Machining Process

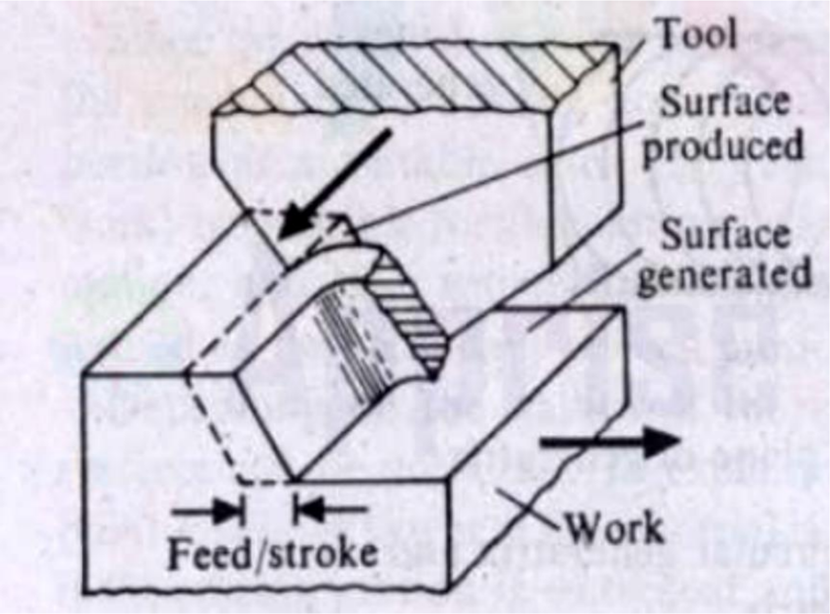
Machining Process: In this process, the desired shape, size, and finish are obtained through the removal of excess material from the original workpiece in the form of small chips.

Cutting Tool: The body which removes the excess material from the workpiece through a direct mechanical contact.

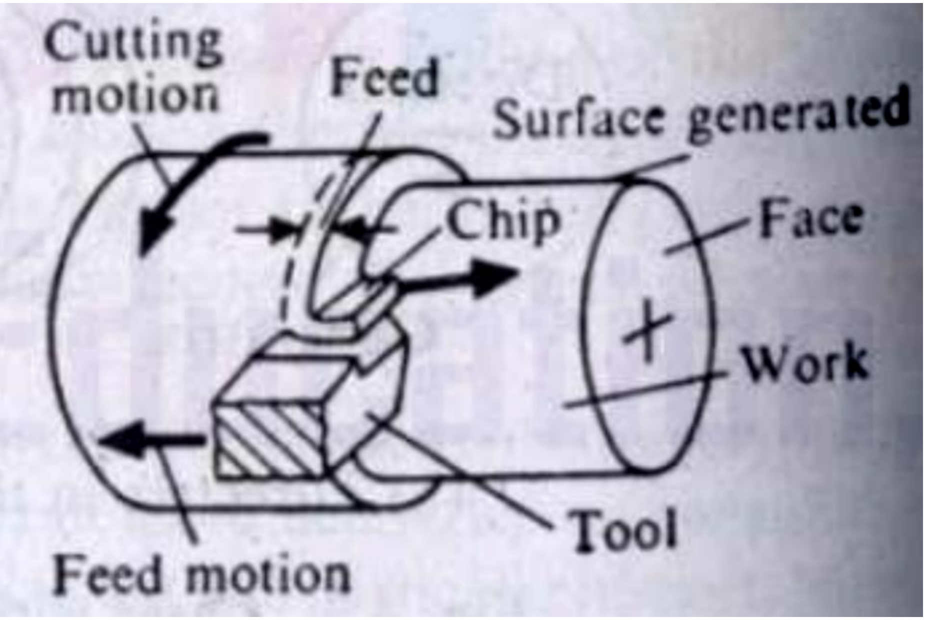
Machine Tool: The machine which provide the necessary relative motions between the work and the tool.

Primary/Cutting Motion: The relative motion between the tool and the work responsible for the cutting action.

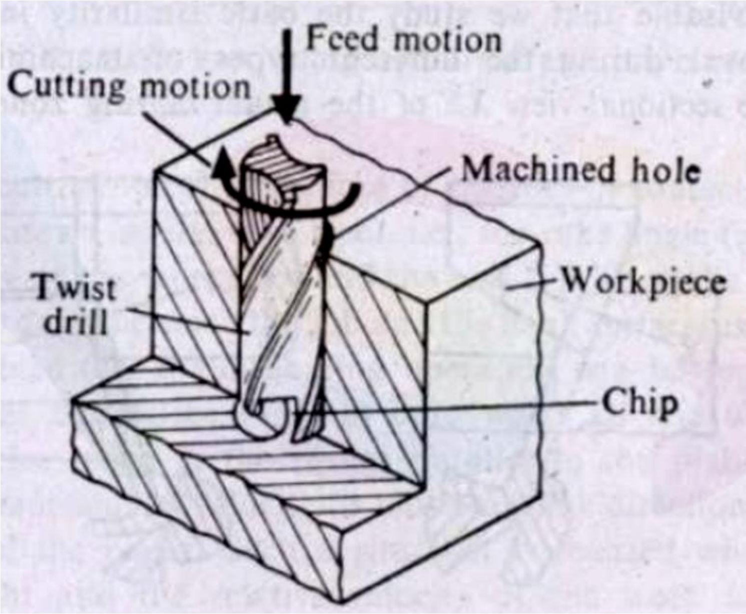
Secondary/feed motion: The relative motion between the tool and the work responsible for gradually feeding the uncut portion.



Shaping

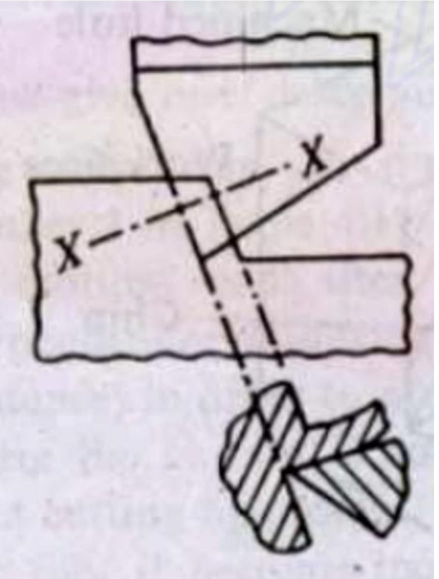


Turning

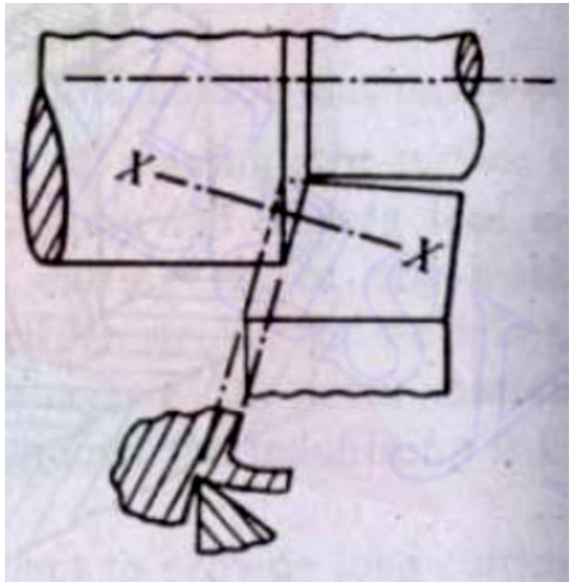


Drilling

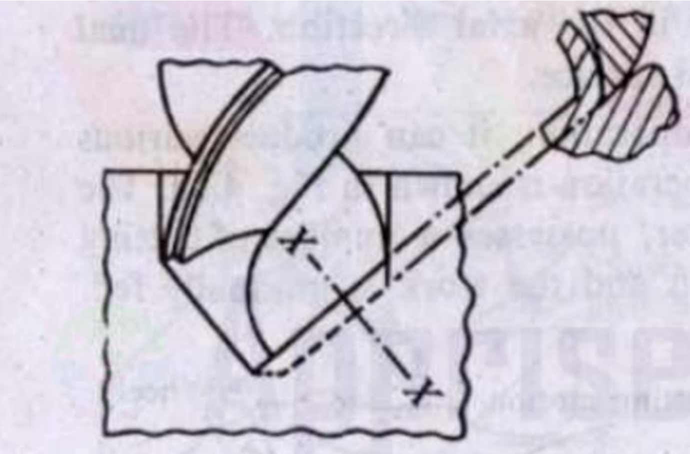
Mechanics of basic machining operation



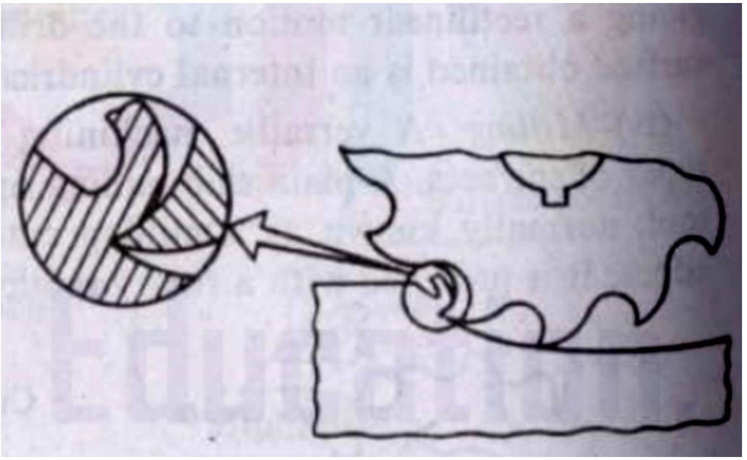
Shaping



Turning

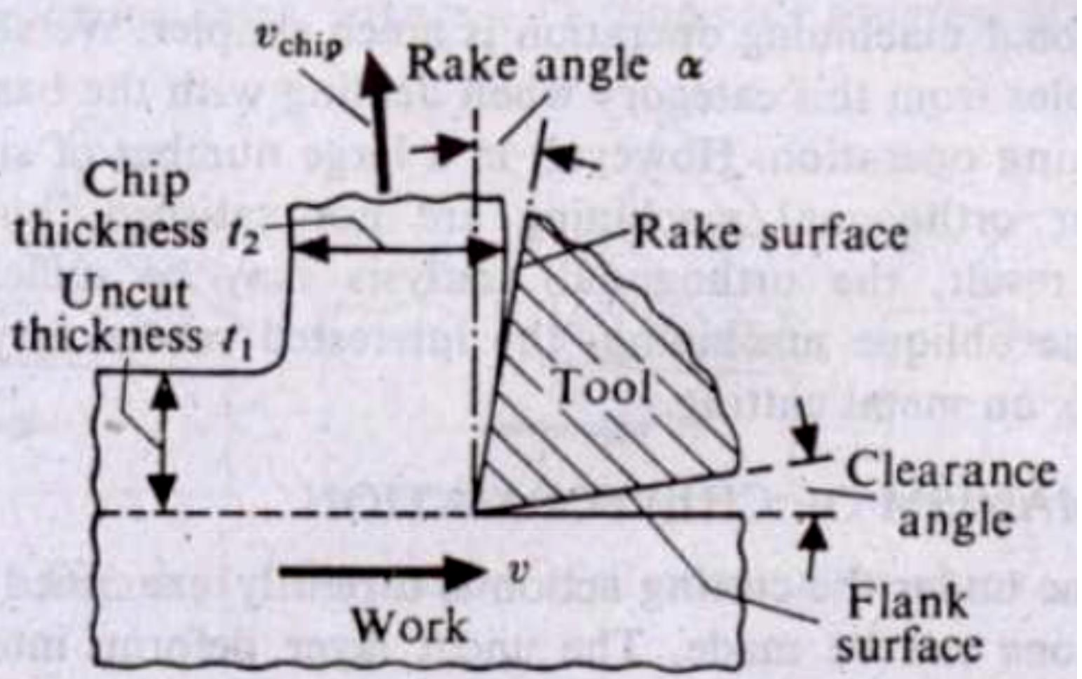


Drilling



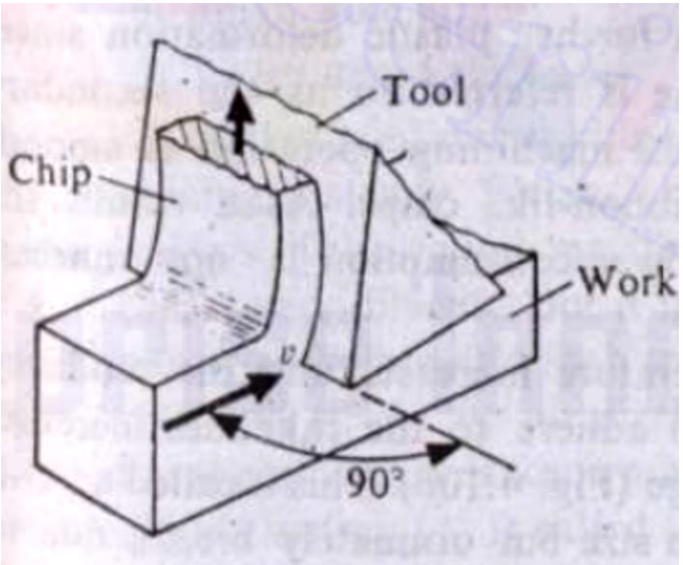
Milling

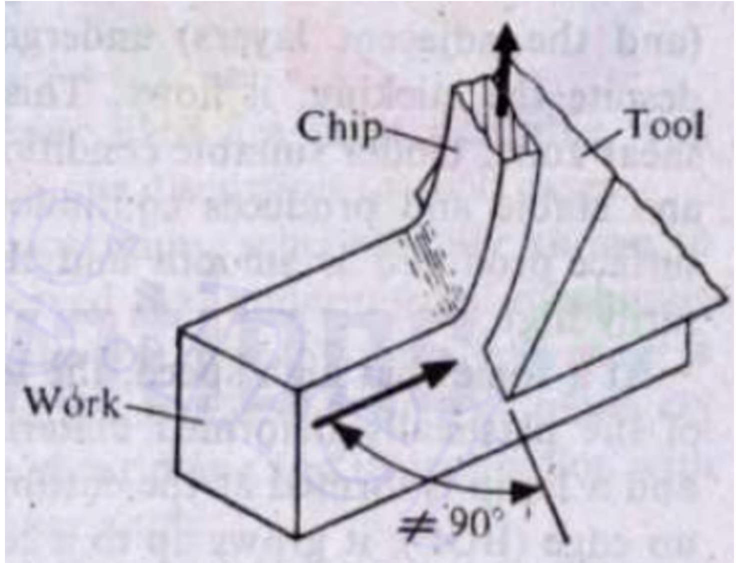
Basic nature of material removal in each of the above operations is similar and can be represented in a 2-D diagram.



Important parameters

1. Thickness of uncut layer (t_1)
2. Thickness of chip produced (t_2)
3. Inclination of chip-tool interface w.r.t. cutting velocity (rake angle, α)
4. Clearance angle between flank surface of tool and workpiece
5. Relative velocity of workpiece and tool (v)



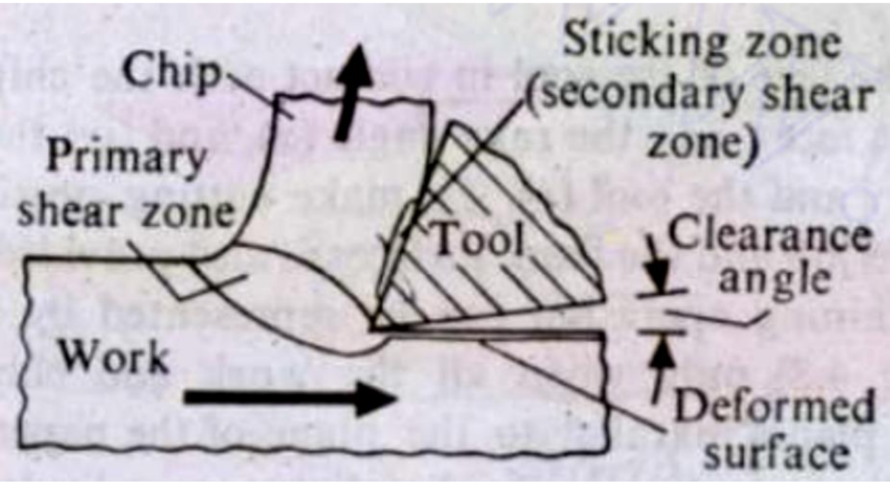


Orthogonal Machining **Oblique Machining**

Orthogonal Machining: Cutting edge is straight and relative velocity of tool and workpiece is perpendicular to the cutting edge.

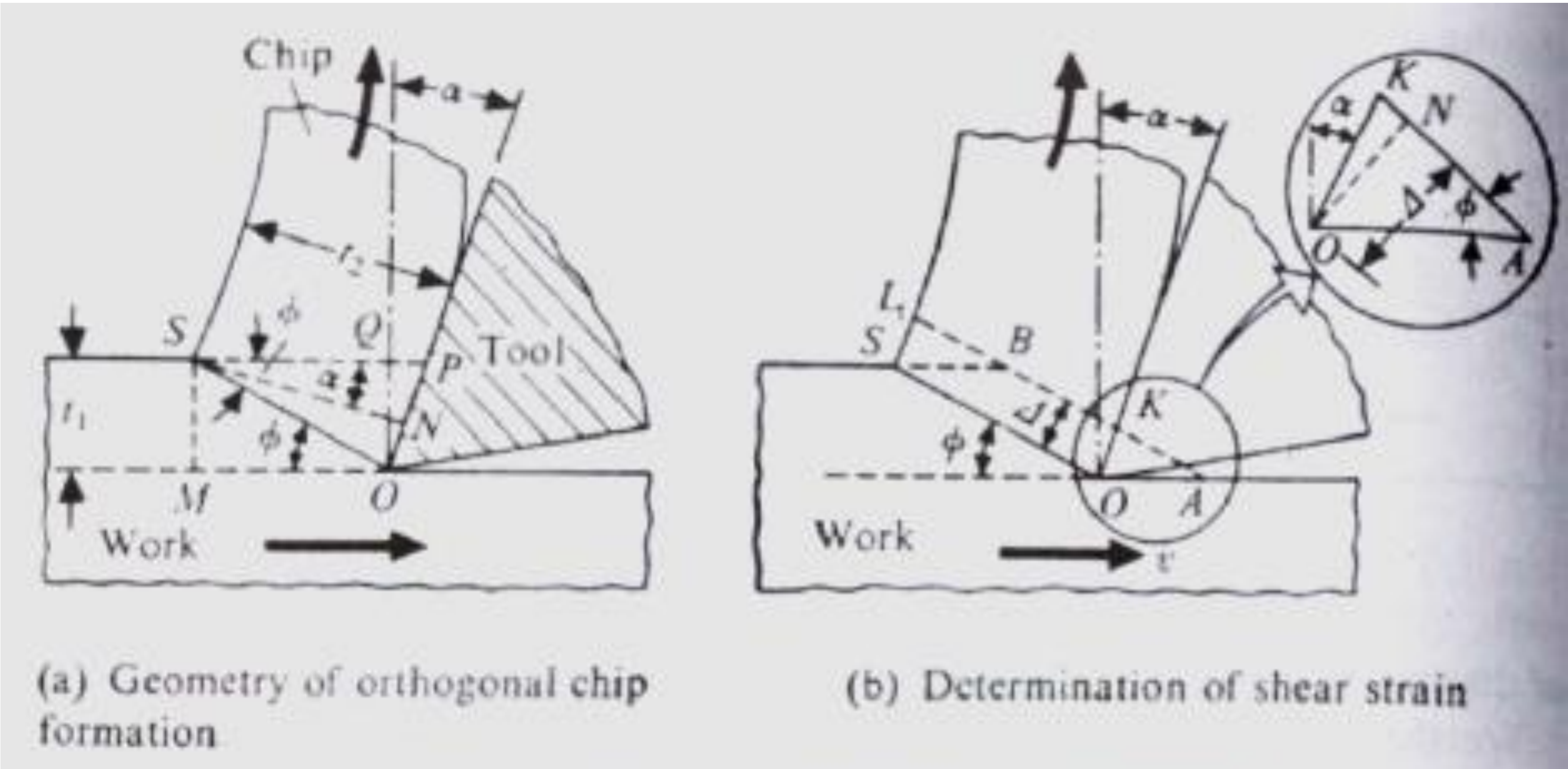
Oblique Machining: Relative velocity of tool and workpiece is not perpendicular to the cutting edge.

Mechanism of chip formation



Shear Zone

At moderate and high speeds the thickness of the shear zone is very small and it can be idealized as a plane. The plane OS Where the shear occurs is known as the shear plane and its inclination with the machined surface is called the shear angle.



Features of orthogonal chip formation.

t_1 = uncut thickness

t_2 = chip thickness

$r = t_1/t_2$ = cutting ratio

ϕ = shear angle

α = rake angle

γ = shear strain

$$\frac{t_1}{t_2} = \frac{\sin\phi}{\cos(\phi-\alpha)} = r \qquad (1)$$

$$\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha} \qquad (2)$$

$$\gamma = \cot\phi + \tan(\phi-\alpha) \qquad (3)$$

Problem

During orthogonal machining with a cutting tool having a 10º rake angle, the chip thickness is measured to be 0.4 mm, the uncut thickness being 0.15 mm. Determine the shear plane angle and also the magnitude of the shear strain.

Solution

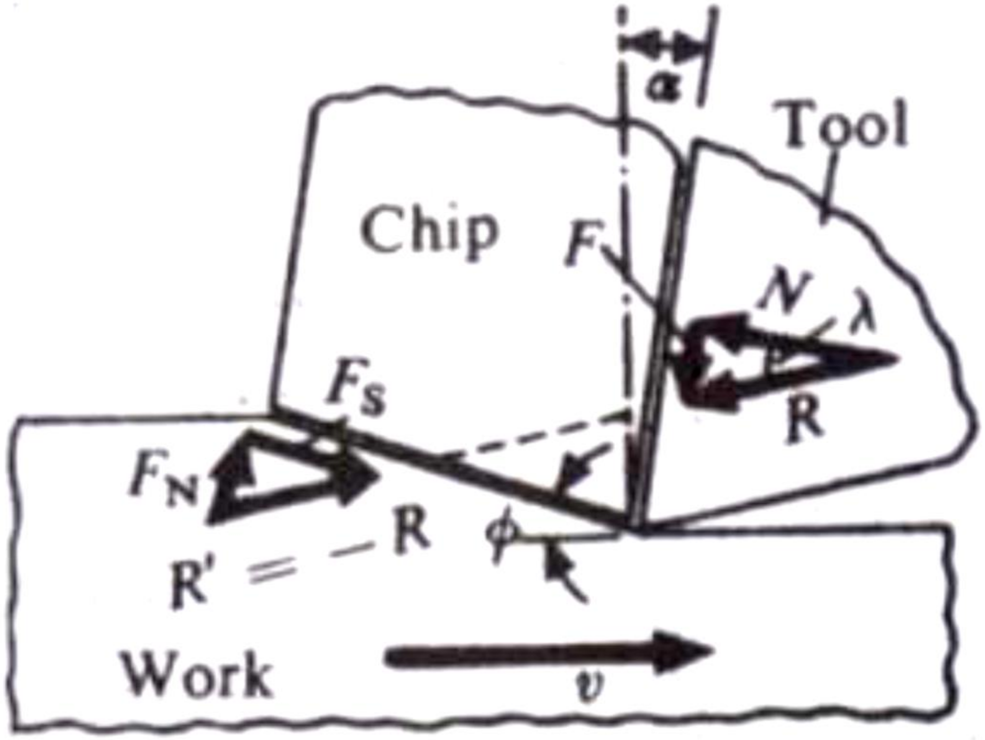
$$\textbf{Cutting ratio}, r = \frac{t_1}{t_2} = \frac{0.15}{0.4} = 0.38$$

$$\boldsymbol{Shear\ plane\ angle}, \emptyset = tan^{-1}\left[\frac{0.38\cos 10^o}{1 - 0.38\sin 10^o}\right] = 21.8^o$$

$$\boldsymbol{Shear\ strain}, \gamma = \cot 21.8^o + \tan(21.8^o - 10^o) = 2.71$$

Forces and Power Consumption During Machining

Ernst and Merchant model of single shear plane



Equilibrium of chip

$F/N = \mu = \tan \lambda$ λ = Friction Angle

α = rake angle ϕ = shear angle

μ = average coefficient of friction between chip and tool

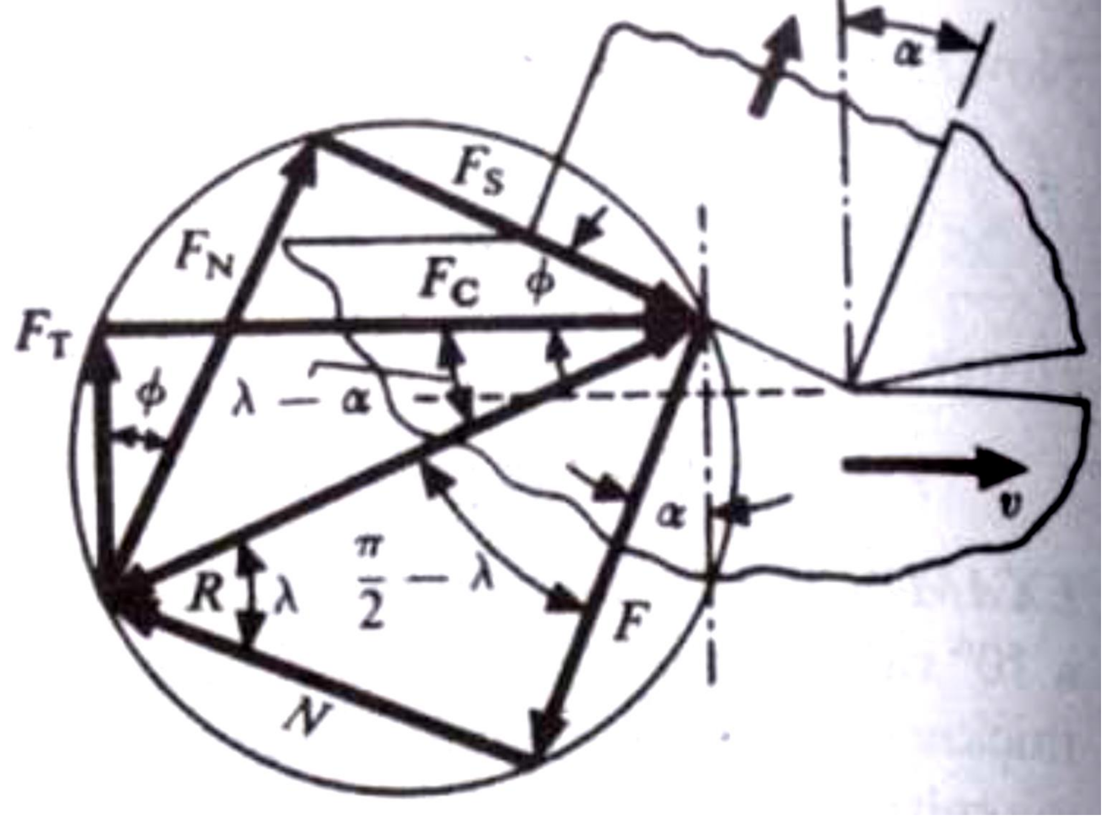
F = friction force N = normal force

F_S = force component parallel to shear plane

F_N = force component normal to shear plane

R = resultant force on chip from tool

R' = - R = resultant force on chip from uncut material



Merchant's Circle Diagram

F_C = cutting force (parallel to relative velocity)

F_T = thrust force (normal to relative velocity)

F_C and F_T are measured by dynamometers

Resultants of (F_C, F_T), (F_N, F_S), (F, N) = R. Therefore, tips of all these force vectors must lie on an imaginary circle of diameter R. This imaginary circle is called as the Merchant's circle.

$$F_C = F_S \cos\phi + F_N \sin\phi, \tag{4a}$$

$$F_T = F_N \cos\phi - F_S \sin\phi, \tag{4b}$$

$$F = F_C \sin\alpha + F_T \cos\alpha, \tag{5a}$$

$$N = F_C \cos\alpha - F_T \sin\alpha, \tag{5b}$$

$$F_S = F_C \cos\phi - F_T \sin\phi, \tag{6a}$$

$$F_N = F_C \sin\phi + F_T \cos\phi, \tag{6b}$$

$$R = \frac{F_S}{\cos(\phi + \lambda - \alpha)}, \tag{7}$$

$$F_C = R\cos(\lambda - \alpha), \tag{8a}$$

$$F_T = R\sin(\lambda - \alpha). \tag{8b}$$

$$\mu = \frac{F}{N} = \frac{F_C \sin\alpha + F_T \cos\alpha}{F_C \cos\alpha - F_T \sin\alpha}, \tag{9}$$

Theoretical estimation of F_C and F_T

$$F_S = wt_1\tau_s/\sin\phi \qquad \textbf{(10)}$$

τ_s = ultimate shear stress of the material, w = width of workpiece, t_1 = uncut thickness, ϕ = shear angle

Combining eqs. (7) and (8a), we get

$$F_C = \frac{F_S\cos(\lambda-\alpha)}{\cos(\phi+\lambda-\alpha)} \qquad \textbf{(11)}$$

Combining eqs. (10) and (11)

$$F_C = \frac{wt_1\tau_s\cos(\lambda-\alpha)}{\sin\phi\cos(\phi+\lambda-\alpha)} \qquad \textbf{(12)}$$

Power consumption

$$W = F_C v = \frac{vwt_1\tau_s\cos(\lambda-\alpha)}{\sin\phi\cos(\phi+\lambda-\alpha)} \qquad \textbf{(13)}$$

Where, v = cutting velocity

For given v, w, t_1, τ_s, λ, α

$$W(\phi) = \frac{constant}{\sin\phi\cos(\phi+\lambda-\alpha)}$$

For minimum power consumption, denominator should be maximum

Differentiating the denominator with respect to ϕ

$$\cos\phi\cos(\phi+\lambda-\alpha) - \sin\phi\sin(\phi+\lambda-\alpha) = 0 \quad \rightarrow \quad \cos(2\phi+\lambda-\alpha) = 0$$

$2\phi + \lambda - \alpha = \pi/2$ **(14)** **Merchant's first solution**

Using eq. (14) in eq. (12) we get $$F_C = \frac{2wt_1\tau_s \cos(\lambda-\alpha)}{1-\sin(\lambda-\alpha)} \qquad \textbf{(15)}$$

Minimum power consumption is obtained by multiplying eq. (15) with cutting velocity, v

Merchant's second solution

Merchant's first solution agrees poorly with the experimental results of machining metals.

Further analysis shows $\tau_s = \tau_{s_0} + k_1\sigma$ **(16)** Where, k_1 = constant, σ = normal stress on the shear plane

$$\sigma = \frac{F_N}{w\,t_1/\sin\emptyset}$$

Further calculations lead to $$F_C = \frac{wt_1\tau_s \cos(\lambda-\alpha)}{\sin\phi[\cos(\phi+\lambda-\alpha) - k_1\sin(\phi+\lambda-\alpha)]} \qquad \textbf{(17)}$$

Applying the principle of minimum energy conservation, we get $2\phi + \lambda - \alpha = C_m$ **(18)**

C_m = machining constant = $\cot^{-1} k_1$

Eq. (18) shows that ϕ increases with increase in α, while ϕ decreases with increase in λ.

Problem

During orthogonal machining operation on mild steel, the following results are obtained:

t1 = 0.25 mm, t2 = 0.75 mm, w = 2.5 mm α = 0 degree, F_C = 950 N, F_T = 475 N.

Determine the coefficient of friction between the chip and the tool.

Determine the ultimate shear stress of the work material.

Solution

$$\mu = \frac{F_C sin\,\alpha + F_T \cos\alpha}{F_C cos\,\alpha - F_T \sin\alpha} = \frac{950 \times sin\,0^o + 475 \times \cos 0^o}{950 \times cos\,0^o - 475 \times \sin 0^o} = \frac{475}{950} = \mathbf{0.5}$$

$$Shear\ angle, \phi = tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right) = tan^{-1}\left(\frac{r\cos 0^o}{1 - r\sin 0^o}\right) = tan^{-1} r = tan^{-1}\left(\frac{t_1}{t_2}\right) = tan^{-1}\left(\frac{0.25}{0.75}\right) = 18.4^o$$

$$F_S = F_C cos\,\phi - F_T \sin\phi = 950 \times \cos 18.4^o - 475 \times \sin 18.4^o = 751.3 \text{ N}$$

$$\boldsymbol{F_S = wt_1\tau_s/\sin\phi} \qquad \tau_s = \frac{F_S \sin\phi}{wt_1} = \frac{751.3 \times \sin 18.4^o}{2.5 \times 0.25} = \mathbf{379.4\ N/mm^2}$$

Problem

Mild steel is being machined at a cutting speed of 200 m/min with a cutting tool of rake angle 10 degree. The width of cut is 2 mm, and uncut thickness is 0.2 mm. Coefficient of friction between the chip and the tool is 0.5. Shear stress of the work material is 400 N/mm2. Determine (i) the shear angle, (ii) cutting force, (iii) thrust force.

Solution

Merchant's first solution $2\phi + \lambda - \alpha = \pi/2$

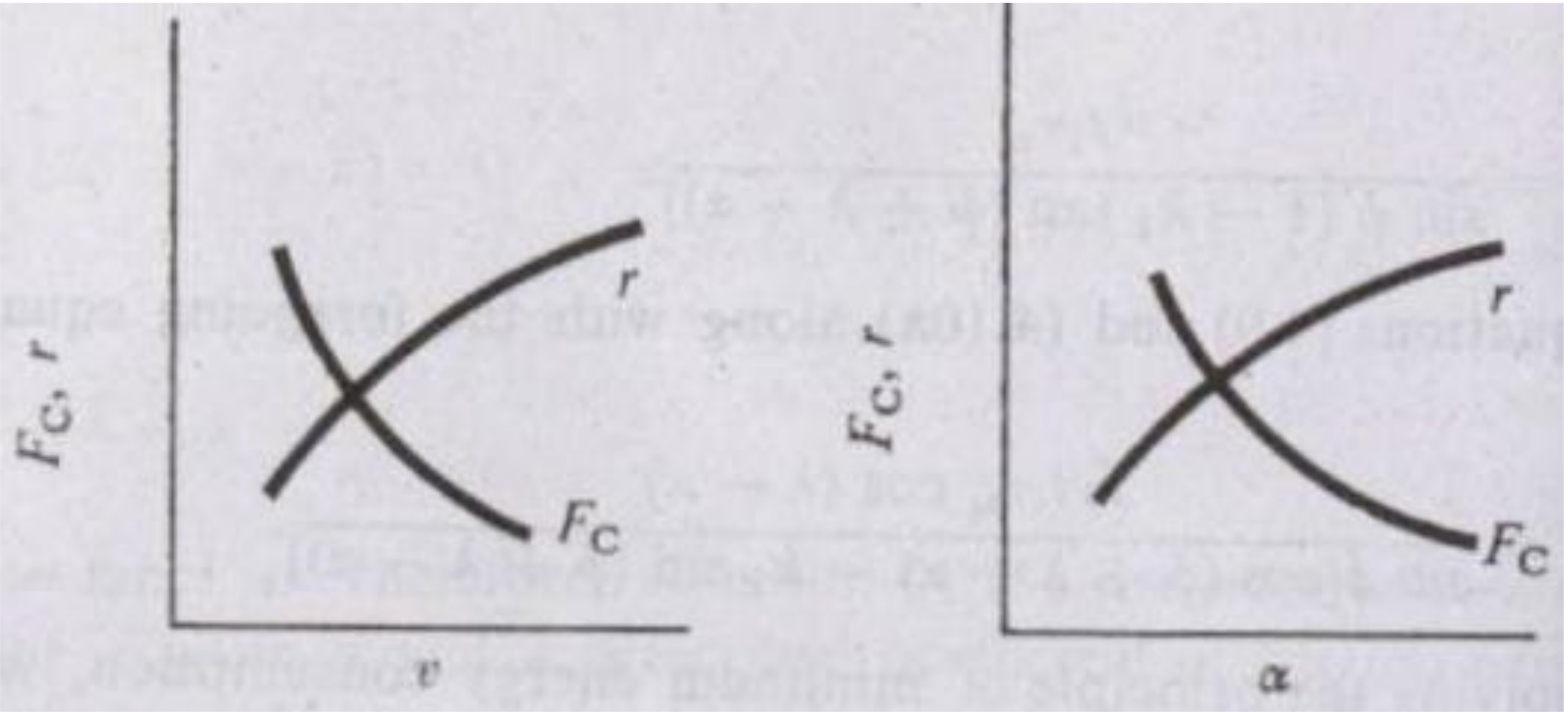
$$\lambda = tan^{-1}\mu = tan^{-1}0.5 = 26.57^o \qquad \alpha = 10^o \quad \rightarrow \quad \phi = (90 + 10 - 26.57)/2 = \mathbf{36.7^o}$$

$$F_S = wt_1\tau_s/\sin\phi = (2 \times 0.2 \times 400)/\times\, sin\, 36.7^o = 262.3\ N$$

$$R = F_s/\cos(\phi + \lambda - \alpha) = 262.3/\cos(36.7^o + 26.57^o - 10^o) = 438.6\ N$$

$$F_C = R\cos(\lambda - \alpha) = 438.6 \times \cos(26.57^o - 10^o) = \mathbf{420\ N}$$

$$F_T = R\, sin(\lambda - \alpha) = 438.6 \times \sin(26.57^o - 10^o) = \mathbf{125\ N}$$



When **v** increases, μ decreases. Accordingly λ decreases, thereby causing increase in ϕ and decrease in $\mathbf{F_C}$.

Increase in **v** and α increases ϕ, causing decrease in $\mathbf{F_C}$ and increase in cutting ratio, **r.**

Machining Constant for different materials

Work material (hot rolled steel)		C_m (degrees)
AISI	1010	69.8
AISI	1020	69.6
AISI	1045	78.0
AISI	2340	76.2
AISI	3140	70.6
AISI	4340	74.5
Stainless	303	92
Stainless	304	82

Different shear angle relations

Source	Result
Ernst and Merchant	$2\phi + \lambda - \alpha = \pi/2$
Merchant's second solution	$2\phi + \lambda - \alpha = C_m$
Lee and Shaffer	$\phi + \lambda - \alpha = \pi/4$
Stabler	$\phi + \lambda - \alpha/2 = \pi/4$

Power consumption during machining, $W = F_C v$

Volumetric rate of material removal, $Q = w\, t_1\, v$

Specific energy consumption (energy consumption per unit volume of material removal), $U_C = W / Q = F_C / w\, t_1$

Experimental data shows $U_C = U_0 \tilde{t}_1^{\,-0.4}$

Therefore, $F_C = 1000 w t_1 U_0 \tilde{t}_1^{\,-0.4}\ N$

Where, w and t_1 are in mm, and U_0 is in J/mm^3

Cutting Tool Materials

The cutting tool must resist any tendency to alter its shape.

Tool material must be harder than the work material by at least 35% - 50%.

Effective hardness of the tool decreases at high temperature of machining.

Effective strength of workpiece increases due to high strain rate of plastic deformation

Condition of hardness ratio should be applied by considering modified hardness values $1.35 < \left[\frac{H_{tool}}{H_{work}}\right]_{modified} < 1.5$

Tool material	Work material	Static hardness ratio	Modified hardness ratio	Remark
Copper	Zinc	1.98	≈1	No successful machining possible
Zinc	Cadmium	2.2	≈1	No successful machining possible
Tin	Lead	1.5	<1	No machining possible
Cadmium	Tin	2.2	<1	No machining possible
Heat treated steel	Steel 65γ	1.45	≈1	No successful machining possible

Performance of various tool/work combinations

Commonly used tool materials

(i) high carbon steel, high speed steel (HSS), cemented carbide, ceramic coated carbide, and ceramic.

(ii) For grinding, abrasive minerals, e.g., silicon carbide, aluminum oxide, and diamond are used.

Properties of an ideal tool material:

- It should maintain its hardness appreciably higher than that of the work at the elevated temperature.
- It should be tough enough to withstand shocks.
- It should provide a large resistance to the wearing action so that excessive wear does not occur.
- The coefficient of friction between the work and the tool should be low.
- Its thermal conductivity and specific heat should be high.

Composition of different tool materials

Material	C	W	Cr	V	Mn	Fe
Carbon tool steel	0.9				0.6	Rest
High speed steel	0.75	18.0	4.0	1.0	0.6	Rest

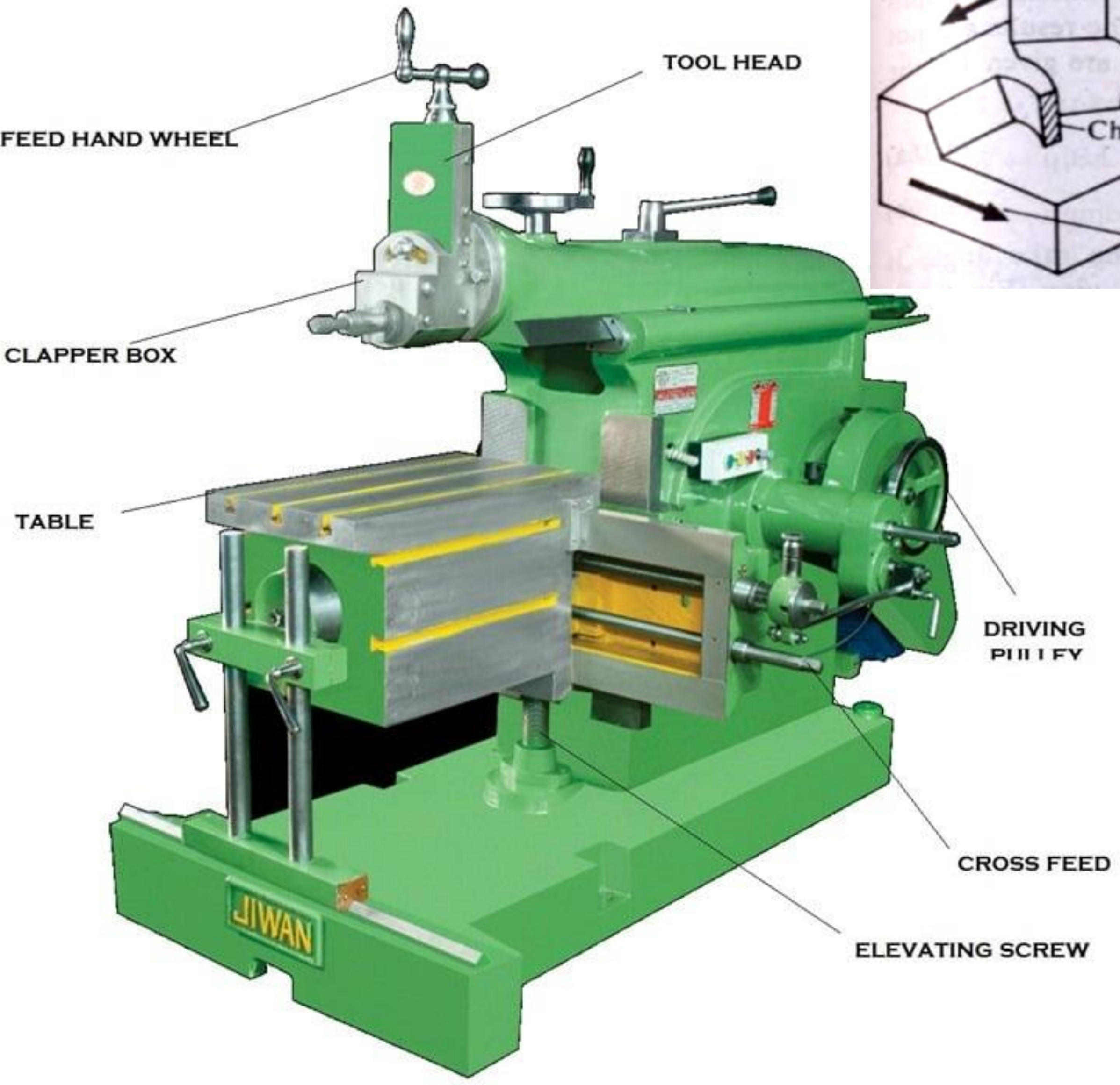
Composition carbide tool materials

WC	Co	TaC	TiC	Use
94	6			Cast iron
70.7	4.5	12.2	12.6	Steels
72	8.5	11.5	8	Ni alloy steels

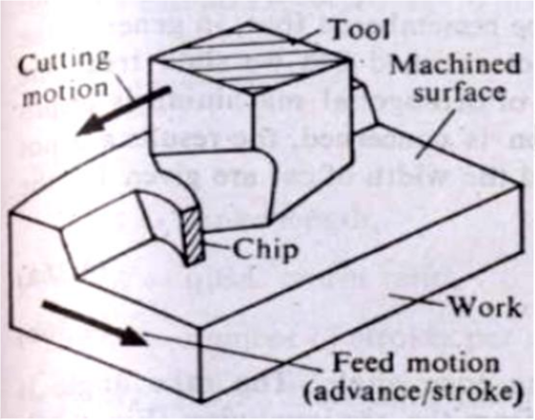
Tool material	Cutting speed (m/min)
Carbon steel	5
High speed steel	30
Cemented carbide	150
Coated carbide	350
Ceramic	600

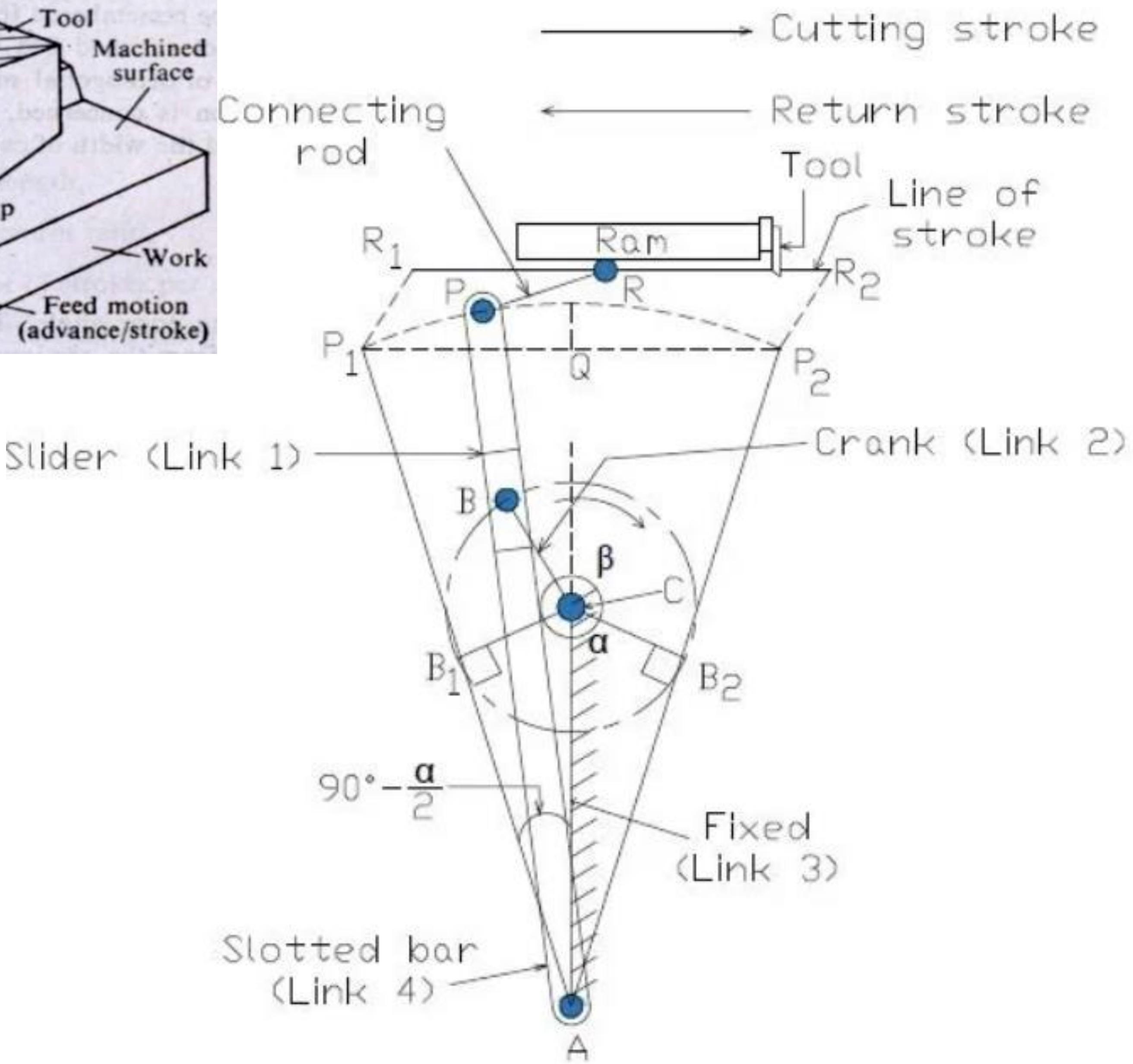
Machining Process – Common Applications

Shaping and Planing

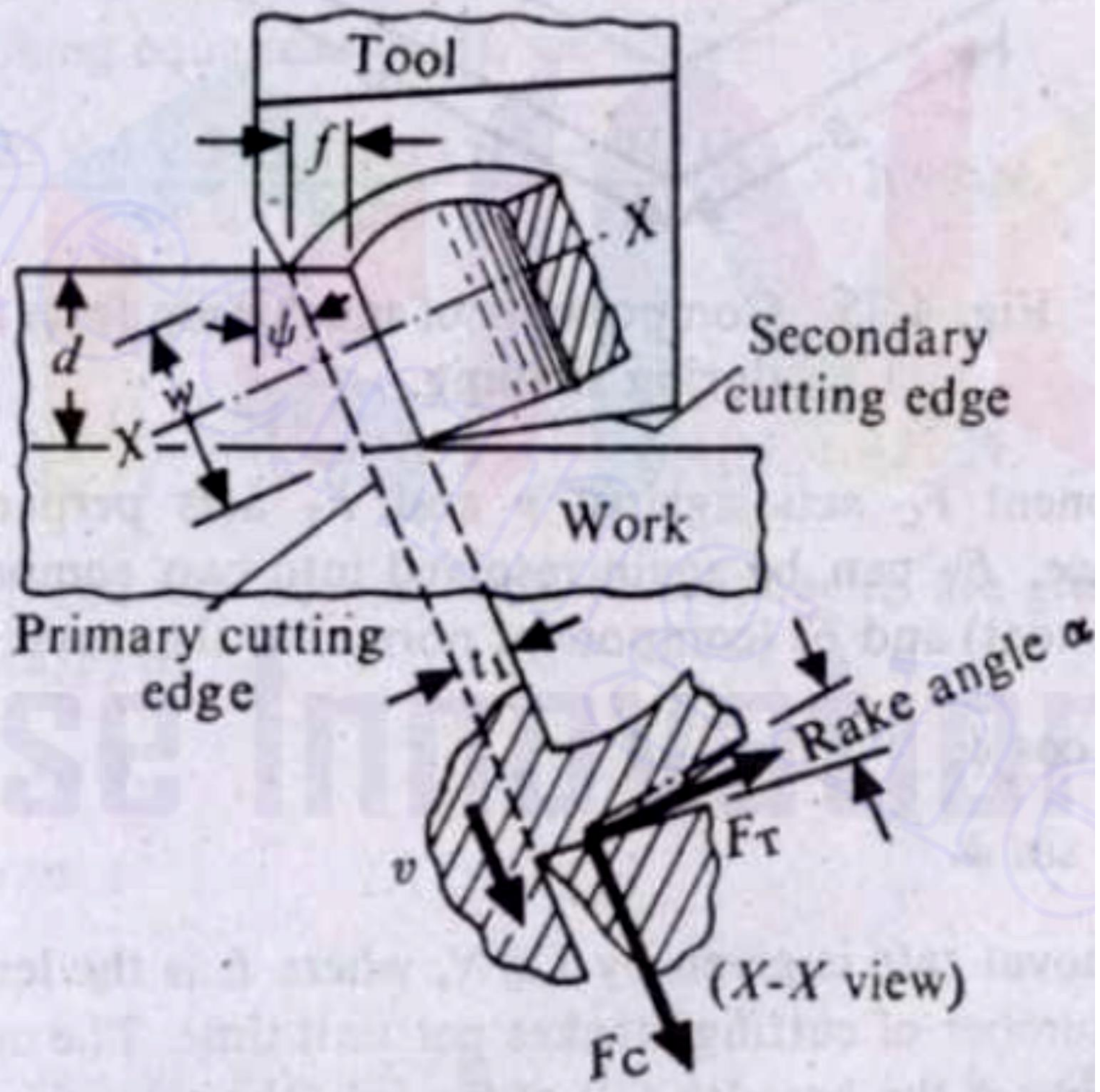


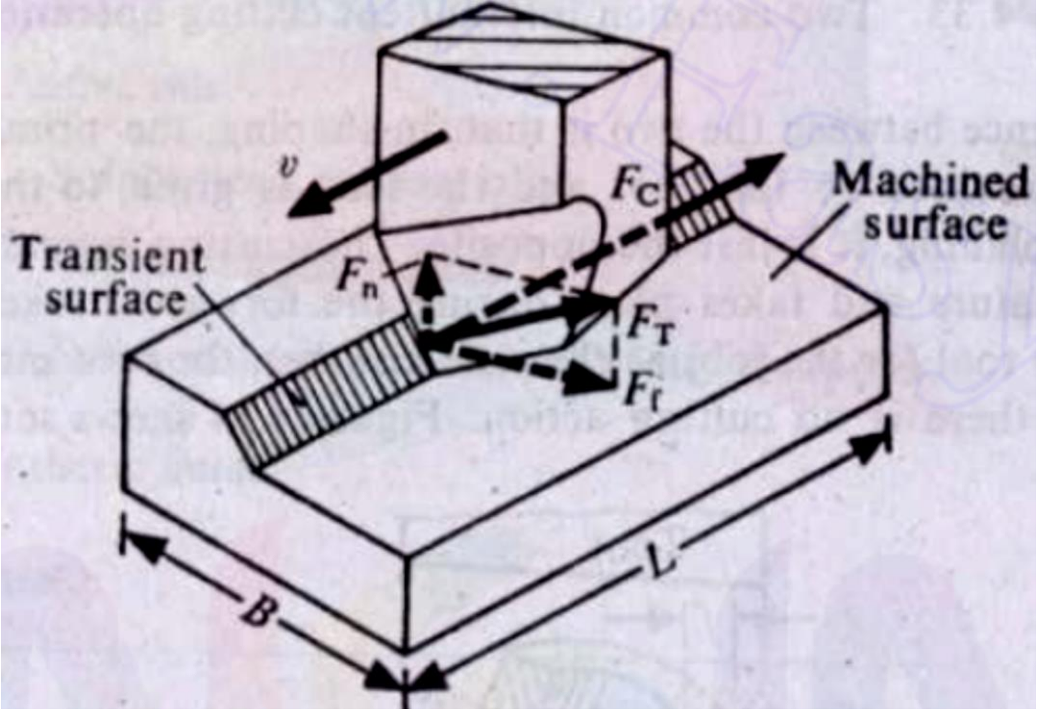
PARTS OF SHAPER MACHINE





Whitworth Quick Return Mechanism





$F_f = F_T \cos\psi$
$F_n = F_T \sin\psi$

Major parameters:

- No. of cutting strokes/time (N)
- Length of the job (L)
- Breadth of the job (B)
- Total depth of metal removal (H)
- Depth of cut (d)
- Feed (f)

Metal removal rate = L d f N

Cutting time,

$$T_c = \frac{H}{d} \times \frac{B}{f} \times \frac{1}{N}$$

Average Cutting Speed,

$$v = \frac{NS(1+R)}{2}$$

S = stroke length
R = quick return ratio

$t_1 = f \cos\psi$
$w = d/\cos\psi$

ψ = principal cutting edge angle

EXAMPLE 4.9 Determine the three components of the machining force when shaping a cast iron block with depth of cut = 4 mm, feed = 0.25 mm/stroke, normal rake angle of tool = 10°, principal cutting edge angle = 30°, coefficient of friction between chip and tool = 0.6, and ultimate shear stress of cast iron = 340 N/mm².

SOLUTION We shall use Lee's and Shaffer's shear angle relationship

$$\phi + \lambda - \alpha = 45°.$$

In the present case, $\lambda = \tan^{-1}(0.6) \approx 31°$. Hence,

$$\phi = 45° + 10° - 31° = 24°.$$

The uncut thickness and width of cut are $0.25 \cos 30°$ mm and $4/\cos 30°$ mm, respectively.

$$F_S = \frac{w t_1 \tau_s}{\sin\phi}$$ and $$F_C = \frac{F_S \cos(\lambda - \alpha)}{\cos(\phi + \lambda - \alpha)}$$

→ $$F_C = w t_1 \tau_s \cos(\lambda - \alpha)\left[\frac{1}{\sin\phi \cos(\phi + \lambda - \alpha)}\right].$$

$$F_C = \frac{0.25 \times 4 \times 340 \times \cos(31^\circ - 10^\circ)}{\sin 24^\circ \times \cos 45^\circ}\ \text{N} = 1099\ \text{N}$$

t_1 = f cos ψ
w = d/cos ψ
→ t_1 w = f d = 0.25x4

Also, $F_C = R\cos(\lambda - \alpha)$ and $F_T = R\sin(\lambda - \alpha)$

→ $$F_T = F_C \frac{\sin(\lambda - \alpha)}{\cos(\lambda - \alpha)} = 1099 \times \frac{\sin 21^\circ}{\cos 21^\circ}\ \text{N} = 422\ \text{N}$$

Finally, $F_f = F_T \cos\psi$ → $F_f = 422 \cos 30^\circ\ \text{N} = 365\ \text{N}$

$F_n = F_T \sin\psi$ → $F_n = 422 \sin 30^\circ\ \text{N} = 211\ \text{N}$

EXAMPLE 4.10 If the operation in Example 4.9 takes place with 60 strokes/min, what will be the average power consumption if the length of the job is 200 mm ?

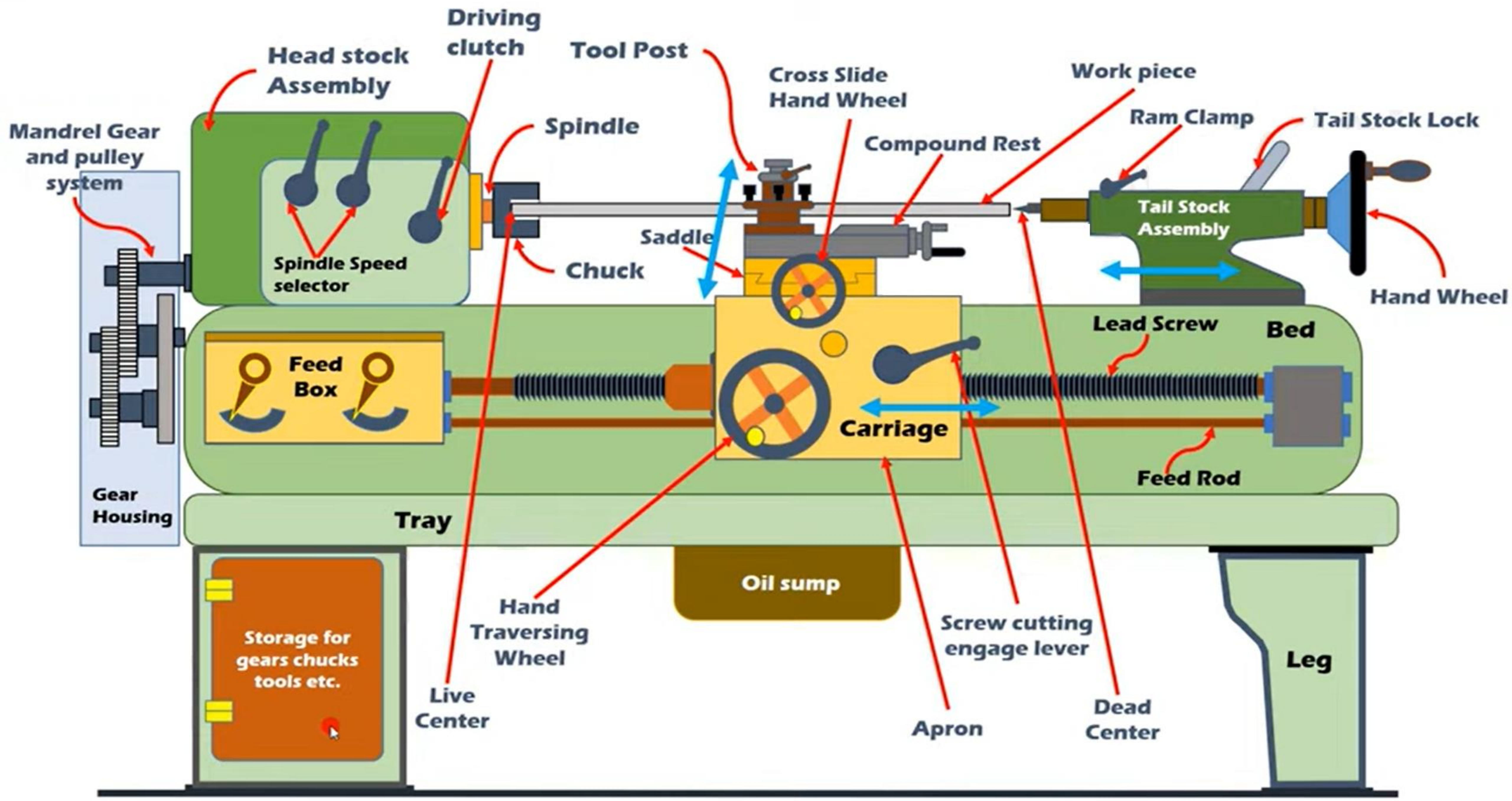
SOLUTION Let us assume that the cutting component of F_C remains constant. Thus, the work done during each forward stroke is

$$F_C \times \frac{200}{1000}\ \text{J} = \frac{1099 \times 200}{1000}\ \text{J} = 220\ \text{J}$$

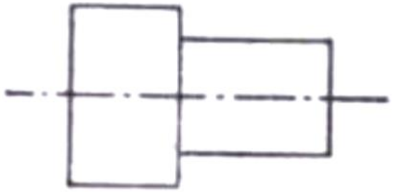
since F_n and F_t do not consume any energy. So, the average power consumption is given by

$$W_{av} = \frac{220 \times 60}{60}\ \text{W} = 220\ \text{W}.$$

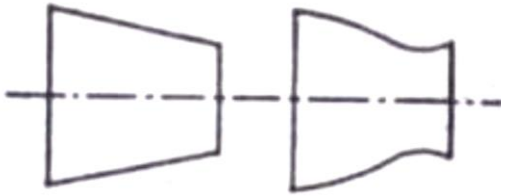
Construction and Operation of a Lathe Machine



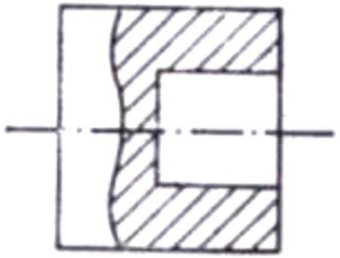
Turning and Boring



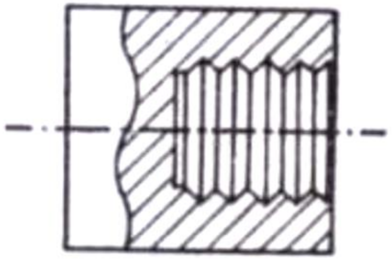
Step turning



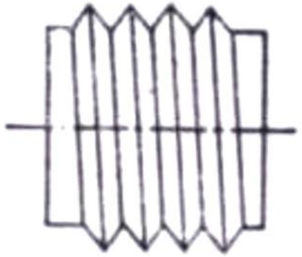
Taper and form turning



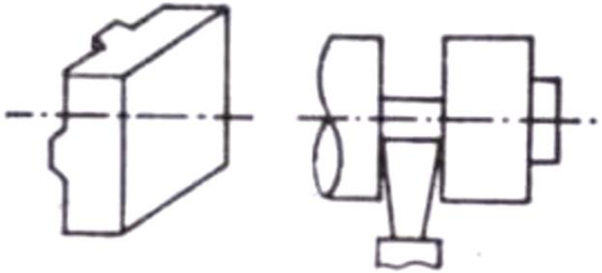
Boring



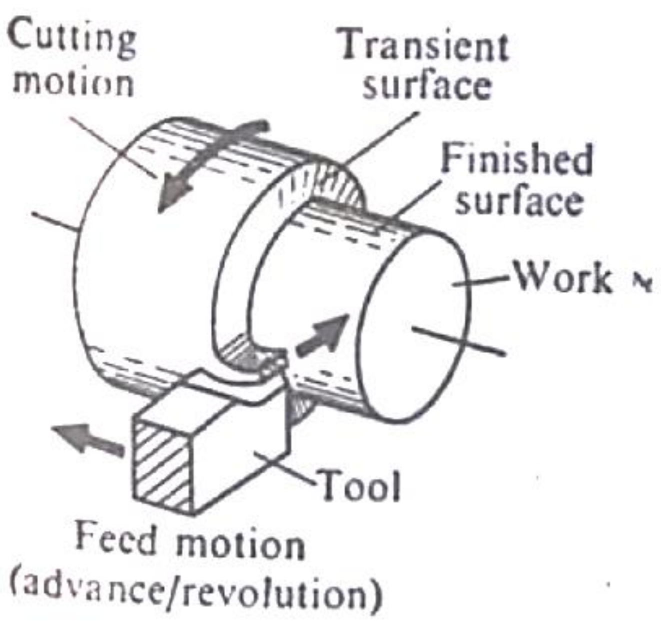
Internal threading



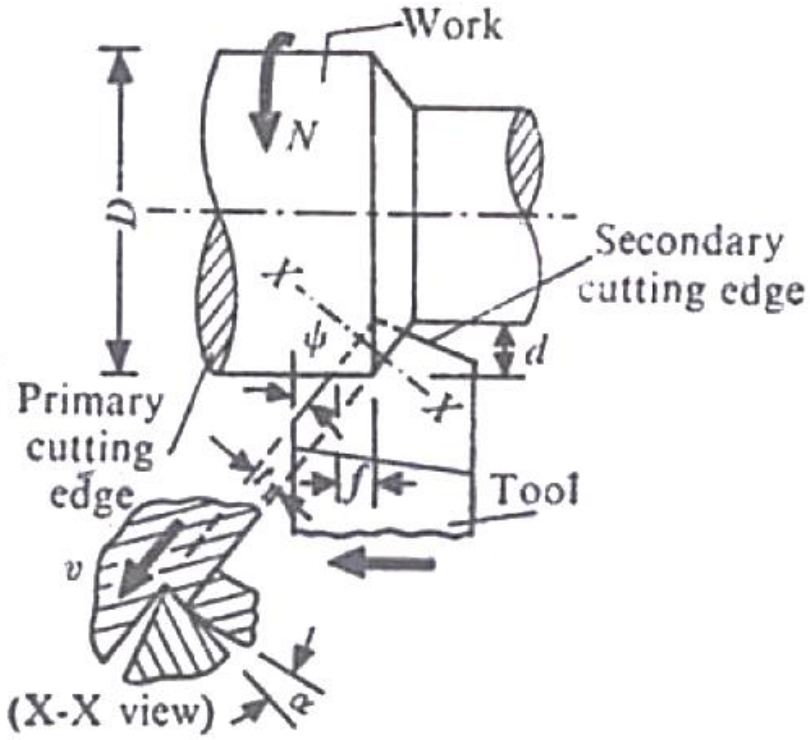
Thread turning



Face turning and cutting off



(a) Basic scheme of turning



(b) Details of turning geometry

$$t_1 = f \cos \psi$$
$$w = d/\cos \psi$$

t1 = uncut thickness
f = feed rate = axial movement of cutting tool per revolution of the workpiece
d = depth of cut
w = width of cut

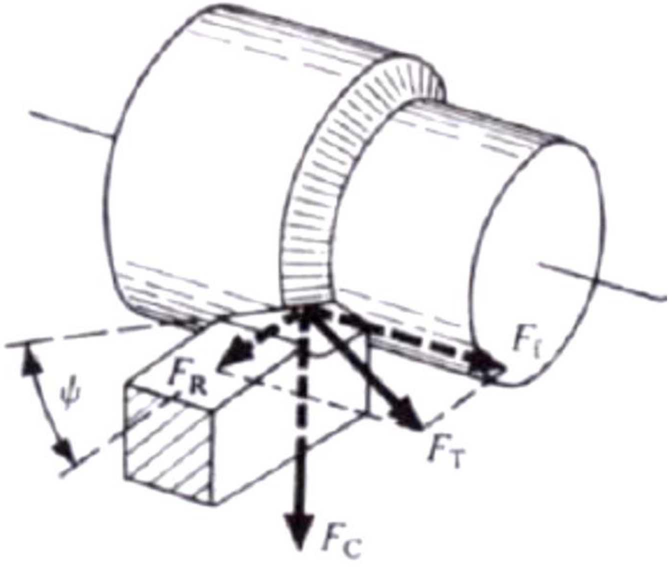
Cutting Velocity $v = \pi D N$

Power consumption $W = F_C v$

Material removal rate = f d v

Total machining time = L/(f N)

D = Job diameter
N = Rotational speed of job
F_C = cutting force
f = Feed rate = tool movement per revolution of job
d = depth of cut
L = Length of job

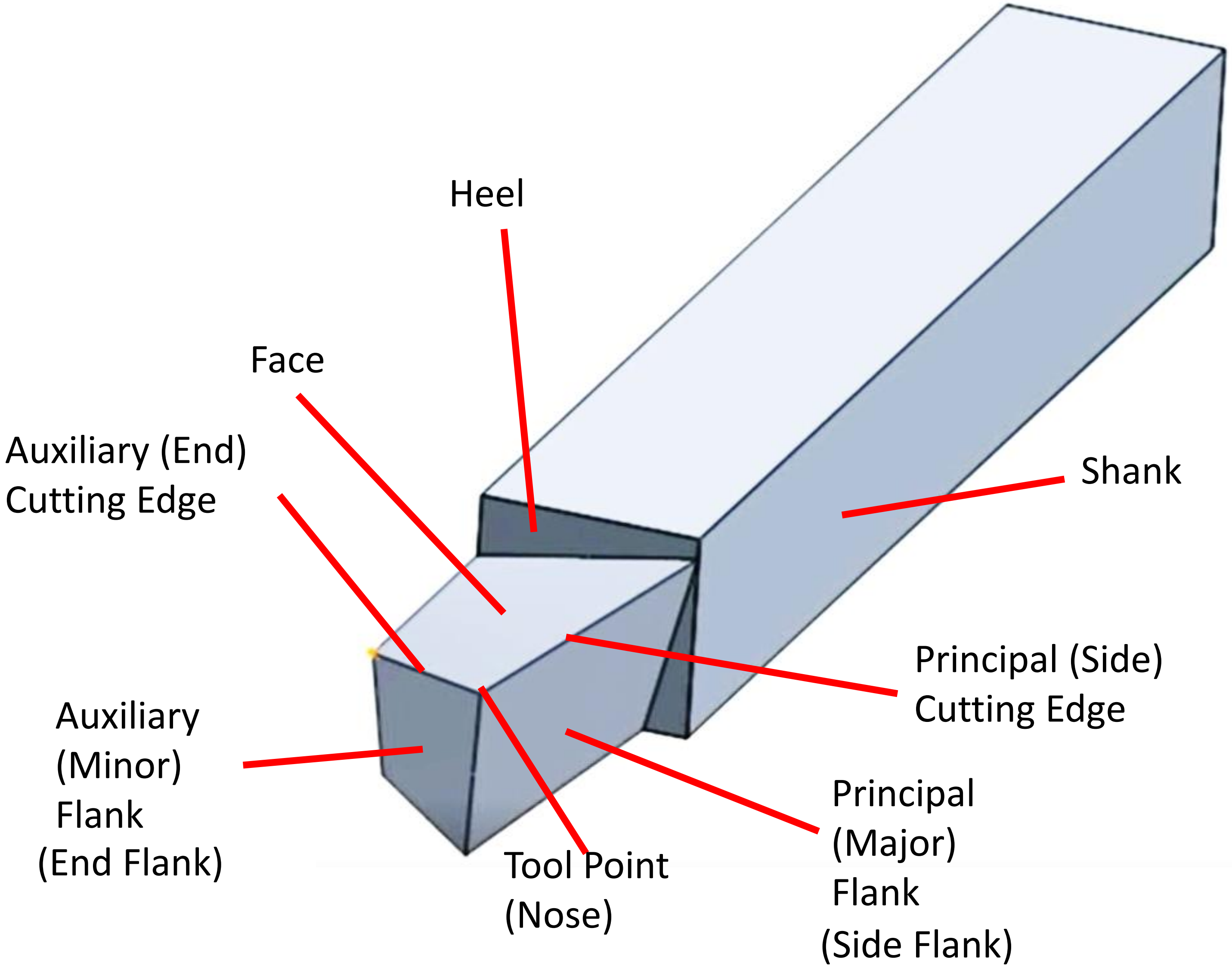


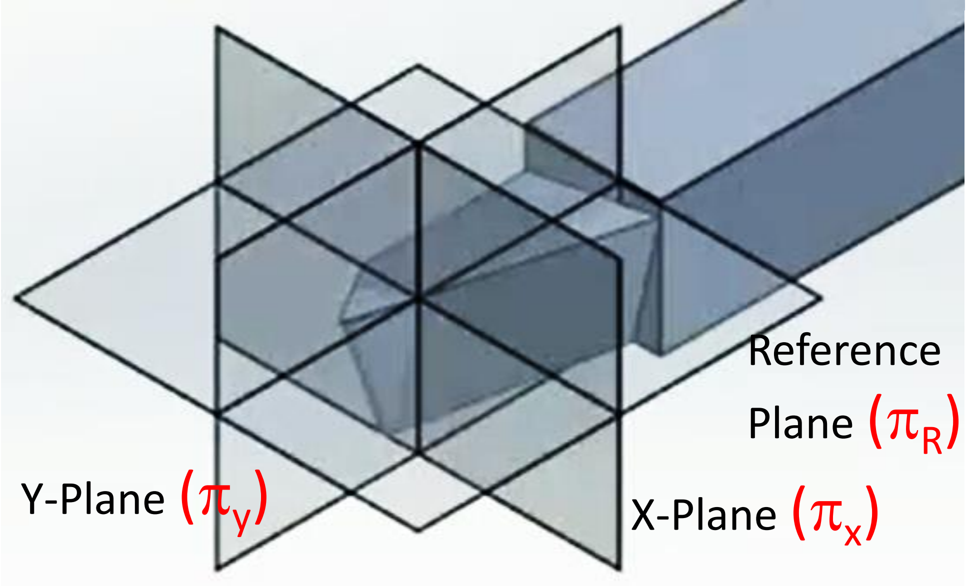
Components of machining force during turning.

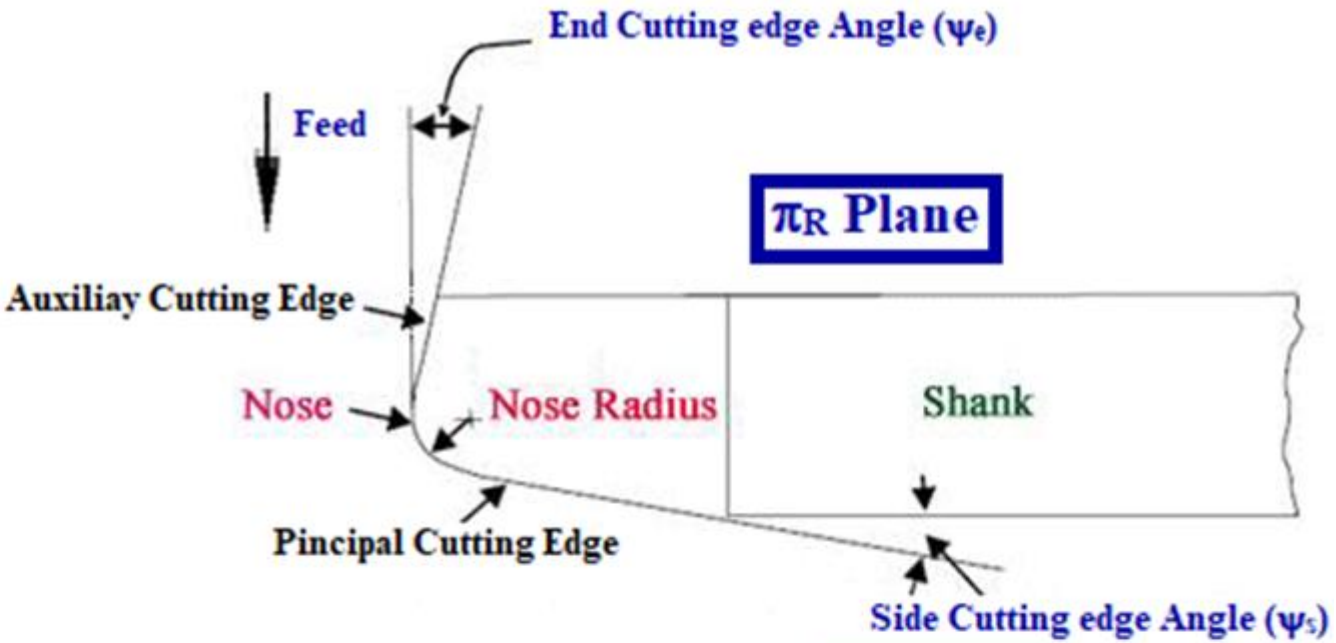
F_C = Cutting force (In the vertical direction, parallel to the cutting velocity)
F_T = Thrust force (Perpendicular to the principal cutting edge, in the horizontal plane)
F_f = Feed (axial)component of thrust force
F_R = Radial component of thrust force

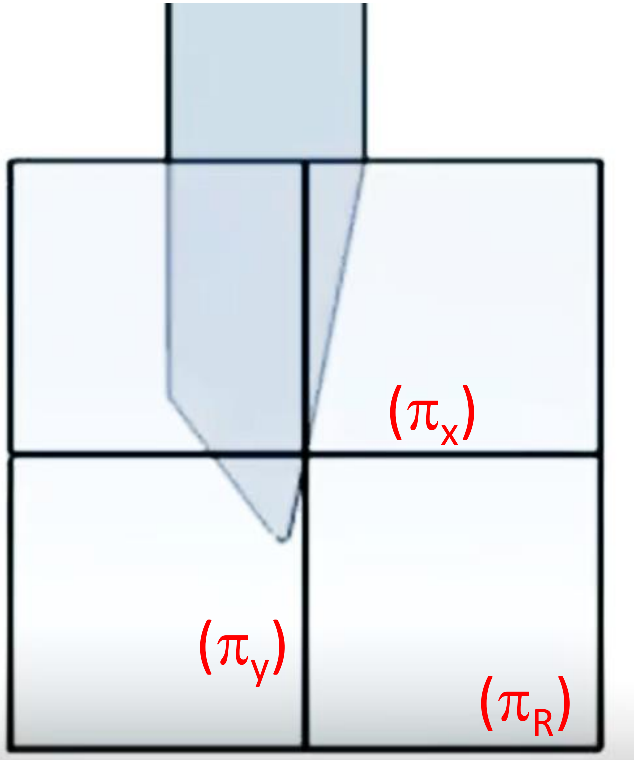
$$F_f = F_T \cos\psi \qquad F_R = F_T \sin\psi$$

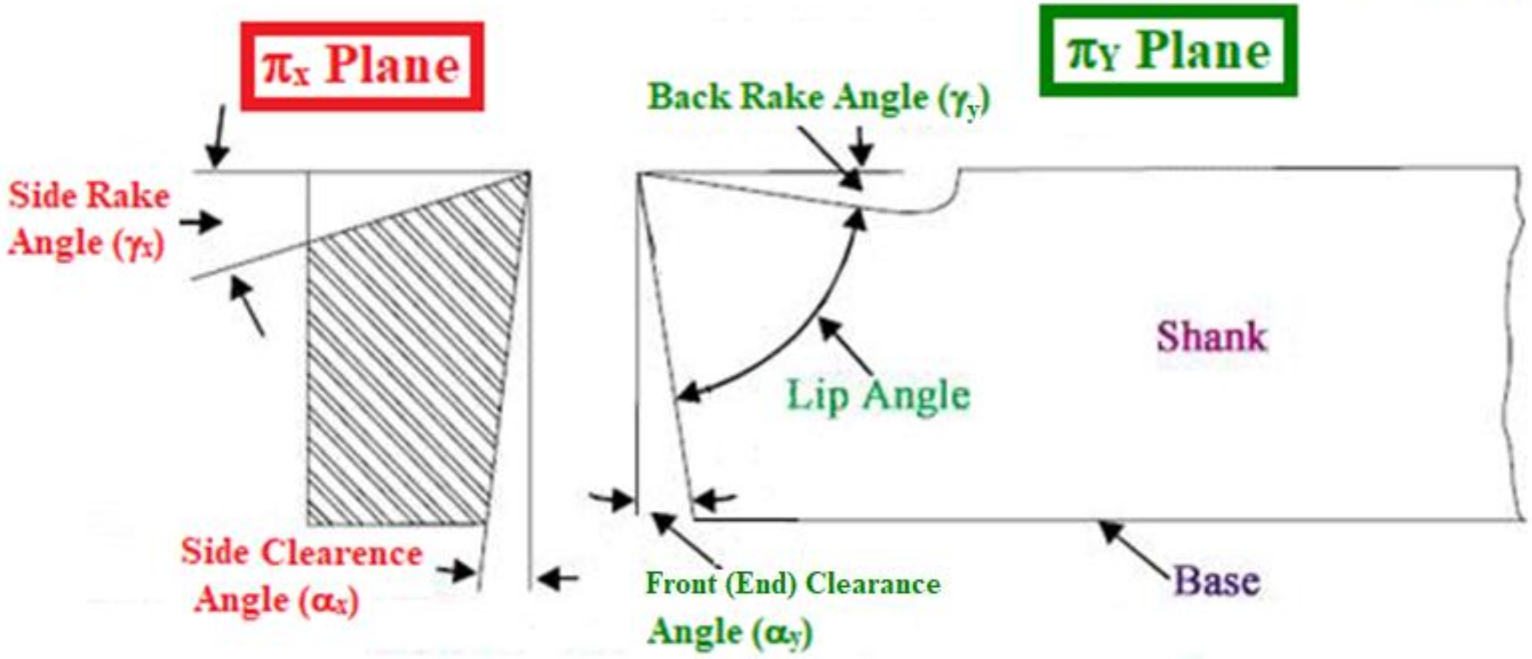
Single Point Tool Geometry




Reference
Plane (π_R)
Y-Plane (π_y)
X-Plane (π_x)


End Cutting edge Angle (ψ_e)
Feed
π_R Plane
Auxiliay Cutting Edge
Nose
Nose Radius
Shank
Pincipal Cutting Edge
Side Cutting edge Angle (ψ_s)


(π_x)
(π_y)
(π_R)


π_x Plane
Side Rake
Angle (γ_x)
Side Clearence
Angle (α_x)
π_Y Plane
Back Rake Angle (γ_y)
Lip Angle
Shank
Front (End) Clearance
Angle (α_y)
Base

Shank: The main body of the tool is known as the shank. It is the backward part of the tool which is held by tool post.

Face: The top surface tool on which chips passes after cutting is known as a face. It is the surface adjacent of cutting edges.

Flank: Sometime flank is also known as cutting face. It is the vertical surface adjacent to the cutting edge. According to cutting edge, there are two flanks – side flank and end flank.

Nose or Cutting Point: The point where both cutting edge meets known as cutting point or nose. It is in front of the tool.

Base: The bottom surface of the tool is known as the base. It is just the opposite surface of the face.

Heel: It is an intersecting line of flank and base.

End Cutting Edge Angle: The angle between the end cutting edge or flank to the plane perpendicular to the side of the shank is known as the end cutting angle. This angle usually varies from 5 to 15 degree

Side Cutting Edge Angle: The angle between the side cutting edge or flank to the plane parallel to the side of the shank known as side cutting edge angle.

Back Rake Angle: The angle formed for smooth flow of chips on the face, is known as rack angle. The back rack angle is the angle between the face and the plane perpendicular to the end cutting edge. Softer the material, greater should be the positive rake angle. The back rake angle may be positive negative or neutral.

Side Rake Angle: The angle between the face and plane perpendicular to the side cutting edge is known as the side rake angle. It allows chips to flow smoothly when material cut by side cutting edge.

The amount by which a chip is bent depends upon this angle. When the side rack angle increases, the magnitude of chip bending decreases. Smoother surface furnish is produced by a larger side rake angle.

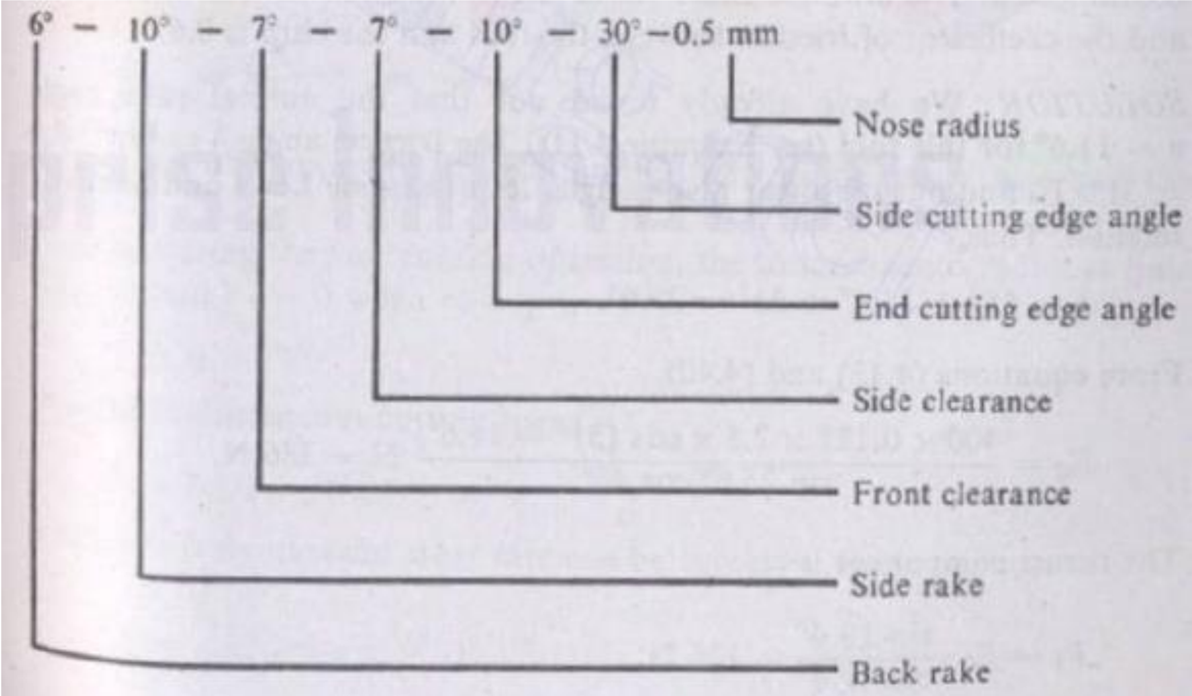
End Relief Angle: It is also known as a clearance angle. It is the angle that avoids tool wear. It avoid the rubbing of flank with a workpiece. End cutting angle made by end flank to the plane perpendicular to the base. This angle may vary from 6 to 10 degrees.

Side Relief Angle: It is the angle made by the side flank to the plane perpendicular to the base. It avoid rubbing of side flank with a workpiece. This angle allows the tool to fed sideways into the job in order to cut the work material without rubbing. When the side relief angle is very small, the tool will rub against the job and therefore it will get overheated and become blunt and the surface finish obtained will be poor.

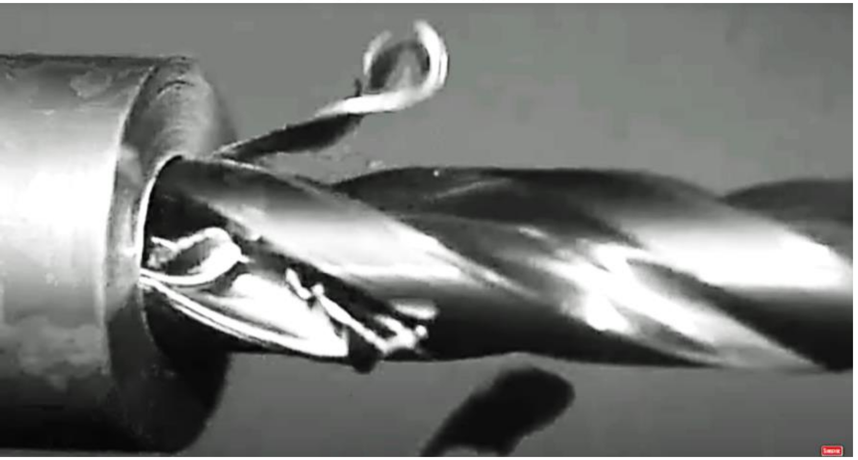
Nose Radius: The intersecting area of both cutting edges is known as the nose of the tool.

Single Point Tool Nomenclature

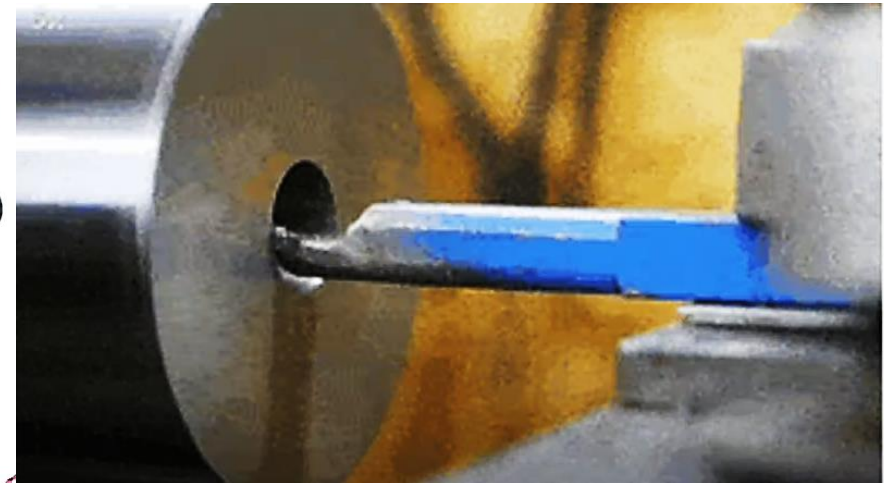
γ_y	γ_x	α_y	α_x	ψ_e	ψ_s	r
Back rake angle	Side rake angle	Front (end) Clearance angle	Side Clearance angle	End Cutting edge angle	Side Cutting edge angle	Nose radius



Drilling is a cutting process that uses a **drill** bit to cut a hole of circular cross-section in solid materials

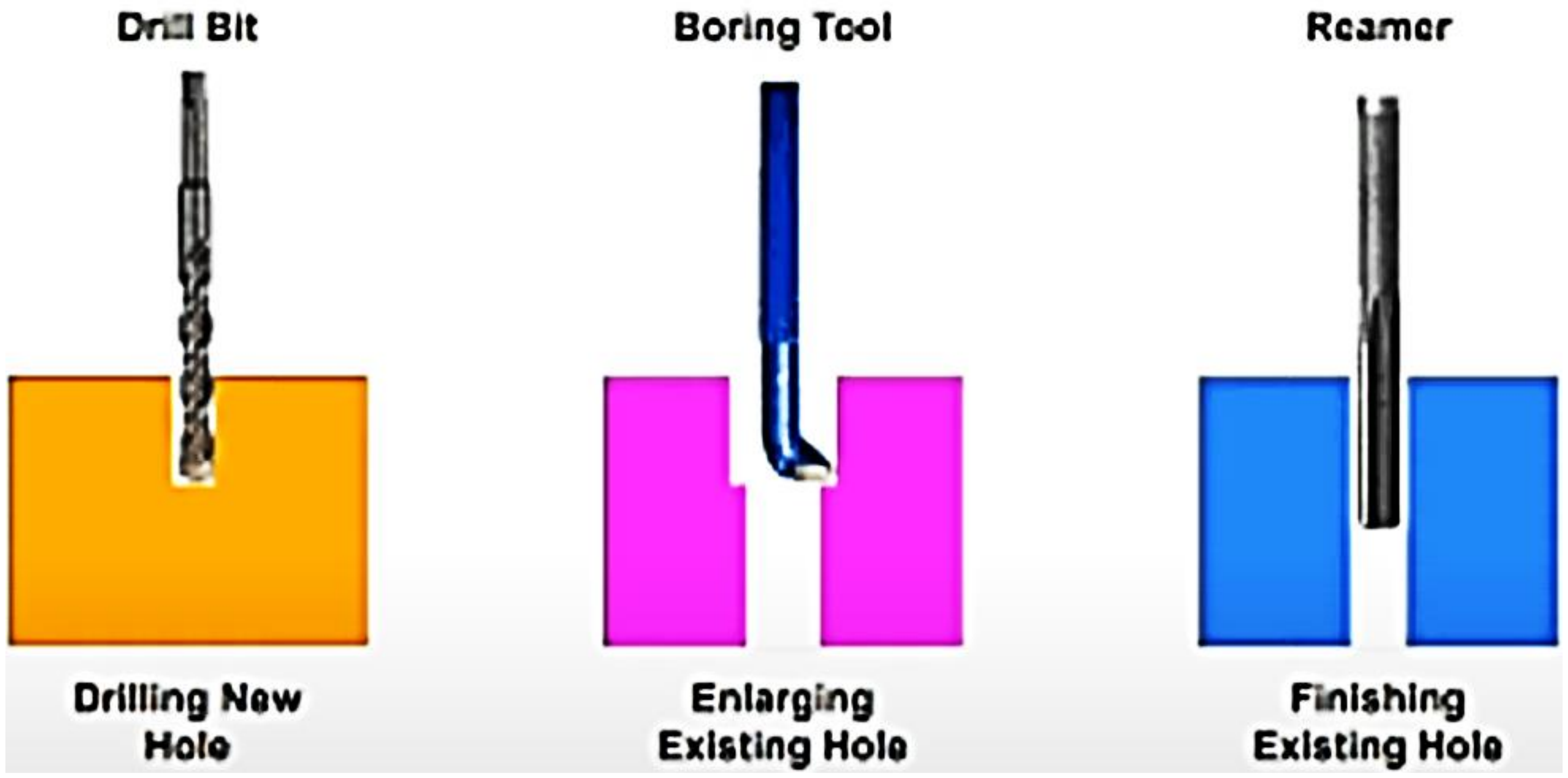


Boring is the **process** of enlarging a hole that has already been drilled (or cast) by means of a single-point cutting tool



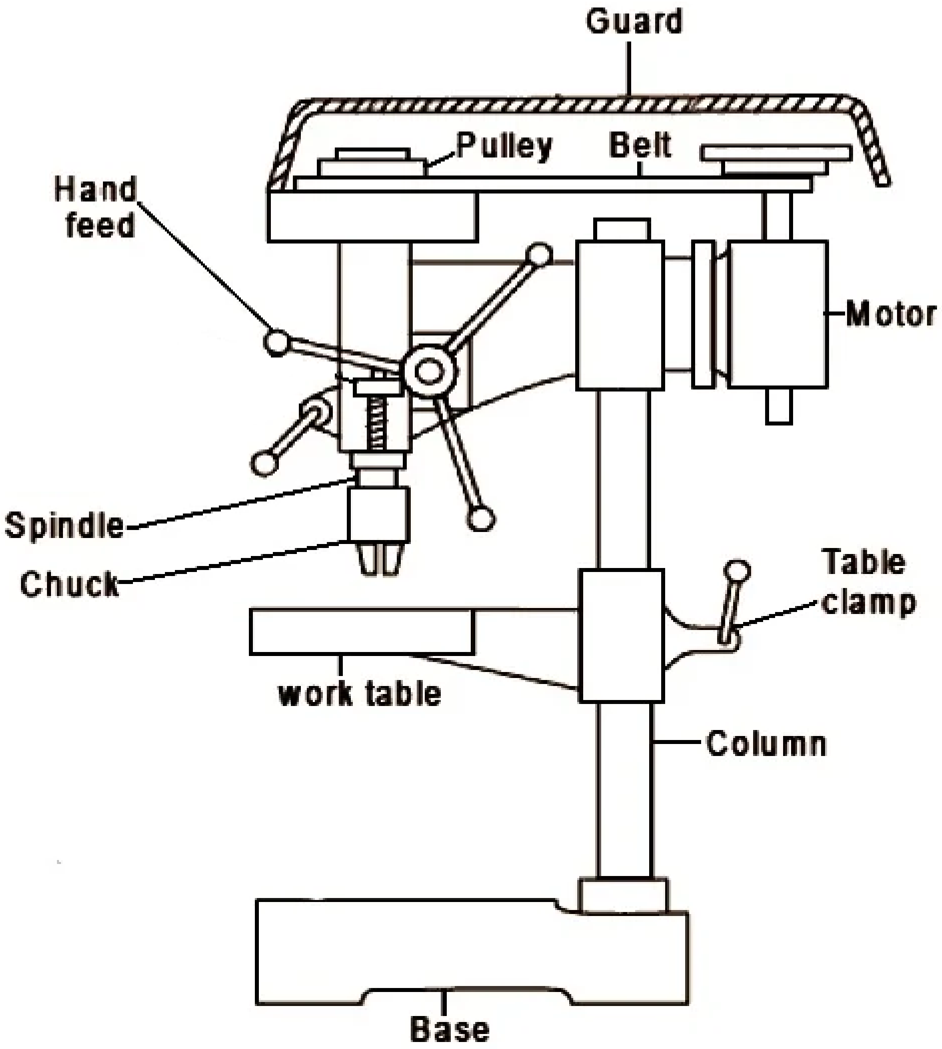
Reaming is a Finishing process of Existing hole

Boring removes more materials than reaming.


Drill Bit
Boring Tool
Reamer
Drilling New Hole
Enlarging Existing Hole
Finishing Existing Hole

Drilling Machine

A drilling machine is a type of machine in which the holes are being made on the workpiece by making use of a rotating tool called drill bit or the twist drill.



Bed: The bed is the main part of the machine on which the whole machine is being mounted. The bed is made up of cast iron, so it has high compressive strength and good wear resistance.

Pillar: The pillar is a type of vertical column that rests on the bed. A pillar is present at the center of the bed. The pillar helps the motor and the spindle head.

Swivel Table: The table is the place where the workpiece is being mounted. The table is attached to the column and it can be rotated around the column and can have an upward and downward moment. A table can be adjusted at any angle as per the requirement.

Motor: The motor is present at the top of the column. The motor shaft is connected to a stepped pulley so that we can increase or decrease the speed of the rotation of the motor.

Stepped pulley: Two steeped pulleys are present at the top. The basic function of the stepped pulley is to control the speed of the rotation of the motor.

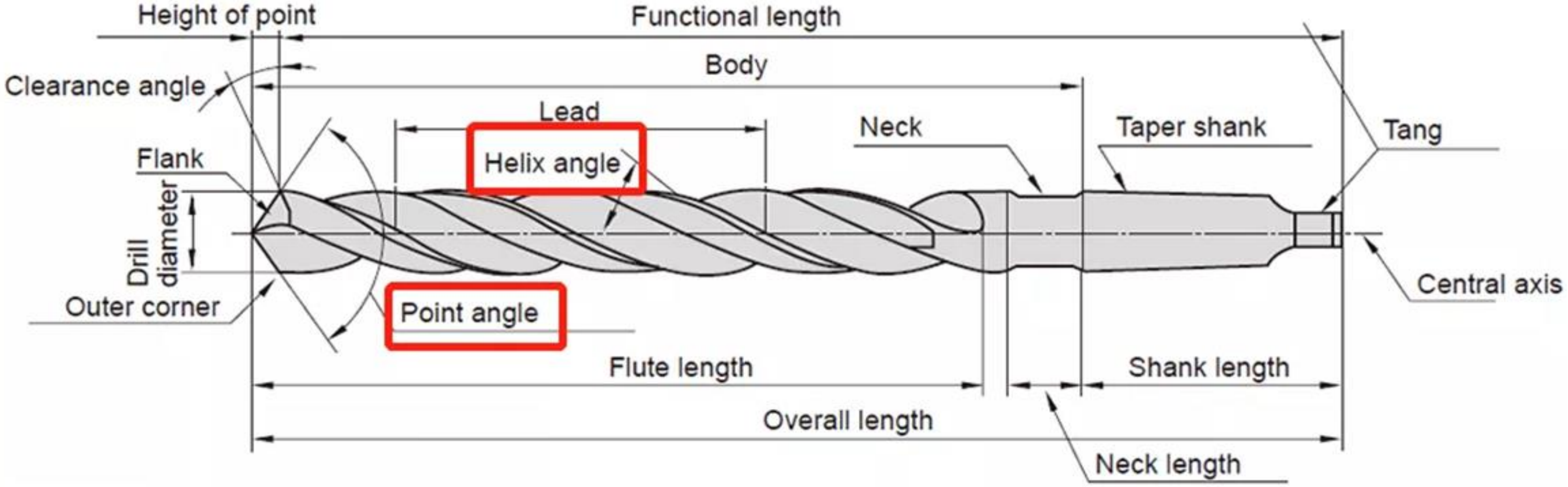
Spindle: Spindle arrangement is present at top of the column opposite to the arrangement of the motor. The top of the spindle is attached to one of the stepped pulleys. The bottom of the spindle is connected to the chuck.

Chuck: Chuck is present at the bottom of the spindle. Function of the chuck is to hold the cutting tool firmly.

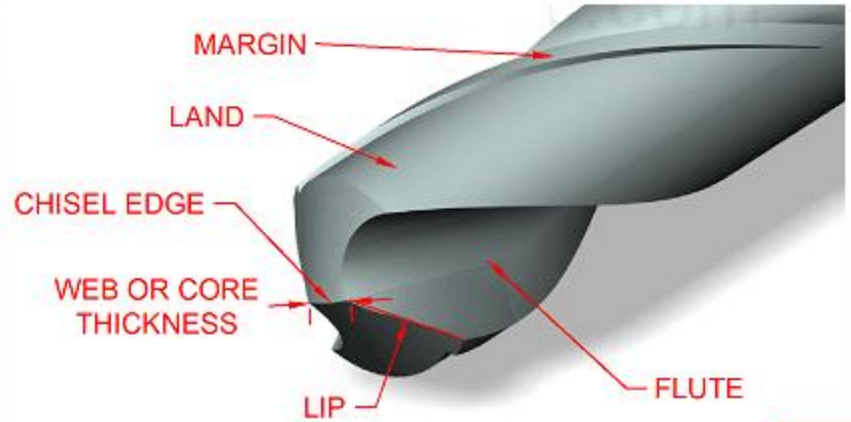
Drill bit: A drill bit is the cutting tool that is used to create a hole in the workpiece.

Hand-wheel: Hand-wheel is used to adjust the spindle position and provide the feed motion to the drill bit.

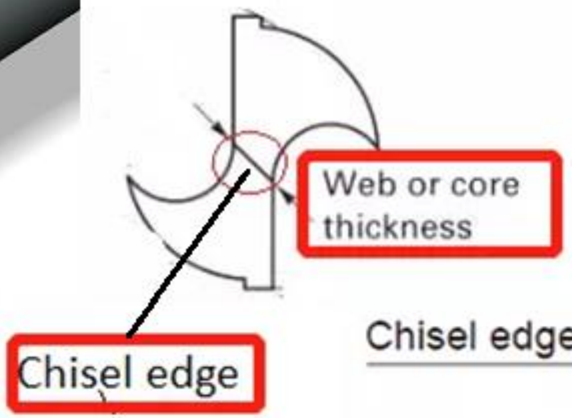
Twist Drill



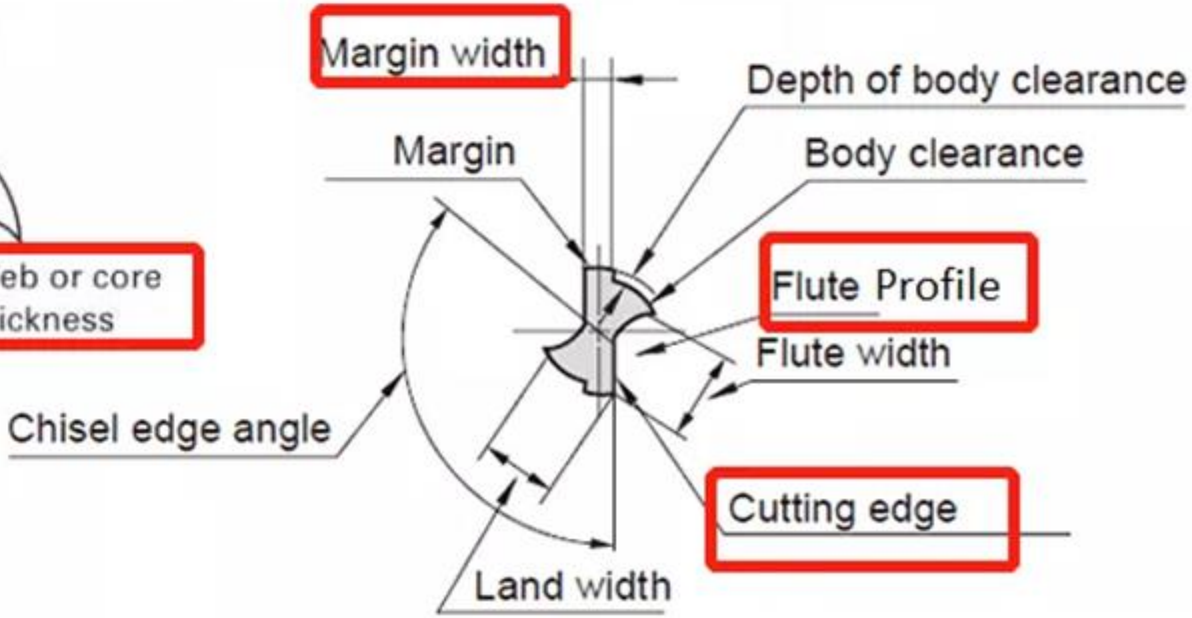
Height of point
Functional length
Body
Clearance angle
Lead
Helix angle
Neck
Taper shank
Tang
Flank
Drill diameter
Outer corner
Point angle
Central axis
Flute length
Shank length
Overall length
Neck length



MARGIN
LAND
CHISEL EDGE
WEB OR CORE THICKNESS
LIP
FLUTE



Web or core thickness
Chisel edge



Margin width
Depth of body clearance
Margin
Body clearance
Flute Profile
Flute width
Chisel edge angle
Cutting edge
Land width

Twist Drill

A twist drill is basically a cylindrical piece of steel with special grooves. One end of the cylinder is pointed and the other end is so shaped that it can be attached to the drilling machine. The grooves are usually called flutes. The flutes formed by twisting a flat piece of steel into a cylindrical shape and such types of cylindrical shape drills are called twist drills.

- **Shank:** The part of the drill bit that holds into the holding is called the 'shank'.
- **Tang:** The tang is flattened end of the taper shank.
- **Body:** The portion between the shank and the drill bit tip is called 'Body. The body is mostly fluted and relieved.
- **Flutes:** The grooves in the twist drill body is known as flutes. The flute is for chips removal. Wider flute, better chips removal performance. Wider profile, flatter flute; Thinner profile, deeper flute. Depth of the flute decides the thickness of the web.
- **Neck:** Neck is the portion of the body with reduced diameter between body and shank.
- **Point**: The entire cone-shaped surface at the cutting end of the tool.
- **Dead Centre:** The sharp edge at the extreme tip end of the drill is formed by the intersection of the cone-shaped surfaces of the point. The dead center is always at the exact center of the axis of the drill.
- **Lips**: The main cutting edges of the drill are formed by the intersection of the flank and the flute surfaces.
- **Face:** The flute surface portion adjacent to the lip. Chip flows over this surface.
- **Flank:** Drill surface which extends behind the lip to flute.

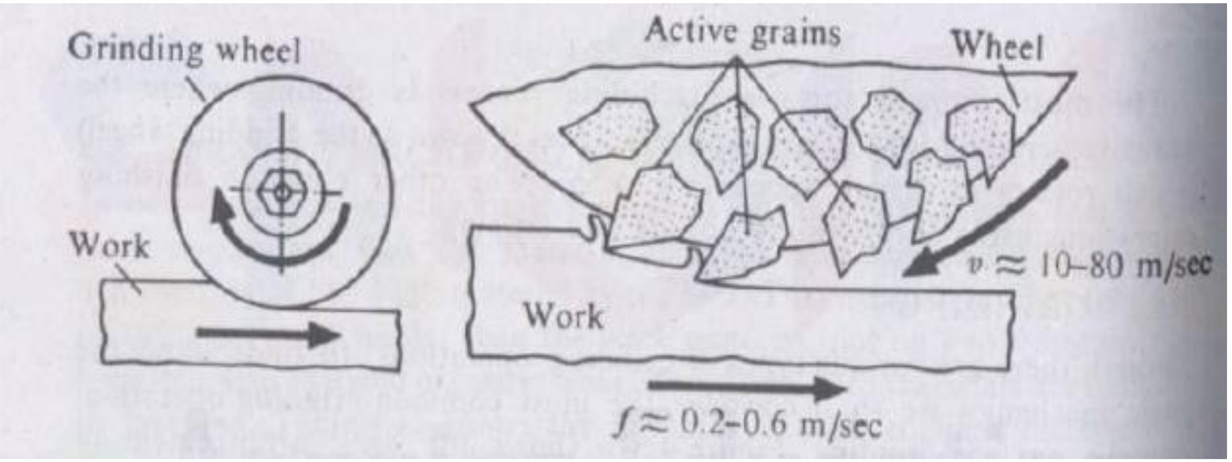
- **Web thickness:** The web thickness is the measure for the stability of the twist drill. Twist drills with thick web have higher stability and suitable for higher torques and harder materials.
- **Body clearance:** To provide diameter clearance the body surface diameter is reduced.
- **Chisel edge**: The chisel edge is the point. Here two cutting lips meet at extreme tip.
- **Chisel edge Angle:** The chisel edge angle is the angle between the chisel edge and cutting lip measured plane normal to the axis.
- **Point angle:** The point angle is located in the head of the twist drill, which is measured between the two main cutting edges at the top. To center the twist drill in the material is the function of the point angle. Generally, 118 degree point angle is suitable for general steel, while 135 degree point angle is suitable for hard material.
- **Helix angle:** The basic feature of the twist drill is the helix angle. The larger angle is suitable for soft material with a long chip, the smaller angle is suitable for hard cutting material with a short chip. Generally it is 23-38 degree.

Abrasive Machining

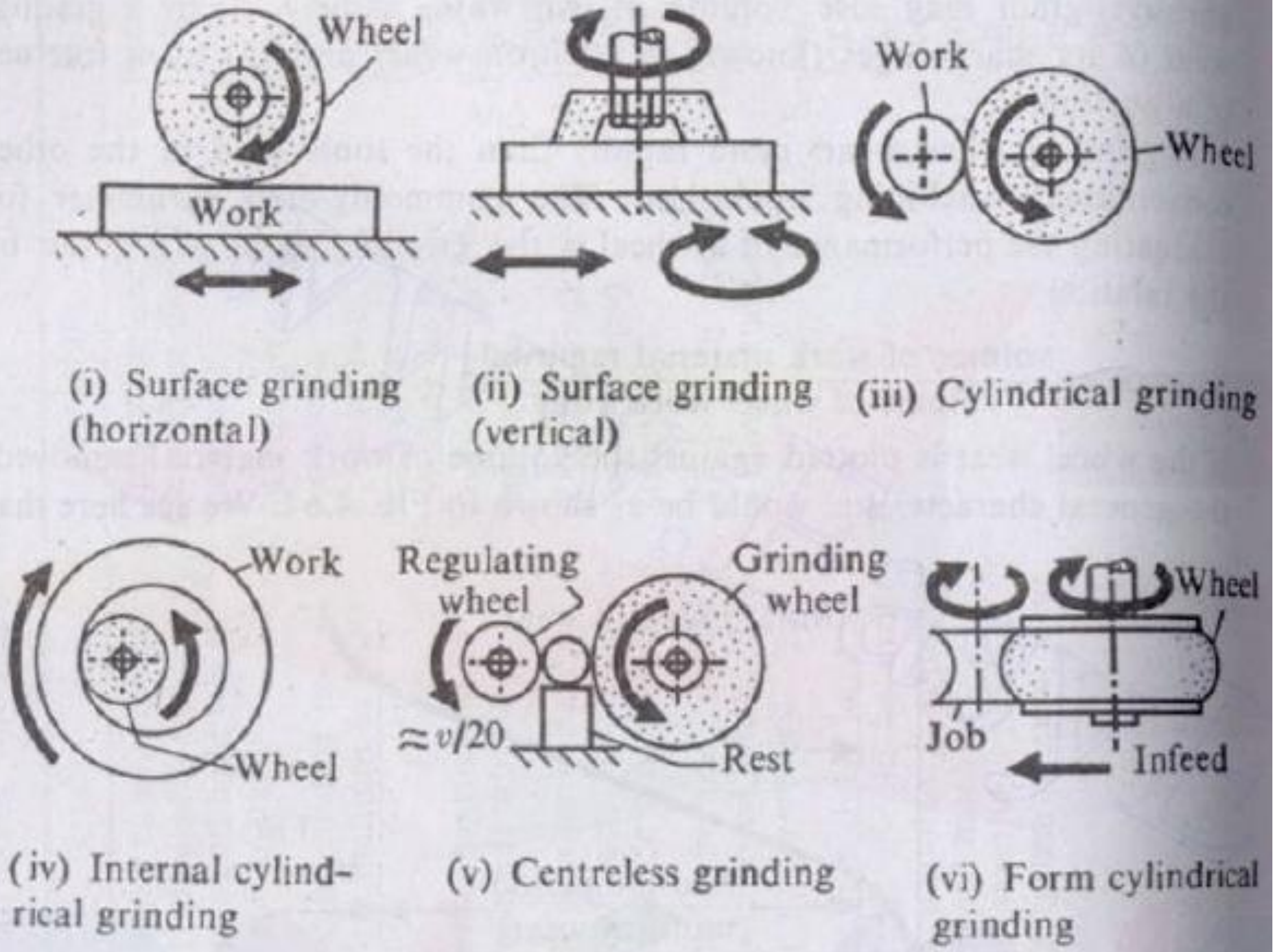
- Hardness of some common materials are given in the table. These include Al_2O_3, SiC, and B_4C as they are naturally available and can also be produced synthetically without much problem. Diamond is also quite suitable but its higher cost restricts its application to special cases.
- It is possible to make use of hard substances as tool materials. However, it is not possible to produce the usual shapes cutting tools with these materials and the only form in which these can be used is grains.
- Since the grains of such materials have the capability to abrade the other materials, these grains are commonly known as abrasives and the machining process using such abrasives is called abrasive machining.
- Abrasives can be used cither as powder or in definite geometric forms obtained by bonding these abrasives with some bonding material.
- The most common abrasive machining process is grinding where the abrasives are bonded to the shape of a wheel (known as the grinding wheel) which rotates at a high speed.

Material	Hardness N/mm^2
Common glass	300–5000
Quartz	8000
Hardened steel	7000–13,000
Emery	14,000
Tungsten carbide	18,000–24,000
Aluminium oxide	20,000–30,000
Titanium carbide	18,000–32,000
Silicon carbide	21,000–30,000
Boron carbide	28,000
Diamond	70,000–80,000

Grinding



- The grains actually taking part in the material removal process are called the active grains.
- Gradually, the sharp edges of the active grains wear out and become blunt. This results in larger forces on the active grains during machining.
- When the cutting edge is too blunt and the force is sufficiently high, the grain may either get fractured or break away from the wheel. When a fracture takes place, new, sharp cutting edges are generated, and when the whole grain is removed, new grains become exposed and active. This gives the grinding wheel self-sharpening characteristics.
- The bonding strength, which dictates the maximum force a grain can withstand, is an important characteristic. The strength of bonding is normally termed as the **grade of wheel.** Wheel with a strong bond is called hard and vice versa.
- Due to the nature of the process, very hot and small chips are produced which may readily get welded to either the grit (abrasive grain) or back on to the workpiece. Moreover, because of random grit orientation, a number of grits may have a very large negative rake angle and may rub rather than cut. These two factors make the of grinding quite inefficient in comparison with the other machining operations from the point of view of specific energy.



Types of grinding operations.

Grinding Wheel Characteristics: Performance of a grinding wheel depends on the following important factors:

- **Abrasive type:**
  - The abrasives generally used are aluminum oxide, silicon carbide, and diamond.
  - Diamond is the hardest and is used for very hard work materials such as glass, carbide, and ceramics.
  - Aluminum oxide and silicon carbide are more commonly used for making the grinding wheels. Silicon carbide is harder than aluminum oxide but dulls more rapidly.
  - Generally, aluminum oxide abrasives are selected for the surface grinding of steels and bronzes, whereas silicon carbide is chosen for the surface grinding of cast iron, brass, aluminum, hard alloys, and carbides.
- **Grain size:**
  - Grain size is generally specified by the grit size. A 60 grit size, for example, is approximately 1/60 inch square.
  - The larger the size of the grains, the more will be the material removal capacity, but the quality of the surface finish deteriorates. Thus, the grain size is determined primarily by the surface quality requirements.

- **Bonding material:**
  - The bond materials commonly used are vitrified clay, resinoid materials, silicates, rubber, shellac, and metals.
  - The vitrified bond is strong and rigid. It is the most common type of bond used.
  - The resin bonds are made from synthetic organic materials. Such bonds are strong and fairly flexible.
  - The silicate bonds are essentially the silicates of soda. These bonds are not as strong as the vitrified bonds, and the grains are dislodged more rapidly. As a result, the operation is cooler. Such bonds are used in grinding tools where the temperature rise should be as small as possible.
  - The rubber bonds are used for making flexible wheels. A high speed operation is possible with a rubber bond wheel when the wheel is subjected to a side thrust. A fairly hard vulcanized rubber is used as the bonding material.
  - The shellac bonds are used in making thin but strong wheels possessing some elasticity. Smooth finish on a hard surface can be achieved with the shellac bonded wheel.

- **Structure:**
  - Since the grinding wheel is similar to a milling cutter with a very large number of teeth randomly oriented, it must have voids to allow space for the chips.
  - If the voids are too small for the chips, the chips stay in the wheel, blocking the voids. This is known as wheel loading of the wheel. Loading causes inefficient cutting.
  - If the voids are too large, again the cutting action is inefficient since there will be too few cutting edges.
  - In an open structure, the grains are not too densely packed. And in a wheel with a closed structure, the grains are tightly packed.
  - For grinding ductile work materials, larger chips are produced, and to reduce the tendency of loading, an open structure is preferred. In the case of hard and brittle work materials, a closed structure is selected.
  - The structure depends on the required grade and also the nature of cut. For a rough cut, an open structure is more suitable.

- **Grade:**
  - The grade is determined by the strength of the bonding material.
  - So, a hard wheel means strong bonding and the abrasive grains can withstand large forces without getting dislodged from the wheel. In the case of a soft wheel, the situation is just the opposite.
  - When the work material is hard, the grains wear out easily and sharpness of the cutting edges is quickly lost. This is known as glazing of the wheel. A glazed wheel cuts less and rubs more, making the process inefficient.
  - To avoid this problem, a soft wheel should be used so that the grains which lose the sharpness get easily dislodged as the machining force on the individual grains increases. Thus, the layers of new grains are exposed, maintaining the sharpness of the wheel.
  - When the work material is soft, a hard wheel should be used since the problem of glazing will be absent and a longer wheel life will be achieved.
  - So, for a work material, there exists an optimal grade—too hard a wheel causes glazing, whereas too soft a wheel wears out very fast.