SYNERGY INSTITUTE OF ENGINEERING & TECHNOLOGY
Department of Mechanical Engineering
LECTURE NOTE (Academic Session 2023-2024)

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Name of Subject : Machining Science and Technology

THEORY OF METAL CUTTING

Process Of Metal Shaping.

Process Of Metal Shaping Is Classified Into Two Types Namely.

i. Non-Cutting Shaping Process
ii. Cutting Shaping Process

Non-Cutting Shaping Process.

The Metal Is Shaped Under The Action Of Force, Heating Or Both. Since There Is No Cutting Of Metal, Chip Formation Will Not Be There. So, It Is Called Non-Cutting Shaping Process.

Cutting Shaping Process.

The Required Shape Of Metal Is Obtained By Removing The Unwanted Material From The Work Piece In The Form Of Chips Is Called Cutting Shaping Process. Example: Turning, Drilling, Milling, Boring Etc.

Machinability Of Metal.

Machinability Is Defined As The Ease With Which A Material Can Be Satisfactorily Machined.

The Factors Affecting The Machinability

a. Chemical Composition Of Work Piece Material.
b. Microstructure Of Work Piece Material
c. Mechanical Properties Like Ductility, Toughness Etc.
d. Physical Properties Of Work Materials.
e. Method Of Production Of The Work Materials.

The Tool Variables Affecting The Machinability

a. Tool Geometry And Tool Material
b. Nature Of Engagement Of Toll With The Work
c. Rigidity Of Tool

The Machine Variables Affecting The Machinability

a. Rigidity Of Machine
b. Power And Accuracy Of The Machine Tool

Machinability Evaluated

The Following Criteria Are Suggested For Evaluating Machinability:

a. Tool Life Per Grind
b. Rate Of Removal Per Tool Grind
c. Magnitude Of Cutting Forces And Power Consumption
d. Surface Finish
e. Dimensional Stability Of Finished Work

f. Heat Generated During Cutting
g. Ease Of Chip Disposal
h. Chip Hardness, Shape And Size

Advantage Of High Machinability.

a. Good Surface Finish Can Be Produced.
b. High Cutting Speed Can Be Used
c. Less Power Consumption
d. Metal Removal Rate Is High
e. Less Tool Wear.

Machinability Index

It Is A Composition Of Machinability Of Different Material To Standard Materials. US Material Standard For 100% Machinability Is SAE 1112 Hot Rolled Steel.

Relative Motion Between Work Piece And Cutting Tool.

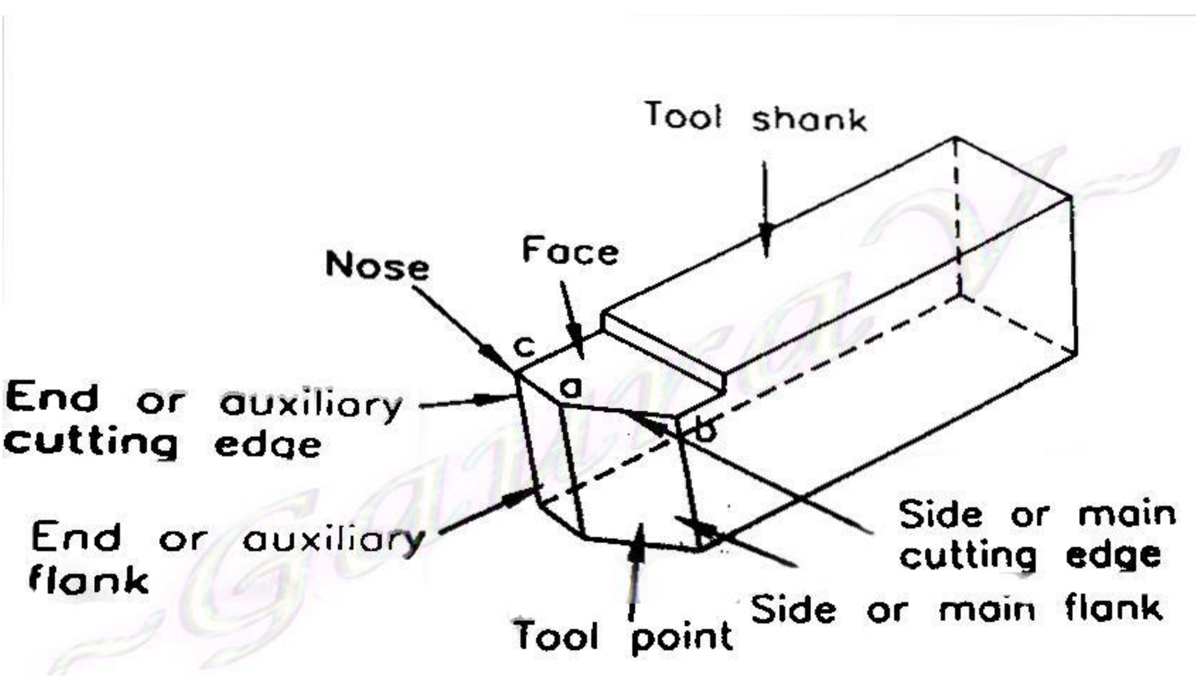
i. Rotation Of Work Against The Tool. Example: Turning
ii. Rotation Of Tool Against Work Piece. Example: Drilling, Milling.
iii. Linear Movement Of The Work Piece Against The Tool Example: Planer.
iv. Linear Movement Of The Tool Against The Work. Example – Shaper

The Different Types Of Cutting Tool

a. Single Point Cutting Tool.
b. Multiple Point Cutting Tool.

The Various Parts of Single Point Cutting Tool.

1. Shank

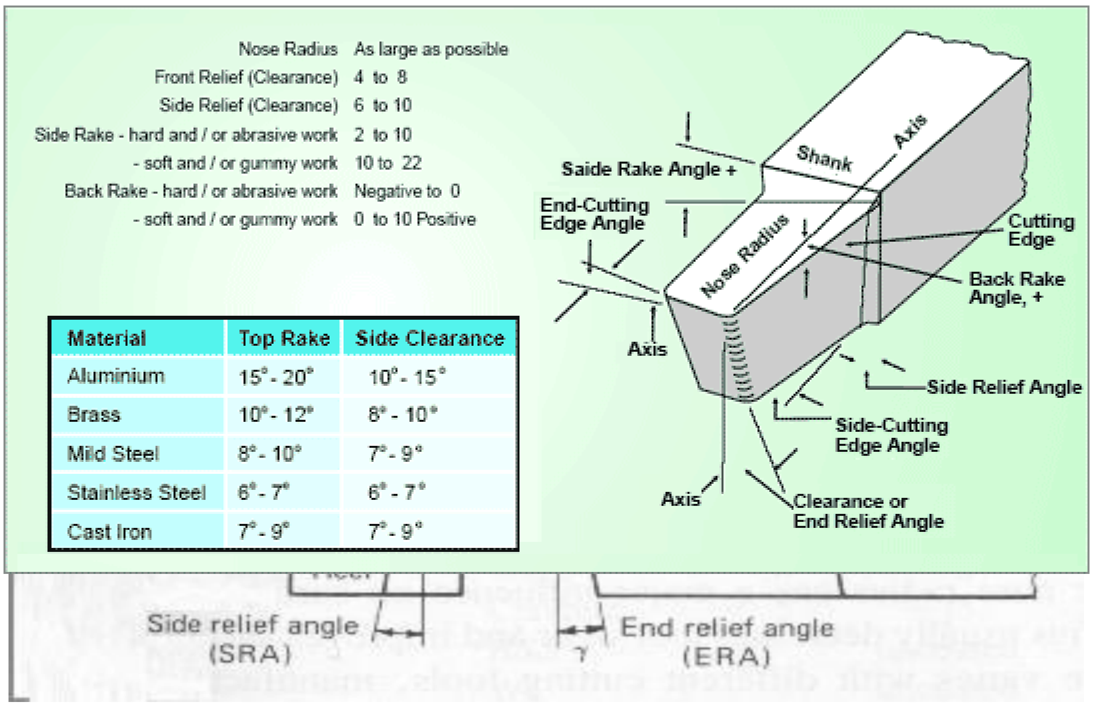


2. Face 3. Flank
4. Base 5. Nose 6. Cutting Edge

The Various Angles In Cutting Tool.

1. Back Rake Angle 2. Side Rake Angle
3. End Relief Angle 4. Side Relief Angle
5. Side Cutting Angle 6. End Cutting Angle.

The Effect Of Back Rake Angle And Mention The Types



Material	Top Rake	Side Clearance
Aluminium	15°- 20°	10°- 15°
Brass	10°- 12°	8°- 10°
Mild Steel	8°- 10°	7°- 9°
Stainless Steel	6°- 7°	6°- 7°
Cast Iron	7°- 9°	7°- 9°

Back Rake Angle Increases The Strength Of Cutting Tool And Cutting Action.

It Is Classified Into Two Types:

1. Positive Rake Angle
2. Negative Rake Angle

Side Rake Angle And Mention Its Effects

The Angle Between The Tool Face And The Line Parallel To The Base Of The Tool Is Known As Side Rake Angle. It Is Used To Control Chip Flow.

Clearance Angle And Mention The Types

These Are The Slopes Ground Downwards From The Cutting Edges. The Clearance Angle Can Be Classified Into Two Types.

i. Side Relief Angle.
ii. End Relief Angle.

The Nose Radius.

It Is The Joining Of Side And End Cutting Edges By Means Of Small Radius In Order To Increase The Tool Life And Better Surface Finish On The Work Piece.

All Conditions For Using Positive Rake Angle

a. To Machine The Work Hardened Materials.
b. To Machine Low Strength Ferrous And Non-Ferrous Metals.

c. To Turn The Long Shaft Of Small Diameters.
d. To Machine The Metal Below Recommended Cutting Speeds.
e. To Machine The Workpiece Using Small Machine Tools With Low Horsepower.

The Negative Rake Angles

a. To Machine High Strength Alloys.
b. The Machine Tools Are More Rigid.
c. The Feed Rates Are High.
d. To Give Heavy And Interrupted Cuts.

Types Of Metal Cutting Process.

The Metal Cutting Processes Are Mainly Classified Into Two Types.

a. Orthogonal Cutting Process(Two Dimensional Cutting)
b. Oblique Cutting Process (Three Dimensional Cutting)

Orthogonal And Oblique Cutting.

Orthogonal Cutting: The Cutting Edge Of Tool Is Perpendicular To The Workpiece Axis.

Oblique Cutting: The Cutting Edge Is Inclined At An Acute Angle With Normal To The Cutting Velocity Vector Is Called Oblique Cutting Process.

Shear Plane

The Material Of Work Piece Is Stressed Beyond Its Yield Point Under The Compressive Force. This Causes The Material To Deform Plastically And Shear Off. The Plastic Flow Takes Place In A Localized Region Called Shear Plane.

CUTTING FORCES IN METAL CUTTING.

- **We need to determine the cutting forces in turning for**

Estimation of cutting power consumption, which also enables selection of the power source(s) during design of the machine tools
Structural design of the machine – fixture – tool system

- **Evaluation of role of the various machining parameters (tool material and geometry, environment – cutting fluid) on cutting forces**

- **Study of behaviour and machinability characterisation of the work materials**

- **Condition monitoring of the cutting tools and machine tools.**

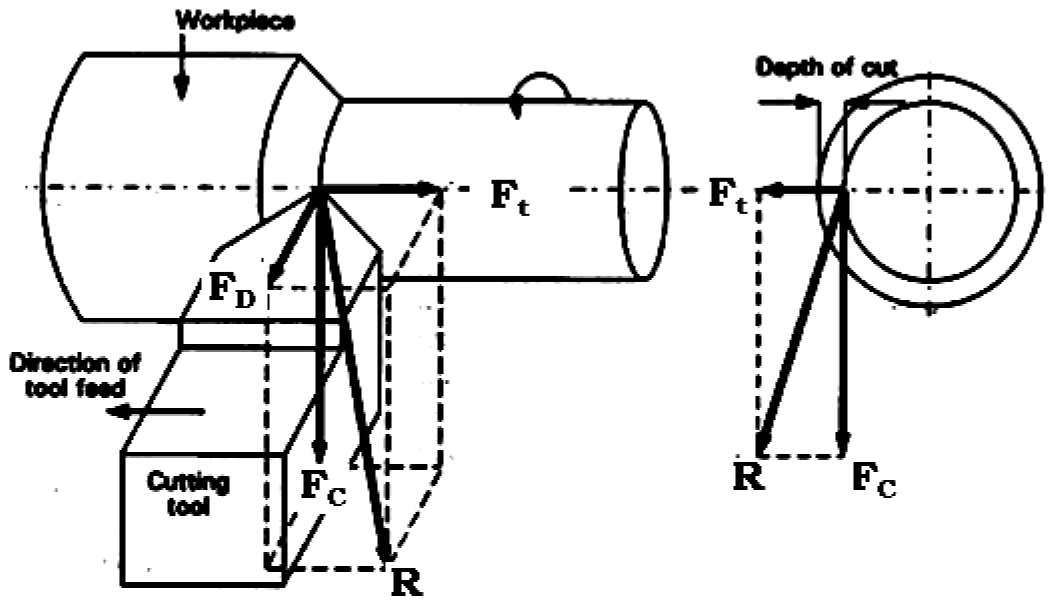


Fig.1: Cutting forces in a turning operation

In orthogonal cutting, the resultant force R applied tothe chip by tool lies in a plane normal to the tool cutting edge. This force is usually determined in experimental work, from the measurement of two orthogonal components: one in direction of cutting (known as cutting force F c), the other normal to the direction of cutting (known as thrust force F t). Figure 1 shows all components of forces in turning operation.

Significance of F c, Fd , and F t

F c : called the main or major component as it is the largest in magnitude. It is also called power component as it being acting along and being multiplied by V c decides cutting power (F c .V c) consumption.

F d : may not be that large in magnitude but is responsible for causing dimensional inaccuracy and vibration.

F t : It, even if larger than F D is least harmful and hence least significant.

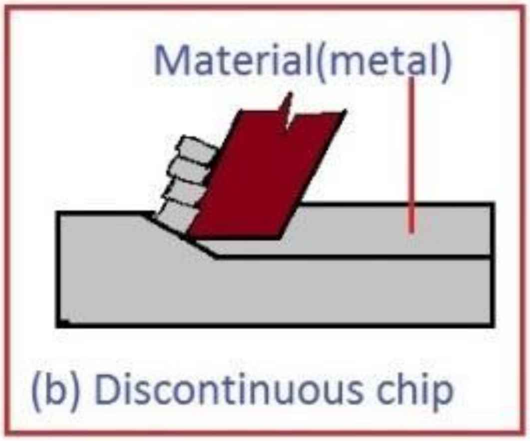
Chip And Its Different Types

The Sheared Material Begins To Flow Along The Cutting Tool Face In The Form Of Small Pieces Is Called Chip. Chips Are Mainly Classified Into Three Types:

Discontinuous Chip
Continuous Chip
Continuous Chip With Built Up Edge.

Types Of Chips :- Every machining operation involves the formation of chips. The chip is formed by deformation of the metal lying ahead of the cutting edge by a process of shear. The chips produced during machining of various metals can be broadly classified into the following three types.

Discontinuous or segmental chip



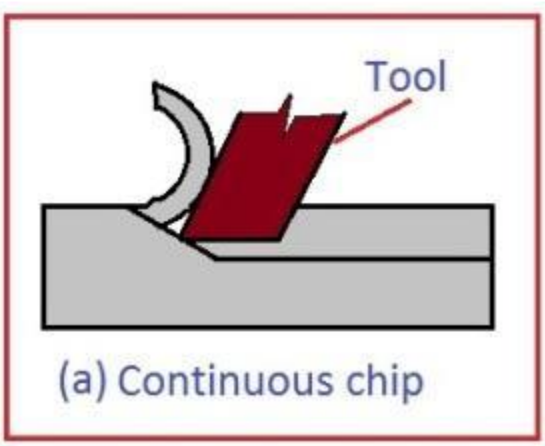
The Favourable Factors For Discontinuous Chip Formation

a. Machining Of Brittle Material
b. Small Rake Angle
c. Higher Depth Of Cut
d. Low Cutting Speeds
e. Excess Cutting Fluid
f. Cutting Ductile Material With Low Speed And Small Rake Angle Of The Tool

This type of chips are produced during machining of hard and brittle metals like bronze, brass and cast-iron. Sometimes, cutting of ductile metals at very low feeds with small rake angle of the cutting tool and high speeds and high friction forces at the chip tool interface also result in the production of discontinuous chips. Discontinuous chips in ductile materials are formed when the hydrostatic pressure near the cutting edge is tensile or the shear energy reaches a critical value. The formation of this type of chip in brittle materials imparts good finish, increases tool life and consumes less power. Presence of discontinuous chips in ductile-materials results in poor-finish and excessive tool-wear. Smaller chips are easier to dispose off.

If discontinuous chips are produced from the brittle materials, then surface finish is fair, power consumption is low and tool life is reasonable. However when these are produced with ductile materials, then finish is poor and tool wear is excessive. Other factors responsible for promoting the production of Discontinuous Chips are smaller rake angle on the tool and too much depth of cut.

Continuous Chip

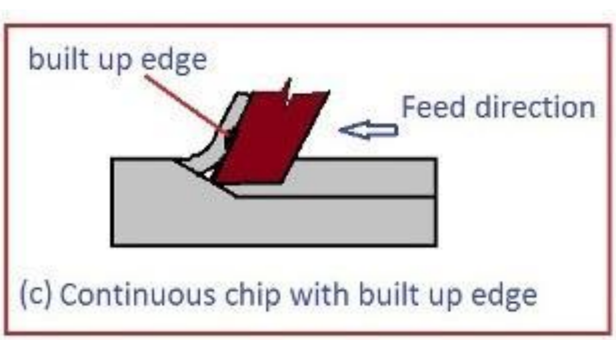


The Following Factors Favour The Formation Of Continuous Chip.
I. Ductile Material Ii. Smaller Depth Of Cut
Iii. High Cutting Speed Iv. Large Rake Angle
V. Sharp Cutting Edge Vi. Proper Cutting Fluid
Vii. Low Friction Between Tool Face And Chips.

As the name itself implies it is continuous, means the presence of separated segmental elements is totally eliminated in this case. This type of chip is produced while machining a ductile material, like mild steel, under favourable cutting condition such as high cutting speed and minimum friction between the chip and the tool face. Otherwise, it will break and form the segmental chip. The friction at the chip-tool interface can be minimised by polishing the tool face and adequate use of coolant. Also, with diamond tool the friction is less. The basis of the production of a continuous chip is the continuous plastic deformation of the metal ahead of the tool, the chip moving smoothly up the tool face.

Sometimes, continous chips are produced at low cutting speed if effective cutting fluid is used because this type of chip is associated with low friction between the chip and the tool. Since finish is best, power consumption is low and tool life high with this type of chip, this is most preferred type. Other factors responsible for promoting its production are bigger Rake angle, finer Feed and Keen cutting edge of the tool.

Continuous chip with built up edge



The Favourable Factors For Continuous Chip With Built Up Edge

i. Low Cutting Speed
j. Small Rake Angle
k. Coarse Feed
l. Strong Adhesion Between Chip And Tool Face.
m. Insufficient Cutting Fluid
n. Large Uncut Thickness

This type of chip is very similar to that of continuous type, with the difference that it is not as smooth as the previous one. This type of chip is obtained by machining ductile material, When high friction exists at the chip tool interface. The upward flowing chip exerts pressure on the tool face. The normal reaction Nr of the chip on the tool face is quite high, and is maximum at the cutting edge or nose of the tool. This gives rise to an excessively high temperature and the compressed metal adjacent to the tool nose get welded to it. The chip is also sufficiently hot and gets oxidised as it comes off the tool and turns blue in colour. The extra metal welded to the nose or point of the tool is called Built up Edge. This metal is highly strain hardened and brittle. With the result, as the chip flows up the tool, the Built-up edge is broken and carried away with the chip while the rest of it adheres to the surface of the workpiece, making it rough. Due to the Built-up-Edge the rake angle is also alterned and so is the cutting force. The common factors responsible for promoting the formation of Build-up Edge are low cutting speed, excessive feed, small rake angle lack of lubricant.

The Purposes Of Chip Breakers

The Chip Breakers Are Used To Break The Chips Into Small Pieces For Removal, Safety And To Prevent Both The Machine And Work Damage.

The Difficulties Involved Due To Long And Continuous Chip

During Machining, Long And Continuous Chip That Are Formed At High Cutting Speed Will Affect Machining. It Will Spoil Tool, Work And Machine. These Chips Are Hard, Sharp And Hot. It Will Be Difficult To Remove Metal And Also Dangerous To Safety.

Tool Signature

The Various Angles Of Tools Are Mentioned In A Numerical Number In Particular Order. That Order Is Known As Tool Signature.

Chip Thickness Ratio

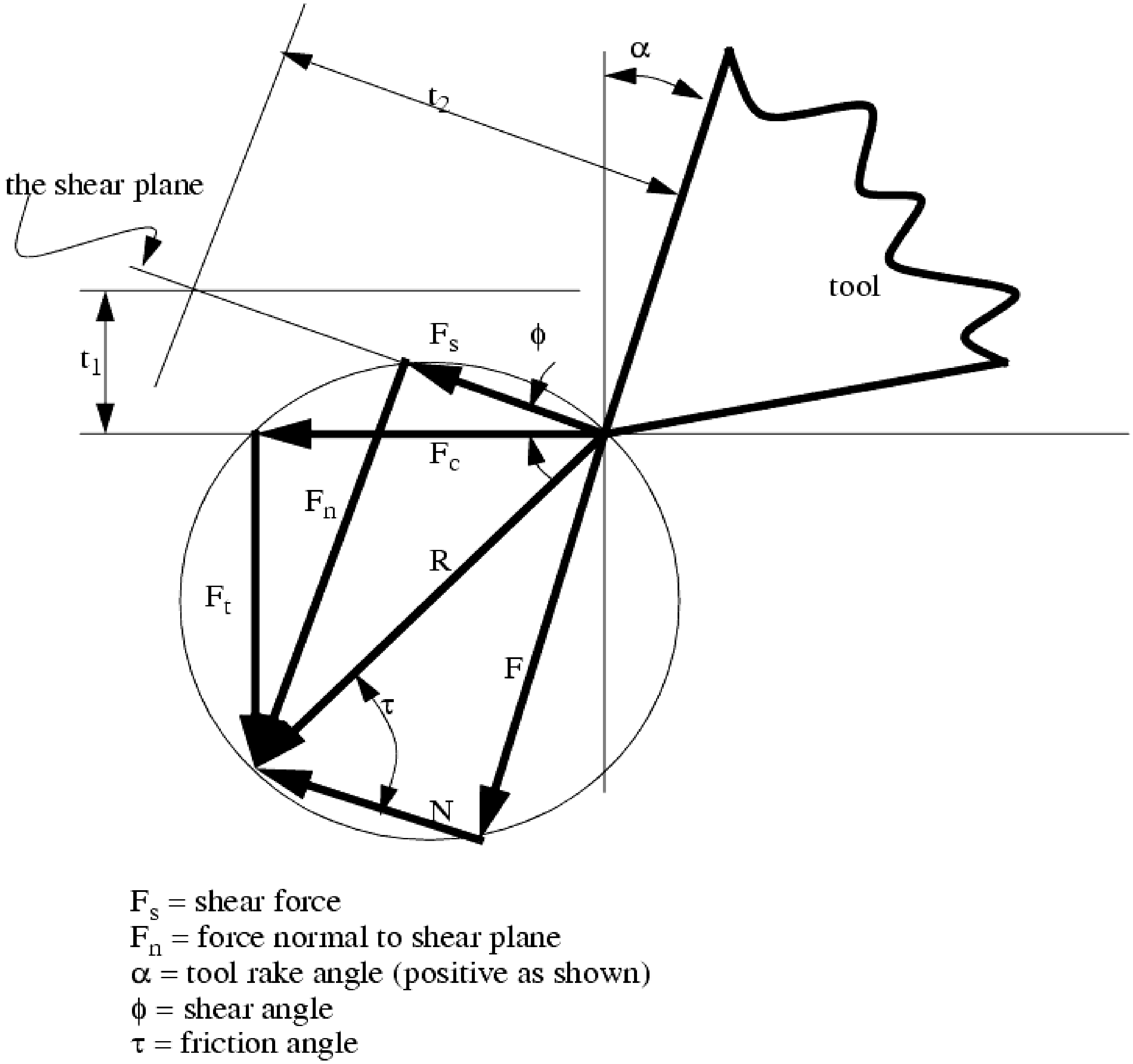
The Ratio Of Chip Thickness Before Cutting To Chip Thickness After Cutting Is Called Chip Thickness Ratio.

Chip Reduction Co-Efficient

The Reciprocal Of Chip Thickness Ratio Is Called Chip Reduction Co-Efficient.

The Assumption Made In Merchant Circle

a. The Chip Formation Will Be Continuous Without Built Up Edge.
b. During Cutting Process, Cutting Velocity Remains Constant.
c. The Cutting Tool Has A Sharp Cutting Edge So That It Does Not Make Flank
d. Contact To The Work Piece.



PROBLEMS:

1. A Mild Steel Work Piece Of 60mm Diameter Is To Be Turned With An Orthogonal Tool To A Feed Rate Of 0.92 Mm/Revolution And At 75 Rpm. If The Chip Thickness Is 2mm, Determine The Chip Thickness Ratio And Length Of Chip Removed In One Minute. Assume A Condition Of Continuous Chip.

Given Data:

$D = 60mm$
$T_1 = 0.92mm$
$T_2 = 2mm$
$N = 75rpm$

To Find:

i. Chip Thickness Ratio R

ii. Length Of Chip Removed Per Minute

Solution:

Chip Thickness Ratio,

$r = \frac{t_1}{t_2} = \frac{0.92}{2} = 0.46mm$ Ans.

$Length$ of chip before cutting, $l_1 = \pi DN$

$= \pi \times 60 \times 75 = 14137.16mm$

We know that, chip thickness ratio = r = $\frac{l_2}{l_1}$

$0.46 = \frac{l_2}{14137.16} = l_2 = 6503mm$ Ans.

Result:

1. Chip thickness ratio, r = 0.46
2. Length of chip removed per minute, $l_2 = 6503mm$

2. During An Orthogonal Cutting A Chip Length Of 160mm Was Obtained From An Uncut Length Of 350mm. The Cutting Tool Has 22^0 Rake Angle And A Depth Of Cut Is 0.8mm. Determine The Shear Plane Angle And Chip Thickness

Given Data:

$l_2 = 160mm$

$l_1 = 350mm$

$\alpha = 22^o$

$t_1 = 0.8mm$

To find:

1. Shear plane angle (β)

2.$Chipthickness(t_2)$

Solution:

$Chip$ thickness ratio, r = $\frac{l_2}{l_1} = \frac{160}{350} = 0.457$

$Shear$ plane angle β= $\tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right]$

$= \tan^{-1}\left[\frac{0.457\times\cos 22}{1-0.457\times\sin 22}\right]$

$\beta = 27^0$ Ans.

We know that, chip thickness

$r = \frac{t_1}{t_2}$

$0.457 = \frac{0.8}{t_2}$

$t_2 = 1.75mm$ Ans.

Result:

1. Shear plane angle, $\beta = 27^o$

2. $Chipthicknes, t_2 = 1.75mm$

3. In Orthogonal Cutting Process The Following Observations Were Made
Depth Of Cut = 0.25mm
Chip Thickness Ratio = 0.45
Width Of Cut = 4mm
Cutting Velocity = 40m/Min

Cutting Force Component Parallel To Cutting Velocity Vector = 1150N
Cutting Force Component Normal To Cutting Velocity Vector = 140N
Rake Angle = 18^0
Determine Resultant Cutting Force, Power Of Cutting, Shear Plane Angle, Friction Angle And Force Component Parallel To Shear Plane

Given Data:

$t_1 = 0.25mm$

$r = 0.45mm$

$b = 4mm$

$V = 40m/\min$

$F_z = 1150N$

$F_x = 140N$

$\alpha = 18^o$

To find:

F, power of cutting, β, γ, and F_s

Solution:

Re*sulting* cutting forces, F = $\sqrt{F_z^2 + F_x^2} = \sqrt{1150^2 + 140^2}$

F = 1158.49N Ans.

Power of cutting forces, P = $F_x \times V = 1150 \times 40$

= 46000Nm/min Ans.

Shear angle, $\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1 - r\sin\alpha}\right]$

$$\beta = \tan^{-1}\left[\frac{0.45 \times \cos 18}{1 - 0.45 \times \sin 18}\right]$$

$\beta = 26.5^o$ Ans.

$$Friction\ \text{angle}, \gamma = \tan^{-1}\left[\frac{F_x + F_z \tan\alpha}{F_z - F_x \tan\alpha}\right]$$

$$\gamma = \tan^{-1}\left[\frac{140 + 1150\tan 18}{1150 - 140\tan 18}\right]$$

$$\gamma = 25^o \qquad \text{Ans}$$

$$\text{Shear force, } F_s = F_z \cos\beta - F_x \sin\beta$$

$$= 1150\cos 26.5^o - 140\sin 26.5^o$$

$$F_s = 966.7N \qquad \text{Ans.}$$

Result:

1. $\text{Re}\,sul\tan t$ cutting force = 11584.9N
2. Power of cutting force = 46000Nm/min
3. Shear plane angle, β=26.5°
4. $Friction\ Angle, \gamma = 25^o$
5. $Shearforce, F_s = 966.7N$

4. A Seamless Tube 32mm Outside Diameter Is Turned On A Lathe. Cutting Velocity Of The Tool Relative To The Work Piece Is 10m/Min. Rake Angle = 35⁰, Depth Of Cut = 0.125m, Length Of Chip = 60mm, Horizontal Cutting Force Of The Tool On The Work Piece = 200N. Cutting Force Required To Hold The Tool Against The Work Piece = 80N. Calculate

- **i. Co-Efficient Of Friction**
- **ii. Chip Thickness Ratio**
- **iii. Shear Plane Angle**
- **iv. Velocity Relative To The Tool, And**
- **v. Velocity Of Chip Relative To The Work Piece**

Given Data:

D = 32mm

V = 10m/Min

□= 35^0

T_1 = 0.125mm

L_2 = 60mm

F_z = 200N

F_x = 80N

To Find:

□, □, R, V_c, And V_s

Solution:

$$1.\ \text{Co-efficient of friction, } \mu = \left[\frac{F_x + F_z \tan\alpha}{F_z - F_x \tan\alpha}\right]$$

$$= \left[\frac{80+200\tan 35}{200 - 80\tan 35}\right]$$

$$\mu = 1.528 \qquad \text{Ans.}$$

$$2.Chip\ \text{thickness ratio,} \quad r = \frac{l_2}{l_1} = \frac{60}{\pi \times D} = \frac{60}{\pi \times 32}$$

$$r = 0.5969 \qquad \text{Ans.}$$

3. Shear plane angle, $\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right]$

$$\beta = \tan^{-1}\left[\frac{0.5968\cos 35}{1-0.5968\sin 35}\right] = 36.6^o$$

4. *Velocity* of chip relative to the tool,

$V_c = V.r = 10\times 0.5968 = 5.968 m/\min$

5. Velocity of chip relative to the work piece,

$$V_s = \frac{V\cos\alpha}{\cos(\beta-\alpha)} = \frac{10\times\cos 35}{\cos(36.6-35)}$$

$V_s = 8.19 m/\min$ Ans

Result:

1. *Co – efficient* of friction, μ=1.528
2. Chip thickness ratio, r = 0.5968
3. Shear plane angle, β=36.6^0
4. *Velocity* of chip relative to the tool, $V_c = 5.968 m/\min$
5. *Velocity of chip relative to the* work piece, $V_s = 8{,}19 m/\min$

5. The Following Data From The Orthogonal Cutting Test Is Available
Rake Angle = 10^0
Chip Thickness Ratio = 0.35
Uncut Chip Thickness = 0.51mm
Width Of Cut = 3mm
Yield Shear Stress Of Work Material = 285N/Mm^2
Mean Friction Coefficient On Tool Face = 0.65
Determine The (I) Cutting Force (Ii) Radial Force
(Iii) Normal Force On The Tool And (Iv) Shear Force On The Tool. [IES–2000]
Given Data:

α = 10^o

$r = 0.35$

$t_1 = 0.51 mm$

$b = 3 mm$

τ = 285N/mm^2

μ = 0.65

To Find:
F_z, F_x, N And F_s

Solution:

$$Shear\ \text{angle},\ \beta = \tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right]$$

$$= \tan^{-1}\left[\frac{0.35\cos 10}{1-0.35\sin 10}\right]$$

$$\beta = 20^0$$

$$\mu = \tan\gamma$$

$$\text{Friction angle, } \gamma = \tan^{-1}\mu = \tan^{-1}[0.65] = 33$$

$$To\ \text{find shear stress, } \tau = \frac{F_s}{A_1} Sin\beta$$

$$F_s = \frac{\tau \times A_1}{\sin\beta} = \frac{285 \times 0.51 \times 3}{\sin 20}$$

$$[\because A_1 = 3 \times 0.51]$$

$$F_s = 1274.92N \qquad \text{Ans.}$$

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

$$F = \frac{F_s}{\cos(\beta+\gamma-\alpha)} = \frac{1274.92}{\cos(20+33-10)}$$

$$F = 1743.23N$$

$$Cutting\ force,\ F_s = F\cos.(\gamma-\alpha)$$

$$= 1743.23\cos(33-10)$$

$$F_z = 1604.6N \qquad \text{Ans}$$

$$F = \sqrt{F_z^2 + F_x^2}$$

$$\therefore Radial\ \text{force, } F_x = \sqrt{F^2 - F_z^2} = \sqrt{1743.23^2 - 1604.6^2}$$

$$F_x = 681.1N \qquad \text{Ans.}$$

Normal force on the tool,

$$N = F_z\cos\alpha - F_x\sin\alpha$$

$$= 1604.6 \times \cos 10 - 681.1 \times \sin 10$$

N=1461.9N Ans.

$Re\,sult$:

1. Shear force, $F_s = 1274.92N$
2. Cutting force, $F_z = 1604.6N$
3. *Radial* force, $F_x = 681.1N$
4. *Normal* force on the tool,N = 1461.9N

6. The Following Observations Are Made From A Metal Cutting Test

Cutting Force	**=**	**180kg**
Feed	**=**	**5 Cuts/Min**
Depth Of Cut	**=**	**5mm**
Cutting Speed	**=**	**30mm/Min**

If Overall Efficiency Of Machine Is 70% Determine

i. **Normal Pressure On Chip**

ii. Power Required At Motor.

Given Data:

$F_z = 180kg$

$t_1 = 5mm$

$V = 30mm/\min$ and η = 70%

To Find:

i. Normal Pressure On Chip

ii. Power Required

Solution:

$$i.\text{ Normal pressure on chip} = \frac{\text{F}_\text{z}}{\text{Area of chip}}$$

$$Area\text{ of chip} = \text{Depth of cut} \times \text{feed/rev}$$

$$= 5 \times \frac{1}{5} = 1mm^2$$

$$Normal\text{ pressure} = \frac{180}{1} = 180kg/mm^2 \quad \text{Ans.}$$

$$ii.Power\text{ required, P} = \frac{\text{F}_\text{z} \times V}{4500} = \frac{180 \times 30}{4500} = 1.2H.P$$

When efficiency of machine is 70% power required

$$\text{at motor} = \frac{1.2}{0.7} = 1.7H.P \quad \text{Ans.}$$

Result:

i. Normal pressure on chip = $180kg/mm^2$

ii.Power required at motor = 1.7H.P

7. In An Orthogonal Cutting Experiment With A Tool Of Rake Angle □ = 7^0, The Chip Thickness Was Found To Be 2.5mm When The Uncut Chip Thickness Was Set To 1mm.

i. **Find The Shear Angle, □**

ii. **Find The Friction Angle □ Assuming That Merchant's Formula Holds Good.**

Given Data:

$\alpha = 7^0$

$t_2 = 2.5$

$t_1 = 1mm$

To find:

β and γ

Solution:

$$i.Shear\text{ angle, } \beta = \tan^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

Where, r - Chip thickness ration = $\frac{t_1}{t_2}$

$= \frac{1}{2.5} = 0.4$

$= \tan^{-1}\left[\frac{0.4\cos 7}{1-0.4\sin 7}\right]$

$= \beta = 22.6^0$ Ans.

ii. As per Merchant's theory, $2\beta + \gamma - \alpha = \frac{\pi}{2}$

$2\times 22.6 + \gamma - 7 = 90^0$

Friction angle, $\gamma = 51.69^0$ Ans.

Result:

i. Shear angle β = 22.6^o

ii.Friction angle, γ = 51.69^o

8. If The Relationship For H.S.S Tools Is $VT^{1/8} = C_1$ And For Tungsten Carbide Tools Is $VT^{1/5} = C_2$ And Assuming That At A Speed Of 25m/Min, The Tool Life Was 3 Hours In Each Case, Compare Their Cutting Lives At 32m/Min.

Given Data:

$VT^{1/8} = C_1$ ......(1)

$VT^{1/5} = C_2$ ......(2)

$V = 25 m/\min$

$T = 3 hrs = 180 \min$

$V' = 32 m/\min$

To Find:

Compare Cutting Lives At 32m/Min

Solution:

From equation (1)

$VT^{1/8} = C_1$

$25\times(180)^{1/8} = C_1$

$C_1 = 47.846$

From equation (2)

$VT^{1/5} = C_2$

$25\times(180)^{1/5} = C_2$

$C_2 = 70.63$

From equation (1)

$32\times T^{1/8} = 47.846$ $(\because C_1 = 47.846)$

$T = 24.97 \min$

From equation (2)

$32\times T^{1/5} = 70.63$

$T = 52.38 \min$

For 32m/min cutting speed, second equation

i.e. $VT^{1/5} = C_2$ gives better life. Ans.

9. In A Tool Wear Test With High-Speed Steel Cutting Tool, The Following Data Were Recorded.

Tool Life	Cutting Speed
30min	25m/Min
2min	70m/Min

Compute The Taylor's Equation [M.U. Oct '97]

Given Data:

T_1 = 30min

V_1 = 25m/Min

T_2 = 2min

V_2 = 70m/Min

To Find:

Compute The Taylor's Equation.

Solution:

Taylor's Equation Is $Vt^n = C$

$$V_1T_1^n = V_2T_2^n$$

$$25\times 30^n = 2\times 70^n$$

$$\frac{25}{2} = \left(\frac{70}{30}\right)n = (2.333)^n$$

$$n\log(2.333) = \log\left(\frac{25}{2}\right)$$

$$n = 2.98$$

$\therefore Taylor's$ equation is $30\times(25)^{2.98} = 2\times(70)^{2.98}$ Ans.

10. The Following Data From An Orthogonal Cutting Test Is Available

Rank Angle = 15^0

Chip Thickness Ratio = 0.383

Uncut Chip Thickness = 0.5mm

Width Of Cut, B = 3mm

Yield Stress Of Material In Shear = 280 N/Mm^2

Average Coefficient Of Friction On The Tool Face = 0.7

Determine The Normal And Tangential Forces On The Tool Face. [M.U.Oct 95]

Given Data:

$\alpha = 15^o$

$r = 0.383$

$t_1 = 0.5mm$

$b = 3mm$

$\tau = 280N/mm^2$

$\mu = 0.7$

To Find:

Normal Force And Tangential Force

Solution:

$$\beta = \tan^{-1}\left[\frac{r\cos\alpha}{1-r\sin\alpha}\right] = \tan^{-1}\left[\frac{0.383\cos 15}{1-0.383\sin 15}\right]$$

$$\beta = 22.3^o$$

$$Shear\ \text{stress},\ \tau = \frac{\mathrm{F_s}}{\mathrm{A_s}}$$

$$\mathrm{A_s} = \frac{A_1}{\sin\beta} = \frac{bt_1}{\sin\beta}$$

$$A_s = \frac{3\times 0.5}{\sin 22.32} = 3.948mm^2$$

$$280 = \frac{F_s}{3.948}$$

$$F_s = 1105.63N$$

$$\mu = \tan\gamma$$

$$\gamma = \tan^{-1}(\mu) = \tan^{-1}(0.7)$$

$$\gamma = 34.99 \approx 35^o$$

$$F = \frac{F_s}{\cos\theta}$$

$$\theta = \beta + \gamma - \alpha = 22.3 + 35 - 15$$

$$\theta = 42.3^o$$

$$F = \frac{1105.63}{\cos 42.3} = 1494.65N$$

Tangential force or cutting force,

$$\mathrm{F_2} = F\cos(\gamma - \alpha)$$

$$= 1494.65\cos(35\text{-}15)$$

$$F_2 = 1404.5N \qquad \text{Ans.}$$

Normal force or feed force,

$$\mathrm{F_x} = \sqrt{F^2 - F_z^2} \qquad \left(\because \mathrm{F}=\sqrt{\mathrm{F_z^2} - F_x^2}\right)$$

$$= \sqrt{1494.65^2 - 1404.5^2}$$

$$F_x = 511.2N \qquad \text{Ans.}$$

Result:

1. Normal force, $\mathrm{F_x} = 511.2N$

2. *Tangential* force $\mathrm{F_z} = 1404.5N$

LATHES

Lathe

Lathe Is A Machine Which Removes The Metal From A Piece Of Work To The Required And Size.

Hold A Workpiece In A Centre Lathe

Between The Two Centers Of Head Stock And Tail Stock

Swing Diameter

The Largest Diameter Of Work That Will Revolve Without Touching The Bed And Is Twice The High Of The Center Measured From The Bed Of The Lathe.

The Specification Of Typical Lathe

1. The Length Of Bed
2. Maximum Distance Between Dead And Live Centers.
3. Type Of Bed I.E. Straight, Semi Gap Or Gap Type.
4. The Height Of Centers From The Bed
5. Swing Over The Bed
6. Swing Over The Cross-Bed
7. Width Of The Bed
8. Spindle Bore
9. Spindle Speed
10. H.P. Of Main Motor And Rpm
11. Number Of Spindle Speeds
12. Spindle Nose Diameter
13. Feeds
14. Floor Space Required.

The Various Operations Can Be Performed On A Lathe

1. Turning
2. Facing
3. Forming
4. Knurling
5. Chamfering
6. Thread Cutting
7. Drilling
8. Boring
9. Recessing
10. Tapping
11. Grooving Etc.

The Principle Parts Of A Lathe

1. Red
2. Headstock
3. Tailstock
4. Carriage
5. Cross-Slide
6. Tool Post

The Main Requisites Of A Lathe Bed

1. Red 2. Headstock 3. Tailstock
4. Carriage 5. Cross-Slide 6. Too, Post

The Main Requisites Of A Lathe Bed

The Lathe Bed Should Be Very Strong To Withstand Cutting Forces And Vibrations During Machining.
Provisions Are Made To Accommodate Other Parts Of A Lathe On The Bed

Guide Ways

The Uses Of Headstock

1. Headstock Carries A Hollow Spindle With Nose To Hold The Work Piece.
2. To Mount The Driving And Speed Changing Mechanisms.

The Types Of Headstock

1. Back Geared Type 2. All Geared Type

The Name Of The Center Mounted On The Tailstock.

Dead Center

The Main Difference Between Live Center And Dead Center

I. Live Center Drives And Rotates Along With The Work Pieces.
Ii. Dead Center Just Supports The Other End Of The Work Piece.

The Names Of Any Four Lathe Accessories.

Lathe Centres, Catch Plates, Carries, Chucks, Mandrels And Rests.

The Taper Is Formed On The Work Piece By Using Tailstock

The Upper Body Of Tailstock Can Be Moved Towards Or Away From The Operator.

The Position Of A Carriage.

The Carriage Is Mounted In Between Headstock And Tailstock.

The Various Parts Mounted On The Carriage.

a. Saddle

b. Compound Rest
c. Cross Slide
d. Tool Post

The Shape And Position Of Saddle.

H Shaped Component Is Fitted Across The Lathe Bed.

Holes Drilled In A Center Lathe

First, The Dead Center Of The Tailstock Is Replaced By A Drill Bit. The Longitudinal Movement Of The Tailstock Is Locked After Setting The Approach Of Drill. Finally, The Hand Wheel Of The Tailstock Is Rotated For Making The Hole On The Specimen.

Compound Rest

A Member Or Part Which Is Mounted On The Top Of The Cross Slide Having A Base Graduated In Degrees.

For Making Taper Portion Of Bigger Diameter At The Left End On The Given Work Piece. How The Tool Post Is Tilted

For Making Taper Portion Of Bigger Diameter At The Left End, The Tool Post End Should Be Set Towards The Bigger Diameter.

Apron

Apron Is An Integral Part Of Several Gears, Levers And Clutches Which Are Mounted With The Saddle For Moving The Carriage Along With Lead Screw While Thread Cutting.

Type Of Mechanism Is Used For Giving Automatic Feed To The Tool While Thread Cutting

Half Or Split Nut Mechanism.

Four Types Of Lathes

1. Engine Lathe 2. Bench Lathe 3. Tool Room Lathe
4. Semi-Automatic Lathe 5. Automatic Lathe.

Bench Lathe

A Small Size Lathe Which Has All Parts Similar To A Center Lathe Which Can Be Mounted On A Bench.

Tool Room Lathe.

A Tool Room Lathe Consists Of All The Necessary Attachments Required For Accurate And Precision Machining.

Semi-Automatic Lathe

A Lathe In Which All The Machining Operations Are Performed Automatically But Loading And Unloading Of Work Piece, Coolant On Or Off Are Performed Manually.

Two Types Of Semiautomatic Lathe

1. Capstan Lathe   2. Turret Lathe

The Semi-Automatic Lathe Differs From Center Lathe

A Hexagonal Turret Head Replaces Tailstock.

The Advantages Semi-Automatic Lathes

1. Production Time Is Minimized
2. Accuracy Will Be High
3. Production Rate Is Increased

Automatic Lathe

In Addition To Automatic Machining Operations Loading And Unloading Are Also Performed Automatically.

Special Purpose Lathe.

The Lathes Which Are Specially Designed For Carrying Out Specific Operations Only.

Copying Lathe

The Tool Of This Lathe Follows A Template Or Master Through A Stylus Or Tracer.

The Various Types Of Headstock

1. Back Geared   2. All Geared.

Feed.

Feed Is Defined As The Movement Of The Tool Relative To The Work And The Work Piece By Form Tool.

Various Feed Mechanism Used For Obtaining Automatic Feed.

1. Tumbler Gear Mechanism
2. Quick Change Gearbox.
3. Tumbler Gear-Quick Change Gearbox
4. Apron Mechanism

Four Work Holding Devices.

1. Chucks
2. Centres
3. Face Plate
4. Angle Plate.

The Use Of Chucks.

Chucks Are Use To Hold The Work Piece Of Small Length And Large Diameter.

The Various Types Of Chucks

5. Three Jaw Chuck (Or) Self Centering Chuck.
6. Four Jaw Chuck Or Independent Chuck
7. Magnetic Chuck

The Application Of Air Operated Chuck

Heavy Work Pieces Are Mounted With The Help Of Air-Operated Chucks. Because They Will Require More Power To Hold The Work Piece.

The Use Of Mandrels

Mandrels Are Used For Holding Hollow Work Pieces.

Steady And Follower Rest.

Steady Rest: It Is Fixed On Bed Way's Of The Lathe By Clamping The Bolts.

Followers Rest: It Is Mounted On The Saddle And Moves Together With The Tool.

The Different Operations Performed On A Lathe

1. Centering
2. Straight Turning
3. Rough Turning
4. Finish Turning
5. Shoulder Turning
6. Facing
7. Chamfering
8. Knurling Etc.

Filing Operation.

Filling Is The Process Of Removing Bars, Sharp Corners And Feed Marks On A Work Piece By Removing Very Small Amount Of Metal.

Forming Operation

Forming Is The Process Of Producing Concave, Convex And Any Irregular Shape.

The Process "Grooving".

Grooving Is The Process Of Reducing The Diameter Of The Work Piece Over A Very Narrow Surface.

Parting Off Is An Operation Of Cutting A Work Piece After Machining

"Eccentric"

The Axis Of One Cylinder Is Off-Set With The Axis Of Other Cylinder.

Drilling Operation

Drilling Is The Operation Of Producing Cylindrical Hole In A Work Piece.

Reaming And Boring Operation

Reaming: It Is The Operation Of Finishing And Sizing Of Already Drilled Hole.

Boring: It Is The Process Of Enlarging A Already Drilled Hole.

Milling Operation

The Operation Of Removing Metal By Using Rotating Cutter Having Multiple Cutting Edges Is Known As Milling.

Tapping

Tapping Is The Operation Of Forming Internal Thread Of Small Diameter By Using A Multipoint Tool.

"Taper".

Taper Is Defined As A Uniform Change In The Diameter Of A Work Piece Measured Along Its Length.

"Conicity".

The Ratio Of The Difference In Diameters Of The Taper To Its Length.

$$K = \frac{D-d}{l}$$

Where, D = Bigger diameter

d = Smaller diameter

l = Length of the work piece

Various Methods For Taper Turning Operation.

a. Form Tool Method
b. Tailstock Set Over Method
c. Compound Rest Method
d. Taper Turning Attachment Method

Formula For Calculating Tailstock Set Over Distance.

$$Set\ \text{over, S} = \frac{\text{D - d}}{2l} \times L = L \tan\alpha$$

Where, D = Bigger diameter

d = Smaller diameter

$l = Length$ of the work piece

L=Distance between live center to dead center.

Formula For Calculating Taper Turning Angle By Compound Rest Method.

$$\tan\alpha = \frac{D-d}{2l}$$

Where, D = Bigger diameter

d = Smaller diameter

l = Length of the work piece

Determine The Angle At Which The Compound Rest Will Be Swiveled When Cutting A Taper On A Piece Of Work Having The Following Dimensions.

- **e. Outside Diameter – 60mm**
- **f. Length Of The Tapered Portion 80mm And**
- **g. Smallest Diameter = 20mm**

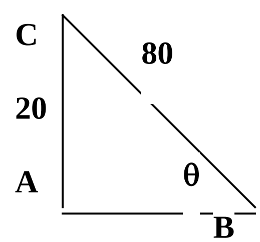
Given Data:

D = 60mm

L = 80mm (Length Of Tapered Portion)

D = 20mm

Solution:



In this case, $\sin\theta = \frac{D-d}{2l}$

$$= \frac{60-20}{2\times 80} = 0.3625$$

$$\theta = 21^{o}15^{'}$$

Thread Cutting Operation

Thread Cutting Is The Operation Of Producing Continues Helical Groove On A Cylindrical Work Piece.

The Number Of Teeth On Various Change Gears Be Calculated

$$\frac{\textit{Driver}\text{ teeth}}{\textit{Driven}\text{ teeth}} = \frac{\textit{Teeth}\text{ on spindle gear}}{\textit{Teeth}\text{ on headscrew gear}}$$

$$= \frac{\textit{Pitch}\text{ to be cut on work}}{\textit{Pitch}\text{ of lead screw}}$$

"Thread Catching".

The Process Of Following The Same Path Of The Tool When It Has Traveled In The Previous Cut Is Called As Thread Catching Or Thread Picking-Up.

Taper Of A Given Work Piece Having ¼ Conicity.

$$\tan\alpha = \frac{D-d}{2l} = \frac{1}{2}\times\frac{1}{4} = \frac{1}{8}$$

61. Write Down The Formula To Find The Following Parameters.

1. Machining time = $\frac{L}{f \times N}$

2. Total length of tool travel = $l + x + y$

3. Number of passes or cuts = $\frac{\text{Total machining allowance}}{\textit{Material}\text{ removal per cut}}$

Where, L = Total length of work piece,

$x = lengthoftoolapproach$

$f = Feed,$

N = speed and

y = Over run,

The Important Requires Of Capstan And Turret Lathe.

1. Bed
2. Head Stock
3. Turret Head
4. Saddle And Cross Slide

The Various Types Of Cross-Slide

1. Reach Over Type
2. Side Hung Type.

The Various Types Of Headstock For Turret Lathes

1. Back Geared
2. All Geared
3. Pre-Selective Stock

The Special Provision Made In Pre-Selective Headstock

The Speed Changing For Different Machining Operation Can Be Done By Simply Pushing A Button Or Pulling A Lever To Select The Speed Of The Next Operation In Advance.

Type Of Mechanism Is Used For Indexing The Turret Head For The Next Operation

Geneva Or Indexing Mechanism

Two Specification Of Capstan And Turret Lathe.

1. Number Of Spindle Speeds
2. Number Of Feeds For The Turret Of Saddle

The Advantages Of Turret Lathe Over Capstan Lathe.

1. Heavier And Larger Work Piece Chucking Can Be Done
2. More Rigid, Hence It Withstands Heavy Cuts.

Four Work Holding Devices.

1. Collets
2. Chucks
3. Fixtures
4. Power Chucks

Four Tool Holding Devices.

1. Multiple Cutter Holder.
2. Offset Cutter Holder
3. Sliding Cutter Holder.
4. Knee Tool Holder.

Problem 1.

The Minimum And Maximum Speed Of A Head Stock Spindle Of A Lathe Are 50 Rev/Min And 1500 Rev/Min. The Number Of Speeds Available Is 18. Find The Intermediate Speeds.

Given Data:

N_{min} = 50rev/Min
N_{max} = 1500rev/Min
Z = 16

Solution:

Step Ratio Is Given By The Formula

$$\phi = \left(\frac{N_{\max}}{N_{\min}}\right)^{\frac{1}{z-1}} = \left(\frac{1500}{50}\right)^{\frac{1}{16-1}}$$

$$= (30)^{0.667}$$

$$\phi = 1.2545$$

The speeds are 50, $\phi \times 50$, $\phi^2 \times 50$,......1500. Ans.

i.e.,50,62,72,78,69,98.7,23.8,155.36,195,....1500.

2. Calculate The Gears For Cutting Metric Threads Of The Following Pitches.
I. 4mm Pitch Ii. 5.25mm Pitch
The Lead Screw Of The Lathe Contains 6tpi. The Lathe Supplied With 20 To 120 Teeths In Steps Of 5 And An Additional Gear Wheel Of Having 127 Teeth.

Solution:

For metric threads,

$$\frac{\text{Driver teeth}}{Driventeeth} = \frac{5np}{127}$$

$where$, n = number of threads per inch i.e. TPI

p = Pitch of the thread to be cut

i. 4mm pitch

$$\frac{\text{Driver teeth}}{Driven\ teeth} = \frac{5np}{127} = \frac{5 \times 6 \times 4}{127} = \frac{120}{127} \quad \text{Ans.}$$

The Gear Train Will Consist Of 120 Teeth On The Spindle Gear And 127 Teeth On The Lead Screw.

Ii. 5.25mm Pitch

$$\frac{Driver\ \text{teeth}}{Driven\ \text{teeth}} = \frac{5np}{127} = \frac{5\times6\times5.25}{127} = \frac{5\times6\frac{21}{4}}{127}$$

$$= \frac{105\times6}{4\times127} = \frac{105}{40}\times\frac{60}{127} \quad \text{Ans.}$$

(∵ Numerators And Denominators Are Multiplying By 10)

For 5.25mm Pitch, Compound Gear Train To Be Used With 105 Teeth On Spindle Gear And 127 Teeth On The Intermediate Gear, 60 Teeth Intermediate Gear Drives A 40 Teeth Gear On The Lead Screw.

Problem 3

Calculate The Cutting Speed On A Piece Of Mild Steel Of 100mm Diameter And Rotting At 300rpm.

Given Data:
D = 100mm
N = 300rpm

Solution:

$$Cutting\ \text{speed, V} = \frac{\pi \text{DN}}{1000} = \frac{\pi\times100\times300}{1000}$$

= 94.25m/min

4. Find The Gear Train For Cutting 2mm Pitch Thread On A Lathe Having Lead Screw Of 10mm Pitch.

Solution:

$$\frac{Driver\ \text{teeth}}{Driven\ \text{teeth}} = \frac{Pitch\ \text{of the work}}{Pitch\ \text{of the leadscrew}}$$

$$= \frac{2}{10} = \frac{2\times10}{10\times10} = \frac{20}{100}$$

The Gear Train Consists Of 20 Teeth On The Driver And 100 Teeth On Driven (Lead Screw Gear) To Be Used Without Intermediate Gear.

Problem 5

Determine The Required Change Gears For Cutting 1.25mm Pitch Thread On A Lathe Having Lead Screw Of 8mm.

Solution:

$$\frac{Driver\ \text{teeth}}{Driventeeth} = \frac{Pitch\ \text{of the work}}{Pitch\ \text{of the leadscrew}}$$

$$= \frac{1.25}{8} = \frac{1.25\times4}{8\times4} = \frac{5}{32} = \frac{5}{8}\times\frac{1}{4}$$

$$= \frac{5\times10}{8\times10}\times\frac{1\times20}{4\times20} = \frac{50}{80}\times\frac{20}{80}$$

The Compound Gear Train Is To Be Used Since 32 Teeth Gear Is Not Available In The Standard Set Of

Gears Which Are Supplied. The Driver Gears Will Have 50 And 20 Teeth And Driven Gears Of Both 80 Teeth

Problem 6

The Pitch Of The Lead Screw Of A Lathe Is 6mm. If The Pitch Of The Thread To Be Cut Is 1.5mm, Find The Change Gear Wheels. Available Gear Wheels Are 20 To 120 In Steps Of 5. Draw A Sketch Showing The Gear Arrangement.

Given Data:
Pitch Of The Lead Screw = 6mm
Pitch Of The Thread To Be Cut = 1.5mm
Available Gear Wheels Are 20 To 120 In Steps Of 5

Solution:

$$\frac{Dirver \text{ teeth}}{Driven \text{ teeth}} = \frac{Pitch \text{ of the thread to be cut}}{Pitch \text{ of the leadscrew}}$$

$$\Rightarrow \frac{1.5}{6} = \frac{1.5\times 4}{6\times 4} = \frac{6}{24} = \frac{6}{4}\times\frac{1}{6}$$

$$\frac{6\times 5}{4\times 5}\times\frac{1\times 20}{6\times 20} = \frac{30}{20}\times\frac{20}{120}$$

Compound Gear Train To Be Used For Making The Above Thread. The Driver Gears Will Have 30 And 20 Teeth. The Driven Gears Will Have 20 And 120 Teeth.

Problem 7

Calculate The Time Taken To Turn A Brass Component 75mm Diameter And 125mm Long If The Cutting Speed Is 52m/Min And The Feed Is 0.8mm/Rev. Only One Cut Is To Be Considered.

Given Data:
D = 75mm
L = 125mm
V = 52m/Min
F = 0.8mm/Rev

Solution:

$$Time,\ \mathrm{T_m} = \frac{L}{fN} = \frac{\pi DL}{1000V\ f} = \frac{\pi\times 75\times 125}{1000\times 52\times 0.8}\left(\because V = \frac{\pi DN}{1000}\right)$$

=0.707min=42.42sec

Problem 8

Calculate The Time To Face A Work Piece Of 80mm Diameter. The Spindle Speed Is 115rpm And Cross Feed Is 0.4mm/Rev

Given Data:
D = 80mm
N = 115rpm
F = 0.4mm/Rev
Solution:

$$T_m = \frac{L}{fN}$$

$$L = D/2 = 80/2 = 40mm$$

$$T_m = \frac{40}{0.4 \times 115} = 0.869\min = 52\sec$$

Problem 9

Calculate The Number Of Teeth On Change Gears To Cut A Mild Start Thread Of Having 4 Starts And Pitch 1.25mm. The Pitch On The Lead Screw Is 8mm.

Given Data:
N = 4
P = 1.25
Pitch Of The Lead Screw = 8mm

Solution:

$Pitch$ on the work = n $\times P$=4×1.25=5mm

$$\frac{\text{Driver teeth}}{Driven \text{ teeth}} = \frac{Pitch \text{ of the work}}{Pitch \text{ of the lead screw}} = \frac{5}{8}$$

$$= \frac{5}{8} \times \frac{5}{5} = \frac{25}{40}$$

Therefore, The Driver Will Have 25 Teeth And Driven Will Have 40teeth.

Problem 10

A Shaft Of Diameter 60mm Is To Be Turned On A Lathe At A Cutting Speed Of 45m/Min. Find The Required Rpm Of The Shaft.

Given Date:
V = 45m/Min
D = 60mm

To Find:
Speed In Rpm

Solution:

$$V = \frac{\pi DN}{1000}$$

$$N = \frac{1000 \times 45}{\pi \times 60}$$

$$= 238.7$$

$$= 239 rpm.$$

Problem 11

Calculate The Time Required For One Complete Cut On A Piece Of Work Having 250mm Long And 40 Mm Diameter. The Cutting Speed Is 32m/Min And The Feed Is 0.4 Mm/Rev.

Given Data:
L = 250 Mm

D = 40mm
V = 32m/Min
F = 0.4mm/Rev

Solution:

$$V = \frac{\pi DN}{1000}$$

$$N = \frac{1000 \times 32}{\pi \times 40} = 255 rpm$$

Number of revolution for one complete cut, Y

$$\text{Y} = \frac{\text{L}}{f} = \frac{250}{0.4} = 625 rev$$

Time required for one complete cut, $\frac{\text{Y}}{\text{N}} = \frac{625}{255} = 2.45 \min$

MACHINE TOOLS

PART – A

One Pass Of The Cutting Tool.

The Combination Of One Forward And One Return Stroke Is Known As One Pass.

$$\text{Number of passes} = \frac{\text{Stock to be removed}}{\text{Depth of cut}}$$

Stroke, The Speed Of The Ram Is Faster

Return Stroke.

Cutting Ratio Of A Shaper.

The Ratio Between The Cutting Stroke Time To Return Stroke Time,

$$in = \frac{\text{Cutting stroke time}}{\text{Return stroke time}}$$

Two Types Of Quick Return Mechanism.

1. Hydraulic Drive Mechanism.

2. Crank And Slotted Lever Mechanism.

The Feed And Depth Of Cut Is Given To The Shaper

Feed Is Given By Rotating The Down Feed Screws Of Tool Head Depth Of Cut Is Given By Rotating By Raising Or Elevating The Table.

The Various Types Of Flat Surface Produced On A Shaper.

1. Horizontal Surface
2. Vertical Surface
3. Inclined Surface

The Various Types Of Shaper According To Various Conditions

Generally, Shapers Are Classified As Follows.

1. According To The Type Of Driving Mechanism.
   a. Crank Drive Type
   b. Whit Worth Driving Mechanism Type.
   c. Hydraulic Drive Type
2. According To The Position Of Ram.
   a. Horizontal Shaper.
   b. Vertical Shaper
   c. Traveling Head Shaper
3. According To The Table Design
   a. Standard Or Plain Shaper
   b. Universal Shaper
4. According To The Type Of Cutting Stroke
   a. Push Out Type
   b. Draw Cut Type

The Other Type Of Shaper

1. Standard Or Plain Shaper
2. Universal Shaper
3. Draw Cut Shaper.

Four Shaper-Specifications.

1. Maximum Length Of Stroke
2. Type Of Driving Mechanism
3. Power Of The Motor
4. Speed And Feed Available

The Apron Is Fitted Away From The Machined Surface During Machining

The Apron Is Fitted Away From The Machined Surface To Avoid Rubbing Of The Tool On The Work Surface.

The Important Part To Control And Divert The Flow Of Oil Into The Cylinder In Hydraulic Drive.

Four – Way Valve.

Two Advantages Of Hydraulic Drive.

1. Higher Cutting To Return Ratio Can Be Obtained.
2. Infinite Range Of Cutting Speeds Is Available.

The Type Of Mechanism Followed On A Shaper And Have It Works.

Rock And Pinion Mechanism Is Used. The Rotary Motion Of Electric Drive Is Converted Into Reciprocating Motion Of The Ram By Using Gears And Slotted Link.

The Precautions Of To Be Carried Out Before Machining Any Surfaces

1. Position Adjustment And
2. Stroke Length Adjustment.

Two Reasons For Making The Stroke Length Greater Than Work Length.

1. If The Crank Pin Is Adjusted In Such A Way From The Centre Of The Bull Gear, The Rocker Arm Reciprocates For A Larger Distance, So, The Stroke Length Is Increased.
2. The Stroke Length Should Always Be Greater Than The Work Length. I.E. Some Amount Of Approach And Over Run Should Be Provided To The Tool Movement.

The Types Of Feed

1) Hand Feed
2) Automatic Feed

Four Types Of Work Holding Devices.

1. Vice
2. Table
3. V-Block
4. Fixture

The Various Types Of Tool

The Tools Are Classified As Below:

1. According To The Shape.
a. Straight Tool.
b. Cranked Tool.
c. Goose Necked Tool.

2. According To The Direction Of Cutting
a. Left Hand Tool.
b. Right Hand Tool.

3. According To The Finish Required
a. Roughing Tool
b. Finishing Tool

4. According To The Type Of Operation
a. Down Cutting Tool
b. Parting Off Tool
c. Squaring Tool
d. Side Recessing Tool.

5. According To The Shape Of The Cutting Edge.

a. Round Nose Tool
b. Square Nose Tool.

Any Four Operations Performed By A Shape.

1. Machining Horizontal Surfaces
2. Machining Vertical Surfaces
3. Machining Inclined Surfaces.
4. Machining Irregular Surfaces

The Tool Is Fitted On The Tool Head For Machining Inclined Surfaces

The Tool Is Set At Required Angle On The Tool Head Position And Stroke Lengths Are Adjusted And Also Proper Cutting Speed And Feed Are Chosen. The Apron Is Et Away From The Machining Surface. Depth Of Cut And Feed Are Given The Same As That The Machining Vertical Surface.

The Dovetail Is Machined

To Make Dovetail, The Vertical Slide With Right Hand Tool Is At The Required Angle On Right Side Of The Work. Just Giving Feed And Depth Of Cut, The Right Side Dovetail Is Finished. Then The Vertical Slide With Left And Tool Is Set The Required Angle On Left Side Of The Work. Here Also Just By Giving Feed And Depth Of Cut. The Left Side Dovetail Is Finished.

The Various Types Of Recessing That Can Be Made By The Shaper

1. Grooves
2. Slots And
3. Key Ways

The Feed And Depth Of Cut Are Given To The Shaper While Machining Irregular Surfaces

For Machining Irregular Surface, A Round Nose Tool Is Set On The Tool Head. By Giving Both The Cross Feed And Vertical Feed At The Same Time The Irregular Surface Is Obtained. The Cross Feed In Given Through The Table And The Vertical Feed Is Given By The Tool Head, The Apron Is Fitted To Some Angle Away From The Machined Surface To Avoid Rubbing Of The Tool On The Work During Return Stroke.

Feed And Depth Of Cut.

1. Feed (F)

   The Relative Movement Of Tool With Respect To The Work Piece Axis Is Known As Feed.
2. Depth Of Cut (T):

Amount Of Metal Removed In One Revolution Or In Cut Is Known As Depth Of Cut.

Write Down The Formula For Calculating No. Of Strokes And Passes Required In A Shaper.

No. Of Strokes Required (S_N)
The Ratio Between The Width Of The Work And Feed Per Stroke.

$$S_N \frac{W}{f}$$

$$\text{Number passes, n=}\frac{\text{Stock to be removed}}{\text{Depth of cut}} = \frac{S_r}{r}$$

The Metal Removal Rate.

Metal Removal Rate (W):
The Volume Of Metal Removed Per Unit Time.
Mmr (Or) W=Ftls

Planer Differs From A Shaper

In Planner:- The Work Reciprocates While The Tool Is Stationary.
In Shaper:- The Tool Reciprocates While The Work Is Stationary.

The Cross Feed And Vertical Feed Are Given In The Planner

The Cross Feed Is Given By Moving The Tool Head Along The Cross Rail And The Vertical Feed Is Given By Moving Down The Tool.

The Uses Of Planer.

The Planer Is Used For Machining Heavy And Large Casting. Ex. Lathe Bed Guide Ways, Machine Guide Ways Etc.

The Various Types Of Planners.

1. Double Hosing Planer
2. Open Side Planer
3. Pit Planer
4. Edge Planer
5. Divided Table Planer

The Various Parts Of A Double Housing Planner.

1. Bed
2. Table
3. Columns
4. Cross Rail
5. Tool Head

The Main Difference In Open Side Planer

The Only Difference In The Type Is Only One Vertical Column Is Provided On One Side Of The Bed And Other Side Is Left Free.

The Main Advantages Of Using Pit Planer.

Heavy And Large Work Can Be Held And Machined Easily.

Special Provision Made In Edge Planner

Yes. A Platform Is Provided To Stand And Travel Along With It While Machining.

The Main Difference Made In Divided Table Planer

The Working Principle Is Similar To That Of A Standard Planer. But It Has Two Reciprocating Tables.

Four Specifications Of Planer.

1. Maximum Length Of The Table.
2. Total Weight Of The Planer.
3. Power Of The Motor.
4. Range Of Speeds And Feed Available
5. Type Of Drives Required.

The Function Of Clapper Block In A Planer

During Cutting Stroke, The Tool Block Fits Inside The Clapper Block Rigidly. During The Return Stroke, The Tool Block Lifts Out Of The Clapper Block To Avoid Rubbing Of The Tool On The Job.

The Various Types Of Quick Return Mechanism

1. Open And Cross Belt Drive
2. Electric Drive
3. Hydraulic Drive

The Various Quick Return Motion Mechanism Used In Slotter.

1. Whitworth Quick Return Mechanism.
2. Variable Speed Reversible Electric Motor Drive.
3. Hydraulic Drive.

The Difference Speeds Available In Slotter.

a. Longitudinal Feed
b. Cross Feed
c. Circular Feed

The Operations That Can Be Performed On A Slotter

I. Machining Flat Surface.
II. Machining Grooves, Slots, Key Ways.
III. Machining Irregular Surface.

“Milling Process”.

Milling Is The Process Of Removing Metal By Feeding The Work Past A Rotating Multipoint Cutter.

The Specifications Of Milling Machine

1. The Table Length And Width.
2. Maximum Longitudinal Cross And Vertical Travel Of The Table.
3. Number Of Spindle Speeds And Feeds.
4. Power Of Driving Motor.
5. Floor Space And Net Weight.

Milling Machine.

1. Column And Knee Types

a. Plain Milling Machine
b. Vertical Milling Machine.
c. Universal Milling Machine
d. Ram-Type Milling Machine
e. Universal Milling Machine.

2. Bed-Type Milling Machine
a. Simplex Milling Machine.
b. Duplex Milling Machine.
c. Triplex Milling Machine.

3. Plano – Type Milling Machine
4. Special Purpose Milling Machine

a. Rotary Table Milling Machine
b. Drum Milling Machine.
c. Profile Milling Machine.

The Two Types Of Column And Knee Type – Milling Machine

i. Horizontal Type.
ii. Vertical Type.

The Principle Parts Of Horizontal Or Plain Milling Machine.

Base. Column, Knee, Saddle, Table, Over Arm, And Arbor.

The Various Movements Of Universal Milling Machine Table.

1. Vertical Movement – Through The Knee.
2. Cross Wise Movement-Through The Saddle.
3. Longitudinal Movement Of The Table.
4. Angular Movement Of The Table –By Swiveling The Table The Swivel Base.

Two Comparison Between Plain And Universal Milling Machine.

1. In Plain Milling Machine, The Table Is Provided With Three Movements, Longitudinal, Cross And Vertical. In Universal Milling Machine In Addition To These Three Movement There Is A Fourth Movement To The Table. The Table Can Swiveled Horizontally And Can Be Fed At Angle To The Milling Machine Spindle.
2. The Universal Milling Machine Is Provided With Auxiliaries Such As Dividing Head, Vertical Milling Attachment, Rotary Table Etc. Hence It Is Possible To Make Spiral, Bevel Gears Twist Drills, Reamers Etc On Universal Milling Machine.

Universal Milling Machine Differs From Universal Milling Machine

This Is A Modified From Of Plan (Horizontal) Milling Machine. It Is Provided With Two Spindles, One Of Which Is In The Horizontal Plane While The Other Is Carried By A Universal Swiveling Head.

Bed Type Milling Machine.

The Bed Type Milling Machines Are Classified As Simplex, Duplex And Triplex Machine.

The Different Ways For Machining Workpieces In Plano- Milling

a. By Moving The Table, The Cutters Rotating In Position.
b. By Keeping The Table Stationary And Feeding The Cutters By Moving The Milling Heads.
c. By Moving The Table And The Milling Heads Simultaneously.
d. By Keeping The Table Stationary Mving The Cross-Rail Down Wards And The Side Cutters Up And Down.

The Various Types Of Special Purpose Milling Machine

1) Rotary Table Or Continuous Milling Machine
2) Drum Type Milling Machine
3) Profile Or Count On Milling Machine

Four Important Types Of Work Holding Devices.

(a) N Blocks
(b) Machine Vises.
(c) Milling Fixture
(d) Dividing Heads

The Cutter Holding Devices

1. Arbors.
2. Adaptors
3. Collets

The Two Types Of Arbor

(i) Standard Arbor.
(ii) Stub Arbor.

Various Types Of Milling Attachments.

(i) Vertical Milling Attachment
(ii) Universal Milling Attachment
(iii) High Speed Milling Attachment
(iv) Rotary Attachment
(v) Slotting Attachment
(Vi) Rack Milling Attachment
(Vii) Universal Spiral Milling Attachment

Milling Cutters.

According To The Shape Of The Tooth, Milling Cutters Are Classified As

(i) Milled Tooth Cutters
(ii) Form Relieved Cutters

According To The Types Of Operation.

(i) Plain Milling Cutters
(ii) Side Milling Cutters

(iii) End Mill Cutters
(iv) Angle Milling Cutters
(v) T-Slot Milling Cutters
(vi) Slitting Saws
(vii) Form Milling Cutters
(viii) Flu Cutters
(ix) Wood Ruff Key Slot Milling Cutter

According To The Way Of Mounting On The Machine

(i) Arbor Cutters
(ii) Shank Cutters
(iii) Face Cutters

Ten Nomenclature Of Plain Milling Cutter.

Body Of Cutter, Cutting Edge, Face, Filter, Gash, Lead, Land, Outside Diameter. Roof Diameter, Cutter Angles.

The Two Main Group Of Milling Processes

i. End Milling
ii. Face Milling

Peripheral Milling Processes.

i. Up Milling Or Conventional Milling And
ii. Down Milling Or Climb Milling

The Rotation Of Cutter With Respect To Workplace Movement In Up Milling

The Cutter Rotates Opposite To The Direction Of Feed Of The Work Piece

The Advantages Of Up Milling Process

1. Safer Operation Due To Separating Forces Between Cutter And Work
2. Less Wear On Feed Screw And Nut Due To The Absence Of Pre-Loaded
3. Milled Surface Does Not Have Built Up Edge

Climb Milling Differs From Conventional Milling

The Cutter Rotates In The Same Direction Of Travel Of The Work Piece

The Advantages Of Down Milling Process

(i) Cutter With Higher Take Angles Can Be Used. This Reduces Power Requirements.
(ii) Cutter Wear Is Less Because Chip Thickness Is Maximum At The Start Of The Cut.
(iii) Finishing Is Generally Good Because The Rubbing Action With Chip Is Eliminated.

The Differences Between Up Milling And Down Milling

Sl.No	`Event Of Operation	Up Milling	Down Milling
(I)	Direction Of Travel	Cutter Rotates Against The Direction Of Travel Of Work Piece	Cutter Rotates In The Same Direction Of Travel Of Workpiece.
(II)	Chip Thickness	Minimum At The Beginning Max When The Cut Terminates	Maximum At The Beginning Greeches Min At Terminates
(Iii)	Cutting Force	Increases From Zero To Max Per Tooth	Decreases From Max To Zero Per Tooth

Face Milling".

Face Milling Is The Operation Performed By A Milling Cutter To Produce Flat-Machined Surfaces Perpendicular To The Axis Of Rotation.

The Various Milling Operations.

1. Plain Or Slab Milling.
2. Face Milling
3. Angular Milling
4. Straddle Milling
5. Gang Milling
6. Form Milling.
7. End Milling.
8. T-Slot Milling.
9. Gear Cutting.

Plain Or Slab Milling

Plain Or Slab Milling Is The Operation Of Producing Flat Horizontal Surface Parallel To The Axis Of The Cutter Using A Plain Or Slab Milling Cutter.

The Following Terms: Straddle Milling And Gang Milling.

Straddle Milling Operation Is The Production Of Two Vertical Flat Surfaces On The Both Sides Of The Job By Using Two Side Milling Cutters Which Are Separated By Collars.

Term Indexing

Indexing Is The Process Of Diving The Periphery Of A Job Into Equal Number Of Divisions.

Three Types Dividing Heads

1. Plain Or Simple Dividing Head.
2. Universal Dividing Head.
3. Optical Dividing Head.

Two Stage In Differential Indexing

Stage 1: The Crank Is Moved In A Certain Direction.
Stage 2: Movement Is Added Or Subtracted By Moving The Plate By Means Of A Gear Train.

The Rule For Gear Ratio In Differential Indexing,

Rule For Gear Ratio In Differential Indexing:

Gear Ratio= $\frac{(A-N)\times 40}{A}$

A Selected No Which Can Be Indexed By Plain Indexing And Approximately Equal To N.
N Required No Of Divisions To Be Indexed.

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The Combination Of Two Movements Takes Place In Differential Indexing

When The Index Plate Rotates In The Same Direction Of The Crack The Resulting Movement Of The Crank Will Increase. When The Index Plate Rotates In The Opposite Direction Of The Crank, The Resulting Actual Movement Is Decreased.

Drilling

Drilling Is The Process Of Producing Hole On The Work Piece By Using A Rotating Cutter Called Drill.

Drilling Machines.

The Drilling Machines Are Classified As Follows:

1. Portable Drilling Machine.
2. Sensitive Drilling Machine.
   a) Bench Type
   b) Floor Type
3. Upright Drilling Machines
   a. Round Column Type Or Square Section Type.
   b. Box Column Type Or Pillar Type
4. Radial Drilling Machine
   a. Plain Type
   b. Semi-Universal Type
   c. Universal Type
5. Gang Drilling Machine
6. Multiple Spindle Drilling Machine
7. Automatic Drilling Machine
8. Deep Hole Drilling Machine

The Power Is Calculated In Drilling Operations

When A Drill Cuts It Should Overcome The Resistance Offered By The Metal And A Twisting Effort Is Necessary To Turn It. The Effort Is Called Torque On The Drill. The Torque Is Depending Upon The Various Factors. The Relation Between Torques Diameter Of Drill And Feed Is As Follows.

$T = C \text{ X } F^{0.75} \text{ X } D^{18}$
Where, T = Torque In N-M
F = Feed In Mm/Rev
D = Diameter Of Drill

C = Constant Depending Upon The Material Being

$$\frac{2\pi NT}{60}\, watts$$

Power, P =

Where, N – Speed Of Drill In R.P.M.

Boring

Boring Is The Process Of Enlarging And Locating Previously Drilled Holes With La Single Point Cutting Tool.

The Applications Of Boring

The Boring Machine Is Designed For Machining Large And Heavy Work Piece In Mass Production Work Of Engine Frame, Cylinder Machine Housing Etc.

The Main Difference Between Boring Bar And Boring Tool

Boring Bar: The Tool Which Is Having Single Point Cutting Edge Known As Boring Bar.

Boring Tool: The Tool Which Is Having Multi Point Cutting Edge Known As Boring Tool.

The Types Of Boring Machines

The Boring Machines May Be Classified As Follows:

1. Horizontal Boring Machine
   a. Table Type
   b. Floor Type
   c. Planner Type
   d. Multiple Head Type

2. Vertical Boring Machine
3. Precision Boring Machine
4. Jig Boring Machine

The Work Is Clamped On The Table

The Work Piece Is Mounted On The Table And Clamped With Ordinary Strap Clamps T-Slot Bolts And Nuts Or It Is Held In A Special Boring Fixture If So Required.

SHAPER MACHINE

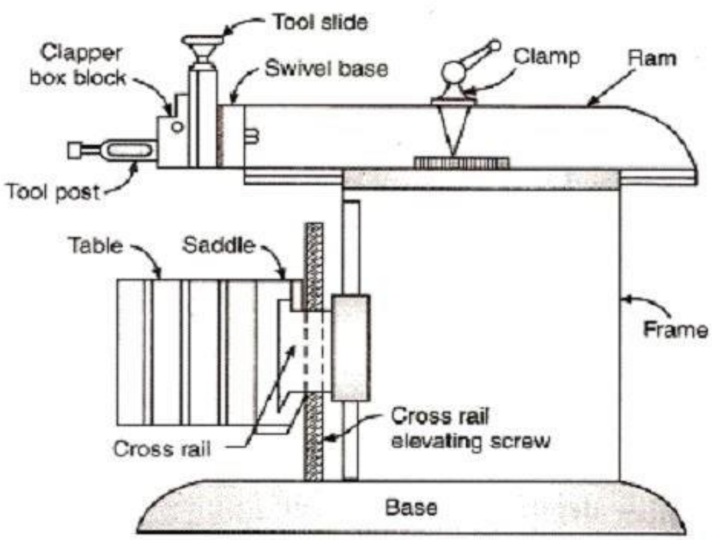
Introduction:

Theshaper isamachine toolusedprimarilyfor:

1. Producingaflator planesurface whichmaybeinahorizontal,a verticaloranangularplane.
2. Makingslots,groovesandkeyways
3. Producingcontourof concave/convexoracombinationof these

WorkingPrinciple:

The job is rigidly fixed on the machine table. The single point cutting tool held properly in the tool post is mounted on a reciprocating ram. The reciprocating motion of the ram is obtained by a quick return motion mechanism. As the ram reciprocates, the tool cuts the material during its forward stroke. During return, there is no cutting action and this stroke is called the idle stroke. The forward and return strokes constitute oneoperating cycle of the shaper.



Construction:

The main parts of the Shaper machine is Base, Body (Pillar, Frame, Column), Cross rail, Ram and tool head (Tool Post, Tool Slide, Clamper Box Block).

Base:

Itis the main body of the machine. Itconsist all elementof machine. Itworksaspillar forother parts. Base is made by cast iron which can take all compressive loads.

Ram:

It is the main part of the shaper machine. It holds the tool and provides the reciprocating motion to it. It is made by cast iron and move over ways on column. It is attached by the rocker arm which provide it motion in crank driven machine and if the machine is hydraulic driven it is attached by hydraulic housing.

Tool head:

It is situated at the front of the ram. Its main function is to hold the cutting tool. The tool canbe adjustedon itby some of clamps.

Table:

It is the metal body attached over the frame. Its main function is to hold the work piece and vice over it. It hastwo T slots which used to clamp vice and work piece over it.

Clapper box:

Itcarriesthetoolholder.Themainfunctionofclapperboxistoprovideclearancefortoolinreturnstock.It prevents the cutting edge dragging the work piece while return stock and prevent tool wear.

Column:

Columnisattachedtothebase.Itprovidesthehousingforthecrankslidermechanism.Theslidewaysare attached upper section of column which provide path for ram motion.

Cross ways:

It consist vertical and horizontal table sideways which allow the motion of table. It is attach with some cross movement mechanism.

Table supports:

These are attached front side of the table and used to support the weight of table during working.

Types of Shaper:

Shaperscan classified intomanytypes basedonseveralcriteria:

1) Based on the type of driving mechanism used

a) Crank andslottedlever drivingmechanismtype

b) Whitworthquickreturn drivingmechanism type

c) Hydraulicdrivingmechanism type

2) Based on the table design

a) PlainShaper

b) Universal Shaper

3) Based on the position of the reciprocating ram used

a) Horizontalshapingmachine(Mostcommontypeofshaper used)

b) Verticalshaping machine

c) Travellinghead shapingmachine

4) Based on the type of cutting stroke of the tool

a) Pushout type

b) Drawcuttype

Types of operations performed in a shaper

1. Machininghorizontalsurface.
2. Machiningverticalsurface.
3. Machiningangularsurface.
4. Cuttingslots,groovesandkeyways.
5. Machiningirregular surface.
6. Machiningsplinesorcuttinggear.
7.

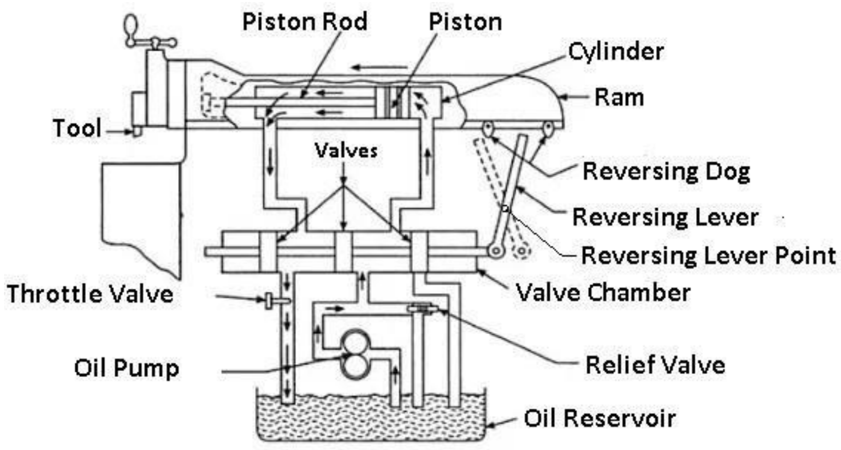
Quick Return Mechanism-Types

A quick return mechanism is an system to produce a reciprocating effect such that time taken by system in return stroke is less time taken by it in the forward stroke.
Inquickreturnmechanism,acircularmotionisconvertedintoreciprocatingmotionjustlikecrankandlever mechanism but it has return stroke time is different from forward stroke time.
This mechanism is used in many machines. Some of them are shaper machines, slotter machines, screw press,mechanical actuator etc.With the help of quick return mechanism, the time needed to cutting is minimized.

Types of Quick Return Mechanism:-

1Hydraulic Drive:
Hydraulic drive mechanism is one of the mechanism used in shaper machine. In this mechanism, the ram is moved forward and backward by a piston moving in a cylinder placed under the ram.
This machine consists of a constant discharge oil pump, a cylinder , a valve chamber and a piston. The pistonro-

disboltedtothetherambody. Hydraulic fluidisusedinhydraulicquickreturn mechanismfor themovement of ram.



Working of Hydraulic Drive :-

Inhydraulic drive, there is a tank atthe bottom which contains the hydraulic fluid. This tank is also known asoil reservoir. At first the oil from the reservoir.This oil is passed through the valve chamber present in the right oftheoilcylinderexertingpressureonthepiston.Anyoilpresentintheleftsideofthepistonisdischargedto thereservoirthroughthethrottlevalve.

At first the fluid in the tank is pumped out and this fluid passes through the passage present in the right side of the cylinder .
Thisfluidexertspressure onthepistonandtheramofthemachine performsforwardstroke.
When the ram moves forward, the lever changes its position and hits the reversing dog. As the lever changes its position, the three valves connected to the lever also change their position and now the oil can pass through the passage present in the left side of the cylinder.
After the forward stroke is completed, the valves changes its position and now the pumped fluid from the reservoir moves from the passage present in the left side of the piston. Also, the passage through which the oil return to the reservoir opens and get connected to the right passage and the fluid present on the right side of the piston is discharge to the reservoir.
As the fluid moves towards the left side of the piston, the piston which is attached to the ram moves towards right and return stroke is performed by the ram.
At the end of the return stroke, another dog hit against the lever and the direction of the lever as well as the stroke changes. In this way, the forward and the return stroke of the ram is repeated.
The quick return takes place due to difference in the stroke volume of cylinder at both ends. The volume of passage at the left side is less than the volume of the passage on the right side. As the pump is constantdischarge pump, same amount of oil will be passed on the both passage. So the pressure n the passage with less volume will be more and the return stroke will be faster than the forward stroke.

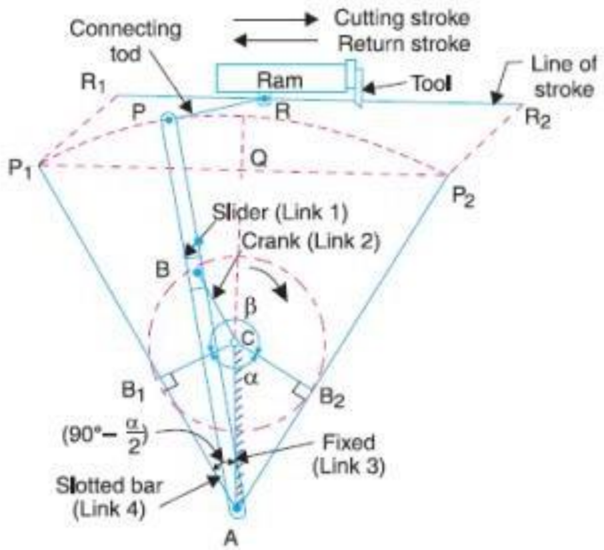
The cutting speed can be controlled by controlling the flow of oil which can be controlled by using the throttle valve.

2.Whitworth Quick Return mechanism:-

Thismechanismchangestherotary motiontooscillatorymotionlikethe crankandlever mechanism.
The difference between the crank and lever mechanism and Whitworth mechanism is that in whitworth mechanism the return stroke is faster than the forward stroke while in the crank and lever mechanism the forward stroke is of same speed as that of return stroke.

PartsusedinWhitworthmechanism:-

1) SlottedBar.
2) Slider
3) Crank–Itwillrotate.

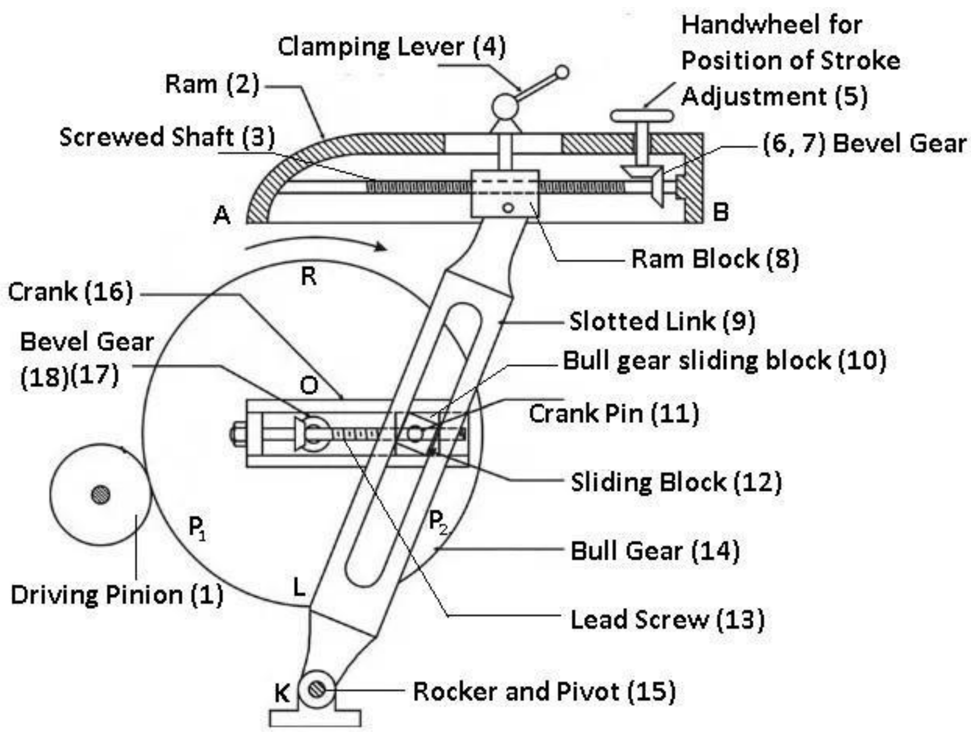


Whitworth quick return mechansim is the second inversion of slider crank mechanism in which the crank is fixed.
In this mechanism, the Slider in slotted bar is connected to the crank. When the crank rotates, the slider willslide inside the slotter bar and the slotted bar will oscillate. As the slotted bar oscillate, the ram will move in forward and backward direction.
Thereturnstrokeor idealisfasterthantheforwardstrokeinthismechanism.

Inthe abovefigureAP is theslotted barand link1, CDis link 2, ACwhichis crank islink 3 andlink 4is the slider.
In thismechanism thelinkCDi.elink2forming theturningpairisfixedas showninthefigureabove. The crank
AC revolves with uniform velocity with its centre at A.
A sliding block attached to the crank pin at B slides along the slotted bar AP and thus causes Ap to oscillate about the pivoted pint A. A short link PR transmits the motion from AP to the ram which carries the tool and thus forward stroke and backward stroke is obtained.
The crank needs to rotate through an angle of (**β**) for the forward stroke and it needs to rotate through an angle of (**α**) for forward stroke.
As crank moves with uniform angular velocity , time taken to cover angle **α** will be less than the time taken to cover angle **β**. Hence time taken in return stroke will be less than time taken in forwaed stroke. In this way, the quick return mechanism works.

3)Crank and Slotted Link Mechanism:-

Incrankandslottedlinkmechanism.Thepoweristransmittedtothebullgearbyapinionwhichrecievesits power from an individual motor.
Inatwogearsystem,thesmallergeariscalled pinionandthelargergeariscalled bullgear.



Working of Crank and Slotted Link Mechanism:-

The radial slide is bolted to the centre of the bull gear. This radial slide carries a sliding block into which the crankpin is fitted.
Asthebullgear willrotate,thecrankwillrevolve atuniformspeed.

The sliding block which is mounted upon the crank pin is fitted upon the crank pin is fitted within the slotted link. This slotted link is pivoted uponat its bottom end attached to the frame of column. The upper end of the sliding link is bifurcated and attached to the ram block by a pin.

When the bull gear rotates, the crank pin revolves at a uniform speed. The sliding block fastened to the crankpin will rotate on the crank pin circle and at the same time this slider will slide up and down in the sliding link.

As the slider will move inside the sliding link, it will provide a rocking movement to the sliding link and this movement will be transferred to the ram providing it a reciprocatory motion.

Hencetherotarymotionofthebullgearisconvertedintoreciprocatorymotionof ram.

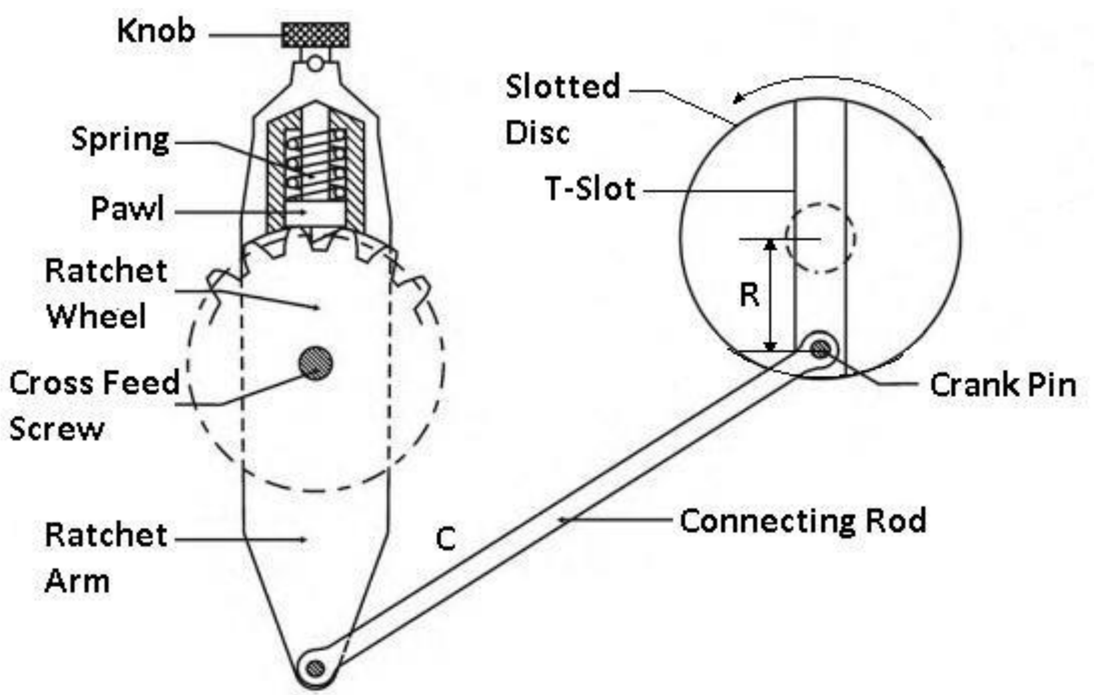
Automatic Table feeding mechanism of shaper

The automatic feed mechanism of the table is very simple. This is done by rotating a ratchet wheel, mounted at the crossfeed screw. This enables a corresponding equal rotation of the crossfeed screw after each stroke.

Arrangement of parts

It consists of a slotted disc, which carries a T-slot, as shown in the figure. In this slot is fitted an adjustable pin and to this is attached a connecting rod. The other end of the connecting rod is attached to the lower end of the rocker arm of the pawl mechanism.

Therocker armswings aboutthescrewC,andatitsupper endcarriesaspring-loadedpawl,asshown.



Working

Note,thatthelower endof thepawlisbevelledononeside.

This arrangement helps the power feed to operate in either direction, but the same should be set to operateduring the return stroke only.If otherwise, the mechanism will be subjected to severe stress. In some latesttypes of shapers, can driven feed mechanisms are provided which are more efficient and provide a wider range of feed.

Variation in the feed can be provided by varying the distance R between the disc centre and the centre of the adjustable pin. Larger the said distance greater will be the feed and vice versa. The amount of feed to be given depends upon the type of finish required on the job.

For rough machining, heavier cuts are employed, and thus, a coarse feed is needed. Against this, a finer feed is employed in finishing operations.

The slotted disc at its back carries a spur gear which is driven by the bull gear. As the disc rotates through this gear the adjustable pin, being eccentric with the disc centre.
This causes the connecting rod to reciprocate. This, in turn, makes the rocker arm to swing about the screw C to move the pawl over one or more teeth. Thus transmit an intermittent motion to the crossfeed screw whichmoves the table.

ShaperMachine–Specifications

a. LengthofRamstroke:(457mm)
b. Rangeof Ramspeeds:(12,24,40& 72strokesperminute)
c. Workingsurface oftable:(483mm *330 mm)
d. MaxTableTravel –Horizontal:(610mm)
e. MaxTableTravel –Vertical: (457mm)
f. Angularmovementoftableoneither side:(600)
g. MaximumsizeofTool ShankinTool Head:(51m* 21mm)
h. MaximumverticaltravelofToolSlide:(152mm)
i. MaximumswivelofToolHead:(600)
j. MainDriveMotor:(3 H.P./950rpm)

CUTTING PARAMETERS OF A SHAPER

CuttingSpeed

It is defined as the average linear speed of the tool during the cutting stroke in m/min, which depends on number of ram strokes (or ram cycles) per minute and length of the stroke.

Feed

Feed f is the relative motion of the work piece in a direction perpendicular to the axis of the reciprocation of the arm.In shaper, feed is normally given to the work piece and can be automatic or manual.It is expressed in mm/double stroke or simply mm/stroke because no cutting is done in return stroke.

DepthofCut

Depthofcutdisthethicknessofthematerialremovedinone cut,in mm.

PLANER MACHINE

Theplanerorplaningmachineisamachinetool,whichliketheshaperproducesflatsurfacesinhorizontal, vertical or inclined plane.

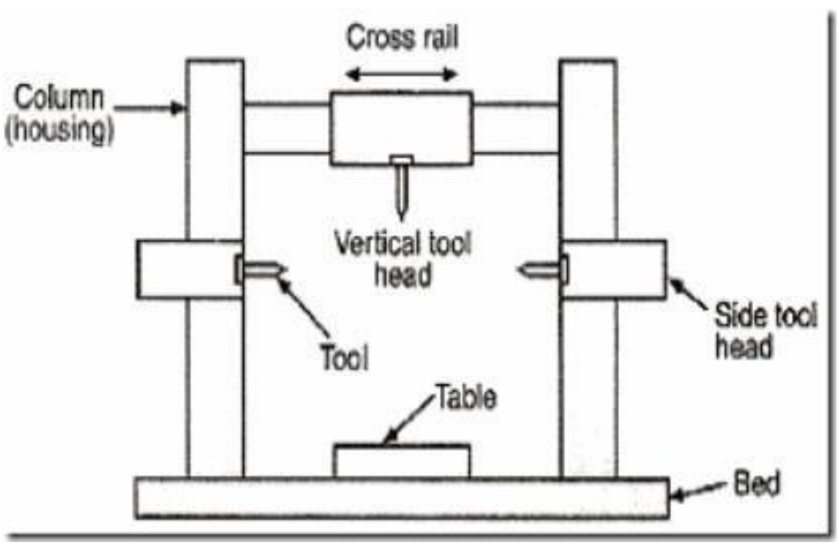
Thefundamentaldifferenceisthattheplaneroperateswithanactionoppositetothatoftheshapers,i.e.,the work piece reciprocates past one or more stationary single point cutting tools.

Planers are meant for machining large sized work pieces, which cannot be machined by the shaping machines. The work table is moved back and forth on the bed beneath the cutting head either by mechanical means , such as a rack and pinion gear or by a hydraulic cylinder.

CLASSIFICATION OF PLANNER

Planersare generallydividedinto5types

1) Doublehousing planer
2) Open sideplaner
3) Edgetypeplaner
4) Dividetable planer
5) Pittype planer



Partsof Planner

1) **BED**
Bedofa planerislarge in sizeandheavyinweight.Itsupportsthecolumnandallothermoving partsofmachine.Itismade slightlylongerthantwice thelengthofthetablemaybemoved

on it. There is av shaped ways on the bed which help to reciprocate or backandforthmotion to the table.

2) TABLE

Tablesupportstheworkand reciprocatesalongthebed.Tableismadefromcastiron. The top face of the table is accurately finished in order to locate the work correctly. T-slotsare providedon-theentire lengthofthetableso that theworkand workholdingdevicesmaybebolteduponit.

3) **COLUMN**

These are rigid box like vertical structure placed on each side of the bed and table.They

are heavily ribbedto trace up severe force due to cutting. It also facilitate tool head

mechanism.

The cross rail may be made to slide up and down for accommodating different heights of work.

4) **CROSS RAIL**

It is rigid box like casting connecting the two columns. It may be raised or lowered on the faceofhousingandcan beclamped atadesired positionbymanual orelectricalclampingdevices.It should remainabsolutely parallel to the top surface of the table.

5) TOOLHEAD

Tool heads are mounted onthecrossrailbysaddle.The saddlemaybemade to move trversely onthecrossrail togive crossfeed.Theclapperblockishinged athingepinstotheclapperblockandit holds the tool post in which the tool is clamped by straps.

WorkHoldingdevices usedinPlanner

a) Heavydutyvices
b) T-boltsandClamps
c) Stepblocks,T-boltsandClamps
d) Poppetsorstoppinsanddogs
e) Angleplates
f) Planercenters
g) PlanerJacks
h) V- blocks
i) Stops

PlanerTools

a. Righthand,left hand-Straightroughingtools
b. Righthand,lefthand- Bentroughingtools
c. Straight,Roundnose,squarenoseandGoose neck -Finishingtools
d. Groovingorslottingtool
e. T-slotcutting tool
f. Dovetailslidecuttingtool

SpecificationofaPlaner

1. Numberofspeedsandfeedsavailable.

2. PowerInput
3. Floorspacerequired
4. Netweightofthemachine
5. Typeof drive

CuttingParametersofPlannermachine

- **Cutting speed** - It is the rate at which the metal is removed during forward cutting stroke and is expressed in m/min
- **Feed** -It is thedistance thetool head travels per double strokeat thebeginning ofeach cutting strokeand is expressed in mm
- **Depth of cut** - It is the thickness of metal removed in one cut. It is measured by the perpendicular distance between machined and unmachined surfaces of the work. It is given in mm.

PLANER OPERATIONS

1. PlaningHorizontalSurfaces.
2. PlaningVertical Surfaces.
3. Planingcurvedsurfaces.
4. Planingslotsand grooves.
5. Planingatanangleand machiningdove-tails.
6. Planingahelix.
7. Gangor multiple planing.

Difference b/w planer and shaper

Shaper machine	Planer machine
In shaper ram moves in reciprocating and back and fourth	Platen/table reciprocates moves and also moves back and fourth
In shaper cutting tool moves back and forth	In planer work piece moves in back and forth
Used for the machining of small jobs	Used for the machining of large jobs
Each stroke of cutting tool ,gives the feed in cross wise.	In Each stroke of Platen or work piece feed are given by feed screw.
For the adjustment of Ram stroke crank mechanism are used	For the adjustment of platen gears and rack mechanism are used
Only one tool are used	Two or more tools are used
In shaper cutting speed ,feed range are in wide range	In planer machine cutting speed , cutting feed are limited

MACHINING CALCULATIONS

1. Cutting Speed (V)

It Is The Velocity At Which The Metal Is Removed By The Tool.

$$Cutting\ speed, V = \frac{Length\ of\ cutting\ stroke}{Time\ taken\ for\ the\ same\ cutting\ stroke}$$

$$= \frac{LN(l+m)}{1000}$$

Where, L – Length Or Cutting Stroke In Mm
N – Speed In Rpm
M - Ratio Between Cutting Time And Return Time

2. Feed (F)

The Relative Movement Of Tool With Respect To The Work Piece Axis Is Known As Feed.

Depth Of Cut (T)

Amount Of Metal Removed In One Revolution Or In Cut Is Known As Depth Of Cut.

Machining Time (T)

Time Required For Machining The Work Surface To The Required Dimensions.

$$T = \frac{L}{NXf} = \frac{L}{V} + m\frac{L}{V} = \frac{L}{V}(1+m)$$

Where,

L – Length Of Stroke = L+Approach + Over Run
N – Speed In Rpm
F – Feed
L – Work Piece Length
L/V – Time For Cutting Stroke
Ml/V – Time For Return Stroke

5. No. Of Strokes Required (S_N)

The Ratio Between The Width Of The Work And Feed Per Stroke

$$S_N = \frac{W}{f}$$

6. Total Machining Time (T)

The Time Required For Machining The Entire Surface Of The Work As Per Requirements.

7. Metal Removal Rate (W)

The Volume Of Metal Removed Per Unit Time.
Mmr (Or) W = Ftls
Where,   F – Feed
T –Depth Of Cut
L – Length Of Work
S – Strokes Per Minute

8. Power Required

P = K X W
Where, K – Machining Constant.

9. Number Passes:

$$n = \frac{Stock\ to\ be\ removed}{Depth\ of\ \ cut} = \frac{S_r}{t}$$

SOLVED PROBLEMS

Problem 1

A Shaper Is Operated At 125 Cutting Strokes Per Minute And Is Used To Machine A Work Piece Of 300 Mm In Length And 125 Mm In Width. Use A Feed Of 0.6mm Per Stroke And A Depth Of Cut Of 6mm. Calculate The Total Machining Time For Machining The Component. The Forward Stroke Is Completed In 230^0. Calculate The Percentage Of The Time When The Tool Is Not Contacting The Work Piece.

Given Data:

S = 125 Strokes/Min
Work Piece Length, L = 300mm
W = 125 Mm
F = 0.6mm/Stroke
T =6mm
Forward Stroke Angle, $\theta_f = 230^o$

Solution

Let Us Assume The Approach And Over Run = 25mm
Stroke Length L = L+25=300+25=325mm

$$S_N = \frac{W}{f} = \frac{125}{0.6} = 208.33 \approx 209$$

Number Of Strokes, $\therefore$
Total Time For Completing One Stroke,

$$T = \frac{L}{S} = \frac{325}{125}$$
$$= 2.6 \min.$$

$\therefore$

Total Machining Time,

$$T_1 = TxS_N = 2.6x209$$
$$= 543.4 \min \ Ans.$$

Percentage Of Time When The Tool Is Not Contacting The Work Piece

$$= \frac{360-0}{360} = \frac{360-230}{360} x100$$
$$= 36.11\% \quad Ans.$$
$$m = \frac{Angle\ of\ \ cutting\ stroke}{Angle\ of\ \ return\ stroke}$$

But, The Angle Of Return Stroke

$$= 360 - \theta_{f=360-230=130^o}$$
$$\therefore Ratio, m = \frac{230}{130} = 1.769 \quad Ans.$$

Problem 2

Calculate The Power Required For Shaping Stect With A Depth Of Cut Of 2.8mm, Cutting Speed 65m/Min And The Work Length 50mm. The Feed Rate Is 0.5mm/Rev. Take Machining Constant K As 70x10—6.

Given Data:

T = 2.8mm
V = 65m/Min = 65x1000mm/Min
L =50mm
F = 0.5mm/Rev

Solution:

Material Removal Rate, W = F T V = 0.5x2.8 X
65 X 1000
P = Kw

Power Required, P = 79 X 10^{-6+} X 91000
= 70189 H.P Ans
= 7.189 X 0.736 = 5.29 Kw

Problem 3

Estimate The Shortest Machining Time Required In A Shaper To Machine A Plate Of 200 X 90 Mm Under The Following Conditions.
Cutting Speed = 13.3m/Min
Feed = 0.57 Mm/Double Stroke

Number Of Passes = One
Approach + Overrun (Longitudinal) =20mm
(Lateral) = 4mm
Ratio Of Cutting Speed To Rapid Return = 0.83

Given Data:
Cutting Speed, V = 13.3m/Min
Feed, F = 0.5mm/Double Stroke
Number Of Pass, N=1
Approach Over Run, A = 20mm
Work Length, L = 200mm
Work Width W = 90mm
Ratio M = 0.83

Solution:

$$Cutting\ speed\ V = \frac{Length\ of\ cutting\ stroke}{Time\ taken\ for\ the\ same\ stroke}$$

$$Total / doublestroke = Time\ for\ forward\ stroke + return\ stroke$$

$$\therefore T = \frac{L}{V} + m\left(\frac{L}{V}\right)$$

$$= \frac{L}{V}(l+m)$$

$$Total\ length,\ L = l + A = 200 + 20$$

= 220mm=0.22m

Total Time T = $\frac{0.22}{13.3}(1+0.83)$

$= 0.0303 \min$

Number Of Strokes S_N = $\frac{w}{f}$

Total Width = W+ Lateral Approach
= 90+4 =94mm

S_N = $\frac{94}{0.57} = 164.9 \approx 165\,stroke,$

$\therefore Total\ time\ required\ for\ finishing\ the\ complete\ job$

$$T_t = TxS_N = 0.0303x165$$

$$= 4.9975mm \approx 5 \min\ Ans.$$

Problem 4

The Cross-Feed On A Shaper Consists Of A Lead Screw Having 0.2 Threads Per Mm. A Ratchet And Pawl On The End Of The Lead Screw Is Driven From The Shaper Crank Such That The Pawl Indexes The Ratchet By One Tooth During Each Return Stroke Of The Ram. Ratchet Has 20 Teeth.

a) **Find The Cross Feed In Mm.**

b) If A Plate 100 Mm Wide Has To Be Machined In 10 Minutes Find The Cutting Speed In M/S. The Ratio Of Return To Cutting Speed Is 2:1 And The Length Of The Stroke Is 150mm.

Given Data

Lead Screw Threads = 0.2 Thread/Mm
Ratchet Teeth = 20
Plate Wide, W = 100 Mm
Machining Time, T = 10min
Ratio Of Return To Cutting Speed 1/M = 2
Stroke Length L = 150mm

Solution

Pitch Of The Lead Screw = $\frac{1}{lead\ screw\ threads}$

$= \frac{1}{0.2} = 5mm$

Pawi Indexes $\frac{1}{20}\ revolution\ per\ each\ storke$

a) Cross Feed:

F= Pawl Indexing X Lead Screw Pitch

$= \frac{5}{20} = 0.25mm$

Number Of Cutting Strokes,

$S_N = \frac{w}{f} = \frac{100}{0.25} = 400$

Total Time Required To Complete The Job,

$T_t = TXS_N$
= 10x400=400min

Cutting Speed, V = $\frac{Length\ of\ cutting\ stroke}{Time\ taken\ for\ the\ cutting\ stroke}$ $Machining\ time, T = \frac{L}{Nf}$

$4000 = \frac{100}{Nx0.25}$

$N = 0.1rpm$

$V = \frac{LN(1+m)}{1000} = \frac{150x0.1(1+0.5)}{1000}$

Cutting Speed, $= 0.02225\ m/\min$

Problem 5

A 75cm X 20 Cm Surface Of Cast Iron Block Of 15 Cm Thick Is To Be Machined On A Shaper. Ram Speed Is 25mpm, Length Of Stroke Is 500 Mm, Depth Of Cut Is 4mm, Feed Id 1.5mm/Stroke Stock To Be Removed Is 7mm Side Cutting Edge Angle Of The Tool Is 45^0, Ratio Of Time Taken In Return Stroke To The Time Taken In Cutting Stroke Is 0.5. Determine The Metal Removal Rate And The Cutting Time.

Given Data:
Cast Iron Block Of 75 X 20 X 15 Cm
V = 25 Mpm
L = 500 Mm
T = 4mm
F = 1.5mm/Stroke
Stock To Be Removed = 6mm
$\alpha = 45^0$
$m = 0.5$

Solution
$$V = \frac{LN\left(l+m\right)}{1000} = \frac{500\ x\ N\left(1+0.5\right)}{1000}$$

$$N = 33.33 \approx 34 rpm$$

Metal Removal Rate W = F T L N = 1.5 X 4 X 500 X34
= 102 X 10^3 Mm^3/Min

Number Of Passes N = $\frac{Stock\ to\ be\ removed}{depth\ of\ \ cut}$

$$\frac{6}{4} = 1.5 \approx 2$$

$$\therefore Total\ cutting\ time\ T_m = \frac{LN}{Nf} = \frac{200x2}{34x1.5}$$
$$= 7.84\ \min\ Ans.$$

Problem 6: Direct Or Rapid Indexing

Find Index Movement To Mill Hexagonal Bolt By Direct Indexing If The Rapid Index Plate Has 24 Slots.

Solution:

Number Of Slots To Be Moved = $\frac{24}{N} = \frac{24}{6} = 4$

After Machining One Side Of The Bolt, Index Plate Has To Be Moved By 4 Slots For 5 Times To Finish The Work.

Problem 7: Compound Indexing

Compound Indexing For 87 Divisions.

Solution:

Required Movement Of The Work Piece = $\frac{40}{N} = \frac{40}{87}$

Suppose We Select Two Circles Of 29 And 33 Holes. Substituting The Values In The Expression 3.1. (Refer Compound Indexing)

$$\frac{87 \times (33 - 29)}{40 \times 29 \times 33} = \frac{1}{110}$$

Since, The Numerator Is One, The Selected Circles Are Correct.

The Required Indexing Is Given By

$$\frac{40}{87} = \frac{110}{33} - \frac{110}{29} = 3\frac{11}{33} - 3\frac{23}{29}$$
$$or\ 3\frac{23}{29} - 3\frac{11}{33}$$

Taking 3 As Common, The Above Expression Becomes

$$\frac{11}{33} - \frac{23}{29}\ or\ \frac{23}{29} - \frac{11}{33}$$

For Indexing, The Index Crank Should Be Moved By 23 Holes Of 29 Circle Forward Directions And Then The Plate And The Crank Together Is Moved By 11 Holes Of 33 Circles In Backward Direction.

Problem: 8

Compound Index For 69 Divisions.

Solution:

Required Index Movement = $\frac{40}{N} = \frac{40}{69}$

Suppose, We Select Two Circles Of 23 And 33 Holes. Substitute The Values In Expression 8.1.

$$\frac{69 \times (33 - 23)}{40 \times 23 \times 33} = \frac{1}{44}$$

Since The Numerator Is Unity, The Circles Selected Are Correct. The Required Indexing Movement Is Given By

$$\frac{44}{69} = \frac{44}{23} - \frac{44}{33} = 1\frac{21}{23} - 1\frac{11}{33}$$

Taking 1 As Common, The Above Expression Become $\frac{23}{33} = \frac{11}{33}$

Thus For Indexing 69 Divisions, The Index Crank Should Be Move By 21 Holes Of 23 Hole Circle In Forward Direction He Then The Plate And The Crank Together Is Moved By 11 Holes Of 33 Hole Circle In The Backward Direction.

Problem 9: Differential Indexing

Find Out The Indexing Movement Of Milling 119 Teeth Spur Gear On A Gear Blank.

Solution:

Assume A = 120

A. Gear Ratio:

$$\text{Gear ration} = \frac{\text{Gear on spindle stud}}{\text{Gear on bevel gear shaft}}$$

$$= (A - N) \times \frac{40}{A}$$

$$= (120 - 119) \times \frac{40}{120}$$

$$= 1 \times \frac{40}{120}$$

$$= \frac{1}{3} = \frac{1 \times 24}{3 \times 24} = \frac{24}{72}$$

A Simple Gear Train Is Used.

Gear On Spindle Will Have 24 Teeth.

Gear On Bevel Gear Shaft Will Have 72 Teeth

B. Index Crank Movement:

$$= \frac{40}{A} = \frac{40}{120} = \frac{1}{3}$$

$$= \frac{1 \times 8}{3 \times 8} = \frac{8}{24}$$

The Index Crank Will Have To Be Moved By 8 Holes In 24 Hole Circle For Each Cut For 119 Times.

C Number Of Idlers:

As (A - N) Is Positive, A Simple Gear Train With One Idler Is Used. The Index Plate Will

Rotate In The Same Direction Of The Crank Movement.

Problem 10

Calculate The Spindle Speed To Drill A Hole Of 50mm Using Cutting Speed As 25m/Min

Given Data:

Diameter Of Hole, D = 50mm
Cutting Speed, V = 25m/Min

Solution:

$$\text{Cutting speed, } V = \frac{\pi DN}{1000}$$

$$25 = \frac{\pi \times 50 \times N}{1000}$$

N = 159.15rpm say 160mm Ans.

Problem :11

Calculate The Feed In Mm/Rev To Drill A Hole Of 30mm In One Minute To A Plate Thickness Of 40mm And Using A Spindle Speed Of 500rpm.

Given Data:

Diameter Of Hole, D = 30mm
Machining Time, T = 1 Minute
Thickness Of Plate, T_p = 40mm
Spindle Speed, N = 500rpm

Solution:

We Know That,

$$\text{Machining Time, } T = \frac{\text{Length of tool travel}}{\text{Feed in mm / rev} \times \text{r.p.m}}$$

$$= \frac{t_p \times 0.3D}{Feed \times N}$$

$$I = \frac{40 \times 0.3 \times 30}{Feed \times 500}$$

$$\therefore Feed = 0.098 mm/rev \text{ Ans.}$$

Problem 12

Calculate The Machining Time Required For Making 15 Holes On A M.S. Plate Of 30mm Thickness With The Following Data:

Drill Diameter = 25 Mm
Cutting Speed = 20m/Min And

Feed = 0.13mm/Rev

Given Data :

Number Of Holes To Be Drilled = 15
Thickness Of The Plate, T_p = 30mm
Drill Diameter, D = 25 Mm
Cutting Speed, N = 20m/Min
Feed, F = 0.13mm/Rev

Solution:

We Know That

$$\text{Cutting speed, V} = \frac{\pi DN}{1000}$$

$$20 = \frac{\pi \times 25 \times N}{1000}$$

$$N = 254.65\text{rpm say } 260 \text{ rpm}$$

$$\text{Machining time, t} = \frac{\text{Length of tool travel}}{\text{Feed in mm / rev} \times \text{r.p.m.}}$$

$$t = \frac{t_p \times 0.3D}{\text{Feed} \times N} = \frac{30 \times 0.3 \times 25}{0.13 \times 260}$$

$$t = 6.66 \text{ minute for one hole}$$

Total Machining Time, T_m = 6.66 X 15 = 9.99 Minute Ans.

Problem 13

A 40 Mm HSS Drill Is Used To Drill A Hole In A Cast Iron Black Of 80mm Thick. Determine The Time Required To Drill The Hole If Feed Is 0.2mm/Rev. Assume An Over Travel Of Drill As 5 Mm. The Cutting Sped Is 22m/Min.

Given Data:

Drill Diameter, D = 40mm
Thickness Of C.I.Block = 80
Feed, F =0.2mm/Rev
Over Travel, S = 5 Mm
Cutting Speed, V = 22m/Min

Solution:

We Know That

$$\text{Cutting speed, } V = \frac{\pi DN}{1000}$$

$$22 = \frac{\pi \times 40 \times N}{1000}$$

$$N = 175 rpm$$

Length Of Travel Of Drill = T_p +0.3D +Over Travel
= 80 + 0.3 X 40 + 5
= 97mm

$$\text{Machining time, } t = \frac{97}{0.2 \times 175}$$

$$= 2.77 \text{minutes} \quad \text{Ans.}$$

Problem :14

Calculate The Power Required To Drill 25mm Diameter Hole In Aluminium Plate At A Feed Of 0.2mm/Rev And At A Drill Speed 400rpm. Determine Also The Volume Of Metal Per Unit Minute.

Given Data:

Drill Diameter, D = 25

Material: Aluminium

Feed, F =0.2mm/Rev

Drill Speed, N = 400rpm

Solution:

We Know That

$$\text{Torque } T = C \times f^{0.75} \times D^{1.8}$$

From Table 3.1 For Aluminium, C = 0.11

$$\therefore T = 0.11 \times (0.2)^{0.75} \times (25)^{1.8}$$

$$= 10.8 \text{ N-m}$$

$$\text{Power. } P = \frac{2\pi NT}{60} = \frac{2\pi \times 400 \times 10.8}{60}$$

$$P = 452.4W \text{ Ans.}$$

Volume Of Metal Removal/Minute
= Area Of Hole X Feed X Speed

$$= \frac{\pi}{4} \times (25)^2 \times 0.2 \times 400$$

= 32.27 X $10^3 mm^3$ Ans.

$$\text{Energy Consumption} = \frac{32.27 \times 10^3}{452.4}$$

$= 86.8 m^3$/Watt Minute Ans.

Compare Peripheral Milling And Face Milling (MU Oct 1996)

What Are The Three Milling Processes

The Three Milling Process Are Face Milling, Slab Milling And End Milling.

In Face Milling, The Cutter Axis And The Work Piece Axis Intersect And The Cutting Teeth On The Periphery Does Not Do The Cutting.

In Slab Milling (Peripheral Milling) The Cutter Axis Do Not Intersect, It Has Teeth On The Periphery Only Which Does The Cutting.

In End Milling, Both The Face And The Periphery Does The Cutting Which Can Be Seen In The Figure. Thus End Milling May Be Said To Be A Combination Of Peripheral As Well As Face Milling.

Grinding

Grinding Is A Process Of Removing Material By The Abrasive Action Of Revolving Wheel On Surface Of A Work Piece In Order To Bring The Required Shape And Size.

Abrasive

It Is The Material Of The Grinding Wheel Which Does The Cutting Action.

Dressing.

The Process Of Removing The Leading And Breaking Away The Glazed Surface So That Fresh Sharp Abrasive Particles Are Again Presented To The Work For Efficient Cutting Is Called Dressing.

Truing

Truing Is The Process Of Changing The Shape Of The Grinding Wheel As It Becomes Worn From An Original Shape, Owing To The Breathing Away Of The Abrasive And Bond.

Types Of Abrasives

- Grain Size
- Grade Of The Wheel
- Structure

- Types Of Bond

NON TRADITIONAL MACHINING PROCESSES

Introduction

Non-traditional machining processes is defined as a group of processes that remove excess material by various techniques involving mechanical, thermal, electrical or chemical energy or combinations of these energies but do not use a sharp cutting tools as it needs to be used for traditional manufacturing processes.

Extremely hard and brittle materials are difficult to machine by traditional machining processes such as turning, drilling, shaping and milling. Non traditional machining processes, also called advanced manufacturing processes, are employed where traditional machining processes are not feasible, satisfactory or economical due to special reasons as outlined below.

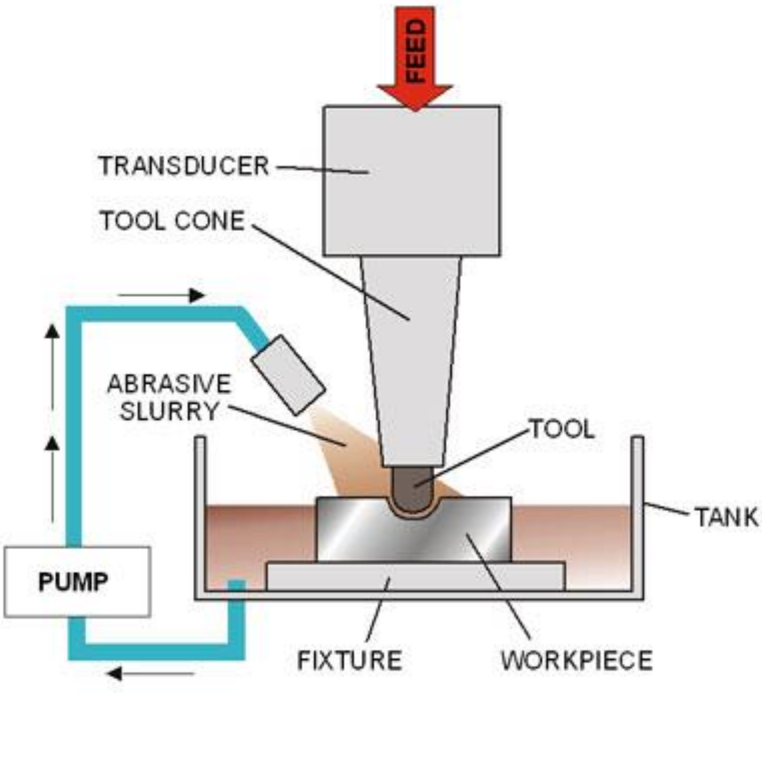
- Very hard fragile materials difficult to clamp for traditional machining
- When the workpiece is too flexible or slender
- When the shape of the part is too complex

Several types of non-traditional machining processes have been developed to meet extra required machining conditions. When these processes are employed properly, they offer many advantages over non-traditional machining processes. The common non-traditional machining processes are described in this section.

Ultrasonic machining

Definition:
Ultrasonic machining is a mechanical metal removal process for brittle materials by using high frequency oscillations of a shaped tool using abrasive slurry.
Ultrasonic Machining is a non-traditional process, in which abrasives contained in a slurry are driven against the work by a tool oscillating at low amplitude (25-100 microns) and high frequency (15-30 kHz).
Ultrasonic machining, also known as ultrasonic impact grinding, is a machining operation in which a vibrating tool oscillating at ultrasonic frequencies is used to remove material from the workpiece, aided by an abrasive slurry that flows freely between the workpiece and the tool. It differs from most other machining operations because very little heat is produced. The tool never contacts the work-piece and as a result the grinding pressure is rarely more than 2 pounds, which makes this operation perfect for machining extremely hard and brittle materials, such as glass, sapphire, ruby, diamond, and ceramics.

Process:
Ultrasonic machining is a mechanical type non-traditional machining process. It is employed to machine hard and brittle materials (both electrically conductive and non conductive material) having hardness usually greater than 40 HRC. The process was first developed in 1950s and was originally used for finishing EDM surfaces.



(Schematic diagram of Ultrasonic machining process)

In ultrasonic machining, tool of desired shape vibrates at ultrasonic frequency (19 to 25 kHz.) with an amplitude of 15-50 Microns over work piece. Generally tool is pressed down with a feed force F. Between the tool and work, machining zone is flooded with hard abrasive particles generally in the form of water based slurry. As the tool vibrates over the work piece, abrasive particles acts as indenter and indent both work and tool material . Abrasive particles , as they indent , the work material would remove the material from both tool and work piece. Abrasive particles are driven into the work by oscillating tool. The force is typically 15000 times the weight of the individual gear. In Ultrasonic machining material removal is due to crack initiation, propagation and brittle fracture of material. USM is used for machining hard and brittle materials, which are poor conductors of electricity and thus cannot be processed by Electrochemical machining (ECM) or Electro discharge machining (EDM). The tool in USM is made to vibrate with high frequency on to the work surface in the midst of the flowing slurry. The main reason for using ultrasonic frequency is to provide better performance. Audible frequencies of required intensities would be heard as extremely loud sound and would cause fatigue and even permanent damage to the auditory apparatus.

Equipment:

Ultrasonic Machining consists of :

1.High Power sine wave generator
2.Magneto-strictive Transducer
3.Tool
4.Tool Cone
5.Liquid media

High power sine wave generator

This unit converts low frequency (60 Hz) electrical power to high frequency (20kHz) electrical power.

Transducer

The high frequency electrical signal is transmitted to traducer which converts it into high frequency low amplitude vibration. Essentially transducer converts electrical energy to mechanical vibration. There are two types of transducer used

i)Piezo electric transducer
ii)Magneto-stricitve transducer.

Piezo electric transducer

:

These transducer generate a small electric current when they are compressed. Also when the electric current is passed though crystal it expands. When the current is removed , crystal attains its original size and shape. Such transducers are available up to 900Watts. Piezo electric crystals have high conversion efficiency of 95%.

Magneto-strictive transducer:

These also changes its length when subjected to strong magnetic field. These transducer are made of nickel , nickel alloy sheets. Their conversion efficiency is about 20-30%. Such transducers are available up to 2000 Watts. The maximum change in length can be achieved is about 25 microns.

Tool

Tools are made of relatively ductile materials like Brass, Stainless steel or Mild steel so that Tool wear rate (TWR) can be minimized. The value of ratio of TWR and MRR depends on kind of abrasive, work material and tool materials.

Tool Cone and Tool Tip

The tool cone (also called horn)amplifies and focuses the mechanical energy produced by the transducer and imparts this to the work piece in such a way that energy utilization is optimum.
The horn mechanically modifies the vibratory energy to give the required force-amplitude ratio.

Liquid media

The abrasive is suspended in liquid.The liquid performes many functions:
a)Acts as an acoustic bond between the workpiece and the vibrating tool.
b) helps efficient transfer of energy between the workpiece and the tool.
c)Acts as a coolant.
d)Provides a medium to carry the abrasive to the cutting zone.

Process parameters :

1.Amplitude of vibration (15 to 50 microns)

2.Frequency of vibration (19 to 25 kHz).

3.Feed force (F) related to tool dimensions

4.Feed pressure

5.Abrasive size

6.Abrasive material : SiC, B4C, Boron silicarbide, Diamond, Al_2O_3

7.Flow strength of the work material

8.Flow strength of the tool material

9.Contact area of the tool

10.Volume concentration of abrasive in water slurry

11. Tool : a)Material of tool b)Shape c)Amplitude of vibration d)Frequency of vibration e)Strength developed in tool

12. Work material : a)Material b)Impact strength c)Surface fatigue strength

13. Slurry

    a)Abrasive – hardness, size, shape and quantity of abrasive flow

    b)Liquid – Chemical property, viscosity, flow rate

    c)Pressure

    d)Density

Surface finish

The surface finish of ultrasonic machining depends upon the hardness of the workpiece/tool and the average diameter of the abrasive grain used. This process simply utilizes the plastic deformation of metal for the tool and the brittleness of the workpiece. As the tool vibrates, it pushes down on the abrasive slurry (containing many grains) until the grains impact the brittle workpiece. The workpiece is broken down while the tool bends very slightly. Commonly used tool material consist of nickel and soft steels.

Machine time

Machine time depends upon the frequency at which the tool is vibrating, the grain size and hardness (which must be equal or greater than the hardness of the workpiece), and the viscosity of the slurry fluid. Common grain materials used are silicon carbide and boron carbide, because of their hardness. The less viscous the slurry fluid, the faster it can carry away used abrasive.

Mechanics of ultrasonic machining

The material removal is believed to be due to some combination of:

- The hammering of the abrasive particles on the work surface by the tool.
- The impact of the free abrasive particles on the work surface.
- The speed of the vibrating tool.
- The erosion due to cavitation, and
- The chemical action associated with the fluid used.

Advantages

1. It can be used machine hard, brittle, fragile and non conductive material
2. No heat is generated in work, therefore no significant changes in physical structure of work material
3. Non-metal (because of the poor electrical conductivity) that cannot be machined by EDM and ECM can very well be machined by USM.
4. It is burr less and distortion less processes.
5. It can be adopted in conjunction with other new technologies like EDM,ECG,ECM.

Disadvantages

1. Low Metal removal rate
2. It is difficult to drill deep holes, as slurry movement is restricted.
3. Tool wear rate is high due to abrasive particles. Tools made from brass, tungsten carbide, MS or tool steel will wear from the actionof abrasive grit with a ratio that ranges from 1:1 to 200:1
4. USM can be used only when the hardness of work is more than 45 HRC.

Applications

1.Machining of cavities in electrically non-conductive ceramics.
2.Used to machine fragile components in which otherwise the scrap rate is high.
3.Used for multistep processing for fabricating silicon nitride (Si_3N_4) turbine blades.

4.Used for machining hard, brittle metallic alloys, semiconductors, glass, ceramics, carbides etc.

5.Used for machining round, square, irregular shaped holes and surface impressions.

6.Used in machining of dies for wire drawing, punching and blanking operations.

7.USM has been used for piercing of dies and for parting off and blanking operations.

8.USM enables a dentist to drill a hole of any shape on teeth without any pain.

9.USM can be used to cut industrial diamonds .

10.USM is used for grinding Quartz, Glass, ceramics .

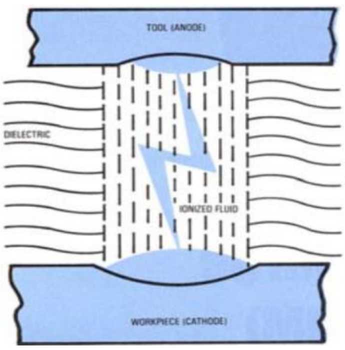
ELECTRIC DISCHARGE MACHINING:

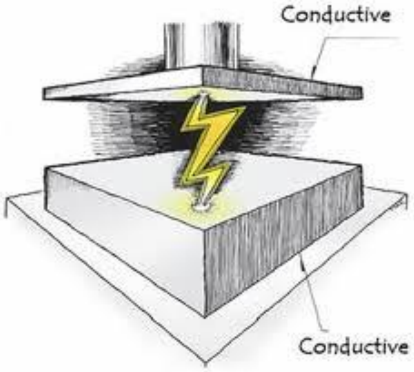
Working Principle of Electric Discharge Machining:

Electric discharge machining process is carried out in presence of dielectric fluid which creates path for discharge. When potential difference is created across the two surfaces of die electric fluid, it gets ionized. An electric spark/discharge is generated across the two terminals. The potential difference is developed by a pulsating direct current power supply connected across the two terminals. One of the terminal is positive terminal given to workpiece and tool is made negative terminal. Two third of the total heat generated is generated at positive terminal so workpiece is generally given positive polarity. The discharge develops at the location where two terminals are very close. So tool helps in focusing the discharge or intensity of generated heat at the point of metal removal.

Definition:

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the workpiece. This removes (erodes) very tiny pieces of metal from the workpiece at a controlled rate.

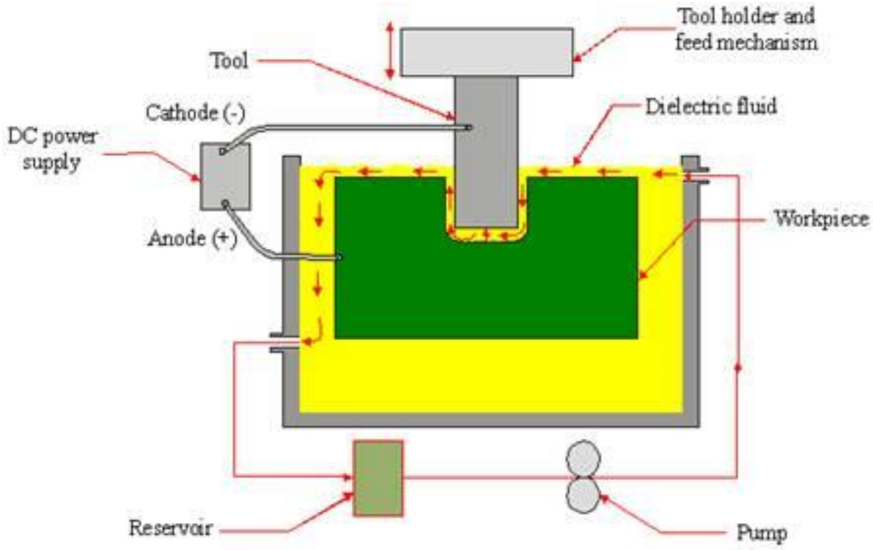




Process:

A preshaped or formed electrode (tool),usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid workpiece. In the EDM process an electric spark is used to cut the workpiece, which takes the shape opposite to that of the cutting tool or electrode. The electrode and the workpiece are both submerged in a dielectric fluid, which is generally light lubricating oil. A servo mechanism maintains a space of about the thickness of a human hair between the electrode and the work, preventing them from contacting each other.

Equipments used in EDM



Base and Container

A container of non-conducting, transparent material is used for carrying out EDM. The container is filled with dielectric solution. A base to keep workpiece is installed at the bottom of container. The base is made of conducting material and given positive polarity.

Tool

Tool is given negative polarity. It is made of electrically conducting material line brass, copper or tungeten. The tool material selected should be easy to machine, high wear resistant. Tool is made slightly under size for inside machining and over sized for cut side machining. Tool is designed and manufactured according to the geometry to be machined.

Dielectric Solution

Dielectric solution is a liquid which should be electrically conductive. This solution provides two main functions, firstly it drive away the chips and prevents their sticking to workpiece and tool. It enhance the intensity of discharge after getting ionized and so accelerates metal removal rate.

Properties of dielectric fluid:

They should

i)Remain electrically non conductive until the required breakdown voltage is reached .

ii)Provide an effective cooling medium.

iii) have a good degree of fluidity.

iv)Be cheap and easily available.

Power Supply

A DC power supply is used, 50 V to 450 V is applied. Due to ionization of dielectric solution an electrical breakdown occurs. The electric discharge so caused directly impinges on the surface of workpiece. It takes only a few micro seconds to complete the cycle and remove the material. The circuit cam be adjusted for auto off after pre-decided time interval.

Tool Feed Mechanism

In case of EDM, feeding the tool means controlling gap between workpiece and the tool. This gap is maintained and controlled with the help of servo mechanism. To maintain a constant gap throughout the operation tool is moved towards the machining zone very slowly. The movement speed is towards the machining zone very slowly. The movement speed is maintained by the help of gear and rack and pinion arrangement. The servo system senses the change in gap due to metal removal and immediately corrects it by moving the tool accordingly. The spark gap normally varies from 0.005 mm to 0.50 mm.

Factors for selection of electrode material:

*i)T*he maximum possible metal removal rate
ii)Wear Ratio
iii)Ease with which it can be shaped or fabricated to tve desired shape.
iv)Cost

Wear Ratio:

It can be defined asthe ratio of volume of work material machined in unit time to the volume of electrode material worn out in unit time.

Flushing

One of the most important factors in a successful EDM operation is the removal of the metal particles (chips) from the working gap. Flushing these particles out of the gap between the workpiece to prevent them from forming bridges that cause short circuits.

Flushing Ram Type EDM

Flushing is the most important function in any electrical discharge machining operation. Flushing is the process of introducing clean filtered dielectric fluid into the spark gap. Flushing applied incorrectly can result in erratic cutting and poor machining conditions.

There are a number of flushing methods used to remove the metal particles efficiently while assisting in the machining process. Too much fluid pressure will remove the chips before they can assist in the cutting action, resulting in slower metal removal. Too little pressure will not remove the chips quickly enough and may result in short-circuiting the erosion process.

Types of flushing methods:

1.Injection flushing
2.Suction flushing
3.Side flushing
4. flushing by dielectric pumping

Workpiece and Machined Geometry

The important point for workpiece is that any material which is electrical conductor can be machined through this process, whatever be the hardness of the same. The geometry which is to be machined into the workpiece decides the shape and size of the tool.

EDM performes good in machining of alloy steel,tungsten carbide,hastalloy,nimonic,stallite and all electric conductive materials.

Advantages and disadvantages

Some of the advantages of EDM include machining of:

- Complex shapes that would otherwise be difficult to produce with conventional cutting tools.
- Extremely hard material can be cut to very close tolerances.

- Very small work pieces where conventional cutting tools may damage the part from excess cutting tool pressure.
- There is no direct contact between tool and work piece. Therefore delicate sections and weak materials can be machined without any distortion.
- A good surface finish can be obtained.
- very fine holes can be drilled.
- This process is very much economical for machining very hard material.
- Maintains high degree of dimensional accuracy so it is recommended for tool and die making.

Some of the disadvantages of EDM include:

- The slow rate of material removal.
- Potential fire hazard associated with use of combustible oil based dielectrics.
- The additional time and cost used for creating electrodes for ram/sinker EDM.
- Reproducing sharp corners on the workpiece is difficult due to electrode wear.
- Specific power consumption is very high.
- Power consumption is high.
- "Overcut" is formed.
- Excessive tool wear occurs during machining.
- Electrically non-conductive materials can be machined only with specific set-up of the process.

Application of Electric Discharge Machining
i)Tool room application
ii)Component Production

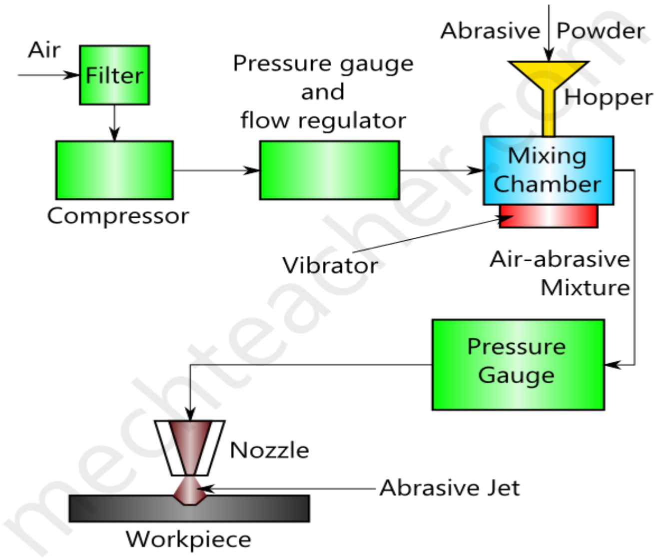
This process is highly economical for machining of very hard material as tool wear is independent of hardness of workpiece material. It is very useful in tool manufacturing. It is also used for broach making, making holes with straight or curved axes, and for making complicated cavities which cannot be produced by conventional machining operations. EDM is widely used for die making as complex cavities are to be made in the die making. However, it is capable to do all operations that can be done by conventional machining. It is used to make hydraulic valve,gear wheel,fine slots in hard blade material used in gas turbine,compressor etc.

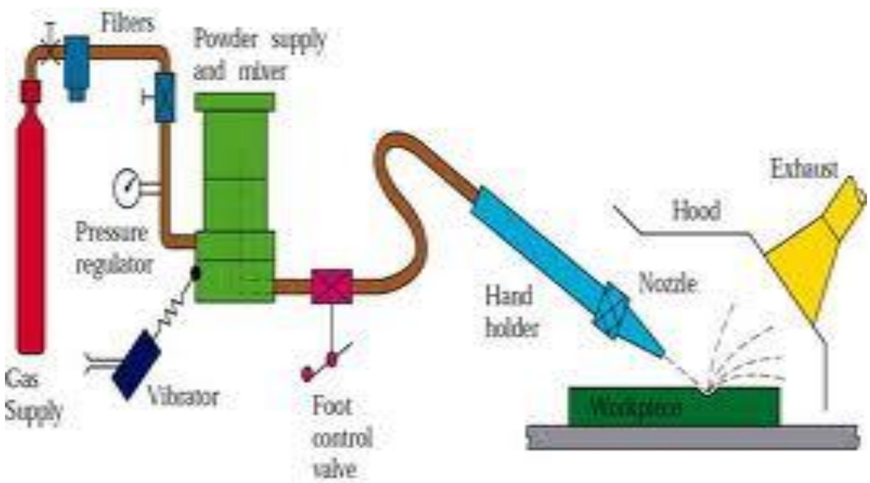
ABRASIVE JET MACHING

Definition:

In abrasive jet machining, a focused stream of abrasive particles, carried by high pressure air or gas is made to impinge on the work surface through a nozzle and the work material is made to impinge on the work surface through a nozzle and work material is removed by erosion by high velocity abrasive particles.

Abrasive jet machining (AJM), also known as abrasive micro-blasting, pencil blasting and micro-abrasive blasting, is an abrasive blastingmachining process that uses abrasives propelled by a high velocity gas to erode material from the workpiece. Common uses include cutting heat-sensitive, brittle, thin, or hard materials. Specifically it is used to cut intricate shapes or form specific edge shapes.





Process:

In Abrasive jet machining abrasive particles are made to impinge on work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by conver ting pressure energy of carrier gas or air to its Kinetic energy and hence high velocity jet. Nozzles directs abrasive jet in a controlled manner onto work material. The high velocity abrasive particles remove the material by micro-cutting action as wellas brittle fracture of the work material.

This is a process of removal of material by impact erosion through the action of concentrated high velocity stream of grit abrasivesentrained in high velocity gas stream. AJM is different from shot or sand blasting, as in AJM, finer abrasive grits are used and parameters can be controlled more effectively providing better control over product quality.

In AJM, generally, the abrasive particles of around 50 microns grit size would impinge on the work material at velocity of 200 m/sfrom a nozzle of ID 0.5mm with a stand off distance of around 2mm. The kinetic energy of the abrasive particles would sufficient to provide material removal due to brittle fracture of the work piece or even micro cutting by the abrasives.

Equipment:

Abrasive jet Machining consists of :

1.Gas propulsion system

2.Abrasive feeder

3.Machining Chamber

4.AJM Nozzle

5.Abrasives

PROCESS PARAMETERS:

i)carrier gas
ii)Type of abrasive
iii)Size of abrasive grains
iv)Velocity of the abrasive jet.
v)Work material
vi)Stand off distance
vii)Nozzle design
viii)shape of cut

However, Process criteria are generally influenced by the process parameters as enumerated below:

•Abrasives

- The abrasive should have a sharpe and irregular shape and be fine enough to remain suspended in the carrier gas and should have excellent flow characteristics.

a)material –Glass beads, Crushed glass, Sodium bicarbonate ,SiC,Al_2O_3

b)shape – irregular/regular

c)Size – 10 to 50 microns

d)Mass flow – 2-20 gm/min

•Carrier Gas

- Gas should be nontoxic, cheap, easily available and capable of being dried and cleaned without difficulty.
- Air is mostly used due to easy availability and little cost.

a)Composition – Air, CO2, N2

b)Density – 1.3 kg/m3

c)Velocity - 500 to 700 m/s

d)Pressure - 2 to 10 bar

e)Flow rate - 5 to 30 microns

•Abrasive Jet

b)Velocity - 100 to 300 m/s

c)Mixing ratio – Volume flow rate of abrasives/Volume flow rate of gas

d)Stand off distance – SOD- 0.5 to 15mm.

e)Impingement angle – 60 to 90 deg.

•Nozzle

- Nozzle has to withstand erosive action of abrasive particles.made of material that can provide resistance to wear.

a)Material – WC/Sapphire

b)Diameter – 0.2 to 0.8 mm

c)Life – 300 hours for sapphire, 20 to 30 hours for WC

•Work material

AJM is recommended for the processing of brittle materials, such as glass, ceramics, refractories, etc.

•Stand off Distance

It is defined as the distance between the face of the nozzle and the working surface of the work .A large SOD results in the flaring up of the jet which leads to poor accuracy.

Application

- This is used for abrading and frosting glass more economically as compared to etching or grinding
- Cleaning of metallic smears on ceramics, oxides on metals, resistive coating etc.
- AJM is useful in manufacture of electronic devices , drilling of glass wafers, de burring of plastics, making of nylon and Teflon parts permanent marking on rubber stencils, cutting titanium foils
- Deflashing small castings, engraving registration numbers on toughened glass used for car windows
- Used for cutting thin fragile components like germanium, silicon etc.

- ❖ Register treaming can be done very easily and micromodule fabrication for electrical contact , semiconductor processing can also be done effectively.
- ❖ Used for drilling , cutting , deburring etching and polishing of hard and brittle materials.
- ❖ Most suitable for machining brittle and heat sensitive materials like glass, quartz, sapphire , mica , ceramics germanium , silicon and gallium.
- ❖ It is also good method for deburring small hole like in hypodermic needles and for small milled slots in hard metallic components.

Advantages

- ❖ High surface finish can be obtained depending upon the grain sizes Particle size (in microns) Surface roughness (in microns) 10 0.152 to 0.203 25 to 27 0.355 to 0.675 50 0.965 to 1.27 .
- ❖ Depth of damage is low (around 2.5 microns) .
- ❖ It provides cool cutting action, so it can machine delicate and heat sensitive material .
- ❖ Process is free from chatter and vibration as there is no contact between the tool and work piece .
- ❖ Capital cost is low and it is easy to operate and maintain AJM.
- ❖ Thin sections of hard brittle materials like germanium, mica, silicon, glass and ceramics can be machined.
- ❖ It has the capability of cutting holes of intricate shape in hard materials.

Disadvantages /Limitations

- ❖ Limited capacity due to low MRR. MRR for glass is 40 gm/minute
- ❖ Abrasives may get embedded in the work surface, especially while machining soft material like elastomers or soft plastics.
- ❖ The accuracy of cutting is hampered by tapering of hole due to unavoidable flaring of abrasive jet.
- ❖ Stray cutting is difficult to avoid .
- ❖ A dust collection system is a basic requirement to prevent atmospheric pollution and health hazards.
- ❖ Nozzle life is limited (300 hours)
- ❖ Abrasive powders cannot be reused as the sharp edges are worn and smaller particles can clog the nozzle.
- ❖ Short stand off distances when used for cutting , damages the nozzle.

Laser–Beam Machining (LBM)

Introduction:

Laser-beam machining is a thermal material-removal process that utilizes a high-energy, coherent light beam to melt and vaporize particles on the surface of metallic and non-metallic workpieces. Lasers can be used to cut, drill, weld and mark. LBM is particularly suitable for making accurately placed holes. A schematic of laser beam machining is shown in Figure 12.
Different types of lasers are available for manufacturing operations which are as follows:

- CO_2 (pulsed or continuous wave): It is a gas laser that emits light in the infrared region.? It can provide up to 25 kW in continuous-wave mode.
- Nd:YAG:? Neodymium-doped Yttrium-Aluminum-Garnet ($Y_3Al_5O_{12}$) laser is a solid-state laser which can deliver light through a fibre-optic cable. It can provide up to 50 kW power in pulsed mode and 1 kW in continuous-wave mode.

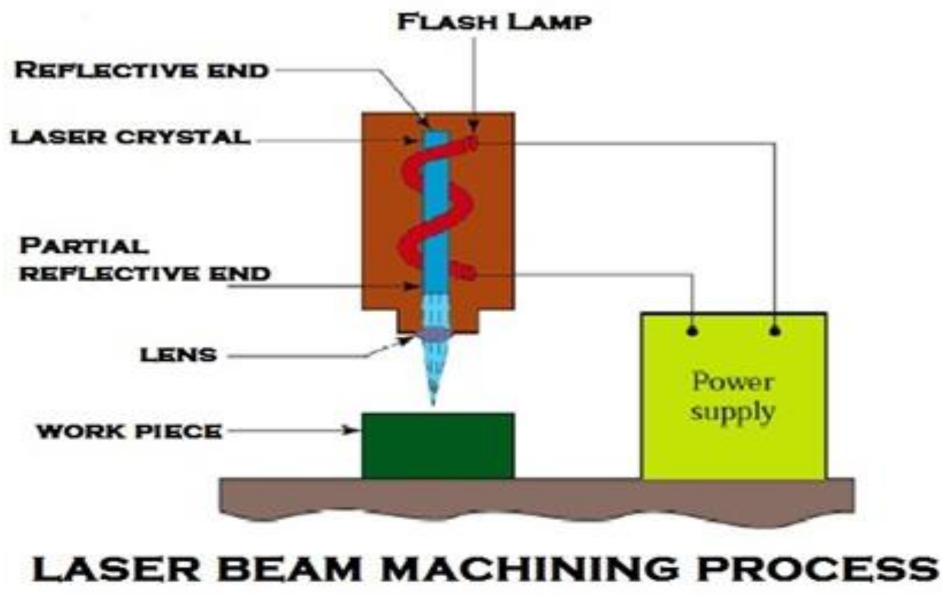


Figure 12: Laser beam machining schematic

Applications

LBM can make very accurate holes as small as 0.005 mm in refractory metals ceramics, and composite material without warping the workpieces. This process is used widely for drilling and cutting of metallic and non-metallic materials. Laser beam machining is being used extensively in the electronic and automotive industries.

Laser beam cutting (drilling)

- In drilling, energy transferred (e.g., via a Nd:YAG laser) into the workpiece melts the material at the point of contact, which subsequently changes into a plasma and leaves the region.
- A gas jet (typically, oxygen) can further facilitate this phase transformation and departure of material removed.
- Laser drilling should be targeted for hard materials and hole geometries that are difficult to achieve with other methods.

A typical SEM micrograph hole drilled by laser beam machining process employed in making a hole is shown in Figure 13.

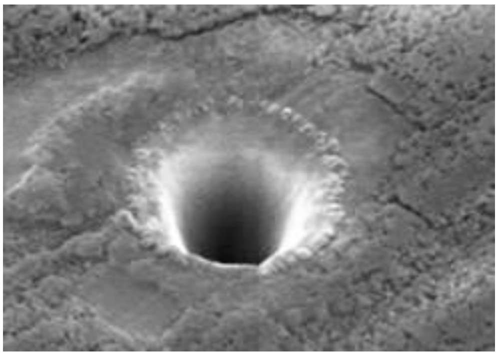


Figure 13: SEM micrograph hole drilled in 250 micro meter thick Silicon Nitride with 3rd harmonic Nd: YAG laser

Laser beam cutting (milling)

- A laser spot reflected onto the surface of a workpiece travels along a prescribed trajectory and cuts into the material.
- Continuous-wave mode (CO2) gas lasers are very suitable for laser cutting providing high-average power, yielding ? high material-removal rates, and smooth cutting surfaces.

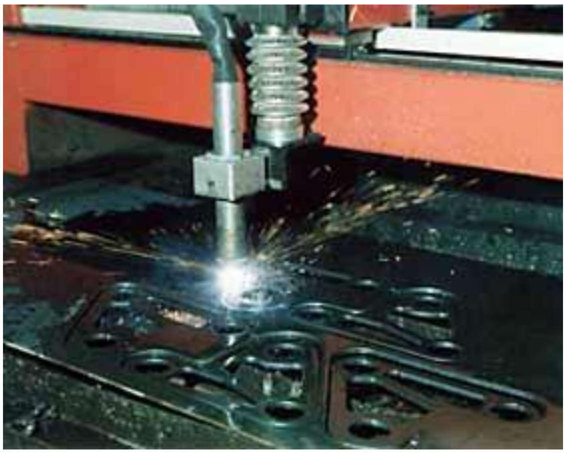
Advantage of laser cutting

- No limit to cutting path as the laser point can move any path.
- The process is stress less allowing very fragile materials to be laser cut without any support.
- Very hard and abrasive material can be cut.
- Sticky materials are also can be cut by this process.
- It is a cost effective and flexible process.
- High accuracy parts can be machined.
- No cutting lubricants required
- No tool wear
- Narrow heat effected zone

Limitations of laser cutting

- Uneconomic on high volumes compared to stamping
- Limitations on thickness due to taper
- High capital cost
- High maintenance cost
- Assist or cover gas required

Plasma Arc Machining



The plasma arc process has always been seen as an alternative to the oxy-fuel process. In this part of the series the process fundamentals are described with emphasis being placed on the operating features and the advantages of the many process variants.

Process fundamentals

The plasma arc cutting process is illustrated in *Fig. 1*. The basic principle is that the arc formed between the electrode and the workpiece is constricted by a fine bore, copper nozzle. This increases the temperature and velocity of the plasma emanating from the nozzle. The temperature of the plasma is in excess of 20 000°C and the velocity can approach the speed of sound. When used for cutting, the plasma gas flow is increased so that the deeply penetrating plasma jet cuts through the material and molten material is removed in the efflux plasma.

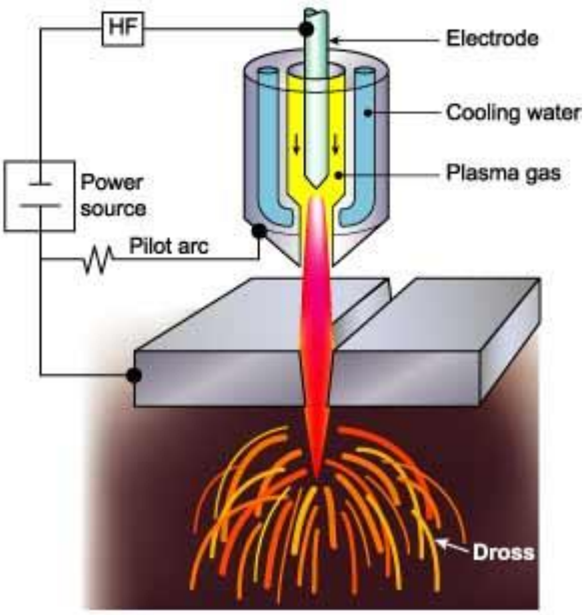


Fig.1. The plasma arc cutting process

The process differs from the oxy-fuel process in that the plasma process operates by using the arc to melt the metal whereas in the oxy-fuel process, the oxygen oxidises the metal and the heat from the exothermic reaction melts the metal. Thus, unlike the oxy-fuel process, the plasma process can be applied to cutting metals which form refractory oxides such as stainless steel, aluminium, cast iron and non-ferrous alloys.

Power source

The power source required for the plasma arc process must have a drooping characteristic and a high voltage. Although the operating voltage to sustain the plasma is typically 50 to 60V, the open circuit voltage needed to initiate the arc can be up to 400V DC.

On initiation, the pilot arc is formed within the body of the torch between the electrode and the nozzle. For cutting, the arc must be transferred to the workpiece in the so-called 'transferred' arc mode. The electrode has a negative polarity and the workpiece a positive polarity so that the majority of the arc energy (approximately two thirds) is used for cutting.

Gas composition

In the conventional system using a tungsten electrode, the plasma is inert, formed using either argon, argon-H2 or nitrogen. However, as described in *Process variants*, oxidising gases, such as air or oxygen, can be used but the electrode must be copper with hafnium.

The plasma gas flow is critical and must be set according to the current level and the nozzle bore diameter. If the gas flow is too low for the current level, or the current level too high for the nozzle bore diameter, the arc will break down forming two arcs in series, electrode to nozzle and nozzle to workpiece. The effect of 'double arcing' is usually catastrophic with the nozzle melting.

Cut quality

The quality of the plasma cut edge is similar to that achieved with the oxy-fuel process. However, as the plasma process cuts by melting, a characteristic feature is the greater degree of melting towards the top of the metal resulting in top edge rounding, poor edge squareness or a bevel on the cut edge. As these limitations are associated with the degree of constriction of the arc, several torch designs are available to improve arc constriction to produce more uniform heating at the top and bottom of the cut.

Process variants

The process variants, *Figs. 2a to 2e*, have principally been designed to improve cut quality and arc stability, reduce the noise and fume or to increase cutting speed.

Dual gas

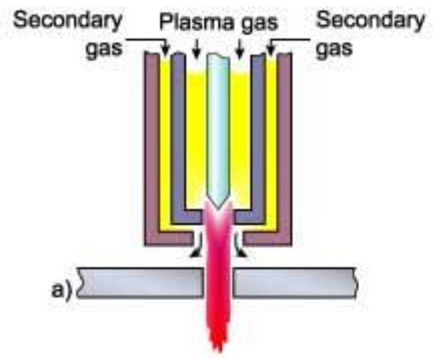


Fig.2a. dual gas

The process operates basically in the same manner as the conventional system but a secondary gas shield is introduced around the nozzle, *Fig. 2a*. The beneficial effects of the secondary gas are increased arc constriction and more effective 'blowing away' of the dross. The plasma forming gas is normally argon, argon-H_2 or nitrogen and the secondary gas is selected according to the metal being cut.

Steel

air, oxygen, nitrogen

Stainless steel

nitrogen, argon-H2, CO2

Aluminium

argon-H_2, nitrogen / CO2

The advantages compared with conventional plasma are:

- Reduced risk of 'double arcing'
- Higher cutting speeds
- Reduction in top edge rounding

Water injection

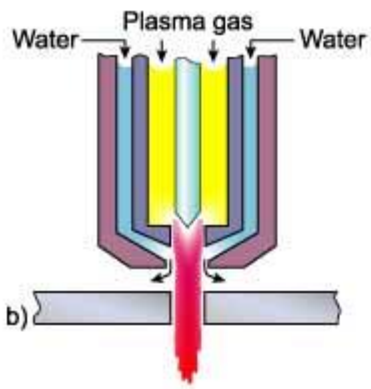


Fig.2b. water injection

Nitrogen is normally used as the plasma gas. Water is injected radially into the plasma arc, *Fig. 2b*, to induce a greater degree of constriction. The temperature is also considerably increased, to as high as 30,000°C.

The advantages compared with conventional plasma are:

- Improvement in cut quality and squareness of cut
- Increased cutting speeds
- Less risk of 'double arcing'
- Reduction in nozzle erosion

Water shroud

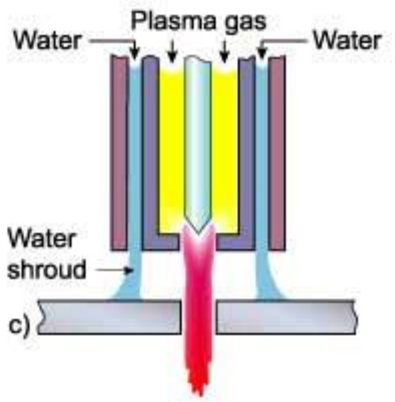


Fig.2c. water shrouded

The plasma can be operated either with a water shroud, *Fig. 2c*, or even with the workpiece submerged some 50 to 75mm below the surface of the water. Compared with conventional plasma, the water acts as a barrier to provide the following advantages:

- Fume reduction
- Reduction in noise levels
- Improved nozzle life

In a typical example of noise levels at high current levels of 115dB for conventional plasma, a water shroud was effective in reducing the noise level to about 96dB and cutting under water down to 52 to 85dB.

As the water shroud does not increase the degree of constriction, squareness of the cut edge and the cutting speed are not noticeably improved.

Air plasma

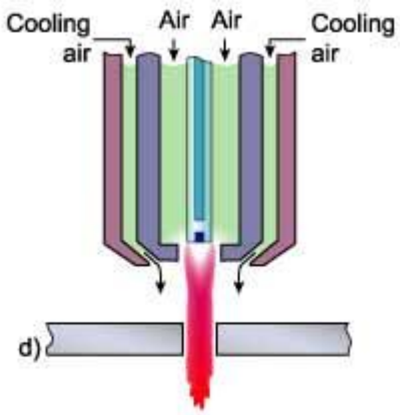
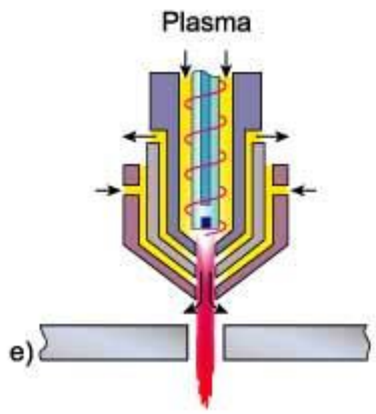


Fig.2d. air plasma

The inert or unreactive plasma forming gas (argon or nitrogen) can be replaced with air but this requires a special electrode of hafnium or zirconium mounted in a copper holder, *Fig. 2d*. The air can also replace water for cooling the torch. The advantage of an air plasma torch is that it uses air instead of expensive gases.

It should be noted that although the electrode and nozzle are the only consumables, hafnium tipped electrodes can be expensive compared with tungsten electrodes.

High tolerance plasma



In an attempt to improve cut quality and to compete with the superior cut quality of laser systems, High Tolerance Plasma Arc cutting (HTPAC) systems are available which operate with a highly constricted plasma. Focusing of the plasma is effected by forcing the oxygen generated plasma to swirl as it enters the plasma orifice and a secondary flow of gas is injected downstream of the plasma nozzle, *Fig. 2e*. Some systems have a separate magnetic field surrounding the arc. This stabilises the plasma jet by maintaining the rotation induced by the swirling gas. The advantages of HTPAC systems are:

- Cut quality lies between a conventional plasma arc cut and laser beam cut
- Narrow kerf width
- Less distortion due to smaller heat affected zone

HTPAC is a mechanised technique requiring precision, high-speed equipment. The main disadvantages are that the maximum thickness is limited to about 6mm and the cutting speed is generally lower than conventional plasma processes and approximately 60 to 80% the speed of laser cutting.