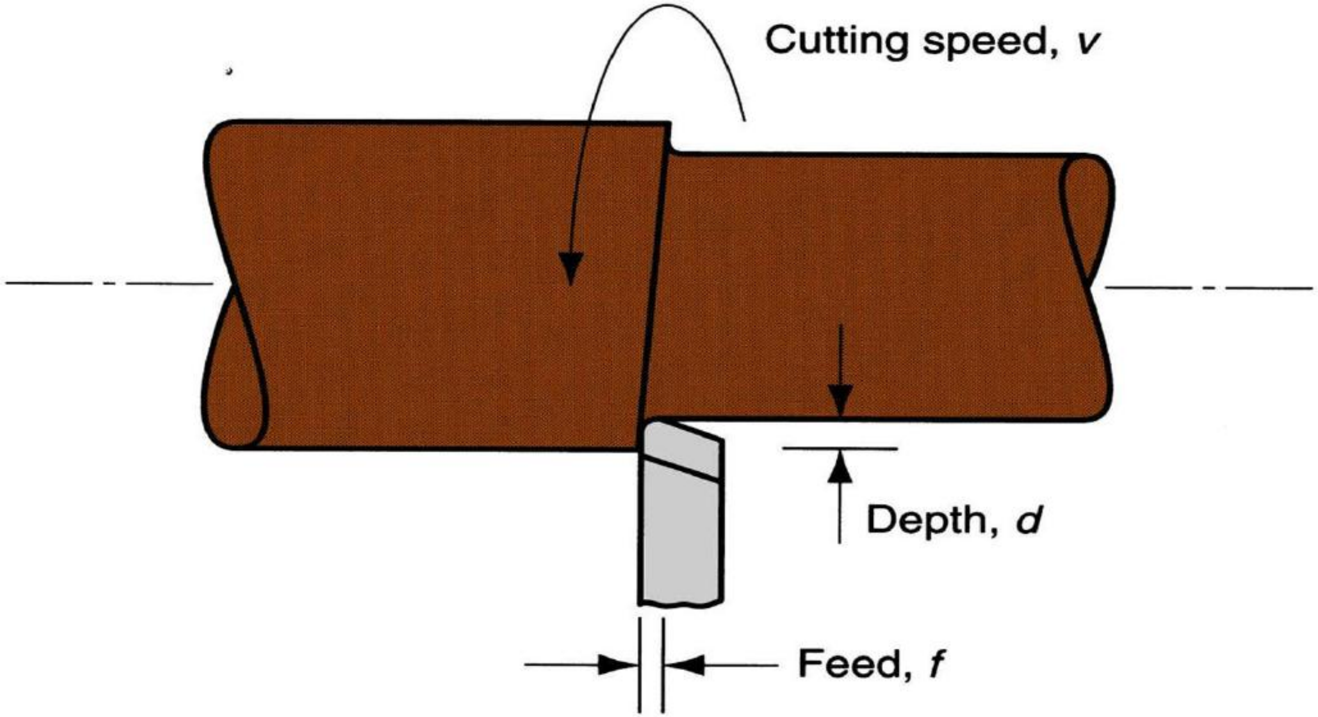
$Finishing(F)$

$f = 0.125 - 0.4 mm/rev$

$d = 0.75 - 2.0 mm$

Process Parameters

- Speed (v), Feed (f), Depth of Cut (d)
- Material Removal Rate (MRR) = f x d x v



Shear angle and its significance

- Shear angle(θ) is the angle made by the shear plane with the cutting speed vector.
- Shear angle is very important parameter in metal cutting. Higher the shear angle, better is the cutting performance.
- In metal cutting it is observed that a higher rake angles give rise to higher shear angles

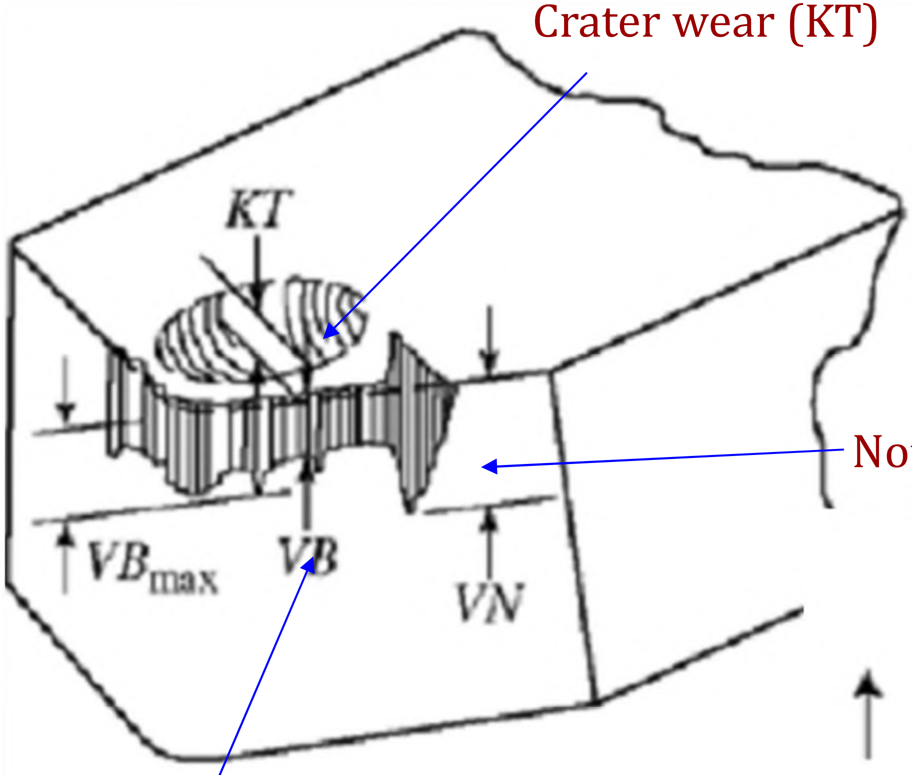
Tool Wear

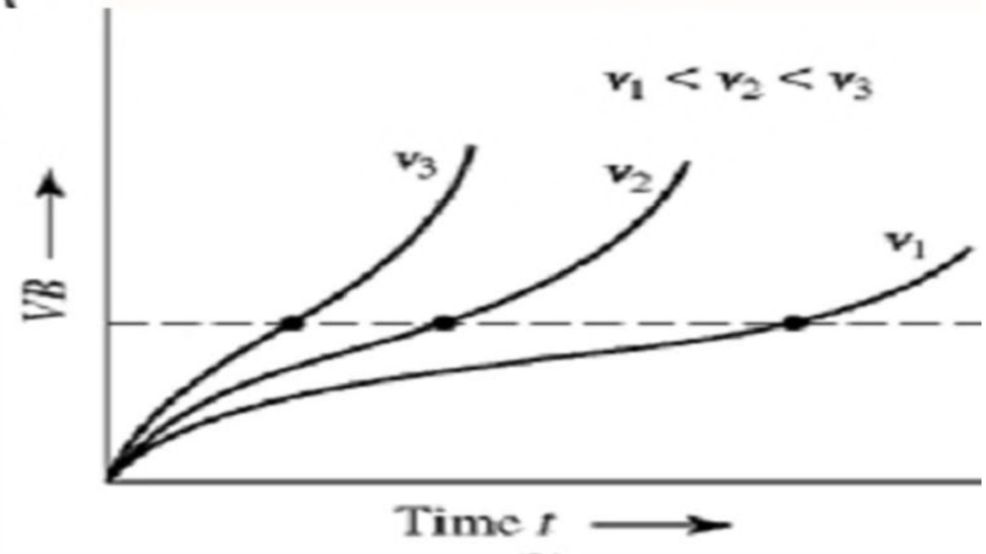
- Tools get worn out due to long term usage

Types of Tool Wear

- Flank wear (VB)
  - It occurs on the relief face of the tool and the side relief angle.
- Crater wear (KT)
  - It occurs on the rake face of the tool.
- Notch wear or Chipping (VN)
  - Breaking away of a small piece from the cutting edge of the tool

Tool Wear





Flank wear rate based on cutting speed

Tool Wear

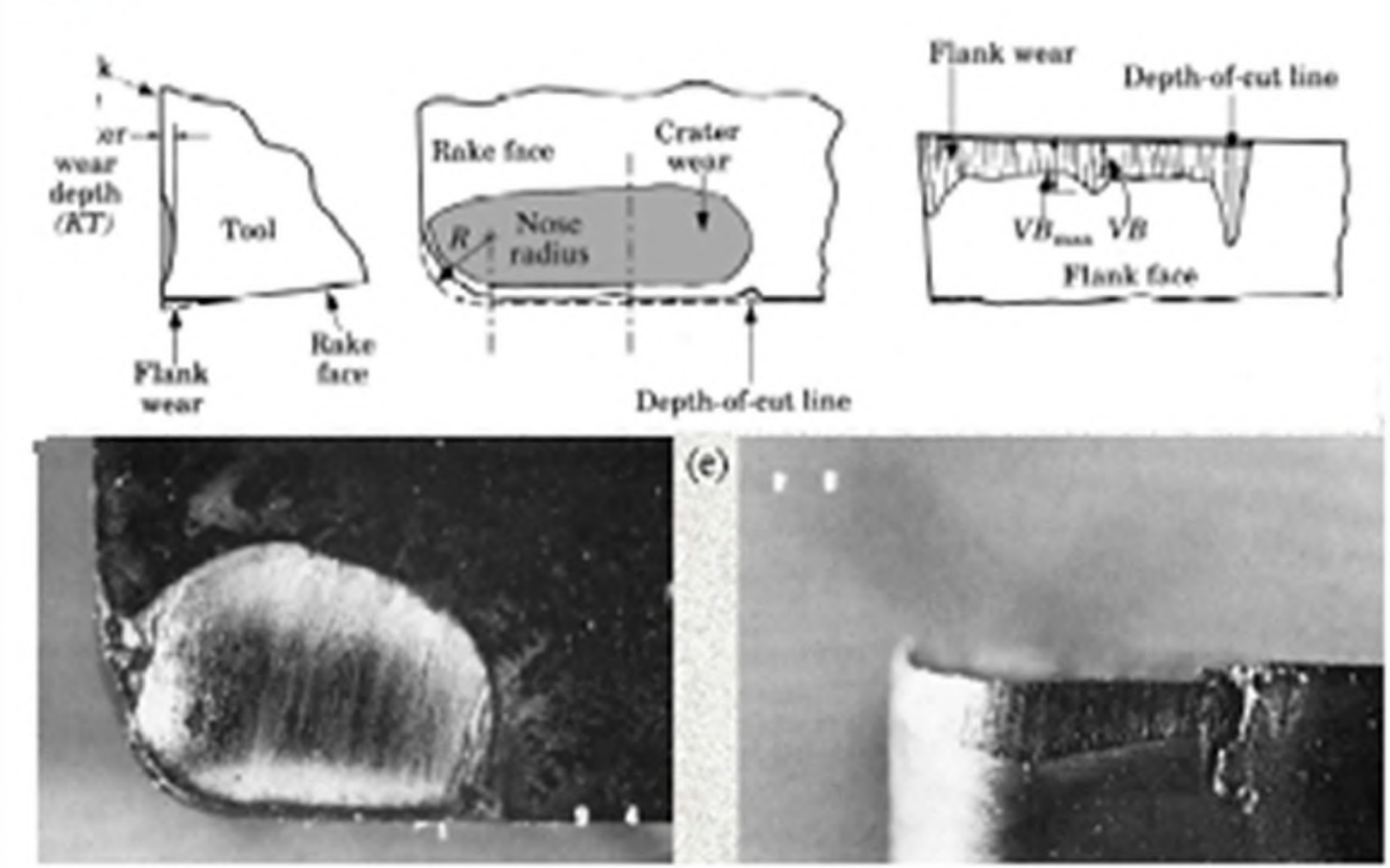


Fig (a) Flank and crater wear in a cutting tool. tool moves to the left. (b) View of the rake of a turning tool, showing nose radius R and crater wear pattern on the rake face of the tool c) View of the flank face of a turning tool, sowing the average flank wear land VB and the depth-of-cut line (wear notch)

Tool Life

- Tool life represents the useful life of the tool, expressed generally in time units from the start of cut to some end point defined by a failure criterion.

Tool Life Prediction

- Taylor's tool life equation predicts tool failure based on flank wear of the tool

$$Vt^n = C$$

where

- V is the cutting speed, t is the tool life,
- n is Taylor exponent.
  - n=0.125 for HSS
  - n=0.25 for Carbide
  - n=0.5 for Coated Carbide/Ceramic
  - C is a constant given for work piece material

Machinability

- Machinability is a system property that indicates how easy a material can be machined at low cost.
- Good machinabililty may mean one or more of the following: cutting with minimum energy, minimum tool wear, good surface finish, etc.

Quantitative measures of machinability

- Machinability index: an average rating stated in comparison with reference materials. This measure can be misleading.
- Tool life: service time in minutes or seconds to total failure by chipping or cracking of the tool at certain cutting speed, or the volume of material removed before total failure.
- Surface finish produced at standardized cutting speeds and feeds.
- Others based on cutting force, power, temperature, or chip formation.

Machinable Materials

Good machinable materials should have the following properties

- Low ductility, low strain-hardening exponent (n), low fracture toughness.
- Low shear strength (low TS), low hardness.
- A strong metallurgical bond (adhesion) between tool and work piece is undesirable when it weakens the tool material.
- Very hard compounds, such as some oxides, all carbides, many inter metallic compounds, and elements such as silicon, embedded in the work piece material accelerate tool wear, thus should be avoided.
- Inclusions that soften at high temperatures are beneficial.
- High thermal conductivity is helpful.

Machinable Materials

Ferrous materials

- Carbon steels: annealed, heat-treated (spheroidized), cold worked
- Free-machining steels: special inclusions
- Alloy steels: hard
- Stainless steels: high strength, low thermal conductivity, high strain hardening rate
- Cast iron: white, gray, nodular cast iron

Non-ferrous materials

- Zinc, Magnesium, Aluminum alloys, Beryllium, Copper-based alloys, Nickel-based alloys and super alloys,
- Titanium, Plastics, composites.

Factors Affecting Machining Operation / Factors Influencing Machining Operation

Parameter	Influence and interrelationship
Cutting speed, depth of cut, feed, cutting fluids	Forces, power, temperature rise, tool life, type of chip, surface finish and integrity
Tool angles	As above; influence on chip flow direction; resistance to tool wear and chipping
Continuous chip	Good surface finish; steady cutting forces; undesirable, especially in automated machinery
Built-up edge chip	Poor surface finish and integrity; if thin and stable, edge can protect tool surfaces
Discontinuous chip	Desirable for ease of chip disposal; fluctuating cutting forces; can affect surface finish and cause vibration and chatter
Temperature rise	Influences tool life, particularly crater wear and dimensional accuracy of workpiece; may cause thermal damage to workpiece surface
Tool wear	Influences surface finish and integrity, dimensional accuracy, temperature rise, forces and power
Machinability	Related to tool life, surface finish, forces and power, and type of chip

Cutting Fluids

- A fluid which is used in machining as well as abrasive machining processes to reduce friction and tool wear

Function of cutting fluids

- Lubrication
- Cooling
- Chip removal

Types

- Straight Oil (Petroleum based oils)
- Soluble Oil (water based oils)

Unit – 2
Lathe

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Assistant Professor
Department of Mechanical Engineering
AITS-Tirupati

Lathe

- ➢ Lathe is a machine, which removes the metal from a piece of work to the required shape and size.
- ➢ Lathe is one of the most versatile and widely used machine tools all over the world in the metal working industry.
- ➢ A lathe operates on the principle of a rotating workpiece and a fixed cutting tool.
- ➢ The job is securely and rigidly held in the chuck or in between centres on the lathe machine and then turn it against a single point cutting tool which will remove metal from the job in the form of chips.
- ➢ The cutting tool is feed into the workpiece, which rotates about its own axis causing the workpiece to be formed to the desired shape.
- ❖ Lathe is a machine tool employed generally to produce cylindrical objects.
- ❖ It is the most commonly used general purpose lathe used in engineering workshops
- ➢ Lathe machine is also known as “the mother/father of the entire tool family”.

Innovator of Lathe

Henry Maudslay (22 August 1771 – 14 February 1831) was an English machine tool innovator, tool and die maker, and inventor. He is considered a founding father of machine tool technology. His inventions were an important foundation for the Industrial Revolution.

Maudslay's invention of a metal lathe to cut metal, circa 1800, enabled the manufacture of standard screw thread sizes. Standard screw thread sizes allowed interchangeable parts and the development of mass production.

Function of lathe

Lathe is to remove excess material in the form of chips by rotating the work piece against a stationary cutting tool

Industrial revolution demanded

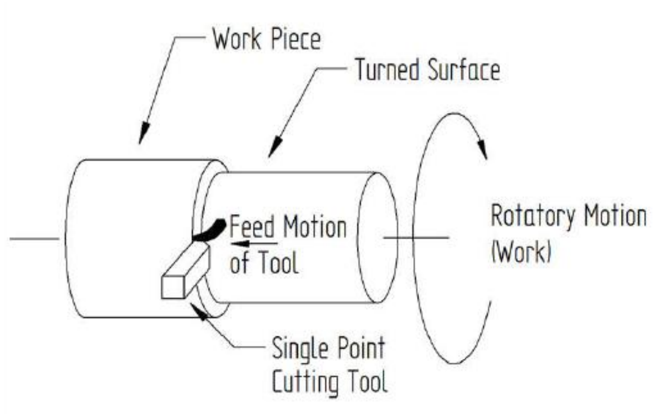
- More production
- More Precision
- Changes in Manufacturing process
- Lead to the Development of High speed
- Special purpose lathes

Principle of Working:

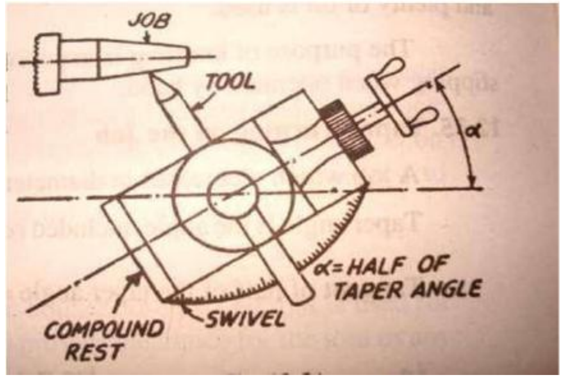
- The principle of working for an lathe involves rotating a workpiece while a cutting tool is brought into contact with the workpiece to remove material and shape it as desired.
- The workpiece is clamped in a chuck or a collet, and the tool is held in a tool post.
- As the workpiece rotates, the cutting tool moves along the workpiece's surface to remove material and shape it according to the desired specifications.
- This process allows for precision machining of cylindrical, conical, and threaded surfaces.
    - It holds the work between two supports called centers.
    - Chuck or Face plate is also used for holding the work. Chuck or face plate is mounted on machine spindle.
    - Cutting tool is held and supported on a tool post.
    - Movement of the job is rotation about spindle axis
    - Tool is fed against the revolving work
    - Movement of the tool is either parallel to or at any inclination to the work axis

- **Workpiece Setup:** The workpiece, which could be a metal rod, is securely mounted between the lathe's headstock and tailstock. The headstock contains the main spindle that rotates the workpiece, while the tailstock provides support.
- **Tool Setup:** The cutting tool, held in a tool holder, is positioned parallel to the workpiece axis. It can move longitudinally (along the workpiece) and crosswise (perpendicular to the workpiece) using various controls.
- **Rotation and Cutting:** The lathe's spindle is engaged, causing the workpiece to rotate at a desired speed. The cutting tool is brought into contact with the rotating workpiece, and it removes material through a combination of rotational and longitudinal movement. The crosswise movement controls the depth of the cut.
- **Feed Control:** The feed rate, which determines how fast the tool advances along the workpiece, can be adjusted to control the amount of material removed per pass.
- **Finishing and Accuracy:** The lathe allows for precise control over the material removal process, enabling the creation of cylindrical shapes, threads, and various geometries. Careful adjustments of the cutting tool, feed rate, and spindle speed are necessary for achieving the desired surface finish and dimensional accuracy.

If the tool moves parallel to work piece cylindrical surface is formed



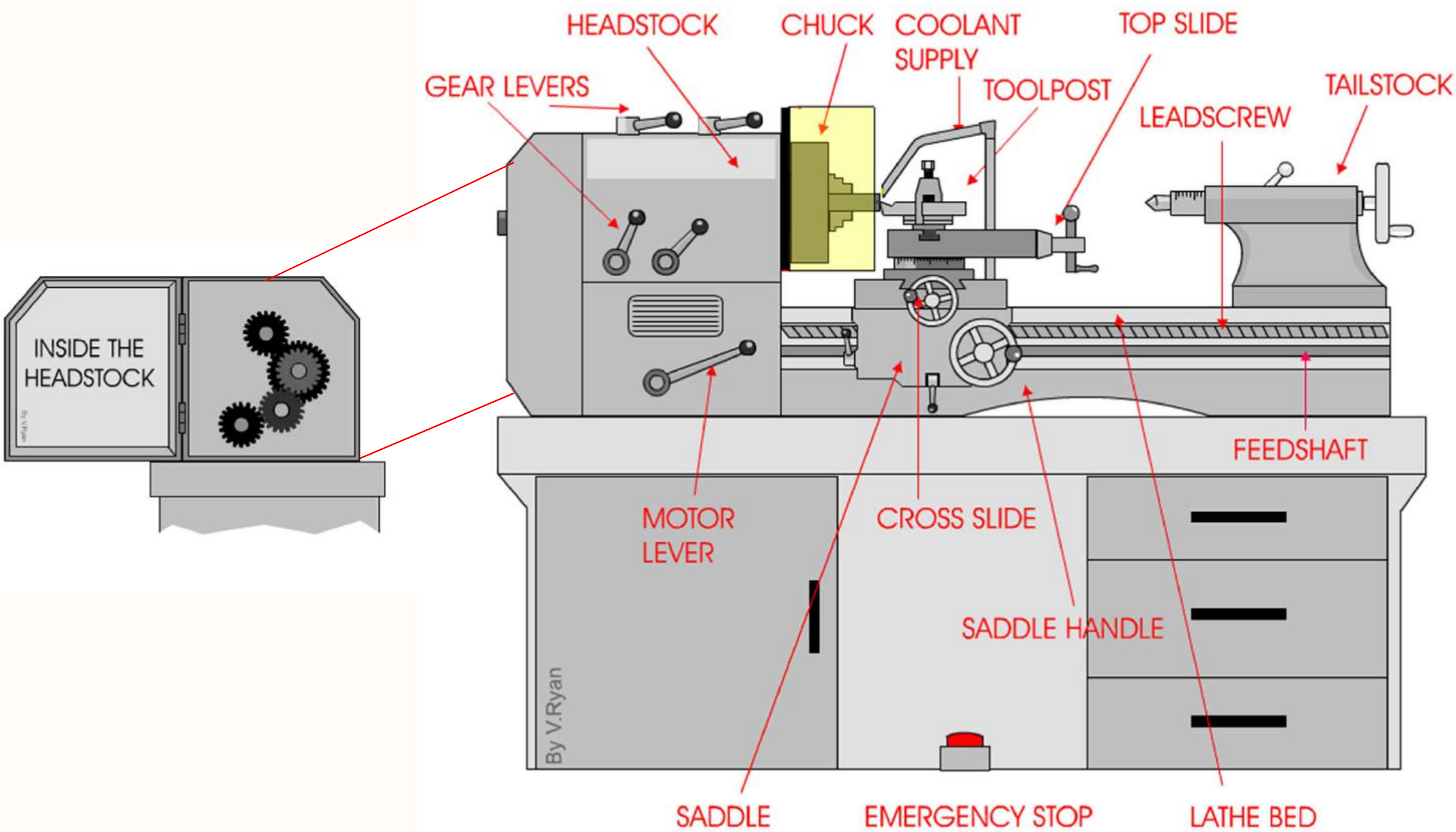
If the tool moves inclined to the axis it produces a taper surface and is called taper turning.



Lathe Components

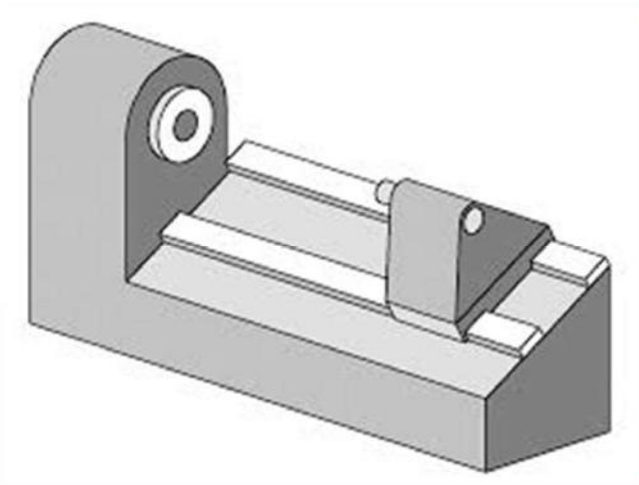
- Bed: supports all major components
- Carriage: slides along the ways and consists of the crossslide, tool post, apron
- Headstock – Holds the jaws for the work piece, supplies power to the jaws and has various drive speeds
- Tailstock – supports the other end of the workpiece
- Feed Rod and Lead Screw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

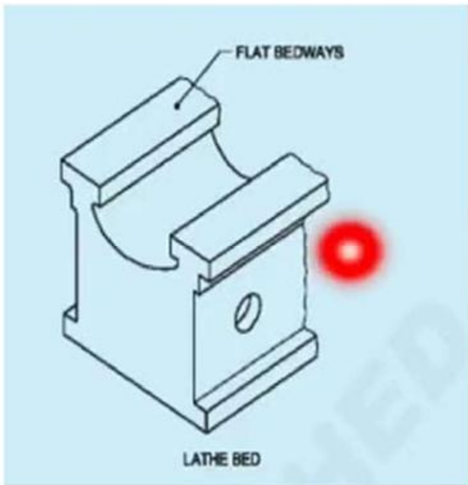
MAJOR PARTS OF LATHE AND THEIR FUNCIONS



Bed

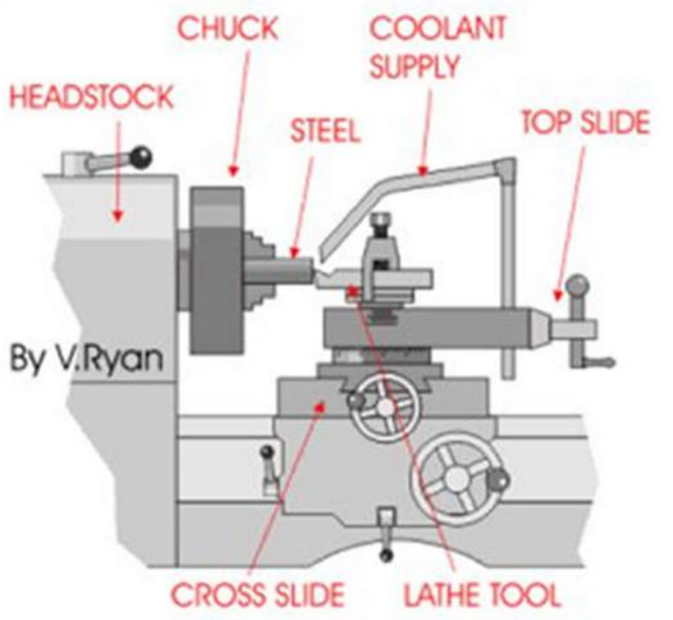
- The bed is the main component of a lathe, which is mounted on the legs of the lathe.
- All the major components are mounted on the lathe bed, like tail stock, headstock, carriage, etc. Tailstock and carriage move over the guide ways provided on top face of the bed.
- Headstock of the lathe is located at the extreme left of the bed and tailstock at the right extreme of the bed. The top of the bed has flat or V shaped guideways.
- The bed is typically made of cast iron to ensure stability and minimize vibrations and also it possess high compressive strength and high wear resistance.

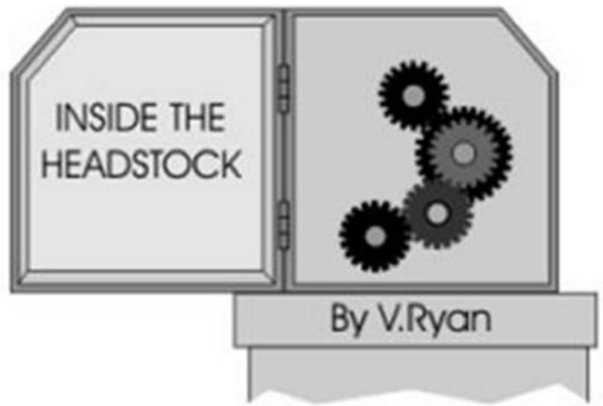




Headstock

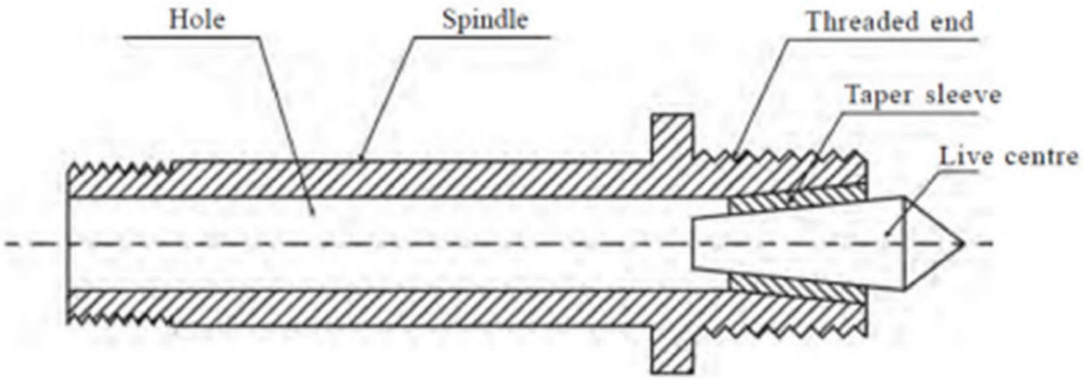
- The main function of headstock is to transmit power to the different parts of a lathe.
- It holds the lathe spindle and gears, however for long bars hollow spindle is used. Also, chuck is fitted to spindle.
- The main spindle is adjusted in it, which possesses **live centre** to which the work can be attached.
- It supports the work and revolves with the work, fitted into the main spindle of the headstock.
- The cone pulley is also attached with this arrangement, which is used to get various spindle speed through electric motor. The back gear arrangement is used for obtaining a wide range of slower speeds.
- Some gears called change wheels are used to produce different velocity ratio required for thread cutting.





Spindle

- The spindle rotates on two large bearings housed on the headstock casting.
- A hole extends through the spindle so that a long bar stock may be passed through the hole.
- The front end of the spindle is threaded on which chucks, faceplate, driving plate and catch plate are screwed.
- The front end of the hole is tapered to receive live centre which supports the work.
- On the other side of the spindle, a gear known as a spindle gear is fitted. Through this gear, tumbler gears and a main gear train, the power is transmitted to the gear on the leadscrew.



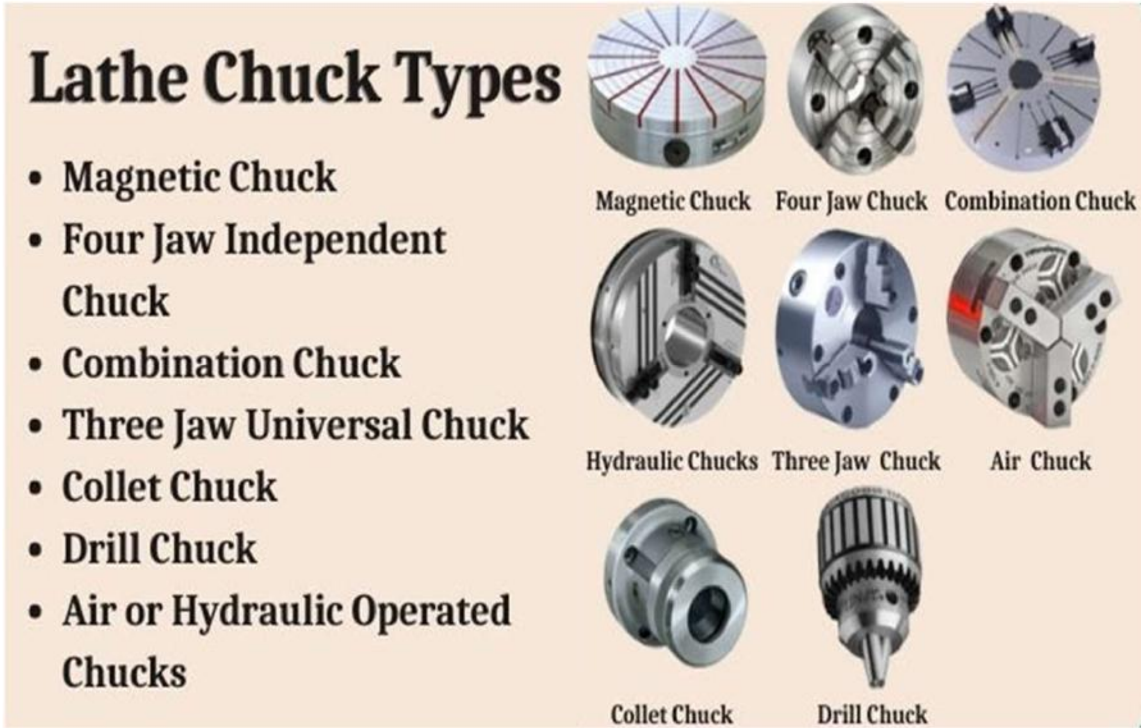
Chuck or Collet:

Workpieces are held securely in a chuck (usually for larger workpieces) or a collet (for smaller and more precise workpieces).

Chuck is classified into two types:

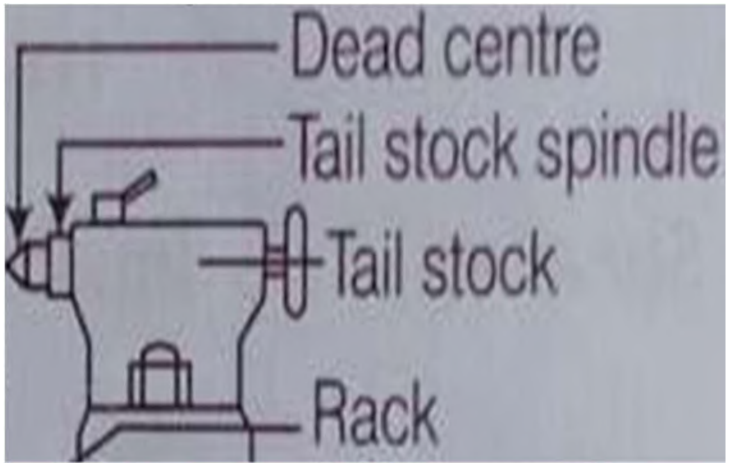
Three jaw chuck: It is used to hold circular or cylindrical shape jobs.

Four jaw chuck: It is used to hold non-circular jobs.



Tailstock

- The tailstock is mounted on the right hand side of the lathe bed, which lies opposite end of the headstock and can be moved along the bed.
- The function of the tailstock is to support the other end of work piece and often includes a center for additional stability.
- It also to accommodate different tools like drill, reaming, boring and tapping, etc.
- The tailstock moves on the guide ways over the bed, to accommodate for different length of work piece.
- Tailstock is known **as dead center**.



Carriage

Carriage is located between the headstock and tailstock on the lathe bed guide ways. It can be moved along the bed either towards or away from the headstock. It has several parts to support, move and control the cutting tool. The parts of the carriage are:

a) Saddle (which moves along the bed)

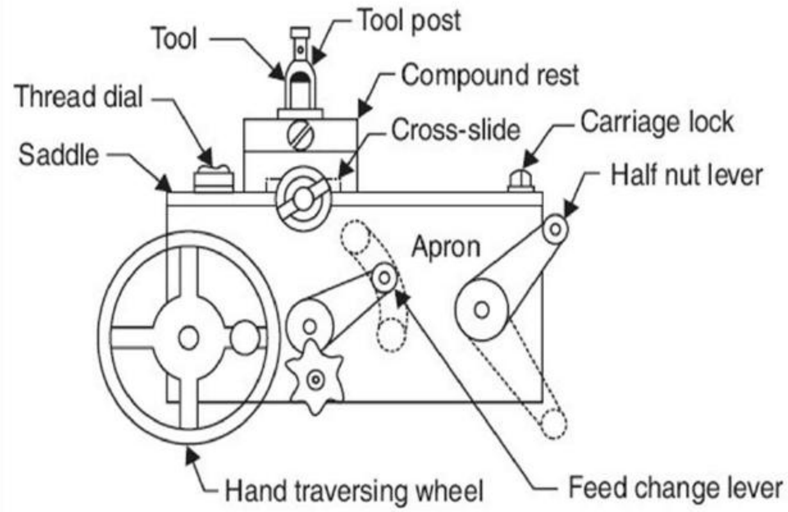
b) Apron

c) Cross-slide (moves perpendicular to the bed)

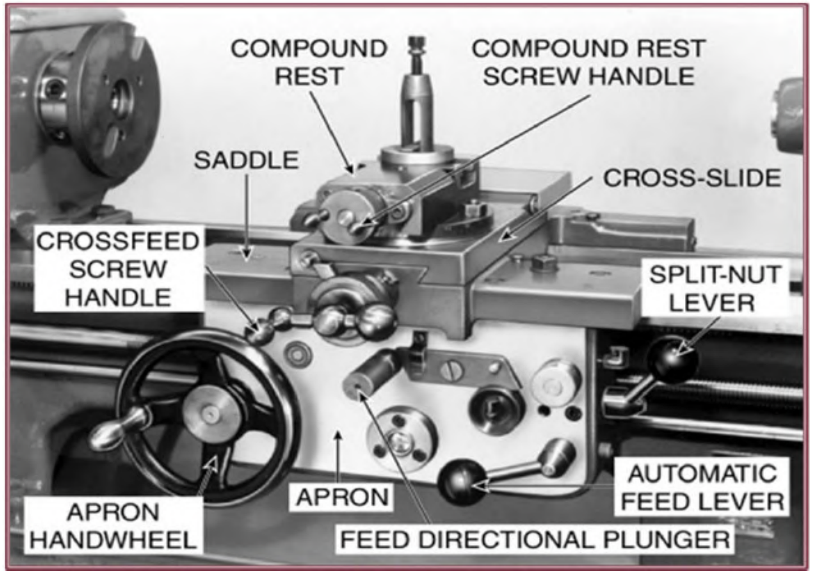
d) Compound rest

e) Compound slide

f) Tool post

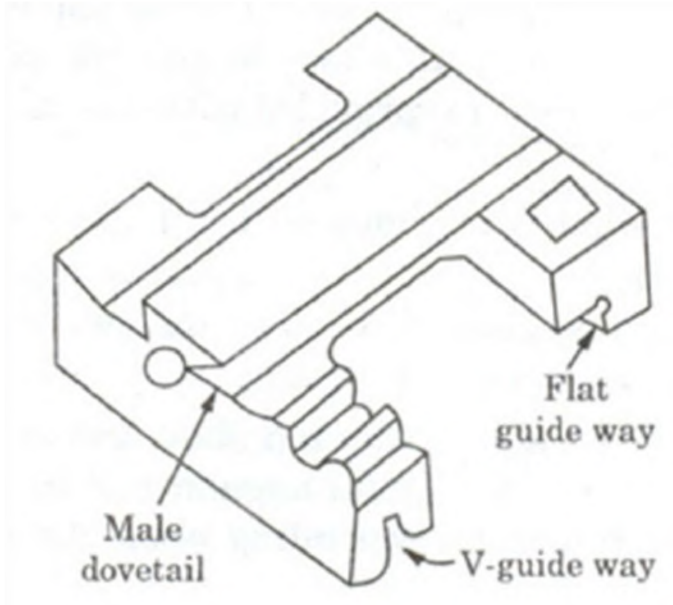


Carriage



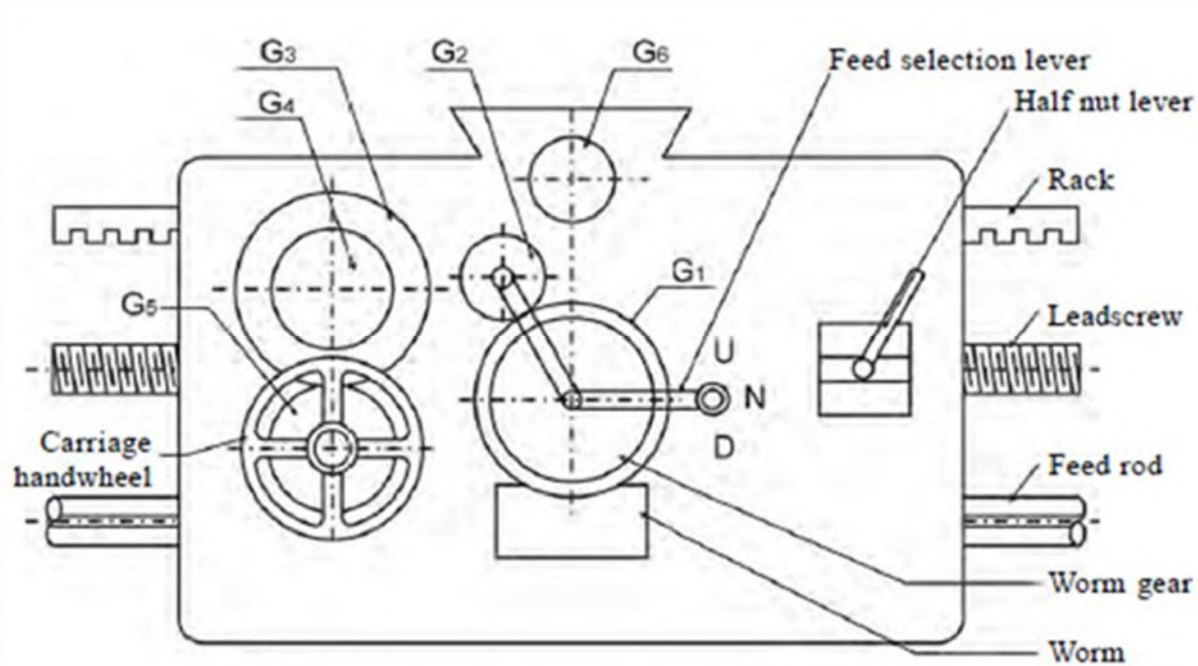
Saddle

- It is an "H" shaped casting.
- The saddle connects the pair of bed guide ways like a bridge.
- It fits over the bed and slides along the bed between headstock and tailstock.
- The cross slide and tool post are mounted on the saddle.
- The movement of the saddle is parallel along the axis of the lathe, it is also known as feed.
- The saddle or the entire carriage can be
- moved by providing hand feed or automatic feed.



Apron

- The front portion of a carriage call as apron. It consists of all control keys, which clamped to the saddle.
- It is useful in providing power and hand feed to both carriage and cross-slide.
- It is also used to provide feed to the carriage during thread cutting through two half nuts.

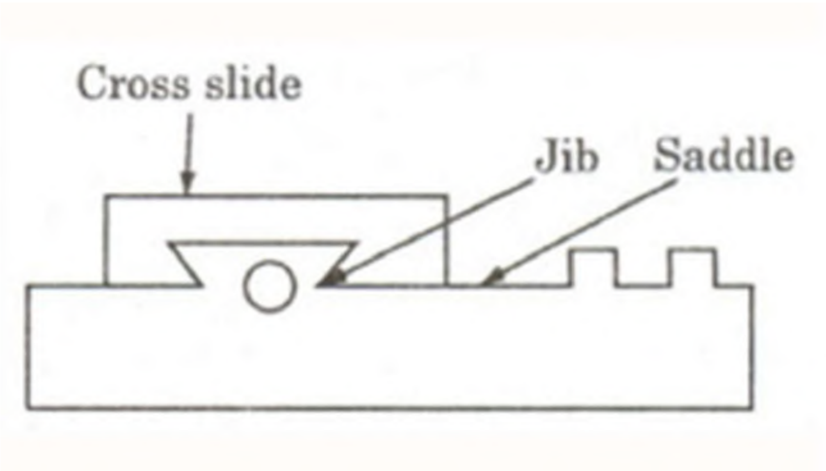


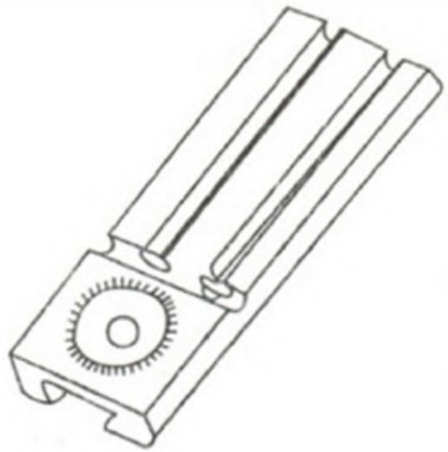
Cross slide

- The cross slide is mounted on the top of the saddle. This moves the tool at perpendicular to the work piece or machine axis.

- The cross slide can be moved either by rotating the cross slide hand wheel.

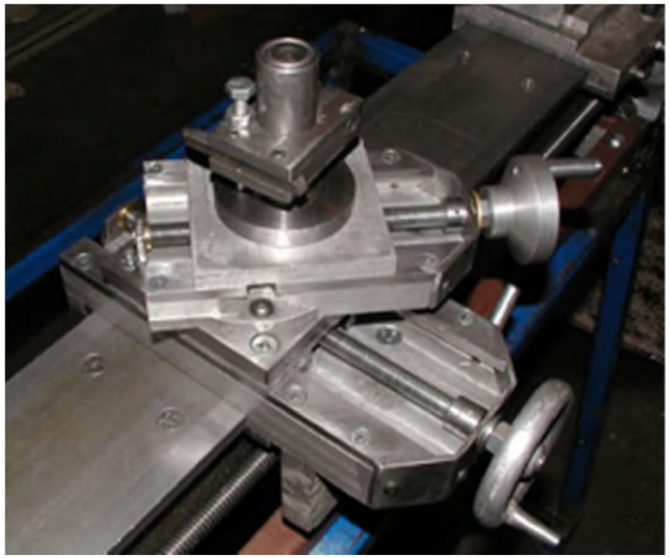
- The perpendicular distance moved by the cross slide is proportional to the amount of metal removed and it is known as depth of cut.

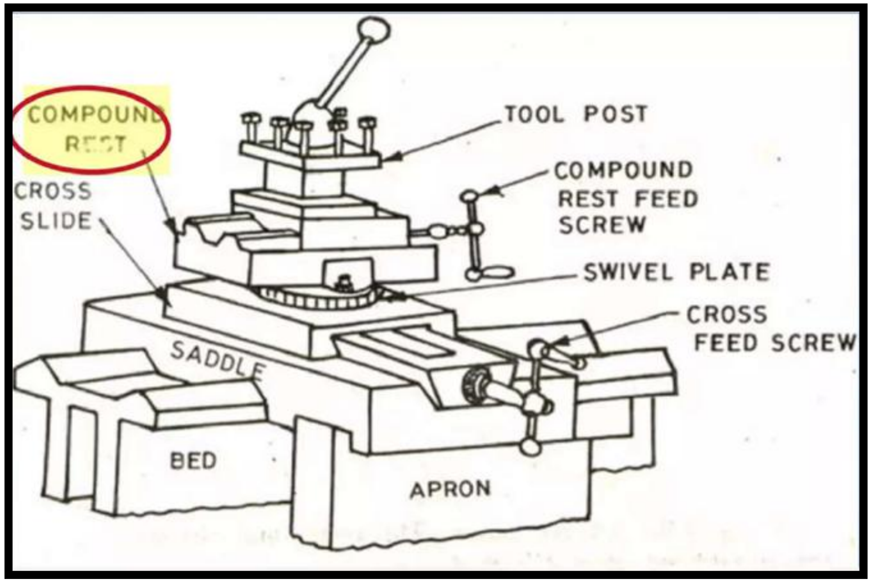




Compound slide / Compound rest

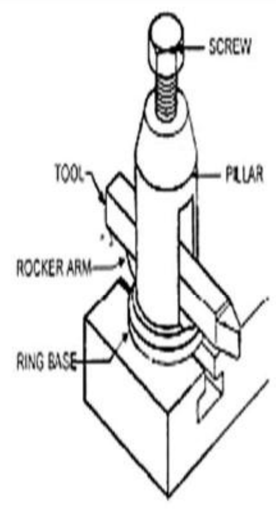
- The compound slide / compound rest is mounted on the top of the cross slide upper surface, which is related to a micrometer sleeve and screw handle with the outer edge of screw. It is used to obtain taper on the work piece.
- The automatic feed is not possible in compound slide.
- **Compound rest** is a part which connects to cross slide and compound slide, which is mounted on the cross slide by tongue and groove joint.
- It can be swiveled to the required angle while turning tapers.



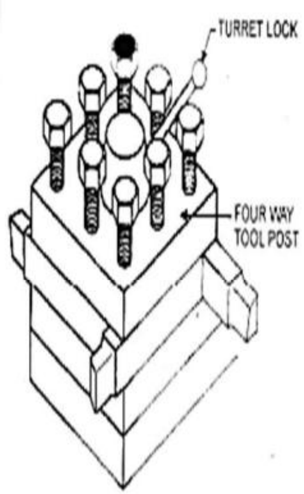


Tool post

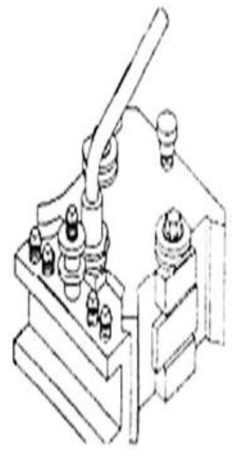
- The tool post is mounted on top of the compound slide.
- It holds the cutting tool rigidly and allows for quick and precise tool changes.
- Different types of tool holders can be used to accommodate various cutting tools.



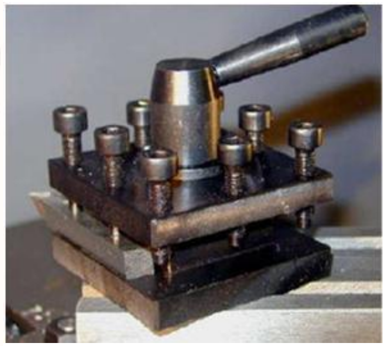
Single way (Pillar Type) Tool Post



Indexing Type 4 way Tool Post

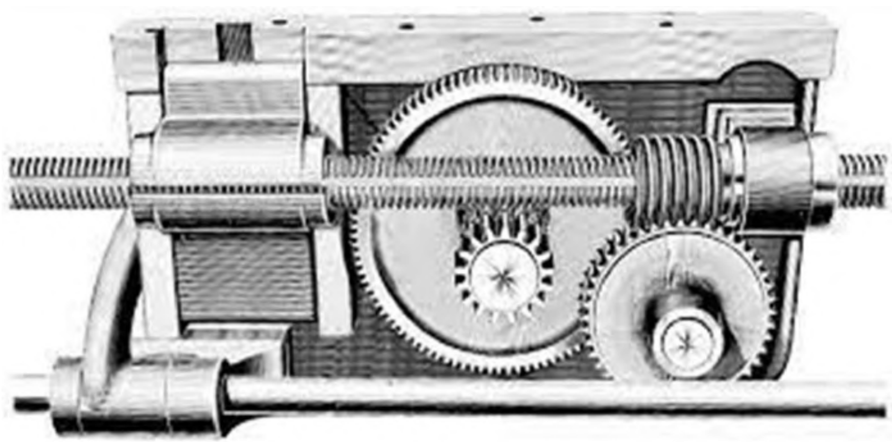


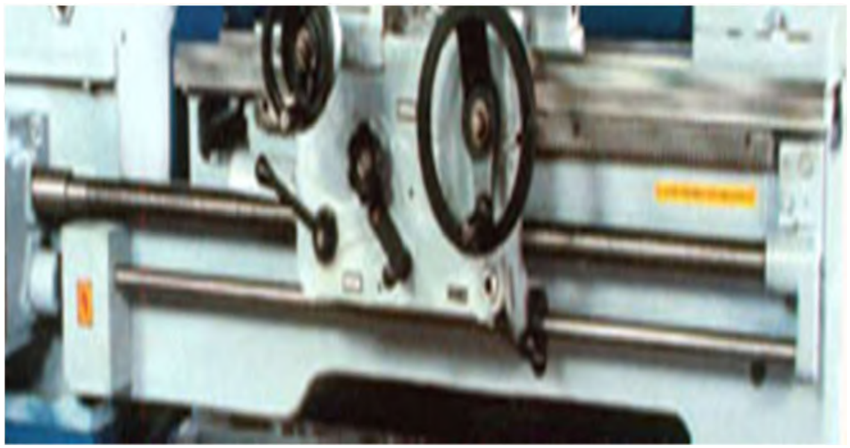
Quick Change Tool Post



Feed Rod

- Feed rod is a long shaft extending from the feed box.
- The power is transmitted from a set of gears from headstock.
- The feed rod is used to move the carriage or cross slide for turning, boring and facing operations.
- The amount of tools relative to the workpiece is called ‘Feed.’





Feed Mechanism

- The amount of tools relative to the workpiece is called 'Feed.'
- Lathes have mechanisms to control the feed rate of the cutting tool as it moves along the workpiece.
- These mechanisms enable the creation of smooth and accurate surfaces.
- A lathe tool has 3 types of feed
  - Longitudinal feed: Here the tool moves parallel to the lathe axis. It is affected by means of the carriage movement.
  - Crossfeed: Here the tool moves at right angles to the lathe axis.
  - Angular feed: By adjusting the compound slide and swivelling it to the required angle to the lathe axis.
- Cross and longitudinal feeds are both hand and power operated, but angular is only hand operated.

Lead screw

- The lead screw is a long threaded shaft connected to the headstock.
- The lead screw is used only when thread cutting operation is to be carried out on the work piece.
- For normal turning operations the lead screw is disengaged.

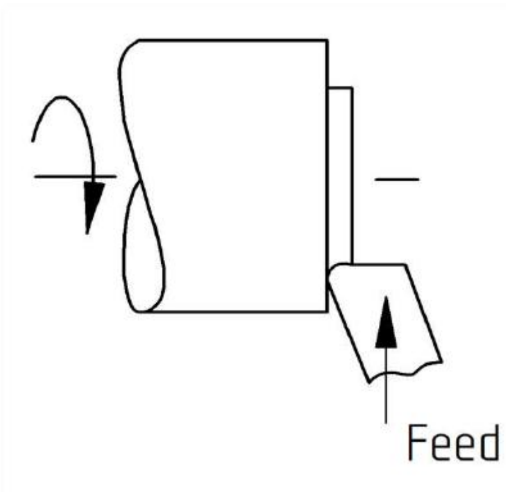
LATHE OPERATIONS

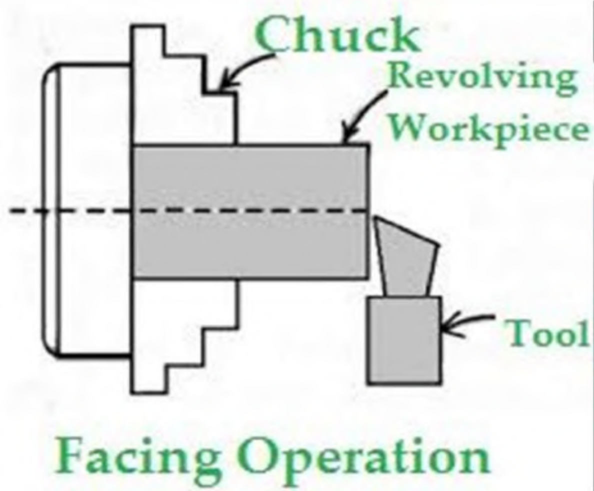
Different types of operations that can be carried out

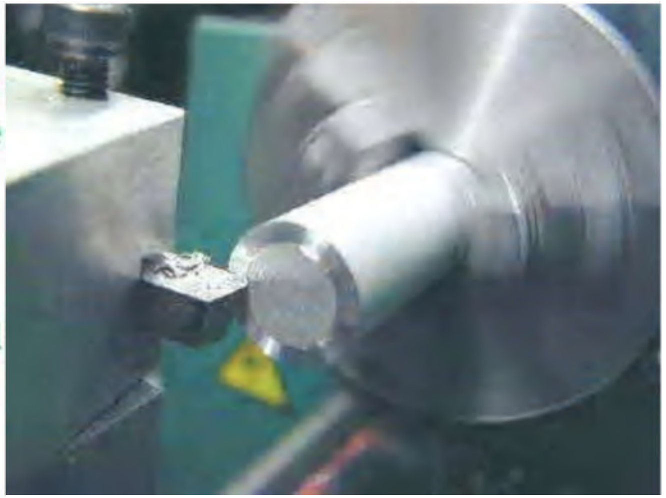
1. Facing
2. Straight Turning
3. Chamfering
4. Knurling
5. Grooving and parting off
6. Drilling
7. Boring
8. Taper turning
9. Thread cutting

FACING

- Facing is the process of removing metal from the end of a work piece to produce a flat surface.
- The work piece rotates about its axis and the facing tool is fed perpendicular to the axis of lathe.







TURNING

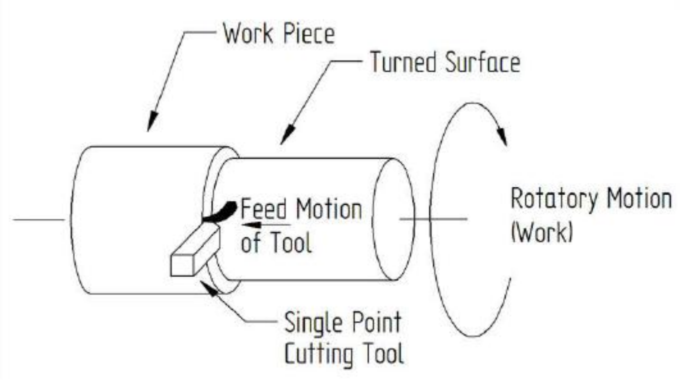
- Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece.
- Turning is used to reduce the diameter of the work piece, usually to a specified dimension.
- A simple single point cutting tools are use for turning operations.
- Turning can be different types like

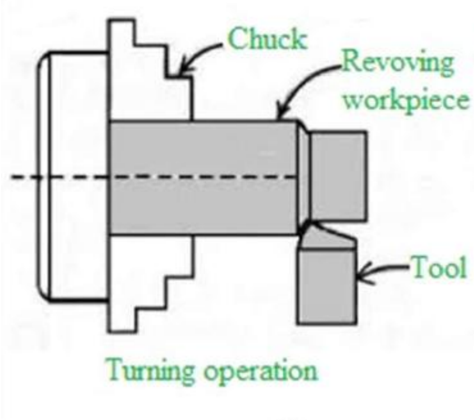
  i. Tapers and Taper Turning

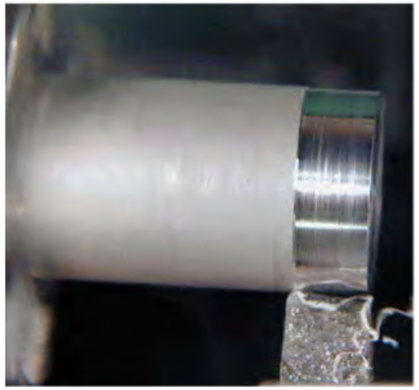
  ii. Straight turning

  iii. Profiling

  iv. External grooving, etc.







Tapers and Taper Turning

A taper may be define as a uniform increase or decrease in diameter of a piece of work measured along its length.

In a lathe, taper turning means to produce a conical surface by gradual reduction in diameter from a cylindrical work piece.

Straight turning

The Straight turning produces a cylindrical surface by removing excess metal from the work piece.

Profiling

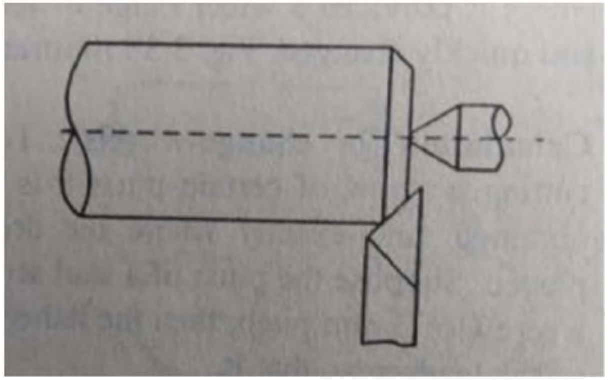
In profiling, the cut can be vary with regard to cutting depth, feed and speed.

External grooving

In external turning operations machines the outer diameter of the work piece.

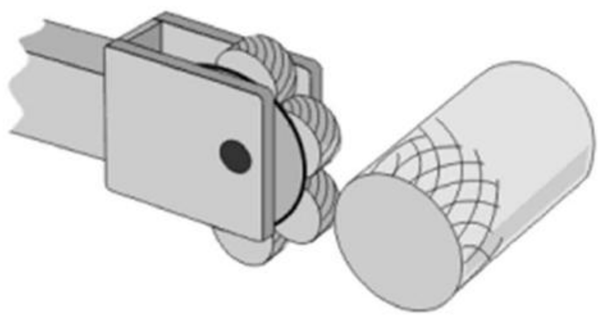
CHAMFERING

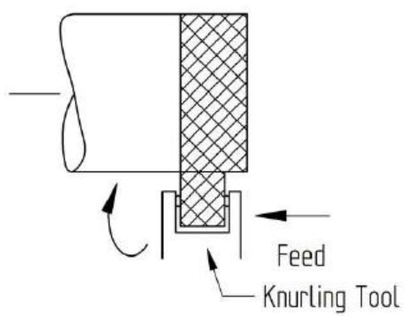
- Chamfering is the operation of beveling the extreme end of a work piece.
- It is a process of creating a slope at the end of the work piece.
- This is done to remove the burrs, to protect the end of the work piece from being damaged and to have a better look.
- This process is carried out for removing the unwanted metals and burrs after turning operation.

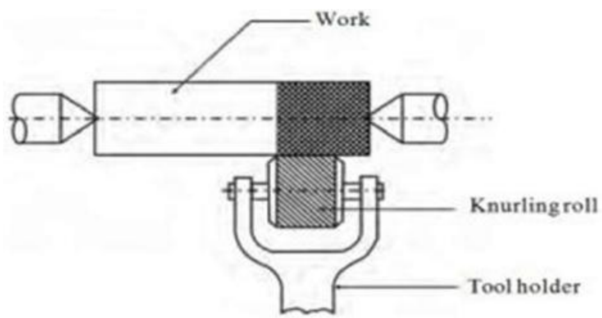


KNURLING

- Knurling is the process of embossing a required (diamond) shaped pattern on the surface of the work piece.
- This diagram shows the knurling tool pressed against a piece of circular work piece.
- The purpose of knurling is to provide an effective gripping surface on a work piece to prevent it from slipping when operated by hand.



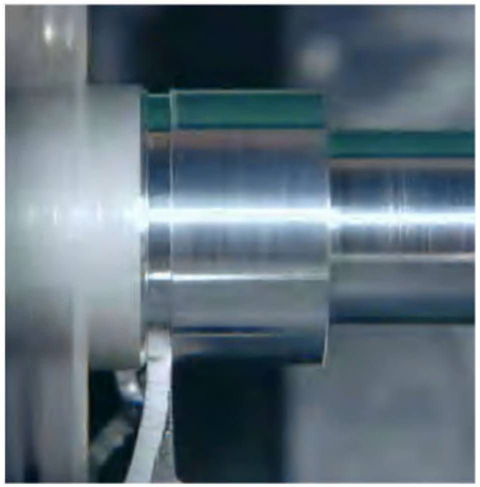


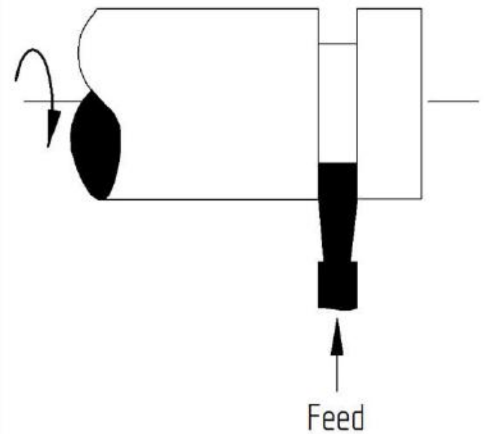


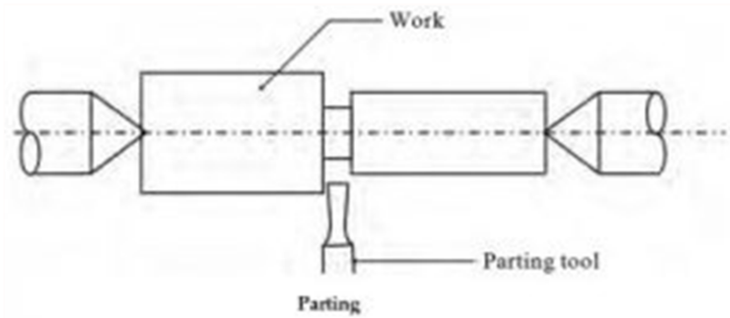
Knurling

PARTING

- Parting off is the operation of cutting a work piece after it has been finished to the desired dimension and shape.
- In parting operation both feed is fixed or locked and depth of cut is controlled properly until the work is cut off in parts.

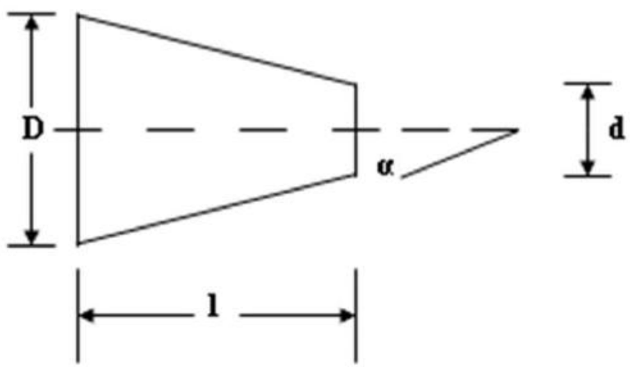






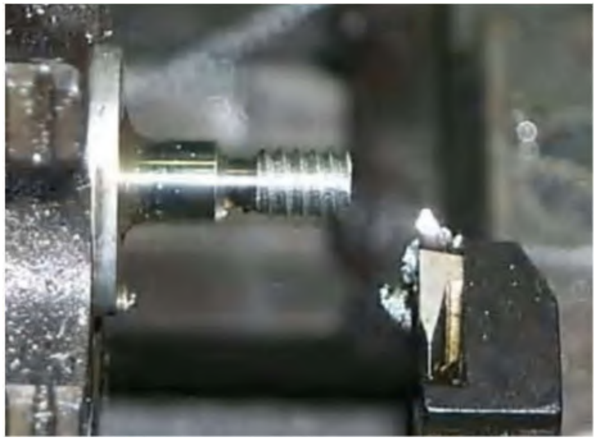
TAPER TURNING

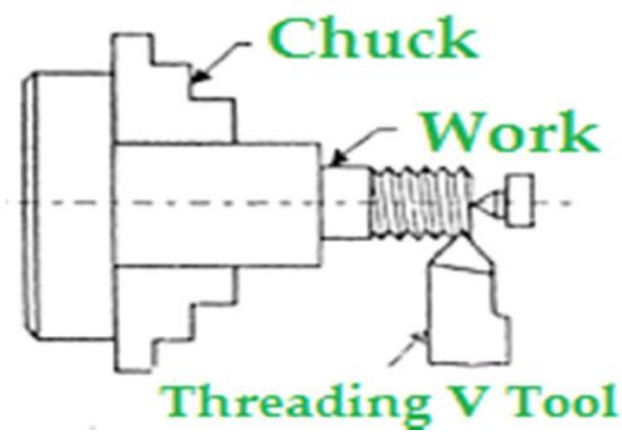
- A taper may be defined as a uniform decrease in diameter of work piece measured along its length.
- Taper surface is generated on a cylindrical work piece.
- The amount of taper in a work piece is usually specified by the difference in diameters of the taper to its length.
    - D-Large diameter of taper in mm.
    - d- Small diameter of taper in mm.
    - l- Length of tapered part in mm.
    - α- Angle of taper or half taper angle.



THREAD CUTTING

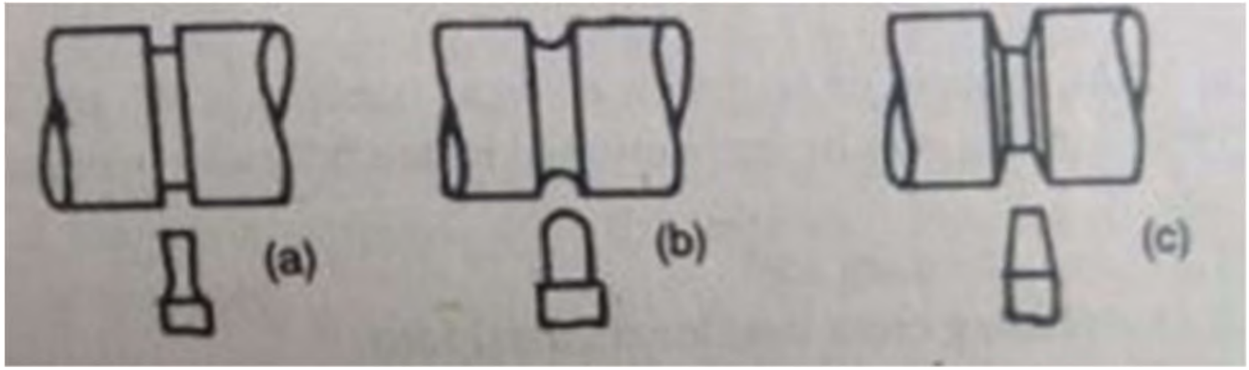
- Thread cutting is the operation of producing helical groove on a cylindrical surface.
- Threads may be square or v threads can be cut on a cylindrical work piece.
- The threads of any pitch, shape and size can be cut on a lathe.
- A single point cutting tool (V-tool or square tool) is used to cut threads on the work piece.
- For thread cutting operation, the tool is moved automatically in longitudinal direction.
- The longitudinal feed should be equal to the pitch of the thread to be cut per revolution of the work.
- Threads can be produced either on internal or external surface of a cylindrical bar.





Grooving

- Grooving is the process of reducing the diameter of a work piece over a very narrow surface.
- It is often done at the end of a thread or adjacent to a shoulder to leave a small margin.

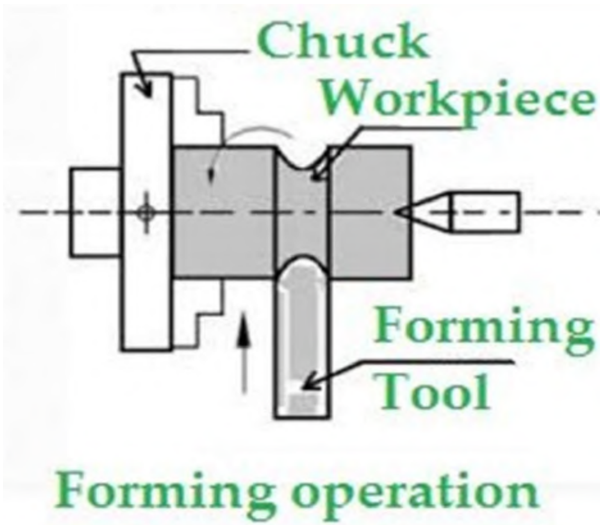


Grooving Operations are:

a. Square Groove
b. Round Groove
c. Bevelled Groove

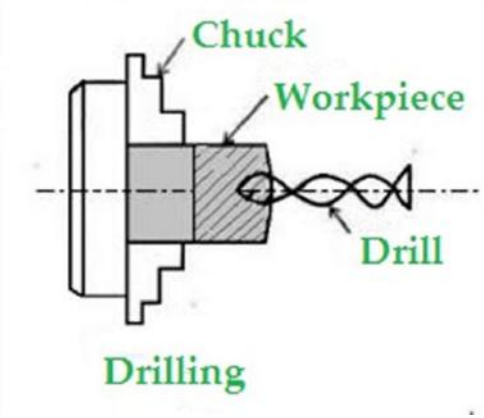
Forming

- Forming is the process of turning a convex, concave or of any irregular shape.



Drilling

Drilling is an operation of producing a cylindrical hole in a work piece by the rotating cutting edge of a cutter known as the drill.



Boring

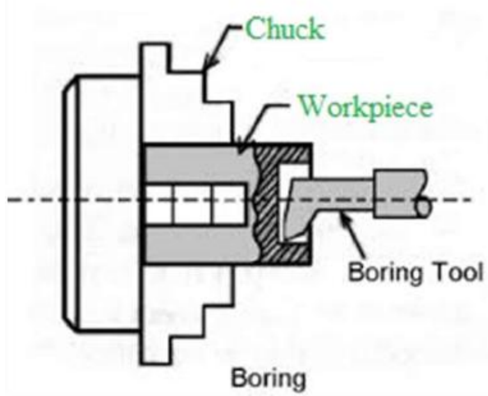
Boring is the operation of enlarge a hole or cylindrical cavity to produce circular internal grooves. Holes may be bore straight and tapered.

i. Counter Boring

- Counter Boring is the operation of enlarging a hole through a certain distance from one end instead of enlarging the whole drilled surface.

ii. Taper Boring

- Taper Boring is similar to the external taper turning operation and is accomplished by rotating the work on chuck or a face plate, and feeding the tool at an angle to the axis of rotation of the work piece.



SPECIFICATION OF A LATHE

1) The length of the bed,

2) The distance between the centers.

3) The swing diameter of work over bed,

4) The swing diameter of work over the carriage,

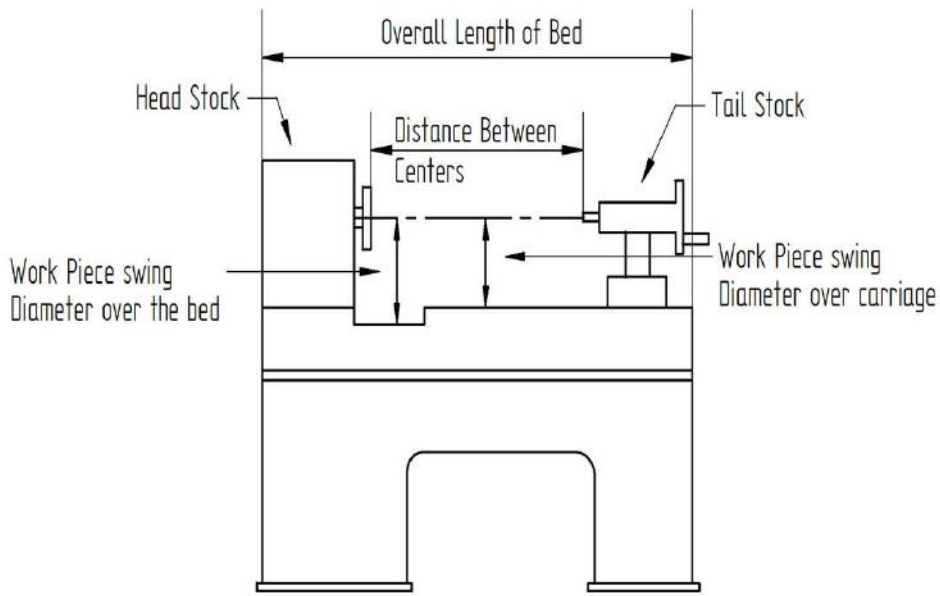
5) Power input

6) Lead screw details,

7) Number of spindle speeds

8) Feeds,

9) Width of bed



1) a) Height of centers

b)type of bed(straight , semi gap, or gap)

c) center distance

2) a)swing over bed

b)swing over cross slide

c) swing in gap

d) gap in front of face place

3) a) spindle speeds range

b) spindle nose

c) spindle bore

d) taper nose

4) a)Metric thread piches

b)lead screw pitch

c)longitudinal feeds

d)cross feeds

5) a) cross slide travel

b)top slide travel

c) tool section

6) a)tailstock sleeve travel

b)taper in sleeve bore

7) Motor horsepower and RPM

8) shipping dimensions ---

length*width*height*weigh

Classification of lathes / Types Of Lathe Machine

Lathes are very versatile of wide use and are classified according to several aspects:

According to configuration:

- Horizontal – Most common for ergonomic conveniences.
- Vertical – Occupies less floor space, only some large lathes are of this type.

According to the purpose of use:

- General-purpose – Very versatile where almost all possible types of operations are carried out on wide ranges of size, shape, and materials of jobs; e.g.: center lathes.
- Single-purpose – Only one (occasionally two) type of operation is done on limited ranges of size and material of jobs; e.g.: facing lathe, roll turning lathe, etc.
- Special purpose – Where a definite number and type of operations are done repeatedly over a long time on a specific type of blank; e.g.: capstan lathe, turret lathe, gear blanking lathe, etc.

TYPES OF LATHE MACHINE

Lathe machines are classified according to their construction and design.

Some of them are:

1. Bench lathe machine
2. Speed lathe machine
3. Engine lathe or center lathe machine
4. Tool room lathe machine
5. Capstan and turret lathe machine
6. Special purpose lathe machine
7. Automatic lathe machine

1. Bench lathe machine

- Bench lathe is a **small sized engine lathe** usually mounted on a bench.
- All the types of operations can be performed on thus lathe that may be done on an ordinary speed.
- This is using for **small and precision work**s such as in the production of gauges, punches and bed for press tools.

2. Speed lathe machine

- **Speed lathe** is the simplest of all types of lathe in construction and operation.
- It consists of a bed , a head stock, a tail stock and a **tool – post** mounted on an adjustable slide.
- The spindle speed is about **4000 rpm**.
- They named because of very **High Speed** of head stock spindle.

3. Engine lathe (center lathe)

- The term " **engine** " is associated with the lathe which is early driven by steam engines.
- An engine lathe is also know as a **reproductive machine** because of its production **capabilitie**s.
- Engine lathes are an **excellent tool,** which aids in the creation of many modern tools.

Advantages

- It is using for **mass production** of products.
- It is using for manufacturing **cylindrical shapes** like steels and plastics.

Disadvantages

- It is very difficult to **program** in machine language.
- corruption, poor service, and racial issues.

Capstan Lathe

- They having features of the basic lathe and have short slide tail stock.
- A Capstan machine is a processing machine uses for making the same parts again and again.

Advantages

  - The production rate is high.

Disadvantages

  - The heavier work-piece cannot machine by capstan lathe.

Turret Lathe

- The turret lathe is a form of metalworking lathe.
- It is used for repetitive production of duplicate parts.
- In a turret lathe, a longitudinally feed able, hexagon turret replaces the tail stock.

Advantages

  - Turret lathe is using to machine the long and heavy workpieces.
  - They having hexagonal tool post or head.
  - There is no need of changing the tool.

Disadvantages

  - They have manual indexes.

4. Tool room lathe machine

- Tool room lathe is similar to an engine lathe.
- This lathe is mainly using for precision work on tools, Dies, Gauges and in making work where accuracy is necessary.
- It is used for making precision components in the tool room.

6. Special purpose lathe machine

Special Purpose lathe are using for special purposes and for jobs which cannot be accommodated or conveniently machined on a standard lathe.

7. Automatic lathe machine

- In the automatic lathe, the various operations are automating like the change of the work piece.
- The working cycle is fully automatic that is repeated to produce duplicate parts without participation of operator.

Advantages

- During machine operation operator is free to operate another machine.
- More economy in floor space.

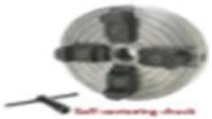
Disadvantages

- Lots of consideration are taking on fixing the setup.

Comparison among Centre lathe, Capstan Lathe and Turret Lathe:

Feature	Centre Lathe	Turret Lathe	Capstan Lathe
Headstock	Cons pulley or all gear driven. Can Provide lesser speed than the other two	Heavy construction, wider range of spindle speeds from more powerful motor than centre lathes	Same as Turret Lathe
Toolpost	Usually a single Toolpost (with a single tool). Sometimes, a square turret type Toolpost is provided which can hold 4 tools.	Its cross slide carries a square turret type Toolpost carrying 4 tools. Additionally, it has a Toolpost at its rear to hold 1 or 2 tools.	Same as Turret Lathe
Tailstock	Usually used for supporting the WP. Sometimes, some cutting tools (drills, reamers etc) installed to perform operations at the end face of WP.	Carries a hexagonal *turret head* instead of tailstock, which may hold a tool or tool head on each of its face. They are automatically indexed in sequence to bring each tool in proper position for performing operations sequentially.	Carries a square, round or hexagonal turret called *Capstan head* in place of tailstock. This provides the same facility of mounting and indexing 4-6 tools as in case of turret lathe.
Leadscrew	Always provided on centre lathe to enable thread cutting by a single point tool.	Thread cutting generally performed by taps and die heads fitted to the turret head.	Same as Turret Lathe
Method of mounting the *Turret* or *Capstan* Head	Not applicable	*Turret head* directly mounted on a saddle and for feeding the tool on the WP the entire saddle has to be moved.	*Capstan head* is mounted on a *ram* or *slide*, which travels on the fixed saddle. The tools are fed on the WP by moving the *slide*.
No. of tools mounted	Usually 1 for single tool post. If a square turret type Toolpost is provided then 4 tools can be mounted.	4 tools on the front tool post, 1 or 2 on the rear tool post and 4-6 tools on the square or hexagonal *turret* head. No. of tools can be increased by using multiple tool holders on the *turret*.	Same as Turret Lathe
Skill required for operator	Very high	Very nominal after setting of tools	Same as Turret Lathe
Tool setting time	High. Tool has to be changed every time a new operation is to be	Initial tool setting time required. During operation all the tool are	Same as Turret Lathe

Work Holding Devices & Tool Holding Devices

S.NO.	Work Holding Devices	Diagram	S.NO.	Tool Holding Devices	Diagram
1.	jaw Chucks		1.	Straight cutter holder	
b.	Self-centering chuck		2.	Multiple cutter holder	
c.	Independent chuck		3.	Offset cutter holder	
d.	Combination chuck		4.	Combination tool holder	
e.	Air operated chuck		5.	Knee tool holder	

2.	Collet chucks		**6.**	Slide tool holder	
a.	Push out type		**7.**	Knurling tool holder	
b.	Draw in type		**8.**	Boring bar holder	
c.	Dead length type		**9.**	Recessing tool holder	

Unit – 3

Boring, Shaping and Slotting

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Boring Machine

The **boring machine** is one of the most versatile machine tools basically used *to bore holes in large and heavy parts* practically impossible to hold and rotate in an engine lathe or a drilling machine.

Also, a **boring machine** is a reciprocating type of machine tools basically used to bore holes in large and heavy parts.

For example ***engine frames, steam engine, cylinders, machine housings***, *etc*.

The boring machines come in a large variety of styles and sizes.

The usage of a machine can be extended still further to include screw cutting, turning, planetary grinding, or gear cutting.

The cutting tool is normally single point which are made of **M2 and M3** high-speed steel or **P10 and P01** carbide.

John Wilkinson was the person who invented first boring machine tool in **1775.**

Types of Boring Machine

- **Horizontal**: The ***rotational axis of w/p is horizontal***
  1. Table type boring machine
  2. Floor type boring machine
  3. Planer type boring machine
  4. Multiple head type boring machine
- **Vertical**: The ***rotational axis of w/p is vertical***
  1. Vertical turret lathe boring machine
  2. Standard vertical boring machine
- **Precision boring machine**
- **Jig Boring Machine**
  1. Vertical milling machine type boring machine
  2. Planer type boring machine

Horizontal Boring Machine:

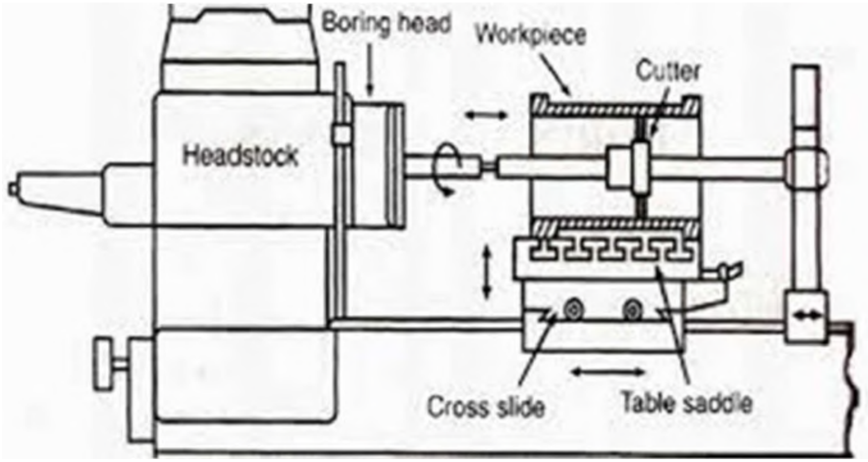
In a horizontal boring machine, the ***work is supporting on a table,*** which is constant and the ***tool turns into a horizontal axis***.

This machine can perform ***boring, reaming, turning, threading, facing, milling, grooving, recessing*** and many other operations with suitable tools.

Any irregular, off-balance and heavy workpieces can conveniently hold and easy to machining.

Table type boring machine

- The table type is the most common of all horizontal boring machines.
- The **work is mounted on the table** which is *adjustable and feed is given by hand power, lengthwise or crosswise with respect to the bed of the machine*.
- The machine basically comprises of a ***bed, headstock supporting column, end supporting column, headstock, saddle and table, and boring bar***.
- This type of machine may be suitable for general purpose work where other operations, in addition to boring, are required to be performed.



Bed

- The bed is that part of the machine ***which is fitting on the floor of the shop*** and has a **box-like casting**.
- The bed supports the column, tables and other parts of the machine.

Headstock Supporting Column

- The **column provides support to the headstock and guides** it up and down accurately by the guideways.
- The column which has **hollow houses and is heavily ribbed to add rigidity**.
- Some columns are stationary, others may be made to slide along the bed.

End Supporting Column

- The *end supporting column situated at the other end of the bed houses*.
- Bearing block is provided for supporting a long boring bar.
- The column may be adjusted on the slideways of the bed towards or away from the spindle for supporting the different length of boring bars.
- It may be **moved at right angles to the spindle** as in the case of a floor type machine.

Headstock

- The **headstock mounting on the column supports, drives, and feeds the tool**.
- A *spindle provides rotary movement to the tool and the quill may be moved longitudinally to provide feeding movement of the boring cutter*.
- The spindle nose is provided with a tapered hole for receiving taper shanks of the boring bar or any other tool.
- A ***headstock may move up and down on the column*** for setting the tool for different heights of the work..

Saddle and Table

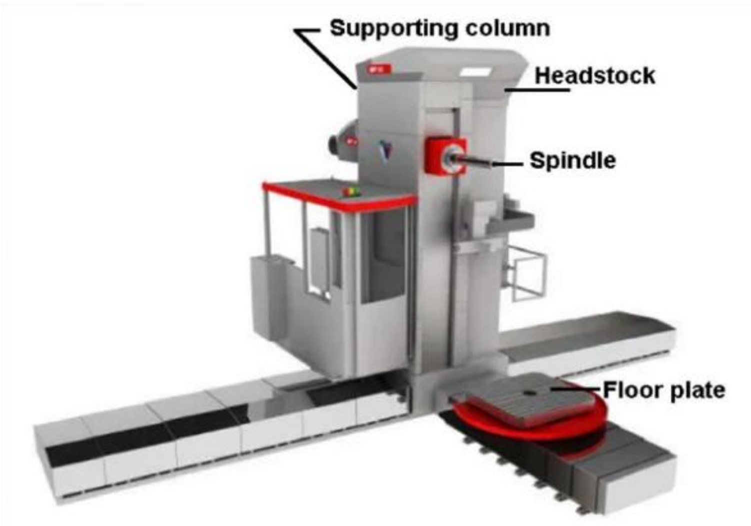
- The ***tables support the work*** and is, therefore, provides **T-slots for holding various devices**.
- The ***saddle allows the work to be moved longitudinally on the bed***. The *table may be moved crosswise on the saddle*.
- These movements may be slow or rapid and are performed by hand or power.

Boring Bars

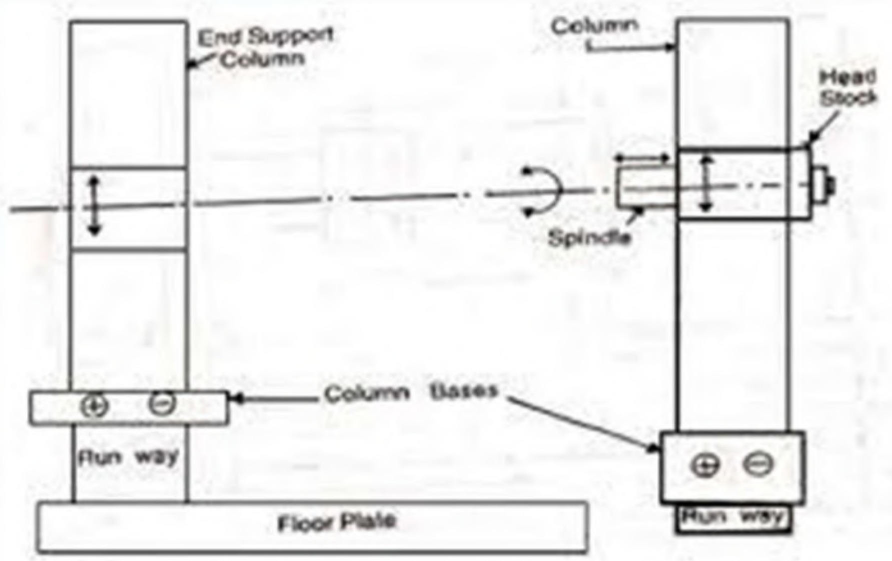
- The ***boring bar supports the cutter*** for holding operations on jobs having large bore diameters.
- For short holes, the bar may support on the headstock spindle end only.
- For long work, the bar is supported on the spindle end and on the column bearing block.

Floor type boring machine

- The floor type horizontal boring machine having *no table uses a fixed floor plate on which T-spaces are given to hold the work*.
- The *headstock supporting column and the end supporting column and the end supporting column are mounted on the runways which are set at right angles to the spindle axis*.
- This is so ***designed for holding very large and heavy workpiece*** which are difficult to be mounted and adjusted on a table.



Floor Type Horizontal Boring Machine



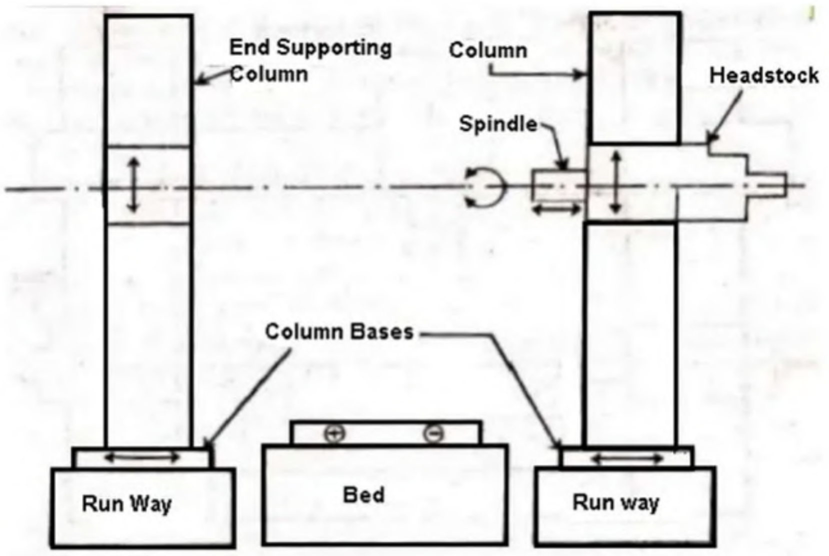
Floor Type Horizontal Boring Machine

Planer Type Horizontal Boring Machine

- The *planer type horizontal boring machine resembles the table type* but the table slides direct on the bed instead of on a saddle angles to the spindle similar to a planer.

- The end of the supporting column and headstock supporting column may adjust towards or away from the table for accommodating different widths of works.

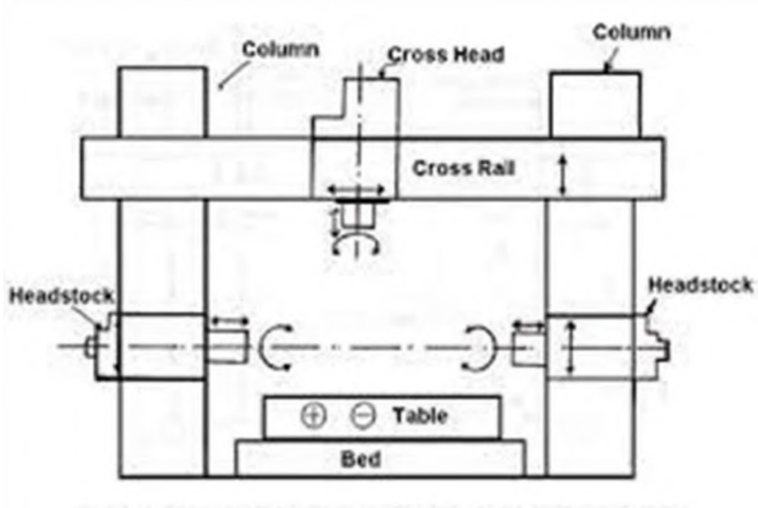
- This type of machine is suitable for supporting a long work.



Planner Type Horizontal Boring Machine

Multiple head type boring machine

- This machine resembles a double housing planer or a Plano – miller.
- The table is supported on a long bed on which it responds.
- There are two vertical columns at different sides of the bed, almost at the center of the bed.
- The two columns are spanned by a cross rail.
- The machine may have two, three or four headstocks.
- This type of machine might be utilized both as a horizontal and vertical machine.
- The machining operations can be performed at the same time at various work surfaces.



Multiple Type Horizontal Boring Machine

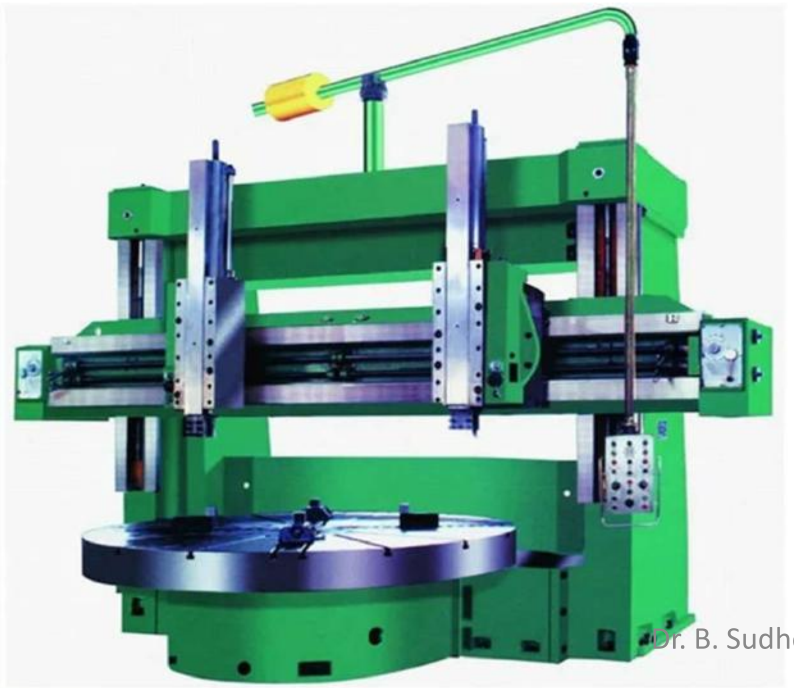
Vertical turret lathe boring machine

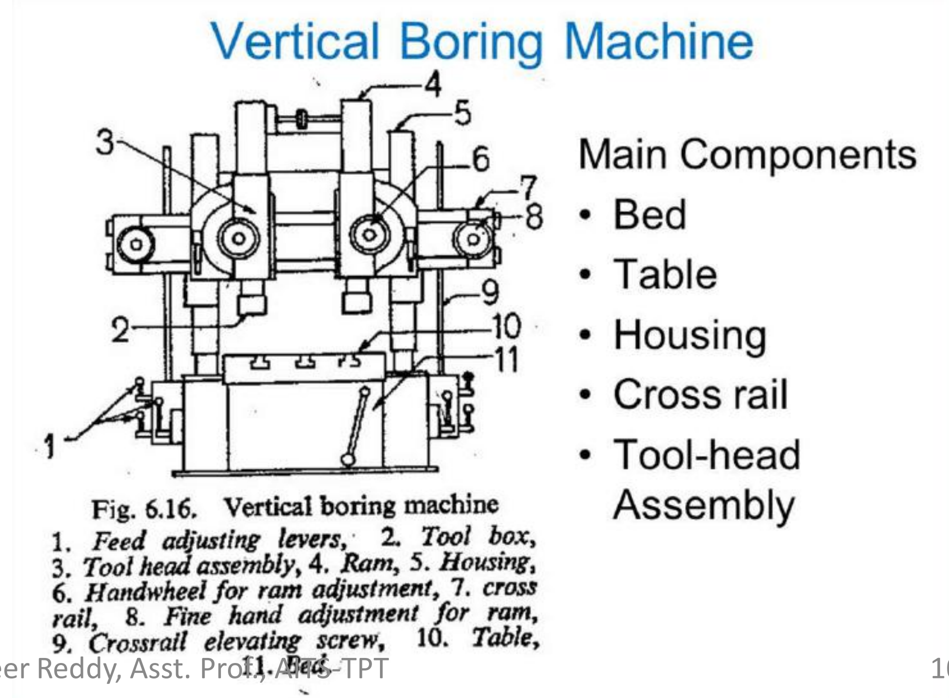
This kinds of boring machine combines the advantages of the vertical boring mill and the turret lathe.

A vertical boring machine of smaller size is known as vertical turret lathe.

It has an index able turret mounted upon the cross rail over the table for different tooling.

The machine is suitable for boring and turning rail road wheels, piston rings, gear blanks etc.



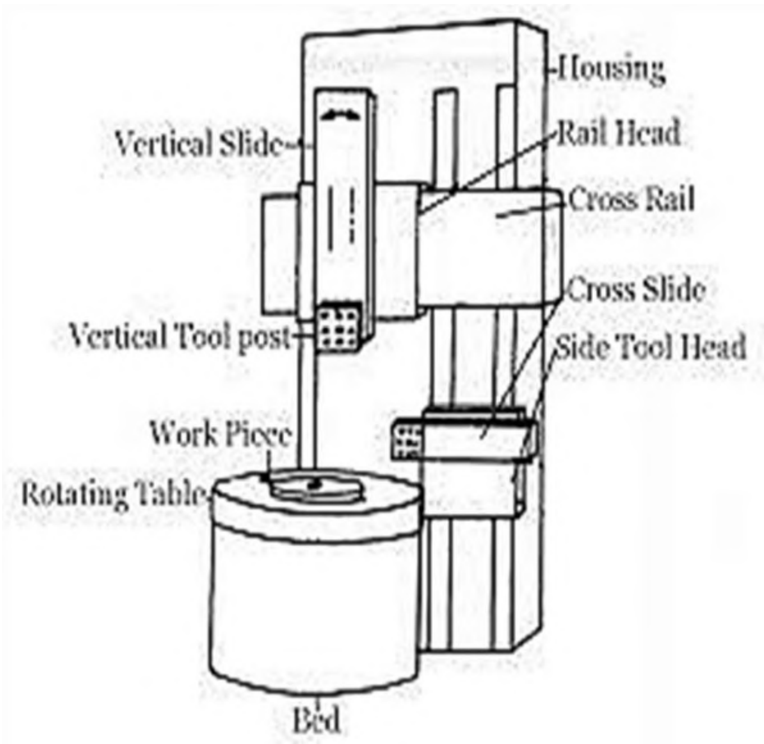


Standard vertical boring machine

This kinds of machines are larger in size than vertical turret lathe and there is no turret head.

The machine is provided with two vertical heads and a couple of side heads.

The machine is especially expected for boring large, cylindrical and symmetrical workpieces.



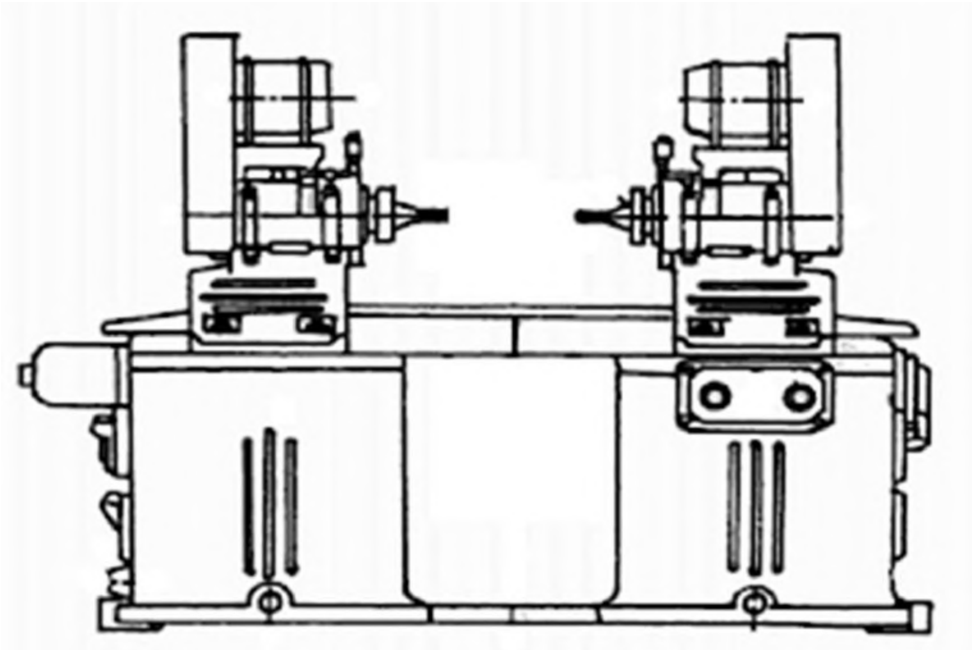
Precision boring machine

The precision boring machine uses single point tools to machine surfaces quickly and precisely.

Cemented carbide and diamond tipped single point tools are worked at a very high cutting speed to produce accurately sized holes with a fine surface finish.

The feeding movement might be given by the tool or by the work.

The machine may be horizontal or vertical type.



Jig Boring Machine

Jig boring machine is used for the production of ***jigs, fixtures, tools***, and other parts that requires a ***high degree of accuracy***.

They are defined by terms of highest accuracy through rigidity, low thermal expansion, and precise means of measuring distance for locating and spacing holes.

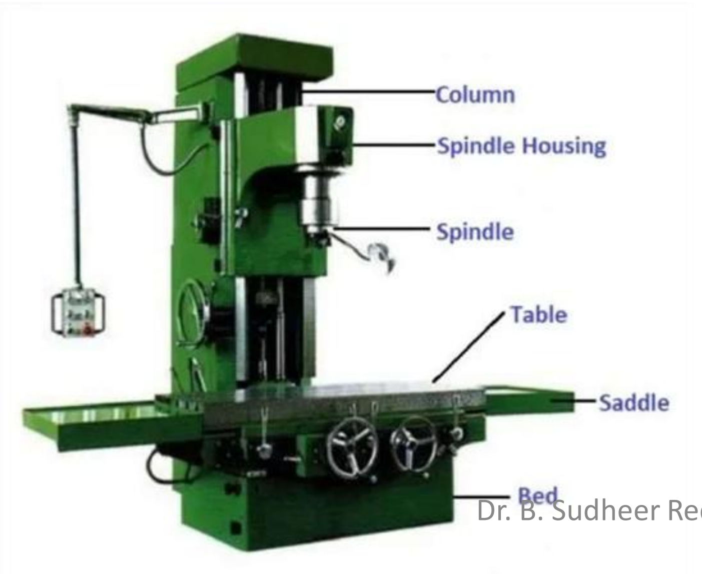
The machining ***accuracy is high, within a range of 0.0025 mm***.

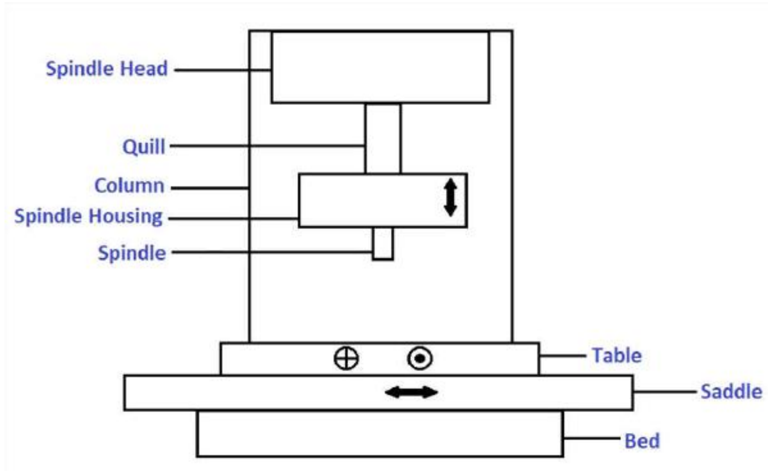
A jig boring machine looks like a vertical milling machine. But so far its operation and accuracy are concerned that there cannot be any comparison between the two.

The spindle and other parts of the machine are ***much hard to resist deflection and the vibration is low***.

A Spindle runs in preloaded antifriction bearings.

The spindle housings are made of invar having a very low coefficient of linear expansion.





Jig Boring Machine

- Jig boring machines need to be operated in temperature-controlled rooms where the temperature can be kept constant.
- This is essential to prevent inaccuracy in the machine and in the work being manufactured due to the thermal expansion of the metal.

Planer type boring machine

It resembles the table type but ***table slides directly on the bed rather than on a saddle*** and reciprocates at right angles to the spindle similar to a planer.

The end supporting column and headstock supporting column might be changed towards or away from the table for accommodating different widths of work.

This type of machine is appropriate for supporting a long work.

Vertical milling machine type boring machine

This may be generate a horizontal flat surface, produce cylindrical turned surface, bore internal hole, perform cutting off, necking or forming operations, and generate internal or external taper surfaces.

For machining a flat horizontal surface, the ram and the cross rail is locked at the desired position and the saddle is fed cross wise while the work revolves on the table.

Some of the main parts of boring machine (all types):

- **Bed**
- **Headstock supporting column**
- **End supporting column**
- **Headstock**
- **Saddle and table**
- **Boring bars**

Follow the theory as discussed under table type boring machine.

Boring Machine Mechanism

The machine contains different controls for movements of the different parts of the machine.

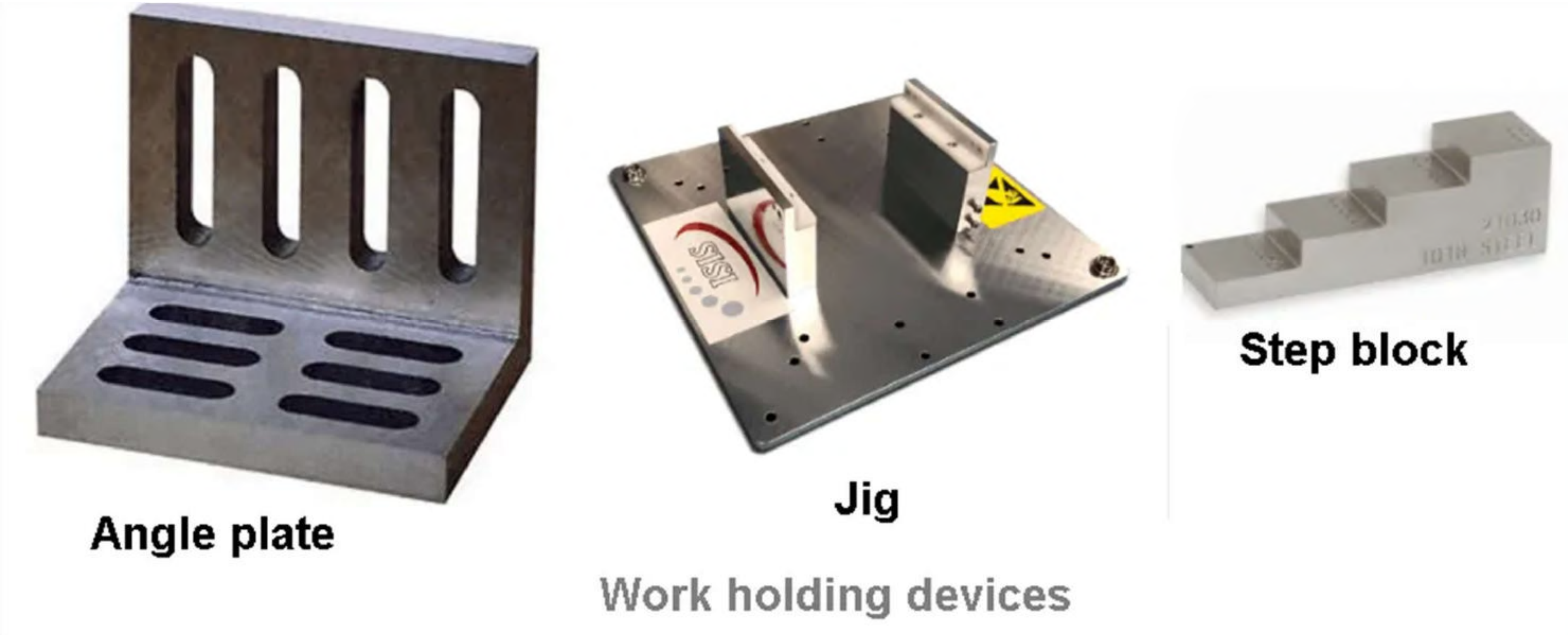
A table type machine has the following movements:

1. The headstock and the end supporting block may be moved up and down.
2. The spindle may be rotating. The spindle has different speeds.
3. A spindle may move in or out by hand or power for feeding.
4. The saddle and the table may move by hand or power.
5. The columns may move by hand or power.

All these movements may be given independently or in combination with two or more movements.

As all the controls are housed in a particular position of the machine the operator may give close attention to the work while controlling the machine.

Work Holding Devices For Boring Machine



Different Types of Boring Tools

Boring bars

Boring deep holes can involve extreme length-to-diameter ratios, or overhang, when it comes to tooling assemblies.

Since it can be difficult to maintain accuracy and stability in these scenarios, so there is a need of boring bars to extend tooling assemblies and while maintaining the rigidity to make perfect circles with on-spec finishes.

- ***Solid boring bars***

  Typically made of carbide for finishing or heavy metal for roughing, solid boring bars have dense structures that make for a more stable cut as axial force is applied.

- ***Damping bars***

  When cutting speeds are compromised, or surface finishes show chatter in a long-reach boring operation, damping bars are an option. They have integrated damping systems.

  Also, he Smart Damper, works as both a counter damper and friction damper so that chatter is essentially absorbed.

Boring heads

- Boring heads are specifically designed to enlarge an existing hole.
- They hold cutters in position so they can rotate and gradually remove material until the hole is at the desired diameter.

  - ***Rough boring heads***

    Once a bore is started with a drill or by another method, rough boring heads are the choice for removing larger amounts of material. They are built more rigid, to handle the increased depths of cut, torque and axial forces needed to efficiently and consistently make the passes to remove materials.

  - ***Fine boring heads***

    Fine boring heads are best used for more delicate and precise removal of material that finishes the work the rough boring head started. They are often balanced for high-speed cutting since that's the best approach for reaching exact specifications.

-

- ***Twin cutter boring heads***

  Most boring heads feature one cutter that cuts as its feed diameter is adjusted by the machine.

  There are twin cutter boring heads that can speed up cutting and add versatility.

  For example, the Series 319 and other BIG KAISER twin cutter boring heads include two cutters that can perform balanced or stepped cutting without additional accessories or adjustments by switching the mounting locations of the insert holders that have varied heights.

- ***Digital boring heads***

  Traditionally, adjusting boring heads has been painstaking and time-consuming, especially when it's done in the machine.

  It's easy to make mistakes when maneuvering to read the diameter dial and adjusting it to the right diameter.

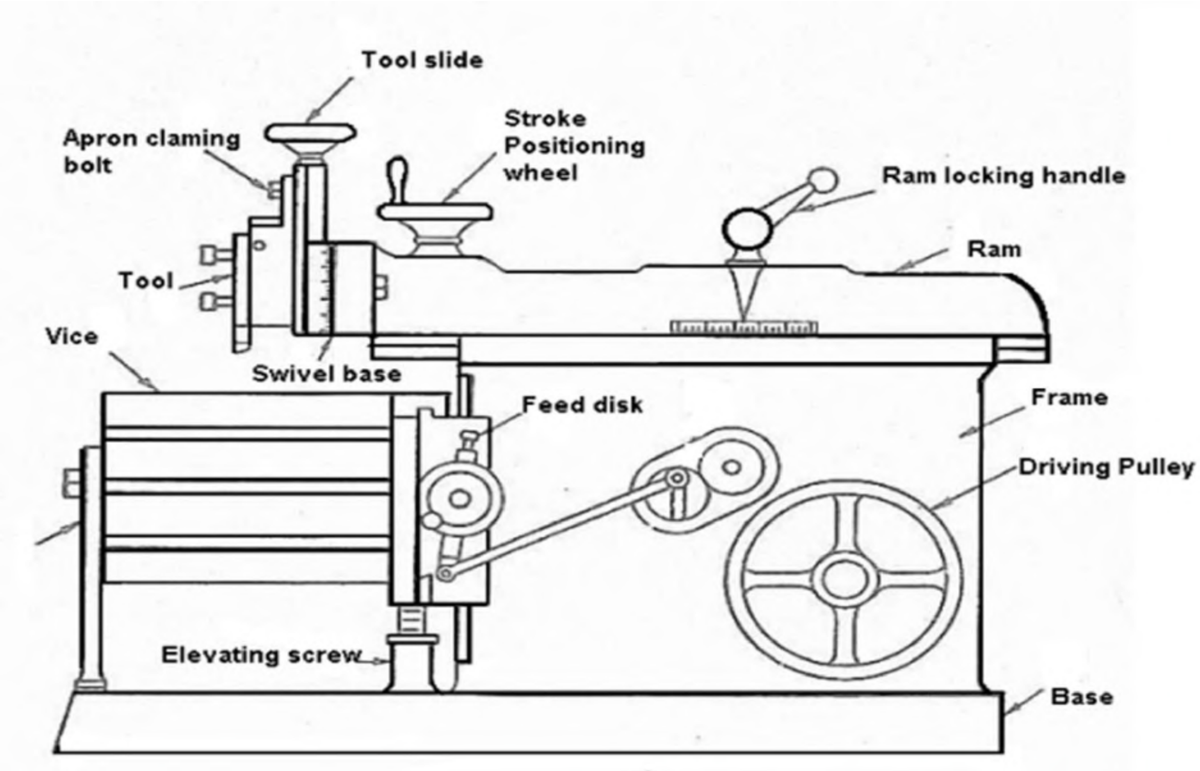
  Digital boring heads have a LED that makes precise adjustments much easier.

SHAPPING MACHINE

- The shaping machine is used ***to machine flat metal surfaces*** especially where ***a large amount of metal has to be removed***. It is a machine designed for giving ***desired shapes to the surfaces that may be horizontal, vertical and flat***.

- A shaping tool is used ***to cut in curves, different angles, and many other shapes***.

- As the disc rotates the ***top of the machine moves forwards and backwards, pushing a cutting tool***.



- The cutting tool removes the metal from work which is carefully bolted down.
- The cutting tool is used to give the shape to the hard surface of metal or wood by removing the excess material.
- The reciprocating motion of the mechanism inside the shaping machine can be seen in the diagram.
- Other machines such as milling machines are much more expensive and are more suited to removing smaller amounts of metal, very accurately

Working Mechanism of Shaping Machine

The shaping machine operates in the ***reciprocating type of machine function***.

Here the ***work piece is fixed on the machine table*** and the ***cutting tool is placed on the work piece***.

Reciprocating movements over the work piece results ***in forward and backward strokes***.

Forward stroke is responsible for ***cutting action over the object and backward movement is responsible for restoring its position without any cutting action***.

Description of Parts of Shaping Machine with its Functions

Base:

The base of shaping machine is ***kind of bed to hold the different parts of shaping machine***, it is made up of cast iron since the strength of a base is very important.

The ***base bears the vibration shock*** of forward and backward movement of stroke responsible for shaping action.

Body:

Body of the machine consists of pats named ***Pillar, Frame, and Column***. The body of the shaping machine is affixed on the base of the shaping machine.

The ***column is also made up cast iron*** and it is box shaped part which is placed on the base.

Column plays the covering role and supports the reciprocating movement in the operation of the machine.

Cross ways: These are the ***sideways affixed vertically and horizontally across the table*** to allow the movement of the table**.**

Stroke adjuster: Stroke adjuster ***absorbs the vibration shock of stock*** by controlling the length of the stroke**.**

Cross rail: The cross rail is ***affixed on the front part of the body which can be moved in an upward and downward direction***. It enables to perform shaping operation at different positions.

Ram: The Ram is responsible for the **reciprocating action of the column sideways**. **Forward and backward movement of ram is called a stroke**.

Table: A table is kind of flat body affixed over the frame to hold the work piece on which shaping action needs to be performed

Clapper box: It is used to carry the shaping tool holder. Clapper box is responsible for the smooth and hindrance free movement of backward stroke to prevent the damage in the form of wear and tear.

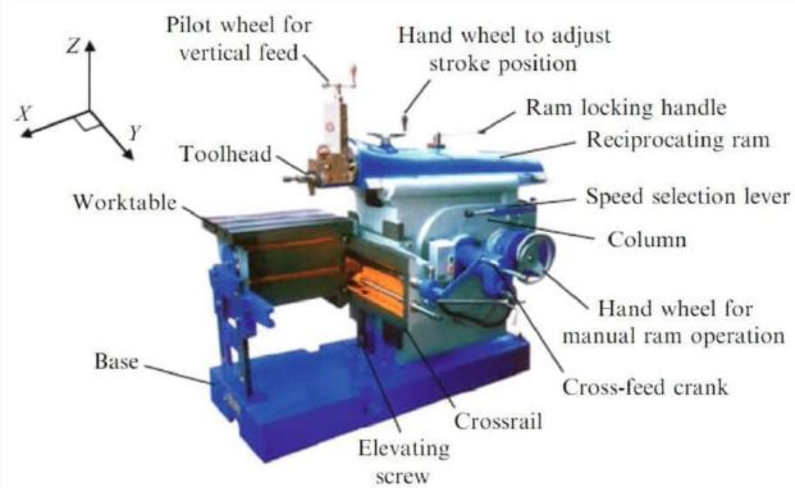
Types of Shapers

1) **Horizontal Shaper**: Ram is Horizontal
   a) Push cut type: Cutting action in outward stroke
   b) Pull cut type: Cutting action in inward stroke

2) **Vertical shaper**: Ram is vertical. Machine is similar to a Slotter.

3) **Mechanical Shaper**: Ram drive is Mechanical

4) **Hydraulic Shaper**: Ram drive is hydraulic



Horizontal shaping machine (Courtesy: Jiwan Singh & Sons)

Based on Mechanisms

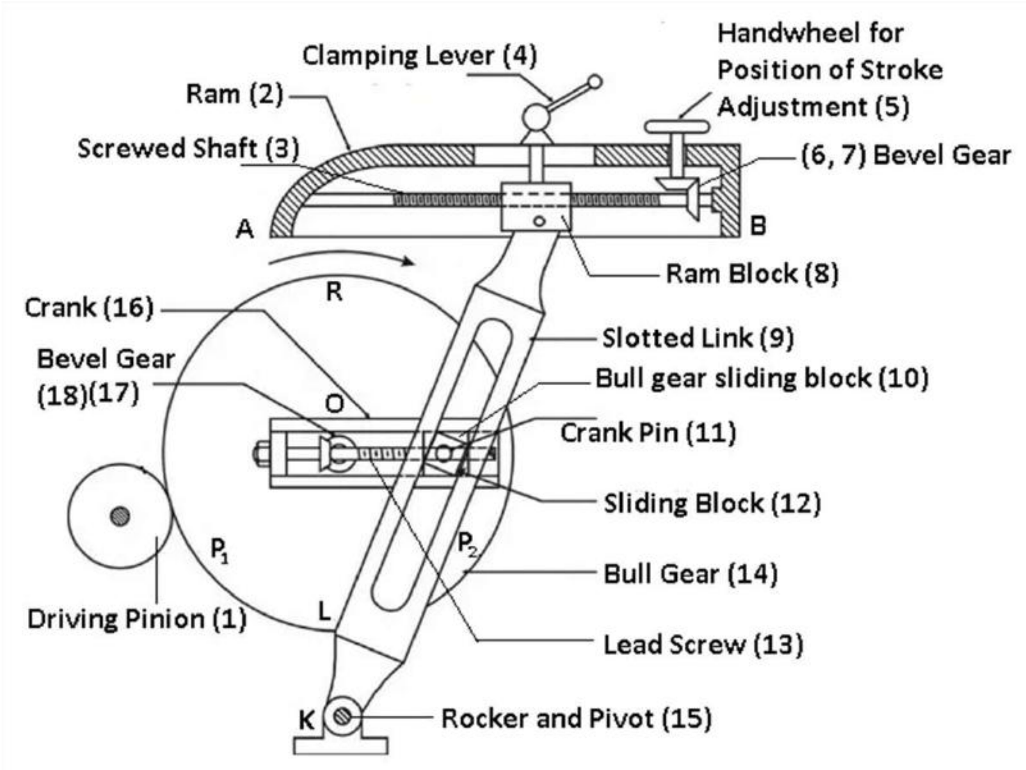
- Crank and slotted link mechanism.
- Whitworth's quick mechanism.
- Hydraulic shaper mechanism.

Vertical shaping machine (Courtesy: Ajax Machine Tools International, Ltd.)

Crank and Slotted Link Mechanism

In this type of shaper machine mechanism, the power is transmitted to the bull gear through a pinion which receives its motion from an individual motor. Or overhead line shaft through a speed control mechanism.

The speed of the bull gear may be changed by a different combination of gearing or by shifting the belt on the step cone pulley.

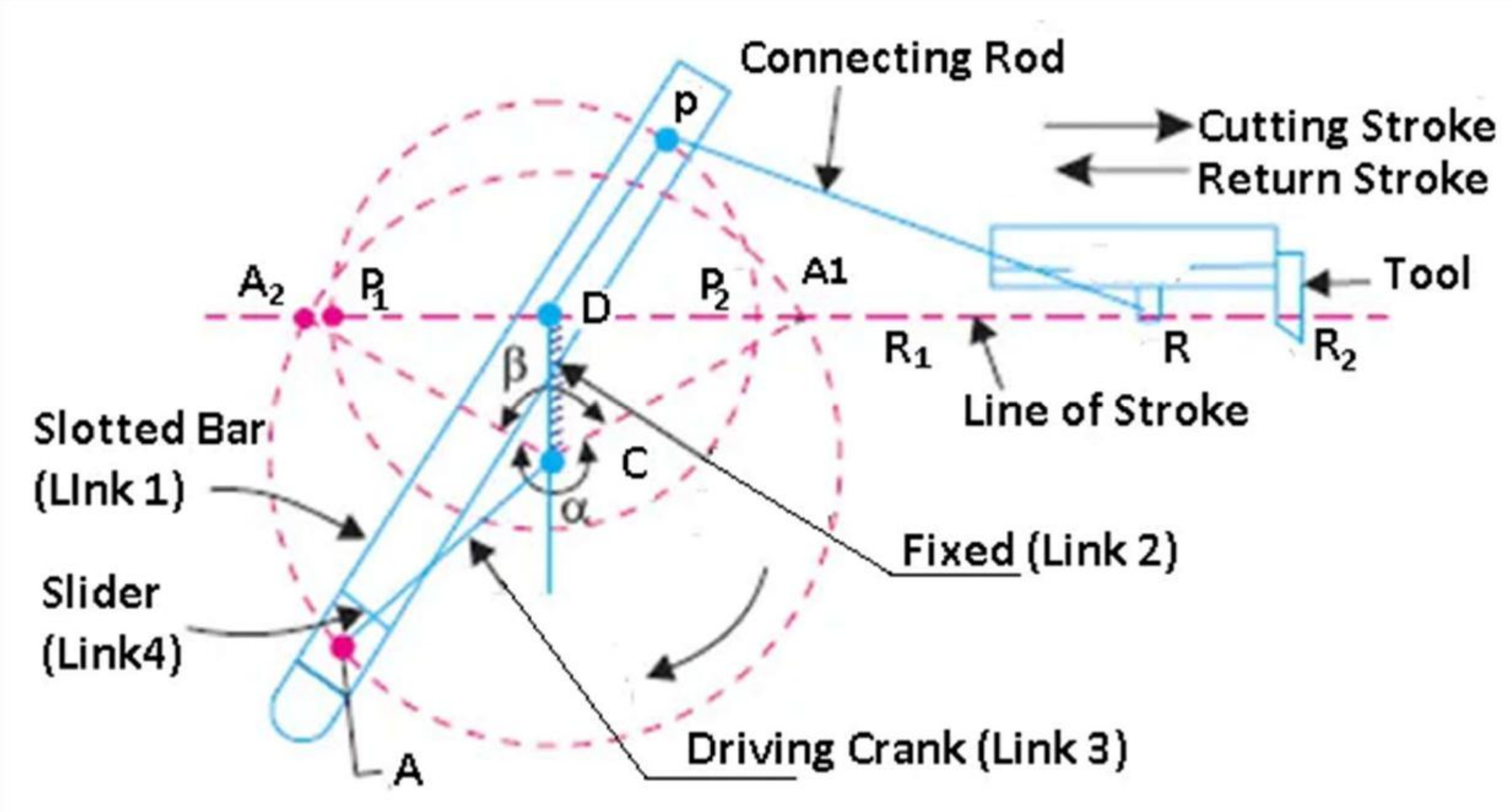


Arrangement and working of parts

- The bull gear is a ***large gear mounted within the column***.
- The radial slide is bolted to the centre of the bull gear it carries a sliding block into which the crankpin is fitted.
- Rotation of the ***bull gear will make the crankpin to revolve at a uniform speed***.
- The ***sliding block which is mounted upon the crankpin is fitted within the slotted link***.
- The ***slotted link which is also known as the rocker arm*** is pivoted at its bottom end attached to the frame of the column.
- The ***upper end of the rocker arm*** is forked and attached to the ***ram block by a pin***.
- As the bull gear rotates causing the crankpin to rotate, the sliding block fastened to the crankpin will rotate on the crank pin circle.
- And at the same time will run up and down the slot in the slotted link providing it with a rocking movement that is communicated to the ram.
- Thus the ***rotary motion of the bull gear is converted to reciprocating movement of the ram***.

Whitworth Quick Return Mechanism

This mechanism is also used in ***slotting machines*** other than a shaper. In this type of shaper machine mechanism, the ***link CD (link 2) forming the turning pair is fixed***.



Arrangement of parts

- The **link 2** matches to ***a crank in a reciprocating steam engine***. The ***driving crank "CA" (link 3) rotates at a similar angular speed***. The ***slider (link 4) connected to the crankpin at "A" moves along the slotted bar "PA" (link 1) which oscillates at a pivoted point D***.

The connecting rod ***PR carries the ram at R to which the cutting tool is fixed***. The movement of the tool is constrained ***along the line RD produced***. i.e. along a line passing through D and perpendicular to CD.

When the ***driving crank CA moves from the point CA1 to CA2*** (or the link DP from the point DP1 to DP2) through an angle α in the clockwise direction, the **tool moves front** from the left-hand end of its stroke to the right-hand end by a distance 2 PD.

Now when the driving crank moves from the **point CA2 to CA1** (or the link DP from DP2 to DP1) through an angle β in the clockwise direction, the **tool moves back** from the right-hand end of its stroke to the left-hand end.

A little consideration will show that the time taken during the right movement of the ram (i.e. during the forward stroke) will be equal to the time taken by the driving crank to move from CA1 to CA2.

Similarly, ***the time needed during the right to left movement of the ram (or during the idle or return stroke) will be equal to the time taken by the driving crank to move from CA2 to CA1***.

$$\frac{Time\ of\ Cutting\ Stroke}{Time\ of\ Return\ Stroke} = \frac{\alpha}{\beta} = \frac{\alpha}{360° - \alpha}\ or\ \frac{360° - \beta}{\beta}$$

Since the crank link CA rotates at a uniform angular velocity, thus, the time taken during the cutting stroke (or forward stroke) is more than the time taken during the return stroke.

In other words, the mean speed of the ram during a cutting stroke is less than the mean speed during the return stroke. The ratio between the time taken during the cutting and return stroke is given by the formula shown in the above image.

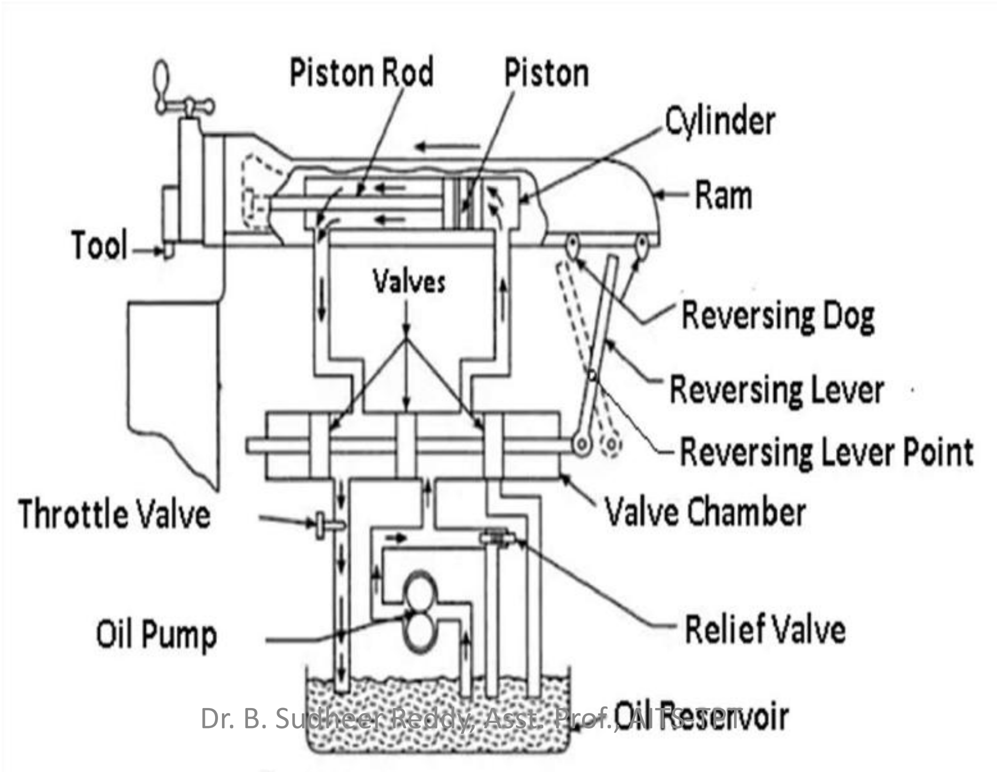
Hydraulic Shaper Mechanism

In this type of shaper machine mechanism, the ram is moved forwards and backwards by a piston moving in cylindrical placed under the ram.

The machine is consists of a constant discharge oil pump, a cylinder, a valve chamber and a piston. The Piston-rod is bolted to the ram body. As shown in the figure.

Arrangement and working

The oil under high pressure is drawn from the reservoir. The oil is passed through the valve chamber to the right side of the oil cylinder exerting pressure on the piston..



This cause the ram connected to the piston to perform forward stroke. Any oil present on the left side of the cylinder is discharged to the reservoir through the throttle valve.

At the end of a forward stroke, the shaper dog hit against the reversing lever causing the valves to alter their positions within the valve chamber.

Oil under high pressure is now pumped to the left side of the piston causing the ram to perform return stroke. Oil present on the right side of the piston is now discharged to the reservoir.

At the end of the return stroke, another shaper dog hits against the reversing lever altering the direction of stroke of the piston and the cycle is thus repeated.

The quick return is affected due to the difference in the stroke volume of the cylinder at both ends. The left-hand end being smaller due to the presence of the piston rod.

As the pump is a constant discharge one, within a fixed period, the same amount of oil will be a pump into the right or to the left-hand side of the cylinder.

This will mean that the same amount of oil will be packed within a smaller stroke volume causing the oil pressure to rise automatically and increase the speed during the return stroke.

The length and position of stroke are adjusted by shifting the position of reversing dogs. The cutting speed is changed by controlling the throttle valve which controls the flow of oil.

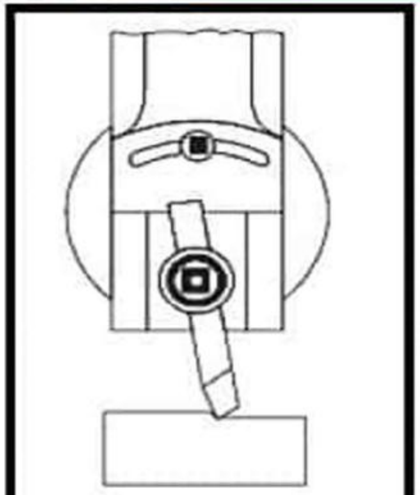
When the throttle valve is lost the excess oil flow cut through the relief valve to the reservoir maintaining uniform pressure during the cutting stroke.

SHAPPING MACHINE OPERATIONS

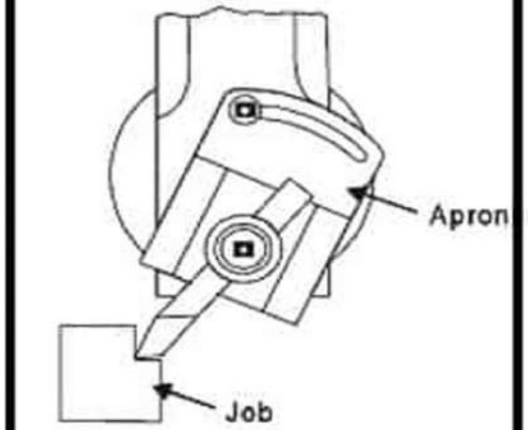
A shaper is a machine tool primarily designed to generate a flat surface by a single-point cutting tool. Besides this, it may also be used to perform many other operations. The different operations, which a shaper can perform, are as follows:

1. Machining horizontal surface
2. Machining vertical surface
3. Machining inclined surface
4. Slot cutting
5. Keyways cutting
6. Machining irregular surface
7. Machining splines and cutting gear

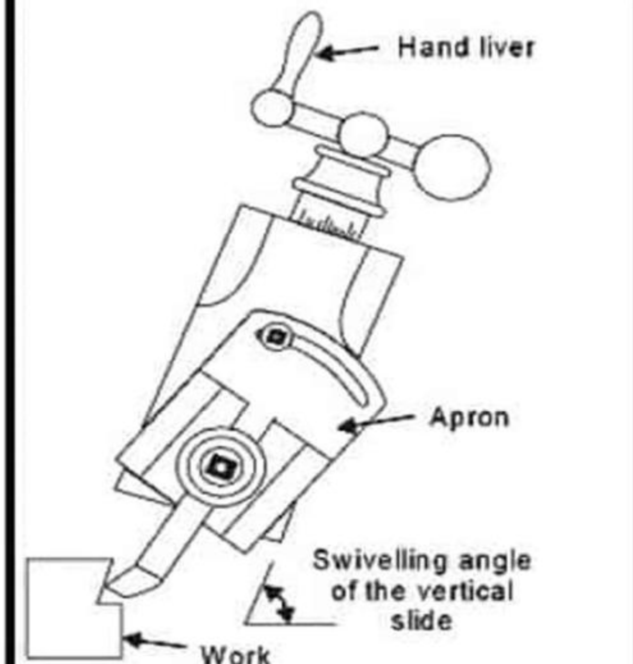
Shaping Machine Operation



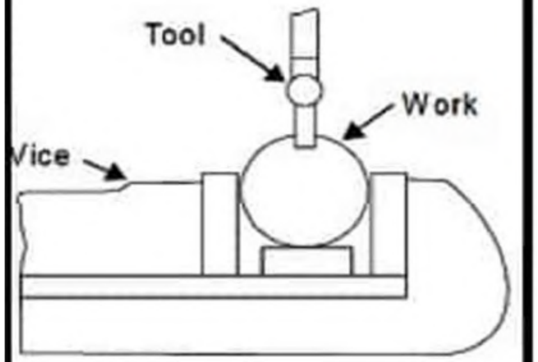
Machining horizontal surface



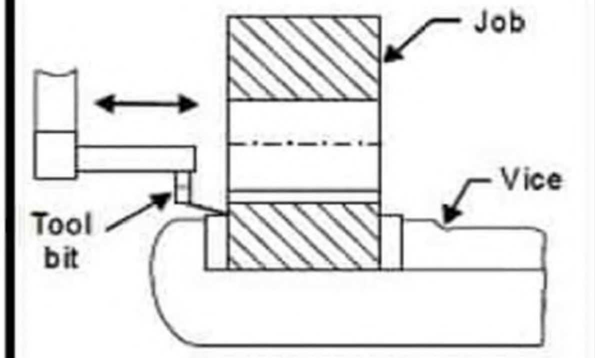
Machining vertical surface



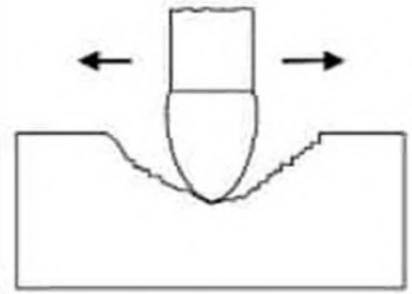
Machining inclined surface



Slot cutting



Keyway cutting



Irregular machining

Operating conditions in shaping machine

Cutting Speed

- Cutting speed on shapers is defined as the average linear speed of the tool during the cutting stroke in m/min, which depends on the number of ram strokes (or ram cycles) per minute and the length of the stroke.
- A ratio of return stroke to cutting stroke time of 2:3 implies that the tool is working three-fifths of the time and the return stroke takes two-fifths of the time.
- This return-to-cutting time ratio m is a machine constant. The cutting speed v is determined by using the formula:

$$cutting\ speed = v = \frac{N\,L\,(1+m)}{1000} \quad \text{m/min}$$

where

N = the number of double strokes or cycles of the ram/min (one double or full stroke comprises of one cutting and one return stroke),

L = Length of the ram stroke, in mm,

m = return stroke time/cutting stroke time.

The ram at each end of the stroke has to come to rest (zero speed) and start moving again.

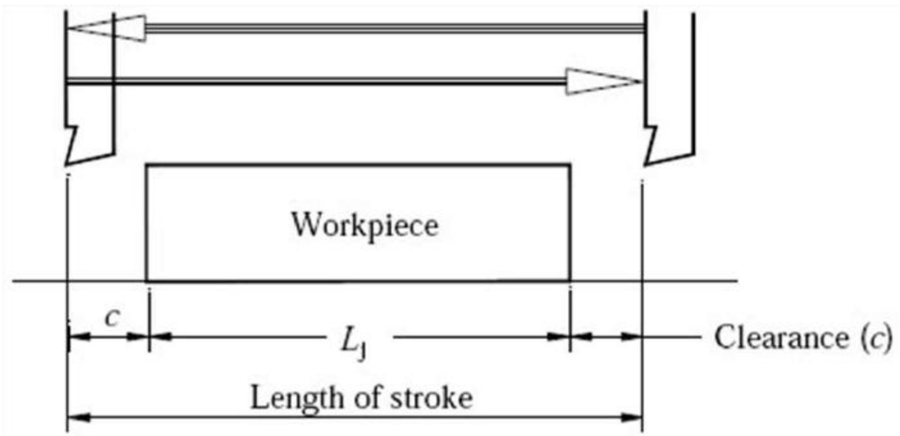
It takes finite time (and distance) to attain the desired cutting speed.

The distance required to attain the speed (and come to rest) is called clearance. Clearance, job length and stroke length.

The clearance is a must in shaping and allied processes unlike approach and overtravel in other metal cutting processes.

Hence, for a job of length Lj a stroke length of L is used with clearance c on both sides of job, where

$$L = Lj + 2 \times c$$



Feed

Feed (f) is the relative motion of the workpiece in a direction perpendicular to the axis of reciprocation of the ram.

In shaper, feed is given to the workpiece. Feed is expressed in mm/double stroke or simply mm/stroke because no cutting is done in return stroke.

Depth of Cut

Depth of cut (d) is the thickness of the material removed in one cut, in mm.

Depth of cut may be given by the toolhead slide or by lifting the table.

Machining time

From the cutting speed, we can find that the time required to complete one double stroke is given by

$$t = \frac{L(1+m)}{1000\,v} \quad \text{min}$$

With a feed of f mm/double stroke, number of double strokes required to machine a surface of width w will be

$$Ns = w/f$$

Hence, total time for machining the surface will be

$$T = L \times w \times (1+m) / (1000 \times v \times f) \text{ min}$$

or, in terms of ram strokes N, the time for machining surface is given by

$$T = w / (f \times N) \text{ min}$$

Material Removal Rate

Material removal rate (MRR) in a shaping machine is given by the formula

$$MRR = f \times d \times N \times L(1+ m) \text{ mm}^3 \text{/min}$$

where d is depth of cut in mm; f in mm/stroke; N in strokes/min; and L is length of stroke in mm.

Advantages of Shaper Machine:

- The tool (Single Point cutting tool) cost is low.
- The workpiece can be held easily in this machine.
- It produces flat or angular surfaces.
- Setup of Shaper is very easy and tool changing is also easy.

Disadvantages of Shaper Machine:

- The cutting speed is not much high.
- Only one cutting tool can be fixed.
- There is no option for more than one cutting tool.

Application of Shaper Machine:

- A shaper Machine is used to make Internal splines.
- It generates straight and flat surfaces either horizontal, vertical or angular planes.
- It also makes gear teeth.
- Make keyways in pulleys or gears.
- It also Producing contour of concave/convex or a combination of these..