Machine Tool Technology

Subject Name:- Machine Tool Technology

Course Code:- 2037573(037)

A) **Scheme of Studies:**

S.No.	Board of Study	Course Code	Course Title	Scheme of Studies (Hours/Week)			
				L	P	T	Total Credits(C) L+T+(P/2)
1	Mechanical Engineering	2037573(037)	Machine Tool Technology	2	-	1	3
2	Mechanical Engineering	2037562(037)	Machine Tool Technology (Lab)	-	2	-	1

A) **Scheme of Assessment:**

S.No.	Board of Study	Course Code	Course Title	Scheme of Examination					
				Theory			Practical		Total Marks
				ESE	CT	TA	ESE	TA	
1	Mechanical Engineering	2037573(037)	Machine Tool Technology	70	20	30	-	-	120
2	Mechanical Engineering	2037562(037)	Machine Tool Technology (Lab)	-	-	-	30	50	80

Unit 1.0 Metal cutting

1.1 **Cutting Tools** – types, requirements, specification & application of different cutting tools, cutting tool materials – high carbon steels, high speed steels, non-ferrous cast alloys, cemented carbides, ceramics, diamond, Cubic Boron Nitride, properties and applications

1.2 **Geometry of Single Point Cutting Tool** - Tool angle, Tool geometry and influence of tool angles, tool signature, Tool angle specification system, ASA, ORS and inter-relationship.

1.3 **Mechanics of Metal Cutting** - Theories of metal cutting, Chip formation, types of chips, BUE formation condition and its effect upon surface finish, chip breakers, Orthogonal and Oblique cutting, stress and strain in the chip, velocity relations, power and energy requirement in metal cutting.

1.1 Cutting Tools

Cutting tools are instruments used to remove material from a workpiece by means of shear deformation. They are essential components in machining operations such as turning, milling, drilling, shaping, and grinding.

1. TYPES OF CUTTING TOOLS

Cutting tools can be broadly classified into **Single-point** and **Multi-point** tools.

1.1 Single-Point Cutting Tools

Used in operations like **turning, shaping, planning, boring**.

Diagram: Single Point Cutting Tool

lua

Copy code

```
      +-------------------+
      |    Shank          |
      +-------------------+
             |
             | Neck
             v
          __________  <-- Face
         /        /|
        /  Tool  / |
       /  Tip   /  |
      +--------+   |
      | Side   |   |
      | Rake   |   |
      +--------+---+
      ^  Cutting Edge
```

Characteristics:

- One main cutting edge.
- Removes material in the form of chips.
- Easy to grind and re-sharpen.

Applications:

- Lathe operations (turning, facing, threading)
- Shaping and planing
- Boring inside holes

1.2 Multi-Point Cutting Tools

Contain more than one cutting edge.

Examples:

- **Drills** (2–4 cutting edges)
- **Milling cutters** (multiple flutes)
- **Broaches** (multiple teeth with progressive rise)
- **Grinding wheels** (abrasive particles)

Diagram: Multi-Point Milling Cutter

javascript

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```
     ___________________________
    / / / / / / / / |
   |__/__/__/__/__/__/__/__|
   |  |  |  |  |  |  |  |  <-- Cutting Edges (Flutes)
   |___|___|___|___|___|___|
```

Applications:

- High-production metal removal
- Milling of slots, faces, surfaces
- Drilling holes
- Precision finishing

2. REQUIREMENTS OF A GOOD CUTTING TOOL MATERIAL

An ideal cutting tool material must have:

1. **High Hardness**
   Tool hardness > Workpiece hardness for effective cutting.
2. **Hot Hardness / Red Hardness**
   Ability to retain hardness at high cutting temperatures.
3. **High Wear Resistance**
   To reduce flank and crater wear.
4. **Toughness**
   To withstand shocks and vibrations.
5. **Good Thermal Conductivity**
   Helps dissipate heat during cutting.
6. **Chemical Inertness**
   Should resist reactions with workpiece material.
7. **Economy & Ease of Fabrication**
   Should be cost-effective and easy to manufacture.

3. SPECIFICATION OF CUTTING TOOLS

Cutting tools are specified using:

1. Tool Material

HSS, carbide, ceramic, etc.

2. Tool Geometry

- Rake angles (side rake, back rake)
- Relief angles (end and side relief)
- Cutting edge angles
- Nose radius

Diagram: Cutting Tool Nomenclature

bash

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```
          Back Rake Angle
             ↑
            /
           /
  _________/__________  <-- Face
 |     /       |
 |  Nose Radius     |
 |______/____________|
      \
       \  Side Relief Angle
        \
```

3. Tool Dimensions

- Shank size (length, width, thickness)
- Overhang
- Insert size (for indexable tools)

4. Cutting Edge / Tip

- Brazed tip
- Mechanical clamping
- Replaceable inserts

4. APPLICATION OF DIFFERENT CUTTING TOOLS

Cutting Tool Type	Typical Applications
HSS Tools	Turning, drilling, milling at moderate speeds
Carbide Inserts	High-speed machining, heavy cuts
Ceramic Tools	Hard turning, dry cutting

Cutting Tool Type	Typical Applications
Diamond Tools	Ultra-precision machining, non-ferrous metals
CBN Tools	Cutting hardened steels (>55 HRC)

5. CUTTING TOOL MATERIALS

Below are major cutting tool materials, their properties, and typical applications.

5.1 High Carbon Steels (0.6–1.5% Carbon)

Properties:

- Hardness about 62 HRC
- Low red hardness (softens above 200°C)
- Inexpensive; easy to sharpen

Applications:

- Woodworking tools
- Hand tools (chisels, saws)
- Low-speed turning and drilling

5.2 High Speed Steels (HSS)

Contain W, Mo, Cr, V, Co (types: M-series, T-series).

Properties:

- Hardness retained up to 600°C
- Good toughness
- Easy to grind
- Less brittle than carbides

Applications:

- Drills, reamers, taps
- End mills, slot drills
- Lathe tools for light–medium machining

5.3 Non-Ferrous Cast Alloys (e.g., Stellite)

Cobalt–Chromium–Tungsten alloys.

Properties:

- High hot hardness (up to 800°C)
- Good wear resistance
- More brittle than HSS

Applications:

- Cutting cast iron and stainless steel
- Machining at slightly higher speeds than HSS

5.4 Cemented Carbides

Composed of Tungsten Carbide (WC) with Cobalt binder.

Properties:

- Extremely hard (90 HRA)
- Hot hardness up to 1000°C
- High wear resistance
- Brittle compared to HSS

Applications:

- High-speed turning and milling
- Roughing and finishing cuts
- CNC machining

Diagram: Carbide Insert (Indexable)

sql

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```
    __________
   / / / /|  <-- Cutting Corners
  |__/__/__/__|
  |   Carbide |
  |   Insert  |
  |___________|
```

5.5 Ceramics (Al_2O_3, Si_3N_4)

Properties:

- Hot hardness above 1200°C
- Chemically inert
- Very high wear resistance
- Very brittle (risk of chipping)

Applications:

- High-speed finishing
- Hard turning (without coolant)
- Machining cast iron, hardened steel

5.6 Diamond Tools (Natural or Synthetic)

Properties:

- Hardest known material
- Outstanding wear resistance
- Excellent for extremely smooth surface finish

Limitations:

- React chemically with iron at high temperature → not suitable for steel

Applications:

- Cutting aluminum, copper, carbide, plastics
- Optical lens machining
- Ultra-precision machining

5.7 Cubic Boron Nitride (CBN)

Properties:

- Second hardest material after diamond
- Excellent thermal stability
- Chemically inert with iron materials
- High hot hardness

Applications:

- Cutting hardened steels (>55 HRC)
- Superalloys (Inconel, Hastelloy)
- High-precision grinding

SUMMARY TABLE: Cutting Tool Materials — Properties & Applications

Material	Hot Hardness	Toughness	Wear Resistance	Applications
High Carbon Steel	Low	High	Low	Wood, low-speed cutting
HSS	Medium	High	Medium	Drills, taps, end mills
Cast Alloys	High	Medium	Medium	Stainless steels, cast iron
Carbides	Very High	Low	Very High	CNC machining, heavy cutting
Ceramics	Very High	Very Low	Very High	Dry cutting, finishing
Diamond	Extremely High	Low	Extremely High	Non-ferrous metals, optics
CBN	Very High	Medium	Very High	Hardened steels, superalloys

1.2 GEOMETRY OF SINGLE POINT CUTTING TOOL

A **single-point cutting tool** is used in turning, shaping, planing, boring, and other operations. It has **one cutting edge**, and its performance largely depends on the geometry of various tool angles.

A. TOOL ANGLES OF SINGLE-POINT CUTTING TOOL

A cutting tool has **three major surfaces**:

- **Face** – where the chip flows
- **Flank** – below the cutting edge
- **Cutting Edge** – line of intersection between face and flank

These surfaces form different angles.

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1. Rake Angles

(a) Back Rake Angle (γb)

- Angle between tool face and a plane normal to cutting edge.
- Controls chip flow in the direction of shank.

(b) Side Rake Angle (γs)

- Angle between tool face and a plane parallel to the shank.
- Controls lateral chip flow.

✔ **Effect:**

- Larger rake angle → less cutting force, smooth chip, low power
- Too large rake → weakens tool tip

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2. Relief (Clearance) Angles

(a) Side Relief Angle (αs)

Prevents rubbing between flank and work surface.

(b) End Relief Angle (αe)

Protects tool from rubbing on cylindrical surfaces.

✔ **Effect:**

- Proper relief → less friction, better finish
- Too much relief → weak cutting edge, vibrations

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3. Cutting Edge Angles
(a) Side Cutting Edge Angle (φs / CSEA)

- Angle between side cutting edge and the tool shank.

(b) End Cutting Edge Angle (φe / ECEA)

- Reduces rubbing between cutting edge and workpiece.

✔ Effect:

- Large side cutting edge angle spreads the cutting load.
- Small angle improves accuracy.

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4. Nose Radius (r_n)

Radius at tool tip between side & end cutting edges.

✔ Effect:

- Large radius → smooth finish, strength ↑, but cutting forces ↑
- Small radius → sharper cut but poor finish

B. DIAGRAM – SINGLE POINT CUTTING TOOL GEOMETRY

perl

Copy code

```
               Chip Flow
                 ↑
            ___________________      ← Face (Rake Surface)
           /                  /|
          /   Back Rake      / |
         /__________________/  |
         |      * Nose      | |
 Side    |     / \          | |
 Cutting →  |_____/___\__________|/
 Edge        ← End Cutting Edge
```

C. INFLUENCE OF TOOL ANGLES

Angle	Influence
Side Rake	Chip flows sideways, reduces cutting force
Back Rake	Chip flows upward, reduces shear angle
Relief Angles	Prevent rubbing, improve life
Cutting Edge Angles	Affect direction of chip & load distribution
Nose Radius	Better finish but increases forces

D. TOOL SIGNATURE (TOOL NOMENCLATURE)

Tool geometry shown in a numerical sequence.

Example (ASA System):

Copy code

```
8 – 10 – 6 – 6 – 15 – 15 – 0.8
```

Represents:

1. Back rake
2. Side rake
3. End relief
4. Side relief
5. End cutting edge angle
6. Side cutting edge angle
7. Nose radius (mm)

E. TOOL ANGLE SPECIFICATION SYSTEMS

There are three major systems:

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1. ASA SYSTEM (American Standards Association)

Angles measured **relative to tool shank**.

Order of tool signature:

Back Rake – Side Rake – End Relief – Side Relief – End Cutting Edge Angle – Side Cutting Edge Angle – Nose Radius

ASA Reference Diagram

bash

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```
     Face
     /
    / )  ← Rake measured from shank plane
____/________
Shank Base
```

---

2. ORS SYSTEM (Orthogonal Rake System / ISO System)

Angles measured **relative to the cutting edge**, not the shank.

Important ORS angles:

- **Orthogonal Rake Angle (γo)**
- **Normal Rake Angle (γn)**
- **Normal Relief Angle (αn)**
- **Cutting Edge Angle (κr)**

ORS Diagram

bash

Copy code

```
        Chip
         ↑
  Face   /
       /
-------/---------  ← Reference plane
```

---

3. NRS (Normal Rake System)

Angles are measured **normal to the cutting edge**.

Used when accuracy is more important.

F. INTER-RELATIONSHIP BETWEEN ASA, ORS & NRS

The relationships are based on trigonometric transformation.

Important formulas:

$\gamma o=\gamma s\cos\phi s+\gamma b\sin\phi s$ $\gamma o=\gamma s\cos\phi s+\gamma b\sin\phi s$ $\gamma n=\gamma o\cos\kappa r$ $\gamma n=\gamma o\cos\kappa r$ $\alpha n=\alpha o\cos\kappa r$ $\alpha n=\alpha o\cos\kappa r$

Where,
φs = side cutting edge angle
κr = principal cutting edge angle

These formulae help convert one system of tool signature to another.

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1.3 MECHANICS OF METAL CUTTING

Mechanics of cutting deals with chip formation, deformation, cutting forces, velocities, and power consumption.

A. THEORIES OF METAL CUTTING
Merchant's Circle Theory (Shear Plane Theory)

Assumptions:

- Sharp tool
- Single shear plane

- Continuous chip
- No strain hardening

Merchant Shear Angle (φ):

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

Where:
r = chip thickness ratio = t_0 / t_c
α = rake angle

B. CHIP FORMATION PROCESS

Chip is formed by shearing along a shear plane.

Diagram: Chip Formation

latex

Copy code

```
        Chip
        /^^^^^^^^
       /       /
Tool  /_______/
--------→ Workpiece
```

Metal ahead of tool deforms plastically → flows over rake face → becomes chip.

C. TYPES OF CHIPS

1. **Continuous Chips**
- Ductile materials
- High speed, large rake angle
- Smooth surface finish
2. **Discontinuous Chips**
- Brittle materials
- Low speed, low rake
- Irregular surface
3. **Continuous Chip with BUE (Built-Up Edge)**
- Material welds to tool tip
- Breaks & sticks to workpiece
- Causes poor surface finish

D. BUILT-UP EDGE (BUE)
Formation Conditions:

- Low cutting speed
- High friction
- Ductile materials
- No cutting fluid
- Small rake angle

Effects:

- Poor surface finish
- Tool wear ↑
- Irregular dimension
- High cutting force

Prevention:

- Increase cutting speed
- Increase rake angle
- Use cutting fluid
- Use sharp tool / carbide tool

E. CHIP BREAKERS

Chip breakers break long continuous chips into small curls.

Diagram:

bash

Copy code

```
      Chip
     /___/
    /   /  ← Chip breaker step
   /___/
Tool Edge →
```

Types:

- Integral chip breaker
- Clamped chip breaker
- Groove type

F. ORTHOGONAL VS OBLIQUE CUTTING

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1. Orthogonal Cutting

- Cutting edge ⊥ direction of tool travel
- Chip flows straight
- Forces lie in 2D plane
- Easy analysis

Diagram:

java

Copy code

```
    | Cutting Edge (⊥)
_____|_____________
    → Motion
```

---

2. Oblique Cutting

- Cutting edge inclined at angle "i"
- Chip flows sideways
- Forces are 3-dimensional

Diagram:

markdown

Copy code

```
 Cutting Edge
   _______/
  /_____/
 Motion →→
```

G. STRESS & STRAIN IN THE CHIP

Shear strain (γ):

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

- Higher strain = more heat
- Ductile materials → large plastic deformation

H. VELOCITY RELATIONS

Merchant Velocity Diagram:

```bash
        Vs  (Shear Velocity)
        ↗
       /
      /φ
 Vc  /________  (Chip Velocity)
    /
   /
 V (Cutting Velocity)
```

Relations:

$V_c = \frac{V t_0}{t_c}$ $V_s = V\cos(\phi-\alpha)$

Where
V = cutting speed
Vc = chip flow velocity
Vs = shear velocity

I. POWER AND ENERGY REQUIREMENT IN CUTTING
Cutting Power (Pc):
$P = F_c \times V$

Where
Fc = cutting force (N)
V = cutting speed (m/s)

Material Removal Rate (MRR):
$MRR = f \times d \times V$

Where
f = feed (mm/rev)
d = depth of cut (mm)

Specific Cutting Energy (u):
u=PMRR*u*=*MRRP*

A lower value means efficient cutting.

Unit 2.0 Mechanics of machining

2.1 **Cutting forces and tool life** - Forces acting on the cutting tool and their measurement, Merchant's circle diagram, dynamometer, force and velocity relationship, Tool wear, Factors causing wear, tool life , tool life equation, variables affecting tool life, Cutting parameters - speed, feed, depth of cut and machining time, economical cutting speed.

2.2 **Machinability** - Concept and evaluation of Machinability, Mechanism of Tool failure, Machinability index, factors affecting machinability.

2.3 **Thermal Aspects in Machining**- Sources of heat generation in machining and its effects, Temperature Measurement techniques in machining, types of cutting fluids, Functions of cutting fluid, Characteristics of cutting fluid, Application of cutting fluids.

UNIT 2.0 MECHANICS OF MACHINING

Mechanics of machining deals with forces, heat, wear, tool life, machinability, and thermal aspects involved during metal cutting.

2.1 CUTTING FORCES AND TOOL LIFE

Machining involves complex interactions between tool, workpiece, chip, and heat generation. Understanding cutting forces and tool life is essential for economic and efficient machining.

A. FORCES ACTING ON THE CUTTING TOOL

During machining, the tool experiences two main force components:

1. Cutting Force (Fc)

- Acts in the direction of cutting velocity.
- Largest component.
- Responsible for actual cutting work and power consumption.

2. Thrust Force / Feed Force (Ft)

- Acts perpendicular to the cutting velocity.
- Affects tool deflection and surface finish.

Resultant Force (R)

R=Fc2+Ft2$R = Fc2 + Ft2$

DIAGRAM: Forces on Single-Point Cutting Tool

```powershell
          Chip
           ↑
          /|
         / | Ft (Thrust Force)
        /__|
       /    Fc (Cutting Force)
Tool  ----→------------------------ Workpiece
```

B. MEASUREMENT OF CUTTING FORCES – DYNAMOMETERS

A **dynamometer** is used to measure cutting forces in turning, drilling, milling, etc.

Types of dynamometers:

1. **Strain-gauge dynamometer**
2. **Piezoelectric dynamometer**
3. **Mechanical dynamometer**
4. **Hydraulic dynamometer**

Function:

- Measures forces Fc, Ft, Ff (feed force), and vertical force in machining.

C. MERCHANT'S CIRCLE DIAGRAM

It shows the relationship between cutting forces and shear forces involved in chip formation.

DIAGRAM: Merchant's Circle

```powershell
```

```
            N (Normal to R)
            ↑
           / |
          /  |
Fs  ---->O---R----> Fc
         |\
         | \
         |  \
         |   \
        Ft    Fn
```

Fs = shear force
Fn = normal force on shear plane
R = resultant force

Important relations from Merchant theory:

1. **Shear angle (φ):**
   $\tan\phi = \frac{r\cos\alpha}{1 - r\sin\alpha}$
2. **Cutting force:**
   $F_c = R\cos(\beta - \alpha)$
3. **Shear force:**
   $F_s = R\cos(\phi + \beta - \alpha)$

   Where:
   r = chip thickness ratio
   α = rake angle
   β = friction angle

D. FORCE AND VELOCITY RELATIONSHIP

Cutting power:

$P = F_c \cdot V$

Velocities:

- **V** = cutting velocity
- **Vc** = chip velocity
- **Vs** = shear velocity
  $V_c = V\frac{t_0}{t_c}$ $V_s = V\cos(\phi - \alpha)$

E. TOOL WEAR

Tool wear is progressive loss of tool material.

Types of tool wear:

1. **Flank wear** (common)
2. **Crater wear** (on rake face)
3. **Notch wear**
4. **Nose wear**
5. **Thermal cracking**

Factors causing tool wear:

- High temperature
- High friction
- Abrasion by hard particles
- Diffusion wear
- Poor cutting fluid
- Inappropriate cutting parameters

F. TOOL LIFE

Tool life is the time between two successive regrinding or tool replacements.

Tool Life Equation (Taylor's Equation):
VTn=C$VT^n = C$

Where:
V = cutting speed (m/min)
T = tool life (min)
n = slope or tool material constant
C = constant depending on tool and work material

Typical values of "n":

- HSS tools → **n = 0.1 – 0.2**
- Carbide tools → **n = 0.2 – 0.5**
- Ceramics → **n = 0.5 – 0.7**

G. VARIABLES AFFECTING TOOL LIFE

1. Cutting speed
2. Feed
3. Depth of cut
4. Tool material
5. Work material hardness
6. Cutting fluids
7. Tool geometry
8. Method of machining (continuous/interrupted)

H. CUTTING PARAMETERS

1. Cutting Speed (V)

Speed at which workpiece surface moves past tool.

$V=\pi DN1000$ (m/min)$V=1000\pi DN(m/min)$

2. Feed (f)

Distance tool advances per revolution (mm/rev).

3. Depth of Cut (d)

Thickness of material removed in one pass.

$d=D1-D22d=2D1-D2$

4. Machining Time

$T=Lf\cdot NT=f\cdot NL$

Economical Cutting Speed

Speed at which cost per component is minimum AND production rate is maximum.

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2.2 MACHINABILITY

Machinability refers to how easily a material can be machined.

A. CONCEPT OF MACHINABILITY

A material with **good machinability** produces:

- Low cutting forces
- Longer tool life
- Good surface finish
- Continuous chips
- Low heat generation

B. EVALUATION OF MACHINABILITY

Machinability is evaluated using:

1. Tool life
2. Surface finish
3. Cutting force
4. Power consumption
5. Chip characteristics

C. MACHINABILITY INDEX

Machinability Index=CmaterialCstandard×100Machinability Index=*C*standard*C*material×100

Where *C* = tool life constant from Taylor's equation.

D. FACTORS AFFECTING MACHINABILITY

1. **Material properties**

- Hardness
- Strength
- Ductility
- Work hardening

2. **Tool material**
- Carbides cut better than HSS
- Ceramics give better wear resistance
3. **Cutting fluid**
- Reduces temperature
- Improves surface finish
4. **Tool geometry**
- Larger rake angle → improves machinability
- Sharp cutting edge reduces forces
5. **Cutting conditions**
- Higher speed → more heat → lower machinability

E. MECHANISM OF TOOL FAILURE

Tool fails due to:

- Abrasion
- Adhesion
- Diffusion
- Oxidation
- Mechanical chipping
- Plastic deformation

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2.3 THERMAL ASPECTS IN MACHINING

Heat plays a crucial role in machining because it affects tool wear, chip formation, accuracy, and surface finish.

A. SOURCES OF HEAT GENERATION IN MACHINING

Heat is generated from three zones:

1. Primary shear zone

- Due to shear deformation of work material.

2. Secondary deformation zone

- Due to friction between chip and tool face.

3. Tertiary zone

- Due to rubbing of tool flank with workpiece.

B. EFFECTS OF HEAT GENERATION

- Tool wear ↑
- Tool softening (especially HSS)
- Dimensional inaccuracy
- Thermal expansion of work material
- Poor surface finish
- Built-up edge formation
- Reduction in tool life

C. TEMPERATURE MEASUREMENT TECHNIQUES

1. **Thermocouples**
   - Tool–work thermocouple
   - Embedded thermocouple
2. **Infrared Pyrometers**
3. **Thermal paints / Melting powders**
4. **Radiation thermometers**

D. CUTTING FLUIDS

Cutting fluids are substances applied to reduce heat and friction.

E. FUNCTIONS OF CUTTING FLUIDS

1. Cooling
2. Lubrication
3. Chip flushing
4. Corrosion prevention
5. Improved surface finish
6. Increased tool life

F. CHARACTERISTICS OF A GOOD CUTTING FLUID

- High heat capacity
- Non-corrosive
- Good lubrication
- High flash point
- Non-toxic
- Ability to remove chips
- Chemically stable

G. TYPES OF CUTTING FLUIDS

1. Cutting Oils

- Mineral oils
- Sulfurized oils
- Chlorinated oils

2. Soluble Oils (Emulsions)

Water + oil mixture → used for general machining.

3. Synthetic Fluids

No oil content, only chemicals.

4. Semi-synthetic Fluids

Oil + synthetic additives.

5. Gaseous Fluids

Air blast, nitrogen, CO_2.

H. APPLICATION OF CUTTING FLUIDS

Methods:

1. Flooding
2. Mist cooling
3. High-pressure coolant
4. Spray jet
5. Through-tool coolant channels

Diagram of Flood Cooling

```bash
       Cutting Fluid ↓↓↓
     ┌─────────────────────┐
Chip ↑   _________     |
    | /      /     |
Tool →| /_______ /--------→ Workpiece
```

Unit 3.0 Shaper, Planner and Drilling machine

3.1 **Shaper:** Principle of operation, classification, specification, Basic parts and their functions and Applications, safety precautions.

3.2 **Slotter:** Principle of working, classification, specification. Basic parts of Slotting machine and their functions and Applications, safety precautions.

3.3 **Planer:** Principle of operation, Classification, Basic parts and their functions, Specifications and Applications, safety precautions.

3.4 **Drilling, Reaming & Boring: Drilling**: Principle of operation, Classification, Basic parts and functions, drill nomenclature, other operations like counter boring, counter sinking, spot facing etc. **Reaming**: Principle of operation, description of reamers, and types of reaming operations, safety precautions, **Boring**: Principle of operation, Classification of boring machines, Basic parts and functions, boring operations, boring tools and applications, safety precautions.

UNIT 3.0 SHAPER, PLANNER AND DRILLING MACHINE

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3.1 SHAPER

A. PRINCIPLE OF OPERATION

A **shaper** removes material in the form of chips by a **single-point cutting tool** that moves in a **reciprocating straight-line motion** (back and forth).

The **cutting action** takes place only during the **forward stroke**, while the **return stroke is idle**, achieved using **quick return mechanism**.

Diagram: Shaper Working Principle

```sql
```

```
Copy code
Forward Stroke (Cutting) →→→→
Tool -----> Workpiece -----> Chips

Return Stroke (Idle) ←←←←
Tool <----- Workpiece
```

B. CLASSIFICATION OF SHAPERS

1. **According to type of drive**
- Crank shaper
- Geared shaper
- Hydraulic shaper
2. **According to table design**
- Standard shaper
- Universal shaper
3. **According to ram travel**
- Horizontal shaper
- Vertical shaper
4. **According to cutting stroke**
- Push type
- Draw type

C. SPECIFICATIONS OF A SHAPER

Shapers are specified by:

- Maximum length of stroke (mm)
- Table size (L × W)
- Type of drive mechanism
- Number of strokes per minute
- Maximum size of workpiece
- Motor power

D. BASIC PARTS AND THEIR FUNCTIONS

Diagram: Main Parts of Shaper

mathematica

Copy code

```
┌──────────────────── Ram ────────────────┐
|                   |
|   Cutting Tool & Tool Head      |
└──────────────────────────────────────────────────┘
       ↑
       |
   Stroke Motion
       |
 Column ┌──────────────────┐ Support
   |       |
   |       |
   └──────────────────┘
       |
   Work Table
```

Parts & Functions

Part	Function
Base	Foundation of the machine; supports column
Column	Vertical body holding ram & mechanism
Ram	Holds tool head; reciprocates to cut metal
Tool Head	Holds cutting tool; adjusts rake, feed
Cross Rail	Supports table, adjusts vertical height
Table	Holds workpiece; gives feed motion
Clapper Box	Lifts tool during return stroke

E. APPLICATIONS OF SHAPER

- Machining flat surfaces
- Cutting keyways & slots
- Making grooves & pockets
- Machining internal splines
- Cutting angular surfaces

F. SAFETY PRECAUTIONS (SHAPER)

- Wear safety goggles
- Keep hands away from ram
- Clamp job rigidly
- Do not change speed while machine is running
- Ensure no obstruction during ram movement
- Remove chips with brush only

==

3.2 SLOTTING MACHINE (SLOTTER)
A. PRINCIPLE OF WORKING

A **slotter** is similar to a shaper but the **ram moves vertically** instead of horizontally. Cutting occurs only in the **downward stroke**, and return stroke is idle.

Diagram: Slotter

less

Copy code

```
     Ram
     |
     v (Cutting Stroke)
  [ Tool ]
     ||
     ||
  ┌──────────┐
 | Table  |
  └──────────┘
```

B. CLASSIFICATION OF SLOTTING MACHINE

1. **Puncher slotter**
2. **Production slotter**
3. **Tool-room slotter**
4. **High-speed slotter**

C. SPECIFICATIONS

- Maximum stroke length
- Maximum size of workpiece
- Table diameter
- Ram speed (strokes/min)
- Type of drive (mechanical/hydraulic)

D. BASIC PARTS AND THEIR FUNCTIONS

Part	Function
Base	Supports the machine
Column	Guides the ram vertically
Ram	Holds cutting tool; moves up/down
Saddle	Supports table
Circular Table	Rotates to position work
Tool Head	Holds tool, adjusts angles
Drive Mechanism	Provides reciprocating motion

E. APPLICATIONS OF SLOTTER

- Cutting internal keyways
- Machining internal splines
- Cutting rectangular & square holes
- Grooves inside blind holes

F. SAFETY PRECAUTIONS

- Keep fingers away from vertical ram
- Check job clamping before starting
- Remove chips with brush
- Ensure table feed is slow and steady
- Do not overload tool

==

3.3 PLANER (PLANING MACHINE)

A. PRINCIPLE OF OPERATION

In a **planer**, the workpiece is mounted on a **moving table**, and the **cutting tool is stationary**. The table moves back and forth to perform cutting.

Diagram: Planer Working

sql

Copy code

```
Table Movement → → → (Cutting)

Tool (Fixed)
  |
  V
──────────────── Workpiece

Return Stroke ← ← ← (Idle)
```

B. CLASSIFICATION OF PLANERS

1. **According to construction**
- Open side planer
- Double column planer
- Pit type planer
2. **According to drive**
- Belt driven
- Geared type
- Hydraulic planer

C. BASIC PARTS AND THEIR FUNCTIONS

Part	Function
Base	Rigid foundation
Table	Holds workpiece; reciprocates
Columns	Provide rigid support
Cross Rail	Vertical movement for tool head
Tool Heads	Hold tools; adjust angles
Feed Mechanism	Moves tool across table

D. SPECIFICATIONS OF PLANER

- Maximum table size (L × W)
- Length of table stroke
- Speed (strokes/min)
- Motor power
- Number of tool heads

E. APPLICATIONS OF PLANER

- Planing large surfaces
- Machining long beds, rails
- Heavy duty operations
- Cutting slots and grooves in large parts

F. SAFETY PRECAUTIONS

- Keep hands away from moving table
- Fix workpiece securely
- Lubricate guideways

- Do not lean over workpiece
- Remove chips with brush only

==

3.4 DRILLING, REAMING & BORING

A. DRILLING
1. Principle of Operation

Drilling is a machining process in which a **rotating multi-point tool (drill)** produces a **round hole** in solid material by removing material.

Diagram: Drilling Operation

diff

Copy code

```
      Drill
       ||
       ||
      (  ) → Rotates & Cuts
-------||--------------- Workpiece
```

---

2. CLASSIFICATION OF DRILLING MACHINES

- **Bench drilling machine**
- **Pillar (column) drilling machine**
- **Radial drilling machine**
- **Gang drilling machine**
- **Multiple spindle drilling machine**
- **Sensitive drilling machine**

---

3. BASIC PARTS AND FUNCTIONS

Part	Function
Base	Supports machine
Column	Guides spindle vertically
Table	Supports workpiece
Spindle	Holds drill & rotates
Drill Head	Contains feed & speed mechanism
Feed Screw	Moves spindle downward
Motor & Pulleys	Provide power & speed

---

4. DRILL NOMENCLATURE

Diagram: Drill Geometry

less

Copy code

```
            Chisel Edge
                |
        Cutting Edges
           /     \
          /       \
     Helix Angle    \
        /           \
       /             \
     Flutes          Body
```

Important terms:

- Point angle (118° for standard)
- Helix angle
- Flutes
- Chisel edge
- Margin
- Lip clearance

---

5. OTHER DRILLING OPERATIONS

Operation	Description
Counterboring	Enlarging top portion of hole to seat bolt head
Countersinking	Conical enlargement for screws
Spot Facing	Machining a flat surface around a hole
Tapping	Producing internal threads
Reaming	Finishing hole to accurate size
Boring	Enlarging an existing hole

==

B. REAMING
1. PRINCIPLE OF OPERATION

Reaming is used to **finish and accurately size a drilled hole** by removing a small amount of material (0.2–0.5 mm).

Diagram: Reaming

nginx

Copy code

```
Reamer →→→ Finishes Hole →→→ Accurate Size
```

---

2. DESCRIPTION OF REAMERS

Reamers have:

- Straight / helical flutes

- Cutting edges
- Chamfer at tip
- Cylindrical body

Types

- Hand reamers
- Machine reamers
- Shell reamers
- Adjustable reamers
- Taper reamers

---

3. TYPES OF REAMING OPERATIONS

- **Through reaming**
- **Blind hole reaming**
- **Taper reaming**
- **Precision reaming**

---

4. SAFETY PRECAUTIONS

- Use proper cutting speed
- Do not force reamer
- Hold workpiece rigidly
- Apply cutting fluid
- Avoid reversal while reaming

==

C. BORING

1. PRINCIPLE OF OPERATION

Boring is a machining process used to **enlarge an existing hole** using a **single-point cutting tool**.

Diagram: Boring

markdown

Copy code

```
    Boring Bar
        |
        V
Hole → Enlarged Hole
```

---

2. CLASSIFICATION OF BORING MACHINES

- **Horizontal boring machine**
- **Vertical boring machine**
- **Jig boring machine**
- **Planetary boring machine**

---

3. BASIC PARTS AND FUNCTIONS

Part	Function
Bed	Base of machine
Column	Supports headstock
Spindle Head	Holds boring bar
Table	Mounts workpiece
Boring Bar	Holds tool
Feed Mechanism	Controls tool movement

---

4. BORING OPERATIONS

- Boring internal surfaces
- Enlarging drilled holes
- Facing internal surfaces
- Internal grooving
- Thread boring

---

5. BORING TOOLS

- Boring bars
- Boring heads
- Adjustable boring tool
- Single-point cutting tools

---

6. APPLICATIONS

- Accurate internal diameters
- Large internal machining
- Precision holes in large components
- Internal turning where lathe cannot reach

---

7. SAFETY PRECAUTIONS

- Clamp job firmly
- Ensure boring bar is balanced
- Use proper feed & speed
- Avoid overhanging boring bars
- Use chip guards and cutting fluids

Unit 4.0 Milling and Broaching operations

4.1 Milling: Principle of operation, Classification of milling machines, Basic parts and their functions, Specifications

4.2 Milling cutters – Different types of cutters used in milling, face milling cutter, end milling cutter, Staggered tooth milling cutter, side and face milling cutter, form milling cutters, metal slitting saw etc.

4.3 Milling operations – Plain milling, face milling, side milling, end milling, straddle milling, gang milling, slotting, slitting, Up milling and down milling, safety precautions.

4.4 Dividing head – types, function of dividing head, method of indexing, index plates.

4.5 Broaching: Principle of operation, types of broaches- horizontal, vertical, pull, surface-internal and external parts and their function, nomenclature of broach. broaching machines, Basic

UNIT 4.0 MILLING AND BROACHING OPERATIONS

==

4.1 MILLING

A. PRINCIPLE OF OPERATION

Milling is a machining process where a **rotating multi-tooth cutter** removes material from a workpiece that is **fed against** the cutter.

- Cutter rotates → **primary motion**
- Workpiece feeds → **secondary motion**

Diagram: Principle of Milling

javascript

Copy code

```
        Rotation of Cutter
              ↑
      ________|________
     | ////// |
     |//////  | ← Milling Cutter
     |//////  |
----------------------------- Workpiece Feed →
```

Cut is taken by each tooth of the cutter producing chips.

B. CLASSIFICATION OF MILLING MACHINES

1. **According to position of spindle**
- Horizontal milling machine
- Vertical milling machine
2. **According to structure**
- Knee and column type
- Manufacturing or production milling machine
- Planer type milling machine
- Rotary table milling machine
3. **According to automation**
- Manual milling
- CNC milling machines

C. BASIC PARTS AND THEIR FUNCTIONS
Diagram: Column and Knee Type Milling Machine

yaml

Copy code

```
       Spindle Head
          |
          v
      [Cutter]
         |
      ┌──────────────┐
     | Over Arm |
      └──────────────┘
          |
   ┌──────────────────────────────┐
   |   Knee & Saddle    |
   |   ┌──────────────────┐    |
   |  | Machine    |   |
   |  | Table      |   |
   └──────────────────────────────┘
          |
      (Base)
```

Parts & Functions

Part	Function
Base	Supports machine structure
Column	Houses spindle and motor
Knee	Supports saddle and table
Saddle	Carries table; gives cross feed
Table	Holds workpiece, moves longitudinally
Spindle	Holds and rotates cutter
Overarm	Supports arbor in horizontal machines
Arbor	Holds cutting tools in horizontal milling
Motor & Gearbox	Provides different speeds

D. SPECIFICATIONS OF MILLING MACHINE

- Table size (L × W)
- Maximum longitudinal, cross, and vertical travel
- Spindle speed range
- Spindle taper
- Motor power
- Number of feed rates

===

4.2 MILLING CUTTERS

Different cutters used depending on milling operations.

1. Face Milling Cutter

- Mounted on spindle.
- Used for facing large surfaces.

mathematica

Copy code

```
   ________
 /  O O O  \
| O O O O O | ← Cutting teeth on face & periphery
 \_________/
```

2. End Milling Cutter

- Cutter with cutting edges on **end** and **periphery**.

diff

Copy code

```
    ||||  ← Cutting Edges
   (====)
    ||||
```

3. Side and Face Milling Cutter

- Teeth on both **side** and **periphery**.

diff

Copy code

```
   ||||| ← Side Teeth
 =========
   |||||
```

4. Staggered Tooth Milling Cutter

- Teeth on alternate sides → prevents chip clogging.

swift

Copy code

```
 /\/\/\/\
```

```
\/\/\/\/\/\/
```

5. Form Milling Cutters

- Special shapes (convex, concave, radius).

6. Metal Slitting Saw

- Very thin cutter used for cutting slots.

markdown

Copy code

```
 ___________
|           |
|   O    |
|__________|
```

7. T-slot & Dovetail Cutters

- Used for special purpose slot cutting.

===

4.3 MILLING OPERATIONS

1. Plain (Surface) Milling

- Producing flat surface parallel to axis of cutter.

scss

Copy code

```
Horizontal Cutter → Surface
```

2. Face Milling

- Producing flat surfaces using face milling cutter.

3. Side Milling

- Producing vertical surfaces on workpiece.

4. End Milling

- Used for pockets, slots, profiles.

5. Straddle Milling

- Two side milling cutters used together.

mathematica

Copy code

```
   O      O   ← two cutters
---|------|--- workpiece
```

6. Gang Milling

- Multiple cutters on the same arbor.

7. Slotting

- Cut slots using side/end mills.

8. Slitting

- Using slitting saw to cut thin slots.

UP MILLING (Conventional Milling)

- Cutter rotates **against** feed direction.

```scss
Feed →
  Teeth rotate ↑
Chip begins thin → thick
```

DOWN MILLING (Climb Milling)

- Cutter rotates **with** feed direction.

```scss
Feed →
  Teeth rotate ↓
Chip begins thick → thin
```

SAFETY PRECAUTIONS (MILLING)

- Wear goggles and keep hands away from cutter
- Use proper arbor supports
- Do not measure work while machine is running
- Remove chips with brush, not hands
- Ensure cutter is sharp and properly mounted

==

4.4 DIVIDING HEAD

A dividing head is used for dividing a circle into equal parts for gear cutting, spline cutting, fluting, indexing, etc.

A. TYPES OF DIVIDING HEAD

1. **Simple dividing head**
2. **Universal dividing head**
3. **Optical dividing head**

B. FUNCTION OF DIVIDING HEAD

- To rotate the workpiece accurately by a required fraction of a circle
- Used for cutting gears, hexagons, splines, cams, etc.

C. DIAGRAM OF DIVIDING HEAD

pgsql

Copy code

```
          Chuck
            |
    Index Plate ---- Crank Handle
       |              |
  Worm Gear Box -----------
       |
  Tailstock Support
```

D. METHOD OF INDEXING

1. Simple Indexing

Index crank rotation=40NIndex crank rotation=N40

Where **N** = number of divisions required.

2. Compound Indexing

Used when simple indexing is not possible.

3. Differential Indexing

Used for large number of divisions.

4. Angular Indexing

Used for indexing specific angles.

===

4.5 BROACHING

A. PRINCIPLE OF OPERATION

Broaching is a machining process in which a **multi-tooth cutting tool called broach** removes material in a **single pass**.

- Each tooth removes a small amount of material.
- Total cut = sum of all tooth depths.

Diagram: Broach Action

markdown

Copy code

```
Increasing Tooth Height →
|_|__|__|___|____|_____|
↑ Cutting Direction
```

B. TYPES OF BROACHES

1. Based on direction of motion

- **Pull type broach** (pulled through)
- **Push type broach** (pushed)
- **Surface broach**
- **Internal broach**

2. Based on use

- Keyway broach
- Spline broach
- Round broach
- Shell broach

3. Based on construction

- Solid broach
- Built-up broach

C. PARTS OF A BROACH AND FUNCTIONS

Part	Function

Part	Function
Shank	Mounting with machine
Neck	Connects shank to body
Body	Main cutting portion
Roughing Teeth	Remove bulk material
Semi-finishing Teeth	Improve accuracy
Finishing Teeth	Provide final dimensions
Land	Supports cutting edges
Chip Breakers	Break and control chips

D. NOMENCLATURE OF BROACH

lua

Copy code

```
← Pulling end
|---- Shank ----|
      | Neck |
|----- BODY -----|
| Roughing Teeth |
| Semi-finish    |
| Finishing Teeth|
```

E. BROACHING MACHINES

1. Horizontal Broaching Machine

- Ideal for long strokes
- Used for keyways, splines

2. Vertical Broaching Machine

- Occupies less floor space
- Used for internal broaching

3. Continuous Broaching Machine

- Used in mass production
- Components move continuously

F. APPLICATIONS OF BROACHING

- Cutting keyways
- Machining splines
- Internal gear cutting
- Surface finishing
- Producing complex shapes in single pass

G. SAFETY PRECAUTIONS

- Ensure broach is sharp and aligned
- Never overload broach
- Use correct feed and lubrication
- Clamp workpiece rigidly
- Remove chips using brush

Unit 5.0 Grinding and Finishing Processes

5.1 Grinder and types of grinding wheel, Types of abrasive materials and their properties, Bonding materials, Grinding wheel classification, condition for selection of grinding wheels, balancing of grinding wheels, glazing, loading dressing and Truing. Designation of grinding wheel

5.2 Principles of working of grinding machines and functions of main parts, types of grinding processes, function of tool and work holding devices, Table drive in surface and cylindrical grinders, Types of lubricants and coolants used in Grinding, Grinding defects, their remedy and safety practices

5.3 Finishing Processes Definition of micro finishing, honing, lapping, super finishing, polishing and buffing operations, equipment involved, materials used, Tolerances obtained and limitations and applications.

UNIT 5.0 GRINDING AND FINISHING PROCESSES

==

5.1 GRINDERS AND GRINDING WHEELS

A. GRINDER (INTRODUCTION)

Grinding is a **material removal process** in which abrasives in the form of a **grinding wheel** remove small chips from the workpiece to produce **accurate dimensions and fine surface finish**.

Diagram: Principle of Grinding Operation

perl

Copy code

```
    Grinding Wheel (Rotating)
        ___________
      /  /////////  \
     |  /////////    |  → Rotation
      \_____________  /
           ||
           || Sparks/Chips
------------------------------ Workpiece (Feed Motion)
```

B. TYPES OF GRINDERS

1. **Surface grinder**
2. **Cylindrical grinder**
3. **Centreless grinder**
4. **Tool and cutter grinder**
5. **Internal grinder**
6. **Bench/pedestal grinder**
7. **Special grinders** (form grinders, jig grinders)

C. TYPES OF ABRASIVE MATERIALS AND THEIR PROPERTIES

1. Aluminium Oxide (Al_2O_3)

- Tough, strong abrasive
- Suitable for steel, alloy steel, malleable iron

2. Silicon Carbide (SiC)

- Hard, sharp abrasive
- Suitable for cast iron, brass, bronze, non-ferrous metals

3. Diamond

- Hardest known material
- Used for carbide tools, glass, ceramics

4. Cubic Boron Nitride (CBN)

- Second hardest
- Used for high-speed steel, hardened steels

D. BONDING MATERIALS

Bond holds abrasive grains together.

1. **Vitrified bond (V)** – strong, rigid (most common)
2. **Resinoid bond (B/R)** – flexible, shock-resistant
3. **Silicate bond (S)** – less heat, good finish
4. **Rubber bond (R)** – used in cut-off wheels
5. **Metal bond (M)** – used for diamond wheels

E. GRINDING WHEEL CLASSIFICATION

Grinding wheels are classified by:

- **Abrasive type**
- **Grain size**
- **Grade (hardness)**
- **Structure**
- **Bond type**

F. CONDITIONS FOR SELECTION OF GRINDING WHEEL

- Workpiece material
- Hardness of material
- Required surface finish
- Amount of stock to be removed

- Cutting speed
- Type of operation (surface, cylindrical, internal)

General rule:
For hard materials → soft wheel
For soft materials → hard wheel

G. BALANCING OF GRINDING WHEELS

Balancing is required to eliminate vibration and ensure smooth operation.

Methods

1. Static balancing
2. Dynamic balancing

Balancing reduces:

- Vibration
- Poor surface finish
- Wear on spindle

H. GLAZING, LOADING, DRESSING AND TRUING

1. Glazing

- Occurs when wheel becomes **dull**
- Wheel surface becomes shiny
- Remedy: **Dressing**

2. Loading

- Wheel gets filled with workpiece metal
- Occurs while grinding soft metals
- Remedy: Dressing with dressing tool

3. Dressing

- Process of **renewing sharpness** of wheel by cutting worn grains.

4. Truing

- Process of **making wheel surface perfectly round and concentric** with spindle.

I. DESIGNATION OF GRINDING WHEEL

A typical grinding wheel designation:

css

Copy code

```
A 46 K 5 V
```

Where:

Symbol	Meaning
A	Abrasive (Aluminium oxide)
46	Grain size
K	Grade (hardness)
5	Structure
V	Bond (Vitrified)

===

5.2 PRINCIPLE AND TYPES OF GRINDING MACHINES

A. PRINCIPLES OF WORKING

Grinding machines use a **rotating wheel** driven at high speed. The workpiece is brought in contact with the wheel.

General Components

- **Wheel head**
- **Work head**
- **Table**
- **Base**
- **Motor & pulleys**

B. MAIN PARTS & THEIR FUNCTIONS
Diagram: Surface Grinder (Horizontal Spindle)

lua

Copy code

```
      Grinding Wheel
          ||
   ----------------------
   |   Wheel Head      |
   ----------------------
           |
     ----------------  ← Table (Reciprocating)
     | Workpiece     |
     ----------------
           |
         (Base)
```

Functions

- **Wheel Head** – holds and rotates grinding wheel
- **Table** – holds work and provides feed
- **Work Head** – rotates work in cylindrical grinder
- **Tailstock** – supports long workpieces
- **Machine Bed** – provides rigidity

C. TYPES OF GRINDING PROCESSES

1. **Surface Grinding**
- Produces flat surfaces
2. **Cylindrical Grinding**
- External cylindrical surfaces
3. **Internal Grinding**
- Inside holes
4. **Centreless Grinding**
- No need to hold work between centers
5. **Form Grinding**
- Produces formed profiles
6. **Tool & Cutter Grinding**
- Re-sharpens cutting tools

D. TOOL AND WORK HOLDING DEVICES

- Magnetic chuck (for surface grinder)
- V-blocks
- Faceplate
- Chuck (3-jaw / 4-jaw)
- Collets
- Between centers

E. TABLE DRIVE IN SURFACE AND CYLINDRICAL GRINDERS

Surface Grinder

- Reciprocating table
- Hydraulic drive system

Cylindrical Grinder

- Work rotates between centers
- Table moves longitudinally
- Cross feed is automatic/manual

F. LUBRICANTS AND COOLANTS USED IN GRINDING

1. **Water-based coolants**
2. **Soda water**
3. **Soluble oils**
4. **Cutting oils**

Functions:

- Reduce heat
- Reduce wear
- Improve finish
- Wash away chips

G. GRINDING DEFECTS AND REMEDIES

Defect	Cause	Remedy

Defect	Cause	Remedy
Burning	Overheating	Use coolant, reduce speed
Chatter marks	Vibration	Balance wheel, tighten machine
Poor finish	Dull wheel	Dressing
Taper grinding	Misalignment	Align work centers

H. SAFETY PRACTICES IN GRINDING

- Use eye and face protection
- Inspect wheel for cracks
- Use correct wheel speed
- Balance wheel properly
- Do not use excess pressure
- Stand aside during wheel startup

==

5.3 FINISHING PROCESSES

Finishing processes produce **high surface finish** and **close dimensional accuracy**.

A. MICRO FINISHING

Processes that remove very small amount of material (microns) to obtain surface finish of **0.025–0.2 µm Ra**.

B. HONING

Definition

Honing uses a **set of bonded abrasive sticks** (honing stones) mounted on a mandrel to improve **hole geometry and surface finish**.

Diagram: Honing Operation

lua

Copy code

```
   Abrasive Stones
     /   |   \
    /    |    \
 --|-----|-----|--  → Workpiece hole
    \    |    /
     \   |   /
```

Equipment

- Honing head
- Abrasive sticks
- Rotary spindle

Applications: engine cylinders, gear bores, hydraulic cylinders.

C. LAPPING

Definition

Lapping uses **loose abrasive grains** between workpiece and lap to produce very fine surface finish.

Diagram: Lapping

diff

Copy code

```
  Lap Tool
     ↓
| Abrasive Paste |
-------------------- Workpiece
```

Uses: Gauges, valves, precision surfaces.
Finish: **0.01 – 0.1 µm Ra**

D. SUPER FINISHING

- Uses fine abrasive stones applied with **oscillating motion**
- Removes microscopic peaks

Finish: **0.01 – 0.05 µm Ra**
Used for: crankshafts, camshafts.

E. POLISHING

- Uses **abrasive belts or wheels**
- Removes scratches and improves appearance
- Abrasive material: emery, Al_2O_3

Application: jewelry, molds, dies.

F. BUFFING

- Final finishing operation
- Uses **buffing wheel** with soft cloth and abrasive paste
- Produces mirror-like finish

Used for: cutlery, ornaments, aluminium parts.

G. LIMITATIONS OF FINISHING PROCESSES

- Not suitable for large stock removal
- Expensive
- Time-consuming
- Requires skilled operation

Unit 6- Installation and Testing of Machine Tools Foundations, leveling and alignment, Factors affecting the working accuracy of machine tools, Acceptance tests for lathe, Test Charts.

UNIT 6 – INSTALLATION AND TESTING OF MACHINE TOOLS

==

6.1 MACHINE TOOL FOUNDATIONS

A machine tool foundation is the **base structure** on which a machine is installed.
It provides rigidity, absorbs vibration and maintains accuracy.

A. FUNCTION OF MACHINE FOUNDATIONS

- Supports the weight of the machine
- Absorbs vibrations produced during machining
- Maintains stable alignment
- Prevents deflection and settlement
- Increases machine accuracy and life

B. REQUIREMENTS OF A GOOD FOUNDATION

1. **Sufficient Rigidity**
- To withstand dynamic and static loads.
2. **Large Mass**
- Heavy foundation reduces vibration.
3. **Proper Damping**
- Dampens vibration to avoid chatter.
4. **Dimensional Stability**
- Should not deform over time.
5. **Proper Anchoring**
- Machine must be firmly bolted to foundation.

C. DIAGRAM: Machine Tool on Foundation

markdown

Copy code

```
        Machine Tool
```

```
┌─────────────────────────────┐
│     LATHE          |        │
└─────────────────────────────┘
        ||  Anchor Bolts
        ||
  ┌─────────────────────┐
  │ Concrete Block  |   │ ← Foundation
  └─────────────────────┘
        ||  Soil
```

D. MATERIALS FOR FOUNDATIONS

- Concrete (most commonly used)
- Steel reinforced concrete (RCC)
- Cast iron block (for precision machines)

E. STEPS IN MACHINE INSTALLATION

1. Prepare the foundation pit
2. Pour concrete and cure
3. Position machine on the foundation
4. Insert and tighten anchor bolts
5. Perform leveling
6. Check alignment
7. Test run the machine

==

6.2 LEVELING AND ALIGNMENT OF MACHINE TOOLS

Leveling and alignment are necessary to ensure **accuracy**, **correct geometry**, and **long machine life**.

A. LEVELING

Leveling refers to setting the machine so that its bed is **perfectly horizontal**.

Tools used for Leveling

- Spirit level / Precision level
- Wedges or leveling screws
- Steel straightedge

Procedure of Leveling

1. Place spirit level on machine bed
2. Adjust leveling screws
3. Ensure bed is horizontal in both directions
4. Tighten bolts without disturbing the level

Diagram: Leveling

mathematica

Copy code

```
    Precision Level
     ┌──────────────┐
Bed ──┤    ||    ├── Bed perfectly horizontal
     └──────────────┘
```

B. ALIGNMENT

Alignment refers to the **correct relative position** of various machine parts.

Types of Alignment

1. **Spindle alignment**
2. **Tailstock alignment**
3. **Guideway alignment**
4. **Tool head alignment**

Methods of Alignment

- Autocollimator
- Dial indicator
- Straightedge and feeler gauges
- Mandrels and test bars

Why Alignment is Needed?

- Prevent taper turning
- Reduce tool wear
- Improve dimensional accuracy
- Ensure proper fit between mating parts

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6.3 FACTORS AFFECTING WORKING ACCURACY OF MACHINE TOOLS

Machine accuracy depends on geometry, conditions, environment and operation.

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1. Geometrical Inaccuracy

- Wear of guideways
- Spindle errors
- Tailstock misalignment
- Improper leveling

2. Cutting Forces

- Heavy forces deflect the tool and work
- Deflection leads to poor surface finish

3. Thermal Effects

- Heat from cutting causes expansion
- Heat from motor and bearings
- Temperature variations in workshop

4. Vibration

- Tool chatter
- Unbalanced rotating components

5. Poor Lubrication

- Causes wear on guideways
- Affects sliding motion accuracy

6. Operator Skill

- Improper tool holding
- Wrong feed or speed
- Excessive depth of cut

7. Machine Tool Stiffness

- Weak frame leads to deformation
- Reduces repeatability

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6.4 ACCEPTANCE TESTS FOR LATHE

Acceptance tests ensure the machine meets required accuracy after installation.

There are two types:

1. **Geometrical Test**

2. **Practical (Machining) Test**

A. GEOMETRICAL TESTS (NO-LOAD TESTS)

These tests verify correctness of alignment and movement.

1. Straightness of Bed

- Checked using straightedge and feeler gauge.

2. Flatness of Bed

- Checked with spirit level and straightedge.

3. Alignment of Headstock Spindle

- Tested using dial indicator and test bar.

4. Tailstock Centre Alignment

- Checked with test mandrel.

5. Radial Run-out of Spindle Nose

- Measured using dial indicator.

6. Movement of Carriage

- Parallelism with bed.

Diagram: Testing tailstock alignment

nginx

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```
Test Mandrel
   ──────────────────
Centre    Centre
  ^         ^
Dial Gauge → 0 0 0
```

B. PRACTICAL OR MACHINING TESTS

These tests check actual cutting performance.

1. Taper Turning Test

- Turn a trial piece → measure diameter at both ends
- No taper means good alignment

2. Surface Finish Test

- Examine machined surface

3. Thread Cutting Test

- Check pitch accuracy

4. Facing Test

- Ensures face is flat and perpendicular to axis

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6.5 TEST CHARTS

A test chart is a **document provided by machine manufacturer** listing all tests to be conducted for acceptance of machine tool.

Importance of Test Charts

- Provides standardized testing
- Ensures accuracy
- Helps in installation
- Identifies faults

Contents of a Typical Test Chart

1. Straightness of bed in longitudinal direction
2. Parallelism of spindle axis to guideways
3. Taper in turning test piece
4. Radial and axial run-out of spindle
5. Concentricity of centers
6. Perpendicularity of carriage movement
7. Surface finish measurement

Sample Representation of Test Chart

markdown

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```
-------------------------------------------------------
TEST NO | DESCRIPTION              | LIMIT | RESULT
-------------------------------------------------------
1       | Bed straightness         | 0.02 mm/300mm | OK
2       | Spindle run-out          | 0.01 mm       | OK
3       | Tailstock alignment      | Within limits | OK
4       | Taper turning test       | ±0.005 mm     | OK
-------------------------------------------------------
```

CONCLUSION

Proper **foundation**, **leveling**, **alignment**, and **testing** are essential to ensure:

- Long machine life
- Improved accuracy
- Stable performance
- Reduced vibration
- Better machining quality

A) **Suggested Specification Table (For ESE of Classroom Instruction):**

Unit Number	Unit Title	Marks Distribution			Total Marks
		R	U	A	
I	Metal cutting	2	2	6	10
II	Mechanics of machining	2	2	6	10
III	Shaper, Planer and Drilling machine	2	3	10	15
IV	Milling and Broaching operations	2	3	10	15
V	Grinding and Finishing Processes	2	2	6	10
VI	Installation and Testing of Machine Tools	-	4	6	10
Total		**10**	**16**	**44**	**70**

Legend: R: Remember, U: Understand, A: Apply and above