Introduction to Manufacturing Process
(1st Year BME)

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Declaration

This is Prepared for the Education Purpose only

Syllabus BME(3rd and 4th Module)

MODULE-3 (7 Classes)

- Introduction to Manufacturing: Classification of engineering materials, Material Properties, Manufacturing processes: Welding, Casting, Forming (Basics only)

MODULE-4 (4 Classes)

- Basic Power transmission devices: Belt, Gear drives, clutch, brakes. (Working principle only) Introduction to Robotics: Robot anatomy, Joints and links and common robot configurations.

COURSE OUTCOMES

CO1: Comprehending the Law of Thermodynamics (Module-1)

CO2: Being aware of how crucial thermodynamics is to IC engines, power plants, refrigerators, and Heat Pump (Module-2)

CO3: Being aware of fluid mechanics and heat transfer concepts (Module-2)

CO4: Recognizing the functions of Engineering materials (Module-3)

CO5: Have a fundamental understanding of welding, Casting, Forming and other manufacturing techniques. (Module-3)

CO6: Recognizing fundamental power transfer mechanisms and aware of the fundamental robotics system. (Module-4)

Books to be followed:

Essential Reading

- Basic Mechanical Engineering by Pravin Kumar, Pearson
- Basic Mechanical Engineering by A R Israni, P K Shah, BS Publications
- Text book of Elements of Mechanical Engineering, S T Murthy, Universities press
- Basic and applied Thermodynamics by P. K. Nag, Tata McGraw Hill

Supplementary reading

- Basic Mechanical Engineering by. D. Mishra, P. KParida, S.S.Sahoo, India Tech Publishing company
- Elements of Mechanical Engineering by J K Kittur and G D Gokak,Willey
- Basic Mechanical Engineering by Basant Agrawal, C M Agrawal,Willey
- Engineering Thermodynamics by P. Chattopadhaya, Oxford University Press

Science and Engineering: Exploring Discovery and Innovation

Join us on a journey through the fascinating worlds of science and engineering, where curiosity meets creation and ideas transform into reality.

Understanding Science

1

Seeks to Understand

Science aims to uncover the fundamental laws of nature through rigorous observation and experimentation.

2

Focus on "Why"

It explores the unknown, asking profound questions about the universe and expanding the boundaries of human knowledge.

3

Radio Wave Discovery

For instance, physicist Heinrich Hertz's discovery of radio waves revealed unseen natural phenomena, paving the way for future innovations.

The Essence of Engineering

Engineering is the practical application of scientific knowledge. It's about designing, building, and optimizing useful products and systems that solve real-world problems.

While science asks "why," engineering asks "how." Engineers focus on making things work efficiently within practical constraints. A prime example is how engineers took Hertz’s discovery of radio waves and transformed it into practical wireless communication devices, from early radios to modern smartphones.

Science vs. Engineering: A Symbiotic Relationship

Knowledge Creation

Scientists create knowledge.

Ask "What is possible?"

Explore theories.

Knowledge Application

Engineers apply knowledge.

Ask "How do we make it practical?"

Optimize solutions.

Though distinct, their relationship is symbiotic. Science provides the foundation, and engineering builds upon it, turning theoretical possibilities into tangible realities.

The Engineering Design Process

01

Identify Problem

Clearly define the challenge or need to be addressed.

02

Analyze & Propose

Examine existing solutions and brainstorm multiple new approaches.

03

Design Solution

Select the most viable option and develop detailed plans.

04

Implement & Test

Build and rigorously test the solution to ensure it meets specifications.

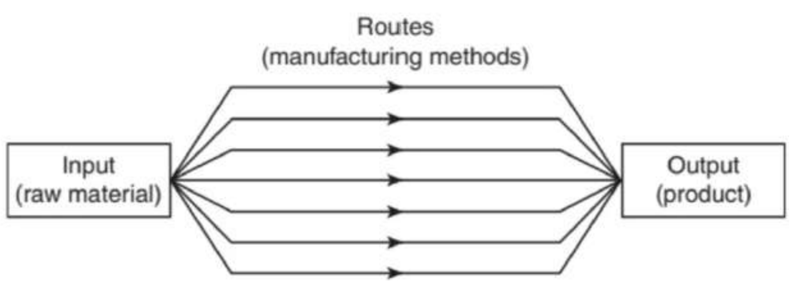
Consider civil engineers designing a bridge: they must balance safety, cost, and material constraints while ensuring the bridge serves its purpose effectively for decades.

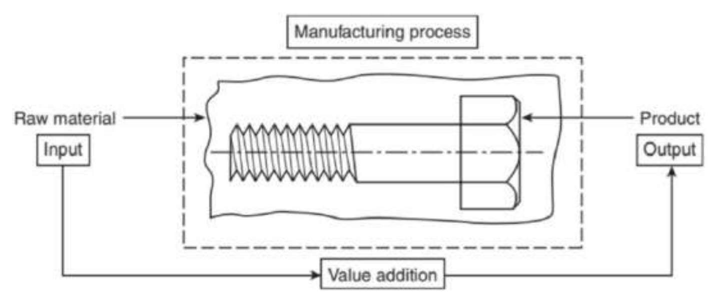
Introduction to Manufacturing: The Foundation of Modern Life

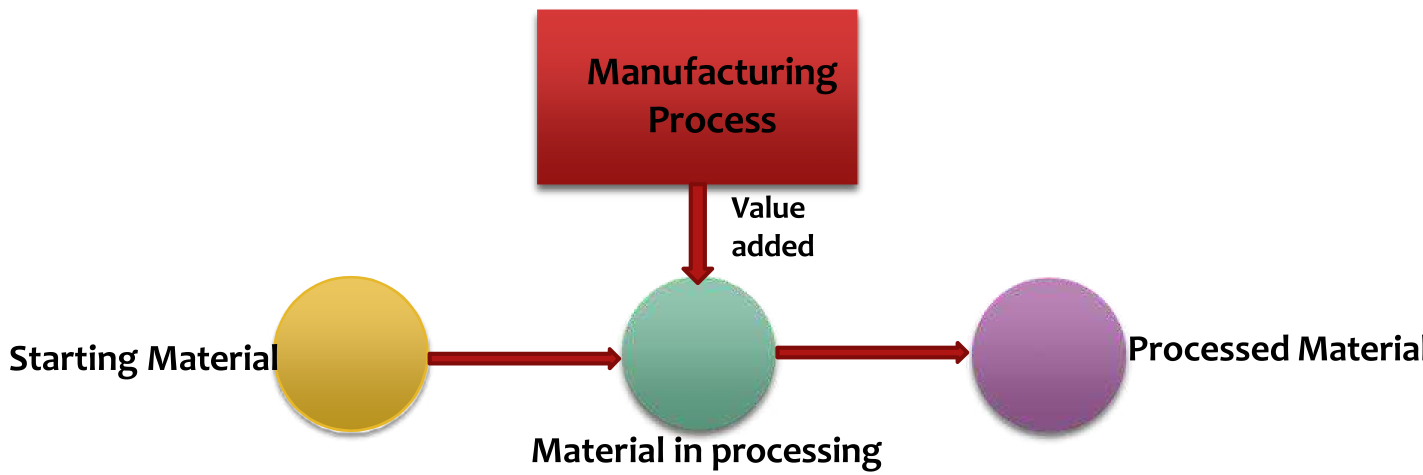
Welcome to the exciting world of manufacturing, where ideas transform into the tangible products that define our daily lives. This course will provide a foundational understanding of manufacturing processes, its impact on society, and the innovative future you can help shape.

Manufacturing

- At its core, manufacturing is about transformation. The term itself comes from the Latin phrase "*manu factus*," literally meaning "made by hand." While methods have evolved dramatically over centuries, the fundamental purpose remains unchanged: converting raw materials into valuable products.
- It is a value-added process by which raw materials or objects, originally of low value due to inadequate material properties and poor or irregular size, shape, and finish, are converted into high-quality and high-value products with proper size, form, dimension, and finish, thereby enhancing some functional ability.







Economic – Manufacturing is the transformation of materials into items of greatervalue by means of one or more processing operations. Therefore, manufacturing is “added value” to the material. “Added Value” by changing the material’s shape or properties, or by combining it with other materials that have been similarly altered.

This transformation process creates not just physical changes but economic value, employing machinery, tools, chemical processes, and human labor in intricate systems designed for efficiency and quality. Manufacturing forms the foundation of our material prosperity, enabling everything from necessities to advanced technologies.

What is Manufacturing?

Manufacturing is the bedrock of our material world, transforming raw materials into finished goods through various processes. From the smallest microchip to the largest airplane, every item we interact with daily is a product of manufacturing. It’s an intricate dance of engineering, design, and production that defines modern living.

From Raw to Refined

The core of manufacturing is taking basic materials—like metals, plastics, or wood—and giving them new form and function.

Shaping Our World

Think about your smartphone, your car, or even the chair you're sitting on. Manufacturing turns concepts into reality, driving progress and convenience.

Life Without It?

Imagine a day without manufactured goods. Life would be fundamentally different, highlighting manufacturing's profound impact.

Evolution of Manufacturing: From Revolution to Robotics

Manufacturing has undergone profound transformations, evolving from manual craftsmanship to highly automated processes. This journey is marked by revolutionary innovations that have reshaped production and society.

1

1760s: Industrial Revolution

Introduction of steam power and mechanized looms, shifting production from homes to factories.

2

Early 1900s: Assembly Line

Henry Ford's innovation dramatically increased efficiency and reduced costs, making goods widely accessible.

3

1970s: Computer-Aided Manufacturing

Computers begin controlling machines, leading to greater precision and complex product designs.

4

Today: Industry 4.0

Automation, robotics, and AI create smart factories, enabling real-time data analysis and interconnected production systems.

Types of Industries in Manufacturing

Primary Industries

These industries extract and harvest raw materials directly from nature:

- Agriculture (crops, livestock)
- Forestry (timber, pulp)
- Mining (metals, minerals, fossil fuels)
- Fishing (seafood)

Primary industries provide the essential inputs that enable all subsequent manufacturing activities.

Secondary Industries

These industries transform raw materials into finished or semi-finished products:

- Manufacturing (consumer goods, industrial equipment)
- Construction (buildings, infrastructure)
- Energy production (refining, power generation)

Secondary industries create the tangible products that form our built environment and material culture.

Tertiary Industries

These service industries support and distribute manufactured goods:

- Transportation and logistics
- Retail and wholesale trade
- Financial services
- Education and healthcare

Tertiary industries facilitate consumption and create additional value around manufactured products.

These sectors are deeply interdependent, forming a comprehensive economic ecosystem. Manufacturing (secondary) depends on raw materials from primary industries and relies on tertiary services for distribution, financing, and workforce development. The health of the manufacturing sector significantly impacts the prosperity of all three sectors.

Introduction to Engineering Materials

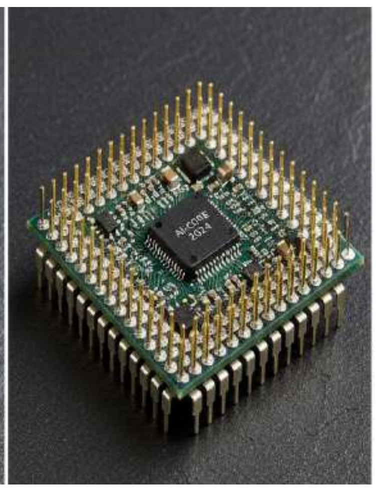
The building blocks of the modern world

Titanic Ship Tragedy

Tacoma Narrows Bridge

What are Engineering Materials?

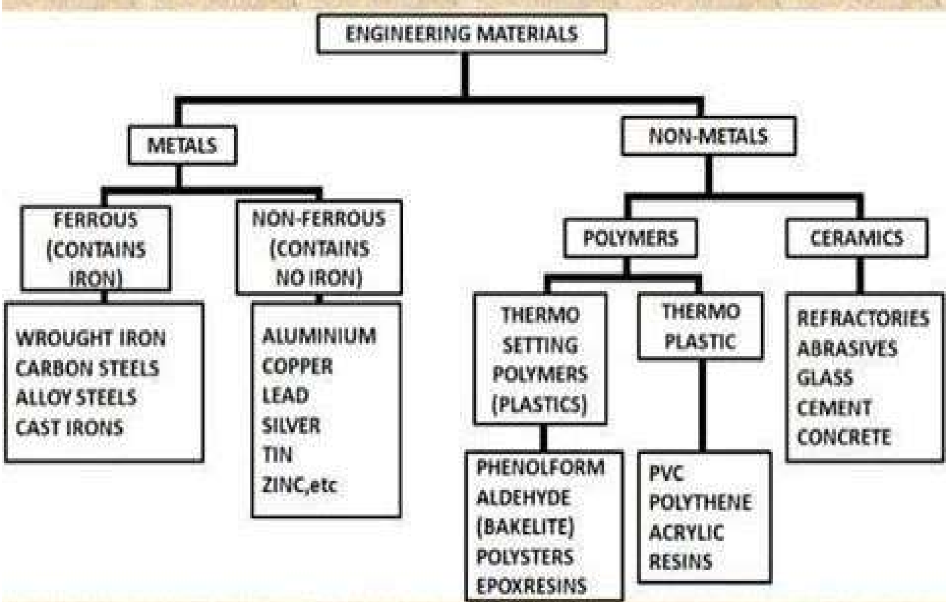
- Substances used to create structures, machines, and products.
- Selected based on specific properties for a particular job.
- Examples range from common items to advanced technology like aircraft and medical implants.

The Four Main Categories

Metals: Strong, ductile, and good conductors of heat and electricity.
Ceramics: Hard, brittle, and highly resistant to heat and wear.
Polymers: Lightweight, flexible, and corrosion-resistant.
Composites: Materials made by combining two or more distinct materials.

CLASSIFICATION OF ENGINEERING MATERIALS

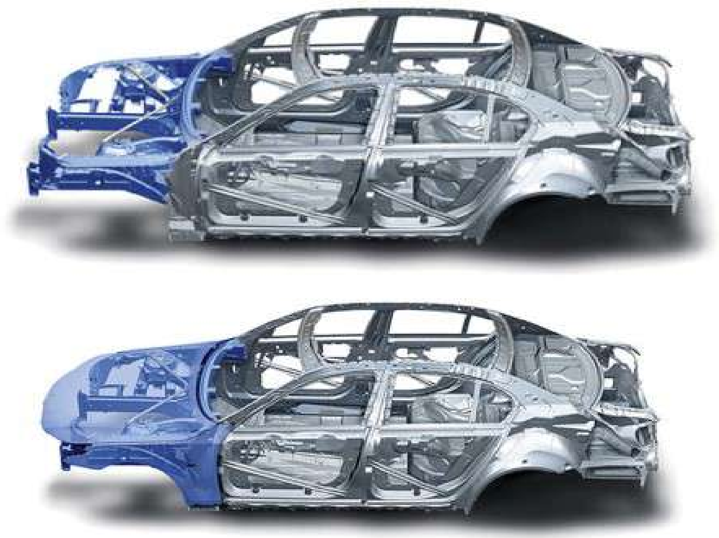


CLASSIFICATION OF ENGINEERING MATERIALS

Metals	Wrought Iron, Carbon Steels, Alloy Steels, Cast Irons
Non-Metals	Polymers, Thermosetting Polymers, Thermoplastics
Composites	Refractories, Glass, Cement, Concrete, Abrasives Reomy Matrix Composites (CMC)
Smart Materials	Fiber-Reinforced Composites (Ni-Ti) Piezoelectric Materials Magnetostrictive Materials Electrochromic & Thermochromic
Biomaterials	Metallic (Titanium alloys, Stainless Steel) Polymeric (Polylactic Acid, PMMA) Ceramic (Hydroxyapatite, Bioglass)
Nanomaterials	Carbon Nanotubes (CNTs), Graphene Nanoparticles (Metallic, Ceramic, Polymeric

Metals

Ferrous Metals: Contain iron. Known for strength. *Examples: Steel, Cast Iron*.
Non-Ferrous Metals: Do not contain iron. Known for corrosion resistance, lighter weight. *Examples: Aluminum, Copper, Titanium*.
Alloys: Combining metals to enhance properties.



Ceramics

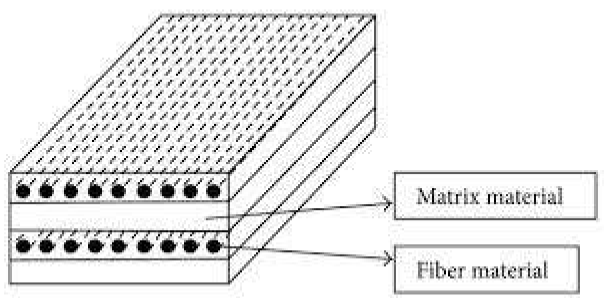
Inorganic, non-metallic compounds.
Excellent thermal and electrical insulators.
Often brittle and sensitive to stress.
Examples: Glass, bricks, porcelain, and advanced ceramics for engine parts.

Polymers

Thermoplastics: Can be melted and reshaped. *Examples: PET bottles, PVC pipes*.
Thermosets: Harden permanently after initial heat treatment. *Examples: Epoxy resins, rubber tires*.
Elastomers: Stretchy and elastic. *Example: Natural rubber*.

Composites

Combination of two or more materials, each maintaining its distinct identity.
Fiber-Reinforced Composites: Fibers in a matrix. *Example: Fiberglass (glass fibers in a polymer matrix)*.
Particle-Reinforced Composites: Particles in a matrix. *Example: Concrete (sand and gravel in a cement matrix)*.



Material Properties

Material properties are fundamental characteristics that determine how substances behave under various conditions, influencing their selection and application in engineering and science.

Types of Material Properties

Mechanical Properties: These include strength, ductility, hardness, and elasticity, which describe how a material responds to applied forces.

Thermal Properties: These properties, such as thermal conductivity and specific heat, determine how materials conduct and store heat.

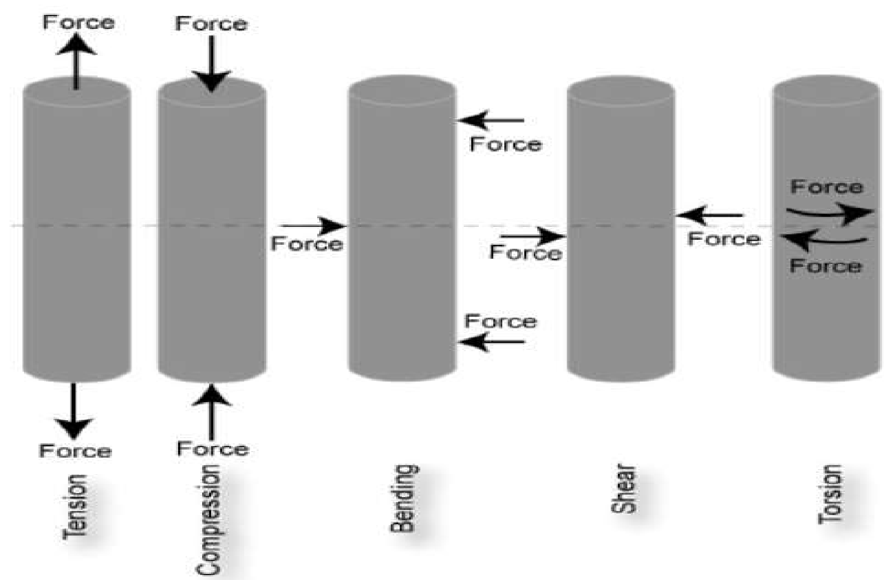
Electrical Properties: Conductivity, resistivity, and dielectric strength are key electrical properties that indicate how materials conduct electricity.

Chemical Properties: These properties describe a material's reactivity with other substances, including corrosion resistance and oxidation potential.

Definition of Mechanical Properties:
Mechanical properties of materials are the characteristics that dictate how a material responds to mechanical forces, such as strength, toughness, and ductility.

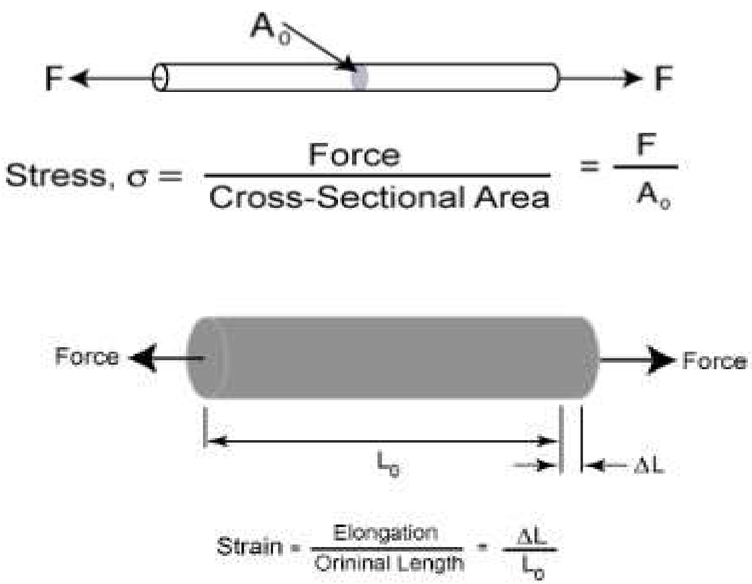
Some of the typical mechanical properties of a material include:

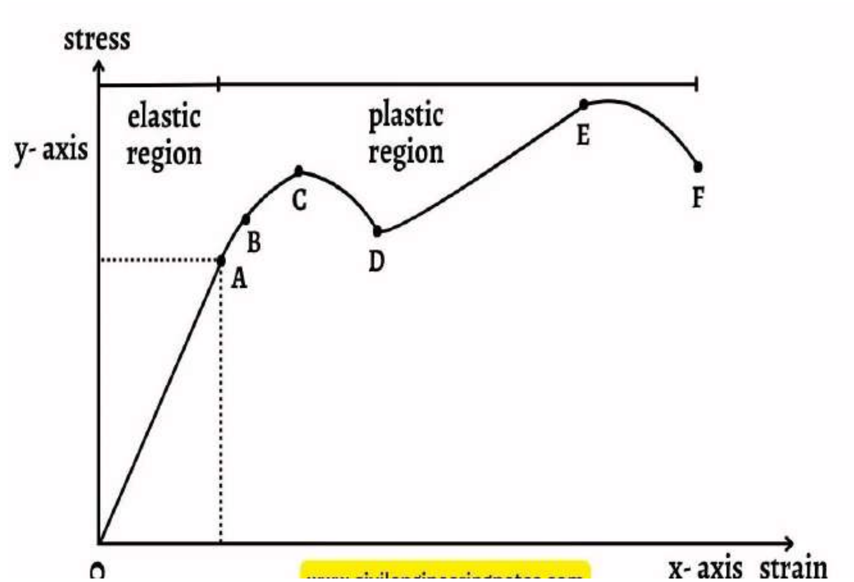
- Strength
- Toughness
- Hardness
- Hardenability
- Brittleness
- Malleability
- Ductility
- Creep and Slip
- Resilience
- Fatigue



Strength

It is the property of a material which opposes the deformation or breakdown of material in presence of external forces or load. Materials which we finalize for our engineering products, must have suitable mechanical strength to be capable to work under different mechanical forces or loads.





Toughness

It is the ability of a material to absorb the energy and gets plastically deformed without fracturing.
Its numerical value is determined by the amount of energy per unit volume.
Its unit is Joule/ m^3.
Value of toughness of a material can be determined by stress-strain characteristics of a material.
For good toughness, materials should have good strength as well as ductility.
For example: brittle materials, having good strength but limited ductility are not tough enough.
Conversely, materials having good ductility but low strength are also not tough enough.
Therefore, to be tough, a material should be capable to withstand both high stress and strain.

Hardness

It is the ability of a material to resist to permanent shape change due to external stress. There are various measure of hardness – Scratch Hardness, Indentation Hardness and Rebound Hardness.

- Scratch Hardness

Scratch Hardness is the ability of materials to the oppose the scratches to outer surface layer due to external force.

- Indentation Hardness

It is the ability of materials to oppose the dent due to punch of external hard and sharp objects.

- Rebound Hardness

Rebound hardness, or dynamic hardness, measures how high a diamond-tipped hammer bounces back after being dropped from a fixed height onto the material

Hardenability

- It is the ability of a material to attain the hardness by heat treatment processing.
- It is determined by the depth up to which the material becomes hard.
- The SI unit of hardenability is meter (similar to length).
- Hardenability is inversely proportional to a material's weldability, meaning materials easier to harden are typically harder to weld.

Brittleness

- Brittleness describes a material's tendency to fracture easily under stress, absorbing little energy and breaking with minimal strain.
- This property is the opposite of ductility and varies with temperature; for instance, some metals that are ductile at room temperature become brittle in cold conditions.

Malleability

- Malleability is a property of solid materials which indicates that how easily a material gets deformed under compressive stress.
- Malleability is often categorized by the ability of material to be formed in the form of a thin sheet by hammering or rolling.
- This mechanical property is an aspect of plasticity of material.
- Malleability of material is temperature dependent.
- With rise in temperature, the malleability of material increases.

Ductility

•Ductility is a property of a solid material which indicates that how easily a material gets deformed under tensile stress.

•Ductility is often categorized by the ability of material to get stretched into a wire by pulling or drawing.

•This mechanical property is also an aspect of plasticity of material and is temperature dependent.

•With rise in temperature, the ductility of material increases.

Creep and Slip

•Creep refers to the slow, permanent deformation of a material under sustained mechanical stress, typically occurring within the yield limit from prolonged exposure.

•This property is exacerbated in materials exposed to high temperatures over long periods.

•Slip, on the other hand, is defined as the movement along a plane densely packed with atoms.

Resilience

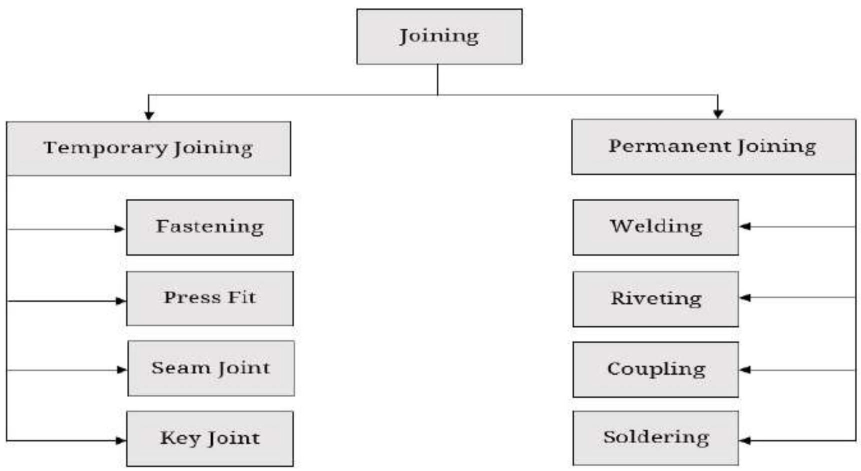
- Resilience is the ability of material to absorb the energy when it is deformed elastically by applying stress and release the energy when stress is removed.
- Proof resilience is defined as the maximum energy that can be absorbed without permanent deformation.
- The modulus of resilience is defined as the maximum energy that can be absorbed per unit volume without permanent deformation.
- It can be determined by integrating the stress-strain cure from zero to elastic limit. Its unit is joule/m^3.

Fatigue

- Fatigue is the weakening of a material due to repeated loading cycles.
- When cyclic loads exceed a certain threshold—yet remain below the material's ultimate strength—microscopic cracks can form at grain boundaries.
- These cracks grow until they reach a critical size, causing sudden fracture.
- Structural design, like the presence of square holes or sharp corners, significantly influences where fatigue cracks initiate.

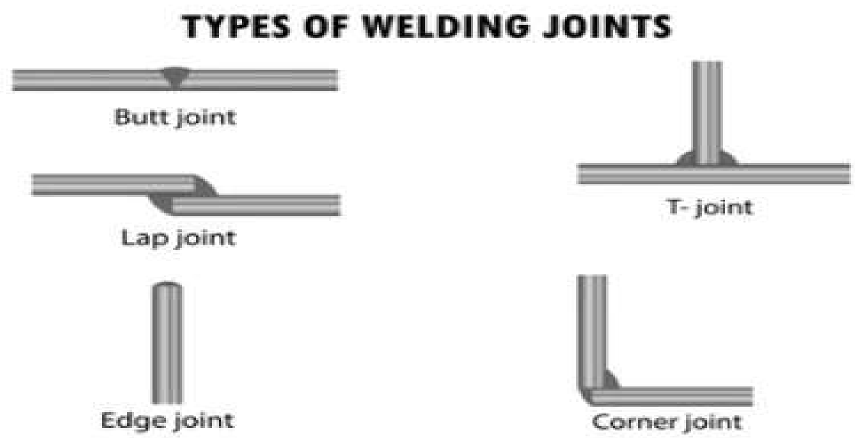
JOINING OF MATERIALS

Joining of materials is the process of connecting two or more components together, which can be done permanently or temporarily using various methods.
Common methods include welding, which uses heat and/or pressure to create a strong, permanent bond; mechanical joining, which uses fasteners like screws and rivets for either permanent or temporary connections; and adhesive bonding, which uses glues or cements to form a bond between surfaces.



WELDING

- Welding is a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone, and with or without the use of filler material.
- Welding is used for making permanent joints.
- It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.



Advantages of welding:

- Welding provides a permanent joint.
- Welded joint can be stronger than the parent materials if a proper filler metal is used that has strength properties better than that of parent base material and if defect less welding is done.
- It is the economical way to join components in terms of material usage and fabrication costs. Other methods of assembly require, for example, drilling of holes and usage of rivets or bolts which will produce a heavier structure.

Disadvantages of welding:

- Labour costs are more since manual welding is done mostly.
- Dangerous to use because of presence of high heat and pressure.
- Disassembly is not possible as welding produces strong joints.
- Some of the welding defects cannot be identified which will reduce the strength.

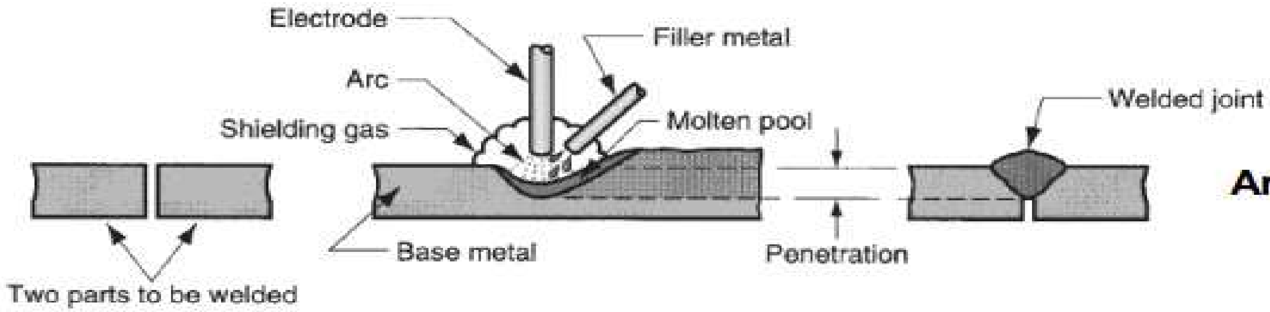
Types of welding:

- Welding processes can be broadly classified into

(i) fusion welding, and (ii) solid state welding

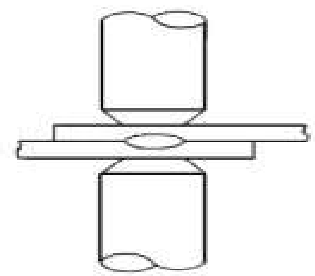
- Fusion welding: In fusion-welding processes, heat is applied to melt the base metals.
- In many fusion welding processes, a filler metal is added to the molten pool during welding to facilitate the process and provide strength to the welded joint.
- When no filler metal is used, that fusion welding operation is referred to as autogenous weld.
- Types: Arc welding, Resistance welding, Oxyfuel gas welding, electron beam welding, laser welding

Arc welding: In this operation, electric arc is used to produce heat energy and the base metal is heated. Sometimes, both pressure and heat are applied.



Arc welding steps

Resistance welding: In this operation, electric resistance is generated to the flow of current that generates heat energy between two contacting surfaces that are held in pressure.



Gas welding: Oxyfuel gas welding is a welding operation in which heat is generated by a hot flame generated mixture gas of oxygen and acetylene. This heat is used to melt base material and filler material, if used.

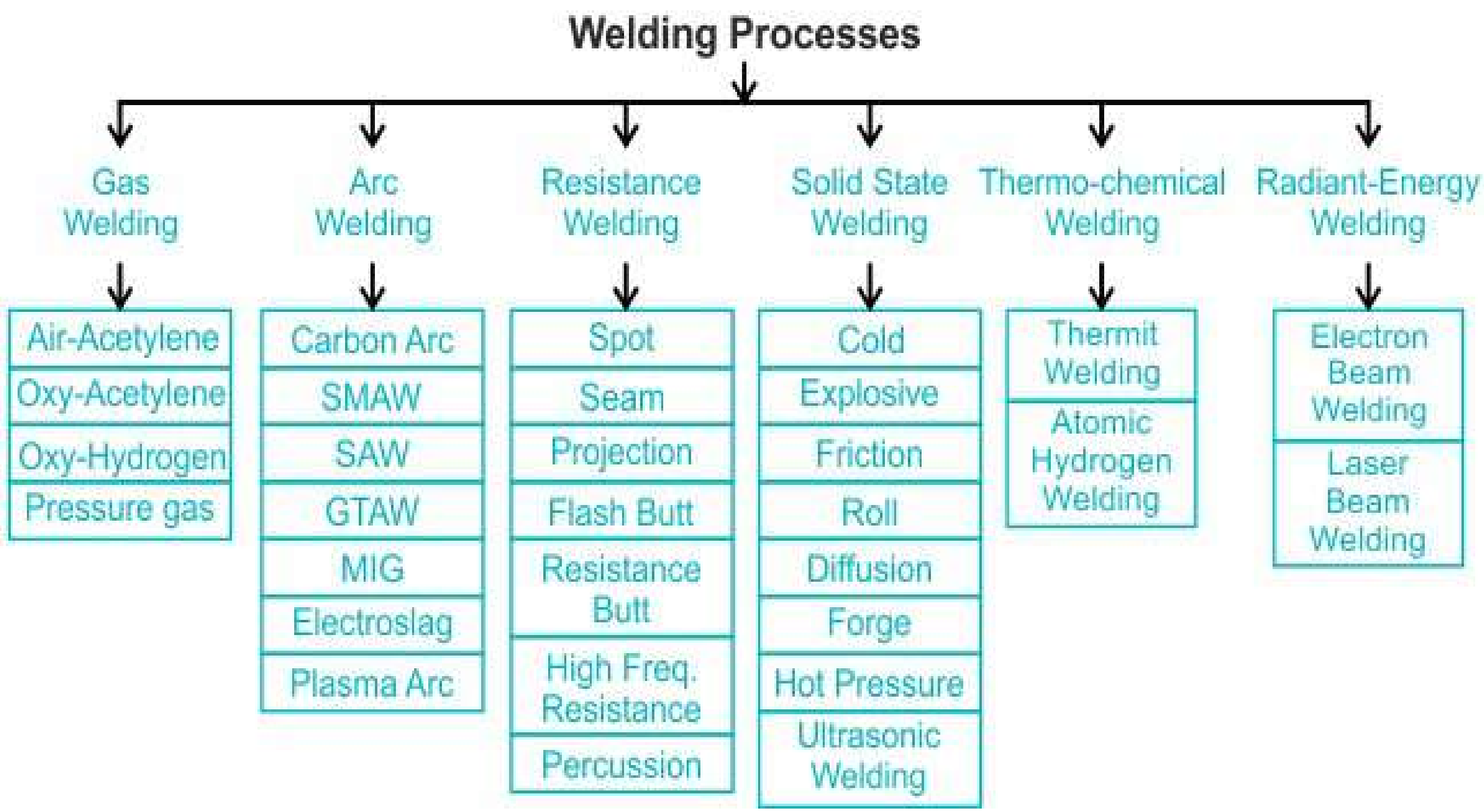
Solid State Welding:

• In this method, joining is done by coalescence resulting from application of pressure only or a combination of heat and pressure.
• Even if heat is used, the temperature in the process is less than the melting point of the metals being welded (unlike in fusion welding).
• No filler metal is utilized.

Diffusion welding: Two part surfaces are held together under pressure at elevated temperature and the parts join by solid state diffusion.

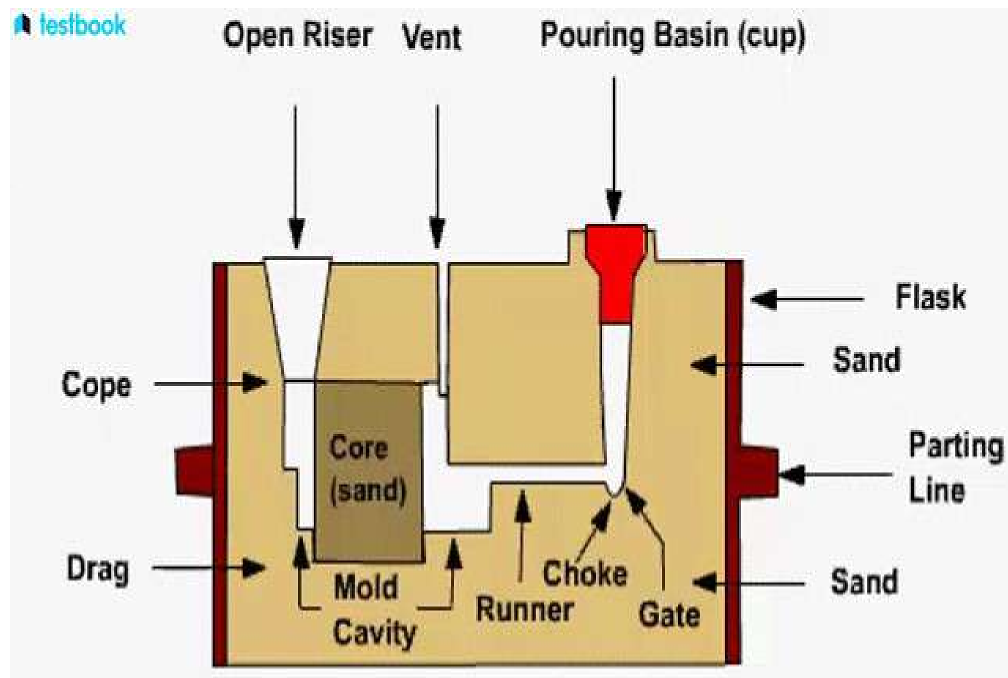
Friction welding/Stir welding: Joining occurs by the heat of friction and plastic deformation between two surfaces.

Ultrasonic welding: Moderate pressure is applied between the two parts and an oscillating motion at ultrasonic frequencies is used in a direction parallel to the contacting surfaces


Welding Processes
Gas Welding
Arc Welding
Resistance Welding
Solid State Welding
Thermo-chemical Welding
Radiant-Energy Welding
Air-Acetylene
Oxy-Acetylene
Oxy-Hydrogen
Pressure gas
Carbon Arc
SMAW
SAW
GTAW
MIG
Electroslag
Plasma Arc
Spot
Seam
Projection
Flash Butt
Resistance Butt
High Freq. Resistance
Percussion
Cold
Explosive
Friction
Roll
Diffusion
Forge
Hot Pressure
Ultrasonic Welding
Thermit Welding
Atomic Hydrogen Welding
Electron Beam Welding
Laser Beam Welding

Metal Casting Process:

- Casting is one of the oldest manufacturing process. It is the first step in making most of the products for which it's called basic manufacturing process.



Steps to be followed for a casting operation:

a) Making mould cavity

b) Liquefy or melt the material by properly heating it in a suitable furnace.

c) Liquid or molten metal is poured into a prepared mould cavity

d) Allowed to solidify

e) Product is taken out of the mould cavity, trimmed and made to shape.

Advantages of casting process:

- Molten material can flow into very small sections so that intricate shapes can be made by this process. As a result, many other operations, such as machining, forging, and welding, can be minimized.
- Possible to cast both ferrous and non-ferrous materials
- Tools are very simple and expensive
- Useful for small lot production
- Weight reduction in design
- No directional property

There are certain parts (like turbine blades) made from metals and alloys that can only be processed this way. Turbine blades: Fully casting + last machining

Limitations casting process:

- Accuracy and surface finish are not very good for final application.
- Difficult to remove defects due to presence of moisture.
- Metal casting is a labour intensive process.
- Automation

Application casting process:

Cylindrical bocks, wheels, housings, pipes, bells, pistons, piston rings, machine tool beds etc.

Flask: A metal or wood frame, without fixed top or bottom, in which the mould is formed. Depending upon the position of the flask in the moulding structure, it is referred to by various names such as:

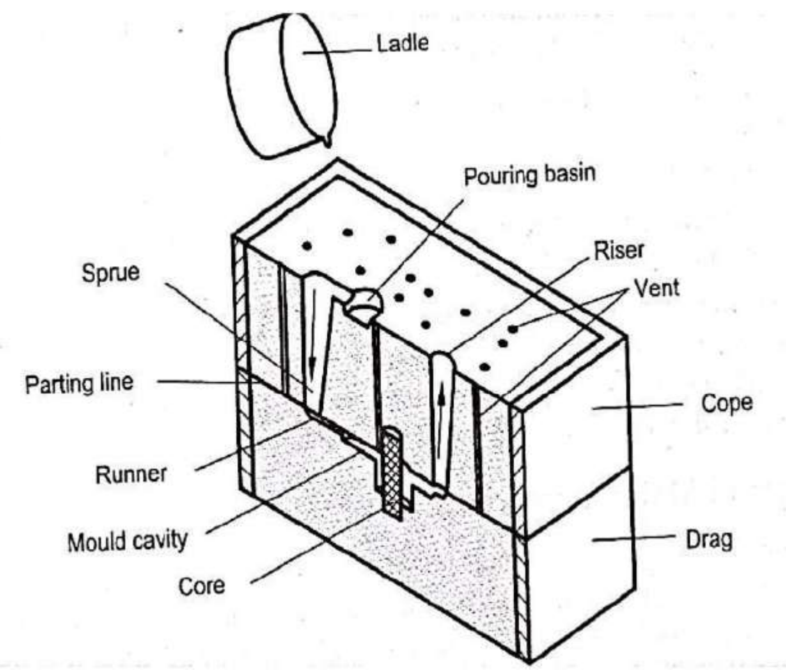
Drag: lower moulding flask, cope – upper moulding flask,

Cheek: intermediate moulding flask used in three piece moulding.

Pattern: It is the replica of the final object to be made. The mould cavity is made with the help of pattern.

Parting line: This is the dividing line between the two moulding flasks that makes up the mould.

Moulding sand: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.



Facing sand: The small amount of carbonaceous material sprinkled on the inner surface of the mould cavity to give a better surface finish to the castings.

Bottom board: Board used to start mould making (wood)

Backing sand: used and burnt sand

Core: A separate part of the mould, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.

Pouring basin: A small funnel shaped cavity at the top of the mould into which the molten metal is poured.

Sprue: The passage through which the molten metal, from the pouring basin, reaches the mould cavity. In many cases it controls the flow of metal into the mould.

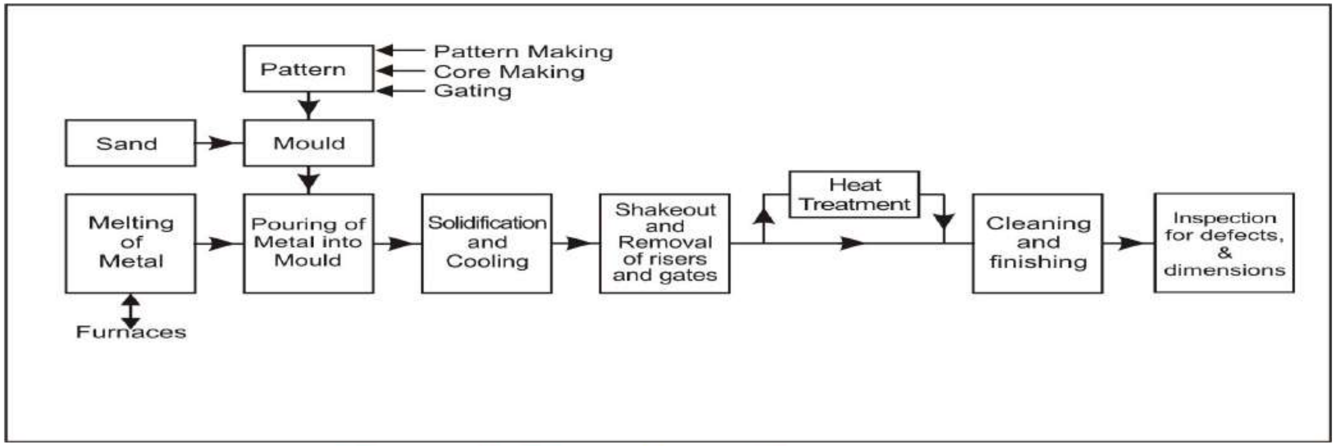
Runner: The channel through which the molten metal is carried from the sprue to the gate.

Gate: A channel through which the molten metal enters the mould cavity.

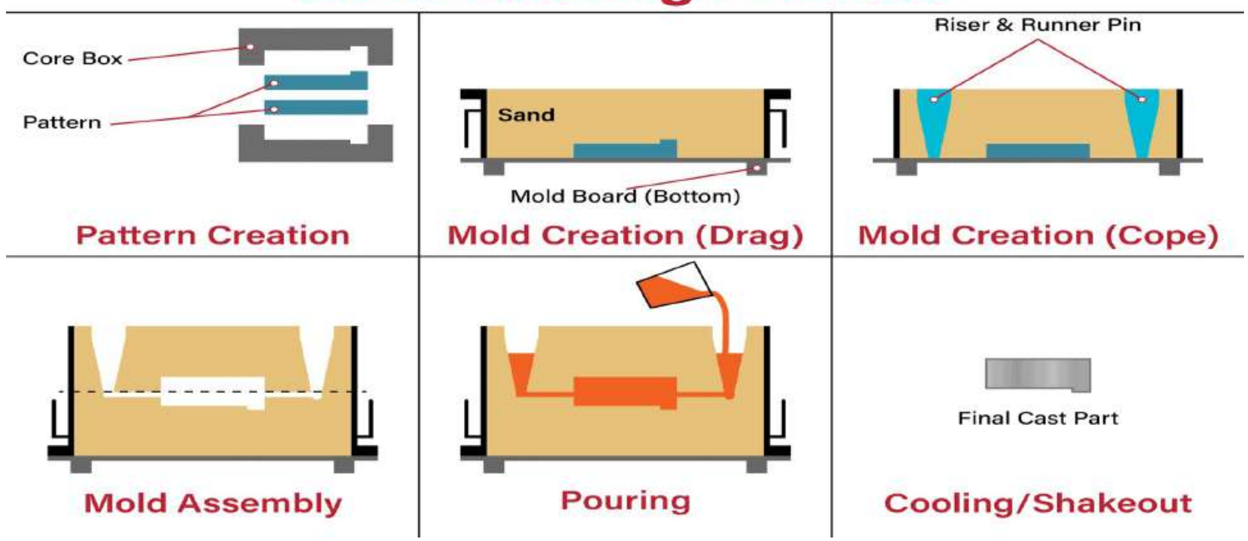
Chaplets: Chaplets are used to support the cores inside the mould cavity to take care of its own weight and overcome the metallostatic force.

Riser: A column of molten metal placed in the mould to feed the castings as it shrinks and solidifies. Also known as “feed head”.

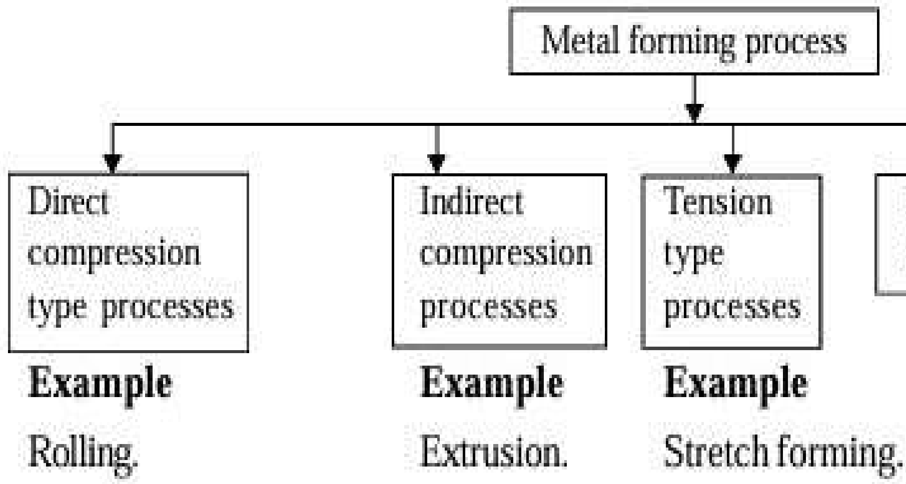
Vent: Small opening in the mould to facilitate escape of air and gases.



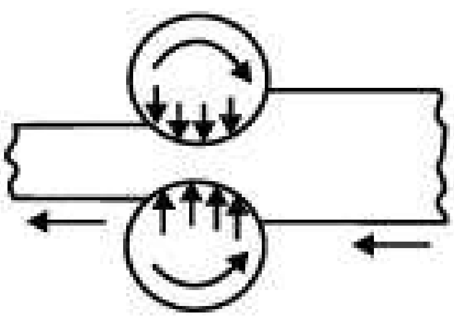
Sand Casting Process



Metal Forming Processes



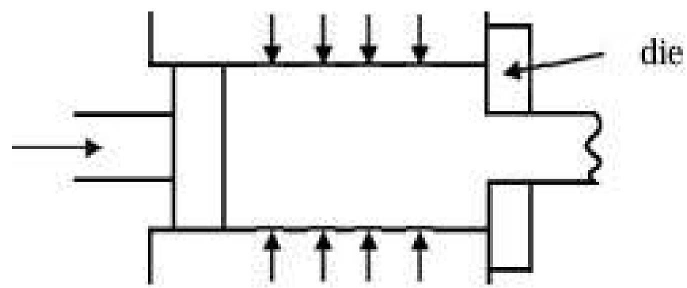
Direct Compression Process



In this process the force is applied to the workpiece surface. Here the metal flows at right angles to the compression direction. Rolling and forging are the examples of direct compression process

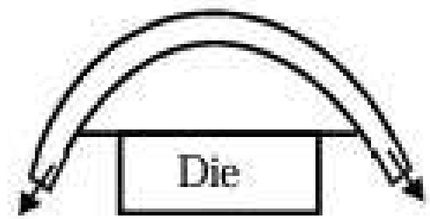
Indirect Compression Process

In this type of process the applied forces are tensile, but the indirect compressive forces are generated by the reaction of workpiece with the die. Extrusion is an example of indirect compression process as shown in Fig.



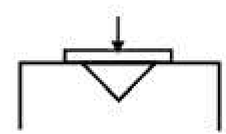
Tension Type Forming Process

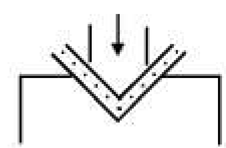
In this type of process the sheet metal is wrapped to the contour of a die applying of tensile force. Stretch forming is an example of tension type forming process as shown in Fig.



Bending Process

Bending is the process where bending moment is applied to the sheet. V–bending is one of the examples of bending process



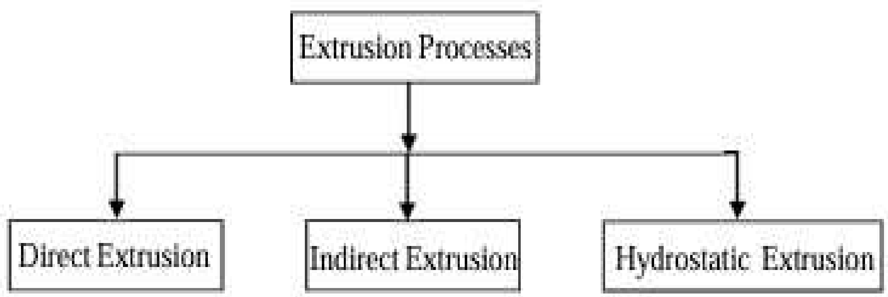


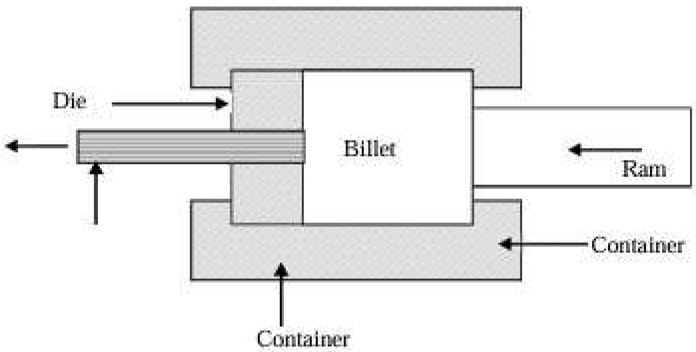
Shearing Process

Shearing is the process where shearing forces are applied to rupture the metal in the shear plane

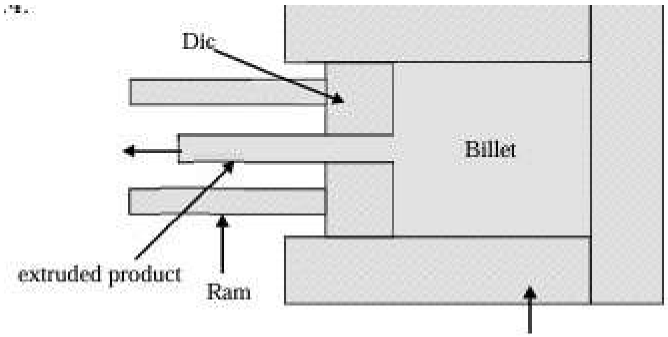
Extrusion

1. In extrusion, a block of metal (billet) is forced to flow through an opening having a smaller cross sectional area than that of the original billet.
2. The opening is provided by a die designed to give the desired shape to the product.
3. More importantly, die geometry remains the same throughout the operation, extended products have a constant section.

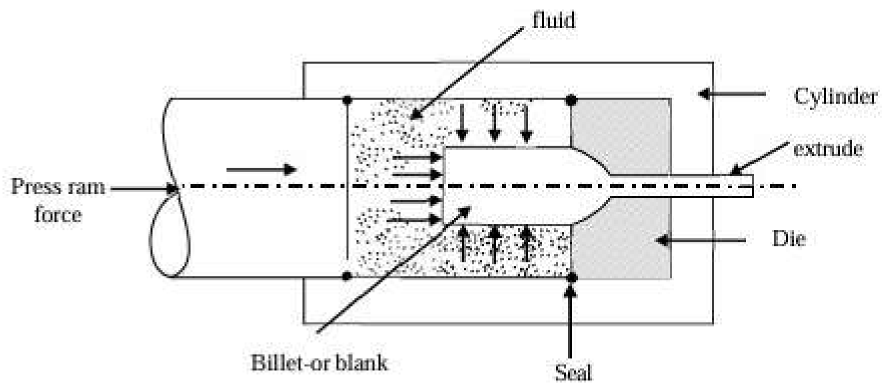




Direct Extrusion



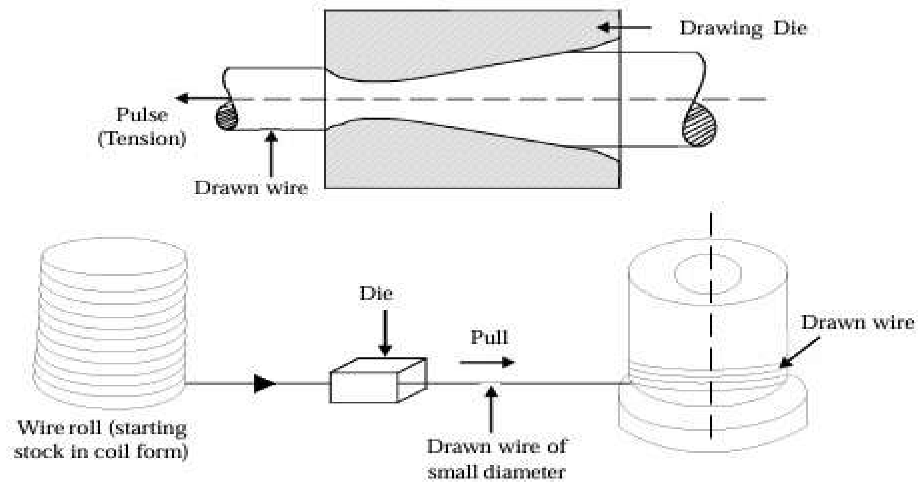
Indirect Extrusion



Hydrostatic Extrusion

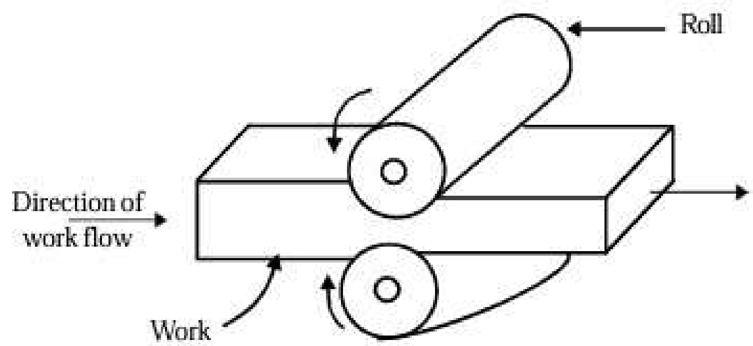
Wire Drawing

1. Drawing operations involve pulling metal through a die by means of a tensile force applied to the exit side of the die.
2. The plastic flow is caused by compression force, arising from the reaction of the metal with the die wire drawing is a bulk deformation process involving pulling the wire, tube or strip through a converging die.



Rolling

1. Rolling is the primary metal forming process.
2. In the rolling process, the piece of metal is passed through two rolls rotating in opposite directions at a uniform speed.
3. The gap between the rolls is adjusted to confirm to the desired thickness of rolled section.
4. Rolling is the process of reducing thickness or changing the cross sectional area of workpiece by means of rolling mills. The metal is subjected to highly compressive force between the rolls for deformation.



TERMINOLOGY USED IN ROLLED PRODUCTS

Bloom

Width of bloom equals to its thickness. This is square cross section varying from billet : 150 mm × 150 mm to 400 mm × 400 mm.

Billet

Minimum cross sectional area is 40 mm × 40 mm and varies upto 150 mm × 150 mm.

Slab

It is a hot rolled ingot with cross section with width varying form 500 mm to 1800 mm and thickness varying from 50 to 300 mm.

Plate

Plate has a thickness greater than 6 mm.

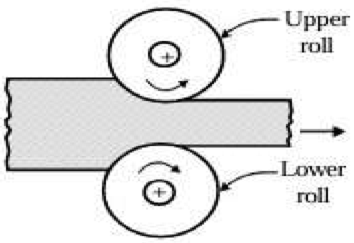
Sheet

Thickness less than 6 mm and has a greater width.

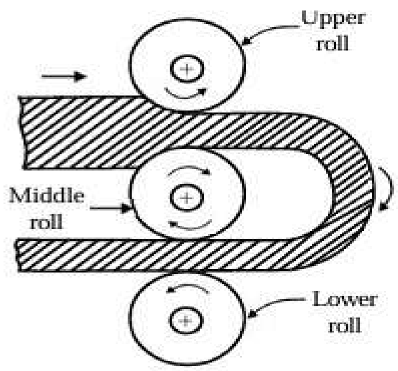
Strip

Strip refers to rolled product with a width not more than 600 mm and thickness less than 6 mm.

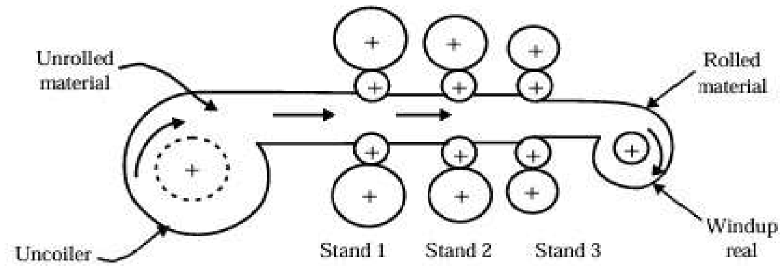
TYPES OF ROLLING MILLS



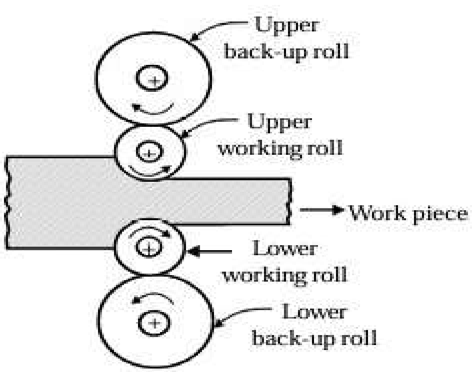
(a) Two-high roll mill



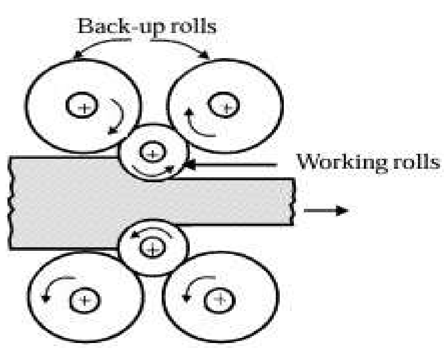
(b) Three high roll mill



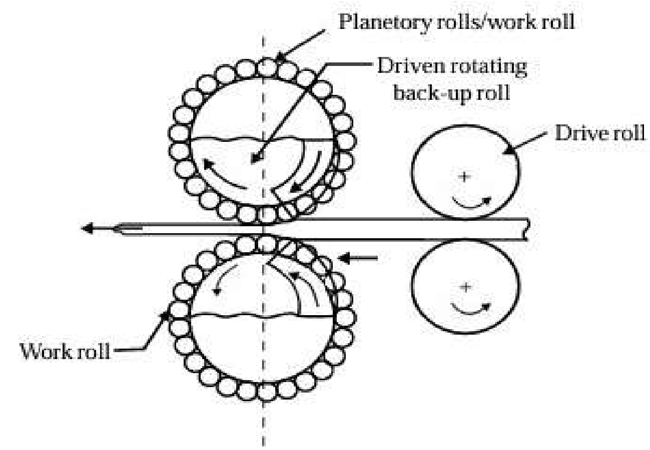
(e) Cluster rolling mill



(c) Four-high roll mill



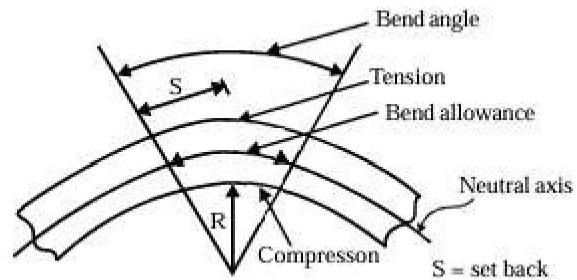
(d) Cluster rolling mill



(f) Arrangement of rolls in a planetary rolling mill.

Sheet Metal Working

BENDING PROCESS



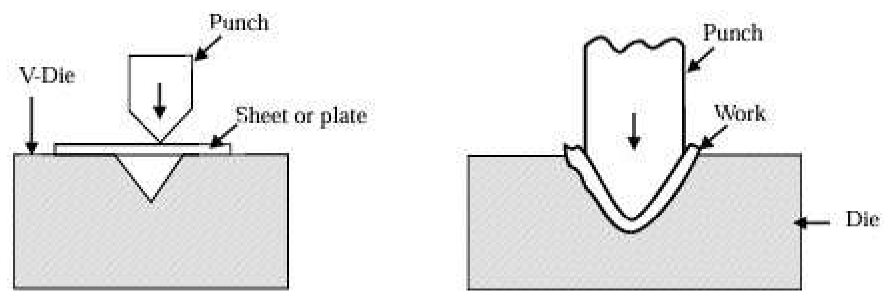


Fig. 7.2 V and U bending

FORMING PROCESS

In the forming process the part takes the shape of the punch or die.
The commonly used forming dies are

- Solid form dies
- Pad type form dies
- Embossing dies
- Coining dies
- Bending dies

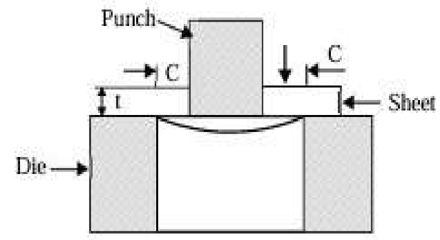
The sheet metal forming processes can be classified into mainly two categories. They are :

1. Shearing process
2. Forming process

Shearing Process

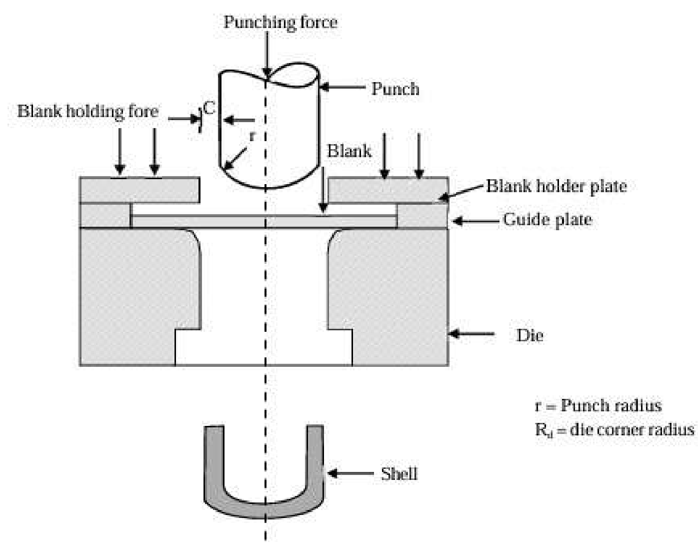
1. Shearing is a cutting operation used to remove a blank of required diemnsions from a large sheet.
2. Shearing process includes.

- Punching
- Blanking
- Perforating
- Parting
- Notching
- Lancing



DEEP DRAWING

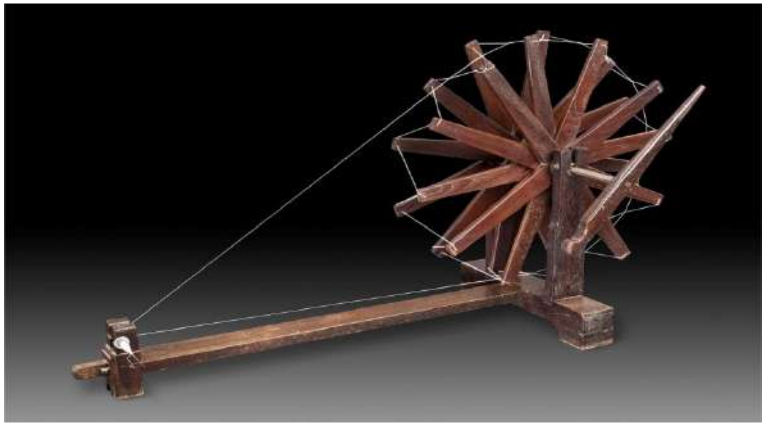
Deep drawing is defined as the process for the making of cup shaped parts from flat sheet metal blanks.



Basic Power Transmission Devices
Belt, Gear Drives, Clutch, Brakes
(Basic Mechanical Engineering)

Traditional Relevance of Power Transmission Devices

Potter’s Wheel



Charkha (Spinning

Ancient Water Mill Wheels

Bullock-Driven Oil Mills (Ghani)

What is Power Transmission?

- The mechanism of efficiently transferring **mechanical energy** (motion/power/torque) from a prime mover (like an engine or motor) to an output device (like a machine, wheel, or pump).
- It often involves changing the **speed** and/or **torque** and sometimes the **direction** of rotation.

Power Transmission Devices

Definition:

- Power transmission devices are **mechanical elements** used to **transfer energy (power) and motion** from one shaft or machine component to another.
- They ensure efficient transfer of mechanical power with desired speed, torque, and direction.

Key Devices:

- **Drives (Belt/Gear):** Used for continuous power transfer between two shafts.
- **Clutch:** Used to **engage** or **disengage** power transmission when required.
- **Brake:** Used to **stop** or **retard** motion by absorbing kinetic energy.

Belt Drive

Definition:

A flexible connector (belt) running over two or more pulleys to transmit power between shafts that are relatively far apart.

Working Principle (Friction Drive):

- The driving pulley rotates, causing tension in the belt.
- Power is transmitted due to **friction** between the belt and the pulley surfaces.
- Tension causes one side of the belt (**tight side**) to pull the driven pulley, while the other side (**slack side**) has lower tension.
- The difference in tension between the tight and slack sides creates the necessary **torque** to drive the second pulley.

Types:

- **Flat Belt:** Simple, economical, used for long distances.
- **V-Belt:** Trapezoidal cross-section, relies on **wedging action** in the pulley groove, providing higher friction and less slip.

Flat Belt

V Belt

A flat belt is running on a pulley of **diameter 0.6 m** at a speed of **8 m/s**.The **maximum tension (T_1)** in the belt is **300 N**, and the **ratio of tight side to slack side tension (T_1/T_2)** is **2.5**.
Find:

1. Tension on the slack side (T_2)
2. Power transmitted by the belt

Given Data

Diameter of pulley, $D = 0.6\ m$
Belt speed, $v = 8\ m/s$
Maximum (tight side) tension, $T_1 = 300\ N$
Ratio $\frac{T_1}{T_2} = 2.5$

Step 1: Find Slack Side Tension (T_2)

$$\frac{T_1}{T_2} = 2.5$$
$$T_2 = \frac{T_1}{2.5} = \frac{300}{2.5} = 120\ N$$

Concept Recap
T_1 :Tension on tight side
T_2 :Tension on slack side
Power transmitted: $P = (T_1 - T_2) \times v$
Speed, $v = \frac{\pi DN}{60}$)if speed is given in rpm)

Step 2: Power Transmitted

Power transmitted by the belt:
$$P = (T_1 - T_2) \times v$$
Substitute values:
$$P = (300 - 120) \times 8$$
$$P = 180 \times 8 = 1440\ W$$
$$\boxed{P = 1.44\ kW}$$

Gear Drive

Definition:

Toothed wheels (gears) that mesh directly to transmit power and motion between rotating shafts.

Working Principle (Friction Drive):

- Power is transmitted by the successive **engagement of teeth** of the driving gear (pinion) with the teeth of the driven gear.
- This direct, positive contact eliminates slip, ensuring a **precise velocity ratio** (ratio of rotational speeds).
- **Speed/Torque Modification:** Changing the ratio of the number of teeth (or gear diameter) changes the output speed and torque.
- The difference in tension between the tight and slack sides creates the necessary **torque** to drive the second pulley.

Types:

- Spur Gears **:** Parallel shafts, straight teeth..
- Helical Gears **:** Parallel shafts, inclined teeth.
- Bevel Gears : Intersecting shafts, used to change the axis of rotation

Spur

Helical

Bevel Gears

A **20 kW** motor drives a **machine shaft** through a pair of **spur gears**. The **motor shaft rotates at 1200 rpm**, and the **machine shaft rotates at 400 rpm**. The **motor gear has 20 teeth**.Find:
The **number of teeth** on the machine (driven) gear.
The **torque** on the motor shaft and on the machine shaft.

Given Data

Power, $P = 20\ kW = 20{,}000\ W$
Speed of driving (motor) gear, $N_1 = 1200\ rpm$
Speed of driven (machine) gear, $N_2 = 400\ rpm$
Teeth on driver gear, $T_1 = 20$

Step 1: Find Number of Teeth on Driven Gear

$$N_2/N_1 = T_1/T_2$$

$$T_2 = T_1 \times \frac{N_1}{N_2}$$

$$T_2 = 20 \times \frac{1200}{400} = 20 \times 3 = 60$$

Step 2: Find Torque on Motor Shaft (Driver)

Power transmitted by a rotating shaft:

$$P = \frac{2\pi NT}{60}$$

For **motor shaft**:

$$T_1 = \frac{20{,}000 \times 60}{2\pi \times 1200}$$

$$T_1 = \frac{1{,}200{,}000}{7539.8} \approx 159.2\ N.m$$

Step 3: Find Torque on Machine Shaft (Driven)

Power is the same (ignoring losses), so:

$$T_2 = \frac{P \times 60}{2\pi N_2}$$

$$T_2 = \frac{20{,}000 \times 60}{2\pi \times 400}$$

$$T_2 = \frac{1{,}200{,}000}{2513.3} \approx 477.5\ N.m$$

Concept Recap

Gear ratio $= \frac{T_2}{T_1} = \frac{N_1}{N_2}$

Power $P = \frac{2\pi NT}{60}$

As speed decreases, torque increases proportionally (for same power).

Clutch

Definition:

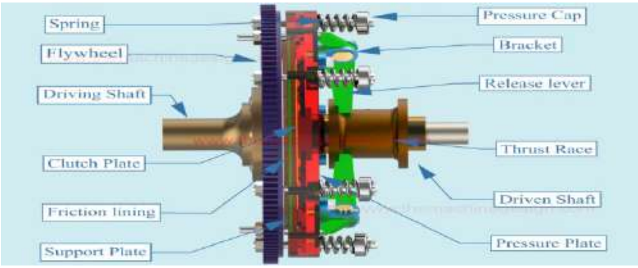
A mechanical device used to **connect** a driving shaft (engine) to a driven shaft (transmission) **selectively** (at the will of the operator).

Working Principle (Friction):

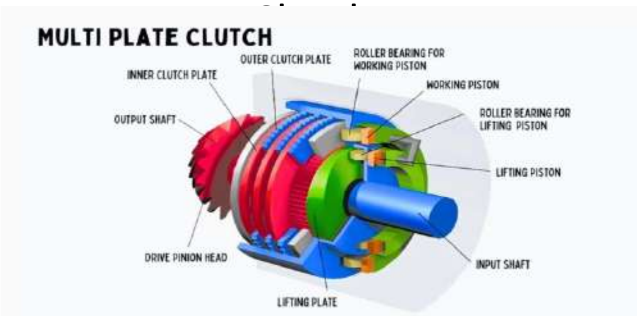
- **Engaged (Power ON):** Springs press the **clutch plate** firmly against the **flywheel** (attached to the engine). The resulting **friction** locks the two components together, transmitting the engine's torque to the driven shaft.
- **Disengaged (Power OFF):** The operator pushes the clutch pedal, causing a release mechanism to pull the pressure plate away from the clutch plate. This breaks the frictional contact, allowing the engine to spin without transferring power to the driven shaft, which is necessary for starting or shifting gears.

Types:

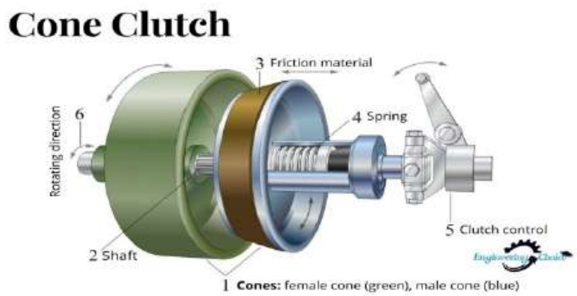
- Single Plate Clutch**:** Parallel shafts, straight teeth.
- Multi Plate Clutch **:** Parallel shafts, inclined teeth.
- Cone Clutch: Intersecting shafts, used to change the axis of rotation



Single Plate



Multi Plate Clutch



Cone Clutch

Brake

Definition:

A device used to slow down or stop a moving machine element (wheel, shaft, axle) by converting its **kinetic energy** into **heat energy**.

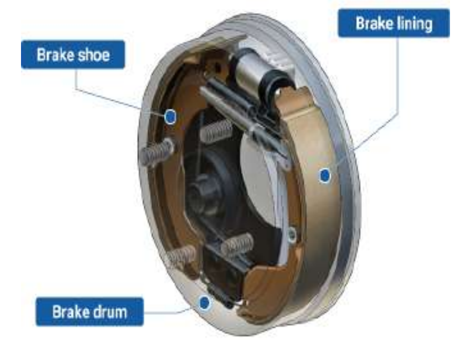
Working Principle (Friction and Energy Conversion**):**

- When activated, **friction material** (pads or shoes) is forced against a rotating element (rotor/disc or drum).
- The resulting **friction** opposes the motion and generates heat.
- This friction force applies a **braking torque** that slows down the rotation.
- The kinetic energy of the moving mass is effectively **dissipated as heat** into the surrounding air.

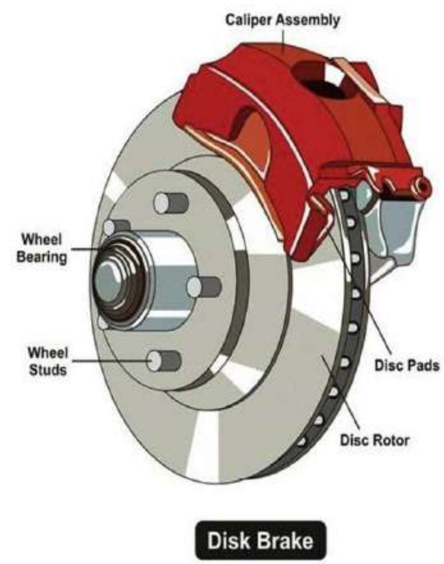
Types:

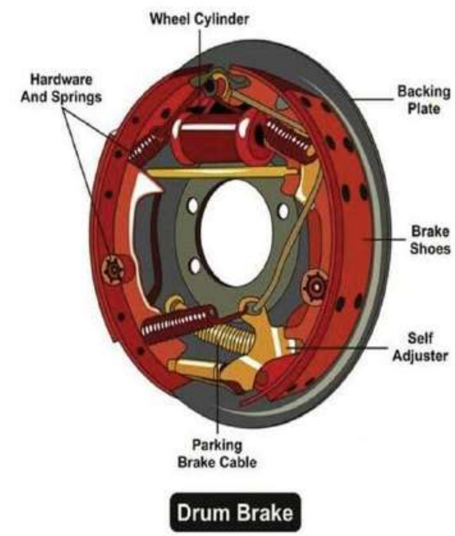
- **Disc Brake:** Pads squeeze a rotating **disc** (rotor).
- **Drum Brake:** Shoes press against the inner surface of a rotating **drum**.

Disc Brake



Drum Brake





A **single shoe brake** is used to stop a rotating drum.The drum has a **diameter of 500 mm** and rotates at **300 rpm**. The **coefficient of friction (μ)** between the shoe and the drum is **0.35**,and the **normal force (N)** acting on the shoe is **200 N**. Find:The **braking torque and** The **power absorbed** by the brake at that speed

Given Data

D=500 mm=0.5 m

$$N = 200\ N$$

$$\mu = 0.35$$

$$\text{Speed} = 300\ rpm$$

Step 1: Find Radius of the Drum

r=D/2=20.5=0.25 m

Step 2: Find the Frictional (Tangential) Force

F=μ×N

$$F = 0.35 \times 200 = 70\ N$$

Step 3: Find the Braking Torque

T=F×r

$$T = 70 \times 0.25 = 17.5\ N.m$$

Step 4: Find Power Absorbed by the Brake

$$P = \frac{2\pi NT}{60}$$

$$P = 2\pi \times 200 \times 17.5/60 = 549.8\,W$$

$$\boxed{P = 0.55\,kW}$$

Concept Recap

Concept Recap

Frictional Force: $F = \mu N$

Braking Torque: $T = F \times r$

Power Absorbed: $P = \frac{2\pi NT}{60}$

When brakes apply, kinetic energy → heat energy

Comparison and Applications

Device	Primary Function	Principle	Key Advantage	Typical Application
Belt Drive	Continuous Power Transmission	Friction (usually)	Used for long shaft distances	Washing machines, factory conveyors
Gear Drive	Continuous Power Transmission	Positive Meshing	High efficiency, compact size	Automotive gearboxes, clock mechanisms
Clutch	Engage/Disengage Power	Friction	Allows smooth starting/gear shifting	Manual transmission vehicles
Brake	Stop/Retard Motion	Friction/Energy Conversion	Converts kinetic energy to heat to stop motion	All types of vehicles and hoisting machinery

Robotics

The three Rs of robotics are Repeatability (consistency of task performance), Reliability (dependability of operation), and Robustness (resilience to varying conditions)

The "4 Ds" of robotics are Dull, Dirty, Dangerous, and Dear, a principle used to categorize tasks that are ideal for automation.
Robots are deployed for these tasks because they are often repetitive, unhygienic, risky, or costly for humans to perform.

Industrial Robotics

- An industrial robot is defined as "an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications."
- Industrial robots commercially and technologically important :

1. Robots can be substituted for humans in hazardous or uncomfortable work environments.

2. A robot performs its work cycle with a consistency and repeatability that cannot be attained by humans.

3. Robots can be reprogrammed. When the production run of the current task is completed, a robot can be reprogrammed and equipped with the necessary tooling to perform an altogether different task.

4. Robots are controlled by computers and can therefore be connected to other computer systems to achieve computer integrated manufacturing.

Laws of Robotics

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

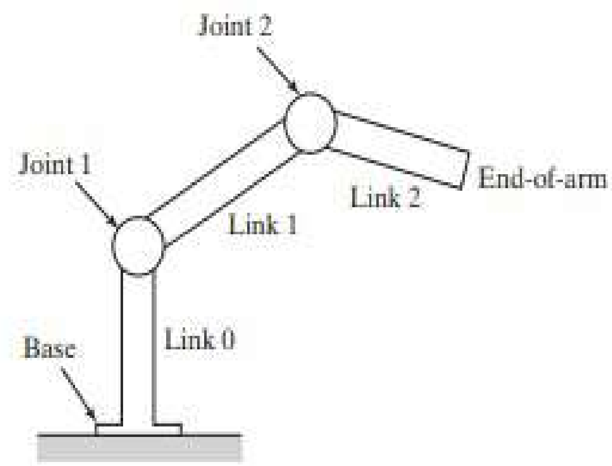
Robot Anatomy

- The physical construction of the body, arm and wrist of the machine
- The wrist is oriented in a variety of positions
- Relative movements between various components of body, arm and wrist are provided by a series of joints
- Joints provide either sliding or rotating motions
- The assembly of body, arm and wrist is called "**Manipulator**".
- The arm or manipulator of an industrial robot consists of a series of joints and links

Source: https://www.thomasnet.com/insights/industrial-robots-can-do-more-than-just-pick-and-place

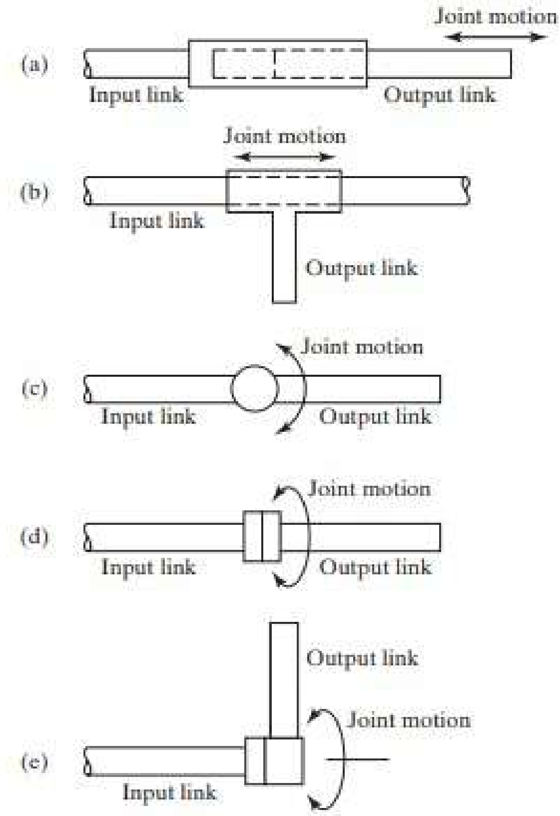
Joints and Links

- A robot's joint is similar to a joint in the human body as it provides relative motion between two parts of the body.
- Connected to each joint are two links, an input link and an output link.
- Links are the rigid components of the robot manipulator.
- The purpose of the joint is to provide controlled relative movement between the input link and the output link.

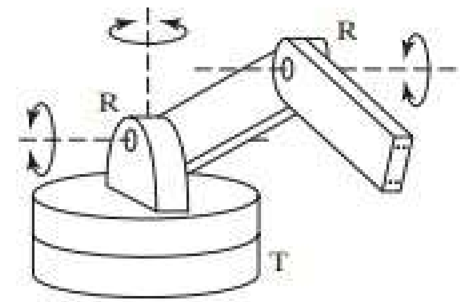


Joints

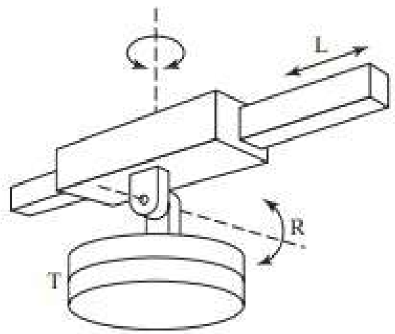
1. Linear joint (type L joint). The relative movement between the input link and the output link is a translational telescoping motion, with the axes of the two links being parallel.
2. Orthogonal joint (type O joint). This is also a translational sliding motion, but the input and output links are perpendicular to each other.
3. Rotational joint (type R joint). This type provides rotational relative motion, with the axis of rotation perpendicular to the axes of the input and output links.
4. Twisting joint (type T joint). This joint also involves rotary motion, but the axis of rotation is parallel to the axes of the two links.
5. Revolving joint (type V joint, V from the "v" in revolving). In this joint type, the axis of the input link is parallel to the axis of rotation of the joint, and the axis of the output link is perpendicular to the axis of rotation.



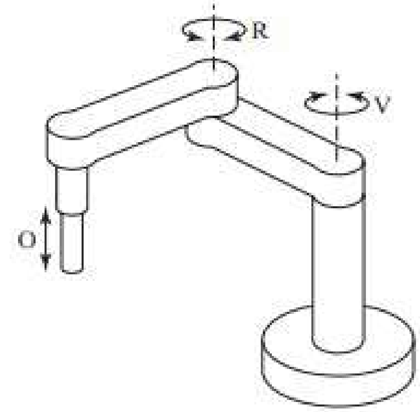
Body and Arm Configurations



- Articulated robot (jointed-arm robot) TRR



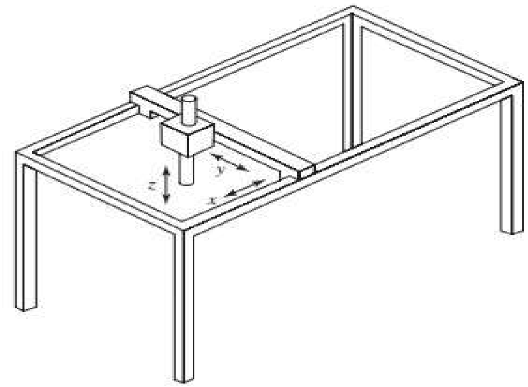
- Polar configuration TRL



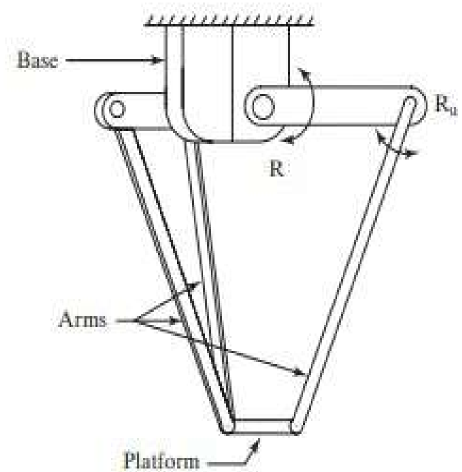
- SCARA(Selectively Compliant Arm for Robotic Assembly) VRO

Body and Arm Configurations

- Cartesian coordinate robot (OOO)

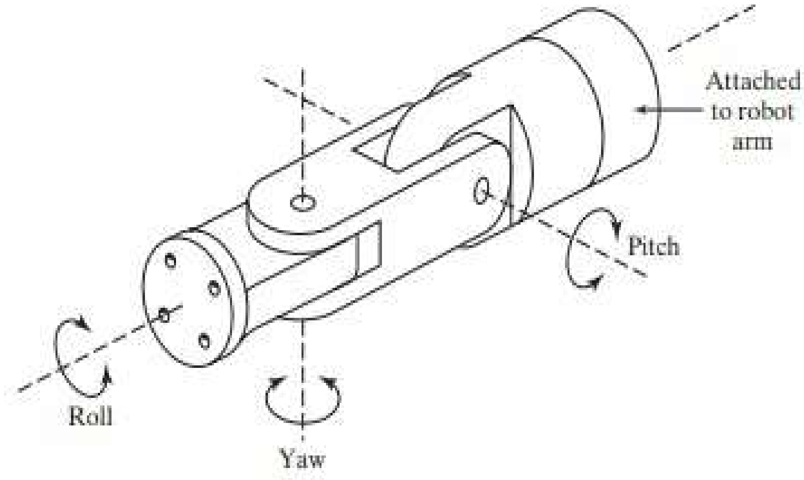


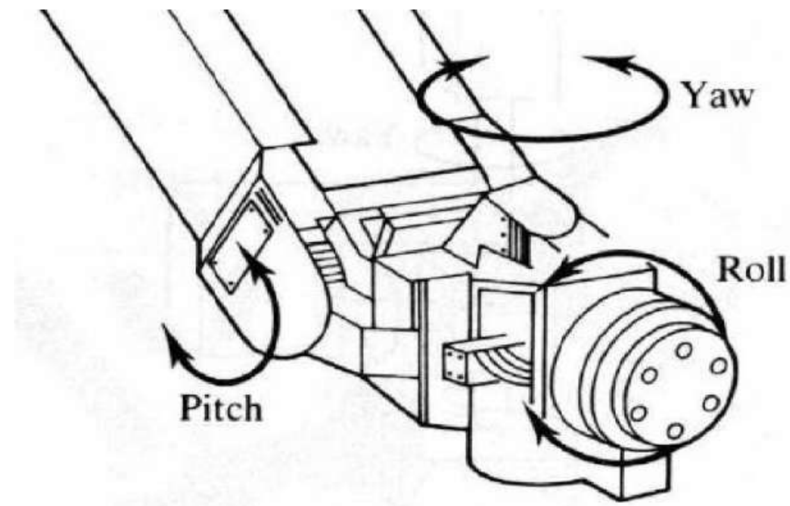
- Delta robot $3(RR_u)$



Wrist Configurations

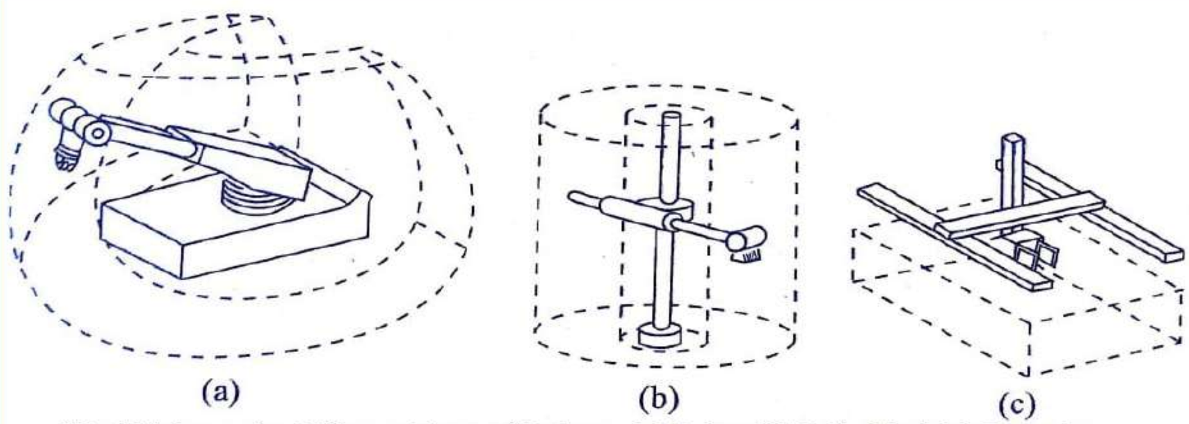
- Wrist movement enable the robot to orient the end effector properly to perform a task
- Provided with up to 3 DOF which are:
  1. Wrist Pitch/Bend: Provide up-and-down rotation to the wrist
  2. Wrist Yaw: Involve right-and-left rotation of the wrist
  3. Wrist Roll/Swivel: Is the rotation of the wrist about the arm axis





Robot Work Volume

- The work volume (also known as work envelope) of the manipulator is defined as the three-dimensional space within which the robot can manipulate the end of its wrist.
- End effector may not be capable of reaching certain points within the robot’s normal work volume
- Larger volume costs more but can increase capabilities of robot
- It depends upon following physical characteristics:
  - Robot’s configuration
  - Size of the body, arm and wrist components
  - Limits of the robot’s joint movements



Work Volumes for Different Types of Robots : **(a) Polor, (b) Cylindrical, (c) Cartesian**

Question Bank for Examination

1. Classify engineering materials and give examples for each category.
2. Explain the mechanical properties of materials such as strength, hardness, toughness, and ductility.
3. Discuss the steps involved in casting and state its advantages and limitations.
4. Explain the working principle of belt and gear drives with neat sketches.
5. What are clutches and brakes? Explain their working principles briefly.
6. Define robot, explain its anatomy, and describe common robot configurations (e.g., Cartesian, Cylindrical, Articulated).
7. Define manufacturing.
8. What is the difference between ferrous and non-ferrous materials?
9. Define elasticity and plasticity.
10. Define forming. What are the advantages of forming over casting?
11. Explain rolling and extrusion processes with sketches.
12. Explain different types of welding joints with neat sketches.
13. A mild steel rod of 20 mm diameter is subjected to a tensile load of 15 kN. Calculate the stress and strain produced if the modulus of elasticity is 2×10^5 N/mm^2.
14. During a rolling process, the input thickness of a metal sheet is 4 mm and the output thickness is 3 mm. Calculate the percentage reduction.
15. Write short notes on (a) Clutch (b) Brake.
16. Explain the anatomy of a robot with labeled parts.
17. Explain the concept of joints and links in robotic arms with examples.
18. Define Work envelop in Robotics.