

**DEPARTMENT OF
MECHANICAL ENGINEERING**



**CONCEPTS OF MECHANICAL ENGINEERING-2
(25ME21I)**

As per DTE C-25 syllabus for II semester

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Ramaiah Polytechnic, Bengaluru-560054

VISION OF THE INSTITUTE

To be center excellence and provide quality technician education.

MISSION OF THE INSTITUTE

Ramaiah polytechnic strives to deliver global quality technician education and provides an environment that enables students to grow academically and to meet the current and future challenges independently.

VISION OF THE DEPARTMENT

- To achieve 100% academic results.
- To update the students with latest developments taking place in the field.
- To produce competent Mechanical Engineer's



Government of Karnataka
DEPARTMENT OF TECHNICAL EDUCATION

Program	Mechanical Engineering	Semester	II
Course Name	Concepts of Mechanical Engineering -II	Type of Course	Integrated
Course Code	25ME21I	Contact Hours	104 hrs/Sem
Teaching Scheme	L: T:P :: 4:0:4	Credits	6
CIE Marks	50	SEE Marks	50 (Theory)

1. Rationale:

Material Science and Surface treatment are the fundamental concepts that equip diploma students with knowledge of various materials, their properties, applications and surface modification techniques. Understanding these concepts is crucial for students pursuing careers in engineering, manufacturing and construction. Diploma Engineers are responsible for supervising production processes to achieve production targets and for optimal utilization of resources. For this purpose, knowledge about various manufacturing processes is essential.

Understanding the basics of **Metal forming and Machine tool techniques** are essential for mechanical engineers that equip students with knowledge of various metal forming and machining processes, tool design, and manufacturing methods. This requires training the students with a focus on **Casting and Sheet metal works**, operations provide essential skills, knowledge, and experience about the various manufacturing processes. Hence this integrated course is introduced to provide strong foundation in practical skills, safety awareness, and problem-solving abilities essential for success in mechanical engineering and related fields.

2. Course Outcomes: At the end of the Course, the student will be able to:

C0-01	Identify and apply suitable heat treatment and surface treatment processes for specific applications.
C0-02	Prepare castings using appropriate patterns, molds, and metal pouring techniques.
C0-03	Select and perform suitable metal forming processes such as forging, rolling, and extrusion.
C0-04	Develop and fabricate sheet metal components for various applications.
C0-05	Operate drilling and grinding machines to perform accurate machining and finishing operations.

WEEK-01

Crystal structure, Types of crystal structures – Crystalline & Non-crystalline, Structure of metal –unit cell, BCC, FCC and HCP structures, Mechanical Properties. Atomic Packing factor for BCC, FCC and HCP crystal structure (no derivations)

CRYSTAL STRUCTURE:

A crystalline structure is any structure of ions, molecules, or atoms that are held together in an ordered, three-dimensional arrangement.

Examples: Table Salt, Sugar, Iron, Copper and Aluminium

Types of Crystal Structures:

1. Crystalline structure
2. Non-Crystalline(Amorphous) Structure

CRYSTALLINE STRUCTURE:

Crystalline materials are materials in which atoms are arranged in a regular and repeating pattern through the materials.

Examples: Iron, Copper, Aluminium, Steel, Salts, Diamond etc

Characteristics of Crystalline materials:

1. Atoms are arranged in a orderly manner
2. Definite geometrical shape and structure
3. High strength
4. Sharp melting point
5. Good mechanical properties

Advantages of Crystalline Materials:

1. More resistant to damage than amorphous solids
2. Strong and durable
3. Good load carrying capacity
4. Suitable for engineering applications

Disadvantages of Crystalline Materials:

1. Less ductile and can display brittle behavior, particularly under high strain rates
2. Cracks may propagate along crystal boundaries
3. Their chemical stability makes them hard to solvent-weld, paint

NON-CRYSTALLINE STRUCTURE:

Non-Crystalline materials are materials in which atoms are arranged in randomly or irregularly, without any regular pattern. These materials do not have a crystal structure. It is also called as amorphous solid.

Examples: Glass, Plastics, Rubber, Polymers, Wax etc

Characteristics of Non-Crystalline materials:

1. Do not have long-rang, regular atomic order
2. No definite sharp melting point
3. No definite shape or form a irregular shape
4. Low strength
5. Soften over a range of temperatures depending on their composition
6. Usually brittle

Advantages of Non- Crystalline Materials:

1. Easy to mould and shape
2. Good electrical insulation
3. Low cost

Disadvantages of Non-Crystalline Materials:

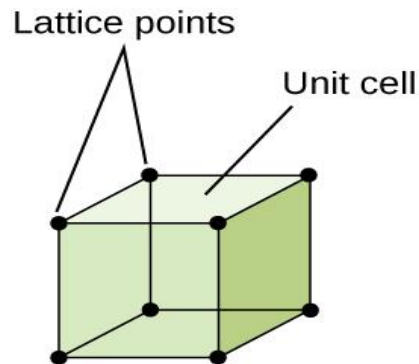
1. Low strength
2. Not suitable for heavy load applications

DIFFERENCE BETWEEN CRYSTALLINE & NON- CRYSTALLINE MATERIALS:

Sl no	Crystalline materials	Non- crystalline materials
1	Regular atomic arrangement	Random/Irregular atomic arrangement
2	Definite crystal structure	No crystal structure
3	High strength	Low strength
4	They have sharp melting point	They do not have sharp melting point
5	They are most stable	They are less stable
6	Examples: Iron, Copper, Aluminium, Steel, Salts, Diamond etc	Examples: Glass, Plastics, Rubber, Polymers, Wax etc

STRUCTURE OF METALS:

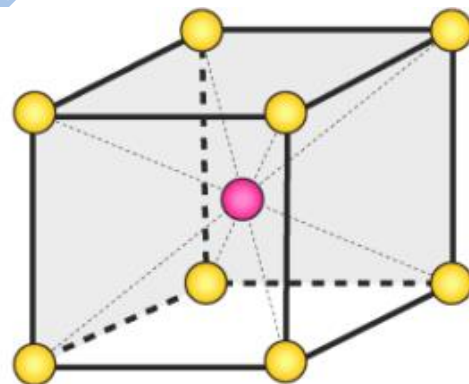
Metals are made up of atoms arranged in a regular, repeating 3D pattern which is called as crystal lattice. The way atoms are packed in unit cell affects the density, strength, ductility and other mechanical properties of the metal.

Unit cell:

A unit cell is the smallest part of the crystal structure which repeats again and again to form the entire metal. A unit cell is the basic building block of a metal crystal. When this unit cell repeats in all directions, it forms the complete 3D crystal structure of the metal. Different metals have different types of unit cells.

Types of Crystal Structures in metals:

1. BCC-Body centered cubic.
2. FCC- Face centered cubic.
3. HCP-Hexagonal close packed.

BCC-Body centered cubic.

Body-centered Cubic Unit Cell (BCC)

- In BCC structure ,atoms are arranged in a 3D cubic pattern.

- There are 8 atoms at the corners of the cube and 1 atom at the centre of the cube. Each corner atom is shared among 8 adjacent unit cells.

Examples: Iron, Chromium, Tungsten, sodium, vanadium etc.

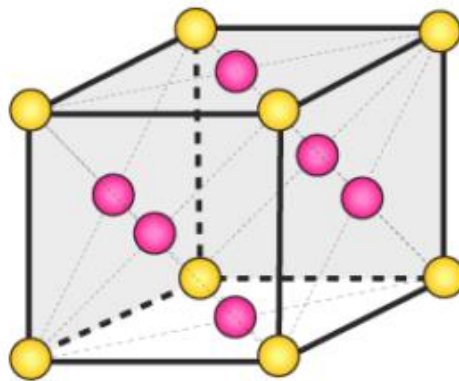
Properties of BCC Metals:

- High strength.
- Harder and Malleable.
- Less ductile
- Stronger but difficult to shape.
- Resistance to deformation under shock load.

Applications:

- Machine components.
- Cutting and drilling tools.
- Armor plates.
- Shafts and Gears.
- Construction steels (beam, frames, tools).

Face-centered cubic (FCC) structure:



Face-centred Cubic Unit Cell (FCC)

In the FCC structure, atoms are arranged in a 3D cubic pattern. There are 8 atoms at the corners of the cube and 1 atom at the center of each face of the cube. Each corner atom is shared among 8 adjacent unit cells.

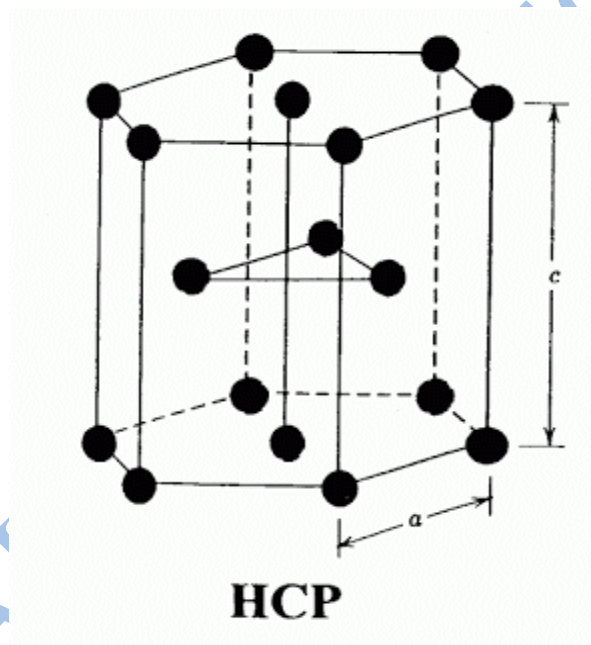
Examples: Aluminium, Copper, Gold, Silver, Nickel etc.

Properties:

- High ductility and Malleable.
- Higher atomic packing factor (74% for FCC).
- Bending or shaping without cracking.

Applications:

- Electrical wires and cables(Copper, Aluminum).
- Metal foils and sheeys(Aluminum foil).
- Kitchen utensils and cookware.
- Automotive and aircraft body panels.

Hexagonal Close-packed(HCP):

In the HCP structure, atoms are arranged in a hexagonal 3D pattern. There are 12 atoms at the corners of the hexagonal prism and 2 atoms inside the prism(one at the center of the top face and one at the center of the bottom face). Additionally, there are 3 atoms in the middle layer forming a triangular arrangement.

Example: Magnesium, Titanium, Zinc, Cobalt, Cadmium etc

Properties:

- High Strength to weight ratio.
- Low ductility.

Applications:

- Aerospace and aircraft components(Titanium, Magnesium alloys).
- Automotive wheels and frames.
- Biomedical implants(Titanium).
- Batteries(Zinc).
- Coating and galvanizing (Zinc).

MECHANICAL PROPERTIES OF METALS:

The following properties are:

1. **Elasticity:** It is the property of metal by virtue of which metals are able to regain their original shape and size after removal of load.
2. **Plasticity:** It is the property of metal by virtue of which metal takes place permanent deformation without fracture whenever it is subjected to the action of external load.
3. **Ductility:** It is the property of metal by virtue of which metal can be drawn into wires
4. **Brittleness:** It is the property of metal by virtue of which metal to break easily without bending
5. **Hardness:** It is the property of metal by virtue of which metal resists to indentation.
6. **Toughness:** it is defined as that property by virtue of which a metal can absorb maximum energy before fracture takes place.
7. **Resilience:** it is defined as the property by virtue of which a metal stores energy and resists shock or impact loads.
8. **Malleability:** It is the ability of metal to be hammered in to thin sheets.
9. **Strength:** strength may be defined as the property of a metal by virtue of which can withstand a load without fracture.

ATOMIC PACKING FACTOR:

It is also called as packing efficiency. The ratio of actual volume of atoms in a unit cell to total volume of unit cell is known as atomic packing factor.

$$APF = \frac{\text{volume of atoms in a unit cell}}{\text{total unit cell volume}}$$

1. Body centered cubic structure:

APF: 0.68(68%). It means 68% of the total volume of the unit cell is actually occupied by atom and the remaining 32% is empty space between atoms.

2. Face centered cubic structure:

APF: 0.74(74%). It means 74% of the total volume of the unit cell is actually occupied by atom and the remaining 26% is empty space between atoms.

3. Hexagonal close packed structure:

APF: 0.74(74%). It means 74% of the total volume of the unit cell is actually occupied by atom and the remaining 26% is empty space between atoms.

EXERCISES**MULTIPLE CHOICE QUESTIONS AND ANSWERS**

1. When each atom in a crystal structure is replaced by a point, then it is known as
- | | |
|--------------------|----------------------|
| a) Lattice Spacing | c) Crystal Lattice |
| b) Atomic Spacing | d) None of the above |

Ans: b)

2. In FCC, the unit cell shares _____ atoms, with the neighbouring unit cells.
- | | | | |
|------|-------|-------|-------|
| a) 8 | b) 14 | c) 12 | d) 20 |
|------|-------|-------|-------|

Ans: c)

3. What does BCC stands for in crystal structures?
- | | |
|-------------------------|-----------------------|
| a) Brave-cubic crystal | c) Body-centred cubic |
| b) Bond-centred crystal | d) Base-centred cubic |

Ans: c)

4. What is the approximate atomic packing factor(APF) for a face centred cubic(FCC) crystal structure?
- | | | | |
|---------|---------|---------|---------|
| a) 0.80 | b) 0.68 | c) 0.52 | d) 0.74 |
|---------|---------|---------|---------|

Ans: d)

5. Which of these materials is non crystalline?
- | | | | |
|---------------|-----------------|--------|------------|
| a) Table salt | b) Window glass | c) Ice | d) Diamond |
|---------------|-----------------|--------|------------|

Ans: b)

6. Which of these crystal structure is NOT considered a close packed structure?
- a) Body-centred cubic c) Hexagonal close packed
b) Face-centered cubic d) Both FCC and HCP

Ans: a)

REVIEW QUESTIONS:

1. Mention one application in each BCC and FCC structures.
2. Sketch the unit cell of FCC and label the atomic position.
3. Define the following terms a) coordination number b) lattice point c) Packing factor.
4. Write the atomic packing factor for FCC and BCC structures.
5. Sketch the unit cell of BCC and label the atomic position.
6. State the mechanical properties commonly associated with BCC, FCC and HCP crystal structure. Give one example of each metal and its application.
7. Sketch the unit cell of HCP and label the atomic position.
8. Compare BCC, FCC and HCP crystal structure based on atomic arrangement and coordination number.
9. Difference between crystalline and non-crystalline materials.
10. Explain Atomic packing factor for BCC, FCC and HCP with its properties and applications.

WEEK-02

Heat Treatment of Steel, Objectives, Types, Annealing (Ductility) Normalizing (Machinability), Hardening (Hardness), Tempering (reduce hardness/ brittleness), Case Hardening – Carburizing, Nitriding, Cyaniding, Surface hardening- Induction Hardening, Flame hardening

HEAT TREATMENT OF STEEL:

Heat treatment is defined as controlled heating and cooling of a metal (steel) component in order to alter its physical and mechanical properties such as hardness, tensile strength, ductility, toughness and wear resistance, without changing the shape as well as chemical composition of the component.

Purpose or Objectives of Heat Treatment:

Heat treatment is carried out to achieve one or more of the following objectives

1. To improve mechanical properties such as tensile strength, impact resistance, ductility etc in metals, especially steels.
2. To increase the toughness or resistance to fracture of the metal.
3. To produce hard surface and tough interior portions.
4. To improve machinability
5. To refine the grain structure after hot working a metal.
6. To improve magnetic and electric properties.

Types of Heat Treatment Process:

The following heat treatment processes are

1. Annealing
2. Normalizing
3. Hardening
4. Tempering
5. Austempering
6. Surface hardening
 - Case hardening or carburizing
 - Cyaniding
 - Nitriding
 - Induction hardening
 - Flame hardening

Steps Involved in Heat Treatment:**1. Heating:**

- The metal is heated to specific temperature depending on the type of metal and desired properties.

- Heating is done below or above the critical temperature depending on the process.
- The heating rate should be controlled to avoid thermal stresses and distortion.

2. Soaking:

- Once the desired temperature is reached, the metal is held (soaked) at the temperature for specific time.
- This allows the metals internal structure to transform uniformly.
- Soaking time depends on size of the parts and the types of metal.

3. Cooling:

- After soaking, the metal is cooled at a controlled rate to obtain desired mechanical properties.

4. Reheating (in some cases):

- Some processes involve reheating to a lower temperature to reduce brittleness and improve toughness.

ANNEALING:

Annealing is heat treatment process, in which the metal is heated to a high temperature, holding (soaking) it there for a considerable time, and then allowing it to cool to room temperature at a predetermined rate.

Purpose of annealing:

The purpose of annealing is to achieve the following objectives:

1. Soften the metal, so improve machinability, formability.
2. To improve ductility.
3. To relieve internal stresses.
4. Refine grain structure.

Types of annealing:

1. Full annealing
2. Process annealing
3. Stress-relief annealing

Applications:

Steel & steel alloys, rails, wires, machine parts and cutting tools.

NORMALIZING OR AIR QUENCHING:

Normalizing is heat treatment process, in which metal is heated to about 50°C above the upper critical temperature, holding it there for certain duration, and then allowing it to cool in the surrounding air to room temperature.

Purpose of Normalizing:

1. To refine the grain structure.
2. To improve machinability.
3. Reduces internal stresses.
4. To obtain a relatively good ductility without reducing the hardness and strength.

Applications:

Used in carbon steel & steel alloys, shafts, gears and automotive components.

HARDENING OR QUENCHING:

Hardening is a heat treatment process carried out in order to increase the hardness of steel. Hardening involves heating steel with a suitable carbon percentage to temperature about 30-50°C above the upper critical temperature, so as to produce an austenite structure. It is held at this temperature for a duration of about 15-30 minutes per 25mm of cross section of steel specimen and then cooled rapidly(Quenched) in a suitable say water, oil or brine etc.

Purpose of hardening:

1. To increase the hardness of the steel for improving their cutting ability.
2. To increase the hardness of the steel articles to improve their wear resistance.
3. To improve magnetization property of steel by increasing its hardness for producing a permanent magnet.

Applications:

Cutting tools, knives, dies, punches, & springs.

TEMPERING:

Tempering is a heat treatment process that reduces the brittleness of steel without significantly lowering its hardness and strength. Tempering is done immediately after quench hardening, when the steel cools to about 40°C. The process involves reheating the hardened steel to a temperature below the lower critical temperature followed by a slow cooling in air.

Purpose of Tempering:

1. To reduce brittleness of hardened steel (ductility increases).

2. To improve toughness of steel.
3. To relieve internal stresses.
4. Increase percentage elongation at high temperature.

Applications: Tools, machine components, automotive parts like gears, axils, springs & steel in constructions.

CASE HARDENING:

Case hardening is the process of hardening the surface of a metal object while allowing the metal deeper to remain soft thus forming a thin layer of harder metal at the surface. Case hardening is simple method of hardening steel. It is less complex than hardening and tempering.

Types of Case Hardening:

1. Carburizing
2. Nitriding
3. Cyaniding

Carburizing:

Carburizing is a method of introducing (adding) carbon to the surface of low carbon steels in order to produce a hard surface, while the inner core remains soft and ductile. Carburizing increases the carbon content of the steel surface by process of absorption and diffusion. Carburizing process is usually carried out on low carbon steels containing less than about 0.2%C.

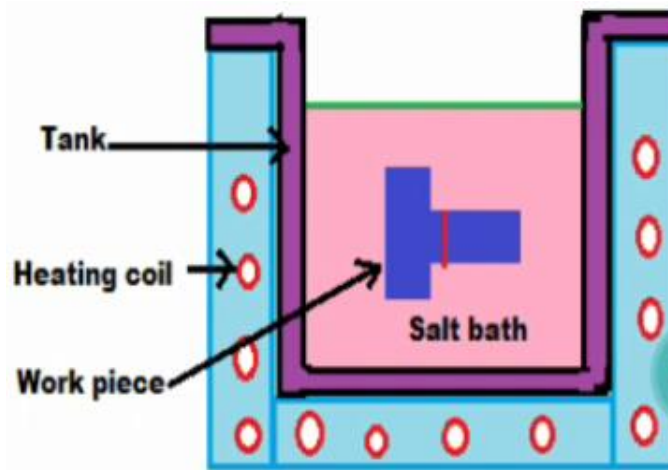
Applications: Gears, cam shafts, pins, pistons, bearings etc.

Nitriding:

Nitriding is a process in which the steel is heated in a nitrogen (N₂) –rich gas (like ammonia, NH₃) at a temperature of about 500-550°C. As a result nitrogen atoms diffuse into the surface, forming hard nitrides. This produces a very hard, wear-resistance and corrosion-resistance surface layer without the need for quenching.

Applications:

Aircraft engine parts, aero engine cylinder, crank pins, gears, fuel injection pumps etc.

Cyaniding:**Figure: Cyaniding**

Cyaniding is also called as liquid carburizing. Cyaniding is mainly used on low carbon steels. In this process in which both carbon and nitrogen are absorbed by metal surface to get it hardened. After heating the piece of low carbon steel is immersed in a bath of cyanide salt such as sodium cyanide maintained at 850 to 950°C. The immersed steel piece is left in molten cyanide salt bath at the above temperature for about 15 to 20 minutes. It is then taken out of bath and quenched in water or oil.

Applications:

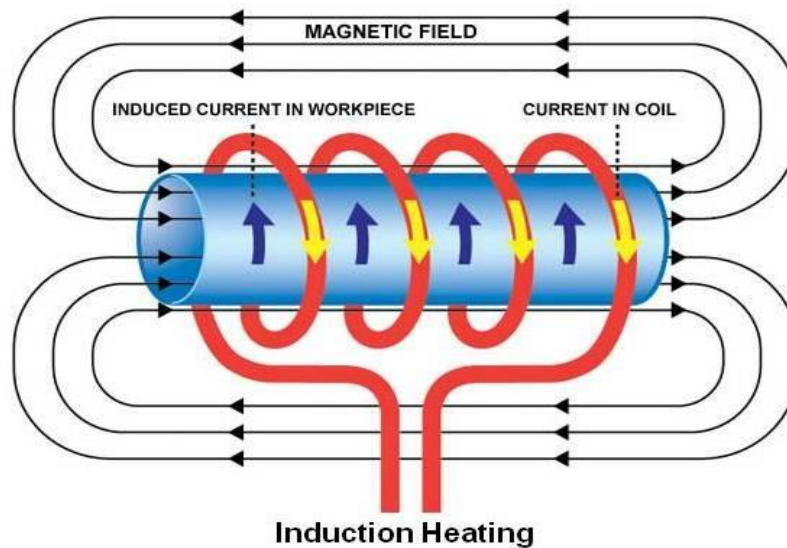
Small components like bolts, screws, small gears and tools.

SURFACE HARDENING:

It is a heat treatment process in which only the surface of a metal is hardened by heating and rapid cooling (quenching), without changing its chemical composition. This produce a hard outer surface and tough inner core, improving wear resistance while maintaining toughness.

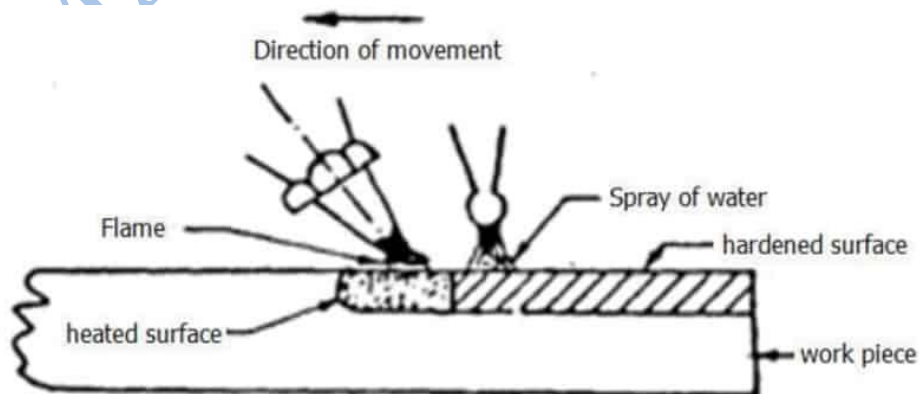
Types of surface hardening.

1. Induction hardening
2. Flame hardening

Induction hardening:**Figure: Induction Hardening**

- It is a process in which the surface of the steel is heated by electromagnetic induction using a high frequency alternating current.
- The steel part is placed inside a coil that generates an alternating magnetic field, inducing eddy currents on surface.
- These eddy current rapidly heat the surface layer to a temperature of about 750-950°C, while the core remains relatively cool.
- After heating, the surface is immediately quenched with water or oil, converting the surface austenite into hard martensite.

Applications: Gears, crankshafts, axles, shafts, camshafts and machine spindles.

Flame hardening:**Figure: Flame Hardening**

- It is a process in which the surface of steel is heated using a high temperature oxy-acetylene flame and then rapidly quenched with water, oil or air.
- The flame is directed only at the surface to heat it to the austenitizing temperature about 800-950°C.
- After reaching this temperature, the surface is quickly cooled forming martensite on the surface while the core remains tough.

Applications: Gear teeth, cams, shafts, rails and machine ways.

COMPARISON BETWEEN CASE HARDENING AND SURFACE HARDENING:

Feature/Aspect	Case hardening	Surface hardening
Material type	Low carbon steel	Alloy steels and stainless steels
Wear resistance	High surface wear resistance	High surface wear resistance but shallower layer than case hardening
Process Duration	Longer duration	Shorter duration
Hardness Depth	Relatively deep hardened layer (0.5 - 2 mm typical)	Usually shallow hardened layer (0.1-0.5 mm)
Applications	Gears, shafts, cams and bearing surface made of low carbon steels	Stainless steel or alloy steel parts like spring, knives, cutting tools and precision components
Cost	Moderate to high depending on depth and method	Usually lower for small treatments, high for laser

EXERCISES

MULTIPLE CHOICE QUESTIONS AND ANSWERS

1. For steel, which one of the following properties can be enhanced upon annealing?
 a) Harness b) Toughness c) Ductility d) Resilience

Answer: c)

2. In normalizing, cooling is done in which of the following medium?
 a) Air b) water c) Oil d) Furnace

Answer: a)

3. Cyaniding is usually done for _____
 a) Plain carbon steel b) Cast iron c) Stainless steels d) Pig iron

Answer: a)

4. Which of the process needs no quenching?
- a) Induction hardening
 - b) Nitriding
 - c) Flame hardening
 - d) Carburizing

Answer: b)

5. How is the heating of surface done in flame hardening technique?
- a) Oxy-acetylene torch
 - b) Carburizing flame
 - c) Electrode
 - d) Direct sunlight

Answer: a)

6. What are the applications of Nitriding?
- a) Gear, Camshafts
 - b) Valve guides and seatings
 - c) Chain links, nuts, bolts and screws
 - d) Gears, nuts, bolts

Answer: a)

7. Which one of the following is a case hardening process?
- a) Recrystallization
 - b) Strain hardening
 - c) Carburizing
 - d) Spheroid zing

Answer: c)

8. Which one of the following is NOT a case hardening process
- a) Carburizing
 - b) Normalizing
 - c) Nitriding
 - d) Cyaniding

Answer: b)

REVIEW QUESTIONS:

1. List objectives of Hardening process.
2. List the steps followed in Annealing process.
3. Explain the purpose of Heat treatment process.
4. Explain the steps involved in Heat treatment process.
5. Explain the purpose of Normalizing.
6. Explain Case hardening process.
7. Which heat treatment processes ensure both strength and surface hardness for engine components? Justify with process details and property changes.
8. Identify and explain the appropriate surface hardening process for the stainless steels used in various industrial applications.

9. Identify the heat treatment process suitable for steel shaft used in a high speed turbine. Highlight the properties improved after heat treatment.
10. Which heat treatment is suitable for shafts requiring hard surface and tough core? Explain principal, process and benefits.

RAMAIAH POLYTECHNIC

WEEK-03

Surface treatment, Corrosion - Types, Methods of reduction of corrosion, Surface coating processes - Traditional methods - Painting, electroplating, Galvanizing, Spraying. Advanced coating technologies - Physical vapor deposition, Chemical Vapor deposition, Laser treatment.

RAMAIAH POLYTECHNIC

SURFACE TREATMENT:

Surface treatment is the process of altering a materials surface using physical, chemical or mechanical methods to improve its properties like hardness, corrosion, resistance and appearance without changing the inner core structure.

Methods of Surface treatments:

1. Mechanical: Shot preening, brushing, grinding to alter surface texture.
2. Chemical: etching, prospecting, passivation, anodizing (for metals).
3. Thermal: case hardening.
4. Electrochemical: Electroplating (adding metal layers), electro polishing.
5. Coating: Painting, powder coating, vapor deposition.

Surface treatments are primarily used to:

1. Improve hardness & Durability.
2. Enhance performance: Modify characteristics like electrical and thermal conductivity, friction control or non-stick properties.
3. Refine Aesthetics: Change the color, texture or reflectivity of a product for decorative purpose.
4. Improve corrosion resistance.

CORROSION:

Corrosion is the slow destruction of metal due to chemical or electro-chemical reaction with the surrounding environment such as air, moisture or chemicals. This process leads to the formation of oxides, salt, hydroxides on metal surface, which weakens the metal, reduce its strength and appearance.

Example: Rusting of iron.

Types of Corrosion.**1. Uniform corrosion:**

This corrosion occurs where metal or alloys is completely homogeneous both chemically and mechanically due to this the galvanic cells are established between any two points on the metals surface in the presence of acids or alkalis. In this case, the rate of corrosion is uniform.

Example: rusting of iron sheets or steel structure exposed to air and moisture.



Figure: Uniform Corrosion

2. Pitting Corrosion:

Pitting corrosion is a class of corrosion caused due to severe damage to metals. It is a localized form of corrosion because of which micro cavities or holes, pits are formed in metals. It is the most dangerous form of corrosion damage because it is more difficult to detect, predict and design against as the corrosion products often cover the pits.

Example: Stainless steel in contact with saltwater, copper pipes in plumbing with imbalanced water.



Figure: Pitting Corrosion

3. Intergranular corrosion:

Intergranular corrosion is a localized corrosion that occurs at grain boundaries of metals, leading to the disintegration of alloys and loss of strength. It can be caused by impurities, variations in alloy composition, especially in environments like welding.

Example: Stainless steel after improper welding or heat treatment.



Figure: Intergranular Corrosion

4. Galvanic Corrosion:

Galvanic corrosion also known as bimetallic or dissimilar metal corrosion is an electrochemical process where one metal corrodes preferentially when it is in electrical contact with another, different metal in the presence of an electrolyte.

Example: Zinc corroding faster when in contact with copper in moist air.



Figure: Galvanic Corrosion

5. Stress Corrosion:

This type of corrosion occurs in the internally stressed engineering components used in corrosive environment and sustained tensile stress.

Example: Cracking in brass (season cracking).



Figure: Stress Corrosion

METHODS OF REDUCTION OF CORROSION:

The following methods are generally adopted to prevent or control the corrosion of metals.

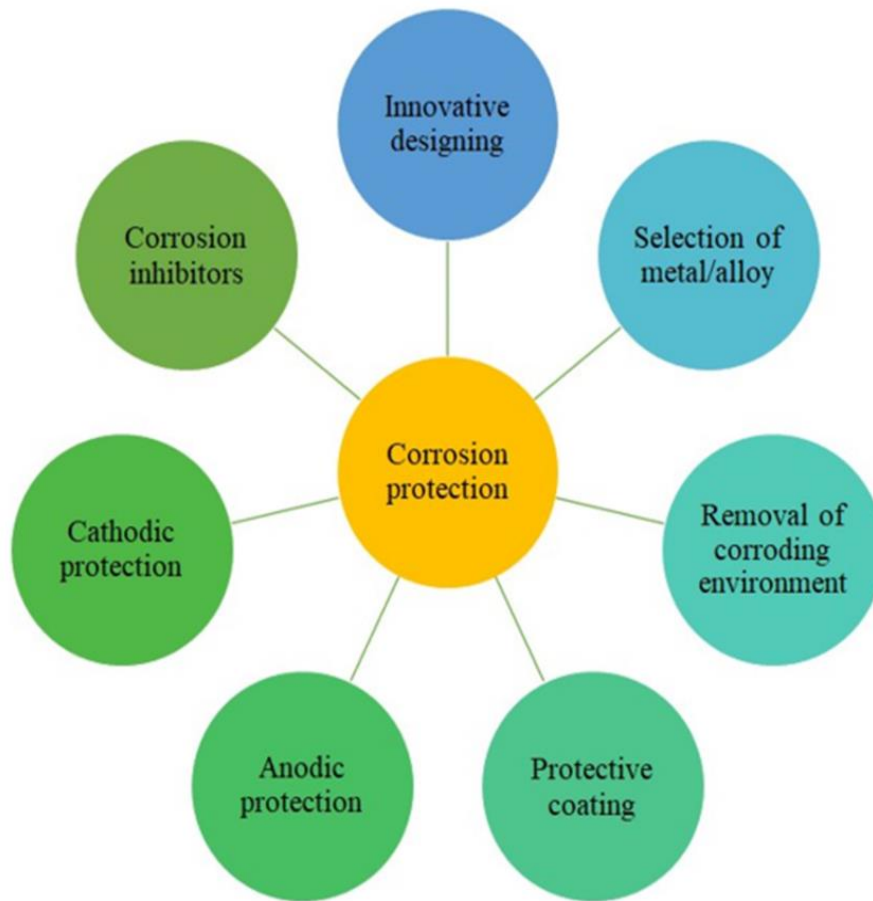


Figure: Methods of Reduction of Corrosion

1. Suitable or Innovative Design:

The corrosion can be prevented by selecting the suitable design and fabrication for a particular shape of the components.

2. Selection of Materials/Metals/Alloys:

This method involves selecting metals or alloys that are naturally resistance to corrosion in a given environment.

Examples: Stainless steel, Aluminium

3. Protective Coating:

In this method, the metal surface is covered with a protective layer to isolate it from corrosive surrounding.

Example: Painting, Galvanizing and Electroplating.

4. Cathodic Protection:

Cathodic protection is a technique that uses direct electrical current to prevent the corrosion of metal structures.

Example: Underground storage tanks and pipelines

5. Corrosion Inhibitors/Use of Inhibitors:

An inhibitor is a substance which is added to the electrolyte. In small quantity to reduce the rate of corrosion. The inhibitors may be organic or inorganic.

Examples: Used in Boilers, Cooling system. Common inhibitors are sodium nitrite, chromates and organic amines.

6. Removal Corroding of Environment/ Modification of Corrosive Environment:

The rate of corrosion can be greatly reduced by small changes in the corroding environment such as changes in composition, nature and temperature.

7. Anodic Protection:

Anodic protection is defined as the protection of a metal by maintaining it in a passive condition through the application of a fixed potential, which facilitates the formation of a passive film that shields the metal from corrosive environments.

8. Alloying of Metals:

This method involves adding specific alloying elements to a base metal to improve its corrosion resistance.

Example: Stainless Steel (iron+chromium+nickel) used in kitchen utensils.

TRADITIONAL SURFACE COATING PROCESSES:

Surface coating is a process where the metal parts are prepared to prevent or reduce the rate of corrosion to increase the life of the metal parts.

Surface of the metals can be protected by means of following processes:

1. Painting.
2. Electroplating.
3. Galvanizing.
4. Spraying.

1. Painting Process:

Painting is the process of applying a pigment liquid, paste or powder to a surface to protect it from corrosion and improve its appearance. The paint is a mixture of pigments, drying oil and a solvent thinner.

2. Electroplating:

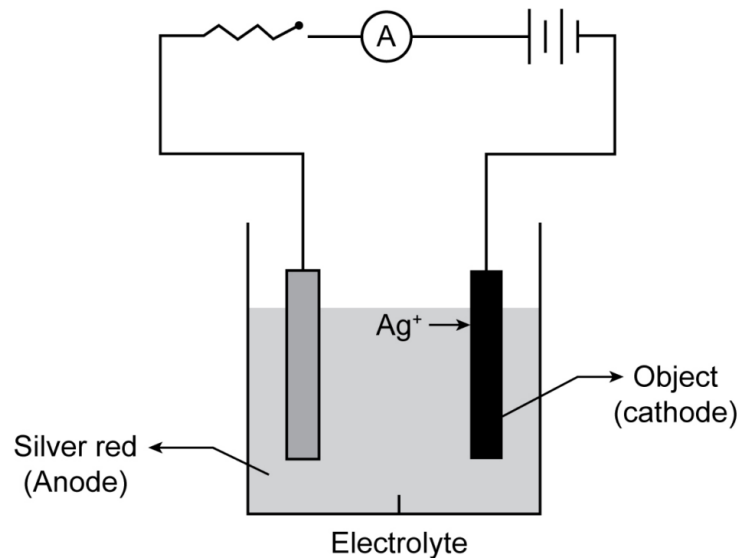


Figure: Electroplating

It is the process of depositing a very thin layer of metal coating, on the base metal by passing direct current through an electrolyte solution. In this process, the component of base metal (object to be coated) is made to act as cathode (negatively charged) whereas the coating metal is an anode (positively charged) in a solution containing some salt of the metal. The commonly used coating materials are copper, nickel, silver, gold, chromium and tungsten etc.

Examples:

- Zinc plating on steel.
- Gold or Silver plating on jewelry, Watch, and Decorative items.
- Nickel plating on machinery parts.
- Silver plating on medical devices.

3. Galvanizing:

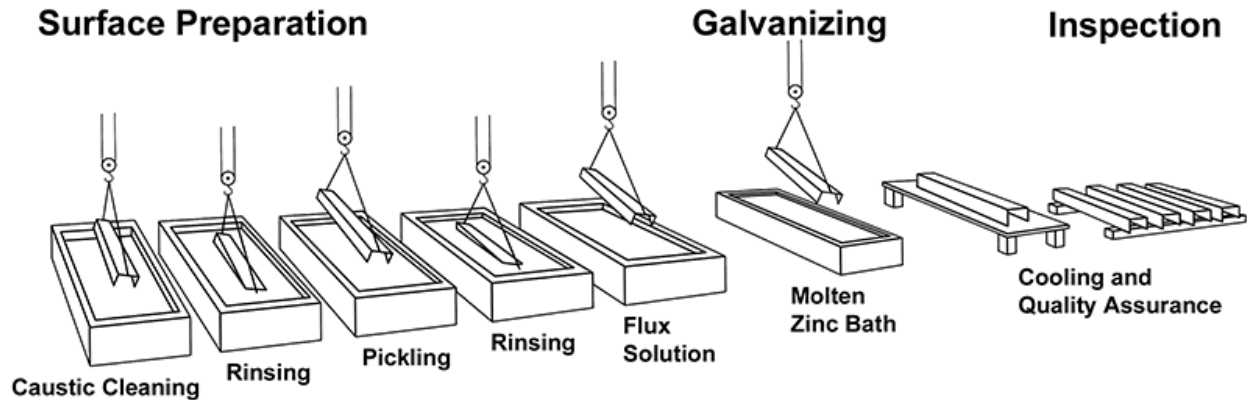


Figure: Galvanizing

Galvanization is the process of applying a protective zinc coating to steel or iron, to prevent rusting by dipping them in a bath of molten zinc. The prepared steel part immersed in a bath of molten zinc at a temperature of about 450°C. The steel part is taken out from bath and molten zinc solidifies on the surface, forming a layer of zinc on steel part surface. The galvanized steel is cooled and then inspected for any defects.

Examples:

- Steel pipes for plumbing.
- Steel poles for power lines.
- Steel beams and columns.
- Iron sheets, fencing, bolts and nuts.

4. Spraying:

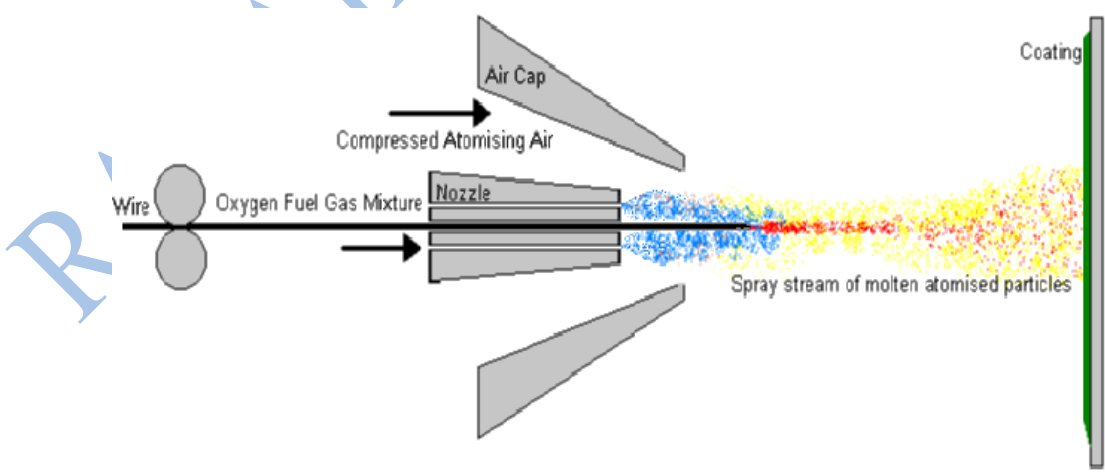


Figure: Spraying

The spraying is a process of providing a thin coating by depositing an atomized metal on the metal surface using compressed air or gas. The spraying can be used for applying coating of aluminium, brass, copper, zinc, tin etc.

ADVANCED COATING TECHNOLOGIES:

Some important advanced coating technologies are:

1. Physical Vapor Deposition Coating (PVD).
2. Chemical Vapor Deposition Coating (CVD).
3. Laser Treatment for Surface Coating.
4. Electron Bean Coating (EBC).
5. Iron-Beam Based Technique.

1. Physical Vapor Deposition Coating (PVD):

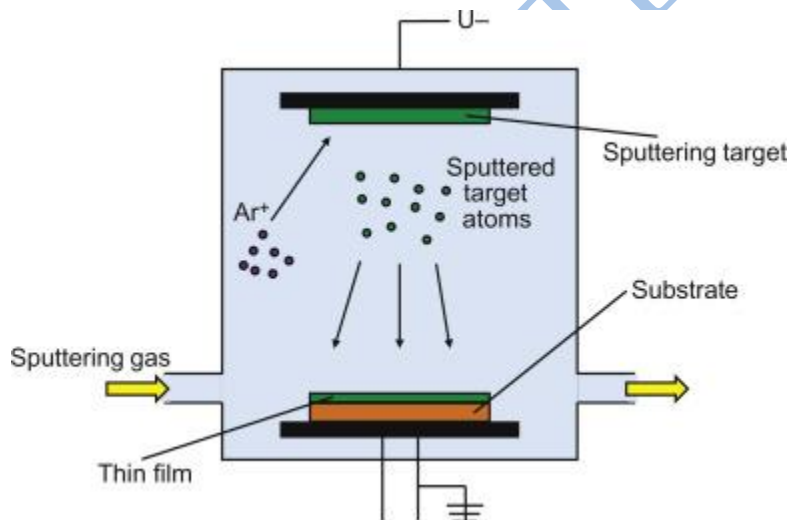


Figure: PVD

PVD uses physical process (such as heating or sputtering) to produce a vapor of material, which is then deposited on the object which is called physical vapor deposition. It consists of vacuum chamber as shown figure. The substrate whose surface is to be coated is placed on a bottom table, and is connected to an anode (+). The material which is to be heated and converted into vapor is fixed over the top plate, which is connected to cathode (-) of power supply unit. The sputtering gas like argon gas is circulated from one end for creating plasma through ionization, which bombard the coating material to vaporize it and deposited into substrate. Vaporized atoms travel through the vacuum toward the substrate. The vapor condenses on the substrate surface, forming a thin, dense and uniform coating.

2. Chemical Vapor Deposition Coating (CVD):

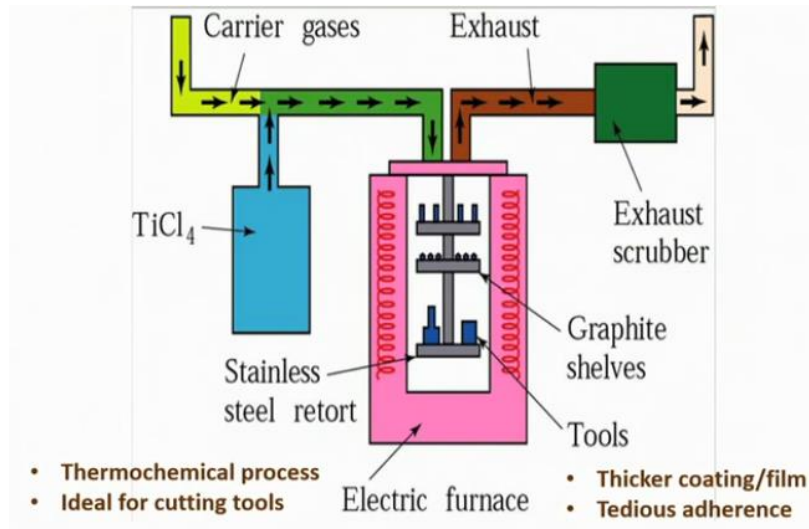


Figure: Chemical Vapor Deposition Coating

CVD involves formation of non-volatile thin solid film by reaction of ions in the vapor state and subsequent deposition. Reactant gases decompose and react on heated surface to form thin film. CVD involves exposing the heated substrate to one or more volatile precursors (reaction gas inlet), which react on the substrate surface to produce the film. CVD is a very versatile process to produce coating, powdered, fibers and monolithic parts. CVD produce almost any metallic/non metallic elements like carbon and silicon and compounds. CVD is widely used in the various industries such as semiconductor, fiber optics and coating, due to its ability to produce high quality thin film with controlled properties.

3. Laser Treatment for Surface Coating.

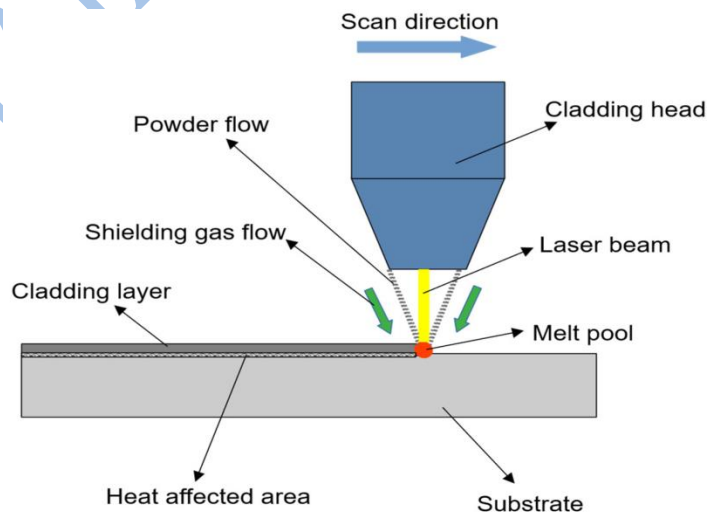


Figure: Laser Treatment for Surface Coating

Laser treatment for surface coating involves using a laser to modify or add a layer of materials to surface, enhancing its properties like hardness, wear resistance and corrosion resistance. Laser treatment works on the principle of localized heating by a focused laser beam. The laser rapidly melts or heats the surface layer of the substrate, which solidifies with improved microstructure.

Laser treatment process:

1. **Surface cleaning:** Remove dirt, grease and oxides from substrate better treatment sufficiency.
2. **Laser setup:** Mount the substrate in the laser system and adjust laser parameters(power, scanning speed, beam focus and spot size) according to the material and desired surface properties.
3. **Surface Modification:** The molten or heated layer rapidly solidifies, forming a fine grained, hardened and wear resistance surface.
4. **Cooling and Finalization:** Allow the treated substrate to cool naturally or using controlled method.
5. Inspect the surface for uniformity, hardness and microstructure.

EXERCISES

MULTIPLE CHOICE QUESTIONS AND ANSWERS

1. Which type of corrosion occurs when two dissimilar metals are in electrical contact in the presence of an electrolyte?
 - a) Stress corrosion cracking
 - b) Erosion corrosion
 - c) Galvanic corrosion
 - d) Pitting corrosion

Answer: c)

2. CVD stands for:
 - a) Chemical vapor deposition
 - b) Corrosion vapor diffusion
 - c) Coated vapor device
 - d) Chromic vapor delivery

Answer: a)

3. In electroplating, the object to be plated is connected to:
 - a) Anode
 - b) Cathode
 - c) Both
 - d) Earth

Answer: b)

Review questions:

1. Define Electroplating.
2. Define corrosion. List its types.
3. Name any two methods to reduce corrosion in metals.
4. Write the purpose of spraying in surface coatings.
5. What are the types of corrosion and explain any one?
6. Explain the methods of reduction of corrosion.
7. What is surface coating? List the surface coating processes.
8. Explain Galvanizing process with its neat sketch.
9. Explain Electroplating process with its neat sketch.
10. Explain spraying process of metal coating.
11. Explain laser surface treatment process.
12. Explain Physical vapor deposition method of surface treatment.
13. Explain Chemical vapor deposition method of surface treatment.
14. Name any three advanced coating technologies.

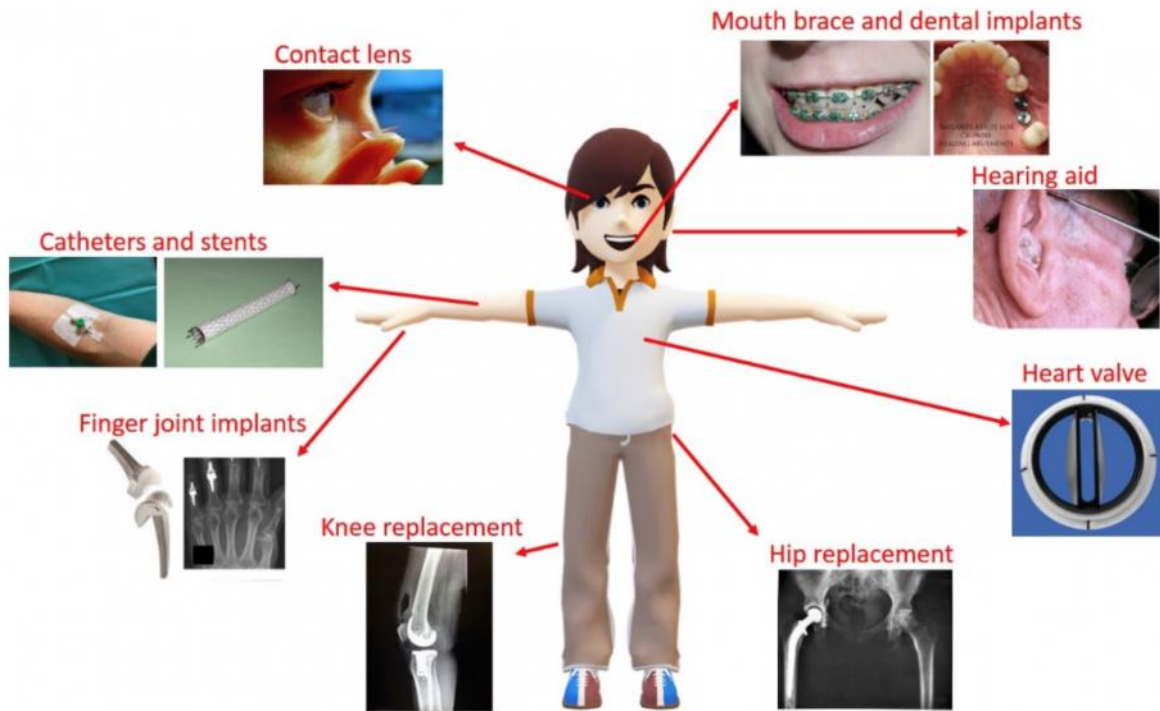
WEEK-04

Advanced materials -Biomaterials- Properties and applications, Smart Material - Piezoelectric materials (Quartz, PZT and PVDF), Shape memory alloys (Nitinol, Ni–Mn–Ga)- Properties and applications, Energy Materials- Solar Energy, Battery- Properties and applications, Nano-Materials-Classification, properties and applications, Carbon – based CNT and Graphene.

BIOMATERIALS:

Biomaterials are defined as the synthetic material that is used to replace or restore function to a body tissue and is continuously or intermittently in contact with body fluids.

Biomaterials

**Properties of Biomaterials:**

Following are the important properties of biomaterials.

1. These materials must not produce toxic substance.
2. Biocompatibility: It must not any allergic or immune reaction in the body.
3. Mechanical strength: It should have sufficient strength to withstand body forces such as movement, pressure and load.
4. Corrosion and Wear resistance: It must resist corrosion, wear and degradation when it contact with body fluids.
5. Biofunctionality: It must perform the desired biological function effectively.
6. They should not cause adverse biological reactions.
7. They should be reliable and durable.

Applications:

Following are the important applications of biomaterials:

1. Used for joint replacement.
2. Used for bone plates.
3. For dental implants for tooth fixation.
4. Used for artificial ligaments and tendons.
5. Used for cancertherapy.
6. For intracular lenses for eye surgery.
7. Used for Cardiovascular -artificial heart valve, stunt, etc.
8. Used for skin repair devices(artificial tissue).

SMARTS MATERIALS:

Smart materials are the intelligent materials which are able to sense changes in their environment and then respond to these changes in predetermined manners.

The smart materials are also called as responsive materials. These are designed materials have one or more properties that can be significantly changed in a controlled fashion by an external stimuli, light, temperature, pH or chemical compounds.

Types of Smart materials:

1. Piezoelectric materials.
2. Electrostrictive materials.
3. Magnetostrictive materials.
4. Thermoresponsive materials.
5. Electrochromic materials.
6. Smart glass.

Properties of Smart materials:

Following are the important properties of smart materials.

1. Excellent response to the change in their environment.
2. They are self detective and self diagnostic.
3. Self corrective, self controlling and self healing.
4. High sensitivity.
5. Their response time very less.

Applications of Smart materials:

Following are the important application are .

1. Used in electronic display.
2. Used in actuator and sensors.
3. Used for data storage units and energy conversion devices.
4. Used for insulin pumps.
5. Used for ultrasonic therapy.
6. Used for ultrasonic cataract removal devices.
7. Used in computer, microactuators for hard discs.
8. Used in micro-electro mechanical systems.

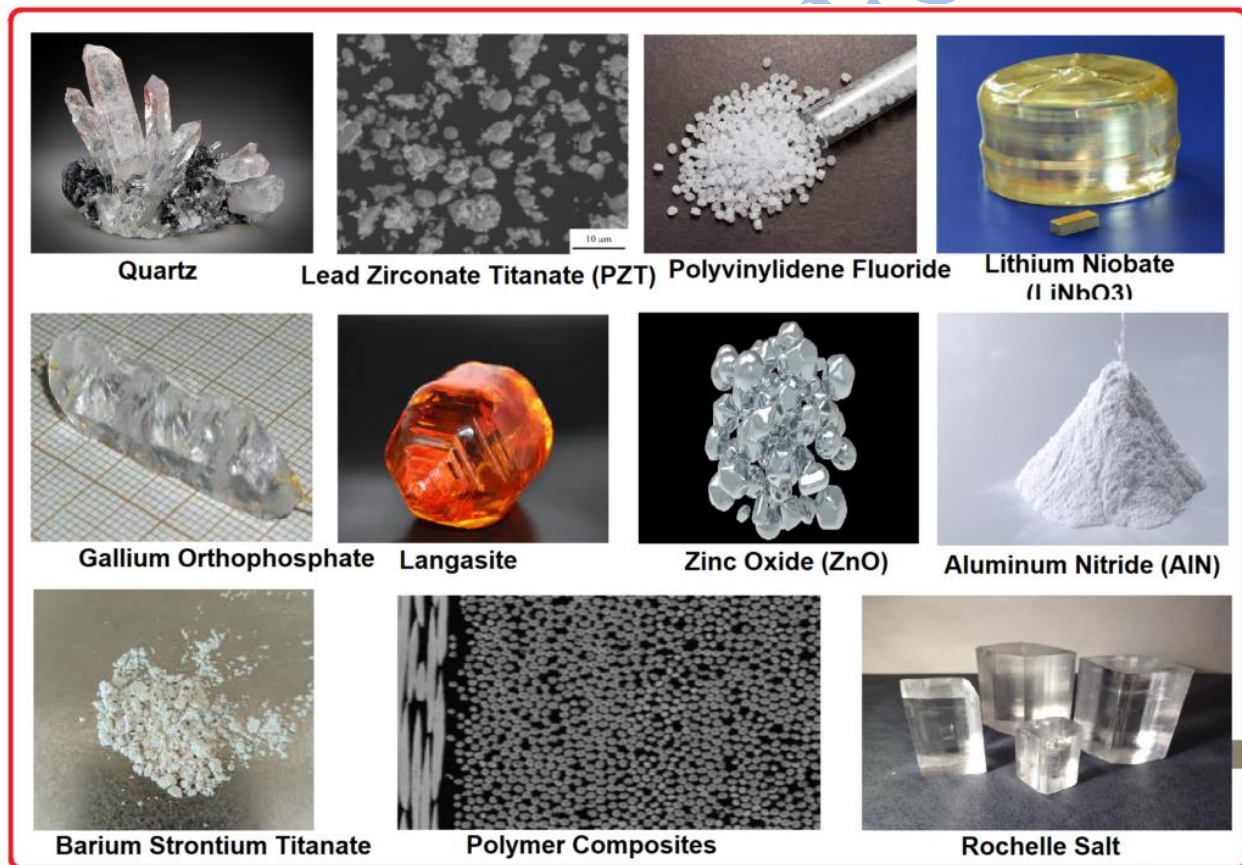
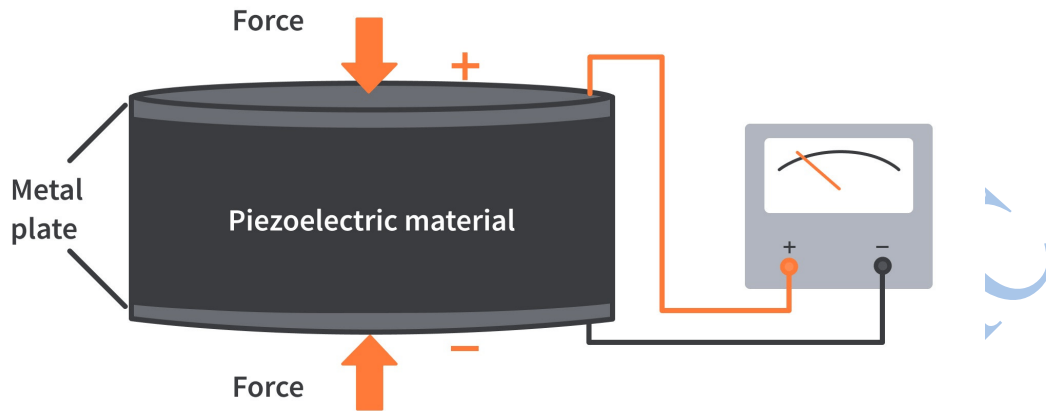
PIEZOELECTRIC MATERIALS:

Figure: Piezoelectric Materials

Piezoelectric materials generate an electric charge (voltage) when mechanical stress is applied and conversely deform when an electric field is applied. This property is known as the piezoelectric effect.

Examples: Quartz, lead zirconate titanate(PZT) , Polyvinylidene fluoride(PVDF).

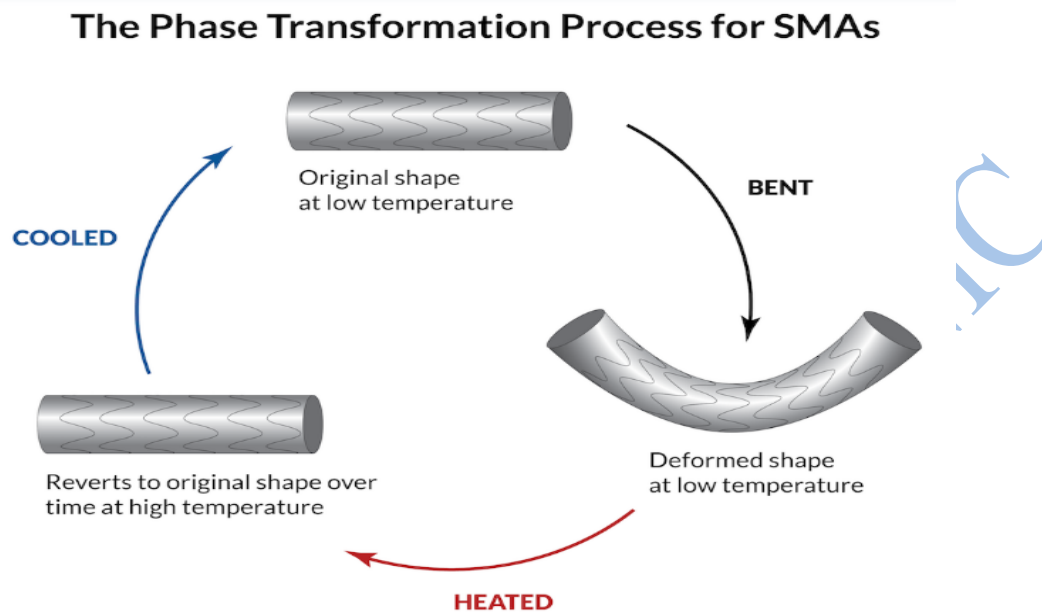


Properties of Piezoelectric materials:

1. Exhibit direct and converse piezoelectric effect.
2. Are anisotropic- behaviour depends on direction of force or field.
3. Possess moderate to high dielectric constant.
4. Show good mechanical strength under stress and vibration.
5. Respond well to high-frequency signals.
6. Must have a non-centrosymmetric crystal structure.
7. Can be natural(quartz) or synthetic.
8. High permittivity- store large amount of electric energy.

Application of Piezoelectric materials:

Sl no	Application Area	Uses of Piezoelectric material
1	Sensors	Convert pressure or force in to voltage (airbags, scale)
2	Actuators	Produce movement from voltage (robotics, optics, camera lenses)
3	Ultrasound devices	Generate and receive sound waves(medical)
4	Microphones/Speakers	Convert between sound and electrical signals
5	Earthquake monitoring	Detect seismic waves through stress-induced charge
6	Ignition system	Spark generation from mechanical parts
7	Accelerometers	Used in smart phones

SHAPE MEMORY ALLOYS(SMA):**Figure: Shape Memory Alloys**

A shape memory alloy is an alloy that can be deformed when cold but returns to its original shape when heated (depends on temperature), transitioning from the deformed martensitic phase to an austenitic phase upon heating.

Examples: Copper-aluminum-nickel and Nickel-titanium (Nitinol)

Properties of Shape Memory Alloys:

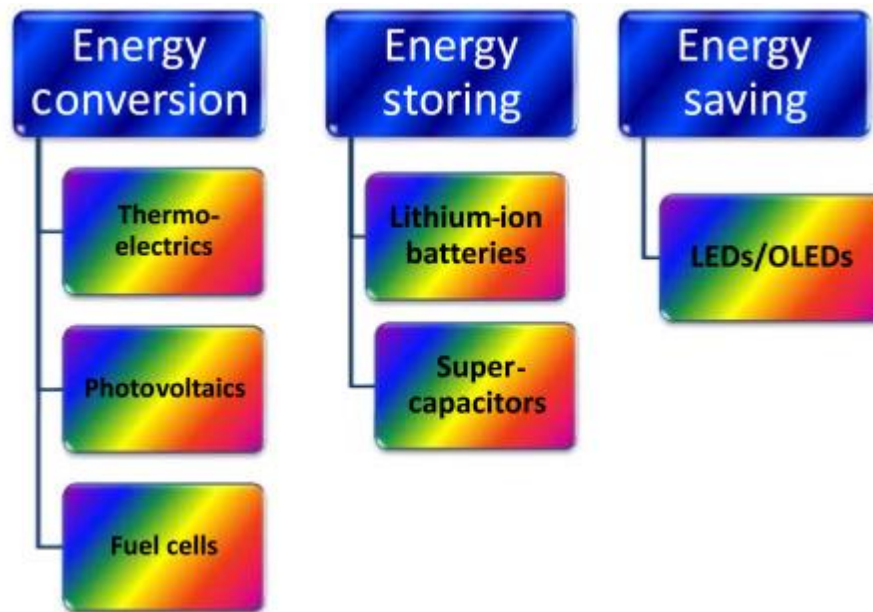
1. Ability to return to a predefined shape when heated, even after being deformed at a lower temperature.
2. Exhibit good corrosion resistance.
3. Ability to undergo large elastic deformation and recover the original shape upon removal of stress.
4. Exhibit changes in electrical resistance during phase transformations.

Applications of Shape Memory Alloys:

1. Biomedical devices- used in stents that can be compressed for insertion and then expand to original shape within the body.
2. Aerospace- Deploying structure and adaptive wing components.
3. Used in seismic protection.
4. Used in Textiles.

ENERGY MATERIALS:

Energy materials are substances engineered for energy related applications like storage, conversion and generation. These materials are crucial for advancements in renewable energy technologies, electric vehicles and grid storage. They consists a wide range of substances, used in applications like batteries, fuel cells, solar cells and thermoelectric device. These materials are important for developing sustainable energy solutions and improving energy efficiency.



Examples: Lithium-ion batteries, Solar cell materials, Fuel cell, Thermoelectrics & Supercapacitors.

Properties of Energy Materials:

1. Good thermal conductivity.
2. Excellent charge carrier mobility.
3. Excellent electrical conductivity.
4. High strength and toughness.
5. Low cost and long lifespan.
6. Materials must be stable under the electrochemical conditions.

Applications of Energy materials:

1. Used in electric vehicles.
2. Used in renewable energy sources.
3. Used in portable electronic equipments like smartphones, laptops etc.
4. Used in industrial processes for improving energy efficiency and reducing emissions.

1. Solar Energy Materials:

Solar energy materials are materials that convert sunlight into electrical energy using the photovoltaic effect.

Examples: Silicon, Cadmium telluride & Copper indium gallium selenide.

Properties of Solar Energy materials:

1. High photoelectric conversion efficiency.
2. Good stability.
3. Durability.
4. Suitable bandgap.

Applications of Solar Energy materials:

1. Solar panels for residential, commercial and industrial power generation.
2. Solar powered calculators, lamps and street lights.
3. Solar cells in satellites and space applications.

2. Battery materials:

Battery materials are materials used to store electric energy chemically and release it on demand through electrochemical reactions.

Examples: lithium-ion batteries, lead-acid batteries, Nickel-metal hydride.

Properties of Battery materials:

1. High energy density- It can store large amounts of energy in a small volume.
2. Long cycle life-It can be charged and discharged multiple times.
3. Good electrical conductivity- It ensures efficient current flow.
4. Safety and stability- resistant to leakage, overheating or short circuiting.
5. Lightweight-Ideal for portable devices.

Applications of Battery materials:

1. Portable electronic devices-Mobile phones, laptops.
2. Electric vehicles- Lithium-ion batteries for cars and bikes.
3. Backup power systems- Lead-acid batteries in UPS.
4. Renewable energy storage- Solar and wind energy storage systems.

3. Nano-materials:

Nanomaterials are substances with at least one dimension between 1 and 100 nanometers (nm), exhibiting unique optical, electrical, mechanical, and magnetic properties different from their bulk counterparts due to their high surface area and quantum effects.

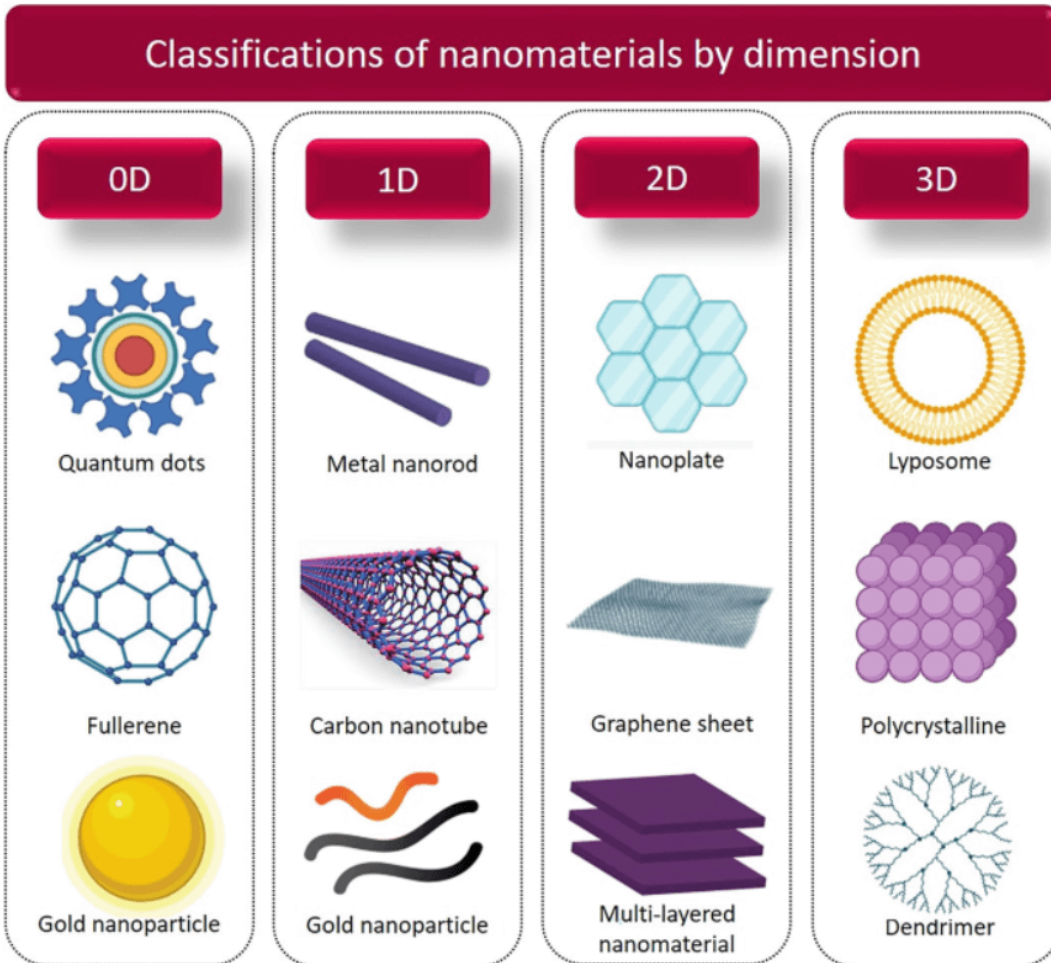


Figure: Classification of Nano Materials

Properties of Nanomaterials:

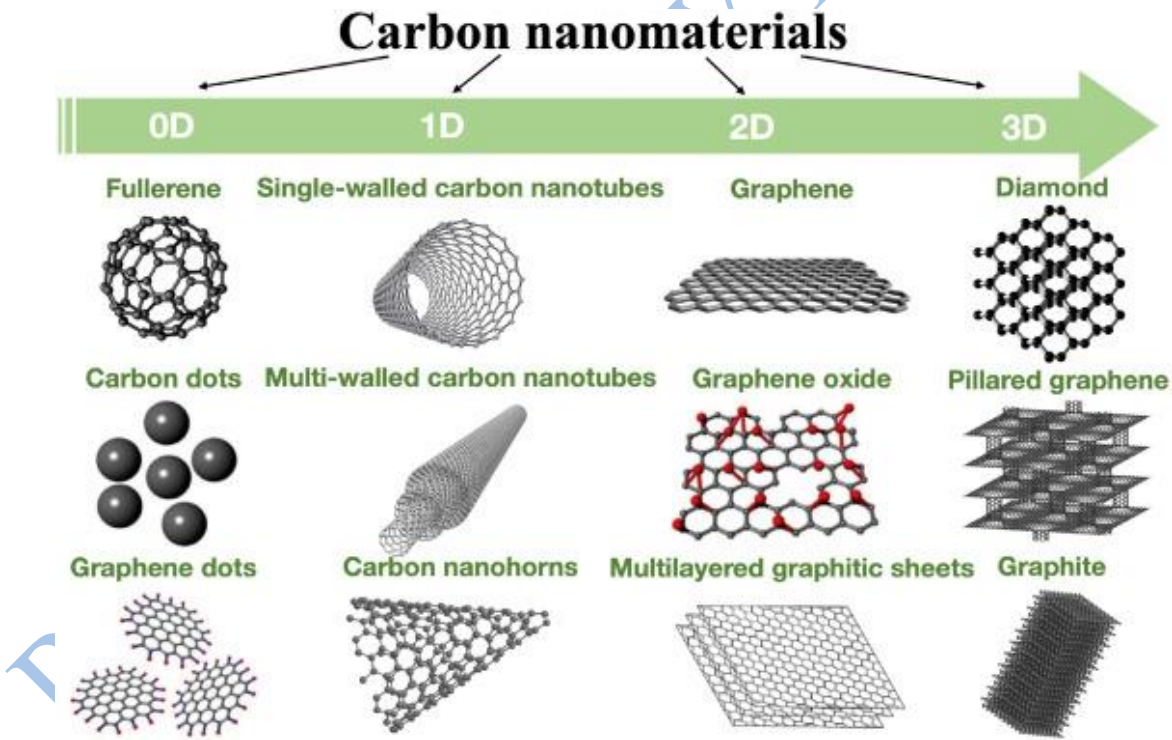
1. Excellent hardness.
2. Higher stiffness.
3. Improved fracture toughness.
4. They can exhibit elastic behaviour.
5. They have a low melting point.
6. Enhanced Electrical and Thermal conductivity.
7. They can exhibit photoconductivity.

Applications of Nanomaterials:

Field	Applications
Electronics	Sensors, Memory devices, Nano transistors
Medicine	Drug delivery systems, Cancer treatment, Diagnostic imaging
Energy	Solar cells, Fuel cells and Batteries
Environment	Water purification, Air filters, Pollution control
Textiles	Antibacterials Fabrics

Carbon nanotubes(CNTs):

A carbon nanotubes is a carbon allotrope (different structural forms) that resembles a tube of carbon atoms. Carbon nanotubes are extremely robust and difficult to break, but they are still light.



Properties:

- Very high tensile strength
- Excellent electrical and thermal conductivity

- High flexibility and chemical stability.

Applications:

- Energy storage devices
- Drug delivery and biosensors
- nanoelectronics

EXERCISES**MULTIPLE CHOICE QUESTIONS AND ANSWERS**

1. Which of the following is a common example of a natural biomaterial?
a) Polyethylene b) Titanium c) Collagen d) Stainless steel

Answer: c)

2. Biomaterials are primarily used for:
a) Power generation b) Structural support in buildings
c) Replacing biological tissues d) manufacturing of semiconductors

Answers:c)

3. Which of the following is a magnetic shape memory alloy?
a) Nitinol b) Copper c) Ni–Mn–Ga d) Titanium

Answer:c)

4. Which of the following is a natural piezoelectric material?
a) PZT b) Quartz c) PVDF d) Nitinol

Answer: b)

5. Nanomaterials typically have particle sizes in the range of:
a) 1–100 mm b) 1–100 cm c) 1–100 nm d) 1–100 μm

Answer: c)

1. Highlight any two properties required for a good solar cell.
2. Highlight the advantages of carbon Nano tubes in engineering applications.
3. What are shape memory alloys (SMAs)? Explain their unique property and mention two applications where SMAs are used.
4. Mention any two properties of Shape Memory Alloy.
5. Mention any two properties of Nano materials.
6. Mention two piezoelectric materials used in electronic devices.

7. Mention any two application of Bio materials in the human body.
8. Mention the advantages of using PVDF in piezoelectric applications.
9. Explain the functions of lithium-ion batteries and silicon-based solar cells. Mention one advantage of each.

RAMAIAH POLYTECHNIC

Week 5

Additive Manufacturing:

- **Introduction to Additive Manufacturing, Materials - metal, polymer, ceramic, and glass materials used in Additive Manufacturing, and its properties & limitations.**
- **Types of Additive manufacturing Technologies- Overview of FDM, SLA & SLS technologies.**
- **Step-by-step additive manufacturing process.**
- **Applications of Additive Manufacturing.**

ADDITIVE MANUFACTURING(AM):

Additive manufacturing is a process of making three dimensional solid objects adding material layer by layer from a digital CAD model. It is also called as 3D printing. By using 3D printing it is possible to produce objects of almost any shape and form.

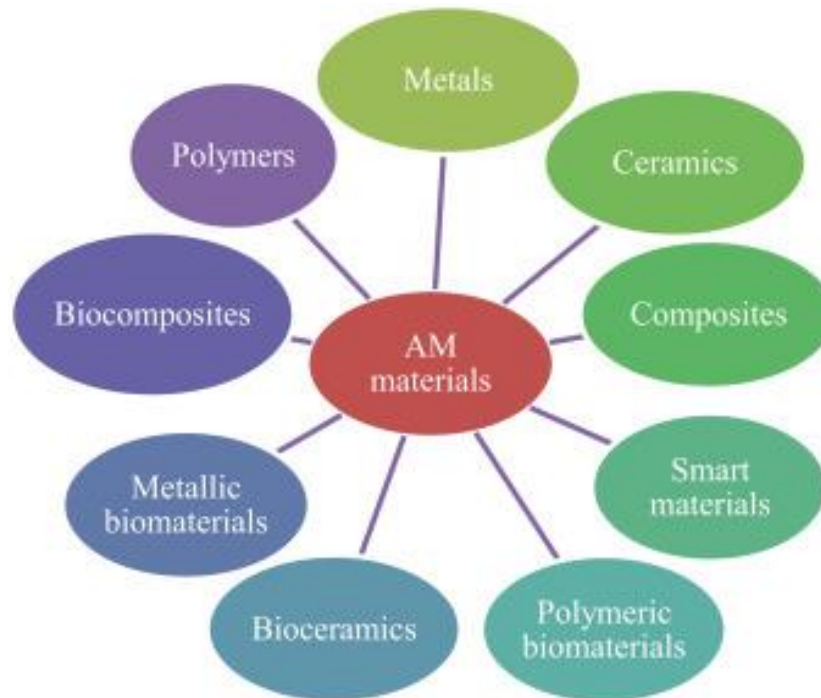
ADDITIVE MANUFACTURING MATERIALS:

Figure: Additive manufacturing materials

1. Metals:

Metals commonly used in additive manufacturing to produce parts such as Stainless Steel, Titanium, Aluminium, Cobalt based alloy, Nickel based alloy, Copper, Gold etc.

Properties:

Following are the properties of metals used in additive manufacturing:

1. High strength to weight ratio.
2. Good corrosion and wear resistance.
3. Good biocompatibility.
4. Excellent thermal & electric conductivity.

Limitations:

Following are the limitations of metals used in additive manufacturing:

1. High cost of metal powder.

2. Requires controlled atmosphere(inert gas or vacuum) during.
3. Post processing(heat treatment or machining) often required.
4. Rapid heating and cooling cycles can induce internal stresses and defects.

Applications:

Metals are widely used in industries such as aerospace (turbine blades), automotive, healthcare and engineering.

2. Polymer:

Polymer or plastic are versatile materials widely used in additive manufacturing due to their ease of processing and wide range of properties. Different types of plastic used are Acrylonitrile Butadiene Styrene(ABS), Polylactide(PLA), Polyethylene terephthalate(PET).

Properties:

1. Lightweight and low cost.
2. Flexible & Chemical stability.
3. Ability to integrate complex functionalities.
4. Good surface finish.
5. Customization.

Limitations:

1. Low strength and temperature resistance compared to metals.
2. High porosity in the polymer parts, affecting their strength and density.
3. Limited long term durability.
4. Not suitable for heavy load or structural parts.

Applications:

Prototypes, consumer goods, automotive and electronics.

3. Ceramics:

A ceramic is a material that is neither metallic nor organic. Different types of ceramics are alumina, zirconia, silicon carbide, silicon nitride & hydroxyapatite.

Properties of Ceramics:

1. High mechanical strength & hardness.
2. High resistance to chemical attack & corrosion.
3. Excellent thermal and chemical stability.
4. Light weight components.

5. Excellent electrical insulation.
6. Biocompatibility.

Limitation of ceramics:

1. Brittle in nature- poor tensile & impact strength.
2. Difficult to process & requires sintering after printing.
3. Achieving a good surface quality and high dimensional precision is also a challenge one.

Applications:

Biomedical implants, turbine components etc.

4. Glass materials:

Glass is a solid like and transparent material that is used in numerous applications in our daily life. Different types of glass materials are silica glass, borosilicate glass, soda-lime glass & bioactive glass.

Properties of Glass materials:

1. High optical transparency.
2. High hardness and compressive strength.
3. Excellent chemical resistance.
4. High temperature stability.
5. Biocompatible.

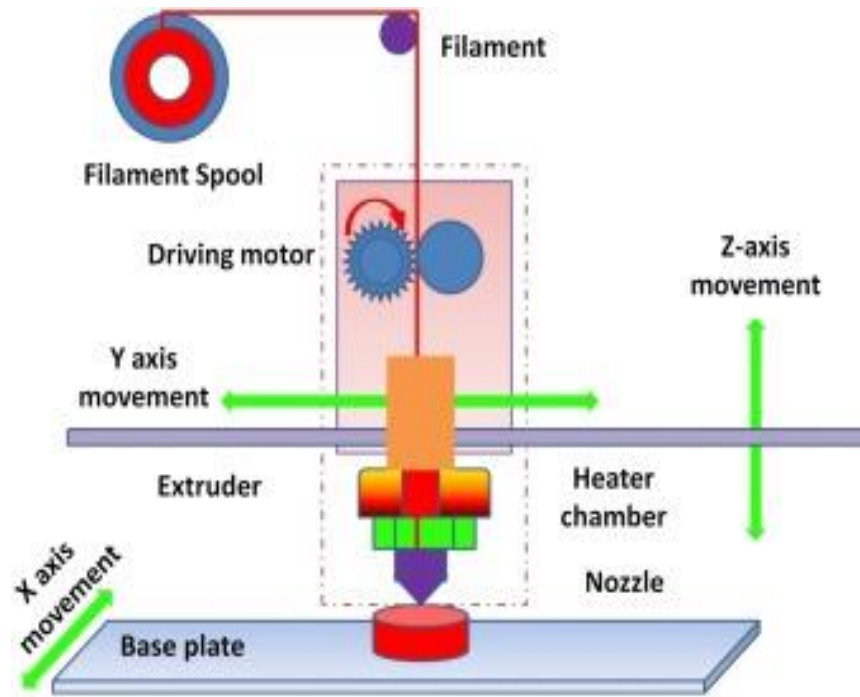
Limitation of Glass materials:

1. Very high melting point.
2. High machining costs.
3. Defects like porosity, cracks & micro-voids can easily form in the printed glass.
4. Lower mechanical strength.

TYPES OF ADDITIVE MANUFACTURING TECHNOLOGIES:

1. VAT Photopolymerization. Vat polymerization uses a vat of liquid photopolymer resin, out of which the model is constructed layer by layer.
2. Material Jetting.
3. Binder Jetting.
4. Material Extrusion.
5. Powder Bed Fusion.
6. Sheet Lamination.

7. Directed Energy Deposition.

Overview of FDM, SLA & SLS technologies:**1. FDM-Fused Deposition Modeling:****Figure: Fused Deposition Modeling**

- FDM is an additive manufacturing process in which a part is created layer by layer by melting and depositing thermoplastics material.
- In FDM nozzle moves in X & Y directions, while the platform moves in Z direction to create the complete 3D part.
- A plastic filament like PLS or ABS is fed from the coil reel into the printer.
- The driving motor pushes the filament in to the extruder, inside the extruder, the filament is heated and converted into molten paste in heating chamber. The molten material flows out through the nozzle tip.
- The nozzle moves in X & Y directions to draw the shape of each layer. The base plate moves in the Z direction, allowing the next layer to be deposited on top of the previous one.
- The molten material quickly cools and solidifies, forming the part. This continues until the entire 3D object is built layer by layer.

2. SLA- Stereolithography:

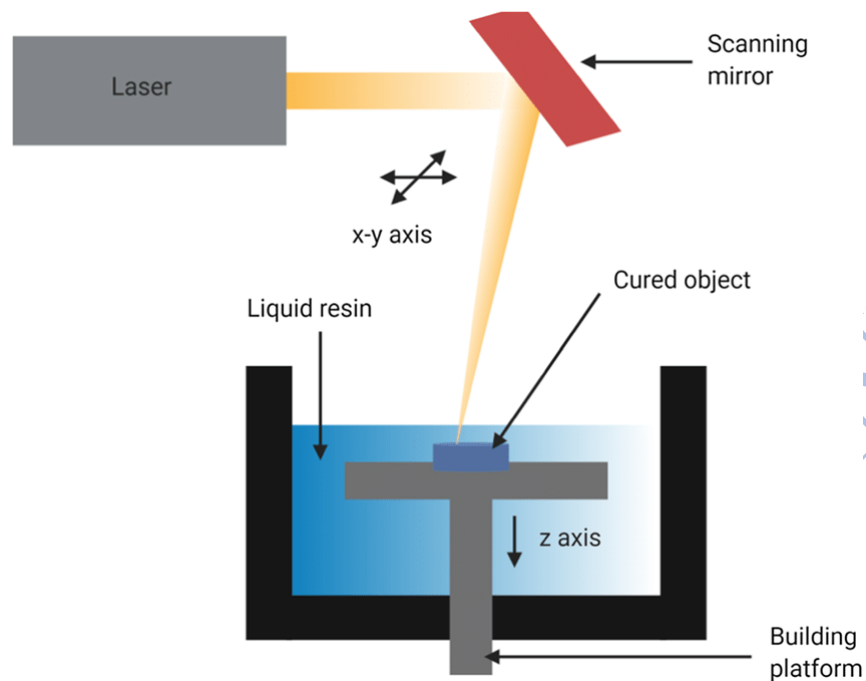


Figure: Stereolithography

- Stereolithography process is one of the rapid prototyping processes in which liquid polymer is used as material for layer by layer 3D part building with the help of laser for solidification of liquid resin.
- Stereolithography is also known as VAT Photopolymerisation.
- Stereolithography machine consist of the following components.
 1. Laser source- Laser source is used to supply a laser to solidify liquid resin to build the part in layer.
 2. Container- Container is filled with the liquid resin, when the laser falls on the liquid resin, the liquid resin gets solidified.
 3. Platform- Platform helps in the part building it moves an upward & downward direction.
- Required model is prepared by the any CAD model software & it is converted into STL file.
- When the laser source gets ON, the laser falls on the liquid resin above the platform. Hence due to the laser, the liquid resin layer above the platform gets solidified.
- Therefore platform moves downwards and a new solidified layer of liquids forms on the old solidified layer.

- The average thickness of one layer is between 0.025 to 0.5mm. After each layer of resin, it must be cured using ultraviolet light.
- This process of photo polymerization uses motor controlled mirrors to direct the UV across the resin surface, causing it to harden. These steps are repeated to add layers.

3. SLS-Selective Laser Sintering:

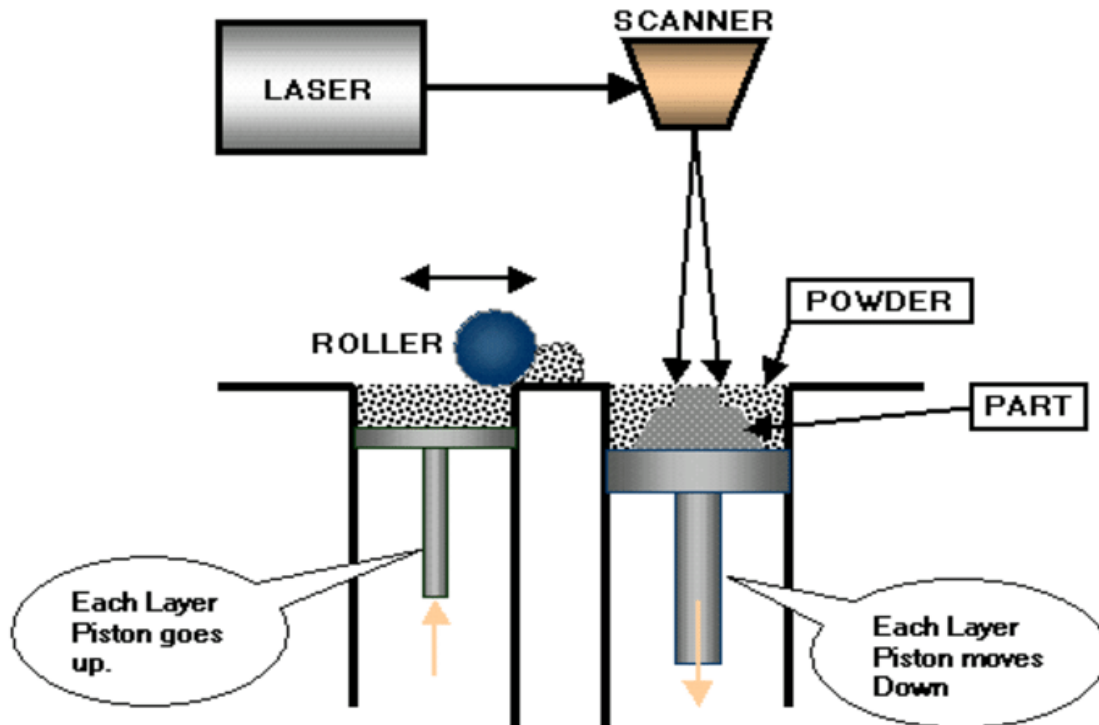
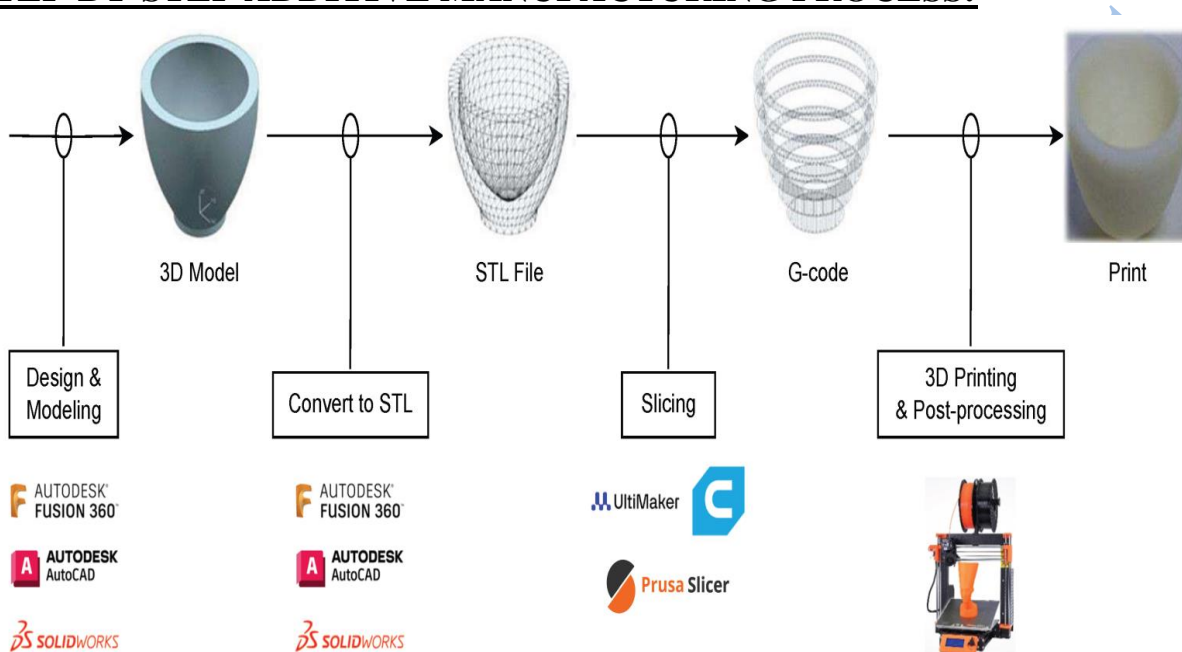


Figure: Selective Laser Sintering

- Selective laser sintering is a powder based additive manufacturing system.
- Selective laser sintering (SLS) uses a moving laser beam to sinter heat-fusible powders in areas corresponding to the CAD geometric model one layer at a time to build the solid part.
- After each layer is completed, a new layer of loose powders is spread across the surface using a counter rotating roller.
- The powders are preheated to just below their melting point to facilitate bonding and reduce distortion.
- Layer by layer, the powders are gradually bonded into a solid mass that forms the three dimensional part geometry.

- In areas not sintered by the laser beam, the powders remain loose so they can pour out of the completed part. Layer thickness is 0.075 to 0.50mm.
- After cooling, the completed part is removed from the build chamber and any excess powder in the build platform is cleaned off.

STEP-BY-STEP ADDITIVE MANUFACTURING PROCESS:



- 1. Design & Modeling:** A 3D model of the part is created using CAD software.
- 2. STL file conversion:** the CAD model is converted into STL file format, which is used by AM machines.
- 3. Slicing in Software:** The STL file is sliced into thin layers using slicing software and G-code is generated.
- 4. Machine setup:** The AM machine must be properly setup prior to the build process, such setting would relate to the build parameters like the materials constraints, energy source, layer thickness, timings etc.
- 5. Part Building:** The machine prints the object layer by layer until the part is complete.
- 6. Post-processing:** Once the part removed from the machine, parts may require an amount of additional cleaning up before they are ready for use. This may involves abrasive finishing, like polishing and sand papering or application of coatings.

7. Quality Control & Testing: After finishing the product, the final step is to inspect the printed products to ensure that the product should meet the required specification and standards.

8. Application: Parts may now be ready to be used.

ADVANTAGES OF ADDITIVE MANUFACTURING:

The following advantages are:

1. Rapid prototyping & design flexibility.
2. Low material waste.
3. Customization and small-batch production.
4. Reducing tooling requirements.
5. Ability to produce complex structures.

LIMITATION OF ADDITIVE MANUFACTURING:

The following are the limitations are:

1. Limited material options.
2. High equipment cost for industrial system.
3. Size constraints of printers.
4. Post-processing often required.

APPLICATIONS OF ADDITIVE MANUFACTURING:

The following are the applications are:

1. Aerospace industry- Lightweight parts.
2. Medical industry- For producing the surgical instrument, implants, dental crowns etc.
3. Construction-Small printed structures, for fabricating the building components.
4. Consumer goods industry- Footwear, eyewear & toys.
5. Automotive industry- production of engine components.
6. Production of products with complex geometries, internal structures.
7. For producing the moulds, patterns, tools & jigs etc.

REVIEW QUESTIONS

Multiple Choice Questions:

1. Additive manufacturing is also known as:
 - a) Subtractive manufacturing
 - b) Casting
 - c) 3D printing
 - d) welding

Answer: c)

2. In additive manufacturing objects are created:
- a) By removing material
 - b) By adding material layer by layer
 - c) By joining sheets
 - d) By molding

Answer: b)

3. Material is commonly used as filament in FDM technology?
- a) Titanium
 - b) ABS plastic
 - c) Epoxy resin
 - d) silicon carbide

Answer: b)

4. The abbreviation SLS in AM refers to
- a) Surface layer simulation
 - b) Selective laser sintering
 - c) Solid light structuring
 - d) Standard laser sheet

Answer: b)

5. What is full form of FDM in additive manufacturing?
- a) Functional design modeling
 - b) Final deposition method
 - c) Fused deposition modeling
 - d) Formed direct machining

Answer: c)

1. Define Additive Manufacturing.
2. Differentiate between Additive and Subtractive Manufacturing.
3. Mention any two common polymers used in AM.
4. Name two application of additive manufacturing in the medical field.
5. List the steps involved in Additive manufacturing process.
6. Highlight the different Additive manufacturing Technologies.
7. Mention any two limitations of Additive manufacturing.
8. Explain the step-by-step AM process for producing a polymer component.
9. Explain the principle of Fused Deposition Modeling.
10. Describe the materials used in Additive manufacturing with properties and limitations.
11. Explain the application of additive manufacturing in different industries.

Week-6

Casting process

- **Types of casting process**
- **Pattern and Mould making: Patterns – Materials, types, Pattern allowances**
- **Mould – Molding sand types, properties.**
- **Core making**
- **Defects in casting processes**
- **Modern Casting processes.**

CASTING PROCESS:

Casting is the process of producing metal parts by pouring molten metal into the mould cavity of the required shape and allowing the metal to solidify. The solidified metal piece is called as "casting".

Advantages

- Design flexibility
- Reduced costs
- Dimensional accuracy
- Versatility in production

Disadvantages

- Lot of molten metal is wasted in riser & gating
- Casting may require machining to remove rough surfaces

Types of Casting:

Casting processes are classified based on how the molten metal is introduced into the mould and the types of mould used.

1. Sand casting:

Molten metal poured into sand mould cavities to make parts, simple, low-cost method for large components like engine blocks.

2. Die casting:

Molten metal is forced under high pressure into a metal mould it produces accurate, smooth and high volume parts like automotive components.

3. Investment casting:

In investment casting a wax pattern is coated with refractory material, wax is melted out and metal is poured.

4. Shell moulding:

In shell moulding thin layers of sand and resin form a hardened mould around a heated pattern. It gives good surface finish and precision for gears and pulleys.

5. Centrifugal Casting:

The molten metal is poured into a rotating mould and centrifugal force spreads it used for cylindrical parts like pipes and bushings.

6. Continuous casting:

Molten metal is poured into a water cooled mould to produce continuous shapes like billets, rods to efficient for mass production.

PATTERN & MOULD MAKING:

Pattern making:

A pattern is a replica or model of the object to be cast. It is used to form the mould cavity into which molten metal is poured. The process of making pattern is called pattern making.

Types of pattern:

1. Single piece pattern(solid):

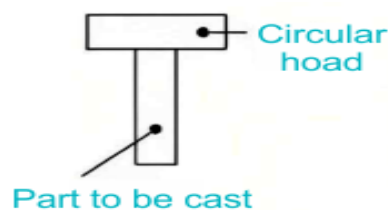


Figure: Single Piece Pattern

- These types of pattern are made of single solid piece without joints, partings or loose piece, it is called solid or one-piece pattern
- It is made exactly into the designed casting to be produced with some allowances.
- It is used for making a few large size simple castings.
- Removal of pattern from the sand is easy.

2. Split pattern(two piece pattern):

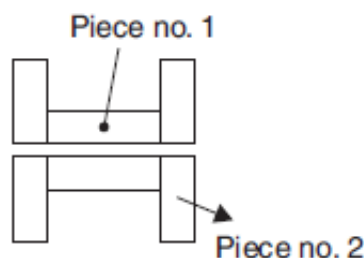


Figure: Two Piece Pattern

- The pattern is divided into two halves to facilitate easy removal from the sand mould.
- Its allows casting of moderately complex shapes without damaging the mould.
- Each half forms one part of the cope or drag mould.
- The line separating the two parts is called parting line.
- Widely used in sand casting for components like brackets or housing.

3. Match plate pattern:

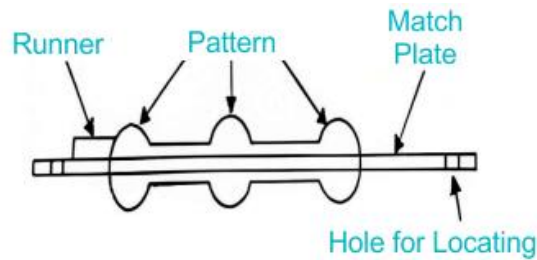


Figure: Match Plate Pattern

- The match plate pattern utilizes a metallic plate to separate the cope and drag sections on the reverse side of the plate. In addition, the gates and runners are held by the plate. These types of patterns require less effort yet manage to produce high-volume results.
- This type of pattern is used for small, accurate size and large number of castings.
- Piston rings of I.C engine are produced by this process.

4. Cope and Drag pattern:

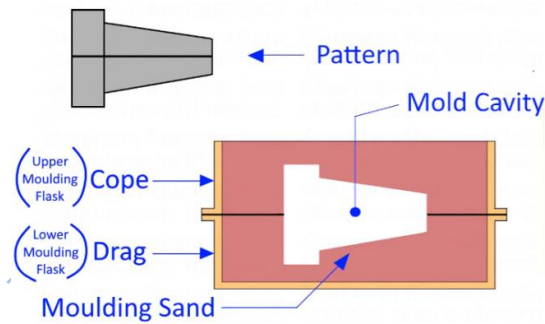


Figure: Cope and Drag pattern

- Cope and drag patterns are mounted on separate plates. It is design specifically for mould split into top and bottom halves.
- It is suitable for large and complex shapes with proper division of the mould castings.

5. Gated pattern:

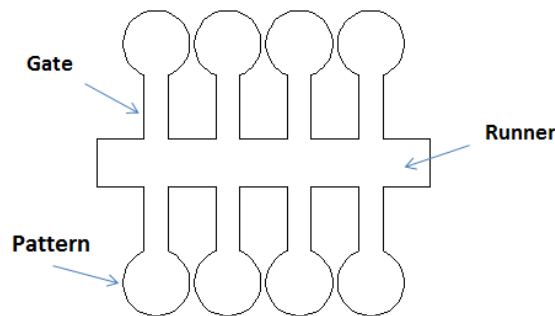


Figure: Gated pattern

- Pattern includes built in channels for metal flow.
- Ensure controlled and uniform filling of the mould cavity.
- It reduces turbulence and minimizes defects like cold shuts or Misruns.
- Used in sand casting and metal casting for uniform distribution of molten metal.

6. Sweep pattern:

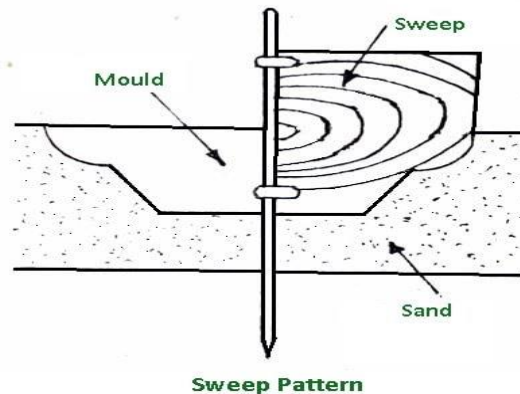


Figure: Sweep pattern

- Sweep patterns are mainly used to generate surfaces of revolution like cylinder, cone, and sphere in large castings.
- A half of the board is fitted in the centre spindle.
- The sand is approximately rammed around the mould cavity.
- The sweep is rotated to form the mould cavity in the sand.
- Sweep patterns are used for making large and circular castings in loam molding

7. Shell pattern:

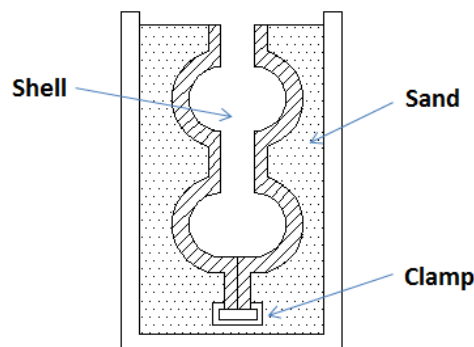


Figure: Shell pattern

- Shell pattern is a hollow pattern its outer shape is used for making the mould.
- The core is prepared using the inner surface of the pattern itself. It is also known as block pattern. These patterns are usually made of metal.

- These patterns are mainly used for making drainage fittings and pipe work like short bends.

8. Skeleton pattern:

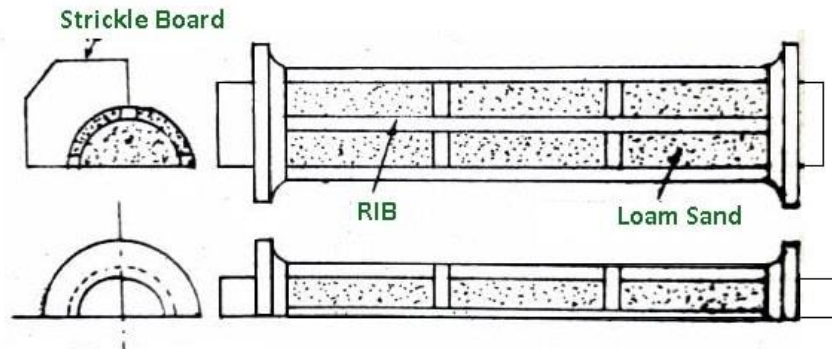


Figure: Skeleton pattern

- For larger casting of simple shape. If a solid pattern is made of wood.
- It is very expensive.
- A skeleton pattern is used instead of a full pattern.
- A skeleton pattern is a ribbed frame of a desired casting.
- A strickle board is used to remove excess sand and to give correct shape.
- Moulds for water pipes, turbine castings, pipe bends are made by skeleton pattern.

9. Loose piece pattern:

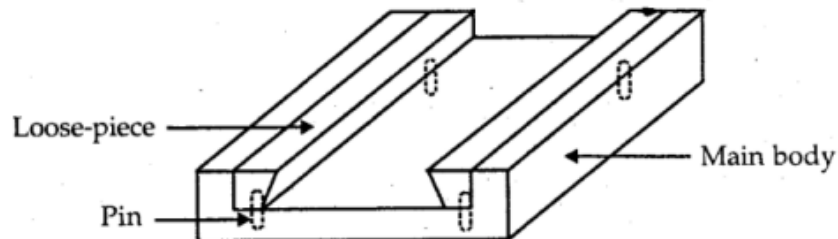
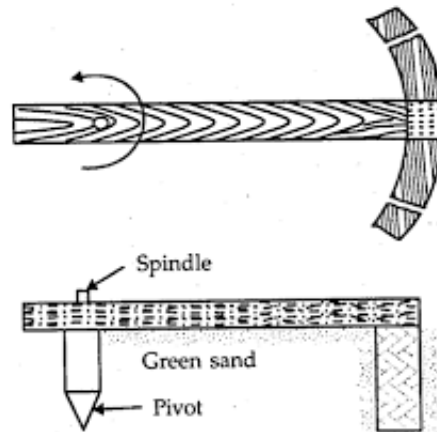


Figure: Loose piece pattern

- If a pattern is made from a single piece having projections or back parting plane is lie above or below, it is impossible to with draw it from the mould.
- In such cases, the pattern is built up into solid pattern and loose pieces.
- After making the mould, first the solid pattern is removed and then the loose pieces are removed without breaking mould. Is called loose piece pattern.
- Loose pieces are attached to the main body of the pattern by pins.

10. Segmental pattern:**Figure: Segmental pattern**

- A segmental pattern is a segment of whole pattern as shown in fig.
- This pattern is also called part pattern.
- The pattern is used for forming circular moulds.
- This pattern is used for casting circular components such as rings, wheel rims, gear blanks, etc.

PATTERN MATERIALS:

Wood: Easy to shape, inexpensive and commonly used for small to medium casting

Examples: White pine, Mahogany, Maple, Birch and Cherry, Teak, Shisham, Kail and Deodar.

Metal: Durable and strong, suitable for mass production

Examples: Cast iron, Brass, Aluminium, White metal and high temperature metals.

Plastic: light weight, easy to machine and reusable for small batch casting.

Examples: Plastics of epoxy resins, acrylates, phenol formaldehyde and polyester resins.

Quick setting compounds: Gypsum, resin-impregnated materials, waxes.

Pattern Allowance:

Pattern allowance are extra dimensions or modifications added to a pattern to compensate for changes that occur during casting such as shrinkage, machining, mould removal or distortion ensuring the final casting has correct size and shape.

OR

Pattern allowances are the extra dimensional compensation give to the pattern in order to attain the correct shape and size of the final solidified metal casting. Five types of allowances were taken into consideration for various reasons. They are

1. Shrinkage Allowance:

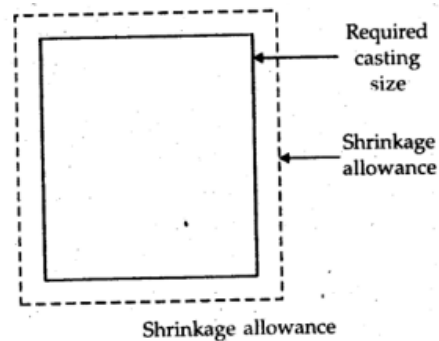


Figure: Shrinkage Allowance

- Metals contract as they cool and solidify, so the pattern must be slightly larger than the desired casting. The amount depends on metal type, mould materials and size of the casting.
- Shrinkage is more significant in larger castings and metals like steel compared to aluminum.
- This allowance ensures the final casting achieves the intended dimensions.

2. Machining Allowance:

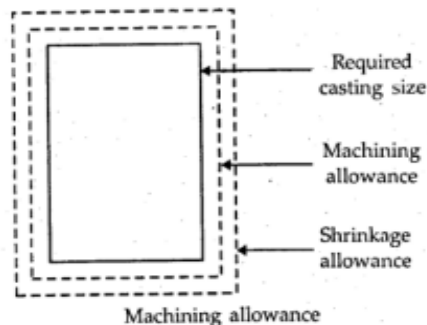


Figure: Machining Allowance

- Extra material is added to allow for machining or finishing operations like turning, milling or grinding.
- Ensure the final product meets precise dimensions and surface quality.
- The allowance depends on the casting process and surface finish required.

3. Draft Allowance:

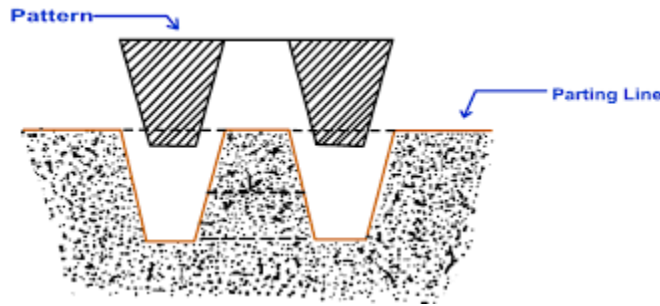


Figure: Draft Allowance

It will be difficult to remove the pattern from the mould cavity (without disturbing the mould) after ramming of sand. Hence the pattern (wooden or metal pattern) is slightly given $2^{\circ} - 3^{\circ}$ TAPER in the z - axis or vertical direction.

4. Rapping Allowance:

Before withdrawing the pattern it is rapped and thereby the size of the mould cavity increases. Actually by rapping, the external sections move outwards increasing the size and internal sections move inwards decreasing the size. This allowance is kept negative and hence the pattern is made slightly smaller in dimensions 05.1.0 mm.

5. Distortion Allowance:

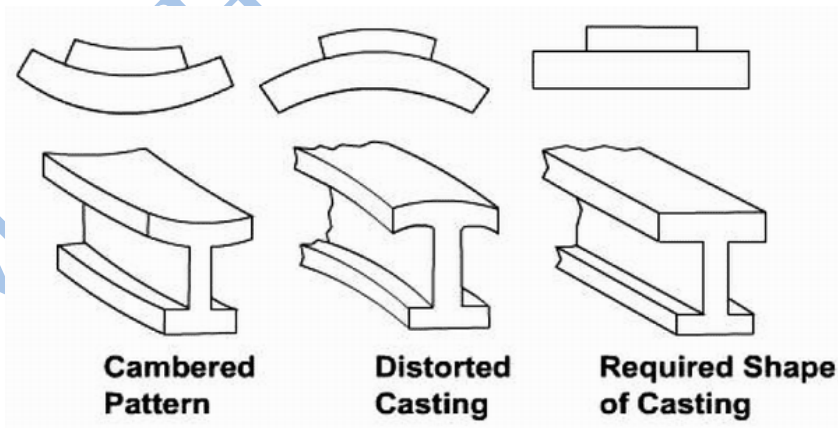


Figure: Distortion Allowance

Some material might tend to bend or distort from the actual size or dimensions. Hence the pattern is give counter balance degree or angle of recess so that the material will be in the required dimension when solidified in the mould cavity.

MOULD MAKING:

Moulding sand is a mixture of silica sand, clay, water and sometimes other additives used to make the mould the mould cavity into which molten metal is poured to form a casting.

1. Green Sand:

The green sand is the natural sand containing sufficient moisture in it. It is mixture of silica and 15 to 30% clay with about 8% water. Clay and water act as a bonding material to give strength. Molds made from this sand are known as green sand mould.

Properties:

- Moderate strength
- High plasticity
- Good permeability
- Reusability

2. Dry Sand:

When the moisture is removed from green sand, it is known as dry sand. The mould produced by dry sand has greater strength, rigidity and thermal stability. This sand is used for large and heavy castings.

Properties:

- Higher strength and rigidity
- Low moisture
- Better surface finish and dimensional accuracy

3. Loam Sand:

Loam sand is a mixture of 50 percent sand and 50 percent clay. Water is added in sufficient amount. It is used for large and heavy moulds e.g., turbine parts, hoppers etc

Properties:

- Excellent plasticity and cohesion
- Good heat resistance

4. Facing Sand:

Sand used for facing of the mould is known as facing sand. It consists of silica sand and clay, without addition of used sand. It is used directly next to the surface of the pattern. Facing sand comes in direct contact with the hot molten metal; therefore it must have high refractoriness and strength. It has very fine grains.

Properties:

- Smooth surface finish and resists metal erosion
- High strength

5. Backing or Floor Sand:

The backing sand is old and repeatedly used sand of black colour. It is used to back up the facing sand and to fill the whole volume of the box. This sand is accumulated on the floor after casting and hence also known as floor sand.

Properties:

- Provides bulk and supports
- Low strength
- Economical

6. Parting Sand:

Pure silica sand employed on the faces of the pattern before moulding is known as parting sand. When the pattern is withdrawn from the mould, the moulding sand sticks to it. To avoid sticking, parting sand is sprinkled on the pattern before it is embedded in the moulding sand. Parting sand is also sprinkled on the contact surface of cope, drag and cheek.

Properties:

- Prevent sticking
- Free flow and non-cohesive
- Does not absorb moisture

7. Core Sand:

Sand used for making cores is known as core sand. It is silica sand mixed with core oil (linseed oil, resin, mineral oil) and other binding materials (dextrine, corn flour, sodium silicate). It has remarkable compressive strength.

Properties:

- High strength
- Good collapsibility
- Smooth surface finish

Properties of Moulding Sand:

1. The sand should have adequate strength in its green, dry and hot states.

2. The sand should have high permeability.
3. The sand should have high thermal stability.
4. It should have good refractoriness.
5. It should have good flowability.
6. It should have uniform sand texture.
7. It should be cheap and reusable.
8. It should have good thermal conductivity.
9. It should have low collapsibility
10. It should be easy to prepare and control.
11. It should have good adhesiveness.

CORE MAKING:

- A core is a sand shape inserted into the mould cavity to form hollow portions or internal cavities in a casting.
- The process of preparing these cores using suitable core sand, binders and baking methods is called core making.

Purpose of Core making:

- To create internal cavities, holes and passages in castings.
- To reduce the weight of the casting.
- To allow the production of complex and intricate shapes.

Steps in core making:

- Core sand preparation: Core sand is mixed with binders and additives to achieve proper strength and plasticity.
- Core moulding: The prepared sand is packed into a core box and compacted.
- Core Baking: The formed core is baked in an oven to harden and gain strength.
- Finishing: the backed core is trimmed, coated and inspected for surface finish and accuracy.

DEFECTS IN CASTING PROCESSES:

The following are the casting defects:

1. **Mould shift:** It results in a mismatching of top and the bottom parts of casting, usually at the parting line.
Remedy: Use of proper alignment pins and secures the mould tightly.
2. **Swell:** It is an enlargement of mould cavity by molten metal pressure resulting in localized enlargement of the casting.
Remedy: Use strong moulding sand and Control pouring temperature.
3. **Blow hole:** It is smooth depression on the outer surface of casting work piece. Blow holes are caused in a casting by the generation of gas in the mould cavity.
Remedy: Use properly dried sand, improve permeability and control moisture content.
4. **Pin holes:** Pin holes are numerous holes of small diameter, usually less than 2mm, visible on the surface of the casting. They are caused by the absorption of hydrogen.
Remedy: Ensure proper degassing and avoid overheating of the metal.
5. **Shrinkage:** It is a crack or void in the casting on the surface of the work piece which results from unequal contraction during solidification.
Remedy: Provide proper risers and maintain correct pouring temperature
6. **Porosity:** Porosity is due to gas formation and gas absorption by the metal while it is poured
Remedy: Ensure proper venting, degassing and riser design.

MODERN CASTING PROCESSES:

1. **Centrifugal Casting:**

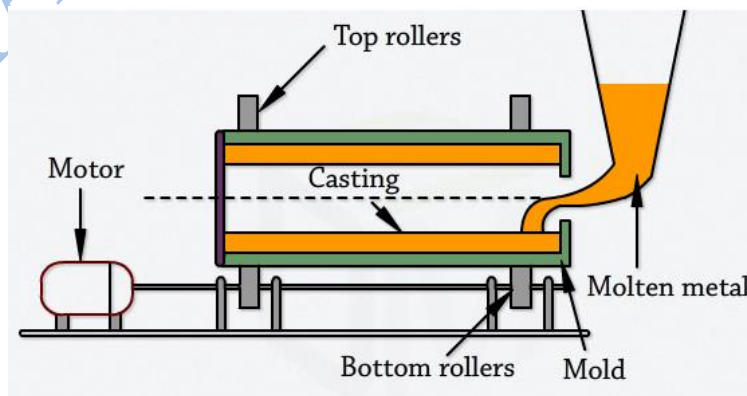


Figure: Centrifugal Casting

Centrifugal casting is a widely used metal casting process for producing strong and high-quality cylindrical components. In this process, molten metal is poured into a rotating mould and due to centrifugal force, the metal is pushed towards the mould walls. This results in a dense and uniform structure with fewer defects. The centrifugal casting process improves the internal quality of the casting by reducing porosity and removing impurities. During rotation, heavier and pure metal moves outward, while lighter impurities remain on the inner surface, which can be removed later by machining.

The working principle of centrifugal casting ensures controlled solidification from the outer surface towards the inner side. This leads to better grain structure and higher mechanical strength. Because of this, the process is mainly used for manufacturing pipes, tubes, cylinder liners and similar components.

Centrifugal casting can be used with different materials such as cast iron, steel, aluminium and alloys depending on the application

2. Investment Casting:

Investment casting produces very high surface quality and dimensional accuracy. Investment casting is commonly used for precision equipment such as surgical equipment, for complex geometries and for precious metals. This process is commonly used by artisans to produce highly detailed artwork. The first step is to produce a pattern or replica of the finished mould. Wax is most commonly used to form the pattern, although plastic is also used. Patterns are typically mass-produced by injecting liquid or wax into a permanent die.

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. Which of the following is a casting defect?
a) Draft Allowance b) Shrinkage cavity c) Permeability d) Loam sand

Answer: b)

2. Which of the following is NOT a metal forming process?
a) Forging b) Rolling c) Casting d) Extrusion

Answer: c)

3. Casting is mainly suitable for producing:
a) Very thin sheets b) Only small parts

- c) Hollow shapes d) Welded assemblies

Answer: c)

4. The first steps in the casting process is :

- a) Mould making b) Machining c) Heat treatment d) Defect removal

Answer: a)

5. Investment casting is also known as:

- a) Die casting b) shell moulding c) Lost wax process d) Vacuum casting

Answer: c)

1. Mention important properties of moulding sand.
2. Explain pattern allowances.
3. Explain any two types of pattern with neat sketch.
4. Explain Shrinkages allowance in a pattern.
5. List types of moulding sand with their properties.
6. Explain the steps in the casting process.
7. Discuss types and properties of moulding sand.
8. Identify common defects in casting and suggest strategies to prevent them.
9. A casting company faces dimensional inaccuracies in products. How would proper selection of pattern material and allowances solve this issue? Justify with examples.

WEEK-07

Metal Forming Processes

- **General classification of metal forming processes**
- **Bulk deformation processes**
- **Forging – Introduction, classification, Applications**
- **Rolling – Introduction, Classification, Applications.**
- **Extrusion – Introduction, Classification, Applications**
- **Wire & Bar Drawing – Introduction, Applications**

METAL FORMING PROCESSES:

Metal forming process is a process where the work piece is reshaped into desired objects by the principle of plastic deformation without adding or removing material. In this process the mass of the work piece remains unchanged. Example: Extrusion, Rolling

Classification of Metal Working Processes**1. General classification**

- Rolling
- Forging
- Extrusion
- Wire Drawing
- Sheet Metal Forming

2. Based on Temperature of Working

- Hot Working
- Cold Working
- Warm Working

3. Based on the applied stress

- Direct Compressive Stress
- Indirect Compressive Stress
- Tensile Stress
- Bending Stress
- Shear Stress

BULK DEFORMATION PROCESSES:

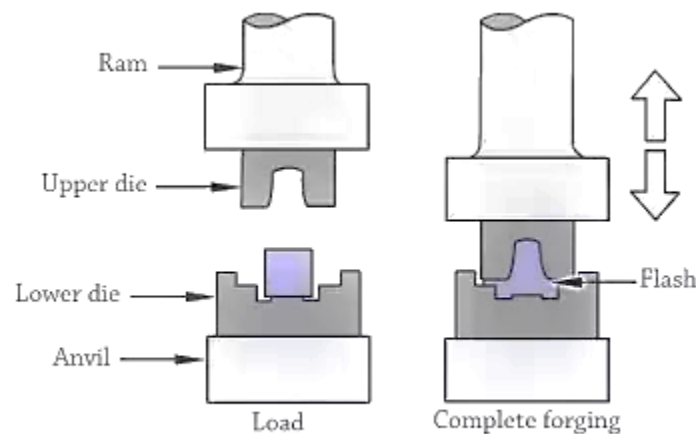
Bulk deformation processes are metal forming operations that entire volume of metal is plastically deformation using compressive, tensile or shear forces. The metal volume remains constant, but the shape changes drastically.

Types:

- Forging
- Rolling
- Extrusion
- Wire & Bar drawing

FORGING:**Definition:**

- Forging is a metal working process in which useful shape is obtained in solid state by hammering or pressing metal.
- It is one of the oldest metalworking arts with its origin about some thousands of years back. Some examples of shapes obtained by forging process: Crane hook, connecting rod of IC engine, spanner, and gear blanks. etc.

Working Principle of forging:**Press forging****Figure: Forging**

Forging is a widely used manufacturing method in which metal is shaped by applying strong compressive forces through hammering, pressing or rolling. To properly understand what is forging process, it is important to know that the metal is usually heated before deformation so that it becomes softer and easier to shape without cracking.

There are various steps known as the forging process steps involved to obtain a final forged part that is discussed briefly below.

Heating

The production of pre-forged metal begins with metal blocks known as "ingots." They are solid materials used as raw materials. They are heated to a state very close to molten, in which the metal has retained its shape but can be easily reshaped through the application of force.

These ingots can be found in a wide variety of sizes and shapes depending on the component or part that will be manufactured.

Preforming:

After the ingot has been heated, the edges are blocked with a press or hammer to form a piece that can be pressed between the closed dies. Edging is performed to increase the working cross-section of the forged part, and blocking is carried out to refine the shape for the 'finish forging' process.

Finish Forging

The preformed metals are compressed into an impression made by two dies to complete the shape. It is in this step that the metal begins to take on the overall form of the finished product. Only one press is optimum for simple parts, but complex parts may need multiple strokes at different values of pressure or even different dies to achieve the desired end design

Cooling

Forging operators can improve the grain flow within the metal by deforming it along with cooling the metal to increase its strength. The "flash" is the term used for extra metal that flows outside of the dies. Rapid cooling and hardening make the metal stronger than the flash by forcefully filling any cavities in the metal.

Finishing

To achieve greater dimensional accuracy in a forged part, after it has been subjected to the pressing process, the part must first be trimmed followed by other surface treatment operations. Surface treatment is done to improve the appearance of the finished forged product which increases its corrosion resistance. These are usually done in the finishing process as a final stage of forging.

Classification of forging:**1. Based on temperature**

- Hot forging
- Cold forging
- Warm forging

2. Based on method of force application

- Open die forging
- Closed die forging
- Press forging
- Drop forging

- Upset forging
- Roll forging

Application of forging:

Common applications are as follows

1. **Automotive industry:** Crankshaft, Connecting rods, Gear, Axels and Steering arms.
2. **Railway:** Wheels axles, Couplers and shafts.
3. **Aerospace Industry:** Turbine shafts, landing gear components and engine parts.
4. **Construction:** Hand tools, hardware.
5. **Energy Sector:** Power plant turbine parts Generator shafts.

ROLLING:

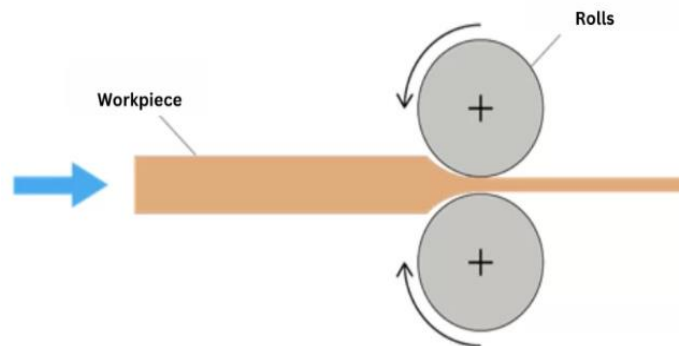


Figure: Rolling

Rolling process involves passing metal through rotating rolls to compress and elongate it. This technique of plastic deformation is known for its efficiency in producing with uniform cross-sections at high speeds. Products range from metal sheets and rods to longer components and even square or round tubular materials.

These rolled parts find extensive use in construction and manufacturing industries. Notably, metal sheets produced through rolling are commonly applied as beverage cans, batteries, and automotive parts.

Rolling processes can be categorized into three types based on the temperature during processing: hot rolling, cold rolling, and warm rolling.

1. Hot rolling:

Hot rolling involves heating metal to make it malleable before processing. For steel, this means working at temperatures between 900°C and 1,200°C, where the metal becomes red-hot and passes through rolls.

2. Cold rolling:

Cold rolling is a metalworking process performed at room temperature. Unlike hot rolling, the material is not heated before processing. However, as the material deforms, it generates heat, causing its temperature to rise. For steel, cold rolling is typically done below 600°C.

3. Warm Rolling

Warm rolling sits between hot and cold rolling processes. For steel, it is typically conducted at temperatures ranging from 600°C to 900°C. This method mitigates some disadvantages of both hot and cold rolling and is commonly used in the production of aluminum foil.

Classification of Rolling:

1. Based on Temperature

- Hot rolling
- Cold rolling
- Warm rolling

2. Based on Roll arrangement

- Two-High rolling mill
- Three-High rolling mill
- Four-High rolling mill
- Cluster mill
- Planetary mill
- Tandem mill

3. Based on Product

- Flat rolling
- Shape rolling
- Ring rolling
- Thread rolling
- Plate rolling

Application of Rolling:

1. **Steel Industry:** Sheets, plates, foils.
2. **Automobile Industry:** Body panels, Chassis components, Bumpers.
3. **Aerospace Industry:** aluminium sheets foils.

4. Electrical Industry: Transformer sheets, laminations.

EXTRUSION:

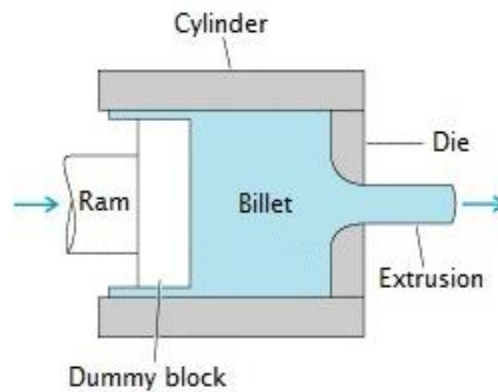


Figure: Extrusion

Extrusion is a metal forming process in which a heated billet is formed through a die opening to produce long components of fixed cross sectional shape such as rods, tubes and channels.

A billet is placed in a container with a die opening at one end. A ram or plunger applies compressive force to push the metal forward. The metal flows plastically and takes shape of the die opening.

The extruded product emerges as a continuous length with uniform cross section. The product is then cut to required lengths and cooled.

Classification of Extrusion:

1. Based on direction of metal flow

- Direct extrusion
- Indirect extrusion
- Hydrostatic extrusion

2. Based on temperature

- Hot extrusion
- Cold extrusion
- Warm extrusion

3. Based on special techniques

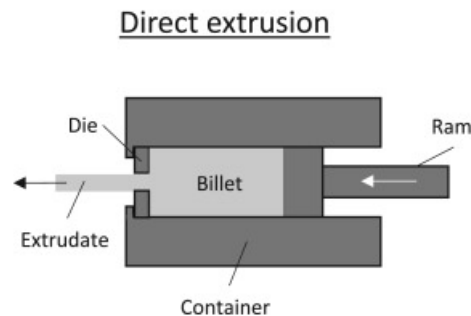
- Impact extrusion
- Continuous extrusion
- Lateral extrusion

Application of Extrusion:

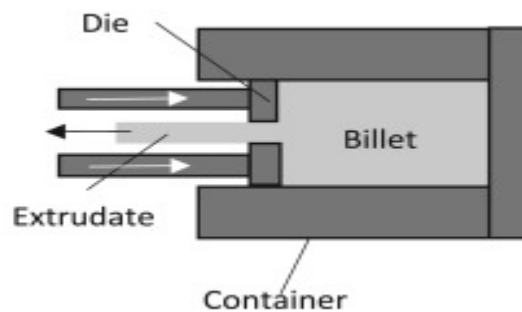
1. **Automobile Industry:** Aluminium frames, rods, tubes.
2. **Aerospace Industry:** Structural parts, heat exchangers.
3. **Construction:** Door frames, pipes.
4. **Electrical Industry:** Copper wires, Cable coverings.
5. **Consumer/Household:** Tubes, Curtain rods, furniture components.

Types of Extrusion Process:

There are various kinds of extrusion processes, depending on the material. The most popular technique is hot extrusion because cold extrusion is typically only used on soft metals and metal deformation resistance is low at high temperatures.

Direct Extrusion:**Figure: Direct Extrusion**

The most common type of extrusion is known as direct extrusion, also known as forward extrusion. Its work process entails packing the billet into a receptacle with thick walls. The billet is forced through the press using a ram or screw. In between the billet and ram, there is a dummy block, which is reusable and is used to keep them separated.

Indirect Extrusion:**Figure: Indirect Extrusion**

The method of indirect extrusion, also known as backward extrusion, involves moving the billet and container while keeping the die stationary. A "stem," which must be longer than the length of the container, is used to maintain the die stationary. The stem's column strength determines the ultimate and maximal extrusion length

Wire and Bar drawing:

Wire and Bar drawing is a metal forming process in which a metal rod or wire is pulled through a conical die opening to reduce its diameter and increase its length.

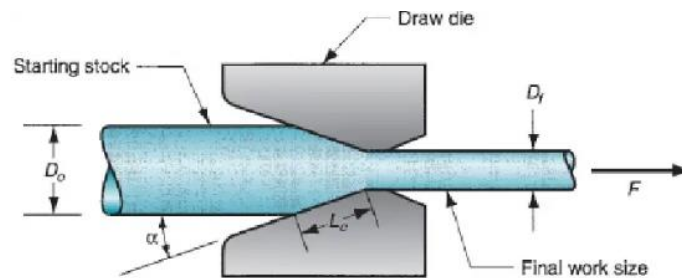


Figure: Wire & Bar drawing

- A metal rod or wire is pointed at one end to allow entry into the die. The pointed end is gripped by drawing tongs or drum.
- The wire is pulled through a tapered die opening. Tensile force causes the metal to plastically deform, reducing diameter and elongating the length.
- Lubrication is used to reduce friction and improve surface finish.

Application of wire and bar drawing:

- Automobile Industry: Control cables, spokes, springs
- Electrical Industry: Copper and aluminium wires
- Construction Industry: Steel rods, reinforcing wires
- Aerospace Industry: High strength alloy wires

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. Which of the following metal forming processes is best suitable for making the wires?
 - a) Forging
 - b) Extrusion
 - c) Drawing
 - d) Rolling

Answers: c)

2. Which of the following articles cannot be made from rolling?
 - a) Rails
 - b) Helmets
 - c) Bars
 - d) Plates

Answers: b)

3. Forging is generally performed at:

- a) Room Temperature
- b) High temperature
- c) Cryogenic temperature
- d) SUB-zero temperature

Answers: b)

4. The hot working in metal forming is done:

- a) Above Recrystallization
- b) Below Recrystallization
- c) At melting point
- d) at freezing point

Answers: a)

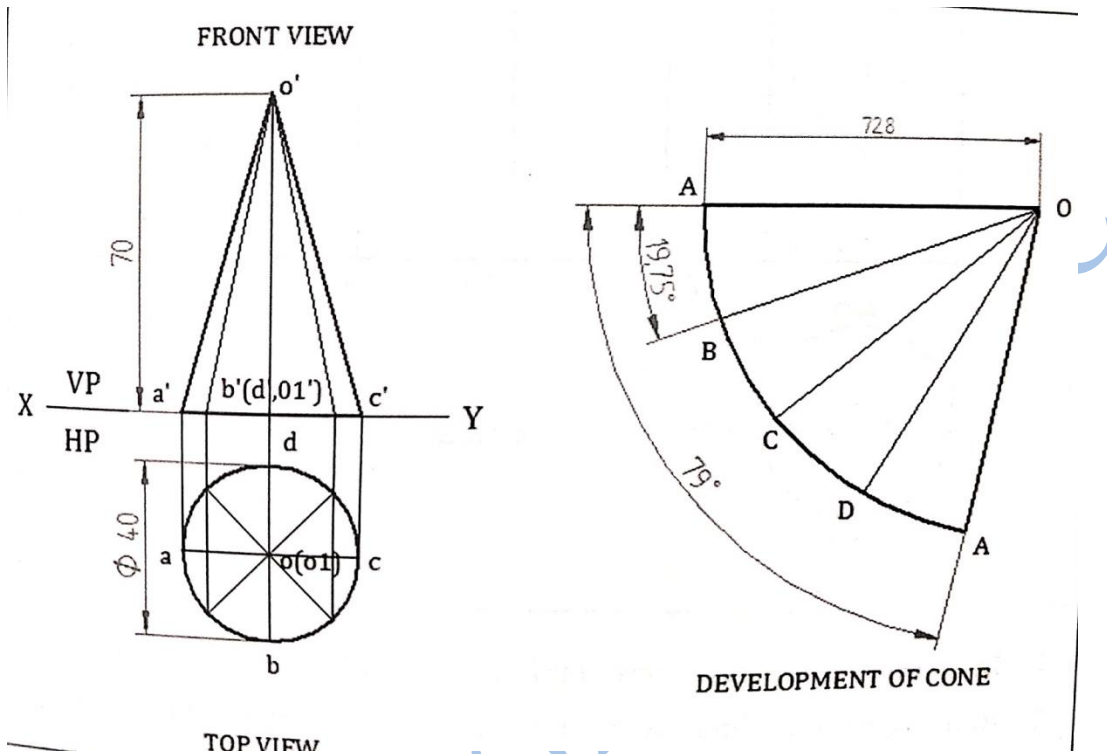
1. Define Extrusion metal forming process.
2. Application of rolling process of metal forming.
3. Define rolling in metal forming.
4. Application or extrusion process in manufacturing.
5. Application of wire drawing metal forming process.
6. Application of forging process.
7. What is bar drawing?
8. Explain the basic principle of forging process.
9. Compare direct and indirect extrusion process.
10. Mention the safety precautions to be followed while performing forging activity.

Week-8

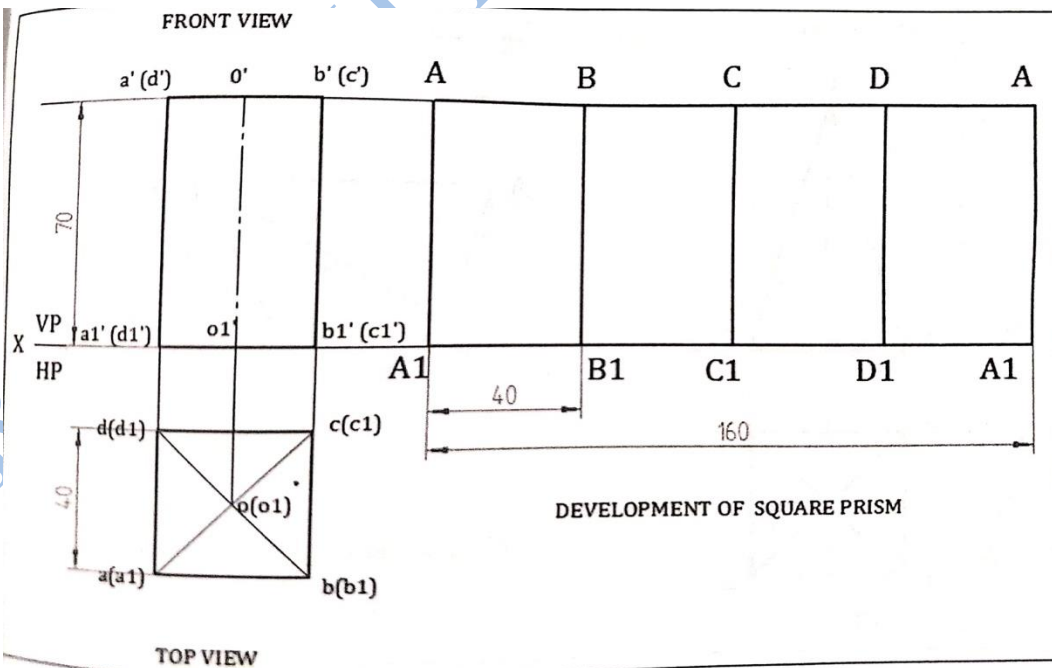
Development and Preparation of surfaces

- **Development of Cone, Cylinder, Prism and Pyramid.**
- **Development of Frustum of cone.**
- **Prepare the development drawing of a cylindrical box.**
- **Prepare the development drawing of a Funnel**

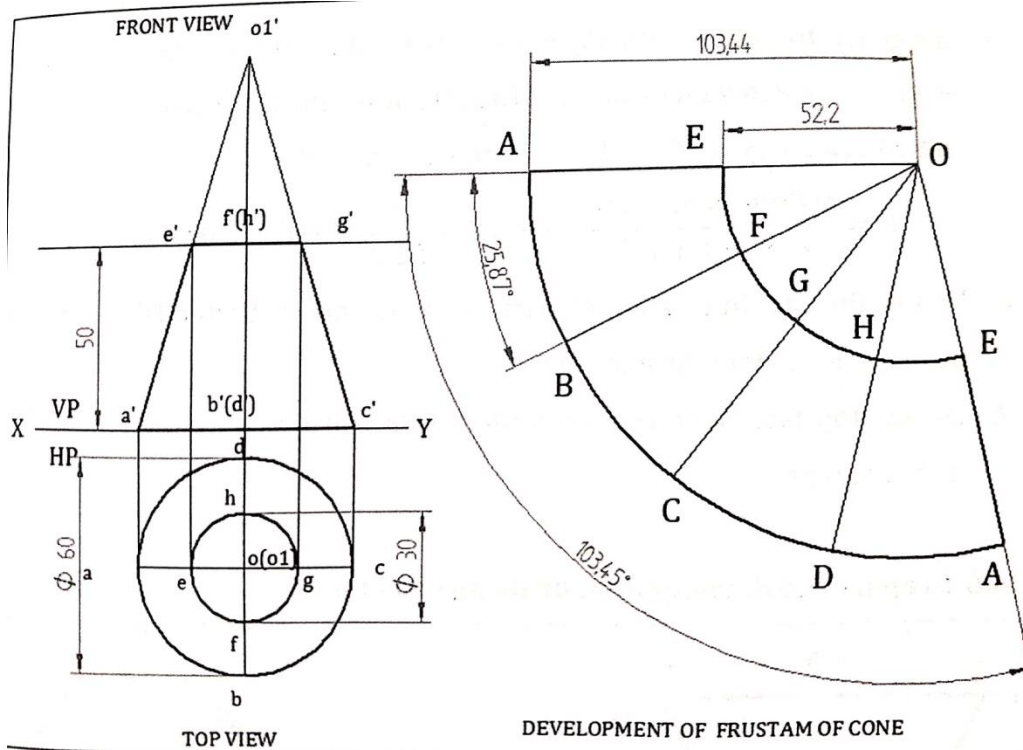
1. A cone of 40 mm diameter and axis 70 mm rests with its circular base on HP. Develop the lateral surface area of the cone.



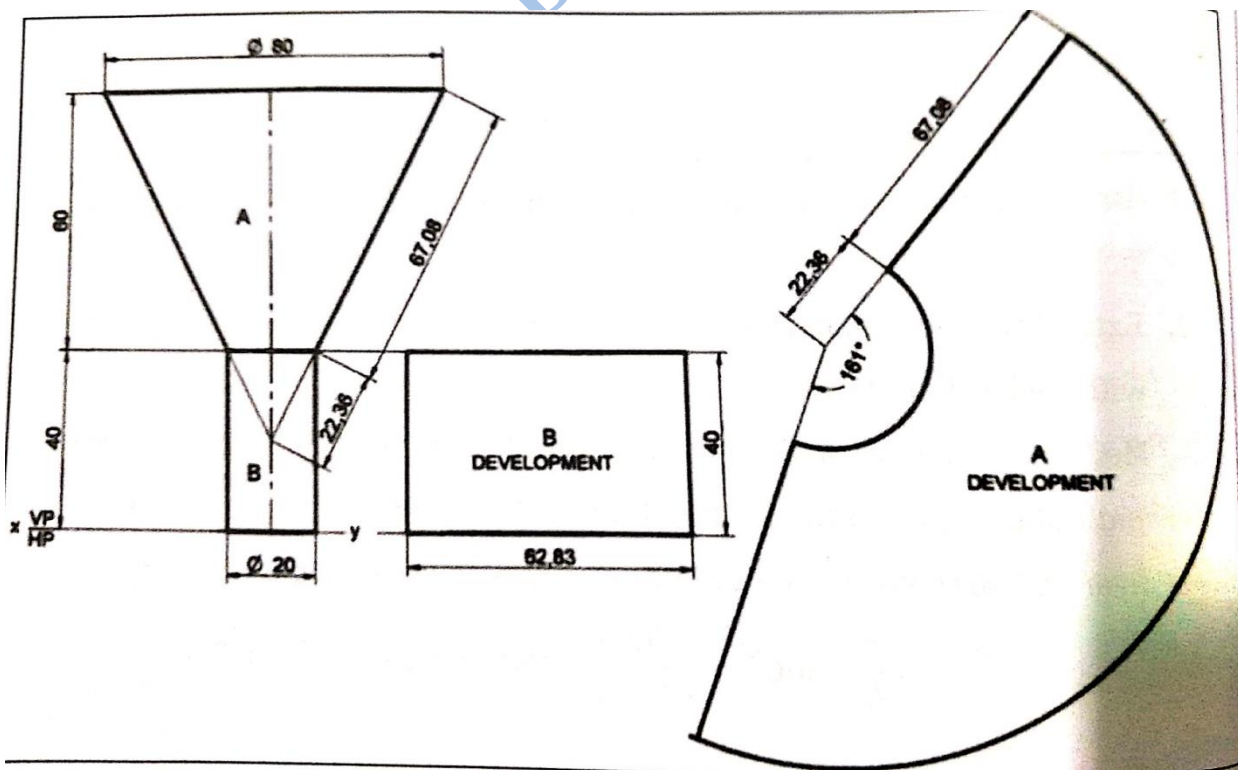
2. Develop the lateral surface area of a square prism of base edge 40 mm and axis height 70 mm resting with its base on HP.



3. A frustum of cone has its base diameter 60 mm, top face diameter 30 mm and height 50 mm. Develop the frustum of cone.



4. Prepare the develop drawing of a funnel



Week 9

Sheet metal work

- Introduction
- IS Standard gages and

Specifications of sheet metal

- Sheet metal operations- Shearing, Bending, Forming.
- Applications of sheet metal work

1. DEFINE SHEET METAL AND LIST ADVANTAGES

Sheet metal work refers to the process of forming and shaping thin metal sheets (usually less than 6mm) into desired shapes and sizes by applying mechanical force such as shearing, bending without removing material.

ADVANTAGES OF SHEET METAL:

- Low cost for mass production.
- High material utilization (Minimal wastage).
- Good dimensional accuracy.
- Easy to rivet, assemble.

2. LIST APPLICATIONS OF SHEET METAL WORKING PROCESS.

1. Automobile body parts such as car doors, hoods and panels.
2. Aircraft bodies and components.
3. Household appliances like refrigerators, washing machines and ovens.
4. Metal containers and cans.
5. Roofing sheets and building panels.
6. Electrical enclosures and cabinets.

3. EXPLAIN INDIAN STANDARD (IS) GAGES AND SPECIFICATIONS OF SHEET METAL.

IS means **Indian Standard**, Standard gauges are numbers used to indicate the thickness of sheet metal. Instead of measuring thickness directly in millimeters, a gauge number system is commonly used in industries.

- In the gauge system, higher gauge number indicates thinner sheet metal.
- Lower gauge number indicates thicker sheet metal.
- Different metals such as steel, aluminium and copper may have different gauge standards.
- Standard gauge tables are used to convert gauge numbers into actual thickness values (mm or inches).

Standard Sheet Metal Gauges (for Steel)

Gauge Number	Thickness (mm)	Common use
10 SWG	3.25 mm	Heavy structured work
12 SWG	2.64 mm	Machine covers, Guards
14 SWG	2.03 mm	Automotive body panels
16 SWG	1.63 mm	Enclosures, Ducting
18 SWG	1.22 mm	Electrical cabinets
20 SWG	0.91 mm	Kitchen utensils
22 SWG	0.76 mm	Light covers, Trays
24 SWG	0.56 mm	Small appliances
26 SWG	0.46 mm	Decorative and thin covers
28 SWG	0.38 mm	Light gauge components
30 SWG	0.31 mm	Fine sheet metal work

4. EXPLAIN SHEET METAL OPERATIONS

Sheet metal operations are performed using press tools, dies, punches. They are classified mainly into cutting and forming operations.

1. Shearing operation:

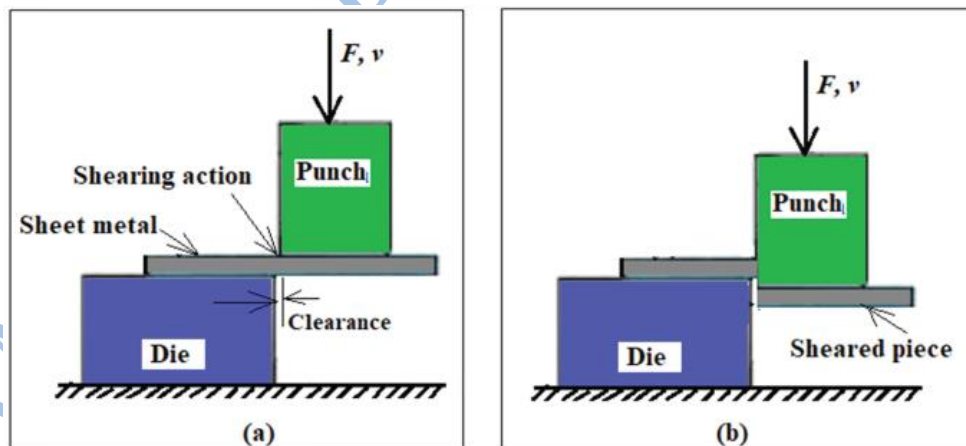


Figure: Shearing Operation

- Shearing is cutting operation in which a sheet is separated into two parts by applying shear force using punch and die.
- The sheet metal is placed between the punch and die.
- The punch moves downward by applying compressive and shear force on the sheet.

- As the shear stress exceeds the materials shear strength, fracture occurs and the sheet separates along the cutting line.
- Examples: Parting, Blanking, Punching, Notching, Slitting and Trimming.

2. Bending Operation:

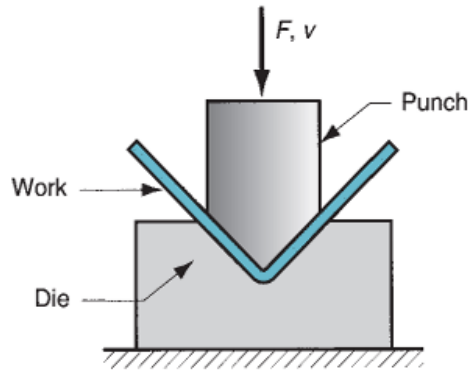


Figure: Bending operation

- Bending is a deformation process in which a sheet metal is stressed beyond its elastic limit to obtain a desired angle.
- Bending changes the shape of the sheet without changing its thickness. The material is plastically deformed around a straight axis.
- The sheet metal is placed on a die block. The punch moves downwards, applying compressive and bending force on the sheet.
- The outer surface of the bend undergoes tension, while the inner surface undergoes compression.
- It produces V-Shapes, U-Shapes, Channels and curved parts by using a punch and die.

3. Forming Operation:

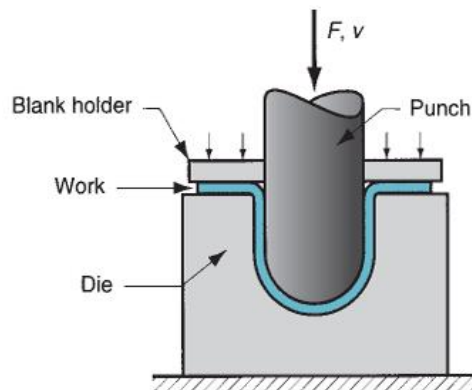


Figure: Forming operation

- Forming is a plastic deformation process where the sheet metal is to obtain a required three dimensional shape without removing materials. It changes the shape of the sheet but not its thickness or volume.
- In forming process metal sheet is placed over a die cavity.
- A punch applies force, causing the sheet to flow plastically into the die shape.
- The metal compresses depending on the operation type. The final component takes the shape of the punch or dies cavity after removal.

5. LIST THE SAFETY PRECAUTIONS TO BE FOLLOWED IN SHEET METAL SHOP.

The following are the safety precautions to be followed in sheet metal shop.

- Wear protective equipment such as gloves, goggles, and safety shoes.
- Handle sharp edges carefully to avoid cuts and injuries.
- Use proper tools and equipment for sheet metal operations.
- Keep the work area clean and free from scrap pieces.
- Do not place hands near moving parts of machines such as presses and shears.
- Ensure machines are properly guarded before operation.
- Switch off machines when not in use or during adjustments.
- Follow proper operating procedures and instructions while working.

6. WHICH SHEET METAL OPERATIONS AND GAUGES ARE SUITABLE FOR CAR BODY PANELS? JUSTIFY YOUR CHOICE.

Sheet Metal Operations and Gauges Suitable for Car Body Panels

Suitable Sheet Metal Operations:

1. **Shearing** – Used to cut sheet metal into the required size before forming.
2. **Bending** – Used to form edges and angles in body panels.
3. **Deep Drawing (Forming)** – Used to produce curved and complex shapes required for car body parts such as doors, hoods and fenders.

Suitable Gauges:

- Generally **18 to 22 gauge sheet metal** is used for car body panels.
- This corresponds to a thickness of approximately **0.7 mm to 1.2 mm**.

Justification:

- These gauges are **thin and lightweight**, which helps in **reducing the overall weight of the vehicle**.
- They are **easy to form into complex shapes** required for automobile body design.
- They also provide **adequate strength and good surface finish** for car body panels.

7. SUGGEST SUITABLE MATERIAL, GAUGE, AND SHEET METAL OPERATIONS FOR AN AIRCRAFT BODY PART. EXPLAIN WHY.

Suitable Material: Aluminium alloy sheets are commonly used for aircraft body parts. Aluminium is lightweight, corrosion-resistant, and has good strength. These properties help improve fuel efficiency and durability.

Suitable Gauge: Thin sheet metal such as 18 to 22 gauges is generally used. Thin sheets reduce the overall weight of the aircraft. At the same time, they still provide sufficient strength for the structure.

Suitable Sheet Metal Operations: Operations like blanking, bending, stretching, and riveting are used. Blanking helps cut the required shape of the sheet. Bending and stretching form curved aircraft surfaces, while riveting is used to join panels securely.

Justification:

Aircraft require high strength with minimum weight. Aluminium sheets with thin gauges provide this balance. The selected sheet metal operations help produce smooth aerodynamic shapes and strong joints.

8. WHAT IS BAR DRAWING?

Bar drawing is a metal forming process in which a metal bar or rod is pulled through a die to reduce its cross-sectional area and increase its length. It is mainly used to improve surface finish and dimensional accuracy of bars. This process is commonly used for producing long components with uniform cross-sections.

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. Sheet metal is defined as
A) Thick metal block B) Thin flat metal sheet C) Liquid metal D) Powder metal

Answer: b)

2. Sheet metal is generally produced by
A) Casting B) Rolling C) Welding D) Drilling
Answer: b)
3. The thickness of sheet metal is usually specified by
A) Length B) Gauge number C) Weight D) Density
Answer: b)
4. In sheet metal gauges, a **higher gauge number** indicates
A) Thicker sheet B) Thinner sheet C) Hard sheet D) Soft sheet
Answer: b)
5. A **lower gauge number** indicates
A) Thicker sheet B) Thinner sheet C) Lighter sheet D) Smaller sheet
Answer: a)
6. IS standard gauges are specified by
A) ASTM B) BIS C) ISO D) DIN
Answer: b)
7. IS stands for
A) International Steel B) Indian Standard C) Industrial Sheet D) Internal System
Answer: b)
8. Sheet metal specifications include
A) Thickness B) Material type C) Size D) All of the above
Answer: d)
9. Sheet metal thickness is usually measured in
A) mm or gauge number B) liter C) kg D) watt
Answer: a)
10. Which of the following is used to specify sheet metal size?
A) Length and width B) Density C) Temperature D) Speed
Answer: a)
11. Shearing is a process of
A) Cutting sheet metal B) Heating sheet metal
C) Rolling sheet metal D) Casting metal
Answer: a)

12. Shearing occurs by applying

- A) Tensile force B) Shear force C) Magnetic force D) Centrifugal force

Answer: b)

13. Which of the following is a shearing operation?

- A) Blanking B) Punching C) Notching D) All of the above

Answer: d)

14. Punching operation produces

- A) Solid part B) Hole in sheet metal C) Thick sheet D) Smooth surface

Answer: b)

15. In blanking operation

- A) Hole is useful product B) Cut piece is useful product
C) Both are waste D) Nothing is produced

Answer: b)

16. Bending is a process of

- A) Cutting sheet metal B) Changing straight sheet into angular shape
C) Melting metal D) Joining metal

Answer: b)

17. During bending, the outside surface of the sheet experiences

- A) Compression B) Tension C) No stress D) Heat

Answer: b)

18. During bending, the inside surface experiences

- A) Compression B) Tension C) No stress D) Friction

Answer: a)

19. The neutral axis in bending

- A) Expands B) Compresses C) Retains original length D) Breaks

Answer: c)

20. Forming operation changes

- A) Shape of sheet metal B) Weight of metal
C) Color of metal D) Density of metal

Answer: a)

21. Deep drawing is used to produce

- A) Cup-shaped parts B) Sheets C) Rods D) Bars

Answer: a)

22. Forming operations generally

- A) Remove material B) Do not remove material
C) Melt material D) Cut material

Answer: b)

23. Sheet metal is widely used in

- A) Automobile body parts B) Aircraft body parts
C) Household appliances D) All of the above

Answer: d)

24. Car body panels are commonly made by

- A) Casting B) Sheet metal forming C) Welding only D) Drilling

Answer: b)

25. Sheet metal work is used in manufacturing

- A) Metal containers B) Roofing sheets C) Electrical cabinets D) All of the above

Answer: d)

1. Define sheet metal work.

2. Mention two advantages of sheet metal work.

3. Define shearing in sheet metal with two examples.

4. Mention any two forming operations.

5. Give two applications of sheet metal working process.

6. Which sheet metal operations and gauges are suitable for car body panels? Justify your choice.

7. List the safety precautions to be followed in sheet metal shop.

8. Suggest suitable material, gauge and sheet metal operations for an aircraft body part.

Explain why.

9. Explain any two sheet metal operations.

Week 10

Press Work

- **Overview**
- **Types of Presses**
- **Press Components**
- **Press Operations**

1. WHAT IS PRESS WORK

Press work is the process of changing the shape of sheet metal by applying pressure with a press tool which consists of punch and dies are used to cut, punch and bend.

2. LIST TYPES OF PRESSES

Types of Presses

1. According to the Action:

- Single action press
- Double action press
- Triple action press

2. Based on design:

- C-frame press
- H-frame press
- Straight side press
- Inclined frame press

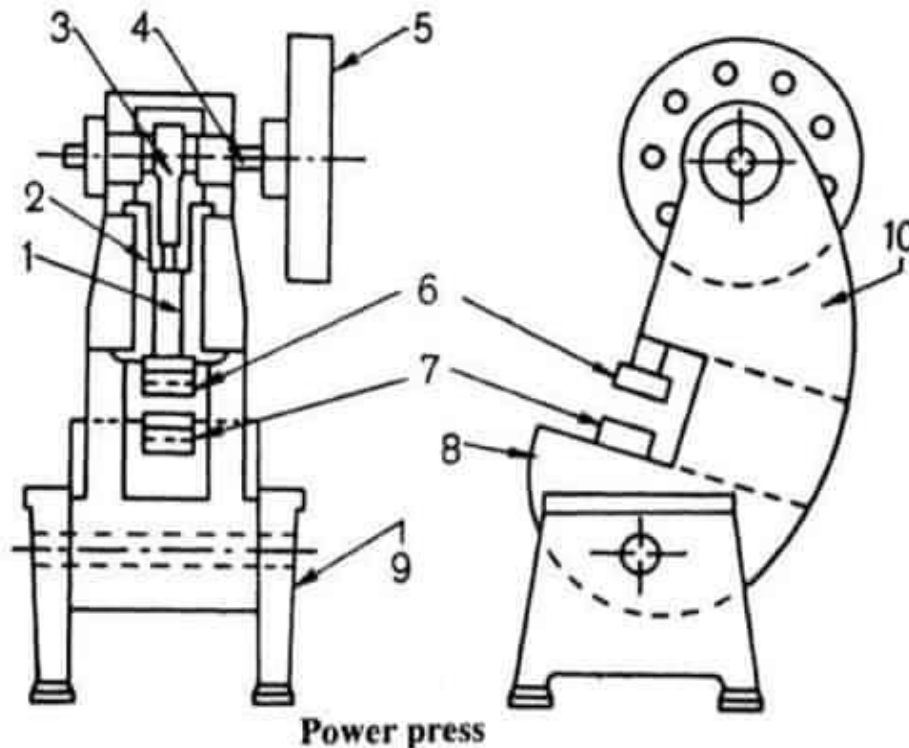
3. According to the Source of Power:

- Mechanical press
- Hydraulic press
- Pneumatic press

4. According to the mechanism of power press:

- Crank shaft press
- Eccentric press
- Cam press
- Toggle press
- Knuckle joint press
- Rack and pinion press
- Gear press

3. EXPLAIN COMPONENTS OF PRESS MACHINE



1. Ram 2. Ram guide, 3. Pitman, 4. Crankshaft, 5. Flywheel, 6. Punch, 7. Die, 8. Bolster plate, 9. Base, 10. Frame.

Figure: Press machine

- **Frame:** The main structure of the press that supports all other components such as the bed, ram and drive mechanism. It must be strong and rigid to absorb vibrations resist deformation during operation. The common types of frame are C-frame,(open type) and H-frame(Closed type).
- **Ram (Slide):** Ram is the reciprocating component that moves up and down to apply pressure on the work piece through the punch or die. The ram stroke length can often be adjusted depending on the operation.
- **Base or Bed:** The lower stationary part of the press, usually a thick, flat steel plate that supports the die set. It is bolted to the frame and designed to withstand high impact forces during pressing.
- **Flywheel:** Flywheel is rotating energy Storage device that maintains consistent motion by storing energy from the motor and releasing it during the pressing stroke.

- Drive Mechanism: Components like the crankshaft, eccentric, or pitman that converts rotational energy from the motor into linear, reciprocating motion of the ram.

4. EXPLAIN PRESS WORK OPERATION

The following press work operations are

- **Blanking:**

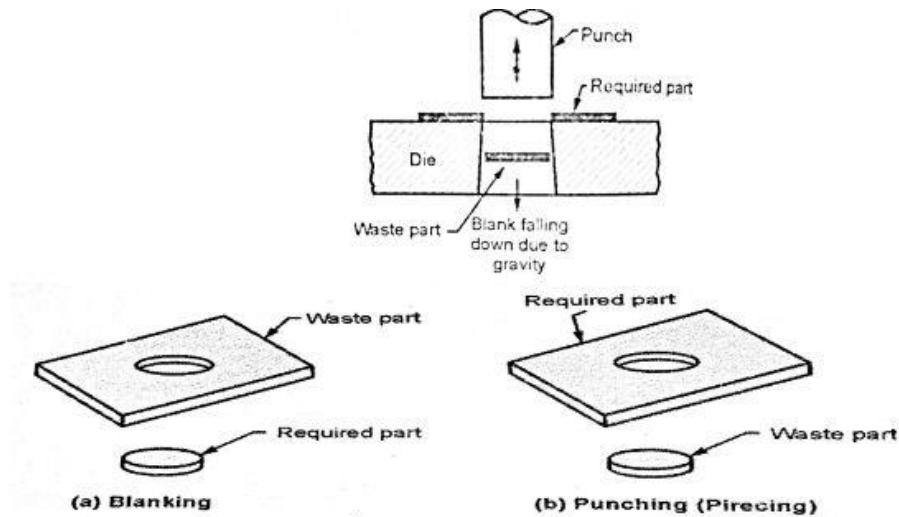


Figure: Blanking & Punching operation

The process of cutting a flat piece from sheet metal so the cut-out part is the required product.

Example: Washers, coins etc

- **Punching:**

The process of cutting holes or shapes in sheet metal so the cut-out portion is waste.

Example: Filters, panels etc

- **Notching:**

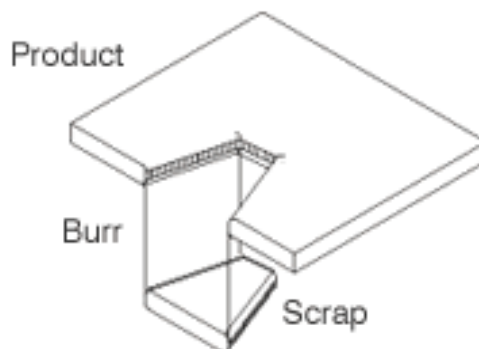


Figure: Notching

Notching is a removing a small section from the edge or corner of a sheet.

Example: Corner cuts, joining edge etc

- **Trimming:**

Trimming is a process to removing excess material from the edges of a formed part.

Example: Automobiles panels, forged parts etc

- **V-Bending:**

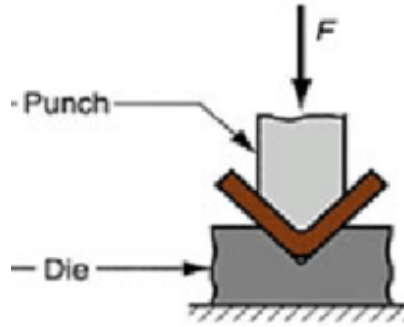


Figure: V-Bending operation

V-bending is a process which bends in a v-shaped die using a punch it is most common bending method.

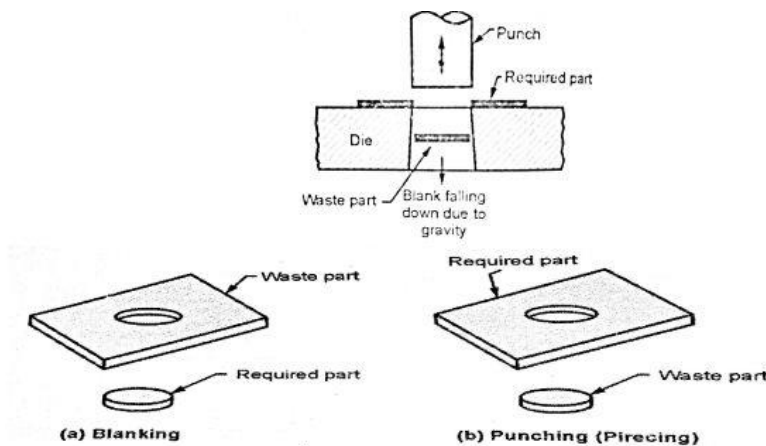
Examples: Brackets, frames, channels etc

5. WHICH PRESS OPERATION IS BEST FOR MASS-PRODUCING WASHERS? EXPLAIN THE PROCESS WITH REASONS.

Best Press Operation: The most suitable press operation for mass-producing washers is blanking and punching.

Explanation of the Process: (refer previous answer)

- **Blanking:**



The process of cutting a flat piece from sheet metal so the cut-out part is the required product.

Example: Washers, coins etc

- **Punching:**

The process of cutting holes or shapes in sheet metal so the cut-off portion is waste.

Example: Filters, panels etc

First, blanking is carried out to cut the circular outer shape of the washer from the sheet metal. In this operation, the blank (washer disc) is the useful part and the remaining sheet becomes scrap. Next, punching is performed to create the hole at the center of the washer. The punch forces the metal through the die to produce the required hole.

Reason:

These operations are suitable because they are fast, accurate, and economical for large-scale.

6. WRITE PURPOSES OF DIE IN PRESS TOOL SET.

1. The die is used to give the required shape and size to the sheet metal component.
2. It supports the sheet metal during press operations.
3. It works together with the punch to perform operations such as cutting, bending, and forming.
4. It ensures accuracy and uniformity in the produced parts.
5. It guides the punch during the pressing operation.
6. It helps in mass production of identical components.

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. Press work is mainly used for
a) Casting b) Sheet metal forming c) Welding d) Grinding
Answer: a)
2. Press work is suitable for
a) Mass production b) Job production only
c) Repair work d) Small testing work
Answer: a)
3. Which press uses flywheel energy?
a) Hydraulic press b) Mechanical press c) Pneumatic press d) Screw press
Answer: b)
4. Hydraulic press works using
a) Air pressure b) Water pressure

13. Die is used for

- a) Shaping sheet metal b) Supporting frame
c) Cooling metal d) Measuring thickness

Answer: a)

14. Bolster plate is used for

- a) Supporting die assembly b) Increasing speed
c) Cutting metal d) Heating workpiece

Answer: a)

15. Clutch and brake are used to

- a) Control ram motion b) Cut sheet metal
c) Support press frame d) Store energy

Answer: a)

16. Pneumatic press is suitable for

- a) Heavy work b) Light work c) Casting d) Welding

Answer: b)

17. Coining operation is used for

- a) Surface detailing b) Welding c) Cutting metal d) Heat treatment

Answer: a)

18. Embossing is used to

- a) Create raised or depressed patterns b) Cut sheet metal
c) Drill holes d) Join metals

Answer: a)

19. Automotive body parts are made by

- a) Press work b) Casting only c) Forging only d) Machining only

Answer: a)

20. Washer is manufactured by

- a) Blanking and punching b) Welding c) Turning d) Drilling only

Answer: a)

21. Press frame is used for

- a) Supporting press structure b) Cutting sheet

Week 11

Cutting tools and Abrasives:

- **Cutting tool – classification of Cutting tools, Characteristics and selection of tool materials.**
- **Nomenclature of single point cutting tools, milling tools**
- **Surface finishing processes – Grinding, Polishing, Coating.**
- **Abrasives used in grinding wheels and its designations**

1. DEFINE CUTTING TOOLS, AND CLASSIFY CUTTING TOOLS

Cutting tools are used for cutting the parts with the required size and shape by removing metal in the form of small chips.

Classification of Cutting Tools

- Single point cutting tools
- Multi-point cutting tools

1. Single Point Cutting Tools

Single point cutting tools have a wedge-like action and find wide application on lathes and slotting machines.

2. Multi-Point Cutting Tools

Multi-point cutting tools have two or more single point cutting edges arranged together as a unit.

2. LIST CHARACTERISTICS OF CUTTING TOOLS.

- **Hot hardness:** The tool material must remain harder than the work material at high operating temperatures.
- **Wear resistance:** The tool material should resist the larger wear during the machining operations.
- **Toughness:** The material must have sufficient toughness to withstand shocks and vibrations and to prevent breakage.
- **Mechanical and thermal shock resistance:** The material must have high mechanical and thermal shock resistance.
- **Ability to retain properties at high temperature:** The material should have the ability to retain all its properties at higher temperatures during operations.
- **Cost and ease of fabrication:** Cost and easiness of fabrication should be within the limits.
- **Low friction:** The material should offer a low coefficient of friction between the chip and tool during operation.

3. EXPLAIN ABOUT SELECTION OF TOOL MATERIALS.

- **Carbon steels** – Used for tools operating at **low cutting speeds** and **hand operated tools**.
- **Medium alloy steels** –
 - **O-tool steels:** Used for **punching dies**
 - **A-tool steels:** Used for **thread rolling dies, coining dies and gauges**.

- **High speed steels (HSS)** – Used for **drilling, tapping, milling, hobbing and turning tools**. They have **high wear resistance and good cutting ability**.
 - **Stellites** – Used for **cutting non-metal materials like rubber and plastics**.
 - **Cemented carbides** – Used for machining **brittle materials** such as **cast iron, bronze and non-ferrous metals**.
 - **Ceramics** – Used for **high-speed machining and finishing of hardened steel and cast iron**.
 - **Diamonds** – Used for cutting **very hard materials like glass, plastics and ceramics**.
 - **Abrasives** – Used for **grinding hard materials** in the form of **wheels, stones, papers and cloths**.
4. **EXPLAIN THE NOMENCLATURE OF A SINGLE POINT CUTTING TOOL AND ITS SIGNIFICANCE IN LATHE OPERATIONS.**

A single point cutting tool consists of a sharpened cutting part called its point and the shank. The point of the tool is bounded by the face, side flank (major flank), end flank (minor flank) and the base.

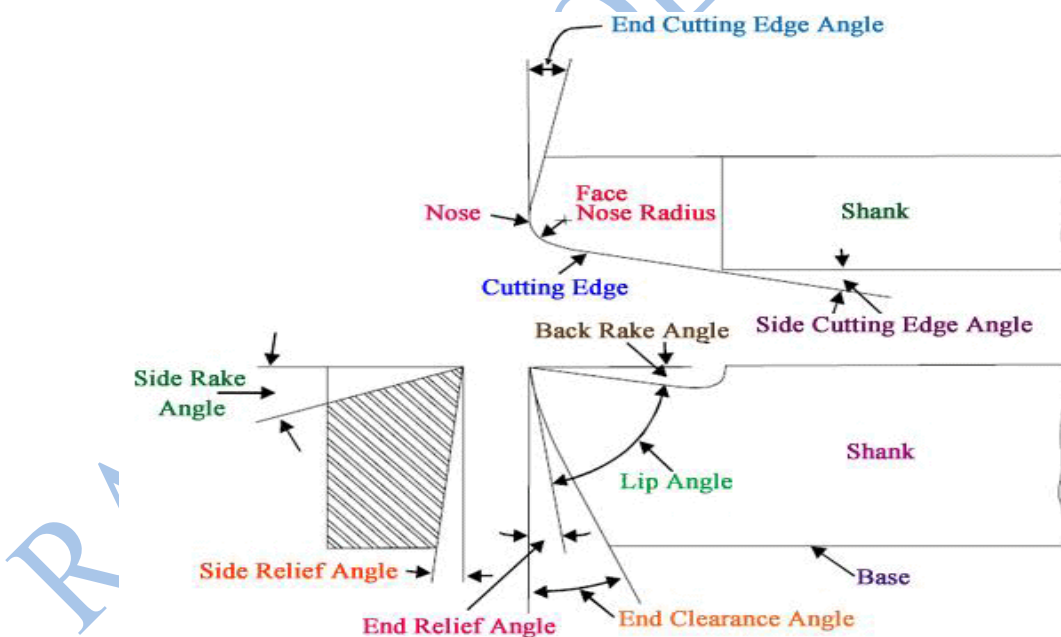


Figure: Single point cutting tool

Elements of a Single Point Cutting Tool

- **Shank:** It is the main body of the tool.
- **Flank:** The surface or surfaces below and adjacent to the cutting edge.

- Face: The surface on which the chip slides is called the face of the tool.
- Heel: It is the intersection of the flank and the base of the tool.
- Nose: It is the point where the side cutting edge and end cutting edge intersect.
- Cutting edge: It is the edge on the face of the tool which removes material from the workpiece.

The total cutting edge consists of:

- Side cutting edge (major cutting edge)
- End cutting edge (minor cutting edge)
- Base: The base of the tool is the underside of the shank.
- Rake: It is the slope of the top away from the cutting edge.
- Side clearance: It is a side relief indicating that the flank or side of a tool has been ground back at an angle sloping down from the side cutting edge.
- End clearance: It is the end relief indicating that the nose or end of a tool has been ground back at an angle sloping down from the end cutting edge.

Significance in Lathe Operations

Material Removal: The cutting edge of the tool removes material from the workpiece, shaping it to required dimensions.

Tool Life and Wear: Proper tool geometry (rake, clearance, cutting edge) reduces wear, extending tool life and reducing tool changes.

Surface Finish: The tool's design affects the surface finish. Well-designed tools achieve smoother finishes in operations like turning and facing.

Cutting Forces: Tool geometry helps minimize cutting forces, improving machining efficiency and stability.

Chip Formation: Proper geometry ensures efficient chip removal, preventing tool damage and improving cut accuracy.

Precision in Operations: A well-designed cutting tool ensures precise machining, critical for high-quality parts in turning, facing, and threading operations.

5. EXPLAIN ABOUT NOMENCLATURE OF MILLING TOOLS.

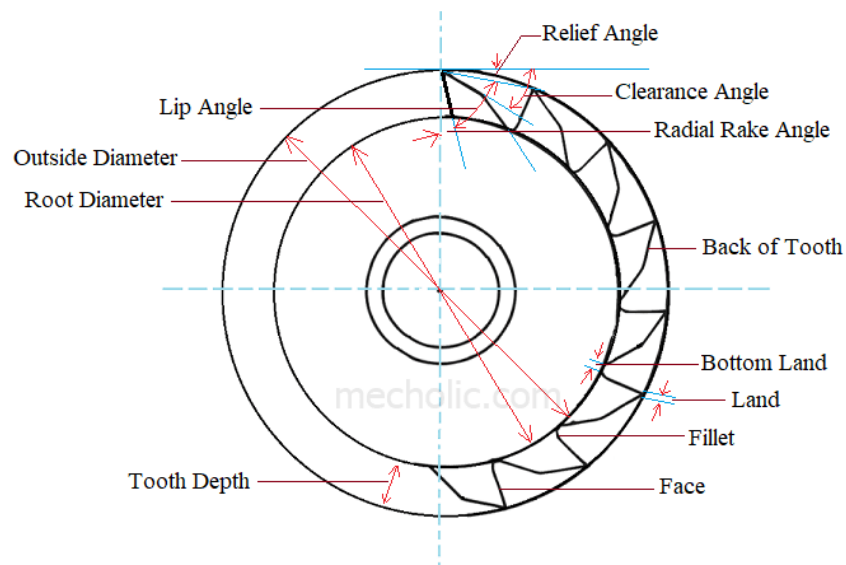


Figure: Nomenclature of milling tool

Nomenclature of Milling Tool

- Body of Cutter: Main part of the cutter excluding the teeth.
- Cutting Edge: The edge formed by the intersection of the face and circular land, responsible for cutting.
- Face: Portion adjacent to the cutting edge where the chip flows during cutting.
- Gash (Chip Space): Space between the back of one tooth and the face of the next for chip flow.
- Fillet: Curved surface connecting the face of one tooth to the back of the next.
- Land: Part of the back of the tooth near the cutting edge, relieved to avoid interference.
- Root Diameter: Diameter passing through the bottom of the fillet.
- Outside Diameter: Diameter passing through the peripheral cutting edge.
- Lead: Axial advance of the helix per revolution.
- Tooth Depth: Distance between outside diameter and root diameter.

Important Angles

- Relief Angle: Angle between land of a tooth and tangent to the cutter's outside diameter.
- Primary Clearance Angle: Angle between the back of the tooth and a tangent line at the cutting edge.

- Secondary Clearance Angle: Angle between the secondary clearance surface and tangent at the cutting edge.
- Radial Rake Angle: Angle between face of the tooth and a radial line passing through the cutting edge.

6. EXPLAIN ABOUT SURFACE FINISHING PROCESSES

1. Grinding

- Removes material to create a smooth, precise finish.
- Uses an abrasive wheel for high-precision grinding.
- Achieving high dimensional accuracy and smoothness, especially on hardened materials.

2. Polishing

- Provides a smooth, reflective surface.
- Uses abrasive compounds or polishing wheels to create a shiny finish.
- Enhances appearance, reduces roughness, and improves corrosion resistance.

3. Coating

- Adds a protective or decorative layer to a surface.
- Involves spraying, dipping, or electroplating to apply a coating.
- Protects from corrosion, improves wear resistance, and enhances appearance.

7. ABRASIVES USED IN GRINDING WHEELS AND ITS DESIGNATIONS

Common Abrasive Types and Designations

- A: Regular Aluminum Oxide (tough, for steel)
- WA: White Aluminum Oxide (friable, for hardened steel)
- PA: Pink Aluminum Oxide (durable, for precision grinding)
- C: Black Silicon Carbide (brittle, for cast iron/non-ferrous)
- GC: Green Silicon Carbide (very hard, for carbides/finishing)
- AZ/ZA: Zirconia Alumina (heavy-duty, self-sharpening)
- SG/Ceramic: Ceramic Alumina (high-performance, long-lasting)
- SD/MD: Synthetic Diamond (extremely hard materials)
- CBN: Cubic Boron Nitride (hardened steels)

Key Components in Designation

- Abrasive: (e.g., A, C, SG)

- Grit Size: Coarse (10–60), Medium (70–120), Fine (150–600).
- Grade (Hardness): Soft (D–H), Medium (I–P), Hard (Q–Z).
- Structure (Spacing): Dense (1–8) to Open (9–15+).
- Bond Type: V (Vitrified), B (Resinoid), R (Rubber).

8. BREAKDOWN OF THE DESIGNATION "A46-K5-V8":

- A: Aluminum Oxide (Abrasive Type)
- 46: Grain size (Medium)
- K: Grade/Hardness (Medium)
- 5: Structure (Dense to Open)
- V: Vitrified Bond
- 8: Manufacturer's identification mark

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. Which of the following is a characteristic of a cutting tool material?
A) High electrical conductivity B) High hardness
C) Low cost D) Low thermal conductivity
Answer: b)
2. Which of the following materials is commonly used for manufacturing cutting tools?
A) Aluminum B) High-speed steel
C) Copper D) Plastic
Answer: b)
3. Which cutting tool material is best suited for cutting hard metals like stainless steel?
A) Cast iron B) Carbide C) Brass D) Bronze
Answer: b)
4. Which of the following is the primary function of the rake angle in a cutting tool?
A) To reduce the cutting force B) To improve tool strength
C) To increase tool life D) To guide the chip flow
Answer: a)
5. What is the classification of cutting tools primarily based on?
A) Type of material cut B) Function of the tool

C) Tool material and geometry D) Price of the tool

Answer: c)

6. In a single-point cutting tool, what is the purpose of the cutting edge?

A) To provide strength B) To cut the workpiece material

C) To support the tool D) To increase the tool's life

Answer: b)

7. What is the term for the portion of the milling cutter that is responsible for removing material?

A) Cutting edge B) Flute C) Body D) Arbor

Answer: a)

8. The relief angle in a cutting tool is designed to:

A) Improve the cutting action B) Prevent rubbing of the tool on the workpiece

C) Increase tool strength D) Control the cutting speed

Answer: b)

9. In milling tools, the term 'flute' refers to:

A) The cutting edge B) The spiral grooves on the tool

C) The body of the tool D) The material the tool is made from

Answer: b)

10. Which of the following is NOT a type of cutting tool material?

A) High-speed steel B) Carbon steel

C) Titanium alloy D) Silicon carbide

Answer: d)

11. Which of the following is the primary purpose of the grinding process?

A) To polish a workpiece B) To remove material and improve surface finish

C) To coat a surface D) To increase the hardness of a material

Answer: b)

12. What is the main difference between polishing and grinding?

A) Polishing removes more material than grinding

B) Polishing is used to create a shiny surface, while grinding is used for rough shaping

C) Grinding is more expensive than polishing

D) Polishing uses harder abrasives than grinding

Answer: b)

13. Which surface finishing process involves applying a layer of material to a surface to improve properties like corrosion resistance?

A) Grinding B) Polishing C) Coating D) Honing

Answer: c)

14. What type of surface finish is achieved by polishing?

A) Rough surface with high material removal B) Smooth and shiny finish
C) Matte finish D) Uneven surface

Answer: b)

15. Which of the following is a commonly used abrasive in grinding wheels?

A) Aluminum oxide B) Glass C) Rubber D) Copper

Answer: a)

16. Which abrasive is best suited for precision grinding of hardened steels?

A) Diamond B) Aluminum oxide
C) Silicon carbide D) CBN (Cubic Boron Nitride)

Answer: d)

17. The abrasive used for grinding very hard materials like ceramics and glass is:

A) Aluminum oxide B) Silicon carbide C) Diamond D) CBN

Answer: c)

18. Which of the following is used to designate a grinding wheel made of aluminum oxide?

A) A B) C C) D D) B

Answer: a)

19. What does the number in the grinding wheel designation represent?

A) The hardness of the abrasive B) The grain size
C) The type of bond D) The type of abrasive

Answer: b)

20. What does the bond type "V" in a grinding wheel designation indicate?

A) Resin bond B) Vitrified bond
C) Metal bond D) Rubber bond

Answer: b)

21. Which of the following grinding wheel designations indicates a soft wheel?

- A) A60K B) A120K C) A30V D) A90V

Answer: a)

22. In the designation "A60J8V", what does the "J" represent?

- A) Bond type B) Grain size
C) Hardness of the wheel D) Structure of the wheel

Answer: c)

23. Which of the following abrasives is most suitable for grinding non-ferrous materials like aluminum?

- A) Aluminum oxide B) Silicon carbide C) Diamond D) CBN

Answer: b)

1. Classify cutting tools.
2. List the characteristics of cutting tool materials.
3. Mention any three properties of an abrasive material used in grinding wheel.
4. Explain the nomenclature of a single point cutting tool and its significance in lathe operations.
5. Explain about surface finishing processes.
6. Explain about selection of tool materials.

Week 12

Drilling Machine

- **Introduction to drilling Machine**
- **Classifications of drilling machine.**
- **Drilling operations - List**
- **Nomenclature of Twist drill.**

1. WHAT IS DRILLING?

Drilling is the operation of producing circular hole in the work-piece by using a rotating cutter called DRILL. The most common drill used is the twist drill.

2. WHAT IS DRILLING MACHINE?

A drilling machine is a machine tool designed for drilling holes in metals. It is one of the most important and versatile machine tools in a workshop. Besides drilling round holes, many other operations can also be performed on the drilling machine such as counter, boring, countersinking, honing, reaming, lapping, sanding etc.

3. LIST THE CLASSIFICATIONS OF DRILLING MACHINES.

Drilling machines are classified on the basis of their constructional features, or the type of work they can handle. The various types of drilling machines are:

- (1) Portable drilling machine
- (2) Sensitive drilling machine
 - (a) Bench mounting
 - (b) Floor mounting
- (3) Upright drilling machine
 - (a) Round column section
 - (b) Box column section machine
- (4) Radial drilling machine
 - (a) Plain
 - (b) Semi universal
 - (c) Universal
- (5) Gang drilling machine
- (6) Multiple spindle drilling machine
- (7) Automatic drilling machine
- (8) Deep hole drilling machine
 - (a) Vertical
 - (b) Horizontal

4. CONSTRUCTION OF DRILLING MACHINE:

Drilling machine consists of following parts

1. Base
2. Pillar/Column
3. Main drive
4. Drill spindle
5. Feed handle
6. Work table

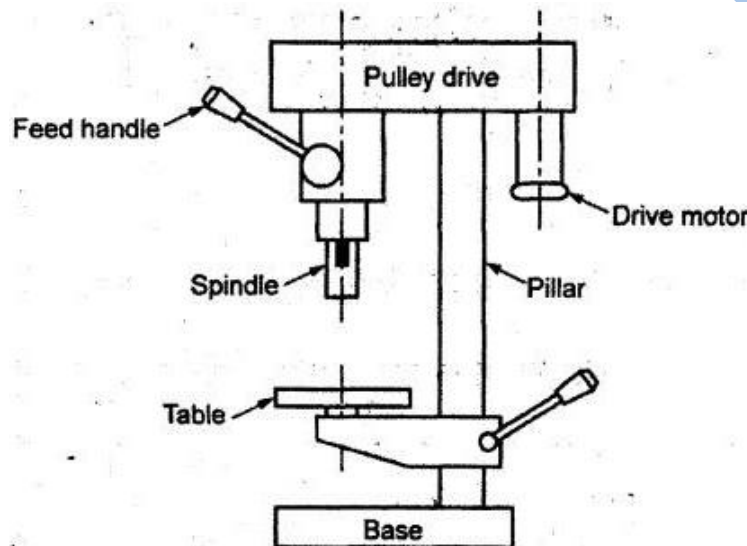


Figure: Drilling machine

Base: A heavy casting, usually made of cast iron, that supports the entire machine, absorbs vibrations, and is bolted to the floor or a bench.

Pillar/Column: The vertical cylindrical pillar mounted on the base, which supports the worktable and the drill head.

Spindle: A rotating shaft that holds the chuck. It moves vertically to provide the feeding motion, powered by the motor

Work Table: Mounted on the column, this holds the work piece. It can move up/down, rotate around the column, and usually features T-slots for clamping the work.

Feed handle: A manual handle (or automatic system) that moves the spindle up and down to push the drill bit into the workpiece.

Pulley Drive (Speed Regulator): Connected by a belt, these allow for changing the rotational speed of the spindle.

5. LIST AND EXPLAIN DRILLING MACHINE OPERATION.

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Countersinking Drilling machine operation
6. Spot facing
7. Tapping
8. Lapping
9. Grinding
10. Trepanning.

1. Drilling:

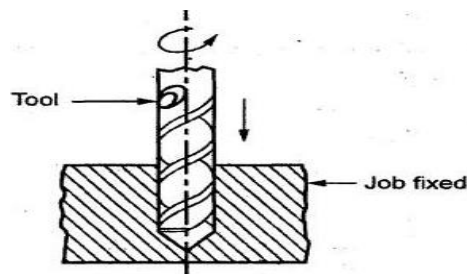


Figure: Drilling operation

It is the process of creating a new round hole in a solid workpiece using a rotating drill bit. The cutting edges of the drill remove material in the form of chips to produce a cylindrical hole.

Purpose: To create holes for fasters, shafts, pins or other components in mechanical assemblies of fabrication work.

2. Reaming:

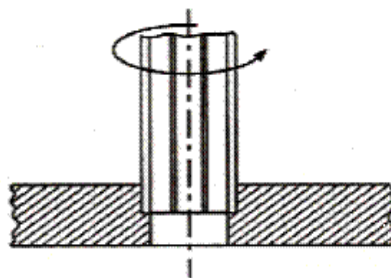


Figure: Reaming operation

It is a process of smoothing the surface of drilled holes with a tool. Tool is called as reamer. It produces a hole with a precise diameter and improves surface finish.

Purpose: To ensure high dimensional accuracy and smooth surface finish, which is essential for components requiring a precise fit, such as shafts.

3. Boring:

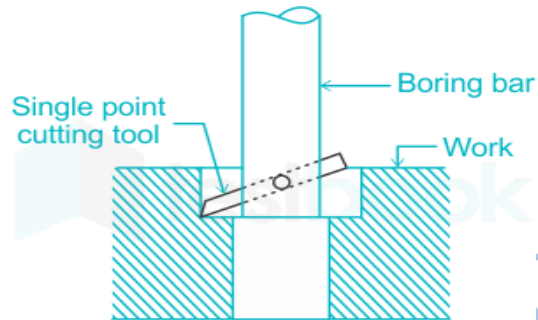


Figure: Boring operation

It is process carried on a drilling machine to increase the size of an already drilled hole. Initially a hole is drilled to the nearest size and using a boring tool the size of the hole is increased. It improves the size, alignment and roundness of the hole.

Purpose: To achieve exact diameter, alignment and concentricity.

4. Counter boring:

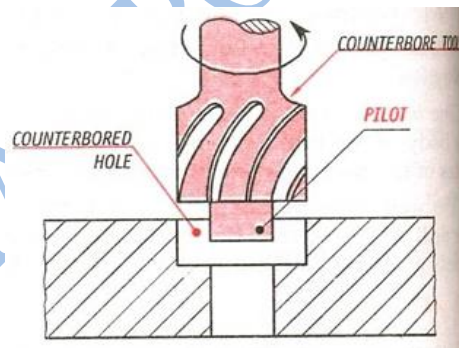


Figure: Counter boring operation

Counter boring is the operation of enlarging one end of an existing hole concentric with the original hole with square bottom.

Purpose: It is done to accommodate the heads of bolts, studs and pins.

5. Countersinking:

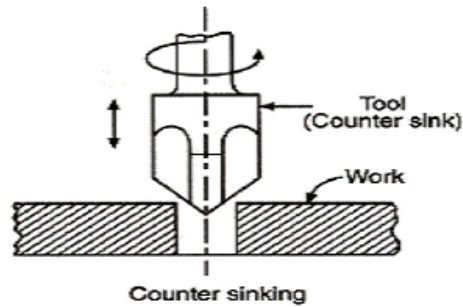


Figure: Countersinking operation

Counter-sinking operation is shown in Fig. This is the operation of making a cone shaped enlargement of the end of a hole using a countersink tool.

Purpose: To enable flat-head screws to sit flush with the workpiece surface, improving appearance and preventing interference with moving parts.

6. Tapping:

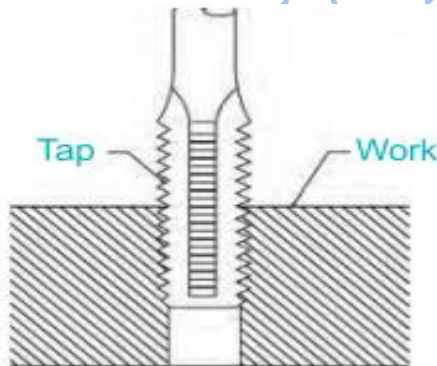


Figure: Tapping operation

Tapping is a machining operation that creates internal threads in a pre-drilled hole using a tap tool, typically performed on a drilling machine.

Purpose: To produce internal threads in a hole for fasteners (bolts/screws).

6. EXPLAIN THE NOMENCLATURE OF A TWIST DRILL AND ITS SIGNIFICANCE IN DRILLING OPERATIONS.

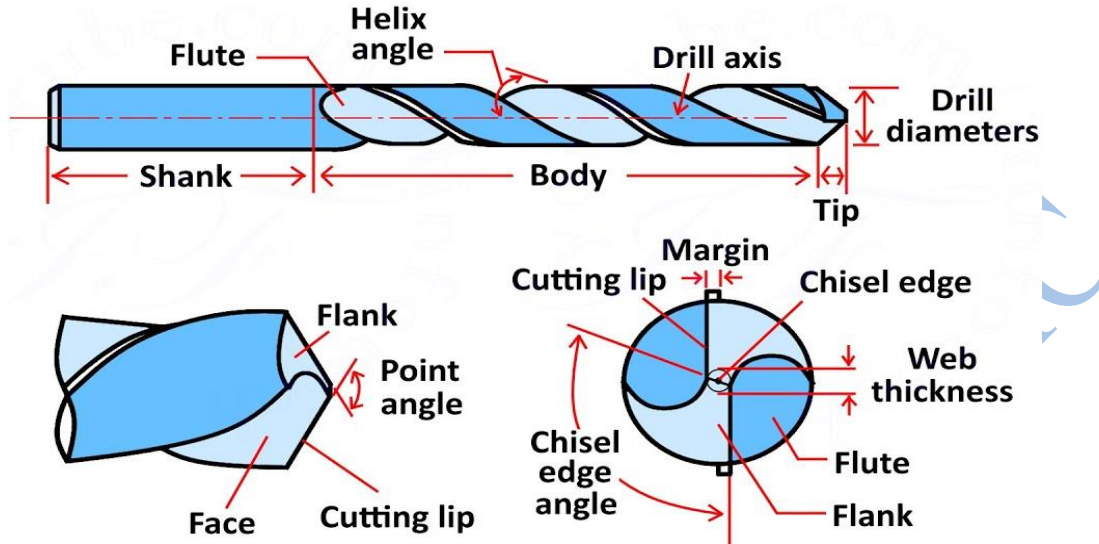


Figure: Nomenclature of Twist drill

- **Shank:** The part held by the chuck, which can be straight, tapered (Morse), or hex.
- **Body:** The main portion containing flutes and lands.
- **Flutes:** Helical grooves that allow chip evacuation and coolant flow.
- **Point:** The cone-shaped tip, which includes the lips, flank, and chisel edge.
- **Chisel Edge:** The edge at the extreme tip that centers the drill.
- **Lip:** The cutting edge, formed by the intersection of the flank and flute.
- **Margin:** A narrow strip on the land that maintains whole size and stability.
- **Neck:** A reduced-diameter section between the body and shank
- **Point Angle:** Typically for general purpose or for harder materials.
- **Helix Angle:** The angle of the flutes; usually 30°.
- **Lip Relief Angle:** The angle that provides clearance to the cutting edge to prevent rubbing.
- **Back Taper:** A slight reduction in diameter toward the shank to prevent binding.

Significance in Drilling Operations.

1. **Efficient Cutting:** Proper cutting edges (lips, rake angle, clearance angle) help in smooth and efficient material removal.
2. **Chip Removal:** Flutes allow chips to escape easily and prevent clogging during drilling.
3. **Accuracy of Hole:** Correct drill geometry ensures accurate whole size and alignment.

4. **Reduced Friction and Heat:** Body clearance and clearance angles reduce contact between the drill and the hole wall.
5. **Strength and Durability:** The web and body design provide strength to withstand drilling forces.
6. **Proper Holding and Driving:** The shank and tang allow the drill to be securely held and rotated by the drilling machine.

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. A radial drilling machine is preferred for:
 - a) Small, precise holes
 - b) Drilling holes in large, heavy work pieces
 - c) High-speed drilling of plastics
 - d) Micro-drilling operations.

Answers: b)

2. The mail cutting tool used in a drilling machine is
 - a) Milling cutter
 - b) Twist drill
 - c) Reamer
 - d) Boring bar

Answers: b)

3. The part of the drilling machine which holds and drives the drill bit is the
 - a) Base
 - b) Table
 - c) Spindle
 - d) Column

Answers: c)

4. The machine that is hand held and used for small holes in light materials is
 - a) Upright drilling machine
 - b) Radial drilling machine
 - c) Portable drilling machine
 - d) Gang drilling machine

Answers: c)

5. The operation that enlarges and finishes a hole to accurate size is
 - a) Drilling
 - b) Boring
 - c) Tapping
 - d) Reaming

Answers: d)

6. The operations used produce internal threads is called
 - a) Tapping
 - b) Reaming
 - c) Counter boring
 - d) Spot facing

Answers: a)

1. Define a drilling machine.
2. List any two main functions of a drilling machine.

3. Name any two types of drilling machines.
4. List applications of drilling machines.
5. List the classifications of drilling machines.
6. Explain any five operations that can be performed on a drilling machine. Describe the purpose of each operation with neat sketches.
7. Discuss the working principal and applications of a drilling machine.
8. Write a short notes on
 - a) Counter sinking
 - b) Counter boring
 - c) Spot facing
 - d) Tapping
 - e) Reaming
9. Explain the nomenclature of a twist drill and its significance operations.

Week 13

Lathe and Milling machines

- **Introduction to Lathe Machine**
- **Classifications of Lathe machines, Lathe operations - List**
- **Introduction to Milling Machine**
- **Classifications of Milling machines, milling operations-List**

1. DEFINE LATHE AND CLASSIFICATIONS OF LATHE MACHINES

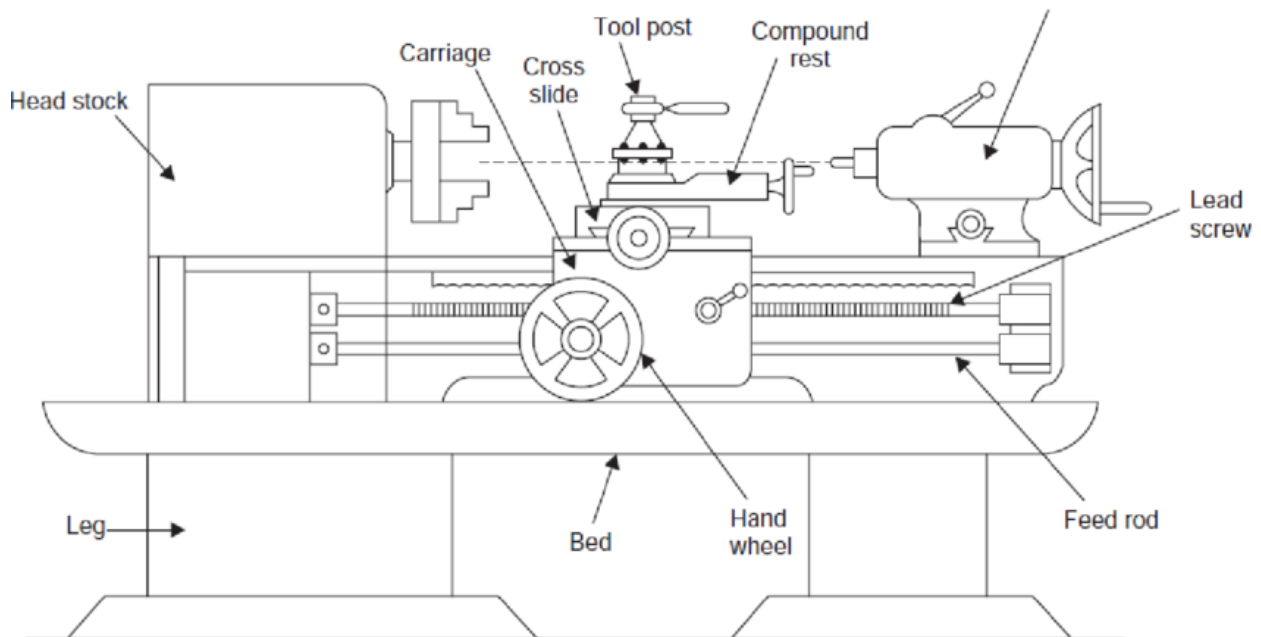


Figure: Lathe machine

A lathe machine is a versatile, foundational industrial tool that rotates a workpiece on its axis to perform various operations—such as cutting, sanding, knurling, or drilling—with a stationary cutting tool.

Classification of Lathe

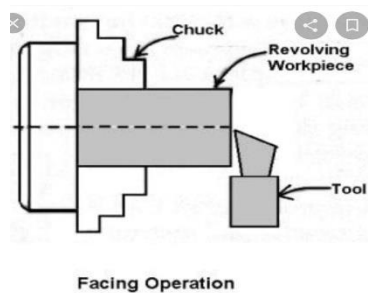
The different types of lathe with classification generally used are:

1. Speed lathe
 - i) Wood working
 - ii) Centering
 - iii) Polishing
 - iv) Spinning
2. Engine or Centre lathe
 - i) Belt drive
 - ii) Individual motor drive
 - iii) Gear head lathe
3. Tool room lathe
4. Special purpose lathe

- i) Wheel lathe
- ii) Gap bed lathe
- iii) Turret lathe
- iv) Tracer lathe
- v) Duplicating lathe
- vi) Automatic lathe
- 5. Capstan and Turret lathe
- 6. Automatic lathe
- 7. CNC lathe

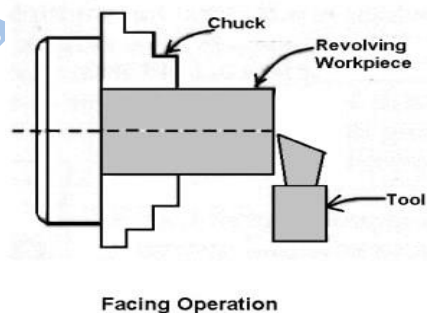
2. LIST AND EXPLAIN LATHE OPERATIONS

1. Turning



It is the process of removing material from the outer surface of a rotating workpiece in the form of chips.

2. Facing: It is the process of removing material from the end of the workpiece to make it flat and smooth.



3. Taper Turning:

It is the process of producing a conical surface by gradually reducing the diameter of the workpiece.

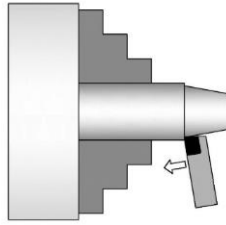


Figure: Taper turning operation

4. Threading

It is the process of cutting threads on the workpiece.

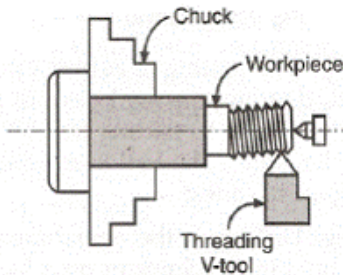


Figure: Thread cutting operation

5. Grooving

It is the process of cutting grooves on the external or internal surface of the workpiece.

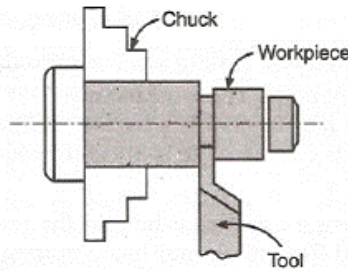


Figure: Grooving operation

6. Knurling

It is the process of producing a roughened surface on the workpiece for better grip.

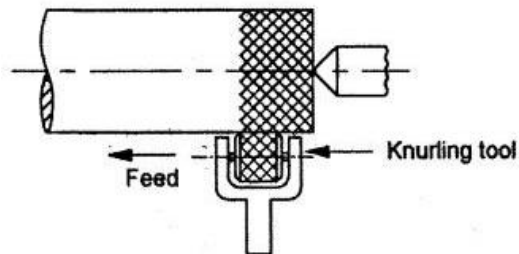


Figure: Knurling operation

7. **Drilling:** It is the process of producing a hole by using a drill tool.
8. **Boring:** It is the process of enlarging an already drilled hole.
9. **Reaming:** It is the process of finishing and sizing a hole accurately.
10. **Parting-off (Cutting-off):** It is the process of cutting the workpiece into two parts.
11. **Chamfering:** It is the process of beveling the edge of a workpiece.
12. **Forming:** It is the process of producing irregular shapes using form tools.

3. WHICH TYPE OF LATHE IS PREFERRED FOR MACHINING LONG WORK PIECES AND WHY?

Reason:

- Can accommodate **long work pieces between centres**.
- Provides support using **tailstock**, preventing bending and deflection.
- Ensures **better alignment and accuracy** during machining.
- Suitable for operations like **turning long shafts and rods**.
- Additional supports like **steady rest and follower rest** can be used for very long jobs.

4. A COMPONENT REQUIRES EXTERNAL THREADS ON A STEEL ROD. DESCRIBE HOW THREAD CUTTING IS DONE ON A LATHE AND MENTION THE PRECAUTIONS TO BE TAKEN.

External Thread Cutting on a Lathe Procedure:

- The workpiece (steel rod) is held in the chuck or between centres.
- A single-point threading tool is set at the correct height and angle (as per thread profile).
- The lathe spindle is connected to the lead screw through change gears.
- The tool is fed longitudinally using the lead screw to maintain correct pitch.
- Depth of cut is given gradually by advancing the cross-slide.
- Multiple passes are taken until the required thread depth is obtained.
- Cutting fluid is applied to reduce heat and improve surface finish.

Precautions:

- Ensure correct **gear setting** for required thread pitch.
- Tool must be **properly aligned** and set at centre height.
- Use **low spindle speed** to avoid tool damage.
- Apply **cutting fluid** to reduce friction and heat.

- Give **small depth of cut** in each pass to avoid overloading.
- Check thread using **gauge or nut** for accuracy.
- Ensure proper engagement and disengagement of **half-nut lever**.

5. DEFINE MILLING MACHINE, CLASSIFICATIONS OF MILLING MACHINES.

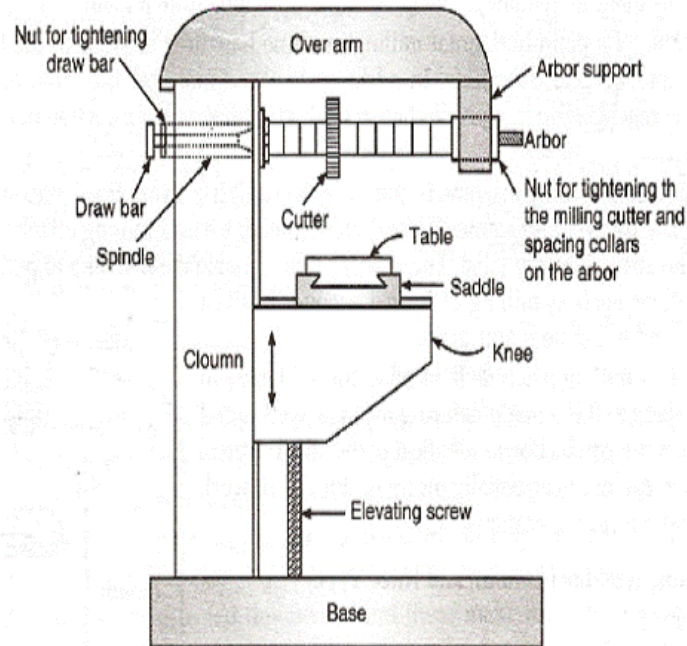


Figure: Milling machine

A milling machine is a machine tool in which a rotating multi-point cutting tool is used to remove material from the workpiece. The workpiece is fed against the rotating cutter to produce flat, curved or irregular surfaces.

Classification of Milling Machines

1. Column and Knee type

- Plain or horizontal milling machine
- Universal milling machine
- Vertical milling machine

2. Fixed bed type (Manufacturing type)

- Simplex milling machine
- Duplex milling machine
- Triplex milling machine

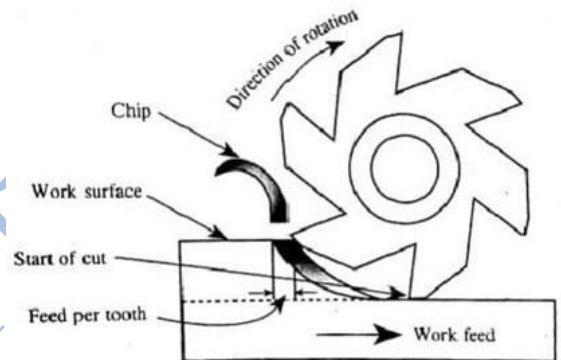
3. Special type milling machines

- i) Rotary table milling machine
- ii) Drum type milling machine
- iii) Planetary milling machine
- iv) Profiling milling machine
- v) Tracer controlled milling machine
- vi) CNC milling machine

6. EXPLAIN UP-MILLING AND DOWN MILLING OPERATION

Up Milling

- 1. Cutter rotates against the direction of feed.
- 2. The chip thickness is zero at the beginning and maximum at the end.
- 3. Cutting force is minimum at the beginning and maximum at the end.
- 4. The chip thickness increases gradually.
- 5. More friction occurs between tool and the workpiece.
- 6. Surface finish is comparatively poor.
- 7. Suitable for rough machining.

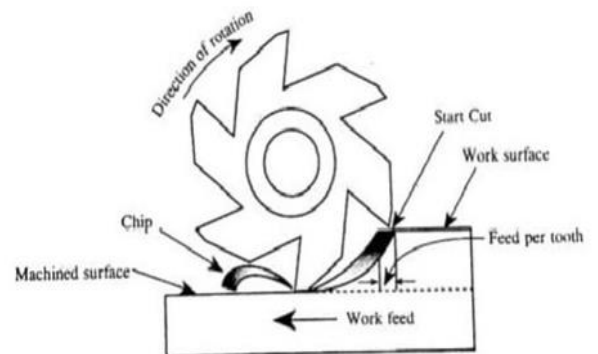


Advantages of Up Milling

- 1. Simple and safe cutting process.
- 2. Less tendency of workpiece being pulled into the cutter.
- 3. Suitable for machines with backlash.
- 4. Suitable for machining rough and uneven surfaces (like castings and forgings).
- 5. Longer tool life due to gradual increase in cutting load.
- 6. No sudden impact load on the cutter, hence smoother operation for beginners.

Down Milling

- 1. Cutter rotates in the same direction as feed.
- 2. The chip thickness is maximum at the beginning and zero at the end.
- 3. Cutting force is maximum at the beginning and



minimum at the end.

4. The chip thickness decreases gradually.
5. Less friction between tool and workpiece.
6. Better surface finish is obtained.
7. Suitable for finishing operations.

Advantages of Down Milling

1. Better surface finish.
2. Less heat generation.
3. Less tool wear.
4. Higher production rate.
5. Less power required for cutting.

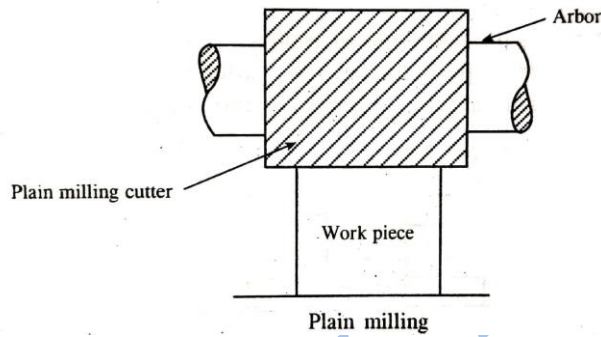
7. DIFFERENCE BETWEEN UP-MILLING AND DOWN-MILLING

Up Milling	Down Milling
<ul style="list-style-type: none"> • Up milling is called as conventional milling 	<ul style="list-style-type: none"> • Down milling is called as climb milling
<ul style="list-style-type: none"> • Cutter rotates against the direction of feed 	<ul style="list-style-type: none"> • Cutter rotates in the same direction as feed
<ul style="list-style-type: none"> • Chip thickness is zero at the beginning and maximum at the end 	<ul style="list-style-type: none"> • Chip thickness is maximum at the beginning and zero at the end
<ul style="list-style-type: none"> • Effective cutting is possible during cutting action 	<ul style="list-style-type: none"> • Effective cooling is possible during cutting action
<ul style="list-style-type: none"> • The chip thickness is zero at the end of the cut 	<ul style="list-style-type: none"> • The chip thickness is zero at the end of the cut
<ul style="list-style-type: none"> • Maximum milling force is at the end 	<ul style="list-style-type: none"> • Maximum milling force is at the beginning
<ul style="list-style-type: none"> • Poor surface finish 	<ul style="list-style-type: none"> • Good surface finish

8. LIST MILLING OPERATIONS, AND EXPLAIN EACH

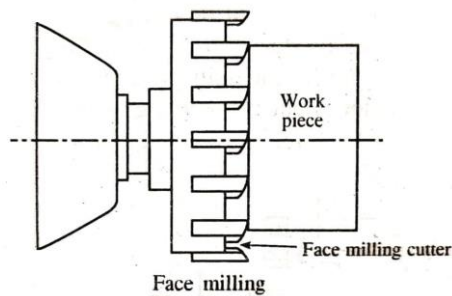
- | | |
|---|---|
| <input type="checkbox"/> Plain milling | <input type="checkbox"/> Gang milling |
| <input type="checkbox"/> Face milling | <input type="checkbox"/> Slab milling |
| <input type="checkbox"/> Side milling | <input type="checkbox"/> End milling |
| <input type="checkbox"/> Angular milling | <input type="checkbox"/> T-slot milling |
| <input type="checkbox"/> Form milling | <input type="checkbox"/> Gear cutting |
| <input type="checkbox"/> Straddle milling | <input type="checkbox"/> Thread milling |

1. Plain Milling



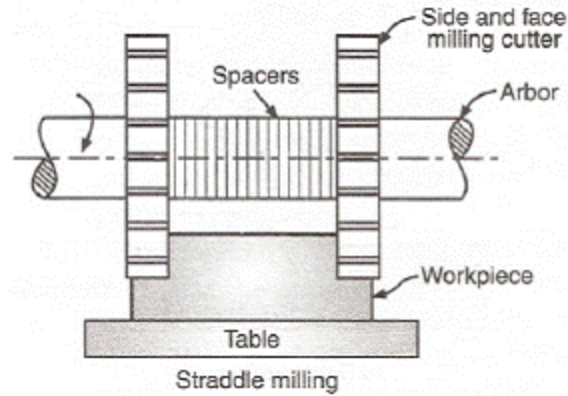
- Produces flat horizontal surfaces.
- Cutter axis is parallel to the workpiece surface.
- Uses plain (slab) milling cutter.

2. Face Milling



- Produces flat surfaces perpendicular to cutter axis.
- Cutting is done by face and peripheral teeth.
- Used for finishing flat surfaces.

3. Side Milling

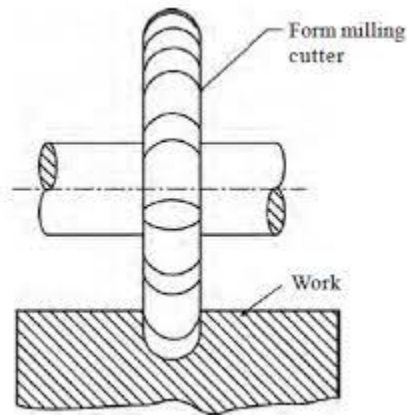


- Machines vertical or side surfaces.
- Cutter has teeth on sides and periphery.
- Used for slots and grooves.

4. Angular Milling

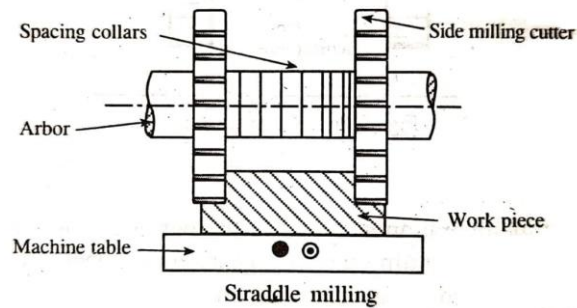
- Produces surfaces at an angle.
- Uses single or double angle cutters.
- Used for V-grooves and chamfers.

5. Form Milling



- Produces irregular contours or shapes.
- Uses specially designed form cutters.
- Used for profiles like gears and curves.

6. Straddle Milling



- Machines two parallel surfaces simultaneously.
- Uses two side milling cutters.
- Ensures accurate spacing between surfaces

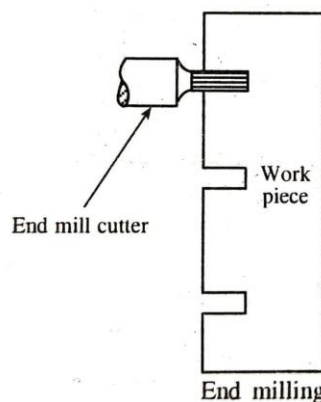
7. Gang Milling

- Multiple cutters are mounted on one arbor.
- Performs several operations in one pass.
- Increases production rate.

8. Slab Milling

- Removes large amount of material from flat surfaces.
- Cutter rotates parallel to work surface.
- Used for heavy machining work.

9. End Milling



- Used for slots, pockets and profiles.
- Cutter has teeth on end and periphery.
- Can produce complex shapes.

9. WHICH MILLING MACHINE TYPE IS PREFERRED FOR MACHINING LARGE WORK PIECES AND WHY?

Milling Machine Preferred for Large Workpiece Planer Type Milling Machine

Reason:

- Specifically designed to handle **very large and heavy workpieces** which cannot be accommodated on ordinary milling machines.
- Has a **very rigid and robust construction**, minimizing vibrations and ensuring better machining accuracy.
- The **workpiece is mounted on a large, stationary table**, reducing the need for frequent repositioning.
- Equipped with **multiple cutting heads**, allowing machining of different surfaces simultaneously.
- Suitable for machining **large flat, vertical and angular surfaces** with high precision.
- Provides **high production efficiency** for heavy-duty operations.
- Capable of handling **long and bulky components** such as machine beds, frames, and structural parts.

REVIEW QUESTIONS

MULTIPLE CHOICE QUESTIONS & ANSWERS:

1. In a lathe, accuracy of long work pieces is improved by using
A) Chuck B) Face plate C) Steady rest D) Tool post
Answer: c)
2. Which lathe is most suitable for mass production?
A) Engine lathe B) Tool room lathe C) Automatic lathe D) Speed lathe
Answer: c)
3. The feed in a lathe during thread cutting is controlled by
A) Cross slide B) Lead screw C) Tailstock D) Compound rest
Answer: b)
4. Which operation is used to produce a smooth and accurate hole?
A) Drilling B) Boring C) Reaming D) Turning
Answer: c)

5. Which lathe is preferred for high precision work?
A) Speed lathe B) Tool room lathe C) Capstan lathe D) Automatic lathe

Answer: b)

6. Which operation reduces the diameter uniformly along the length?
A) Facing B) Turning C) Knurling D) Threading

Answer: b)

7. The function of tailstock is to
A) Hold cutting tool B) Support long workpiece
C) Rotate workpiece D) Change speed

Answer: b)

8. Taper turning is done to produce
A) Flat surface B) Cylindrical surface C) Conical surface D) Thread

Answer: c)

9. Which operation is used to cut the workpiece into two parts?
A) Facing B) Parting-off C) Knurling D) Boring

Answer: b)

10. Gear cutting on lathe requires
A) Lead screw only B) Indexing mechanism C) Drill chuck D) Tool post

Answer: b)

11. In milling, the feed motion is given to
A) Cutter B) Workpiece C) Both D) None

Answer: b)

12. Which milling machine is most versatile?
A) Plain milling machine B) Universal milling machine
C) Vertical milling machine D) Planer type

Answer: b)

13. In face milling, the cutter axis is
A) Parallel to surface B) Perpendicular to surface
C) Inclined D) Horizontal

Answer: b)

14. Which milling operation uses multiple cutters simultaneously?
A) Straddle milling B) Gang milling C) Form milling D) Angular milling

Answer: b)

15. Which operation is suitable for cutting V-grooves?

A) Plain milling B) Face milling C) Angular milling D) Slab milling

Answer: c)

16. Which milling machine is best for heavy-duty work?

A) Vertical milling B) Universal milling C) Planer type D) Bench milling

Answer: c)

17. In up-milling, chip thickness is

A) Maximum at start B) Zero at start C) Constant D) Zero at middle

Answer: b)

18. Down milling is also called

A) Conventional milling B) Climb milling
C) Angular milling D) Form milling

Answer: b)

19. Which operation produces T-slots?

A) End milling B) Side milling C) T-slot milling D) Form milling

Answer: c)

20. In slab milling, cutter axis is

A) Perpendicular B) Parallel C) Inclined D) Vertical

Answer: b)

21. Which machine is preferred for long shafts?

A) Milling machine B) Lathe C) Drill machine D) Grinder

Answer: b)

22. Which machine is best for producing flat surfaces?

A) Lathe B) Milling machine C) Drilling machine D) Shaper only

Answer: b)

23. For mass production of identical parts, use

A) Engine lathe B) Tool room lathe C) Automatic lathe D) Speed lathe

Answer: c)

24. Which operation gives best surface finish in milling?
A) Up milling B) Down milling C) Plain milling D) Slab milling

Answer: b)

25. Which machine can machine multiple surfaces in one setup?
A) Lathe B) Milling machine C) Drill D) Grinder

Answer: b)

26. Which lathe is used for repetitive production?
A) Tool room lathe B) Capstan lathe C) Speed lathe D) Engine lathe

Answer: b)

27. Which milling operation is used for irregular profiles?
A) Plain milling B) Face milling C) Form milling D) Side milling

Answer: c)

28. Which device is used to divide work into equal parts in milling?
A) Tailstock B) Indexing head C) Tool post D) Chuck

Answer: b)

29. Which machine is more suitable for gear cutting?
A) Lathe B) Milling machine C) Drill machine D) Grinder

Answer: b)

30. Which process uses multi-point cutting tool?
A) Turning B) Drilling C) Milling D) Boring

Answer: c)

1. Define a lathe machine.
2. Define milling machine.
3. Describe the classifications of lathe machine. Which type of lathe is preferred for machining long work pieces and why?
4. Explain up and down milling.
5. Difference between up milling and down milling.
6. Explain the main parts operations with brief explanations
7. Explain taper turning operation in lathe.
8. Explain the nomenclature of single point cutting tool and its significance in lathe operations.

9. A component requires external threads on steel rod. Describe how thread cutting is done on a lathe and mention the precautions to be taken.
10. Describe the classifications of milling machines. Which milling machine type is preferred for machining large workpiece and why?
11. Explain lathe machine operation with neat sketch.
12. Explain milling machine operation with neat sketch.

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