



**CONCEPTS OF MECHANICAL ENGINEERING
25ME11I**

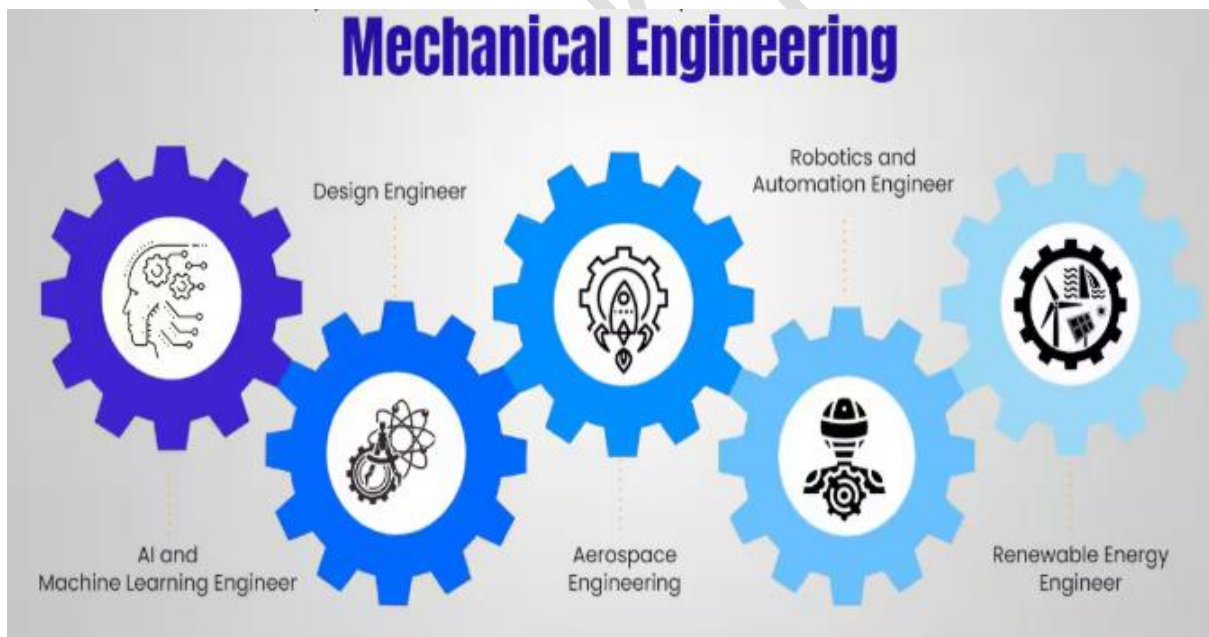
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WEEK 01

INTRODUCTION TO MECHANICAL ENGINEERING

- ❖ Introduction to Mechanical Engineering,
- ❖ Scope of Mechanical Engineering
- ❖ Career's opportunities for Mechanical Engineers
- ❖ Fundamental Units – Definition and units of Length, Mass, Time & Temperature in CGS, FPS, MKS & SI Units with conversions.
- ❖ Derived Units – units of Area, Volume, Density, Velocity, Acceleration, Force, Work, Energy Power in CGS, FPS, MKS & SI Units with conversions.
- ❖ (Formulae & Simple numerical examples)



1.1 Introduction to Mechanical Engineering:

Mechanical engineering is the study of physical machines that may involve force and movement. It is an engineering branch that combines engineering physics and principles of mathematics with materials science, to design, analyse, manufacture and maintain mechanical systems.

Its primary goals are to convert energy into productive forms; design, develop, produce and test machines; and understand and apply the interactions of solids, liquids and gases.

It is one of the oldest and broadest branch in the engineering field, Mechanical engineering requires an understanding of main areas such as mechanics, dynamics, thermodynamics, materials science, design, structural analysis and electricity.

In addition to above core principles, mechanical engineers use the tools such as computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE) and product lifecycle management to design and analyse the manufacturing plants, industrial equipment and machinery, heating and cooling systems, transport systems, motor vehicles, aircraft, watercraft, robotics, medical devices, weapons and others.

Mechanical engineering emerged as a field during the Industrial Revolution in Europe in the 18th century; however, its development can be traced back several thousand years around the world. In the 19th century, developments in physics led to the development of mechanical engineering science.

This field is continually developing to incorporate advancements, today mechanical engineers are pursuing developments in such areas as composites, mechatronics and nanotechnology. It also overlaps with aerospace engineering, metallurgical engineering, civil engineering, structural engineering, electrical engineering, manufacturing engineering, chemical engineering, industrial engineering and other engineering

Disciplines to varying amounts. Mechanical engineers may also work in the field of biomedical engineering, specifically with biomechanics, transport phenomena, bio-mechatronics, bio-nanotechnology and modelling of biological systems.

They also explore the behaviour of these systems in response to forces and understand how they interact with their environment. Mechanical engineering is a broad field that covers a wide range of topics, such as thermodynamics, fluid mechanics, material science, robotics and control systems.

1.2 Scope for Mechanical Engineering:

Mechanical engineering in India has a wide scope, with opportunities in many sectors. Mechanical engineers are in high demand and the field is expected to grow in the future.

Sectors:

Manufacturing Mechanical engineers can work in manufacturing plants.

- 1) **Automotive:** Mechanical engineers can work in the automotive industry.
- 2) **Aerospace:** Mechanical engineers can design and test aircraft, missiles and spacecraft.
- 3) **Energy:** Mechanical engineers can work in the energy sector.
- 4) **Construction:** Mechanical engineers can work in construction and infrastructure.
- 5) **Research and development:** Mechanical engineers can work on developing new technologies and products.
- 6) **Biomedical:** Mechanical engineers can work in the biomedical field.
- 7) **Robotics:** Mechanical engineers can work in robotics.
- 8) **HVAC:** Mechanical engineers can work in HVAC systems.

Design Engineer:

Design engineers work on creating and developing new products and systems using computer-aided design (CAD) software.

❖ Manufacturing Engineer:

Manufacturing engineers focus on improving the efficiency and productivity of manufacturing processes.

❖ Quality Control Engineer:

Quality control engineers ensure that products meet the required quality standards by testing and analyzing materials and products.

❖ Maintenance Engineer:

Maintenance engineers are responsible for maintaining and repairing mechanical systems and equipment.

❖ Research and Development Engineer:

Research and development engineers work on developing new technologies and products by conducting research and experimentation.

Job Roles:

- 1) **Aerospace engineer:** Designs and tests aircraft, missiles and spacecraft.
- 2) **Research and development engineer:** Develops new technologies and products through research and experimentation.
- 3) **Chief mechanical engineer:** A high-paying job for mechanical engineers.
- 4) **Mechanical developer:** A high-paying job for mechanical engineers.

Benefits:

Mechanical engineers enjoy good job stability, job prospects and salaries.

Mechanical engineering skills are in demand worldwide.

Mechanical Engineering is one of India's most popular and sought after fields. It is a field of engineering which involves the application of principles of physics, mathematics, and materials science for the design, development, manufacture, operation and maintenance of machines, tools, engines and other mechanical products.

Scope of Mechanical Engineering in Future:

Mechanical engineering is an ever-evolving field with a promising future due to the increasing demand for mechanical systems and technologies across various industries.

Here are some of the key areas where mechanical engineering is expected to have significant scope in the future:

1) Renewable Energy:

With the growing concern about climate change and the need to reduce greenhouse gas emissions, renewable energy sources like wind, solar and hydropower are gaining popularity. Mechanical engineers will be crucial in designing and developing efficient renewable energy systems.

2) Robotics and Automation:

Robotics and automation are transforming various industries, from manufacturing to healthcare. Mechanical engineers will be in demand to design and develop robots and automated systems that can work efficiently and safely.

3) Nanotechnology:

Nanotechnology is an emerging field that deals with designing and manipulating materials at the nanoscale. Mechanical engineers will be required to design and develop nanoscale materials and devices for various applications.

4) Artificial Intelligence:

Artificial Intelligence (AI) is increasingly used to optimize various systems and processes. Mechanical engineers will be required to design and develop mechanical systems that integrate AI technologies.

5) 3D Printing:

3D printing is revolutionizing the manufacturing industry by enabling the creation of complex geometries and custom parts. Mechanical engineers will be required to design and develop 3D printers and create optimized designs for 3D printing.

The future of mechanical engineering looks promising with new and emerging technologies and their integration with traditional mechanical systems. Mechanical engineers will be critical in designing, developing and implementing these technologies in various industries.

1.3 Career Opportunities for Mechanical Engineers:

Mechanical engineering is a vast field with numerous career opportunities in various sectors. Here are some of the popular career opportunities for mechanical engineers:

1. *Automotive Engineering:*

This field involves designing and developing automobiles like cars, trucks, buses and motorcycles.

2. *Aerospace Engineering:*

Aerospace engineering involves designing and developing of aircraft, spacecraft and satellites.

3. *Energy Engineering:*

This field focuses on designing and developing of renewable energy sources like wind turbines, solar panels and hydroelectric power systems.

4. *Manufacturing Engineering*

Manufacturing engineering involves designing and developing of manufacturing processes to improve efficiency, productivity and quality.

5. *Robotics Engineering:*

Robotics engineering involves designing and developing robots for industrial and personal use.

6. *Bio-mechanical Engineering:*

Biomechanical engineering involves designing and developing 1 medical devices, prosthetics and implants.

7. *Materials Engineering:*

Materials engineering involves designing and developing of new materials for various applications, such as aerospace, construction and medical fields.

8. *HVAC Engineering:*

HVAC engineering involves designing and developing of heating, ventilation and air conditioning systems for buildings.

These are just a few of the many career opportunities available in mechanical engineering. Mechanical engineers can also work in research, development, consulting and management positions. Regenerate response.

Here are some job possibilities in various sectors for mechanical engineers:

1) *Manufacturing Sector:*

Production Engineer, Quality Control Engineer, Process Engineer, Plant Manager, Maintenance Engineer and Operations Manager.

2) *Automotive Industry:*

Design Engineer, Manufacturing Engineer, Automotive Technician, Quality Engineer, Research and Development Engineer, Production Engineer.

3) *Aerospace Industry:*

Aerospace Engineer, Design Engineer, Research and Development Engineer, Flight Test Engineer, Propulsion Engineer and Manufacturing Engineer.

4) *Energy Sector:*

Energy Engineer, Thermal Engineer, Renewable Energy Engineer, Power Plant Engineer, Operations Manager, Research and Development Engineer.

5) Consulting Firms:

Mechanical Engineer Consultant, Design Consultant, Project Manager, Technical Consultant and Operations Consultant.

6) Construction and Infrastructure:

Product Manager, Site Engineer, HVAC Engineer, Structural Engineer, Project Co-ordinator and MEP Engineer.

7) Government Sector:

Public Works Department (PWD), Indian Railways, Indian Army, Indian Navy, Defence Research and Development Organisation (DRDO), Indian Space Research Organisation (ISRO).

8) Research and Development:

Research Engineer, Product Development Engineer, Test Engineer, Design Engineer and Quality Control Engineer.

Mechanical engineering graduates have plenty of career options across various sectors and choosing a career path that aligns with their interests and skillset is essential.

Mechanical Engineering a Good Career in India:

Yes, mechanical engineering is a good career option in India as it is one of the oldest and broadest fields of engineering. The scope of mechanical engineering in India is vast, with opportunities available in various sectors like automobile, aerospace, energy, construction and many more. Mechanical engineers are in high demand in India, and the field offers good job prospects and competitive salaries. The Indian government is also investing heavily in various infrastructure projects, which is leading to a surge in demand for mechanical engineers.

Some of the popular job profiles for mechanical engineers in India include:

1) Design Engineer:

Design engineers work on creating and developing new products and systems using computer-aided design (CAD) software.

2) Manufacturing Engineer:

Manufacturing engineers focus on improving the efficiency and productivity of manufacturing processes.

3) Quality Control Engineer:

Quality control engineers ensure that products meet the required quality standards by testing and analyzing materials and products.

4) Maintenance Engineer:

Maintenance engineers are responsible for maintaining and repairing mechanical systems and equipment's.

5) Research and Development Engineer:

Research and development engineers work on developing new technologies and products by conducting research and experimentation.

1.4 Fundamental Units:

The units in which the fundamental quantities are measured are called fundamental units. Fundamental units are the basic units of measurement defined by the international system of units (SI). They include the meter (m) for length, kilogram (Kg) for mass, second (s) for time, kelvin (K) for temperature.

Definitions:

1. **Length (L or l):** It can be defined as the distance between two points and it can be measured in terms of metre (m).
2. **Mass (M or m):** It can be defined as the amount of matter in an object and it can be measured in terms of kilogram (Kg).
3. **Time (t):** It can be defined as the duration of an event and it can be measured in terms of second (s).
4. **Temperature (T):** It can be defined as the degree of hotness or coldness of an object and it can be measured in terms of kelvin (K).

Units of Length, Mass, Time and Temperatures in CGS, FPS, MKS and SI Units :

Units Table					
Sl.No.		CGS	FPS	MKS	SI
1.	Length	Centimeter (cm)	Foot	Meter	Metre
2.	Mass	Gram	Pound	Kilogram (Kg)	Kilogram (Kg)
3.	Time	Second	Second	Second	Second
4.	Temperature	Degree Celsius(⁰ C)	Degree Fahrenheit(⁰ F)	Kelvin (K)	Kelvin (K)

1.5 Derived Units:

These are the units generated from a combination of base units, supplementary units and other derived units.

Definitions:

Area (A): Area can be defined as the amount of space inside a two-dimensional shape. It is measured in square units, like square meters (m²) or square feet.

Volume (V): Volume is defined as the space occupied within the boundaries of an object in three-dimensional space. It is measured in terms of m³.

Density (p): Density can be defined as mass per unit volume of a given material and it is measured in terms of kg/m³ in SI unit for solids.

$$\text{Density } \rho = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{v}$$

Velocity (v): Velocity can be defined as the rate of change in displacement of an object or particle with respect to time and it is measured in terms of m/s in SI unit.

Acceleration (a): Acceleration can be defined as the rate of change of velocity with respect to time and it is measured in terms of m/s².

$$\text{Acceleration, } a = \frac{(\text{Initial velocity} - \text{Final velocity})}{\text{Time}}$$

$$a = \frac{\text{Change in velocity}}{\text{Time}}$$

Force: Force is an external agent capable of changing a body's state of rest or motion and it can be measured in terms of newton (N) in SI unit.

Push or pull of an object is considered a force. Forces can change an object's speed, its direction and even its shape.

$$F = m \times g \text{ (Mass } \times \text{ Acceleration due to gravity.) kg.m/s}^2$$

Where, m= mass, g=acceleration due to gravity.

Work: Work can be defined as the product of force and the magnitude of displacement in the direction of force and it is measured in terms of N-m in SI unit.

$$\begin{aligned} \text{Work or work done} &= \text{Force} \times \text{displacement} \\ W &= F \times d \quad \text{N - m or Joule (J)} \end{aligned}$$

Power: Power can be defined as the workdone per unit time or the rate of doing work and it can be measured in terms of N-m/s

$$\text{Power} = \frac{\text{Workdone}}{\text{Time taken}} = \frac{W}{t} = \frac{\text{N - m}}{s}$$

Energy: Energy can be defined as the capacity to do work and it can be measured in terms of N-m or Joule (J).

Mechanical energy is equal to the workdone on a body in changing either its position or its velocity and these are:

1. **Potential energy:** It is the energy possessed by a body for doing work, by the virtue of its position. For example, a body raised to some height above the ground level possesses potential energy because it can do some work by falling on earth's surface. The potential energy

$$PE = W \times h = m \times g \times h \quad \text{N - m}$$

Where, W=Weight of the body

m=Mass of the body

h = Distance through which the body falls.

2. **Kinetic energy:** It is the energy possessed by a body, for doing work, by the virtue of its mass and velocity of motion. If a body of mass m attains a velocity v from rest in time t, under the influence of force F and moves a distance 's', then

$$\text{Workdone} = F \times s = m \times a \times s \text{ (Where, } F = ma)$$

Kinetic energy of a body,

$$KE = m \times a \times \frac{v^2}{2a}$$

$$KE = \frac{1}{2}mv^2 \quad N - m$$

We know that $v^2 - u^2 = 2as$

Since, $u = 0$ because body starts from rest

Then $v^2 = 2as$

Therefore $s = (v^2/2a)$

Sl.No.		CGS	FPS	MKS	SI
1.	Area	cm ²	ft ²	m ²	m ²
2.	Volume	cm ³	ft ³	m ³	m ³
3.	Density	g/cm ³	lb/ft ³	kg/m ³	kg/m ³
4.	Velocity	cm/s	ft/s	m/s	m/s
5.	Acceleration	cm/s ²	ft/s ²	m/s ²	m/s ²
6.	Force	dyne/(dyn)	poundal(pd/l)	N	N
7.	Work	g × cm/s ²	lb × ft/s ²	kg × m/s ²	Joule (J) or N-m
8.	Energy	erg	foot-pound		Joule (J)

Week 01 Review Questions

1. What is mechanical engineering?
2. What is mechanical engineering? Explain.
3. Write the scope for mechanical engineering.
4. Explain the scope for mechanical engineering.
5. Write the scope for mechanical engineering in future.
6. What are the career opportunities for mechanical engineers?
7. What are the popular job profiles for mechanical engineers in India?
8. Explain fundamental units.
9. What are the derived units?

WEEK 02
FERROUS METALS

- ❖ Classification of Engineering Materials Ferrous Materials
- ❖ Cast Iron- Types of cast iron- Grey, White, and Malleable. Properties, composition and applications of cast iron.
- ❖ Steel –Types, Designation of steel, Types -Plain Carbon Steel- Low (0.15 0.25%C), Mild (0.25%C), Medium (0.25-0.65%C), High Carbon (0.65 1.5%C), Properties, composition and applications of steel.
- ❖ Alloy Steel- Tool Steel, Tungsten steel, Stainless-Steel, High-Speed Steel, Properties, composition and applications of alloy steel.



2.1 Introduction:

The ferrous metals i.e., steels and its alloys are extensively used in engineering industries due to their following characteristics:

1. Good resistance of corrosion.
2. Strength to weight ratio.
3. Excellent mechanical properties and
4. Excellent magnetic properties.

The important ferrous metals used in the engineering industries are the cast iron and steel and its alloys. We shall discuss only about cast iron, steel and its alloys, which are important from the subject point of view.

2.2 Cast Iron:

Cast iron is a eutectic alloy of iron and carbon. It has relatively low melting point, therefore it can be melted very easily. It requires less fuel and more easily operated in furnaces. The carbon content of the cast iron varies from 2% to 4.5%. It also contains small amounts of silicon, sulphur, manganese and phosphorus.

The molten metal of cast iron easily fills intricate moulds completely and easily.

2.2.1 Types of Cast Iron:

Following are the important types of cast iron:

1. White cast iron
2. Gray cast iron
3. Nodular cast iron
4. Malleable cast iron
5. Chilled cast iron
6. Molted cast iron
7. Alloy cast iron.

2.2.2 Gray Cast Iron:

It is an ordinary commercial cast iron and it has the following compositions:

Carbon	3% to 3.5%
Manganese	0.4% to 1%
Silicon	1% to 2.75%
Phosphorus	0.15% to 1%
Sulphur	0.02% to 0.15% and remaining is iron.

The gray colour of this cast iron is due to the fact that the carbon is present in the form of free graphite which acts as a lubricant, due to this reason, it is very suitable for those parts where the sliding action is desired.

Properties:

- 1) It has a low tensile strength.
- 2) High compressive strength.
- 3) No ductility.
- 4) It can be easily machined.

Applications:

- 1) Gray cast iron is widely used for:
- 2) Machine tool bodies.
- 3) Automobile cylinder blocks.
- 4) Pipes and pipe fittings.
- 5) Agricultural implements.

2.2.3 White Cast Iron:

It is a particular variety of cast iron, which shows a white fracture. It has a following compositions:

Carbon	2% to 2.3%
Manganese	0.1% to 0.4%
Silicon Phosphorus	0.85% to 1.2%
Sulphur	0.05% to 0.2%
And remaining is iron.	0.12% to 0.35%

The white colour of cast iron is due to the fact that the carbon is in the form of carbide known as cementite and it is the hardest constituent of iron. This cementite is caused by quick cooling of molten iron.

Properties.

- 1) High tensile strength
- 2) Low compressive strength
- 3) It is hard
- 4) It cannot be machined
- 5) It is white in colour.

Applications.

- 1) It is used for inferior casting and in place where hard casting is required.
- 2) It is used for car wheels.
- 3) It is used as raw material for the production of wrought iron and malleable cast iron.

2.2.4 Malleable Cast Iron:

The malleable cast iron is obtained from white cast iron by a suitable heat treatment process i.e. by annealing.

The annealing process separates the combined carbon of the white cast iron into nodules of free graphite.

It is a ductile in nature and may be bent without breaking or fracturing the section. Its tensile strength is higher than the gray cast iron and has an excellent machining qualities.

Composition:

- | | |
|---------------|------------|
| 1) Carbon | 2.3-2.7% |
| 2) Silicon | 1.0-1.75% |
| 3) Manganese | 0.15-1.25% |
| 4) Sulphur | 0.02-0.20% |
| 5) Phosphorus | 0.02-0.15% |

Properties:

- 1) It is highly ductile.
- 2) Can be bent without fracture.
- 3) High tensile strength than gray CI.
- 4) Excellent machinability.

Applications:

It is used for the following:

- 1) Hubs of wagon wheels.
- 2) Small fittings for railway rolling stock.
- 3) Brake supports.
- 4) Parts of agricultural machinery.
- 5) Pipe fittings.
- 6) Door hinges, locks, etc.

2.3 Steels:

Steel is an alloy of iron and carbon with carbon content upto a maximum of 1.4%. The carbon occurs in the form of iron carbide. Iron carbide increases the hardness and strength of the steel. The other elements like silicon, sulphur, phosphorus and manganese are also present to impart the desired properties.

Types of Steels:

Steels can be classified into the following:

1. Plain carbon steels
2. Alloy steel
3. Tool steels
4. High speed steel
5. Heat resisting steel
6. Stainless steel
7. Free cutting steels
8. Spring steels.

2.3.1 Plain Carbon Steels:**Definition:**

It can be defined as a steel which has its properties mainly due to its carbon content and does not contain more than 0.5% of silicon and 1.5% of manganese.

The plain carbon steels contains the carbon varying from 0.06% to 1.4%. These steels are strong, tough, ductile and used in expensive materials. They can be cast, worked, machined and heat treated to a wide range of properties. Plain carbon steel has a poor atmospheric corrosive resistance, but it can be protected easily by painting, enamelling or galvanizing. The strength and hardness of the steel increases with an increase in carbon content. The ductility and toughness decreases with an increase in the carbon content.

Types of Plain Carbon Steels and their Compositions:

Following are the different types of plain carbon steels:

- | | |
|-----------------------------|--------------------------|
| 1) Dead mild steel | 0.06% to 0.12% carbon. |
| 2) Low carbon or mild steel | 0.10% to 0.25% of carbon |
| 3) Medium carbon steel | 0.25% to 0.55% of carbon |
| 4) High carbon steel | 0.55% to 1.4% of carbon |

Properties of Plain Carbon Steels:

Following are the properties of plain carbon steels:

- 1) These are highly ductile and soft.
- 2) These are harder and tougher.
- 3) Poor atmospheric corrosive resistance.
- 4) They can be easily forged.
- 5) They can be easily welded and machined.

Applications of Plain Carbon Steels:

Types of Steels	Applications or Uses
1) Dead mild steels	1) Nails, rivets, plates, chains, stampings etc.
2) Low carbon steels or mild steels	2) Chain links, nails, rivets, ship hulls, car bodies, bridges, cams, light duty gears etc.
3) Medium carbon steels	3) Axles, connecting rods, gears, wheels for trains and rails etc.
4) High carbon steels	4) Clutch plates, razor blades, scissors, knives, files, punches, dies etc.

2.4 Alloy Steel:**Definition:**

The alloy steel can be defined as the steel in which elements other than carbon are added in sufficient quantity in order to obtain special properties is known as alloy steel.

These steel contain carbon together with small amounts of manganese and silicon.

The alloying of steel is generally done to increase its strength, hardness, toughness, resistance to abrasion and wear and to improve electrical and magnetic properties. The various alloying elements are nickel, chromium, molybdenum, cobalt, vanadium, manganese, silicon and tungsten.

Purposes of Alloying:

The alloying elements are added to accomplish one or more of the following:

1. To impart a fine grain size to steel.
2. To improve casehardening properties.
3. To improve elasticity;
4. To improve corrosion and fatigue resistance.
5. To improve hardness, toughness and tensile strength.
6. To improve machinability.
7. To strengthen the ferrite.
8. To improve high or low temperature stability.
9. To improve cutting ability.
10. To improve wear resistance.
11. To improve ductility.

The Effects of Alloying Elements

Metal	Remarks
Nickel	1) Increase toughness,
	2) Improve response to heat treatment especially in large sections.
	3) In large amounts provides special electrical and magnetic properties.
	4) Improves forming properties of stainless steel
Chromium	1) Provides stainless property in steel.
	2) Used widely in tool steels and in electric plates.
Vanadium	1) Improves response to heat treatment.
	2) Provides control of structure.
	3) Used in high speed tool steels.
Tungsten	1) Retention of hardness and toughness at high temperatures
	2) Used in tools, dies, valves, magnets etc.
Silicon	1) High electrical resistance and magnetic of permeability.
	2) Used in electrical machinery.
Copper	1) In small amounts improves atmospheric corrosion resistance.
	2) Acts as a strengthening agent.
Carbon	1) Affects melting point.
	2) Affects tensile strength, hardness and machinability.
Titanium	1) Prevents formation of austenite in high chromium steel.
	2) Reduces martensitic hardness and hardenability in medium chromium steels.
	3) Prevents localized depletion of chromium in stainless steel during long heating

Molybdenum	1) Enhances corrosion resistance in stainless steels.
	2) Makes steel usually tough at various hardness levels.
	3) Forms abrasion resisting particles.
	4) Promotes hardenability of steel.
	5) Raises tensile and creep strength at high temperatures.
	6) Makes steel fine grained.
	7) Counteracts tendency towards temper brittleness.
Manganese	1) Counteracts brittleness from sulphur.
	2) Increases strength and hardness markedly.
	3) Lowers both ductility and malleability if it is present in high percentage with high carbon content in steel.
Boron	1) Increases hardenability or depth to which steel will harden when quenched.
Aluminium	1) Acts as a deoxidiser.
	2) If present in an amount of about 1%, it helps promoting Nitriding.
Cobalt	1) Refines the graphite and pearlite.
	2) Improves heat resistance.
	3) Contributes to red-hardness by hardening ferrite.
	4) It is a mild stabilizer of carbides.
	5) Improves mechanical properties such as tensile strength, fatigue strength and hardness.

2.4.1 Tool Steels:

These are the steels for making the tools and dies which are required for cutting, forming, shaping and blanking of materials. Tool steels should have high resistance, greater wear resistance, greater toughness, high thermal conductivity, high impact strength, low coefficient of friction, etc.

Tool steel is typically composed of iron and carbon with additions of alloying elements like chromium, tungsten, molybdenum and vanadium. The carbon content usually ranges from 0.1% to 1.6%.

Composition:

Carbon	0.1% to 1.6%
Chromium	0.5 to 15% or more
Molybdenum	0.1 to 1.5% or more
Vanadium	0.1 to 2% or more
Tungsten	0.1 to 5% or more

Properties:

Following are the properties of tool steel:

1. Excellent wear resistance.
2. Greater toughness.
3. Hard material.
4. High thermal conductivity.
5. It withstand high temperature.

6. Good impact resistance.
7. Low co-efficient of friction.
8. Good machinability.
9. Good corrosive resistance.

Applications:

Following are the uses of tool steel:

1. It is used for cutting tools (e.g. drill bits, lathe tools)
2. Used for making dies and moulds for shaping materials.
3. Used for making forming dies.
4. Used for stamping and forming tools.
5. Used for hot working tools.

2.4.2 Tungsten Steel:

Tungsten steel is a composite material made of tungsten and other alloying elements, such as carbon, cobalt, molybdenum and chromium. It is also known as cemented carbide.

Composition:

Tungsten	2% to 18% of alloy by weight
Cobalt	0 to 20% depends on type of alloy.
Carbon	0.6% to 0.8%
Molybdenum	Depends on type of alloy, varies up to 70%
Chromium	4%
Vanadium	less than 0.5% but can be high in high speed steels.

Properties:

1. Tungsten steel is extremely hard and wear resistant.
2. It is very strong and improves the strength of steel at higher temperature.
3. Resistant to corrosion.
4. It has high melting point, 3422°C making it suitable for higher temperature.
5. It is very dense material i.e. 19.3 g/cm³.

Applications:

1. It is used for making permanent magnets.
2. It is used for making high speed cutting tools and high speed machineries.
3. Used for making nozzles for rocket engines
4. Used for making micro drill bits.
5. Used for making filaments for light bulbs.
6. Used for making heating elements.
7. Used for making electrodes and engine parts.

2.4.3 Stainless Steel:

A stainless steel is a group of iron based alloy which when heat treated and finished, resists oxidation and corrosive attack from corrosive media. It contains a minimum of approximately 11% of chromium a composition that prevents the iron from rusting and also provides heat resistant properties.

A typical composition of stainless steel (i.e. 316 Austenitic stainless steel)

Carbon	-0.08%
Manganese	-2.00%
Phosphorus	-0.045%
Sulphur	-0.030%
Chromium	-16 to 18%
Silicon	-0.75%
Nickel	-10 to 14%
Molybdenum	-2 to 3%
Nitrogen	-0.10%

Properties:

Following are the properties of stainless steel:

1. Excellent corrosion resistance.
2. High strength.
3. High durability.
4. Good temperature resistance.
5. High tensile strength.
6. Greater toughness
7. Good resistance to oxidation.

Application

1. Used for making cookware, cutlery etc.
2. Used for making medical equipment's.
3. Used for making scissors, gears and springs.
4. For making ball bearings, cutting and dental equipment's.
5. For manufacturing bars, sheets, strips, pipes, wires, etc.
6. Used for plumbing fittings.
7. Used for kitchen utensils.
8. Equipments of food processing and chemical plants.

2.4.4 High Speed Steel (HSS):

High speed steel is a special alloy steel typically containing.

Composition:

Tungsten	18%
Chromium	4%
Vanadium	1%
Carbon	0.6 to 0.8%

Sometimes it also contains cobalt or molybdenum. These are used for cutting metals at a much higher cutting speed than ordinary carbon tool. These steels have a valuable property of retaining their hardness even when heated to red hot.

Properties:

Following are the properties of HSSs at fate

1. It has an excellent toughness.
2. Exceptional hardness.
3. Good wear resistance.
4. Ability to maintain its cutting properties at higher temperatures.
5. Excellent machinability.
6. Good regrindability.
7. Good corrosion resistance.no

Applications:

Following are the uses of HSS:

1. For making cutting tools like drills, taps and milling cutters.
2. For making Lathes, planer and shaper tools.
3. Used for saw blades.
4. Used for broachers and gear cutters,
5. Used for punches and dies.
6. Used for rolling equipment's.
7. Used for medical instruments like surgical blades and dental tools.
8. Used for manufacturing the aerospace components.
9. Used for manufacturing automotive parts etc.

Week 02 Review Questions

1. What is cast iron? Write the types of cast iron.
2. Write the composition of gray cast iron.
3. What are the properties and applications of gray cast iron?
4. What is the composition of white cast iron?
5. What are the properties and applications of white cast iron?
6. What is malleable cast iron? Write its properties.
7. What are the properties and applications of malleable cast iron?
8. What is steel? List the types of steel.
9. Write the properties of plain carbon steel.
10. List the different plain carbon steel with their composition.
11. What are the applications of plain carbon steel?
12. What is alloy steel? List the purpose of alloying.
13. What are the purposes of alloying?
14. What is tool steel? List the types of tool steel.
15. What is tungsten steel? List the types of tungsten steel.
16. What are the properties and applications of tungsten steel?
17. What is tungsten steel? Write its composition.

WEEK 03
NON- FERROUS METALS

Non-Ferrous Materials Properties, composition and applications of

- ❖ Alluminium and Alluminium Alloys – Duralumin, Y-Alloy, Magnesium, Hindalium.
- ❖ Copper and Copper Alloys - Brass, Bronze, Gun Metal, lead, Tin. Bearing Metals.
- ❖ Zinc Based Alloys – Solder, German silver.
- ❖ Nickel Based Alloys – Inconel, Monel metals.



3.1 Introduction:

Non-ferrous metals are those which contain metal other than iron as their chief constituent. Non-ferrous metals are generally employed in industry due to its excellent characteristics.

Characteristics or Properties of Non-ferrous Metals:

- 1) Good resistance to corrosion.
- 2) Light in weight.
- 3) Good electrical and thermal conductivity.
- 4) Good machinability.
- 5) Easily rolled, forged and casted.
- 6) Soft and easily cold worked.
- 7) Easily joined by brazing, fusing and resistance welding.

The various non-ferrous materials used in engineering practice are:

- 1) Aluminium and its alloys
- 2) Copper and its alloys
- 3) Lead and its alloys
- 4) Zinc and its alloys
- 5) Tin and its alloys
- 6) Nickel and its alloys.

3.2 Aluminium and Aluminium Alloys:

Aluminium:

Aluminium is a white metal produced by electrical process from the oxide (Alumina), which is prepared from a Bauxite. It is light in weight with specific gravity of 2.7 and melting point is 660° C.

It is available in pure state and it is a weak and soft material, when it is mixed with small amounts of other alloys, it becomes hard and rigid. So, it can be blanked, formed, drawn, turned, cast, forged and die casted.

Properties:

Following are the properties of aluminium

1. It is a good conductor of electricity.
2. Greater resistance to corrosion.
3. Non-toxic.
4. Non-magnetic and ductile.
5. Light in weight.
6. Specific gravity is 2.7.
7. Good conductor of heat.
8. It is a good reflector
9. It can be forged, formed, blanked, casted, drawn, turned and die casted.

Applications

1. It is used for overhead
2. Used for cooking utensils.
3. Used for aircraft and automobile components.
4. Used in furniture's, rail road and trolley cars.
5. Aluminium foils are used for food protection elements.

3.2.1 Aluminium Alloys:

Aluminium may be alloyed by using one or more elements. Such as copper, magnesium, manganese, silicon and nickel. The main

Aluminium alloys are:

1. Duralumin
2. y-alloy
3. Magnesium
4. Hindalium

1. Duralumin:

It is an important wrought alloy. This alloy possess maximum strength after heat treatment and age hardening. It can be hot worked at 500° C, but after forging and annealing, it can be cold worked.

Composition:

- i. Copper 3% to 4.5%
- ii. Manganese 0.4% to 0.7%
- iii. Magnesium 0.4% to 0.7%
- iv. Rest in aluminium.

Properties:

1. Excellent strength.
2. Light in weight.
3. It can be hot worked at 500° C.
4. It is relatively soft and ductile.
5. It can be forged, rolled and extruded into various forms.

Applications:

1. It is widely used in wrought conditions for forging, stamping, bars, sheets, tubes and rivets.
2. It may be used in automobile and aircraft components.

2. Y Alloy:

It is a copper aluminium alloy. The addition of copper to a pure aluminium increases its strength and machinability. This alloy can be heat treated and age hardened.

Composition:

- i. Copper 3.5% to 4.5%
- ii. Manganese 1.2% to 1.7%
- iii. Nickel 1.8% to 2.3%
- iv. Silicon, Magnesium, Iron 0.6% each
- v. Rest is aluminium.

Properties:

1. It has a better strength at high temperatures.
2. Good strength.
3. Good machinability.
4. It can be heat treated and age hardened.

Applications:

1. It is used for castings.
2. It is used for forged components.
3. It is used in aircraft engines.
4. Used for cylinder heads and pistons.

3. Magnesium:

It is made by melting the aluminium with 2% to 10% magnesium in a vacuum and then cooling it in a vacuum or under pressure of 100 to 200 atmospheres. It also contains about 1.75% copper. It is light in weight

And good mechanical properties. It is mainly used for aircraft and automobile components.

4. Hindalium:

It is an alloy of aluminium and magnesium with small quantity of chromium. It is mainly used for atomised utensils manufacture.

3.3 Copper and Copper Alloys:

Copper:

Copper is one of the most widely used non-ferrous metals in the industry. It is soft, ductile and malleable material with a reddish-brown, appearance. Its specific gravity is 8.9 and its melting point is 1083° C. Copper is a good conductor of electricity and it is largely used in making the electrical cables and wires for electrical machineries and appliances in electrotyping, electroplating in making coins and household utensils.

It is a non-corrosive under ordinary conditions and resists weather very effectively. It may be casted rolled, forged and drawn into wires. Copper in the form of tubes is widely used heat exchanges. It is also used in making the ammunitions. It is used in making useful alloys with tin, zinc, nickel and aluminium.

Properties:

Following are the properties of copper:

1. Good conductor of electricity.
2. High ductile material.
3. Low hardness with moderate strength.
4. Specific gravity is 8.9.
5. Melting point is 1083° C and boiling point is 2595° C.
6. Easily casted, forged, rolled and drawn into wires
7. Good resistance to corrosion.
8. Good non-magnetic properties.
9. Easily alloyed with other metals.

Uses:

Copper can be used for following purposes:

1. For making coins and electroplating.
2. For making thin sheets, water pipes tanks, taps, etc.
3. Used for hardware fittings, washers etc.,
4. Telephone cables, electrical cables, electrical equipment's like bushes, solders, switch gears, coils.
5. Heat exchangers, etc.

3.3.1 Copper Alloys:

Copper alloys are the following:

1. Brass
2. Bronze
3. Gun metal
4. Lead
5. Tin
6. Bearing metals.

1. Brass:

Brass is an alloy of copper and zinc, in which zinc is the principle alloying metal. There are various types of brasses depending on the proportion of copper and zinc. This is fundamentally a binary alloy of copper with zinc each 50%, by adding small quantities of other elements, the brass material properties can be changed. For example, addition of lead from 1% to 2% improves the machining qualities of brass. It has a greater strength than the copper, but lower

thermal and electrical conductivity. It has a good corrosion resistance and can be easily fabricated.

Properties of Brass:

Brass has the following properties:

1. It has a greater strength than the copper.
2. It has a low thermal and electrical conductivity.
3. It has a good corrosion resistance.
4. It can be easily fabricated.
5. Its melting point ranges from 800° C to 1000° C.
6. It is soft and ductile.
7. It is non-magnetic.

Applications of Brass:

Following are the uses of brass:

1. It is used for hydraulic fitting and pump linings.
2. Used for making utensils.
3. Used for making bearings and bushes etc.
4. Used for valves, automobile fittings and type writer parts.
5. Used for musical instruments.
6. Used for cold rolled sheets, wire drawing pressing.
7. For tube and plate manufacturing

<i>Types</i>	<i>Composition</i>	<i>Uses or Applications</i>
1. Cartridge Brass	• Copper-60% • Zinc -40%	Suitable for cold working. For cold rolled sheets, wire drawing, deep drawing pressing and tube manufacturing.
2. Yellow Brass (Montz metal)	• Copper-70% • Zinc -30%	It is suitable for hot working by rolling, extrusion and stamping.
3. Leaded Brass	• Copper -62.5% • Zinc-36% • Lead-1.5%	These are used for plates. Tubes etc.
4. Admiralty Brass.	• Copper-70% • Zinc-29% • Tin-1%	
5. Naval Brass	• Copper = 59% • Zinc = 40% • Tin =1%	Used for marine casting.
6. Nickel Brass (German silver)	• Copper 60.45% • Zinc =35.20% • Nickel 5.35%	Used for plumbing fittings. Valves, Automobile fittings, type writer parts and musical instruments.

2. Bronze:

Bronze is an alloy of copper and tin. The composition of Bronze is as follows:

- 1) Copper 75 to 95%
- 2) Tin 5 to 25%.

By adding other elements its properties can be changed.

Following are the Properties of Bronze:

- 1) It is comparatively hard and resists the surface wear. .
- 2) It can be easily shaped or rolled into rods, wires and sheets.
- 3) It has a good corrosion resistance than the Brass.

Applications:

- 1) Used for bearings, worm wheels, gears, nuts, pump parts and springs.
- 2) Used for boilers, tanks, stoves etc.
- 3) Used for bushes, plungers, feed pumps, rods etc.
- 4) Used for imitation jewellery and decorative purposes.
- 5) Used for air pumps, slide valves, bushes, cam rollers etc.

3. Gun Metal:

Gun metal is a type of bronze and an alloy of copper, tin and zinc that is used to make variety of objects. It is also known as red brass.

Composition:

The typical composition of gun metal is:

- i. Copper-88%
- ii. Tin -8-10%
- iii. Zinc 2-4%

Properties:

1. Good corrosive resistant
2. It has a high tensile strength of 221 to 310 Mpa.
3. Good thermal conductivity.
4. Its melting point is around 1000°C,
5. Good casting quality
6. Good hardenability.
7. Relatively high density.
8. Good wear resistant.
9. Good corrosion resistant,
10. Good electrical conductivity.
11. It is easy to weld.

Applications:

1. It is used to make gears, bushings and bearings.
2. Used for pump parts and steam fittings.
3. It is used to make statues, buttons etc.
4. Used for ship components.
5. Used for bushings and valves.
6. Used for making steam fittings.

4. Lead:

Lead (Pb) occurs occasionally in free state in nature. In combined form it occurs as sulphide. The ore of a lead is Galena (PbS). Lead is bluish-grey colour and heavy metal. It can be easily cut, cold worked and extruded.

Composition:

It consists of stable isotopes and traces of radio isotopes, stable

- | | | |
|------|----------|------------------------|
| i. | Lead-204 | -1.48% of natural lead |
| ii. | Lead-206 | -23.6% of natural lead |
| iii. | Lead-207 | -22.6% of natural lead |
| iv. | Lead-208 | -52.3% of natural lead |

Radio Active Isotopes:

Lead-209, Lead-210 and Lead-212

Properties:

Following are the properties of lead:

1. It is bluish-Gray in colour and heavy metal.
2. It can be cut by a knife.
3. It makes impression on paper.
4. It is soft and little strength.
5. It melts at 328 °C and boils at 1620 °C.
6. Specific gravity is 11.36.
7. It is highly malleable
8. It is a poor conductor of electricity.
9. High coefficient of expansion.

Applications:

1. It is used for making shots, bullets, alloys.
2. Used for sanitary fittings, cisterns, water-proof and acid-proof Chambers.
3. Used in gas pipes, roof gutters etc.

5. Tin

Tin is usually obtained from its oxide known as tinstone through refining process. It is also available in nodules known as stream tin. It has a brilliant shining white metal.

Composition:

Pure tin is 99.99% pure with small amounts of other elements.

Properties:

Following are the properties of tin:

1. It is ductile and soft malleable material.
2. Having low strength.
3. If tin bar is bent, produces noise called as cry of tin.
4. It becomes brittle when heated above 200 °C.
5. It has excellent corrosion resistance.
6. Good conductor of heat and electricity.
7. It melts at 232 °C and boils at 2260 °C.
8. Specific gravity is 7.31.
9. Not affected by dry air and pure water.

Applications:

1. It is used for plating, lining lead pipes.
2. For preparation of alloys and solders.
3. Used in food industries for coating cans, dies etc.
4. Used for wrapping up cheese and chocolates.
5. Used for packing of tobacco, soaps etc.

Bearing Metals:

Followings are the widely used bearing metals:

1. Hard bearing bronze
2. Phosphors bronze
3. Admiralty gun metal
4. Lead bronze
5. White metals
6. Babbitt metal
7. Cadmium silver bearing alloy
8. Beryllium copper bearing
9. Graphite bearing metals.

Properties of Bearing Metals:

1. Good wearing quality.
2. Low co-efficient of friction.
3. High thermal conductivity.

4. High melting point.
5. Good casting qualities.
6. Ability to withstand continuous bearing pressure and impact.
7. Low shrinkage after casting.
8. Economical in cost.
9. Non-corrosive property.
10. Desired plasticity under the load it is called upon to bear.
11. Non-corrosive property.

1. Hard Bearing Bronze:

Composition:

Cu-85%

Sn-15%

Properties:

1. Its tensile strength is 220 MN/m²
2. Elongation in 5 cm length is 2%
3. It has brinell hardness 100

Applications:

1. It is used in heavy compressive loads.
2. It is used in locomotive slide valves.
3. It is used in bearings for turn tables.

2. Phosphor Bronze:

Composition:

Cu-89%

Sn -11%

Properties:

1. Its tensile strength is 280 MN/m²
2. Its elongation in 5 cm length is 4%
3. It has Brinell hardness 100

Application:

1. It is used for heavy loadings.

3. Admiralty Gun Metal:

Composition:

Cu-88%

Sn-10%

Pb-2%

Properties:

1. Tensile strength is 270 MN/m².
2. Elongation in 5 cm length is 20%
3. Brinell hardness is 65.

Applications:

1. Used for general casting process.
2. Used for resist to marine corrosion.

4. Lead Bronze:

Composition:

Cu-80%

Sn 10%

Pb -10%

Properties:

1. Tensile strength is 230 MN/m²
2. Elongation in 5 cm length is 15%.

5. White Metal:

These metals are copper-lead alloys and are generally used for heavy duty bearings.

6. Babbitt Metal:

It is a white metal bearing alloy.

Composition:

Tin-89.2%

Cu-3.8%

Antimony-7%

Properties:

1. It is soft metal.
2. Possesses sufficient mechanical strength for normal use.
3. It is easy to cast.
4. Used for bearing linings.

7. Cadmium Silver Bearing Alloy:

Composition:

Cadmium-97.6%

Copper-1.9%

Silver-0.5%

These bearings are used for loads up to 14.5 MN/m².

8. Beryllium Copper Bearing:

Composition:

Copper-97.5%

Beryllium-2.25%

It has a self-lubricating properties.

Application:

Used as a hard bearing metal in place of phosphor bronze.

9. Graphite Bearing Metals:

This metal sometimes known as spongy bearing bronze. These metal contains graphite uniformly distributed throughout their composition and when used for bearings they are therefore, self-lubricating.

These bearings are used in slow running machinery both marine and stationary.

3.4 Zinc Based Alloys:

3.4.1 Zinc:

The zinc does not occur in Free State in nature. Its main ores are zincite or red zinc ZnO , franklinite ZnO , FeO , Zinc copper ZnCO , and Zinc blende ZnS .

A good quality zinc may contain 50% zinc. A pure ZnS contains about 65% zinc.

Properties:

1. Low ductility and malleability.
2. High resistance to corrosion.
3. It is weak and soft metal.
4. It has a low melting point i.e., 409°C .
5. It is bluish white metal.
6. It is not affected by dry air and pure water.
7. Specific gravity is 7.14.
8. It can be easily cast and bent into any shape.

Applications:

1. It is used for electric coils.
2. For galvanizing
3. In preparation of alloys and paints.
4. Used as a coating over iron sheets, corrugated sheets etc.

3.4.2 Zinc Based Alloys: German silver:

German silver is an alloy of copper, nickel and zinc, which is used to make jewellery, diyas and other items. It is also known as nickel, silver and argentan.

Composition:

Copper-60%

Nickel-20%

Properties:

1. It has a silvery appearance.
2. It is hard and tough.
3. Resistance to corrosion.
4. Light weight.
5. High electric resistance.

Applications:

1. It is used for making table ware such as spoons, forks etc.
2. Jewellery such as earrings, bracelets etc.
3. Musical instruments like tubes, keys, braces etc.
4. Fittings for ships and plumbing systems.
5. Heating coils etc.

3.5 Nickel Base Alloys:

Following are the important nickel base alloys

1. Monel metal
2. Inconel
3. Nichrome
4. Nimonic

1. Monel Metal:

It is an alloy of nickel and copper.

Composition:

It contain

Nickel -68%

Copper- 29%

Other constituents – 3%

Like iron, manganese

Silicon and carbon.

Properties:

Following are the properties of monel metal

1. Its specific gravity is 8.87.
2. Its melting point 1160°C
3. It is strong, ductile and tough
- 4 It is superior to beans and brass and bronze in corrosion resistance.

Applications:

Following are the applications of monel metal:

It is used for propellers, pump Stings, condenser des

Used for steam turbine blades, sea water exposed parts and tanks

Used for chemical and food handling plants.

2. Inconel:

Compositions:

Nickel- 80%

Chromium- 14%

Rest is iron

Properties:

Following are the properties of Iconel

1. Its specific gravity is 8.55.
2. Melting point is 1395°C.
3. Excellent mechanical properties at ordinary and elevated temperatures.
4. It can be casted, rolled and cold drawn.

Applications:

Following are the applications of Iconel:

1. It is used for making springs.
2. It is used for exhaust manifolds of aircraft engines.
3. Used in oil and gas extraction plants.
4. Used in pollution and waste processing plants.

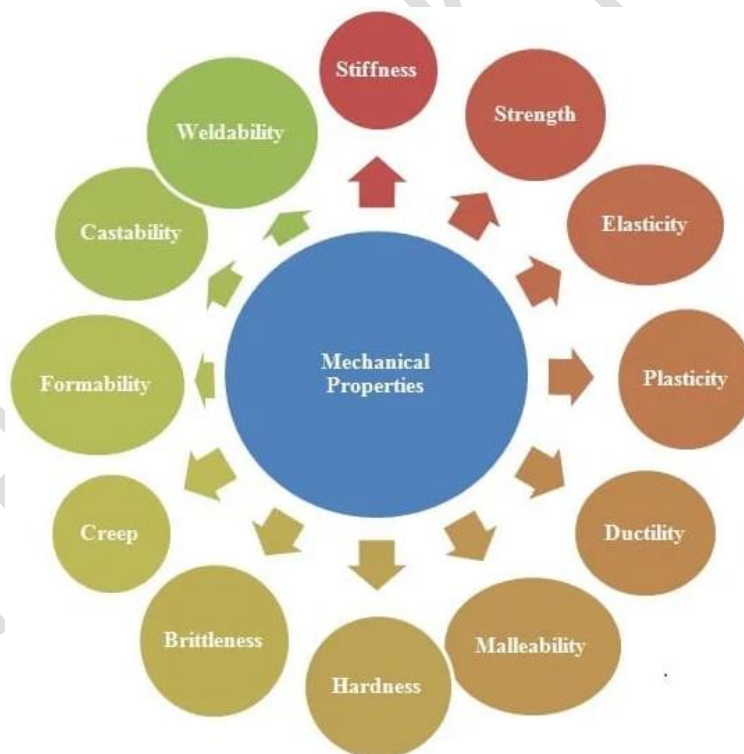
Week 03 Review Questions

1. Write the properties of non-ferrous metals.
2. What are the non-ferrous metals?
3. What is aluminium? List the properties of aluminium.
4. What are the application of aluminium?
5. List the aluminium alloys.
6. What is γ -alloy? List the composition of γ -alloy.
7. Write the properties and applications of γ -alloy.
8. What is duralumin? Write its composition.
9. Explain the properties and applications of duralumin.
10. What is copper? Write its properties.
11. List the types of copper alloys.
12. What is brass metal? Write its composition.
13. What are the properties and applications of brass metal?
14. Explain brass metal and bronze metal with their compositions.
15. Write any five properties and five applications of bronze metal.
16. What is gun metal? Write any five properties and four applications.
17. What is lead? Write any five properties and four applications.
18. What is tin metal? Write the properties and applications.
19. List the different bearing metals.
20. What are the properties of bearing metal?
21. Explain any three bearing metals.
22. What is zinc? Write its properties and applications.
23. What is German silver? Write its composition and properties.
24. Explain Monel metal.

WEEK 04
PROPERTIES OF ENGINEERING MATERIALS

Properties of Engineering Materials

- ❖ Mechanical Properties - Elasticity, Plasticity, Malleability, Ductility, Brittleness, Strength, Toughness, Hardness, Stiffness, Resilience, Creep, Endurance, Fatigue & Machinability.
- ❖ Thermal Properties - Thermal conductivity, Specific Heat, Thermal Expansion.
- ❖ Electrical Properties – Resistivity, Conductivity, Dielectric Strength, Temperature Coefficient.
- ❖ Chemical Properties – Reaction with Oxygen and Water.
- ❖ Magnetic Properties- Magnetic permeability, Magnetic Flux Density.



4.1 Mechanical Properties:

These properties include the nature and behaviour of metals under the action of external forces. These are:

1. Elasticity:

It is that property of the metal by virtue of which the metals are able to regain their original shape and size after removal of the load.

2. Plasticity:

It is that property of the metal by virtue of which a metal takes place permanent deformation without fracture whenever it is subjected to the action of external forces. Ex: Rolling of structural steel or forging of metals, etc.

3. Malleability:

It is the ability of metal to be hammered into thin sheets. Gold and silver are highly malleable.

4. Ductility:

It is that property of the metal by virtue c. which a metal can be drawn into wires or elongated before rupture takes place.

5. Brittleness:

It is that property of the metal by virtue of which a metal will fracture suddenly without any appreciable deformation.

6. Strength:

Strength may be defined as the property of a metal by virtue of which it can withstands or support an external force or load without rupture.

7. Toughness:

It is defined as that property by virtue of which a metal can absorb maximum energy before fracture takes place.

8. Hardness:

It is that property of the metal by virtue of which a metal resists abrasion, indentation and scratching by relatively harder materials.

9. Stiffness:

It is defined as that property by virtue of which a metal will not deform or deflect when load is applied.

10. Resilience:

It is defined as that property by virtue of which a metal stores energy and resists shock or impact loads.

11. Creep:

It is defined as that property by virtue of which a metal deforms continuously and slowly under a steady load.

12. Endurance

It is defined as that property of a metal by virtue of which it can withstand varying stresses (same or opposite nature).

13. Fatigue:

Loading. Fatigue is the gradual weakening of a material due to repeated
This can lead to the development of cracks and the subsequent failure of material.

14. Machinability:

It is a measure of how easily a metal can be cut, shaped or finished using machining processes. It is also known as the ability of a material to be machined with a satisfactory finish at a low cost.

Thermal Properties:

Following are the important thermal properties of a metals:

1. Thermal conductivity: Thermal conductivity of a metal can be defined as the number of Kilo Joules of heat that would flow per second through a specimen of one sq. metre in cross-section and 1 metre in length when the temperature gradient is 1° C.

2. Specific heat: Specific heat of a metal can be defined as an amount of energy required to raise the temperature of one gram of the substance through one degree Celsius. It can be measured in Joules or Calories.

3. Thermal expansion: Thermal expansion of a metal can be defined as a tendency to expand when they are heated to a considerable temperature.

For example: The linear co-efficient of expansion of a metal can be defined as the increase in length per unit length for each degree rise in temperature.

4. Thermal diffusivity: Thermal diffusivity is defined as the ratio of the thermal conductivity to the heat capacity of a material.

Thermal diffusivity of a material can be defined as thermal conductivity divided by the product of its density and specific heat capacity where the pressure is held the constant.

Thermal diffusivity of a material can also be defined as the measure of the rate at which particles or heat can spread.

5. Thermal fatigue: Thermal fatigue is defined as a type of mechanical failure that occurs where a material is repeatedly heated and cooled, causing it to expand and contract.

6. Thermal shock: When a material experiences a rapid change in a temperature, causing internal stresses that can lead to cracking or breaking is known as thermal shock

7. Melting point: It can be defined as the temperature at which the material changes from a solid state to a liquid state.

4.3 Electrical Properties:

1. Resistivity: It is the electric property of a material due to which, it resists the flow of electricity through it.

$$\text{Resistivity, } \rho = \frac{RA}{l}$$

Where, R = Resistance of a material

A = Area of cross section

L = Length of a material

2. Conductivity: It is the electric property of a material due to which the electric current flows easily through the material.

$$\sigma = \frac{l}{RA}$$

It is the reciprocal of electrical resistivity.

3. Dielectric strength: It is the insulating capacity of a material against high voltage. A material having high dielectric strength can withstand sufficiently high voltage field across it before it will break down and conduct.

4. Temperature co-efficient of resistance: It is usually employed to specify the variation of resistivity, ρ with the temperature.

Temperature co – efficient of resistance

$$\alpha_T = \frac{\rho - \rho_0}{\rho_0} \times \frac{1}{T - T_0}$$

Where, ρ = Resistivity at temperature T

ρ_0 = Resistivity at temperature T_0

T and T_0 , are degrees in Kelvin

4.4 Chemical Properties:

1. Reaction with oxygen: Many metals produce metal oxide by burning in the oxygen of the air.

2. Reaction with water: Metals produce metal oxide and hydrogen gas while reacting with water, the metals like sodium and potassium react with water violently and an exothermic reaction takes place.

3. Reaction with acid: Salt and hydrogen are produced when a metal reacts with an acid.

4. Reaction with Base: When metal reacts with base, the outcome is the formation of salt and the release of hydrogen

4.5 Magnetic Properties:

1. Diamagnetic materials: These are the materials whose relative permeability is slightly less than unity and they repel the lines of force slightly.

2. Paramagnetic materials: These are the material's whose relative permeability is slightly greater than unity and are magnetised slightly. They attract the lines of forces weakly

3. Ferro-magnetic materials: These are the materials whose relative permeability is much greater than unity and t dependent on the field strength. They act the lines of force strongly.

4. Magnetic permeability: It is an ability of a material to allow the magnetic flux when the object is placed inside the magnetic field.

The readiness of a material to accept magnetism is expressed by its permeability.

Permeability is the measure of magnetization produced in a material when it placed in the magnetic field.

5. Magnetic flux density: It is defined as the flux or lines of force passing per unit area through many substance through a plane at right angles to the direction of magnetic flux.

6. Magnetic field strength: It may be defined as the field strength at any point within a magnetic field is the number of lines of force passing through a unit area round the point considered and held perpendicular to the lines.

It may also be defined as the field strength at any point within a magnetic field is the force exerted by a unit North pole at that point.

7. Magnetic moment: When a coil carrying a current I is located in a region of uniform magnetic flux density, will experience a torque whose magnitude is depends on the area of the coil, the current and the component of flux density in the plane of the coil, then the magnetic moment or magnetic dipole moment can be defined as the product of current and the area of the coil i.e.

$$P_m = I \times A \quad \text{Ampere-m}^2 (\text{A-m}^2)$$

It is a vector quantity, where, I =Current in Ampere, A = area of the coil.

8. Magnetization (M): The magnetization can be defined as the magnitude of magnetic moment per unit volume when the materials are placed in presence of magnetic field. It is a vector quantity.

The magnetization M is given by

$$M = N \times P_m$$

Where, N = Number of magnetic dipoles per unit volume

P_m =Magnetic moment.

9. Magnetic susceptibility: It can be defined as the ratio of the magnetization (M) to the magnetizing force (H).

$$\text{Magnetic susceptibility (Z)} = \frac{\text{Magnetization}}{\text{Magnetizing force}} = \frac{M}{H}$$

Magnetic susceptibility is a dimensionless quantity.

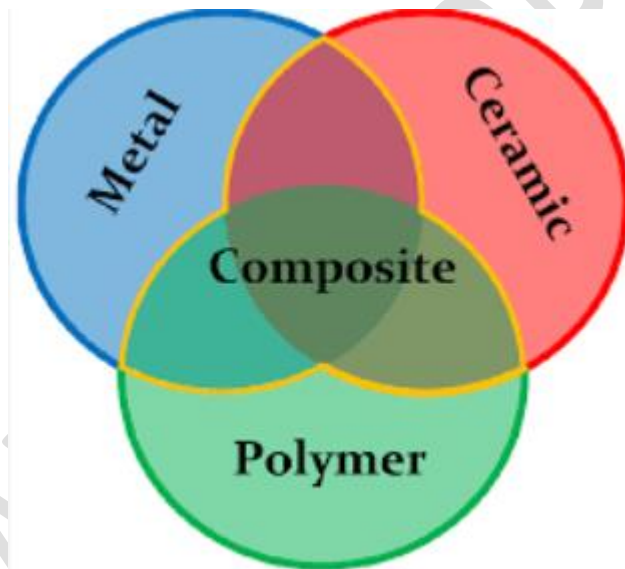
Week 04 Review Questions

1. What are the mechanical properties of metals?
2. Explain any five mechanical properties.
3. What are the thermal properties of metals?
4. Explain thermal properties of metals.
5. Define:
 - a. Specific heat
 - b. Thermal conductivity
 - c. Thermal expansion.
 - d. Thermal diffusivity and
 - e. Thermal fatigue
 - f. Define the magnetic properties of med
7. Explain the following:
 - a. Diamagnetic materials.
 - b. Paramagnetic materials
 - c. Ferromagnetic materials.
 - d. Magnetic permeability.
 - e. Magnetic flux density.
8. Explain chemical properties of metal.
9. Explain electrical properties of metal.
10. Define: Elasticity, Plasticity, ductility hardness and Toughness.

WEEK 05
NON - METALS

Non- Metals Properties, composition and applications of

- ❖ Polymers: Thermoplastics (PE, PLA, PVC, Nylon, ABS), thermosetting polymers (Bakelite, Epoxy) and Biodegradable Polymers.
- ❖ Ceramics- Types - Oxides, Carbides, properties and applications.
- ❖ Composites- Types, Properties and Applications.



5.1 Polymers:

Polymer is a substance composed of a large number of monomers bounded by a chemical reaction. Thus polymer is made up of thousands of monomers joined together to form a large molecule. Each molecule of a polymer is either a long chain or a network of repetitive units or monomers

5.1.1 Thermoplastics:

The plastics which are softened by the application of heat without pressure and hardened on cooling are known as thermoplastic polymers.

Thermoplastics are formed by addition polymerization. Addition polymerization produces chain molecules or linear molecules therefore, thermoplastics can be mechanically deformed and softened at high temperatures. They can be easily moulded or extruded due to the absence of cross links on cooling, they can regain their original low temperature properties. They can be reshaped while in the softened state and they can be rehardened. Therefore, the scrap can be reused again and retain the shape and size into which they are moulded.

Properties of Thermoplastics:

Following are the properties of thermoplastics

- 1) Good compressive strength.
- 2) Excellent tensile strength.
- 3) Good machining properties.
- 4) Good electrical insulation properties.
- 5) Good chemical resistance.

5.1.2 Types of Thermoplastics:

Following are the some important types of thermoplastics:

1. Polyethylene [Polythenes (PE)]:

Polyethylene polymers are produced by polymerizing ethylene molecules. They have excellent electrical insulation properties and are widely used as insulating coatings for electric wires, films, sheets, pipes, bottles and buckets etc.

Properties:

1. Highly flexible.
2. Good chemical resistance.
3. Available in low cost.
4. Good electrical insulator.
5. Greater toughness.
6. Good weather resistance.
7. Density varies from 0.91 to 0.979 cm³.
8. Sensitive to heat (relatively low melting point).

Applications:

1. It is used for packaging.
2. It is used to make containers.
3. Used for pipes and fittings.
4. Used for insulating wires.
5. Used in a building materials.
6. Used in medical implants.
7. Used for bumpers, fuel tanks and interior items.
8. Used for fishing nets.

2. Polylactic Acid (PLA):

Polylactic acid is also known as polylactide, and it is a biodegradable, bio-based thermoplastic polymer derived from renewable resources like corn or sugar cane. Polylactic acid is synthesized by condensing lactic acid monomers and has a similar structure to polyethylene (PE) but it is more rigid due to its higher glass transition temperature.

Properties:

1. PLA is Biodegradable.
2. It is Bio-based product.
3. It can be moulded and shaped through heating.
4. Greater rigidity.
5. PLA can be used in various forms such as films, fibres, nanoparticles etc.

Applications:

1. Used for making medical devices such as sutures, implants etc.
2. Used in 3D printing.
3. Used for food packaging, bags and containers.
4. Used in clothing and other fabrics.

3. Poly-Vinyl Chloride (PVC)

Poly-Vinyl Chloride (PVC) is a widely used synthetic plastic polymer produced through the polymerization of Vinyl Chloride monomers. It is a versatile and cost effective thermoplastic, offering durability and chemical resistance.

Properties:

1. Excellent durability.
2. Good wear and tear resistance.
3. Good chemical resistance.
4. It can be readily moulded, extruded and formed into various shapes and sizes.
5. Cheaply available.

Applications:

1. Used for pipes, window frames.
2. Used as a flooring materials.
3. Used for wire insulation.
4. Used as packaging materials.
5. Used for medical devices.
6. Used for raincoats, shower curtains etc.

4. *Nylon:*

Nylon is a synthetic polymer characterized by repeating amide linkages. It is a strong, elastic and versatile material used in various applications, including textiles, plastics and industrial products.

Nylon can be processed into fibers, films and moulded into different shapes.

Properties:

1. High tensile strength.
2. Good resistance to abrasion and wear.
3. Excellent elasticity.
4. Good chemical resistance.
5. High thermal resistance.
6. Light in weight.
7. Recyclable.

Applications:

1. Used in textiles.
2. Used for ropes and parachutes.
3. Used for seat belts, tyres, etc.
4. Used for machine parts, gears etc.
5. Used for 3D printing.
6. Used for electrical components.

5. *Acrylonitrile Butadiene Styrene (ABS):*

It is one of the versatile thermoplastic polymer known for its high strength, durability and resistance to impacts and chemicals. It is made up of three monomers acrylonitrile, butadiene and styrene. It is widely used in manufacturing various products due to its easy to processing.

Properties:

1. High impact resistance.
2. Good heat resistance.
3. High chemical resistance.
4. Easy to mould and machine.
5. Greater toughness.

6. High rigidity.
7. Can be finished with smooth and glassy surface.

Applications:

1. Used for control panels of vacuum cleaners, food processors,
2. Used in computer keyboards, remote controls.
3. Used for toys.
4. Used for housings of audio/video equipment's.
5. For suitcases, travel bags etc.
6. Used for helmets, pads, etc.
7. Used for dashboards, bumpers, mirror housings etc.
8. Used for pipe fittings, wall panels.
9. Used for decorative items.

Thermosetting Polymers:

The plastics which are softened by the application of heat and pressure and harden on cooling are known as thermosetting plastics.

Thermosetting plastics are the polymers which do not deform on mechanical stressing. The important examples are polyster, phenolics, urea formaldehyde, epoxide, phenol formaldehyde, silicon's etc.

Thermosetting plastics are formed by condensation polymerization. The condensation polymerization produces cross linked molecules, therefore, the thermosetting plastics cannot be softened once they are moulded, even at high temperatures i.e., their plasticity does not change with the temperature. As the result of this, they cannot be remoulded into any new shape. Therefore, these plastics cannot be reused.

It has been observed that on raising the temperature up to the point, where the cross links are broken, and irreversible takes place. At this temperature, all the useful properties of the material, are destroyed, such a reaction is known as degradation polymerization of the polymers.

Characteristics or Properties of Thermosetting Plastics:

Following are the characteristics or properties of thermosetting Plastics:

1. These are hard and brittle.
2. High heat resistant.
3. They have an excellent tensile strength.
4. Good resistance to chemicals.
5. They cannot be reused.
6. They have an excellent adhesive properties.
7. Good toughness.
8. Good electrical insulation properties.

Applications:

Following are the uses of thermosetting plastics:

1. Used for printed circuit boards, boat bodies etc.
2. Used in papers, mat, cloth, insulation for wire and cables etc
3. Used for rubber compounds, resins, oils, grease etc.
4. Used for instrument dials, electric mixer housings, cosmetic Boxes, distributor heads etc.
5. Used for plastic crockery, automobile parts, laminates Varnish etc.

Types of Thermosetting Polymers:

1. Bakelite:

Bakelite is a thermosetting plastic, specifically a phenolic resin formed by the reaction of phenol and formaldehyde under high temperature and pressure. It was the first commercially produced synthetic plastic, known for its excellent electrical insulation, heat resistance and mouldability.

Composition:

Bakelite is a phenol-formaldehyde resin, it's created from the chemical reaction of phenol and formaldehyde.

Properties:

- 1) Bakelite is a rigid material.
- 2) Very hard material with
- 3) Excellent electrical insulation.
- 4) High heat resistance.
- 5) It is also high mouldable.

Application:

- 1) Used for electrical insulators.
- 2) Used for radio and telephone casings.
- 3) Used for kitchenware, jewellery, pipe stems.
- 4) Used for children's toys and firearms.

2. Epoxy:

Epoxy is a type of polymer that hardens or cures through a chemical reaction when mixed with a curing agent and heated or exposed to specific conditions. Once cured, it cannot be reshaped or melted. Epoxy resins contain epoxide groups, which are reactive molecules that react with a curing agent to form the cross-linked polymer network.

Properties:

1. High durable.
2. High resistant to chemicals and heat.
3. High strength-to-weight ratios.
4. Ability to create a glossy finish.

Applications:

1. Used for coating the automotive parts Epoxy coatings are durable and resistant to chemicals and heat, making them ideal for industrial floors.
2. Used for coating industrial floors.
3. Used as adhesive in bonding various materials like wood, metal, glass, and plastic.
4. Used to bind fibre glass or carbon fibre in composite materials.
5. Used in electronics, furniture and crafts.

3. Biodegradable Polymers:

Biodegradable polymers may be made from bio-sources like corn, wood cellulose etc., or can also be synthesized by bacteria from small molecules like butyric acid or valeric acid that give polyhydroxybutyrate (PHB) and polyhydroxyvalerate (PHV). Biodegradable polymers are materials that can break down naturally through microbial action or other environmental factor into simpler harmless substances like water carbon dioxide and biomass. These polymers are a sustainable alternative to traditional plastics, which can take centuries to decompose and can be harmful to the environment.

Properties:

1. Biodegradable polymers can be broken down into simpler molecules, such as water, carbon dioxide and compost by micro-organisms in the environment.
2. Having controlled degradation.
3. They are generally hydrophilic, which allows for easier interaction with water-soluble enzymes and micro-organisms responsible for degradation.
4. Provides high surface area for degradation.
5. Lower levels of crystallinity.
6. These are generally non-toxic.

Application:

1. Used to create new tissues, such as skin, bone and nerve tissue.
2. Used to deliver drugs and vaccines.
3. Used to make food containers, bottles and other packaging.
4. Used to collect organic waste.
5. Used to package fruit and vegetables.
6. Used to create soil compostable much that disappears in few months.
7. Used to make cosmetics.
8. Used to make electronic devices.

9. Used for waste water treatment.
10. Used to make textiles and hygiene.
11. Used to make biofuel.

Difference between Thermoplastics and Thermosetting Plastics:

Thermoplastics	Thermosetting plastics
1) These are composed of chain molecules.	1) These are composed of cross linked molecules.
2) They are produced by addition polymerization.	2) They are produced by condensation polymerization.
3) They undergo no chemical change in the moulding operation.	3) They undergo chemical change in the moulding operation.
4) They can be mechanically deformed and softened at high temperatures.	4) They cannot be mechanically deformed and softened at high temperatures
5) Their plasticity increases with increase in temperature.	5) Their plasticity does not increases with increase in temperature.
6) They can be easily moulded and remoulded into any shape.	6) They cannot be moulded into any new shape.

5.2 Ceramics:

Ceramics are these products which are made from inorganic materials and have non-metallic properties.

Ceramics can also be defined as those materials containing phases that are compounds of metallic and non-metallic elements.

Example: Ionically, bounded Magnesia (Mgo) and Covalently bonded Silicon Carbide (Sic). The traditional ceramic materials are stone, brick, concrete, clay, glass, vitreous enamel and refractories. Majority of these are composed of silicates. New ceramic materials include oxides, carbides, borides and other similar compounds which are being developed. Such materials have properties of special advantages in particular applications such as high temperature work, solid state electronics and in nuclear reactors.

The ceramics have high melting points. It is because of the strong primary bonding (ionic or covalent) between the constituent atoms. Materials such as magnesia and alumina, which have melting points of 2800° C to 2040° C respectively make excellent refractory materials for lining of high temperature furnaces. They are also used for metallurgical polishing. Silica particles are used in sand-stone and glass paper. Corundum (alumina contaminated with iron-oxide) is used in energy paper and grinding wheels. Alumina is used for tips of lathe tools etc.

Properties of Ceramic Materials:

1. They are hard, brittle and durable.
2. They have high melting points.
3. Good corrosive resistance.
4. These are excellent refractory materials.

5. Low thermal conductivity.
6. Low electric conductivity.
7. Good chemical and thermal stability.
8. Not affected by oxygen.
9. High wear resistance with low density.
10. High compressive strength.

Applications of Ceramic Materials:

Following are the general applications of ceramics:

1. Used for metallurgical polishing, cutting tools and engine components.
2. Used in sand stone and glass papers, energy paper and grinding wheels.
3. Used in furnaces and chemical processing systems.
4. Used for coating of cutting tools and engine components.
5. Used as a thermal barriers.
6. Used in fuel cells, glassware, corning ware, dinner ware, etc.
7. Used in a ceramic filters, ceramic rotors, valves, thermistors, sensors, piston rings, safety glass windshields in automobiles.
8. Used as a structural components for ground and naval vehicles, etc.
9. Used for flooring and as a decorative material.
10. Used in glass fibres and optical fibres.
11. Used in insulators, capacitors and IC packages.
12. Used in bricks, lab equipment's, cements, membranes, etc.
13. Used in communication equipment's like TV and radio components, microphones.
14. Ceramic abrasives are used for polishing, lapping and pressure blasting of materials.
15. Used in refractories, chemical industries.
16. These are used in turbine blades, knife, exhaust manifolds in automobiles etc.
17. To build the ceramic balls for bearings.
18. To replace human body parts like orthopaedic joint replacement, bone implants, dental restoration etc.

Types of Ceramics:

1. Oxide Ceramics:

Oxide ceramics are inorganic compounds formed by metallic or metalloid elements (like aluminium, zirconium, titanium, magnesium or silicon) bonded with oxygen. They are known for their high melting points, chemical stability, and ability to withstand high temperatures. Examples include alumina (Al_2O_3), zirconia (ZrO_2) and silica (SiO_2).

Properties:

1. High melting points.
2. Chemical inertness: They are resistant to chemical attack from various substances, including acids and other harsh Environments.
3. High strength and hardness.

4. Durable and abrasion-resistant.
5. Excellent electrical insulation.
6. Low density.

Applications:

Oxide ceramics are used in a wide range of industries, including:

1. **Electronics:** Used for insulators, substrates and packaging in electronic devices.
2. **Aerospace:** Used for high-temperature parts, such as engine
3. **Manufacturing:** Used in cutting tools, dies and wear parts.
4. **Biomedical:** Used in dental implants and other biocompatible applications
5. **Chemical processing:** Used in acid-resistant pump parts and piping.

2. Carbide Ceramics:

Carbide ceramics are a class of non-oxide ceramics known for their exceptional hardness, high-temperature resistance, and wear resistance. They are typically composed of a metal (like silicon, boron or titanium) combined with carbon. Key examples include silicon carbide (SiC), boron carbide (B₄C) and titanium carbide (TiC). These materials are widely used in various applications due to their robust properties, including abrasives, cutting tools, armor plating and high-temperature engineering components.

Properties:

1. High Hardness.
2. High Temperature Resistance.
3. Thermal Shock Resistance.
4. Corrosion Resistance.
5. High Thermal Conductivity.
6. Good Stiffness.
7. High Toughness.

Applications:

1. **Abrasives:** Silicon carbide is a common abrasive used in grinding wheels, polishing materials and sandpaper.
2. **Cutting tools:** Tungsten carbide and other carbide ceramics
3. **Ballistic armor:** Boron carbide is used in bullet proof vests and tank armor due to its high hardness and low density.
4. **High temperature engineering:** Silicon carbide is used in furnace linings, heat exchangers and other high temperature components.
5. **Electronics:** Silicon carbide is used in semiconductors and other electronic components due to its semiconducting properties and high thermal conductivity.

5.5 Composites:

Sometimes two or more materials are combined together to produce a new material, which possesses much superior properties than any one of the constituent materials. Such a material is known as composite material. The common example of a natural composite material is wood, which consists of long cellulose fibre held together by amorphous lignin. Some of the artificial (or synthetic) composite materials are cement concrete, glass reinforced plastic plywood etc.

A composite material is a combination of two or more materials having compositional variations depicting properties distinctively different from those of the individual materials of the composite. The composite material is generally better than any of the individual components as regards their strength, heat resistance or stiffness.

The compound materials are incorporated into the composite to take advantage of their properties and their applications.

Properties of Composite Materials:

Following are the properties of composite materials:

- 1) High strength of weight ratio.
- 2) High stiffness to weight ratio.
- 3) Good wear resistant.
- 4) Superior magnetic properties.
- 5) High modulus of elasticity.
- 6) Superior mechanical properties.
- 7) High resistance to thermal expansion.
- 8) Good corrosive resistivity.
- 9) Excellent fatigue resistance.
- 10) Improved toughness.
- 11) Occupy less space.
- 12) High temperature performance.

Applications or Uses of Composite Materials:

Following are the applications of composite materials:

- 1) High temperature structures.
- 2) Aerospace applications where light weight, stiffness and fatigue resistance are essentially required.
- 3) Used in gas turbines.
- 4) Storage battery plates.
- 5) High temperature engine parts.
- 6) Structural walls, shells, cylinders, pipes, etc.
- 7) Used in reactors.
- 8) Electrical components.

- 9) Used in pressure vessels.
- 10) Used in deep sea mining equipment's.
- 11) Used in aircrafts

5.6 Types of Composites:

- 1) GFRP (Glass Fibre Reinforced Polymer)
- 2) CFRP (Carbon Fibre Reinforced Polymer).

GFRP (Glass Fibre Reinforced Polymer):

Glass Fibre Reinforced Polymer is a composite material where fine glass fibers are embedded in a polymer resin matrix, which is then cured to harden the material. It is a lightweight yet strong and durable material. GFRP is gaining popularity in various industries, including construction, due to its strength, corrosion resistance and flexibility.

Properties:

- 1) High strength,
- 2) Resistance to cracking.
- 3) Resistance to deformation.
- 4) Lightweight.
- 5) Reduced maintenance.

Applications:

GFRP is used in various construction applications, including:

- 1) **Rebar (reinforcement bars):** Replacing traditional steel rebar in concrete structures.
- 2) **Structural components:** Used in beams, columns and other structural elements.
- 3) **External strengthening:** Used to reinforce existing structures.
- 4) **Automotive:** Used in body panels, engine components and other parts.
- 5) **Aerospace:** Used in aircraft parts and components.
- 6) **Medical:** Used in hospital settings for non-conductive materials.

2. CFRP (Carbon Fibre Reinforced Polymer):

Carbon Fibre Reinforced Polymer is a composite material when carbon fibres are embedded in a polymer resin matrix, which is then cured to harden the material. This is known for its high strength-to-weight ratio. This material is widely used in various industries, particularly in aerospace, automotive and sports equipment.

Properties:

- 1) High strength-to-weight ratio.
- 2) High resistance to corrosion.
- 3) High fatigue resistance.
- 4) High resistance to moisture and chemicals.
- 5) Lightweight.

Applications:

CFRP is used in a wide range of applications:

- 1) **Aerospace:** Aircraft components like fuselages, wings and rotor blades.
- 2) **Automotive** Body panels, chassis and other structural components.
- 3) **Sports equipment:** Bicycles, golf clubs and tennis rackets
- 4) **Civil engineering:** Strengthening concrete structures, bridge and buildings.
- 5) **Consumer goods:** Laptops, tripods and musical instruments

WEEK 05 Review Questions:

- 1) What is polymer? List its types.
- 2) What is thermoplastic? Explain briefly.
- 3) Explain the following briefly: a) PE b) PLA c) PVC.
- 4) What are the properties and applications of Polylactic acid?
- 5) Write the properties of polyethylene.
- 6) Explain the applications of polyethylene.
- 7) Mention the properties and applications of polyethylene.
- 8) Explain the properties and applications of polyvinyl chloride (PVC).
- 9) State the properties of thermoplastic.
- 10) State the properties of thermosetting plastic.
- 11) State the applications of thermosetting plastic.
- 12) What are the properties and applications of Polylactic acid (PLA)?
- 13) Explain polyvinyl chloride and state its properties.
- 14) What is Nylon? State its properties and applications.
- 15) What is ABS polymer? State its applications.
- 16) Explain ABS polymer. State its properties.
- 17) State the properties of Bakelite.
- 18) What are the properties and applications of Epoxy?
- 19) Explain biodegradable polymer and state its properties.
- 20) Differentiate thermoplastics and thermosetting plastics.
- 21) Define ceramics and state its properties.
- 22) Write the properties and applications.
- 23) What is oxide ceramic, state its properties.
- 24) Explain carbide ceramics and state its applications.
- 25) State the properties and applications of carbide ceramics.
- 26) Define composite material and state its properties.
- 27) Explain composite materials.
- 28) Explain GFRP composite and write its properties.
- 29) What is CFRP? Explain its properties.
- 30) State properties and applications of GFRP.
- 31) State the properties and applications of CFRP.

WEEK 06
CARPENTRY SHOP

Carpentry Practice

- ❖ Explain and show the different Types of wood, their Properties and applications.
- ❖ Demonstrate the Safety precautions to be followed in Carpentry shop.
- ❖ Demonstrate the tools and equipment's used in Carpentry shop.



6.1 Introduction:

Carpentry may be designed as the process of making wooden articles and components such as floors, partitions, doors and windows. Carpentry involves cutting, shaping and fastening wood and other materials together to produce a finished product. Preparation of joints is one of the important operations in wood work. Joinery denotes connecting the wooden parts using different points such as lap joints, mortise and T-joints, bridle joints, etc.

Types of Wood, their Properties and Applications:

Most common woods used in carpentry shop are given below:

1. **Babul:** It is obtained from a thorny tree, which bears small leaves and yellow flowers. The wood have close grained, tough and pale red colour. It grows abundantly all over India and is used for agriculture equipment's, tools, handles, bodies of carts and wheels, tent pegs etc.
2. **Deodar:** It is found in Himalayas. It is light-coloured and has close grains. It is light and can be easily worked. It is used for the manufacture of table, chair and furniture etc.
3. **Mahogany:** It has rich golden brown colour, which deepens with age. It contains resinous oil which prevents attack of insects. It is very tough, strong, and highly stable in fashioned form. This wood is extensively used in the manufacture of furniture's, boats, and in pattern making.
4. **Mango:** It is largely found all over India. It has coarse and open grained fibres. It has deep grey colour. It is cheap and readily available in large quantity and is extensively used in manufacture of doors, windows and furniture but not of good quality.
5. **Sal:** The wood is of dark brown colour. It is hard, close-grained, heavy and durable. It is considered to be the most useful and valuable wood for almost all engineering works. This tree is found all over India and is used in the manufacture of beams, posts, roofing, railway sleepers etc.
6. **Teak:** It is native to India and Burma. It is known for its extreme durability and long lasting quality. The wood is moderately hard, strong and straight grained. It can be easily worked. It is oily and fragrant and takes a beautiful polish. It possesses a lovely golden-yellow colour, which darkens with age. The teak is most important ship-building timber, and outdoor work like gates, external doors, windows etc., are made from teak as well. It is also used for staircases, flooring, panelling and furniture.
7. **Kail:** It is a close-grained, heavy wood. It has brown colour. It is moderately hard and durable wood and does not permit easy workability. It is used for carpentry and joinery, furniture making and for railway sleepers.
8. **Chir or Cheel:** It has coarse grained fibres. It is soft and brown in colour. It is mostly found in Himalayan region. It is used for interior wood work in low cost house building.

6.2 Safety in a Carpentry Shop:

To ensure safety in a carpentry shop, you can follow these precautions:

- 1) **Wear appropriate clothing:** Avoid wearing loose clothing that can get caught in machinery. Remove rings, watches, and scarves.

- 2) **Keep your work area clean:** This reduces the risk of tripping or getting sawdust in your eyes.
- 3) **Use tools properly:** Know how to use your tools and use them for their intended purpose.
- 4) **Inspect tools:** Check that tools are clean, sharp and in good in condition, if any repair before using them.
- 5) **Avoid distractions:** Focus on the task at hand and avoid distractions when using power tools.
- 6) **Avoid drugs and alcohol:** Avoid using drugs and alcohol while working with dangerous tools.
- 7) **Follow lockout/tag-out procedures:** Follow safety procedures for working with power tools and electricity.
- 8) **Be careful with sharp tools:** Sharp tools can cause severe injuries if not handled properly.
- 9) **Be careful around elevated surfaces:** Working on elevated surfaces poses a risk of falling.
- 10) **Be careful around chemicals:** Some wood working materials release toxic fumes.

6.3 Carpentry Tools:

Carpentry tools are used to produce components to an exact size.

The types of carpentry tools are as follows:

- 1) Marking tools
- 2) Measuring tools
- 3) Holding tools
- 4) Cutting tools
- 5) Planning tools
- 6) Boring tools
- 7) Striking tools
- 8) Miscellaneous tools.

1. Marking Tools:

It is used for marking lines parallel to the edges of a wooden piece. It consists of a square wooden stem with a sliding wooden stock on it. On the stem, a marking pin is attached which is made up of steel. This consists of two pins; the distance between the pins is adjustable. It is used to draw parallel lines on the stock.

2. Measuring Tools:

The carpentry measuring tools are classified as follows:

- 1) Steel tape
- 2) Steel rule
- 3) Calliper.

Steel tapes and steel rules are mainly used for measuring short and lengths in millimetres.

- ❖ A **try square** is used for testing squareness and marking o joints.
- ❖ A **meter square** is used for marking and measuring an angle of 45 degree.
- ❖ A **bevel square** is used for marking and listing angles between 0 degree to 180 degree.

Callipers are used for the precision measurement of cylindrical surface. Inside callipers are used for measuring outside diameter an outside callipers are used to measure inner diameter of a pipe.

3. Holding Tools:



The carpentry holding tools are shown in fig.

Carpentry Vice:

A carpentry vice is the common work holding device. It consists of one fixed jaw and one movable jaw. It's one jaw is fixed to the side of the table while the other is movable by means of a screw and a handle.

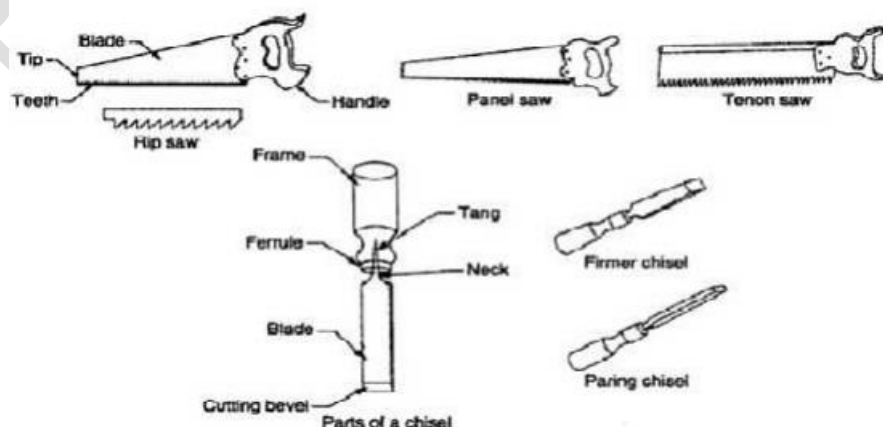
Bar Clamp:

The bar clamp (or) sash clamps are generally used in pairs in gluing up operations at the final assembly of joinery work. It is made up of a steel bar of T-section, wine malleable iron fittings and a steel screw.

G-Clamp:

G-clamp is made up of malleable iron with acme threads of high quality steel. It can be used for clamping small work when gluing up.

4. Cutting Tools:



Saws

A saw is used to cut wood into pieces. There is different type of saws, designed to suit different purpose. A saw is specified by the length of its tooled edge. The following saws are used in the carpentry section.

Rip Saw:

The blade of rip saw is either straight or skew-backed. The teeth are so set that the cutting edge of this saw makes a steeper angle about 60° .

Cross Cut Saw:

This is similar in shape of a rip saw. It is used to cut across the grain of the stock. The correct angle for cross cutting is 45° . The teeth are so set that the saw kerf is wider than the blade thickness. This allows the blade to move freely in the cut without sticking.

Tenon or Back Saw:

A tenon saw is used for fine and accurate work. It consists of a very fine blade, which is reinforced with a rigid steel back. The teeth are shaped like those of cross cut saw.

Chisels:

Chisels are used for cutting and shaping wood accurately. Wood, chisels are made in various blade widths, ranging from 3 to 50 mm. Most of the wood chisels are made into tang type, having a steel shank which fits inside the handle.

Firmer Chisels:

These are general purpose chisels and are used either by hand pressure or by a mallet. The blade of a firmer chisel is flat and their sloping face is at an angle 15° to 52° .

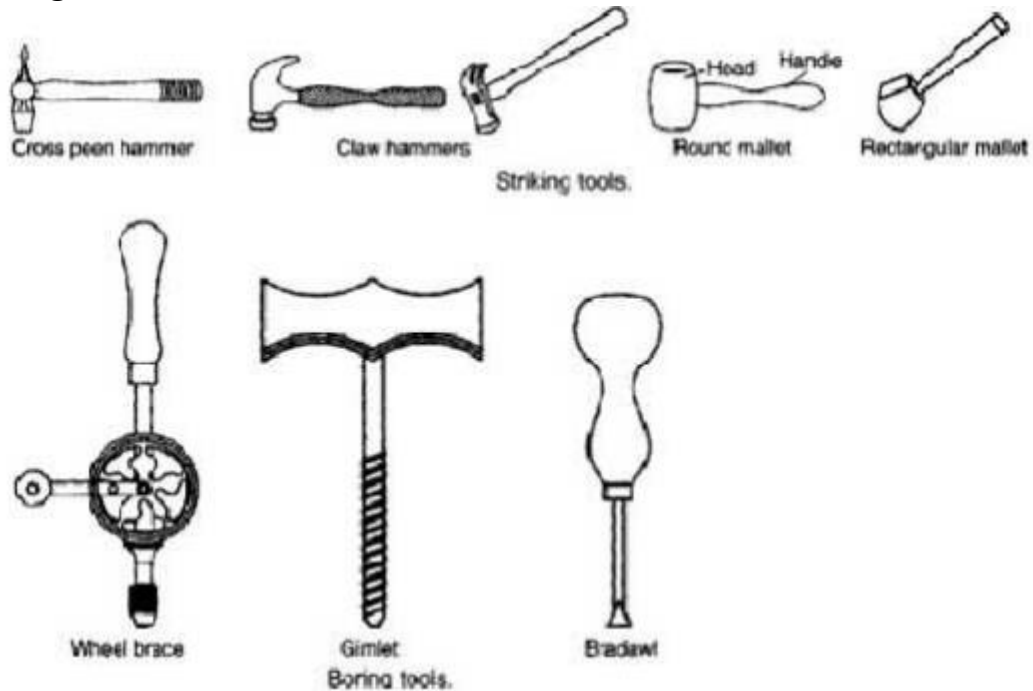
5. Boring Tools:

Boring tools are used to make holes in wood. Common types of boring tools are as follows:

- 1) Bradawl
- 2) Gimlet
- 3) Brace
- 4) Bit and drill.

A brace holds and turns the bit and boring of a hole is obtained. A brace having two jaws is used for holding the bit in one end. It has two types, namely ratchet brace and wheel brace. A bradawl and a gimlet are used for boring small holes. These tools are hand operated.

6. Striking Tools:



WEEK 06 Review Questions

- 1) List the different types of wood used in carpentry shop
- 2) List the properties of different woods used in carpentry shop.
- 3) List the applications of different woods used in carpentry shop.
- 4) Explain the safety in a carpentry shop.
- 5) List the safety measures to be taken in a carpentry shop.
- 6) List the tools used in carpentry tools.
- 7) List the cutting tools used in carpentry shop.
- 8) List the striking tools used in carpentry shop.
- 9) Explain the measuring tools used in carpentry shop.
- 10) List the different cutting tools used in carpentry shop.

WEEK 07
FITTING SHOP

Fitting Practice

- ❖ Demonstrate the Safety precautions to be followed in Fitting shop.
- ❖ Demonstrate the tools and equipment's used in Fitting shop.
- ❖ Demonstrate the different operations like chipping, filing, drilling, tapping, sawing, cutting etc.



7.1 Introduction:

In a workshop, a fitting shop is the area where components are assembled and fitted together, typically using hand tools and processes like marking, filing, sawing and drilling. It focuses on hand work to achieve a precise shape and fit to the parts, often it is done on a work bench with hand tools.

In fitting shop unwanted material is removed with the help of hand tools. It is done for mating, repair and manufacturing purposes. Commonly used tools in fitting shops are hacksaw, files, chisels, etc.

7.1.1 Safety in a Fitting Shop:

To ensure safety in a fitting shop, you should follow these precautions:

- 1) **Wear protective things:** Wear closed-toe shoes, safety glasses, and an apron. Avoid loose clothing, jewellery and neckties.
- 2) **Keep workspaces clean:** Keep the floor free of debris, oil and grease. Clean tools are safer to use.
- 3) **Use tools safely** Use the right tools for the job. Do not force machines.
- 4) **Be aware of others:** Keep others away from the direction of chisels.
- 5) **Position workpiece correctly:** Position workpiece close to the vice to prevent injury.
- 6) **Use tools properly** apply force in the forward stroke when filing and sawing.
- 7) **Take care with measuring instruments:** Handle measuring instruments like micrometres and vernier calliper's with
- 8) **Be careful with sharp tools:** Do not carry sharp tools in your pockets. Keep hands away from sharp tools.
- 9) **Be careful with vices:** Do not use a vice as an anvil. Provide guards between opposite vices.
- 10) **Be careful with liquids** Clean up oil and grease spills immediately.
- 11) **Be careful with hacksaws:** Ease up pressure when nearly finished,
- 12) **Ask for help:** If you are unsure about how to use a tool or aspect of a job, ask for help

7.2 Tools Used in Fitting Shop:

1. **Clamping Tools:** Clamping tools are used for holding the job firmly during various fitting operations

i) **Bench vice:** It is a common tool for holding the jobs. It do consists of cast iron body and iron jaws. The jaws are opened up to required length, job is placed in the jaws and is fully tightened with handle.

ii) **Leg vice:** It is stronger than bench vice and used for heavy work.

iii) **Hand vice:** It is used to grip very small objects.

iv) **Pin vice:** Pin vice is used to hold wire or small diameter rods.

v) **Pipe vice:** It is used to hold pipes. It grips the pipe at four places and is fixed on bench or can be grouted.

2. **Measuring and Marking Tools:**

- i) **Try square:** It is used for checking squareness of two surfaces. It consists of a blade made up of steel which is attached to base at 90°.
- ii) **Bevel protector:** It consists of a steel dial divided into 360° divisions.
- iii) **Combination set:** Multipurpose instrument can be used as a protector, a level, a meter, a centre square and a Try square.
- iv) **Centre square:** It is used to find the centre of the round jobs.
- v) **Scriber and surface gauge:** It is used for marking of lines parallel to a surface. Scriber mounted on a vertical bar is called surface gauge.
- vi) **Dot punch.** It is used for marking dotted lines. Angle of punching end is 60°.
- vii) **Centre punch:** It is like a dot punch used to mark the centre of hole before drilling. Angle of punch end is 90°.
- viii) **Surface plate:** Surface plate is used for testing the flatness, trueness of surfaces, its upper face is planed to form a very smooth surface.
- ix) **Angle plate:** it consists of cast iron in which two ribs of metal are standing at right angle to each other, used for holding and supporting the jobs.
- x) **'V' block:** It is used for supporting as well as marking of round jobs
- xi) **Steel rules:** It is made up of stainless steel and marked in inches or millimetres, available in various sizes ½ ft. to 3 ft.
- xii) **Vernier calliper:** It is a precision instrument used for measuring lengths and diameters. Minimum dimension that can be expressed on vernier calliper is known as least count which is usually 0.001 or 0.02 mm.
- xiii) **Micrometer:** It is used for measuring diameters or thickness of any job. The graduation on micrometres is available in inches as well as in millimetres.
- xiv) **Dial indicator:** A round gauge in which a pointer moves over a graduated scale. The movement is magnified through links. It is used to check the run out or ovality of jobs.
- xv) **Dividers:** Dividers have two legs having sharp feet, It is used for marking arcs, dividing a line or transferring the dimensions.
- xvi) **Callipers:** It is generally used to measure the inside or outside diameters. There are four types of callipers.
 - a) Outside calliper's
 - b) Inside calliper's
 - c) Spring calliper's
 - d) Odd leg callipers.

Gauges:

- i) **Depth Gauge:** It is used to measure the depth of a hole. The beam is graduated in inches or millimetres.
- ii) **Feelers Gauge:** It is used to check the gap between two mating parts. It consists of a number of metal leaves of different thickness marked on the leaves.

- iii) **Radius Gauge:** It is used to check the radius of outer and inner surfaces. Every leave has different radius.
- iv) **Vertical Height Gauge:** It is used to measure the height of the work pieces.
- v) **Thread Gauge:** It is used to check the pitch of the threads. It consists of a number of leaves, pitch of the threads marked on each leaves,
- vi) **Wire Gauge:** It is used to check the diameter of wires and thickness of sheets.

Cutting Tools:

These tools are used to remove the materials:

1. Hacksaw: It is used for cutting the flats, rods etc. The blade of hacksaw is made up of high carbon steel and frame is made from mild steel. The blade is placed inside the frame and is tightened with the help of a flange nut. The teeth of hacksaw blades are generally forward cut. There are two types of hacksaw frames, fixed frame and adjustable frame. The material to be cut with hacksaw is clamped in a vice. The hacksaw should be moved perfectly straight and horizontal.

2. Files: It is used to remove material by rubbing it on the metal. Classification of files.

i) **Size:** The length of file vary from 4 inch to 14 inch.

ii) **Shape:** The shapes available are flat, square, round, half-round, triangular etc.

iii) **Cuts:** Single and double cut.

iv) **Grade:**

- Rough 20 teeth per inch
- Bastard 30 teeth per inch
- Second cut 40 teeth per inch
- Smooth-50-60 teeth per inch
- Dead smooth 100 teeth per inch.

Rough and bastard files are used for rough cutting, smooth and dead smooth files are used for finishing work. Files should be used in perfect horizontal position. Pressure should be applied on the forward stroke only. Work is held in a vice.

3. Chisels: They are used for chipping away the material from the piece. Commonly used forms of chisels are flat, cross cut, half round, and diamond point chisels. Flat chisel is used for chipping a large surface. Cross cut chisel is used for grooves. Half round chisel is used to cut oil grooves. Diamond point chisel is used for chipping plates.

Striking Tools:

Hammers are the only tools used for striking in fitting shop like chipping, fitting, punching etc. Main types of hammer:

- Ball Pean Hammer
- Straight Pean Hammer
- Cross Pean Hammer.

Miscellaneous Tools:

- 1) **Drill:** It is used for making round holes. Twist drill is most commonly used for making holes.
- 2) **Reamer:** It is used to finish the drilled hole to accurate size.
- 3) **Taps:** It is used for making internal threads. Tap is held by the tap holder, normally it comes in a set of three, taper tap, intermediate tap, and plug tap.
- 4) **Die:** It is used for cutting external threads. It is held in a die stock, the handle is rotated by hand and job is held firmly in a vice.

7.3 Operations Performed in a Fitting Shop:

The operations performed in a fitting shop include marking, sawing, filing, drilling, tapping and grinding. These operations are performed on metal work pieces to achieve the desired shape, size and accuracy.

Fitting shop operations:

1. **Marking:** Using a scribe to mark lines on metal workpieces.
2. **Sawing:** Using a hacksaw to cut rods, bars, pipes, and flats. علم
3. **Filing:** Using a file to shape the workpiece.
4. **Drilling:** Using a drilling machine and twist drills to make holes.
5. **Reaming:** Using a reamer to size and finish a drilled hole.
6. **Tapping:** Using a tap to create internal threading.
7. **Dieing:** Using a die to create external threading.
8. **Grinding:** Using a grinder to shape the workpiece.
9. **Other Fitting Shop Operations:** Chipping, scraping, boring, counter sinking, striking, and holding.
10. **Fitting shop tools:** Steel rule, scribe, hacksaw, twist drills and reamers.
11. **Fitting shop Equipments:** Bench vices, holding devices and drilling and threading tools.

WEEK 07 Review Questions

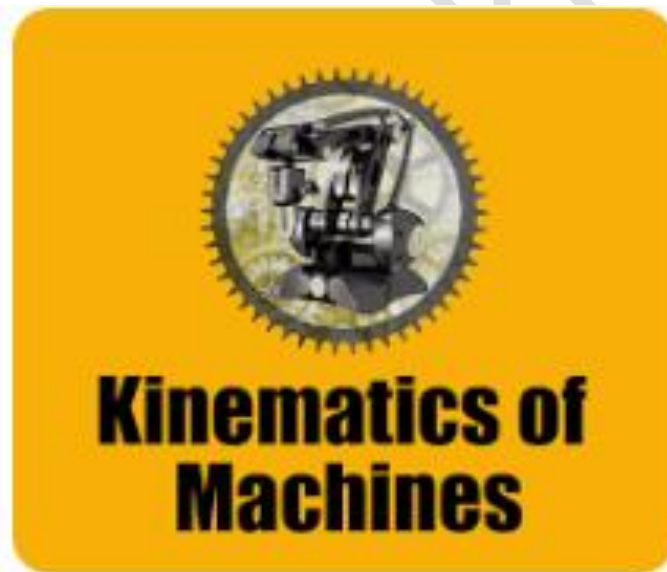
- 1) List the safety measures of fitting shop.
- 2) Explain the safety measures in a fitting shop.
- 3) List the tools used in fitting shop.
- 4) Explain the different tools used in fitting shop.
- 5) List the different gauges used in fitting shop.
- 6) List the cutting tools used in fitting shop.
- 7) Explain the different cutting tools used in fitting shop.
- 8) List the different operations performed in fitting shop.
- 9) Explain the different operations performed in fitting shop.
- 10) List the clamping tools used in fitting shop.
- 11) List the measuring and marking tools used in fitting shop.

WEEK 08

BASICS OF KINEMATICS OF MACHINES

Basics of Kinematics of Machines

- ❖ Kinematic link or Element- Types of links Kinematic pair–Types.
- ❖ Types of constrained Motions, Kinematic chain- Definition of Machine, Structure and Mechanism.
- ❖ Inversions-Types of Kinematic Chains, Four Bar Chain, Beam Engine.



8.1 Introduction:

When the number of bodies are assembled in such a way that the motion of one causes constrained and predictable motion to the others is known as a mechanism. The function of a mechanism is to transmit and modify a motion.

A machine is a mechanism or a combination of mechanisms which, apart from imparting definite motions to the parts, also transmits and modifies the available mechanical energy into some kind of desired work. It is neither a source of energy nor a producer of work but helps in proper utilization of the same. The motive power for the machine has to be derived from external sources.

8.2 Kinematic Link or Element (Simply Link):

The kinematic link or element can be defined as each part of a machine, which moves relative to some other part.

Kinematic link or element can also be defined as a member or a combination of members of a mechanism, connecting other members and having motion relative to them. Therefore, a link may consist of one or more resistant bodies which are rigidly fastened together. So that, they do not move relative to one another.

For example: A slider-crank mechanism consists of four links as shown in fig. 8.1.

Links:

1. Frame and guides
2. Crank
3. Connecting rod
4. Slider.

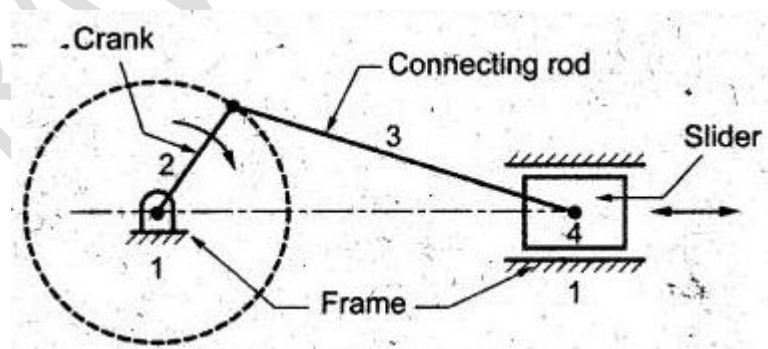


Fig. 8.1: Slider crank mechanism

A link or element need not be a rigid body, but it should be a resistant body. A body is said to be a resistant body, if it is capable of transmitting the required forces with negligible deformation.

Characteristics of a Link:

The link or element should have the following characteristics:

1. It should be a resistant body.
2. It should have a relative motion to some other part.

8.3 Types of Links:

Following are the different types of links

1. Rigid link
2. Flexible link
3. Fluid link.

1. **Rigid link:** A link which does not undergo any deformation while transmitting the motion is known as rigid link.
2. **Flexible link:** A link which is partly deformed in a manner not affecting the transmission of motion is known as flexible link.
3. **Fluid link:** A link which is formed by having a fluid in a receptacle and the motion is transmitted through fluid by pressure or compression only, as in case of hydraulic jacks, brakes and presses.

8.4 Kinematic Pair:

A kinematic pair or simply a pair is a joint of two links having a relative motion between them.

The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely constrained i.e. in a definite direction, then the pair is known as kinematic pair.

8.4.1 Types of Kinematic Pair:

Kinematic pairs can be classified:

A) According to the type of relative motion between elements:

1. Sliding pair
2. Turning pair
3. Rolling pair
4. Screw pair
5. Spherical pair.

B) According to the type of contact between the elements:

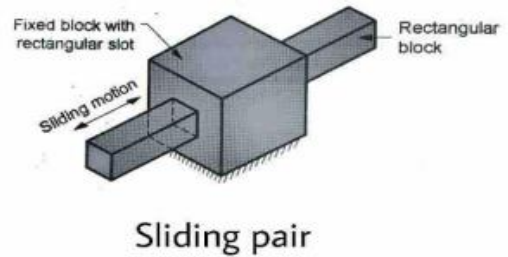
1. Lower pair
2. Higher pair.

C) According to the type of closure:

1. Self-closed pair
2. Force-closed pair.

1. Sliding Pair:

When the two elements of a pair are connected in such a way that they have only sliding motion relative to each other, then the pair is known as sliding pair. Sliding pair has a completely constrained motion.

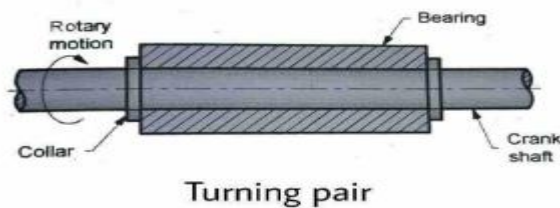


For example:

- A rectangular rod in a rectangular hole in a prism is a sliding pair as shown in fig.
- The piston and cylinder, cross head and guides of a reciprocating steam engine are the sliding pairs.
- Ram and the guides in a shaper.
- Tail stock on a lathe bed etc.

2. Turning Pair:

When the two elements of a pair are connected in such a way that one link has a turning or revolving motion relative to the other, then the pair is known as turning pair. A turning pair is shown in fig.

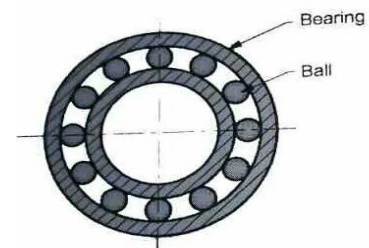


For example:

- A circular shaft revolving inside a bearing is a turning pair.
- Lathe spindle supported in head stock.
- Cycle wheel turning over their axles etc.

3. Rolling Pair:

When the two elements of a pair are connected in such a way that they have a rolling motion relative to each other, then the pair is known as rolling pair as shown in fig.



For example:

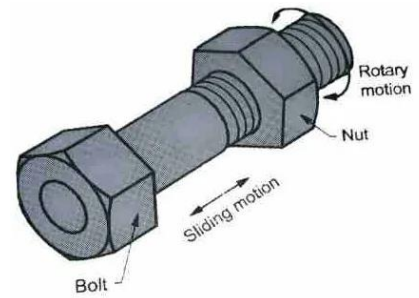
- Ball and roller bearings.
- A rolling wheel on a flat surface etc.

4. Screw Pair:

When the two elements of a pair are connected in such a way that they have a turning as well as sliding motion between them, then the pair is known as screw pair as shown in fig.

For example:

- i) The lead screw and the nut of a lathe.
- ii) Bolt with nut etc.



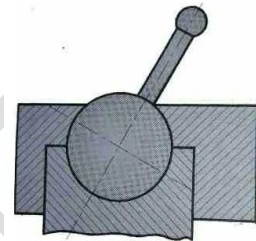
Screw or Helical pair

5. Spherical Pair:

When the two elements of a pair are connected in such a way that, one link in the form of sphere turns inside a fixed link, then the pair is known as a spherical pair as shown in fig. 8.6.

For example:

- i) The ball and socket joint.
- ii) Attachment of car mirror, etc.



spherical pair

6 Lower Pair:

When the two elements of a pair have a surface or area contact between them and when the relative motion takes place, the motion between two elements is purely sliding, then the pair is known as lower pair.

For example: Sliding pairs, turning pairs and screw pairs.

7 Higher Pair:

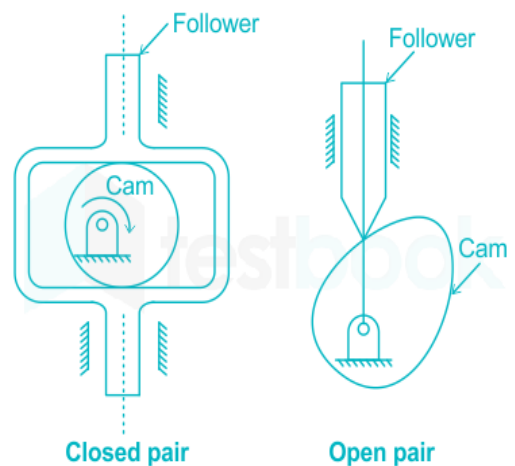
When the two elements of a pair have a line or point contact between them and when the relative motion takes place, the motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair.

For example: Wheel rolling on a surface, cam and follower pair, ball and roller bearings, etc.

8 Self-Closed Pair:

When the two elements of a pair are connected together mechanically in such a way that only a required kind of relative motion occurs, then the pair is known as self-closed pair.

For example: A cam and follower pair as shown in fig a screw pair. The lower pairs are self-closed pairs.



9 Force Closed Pair.

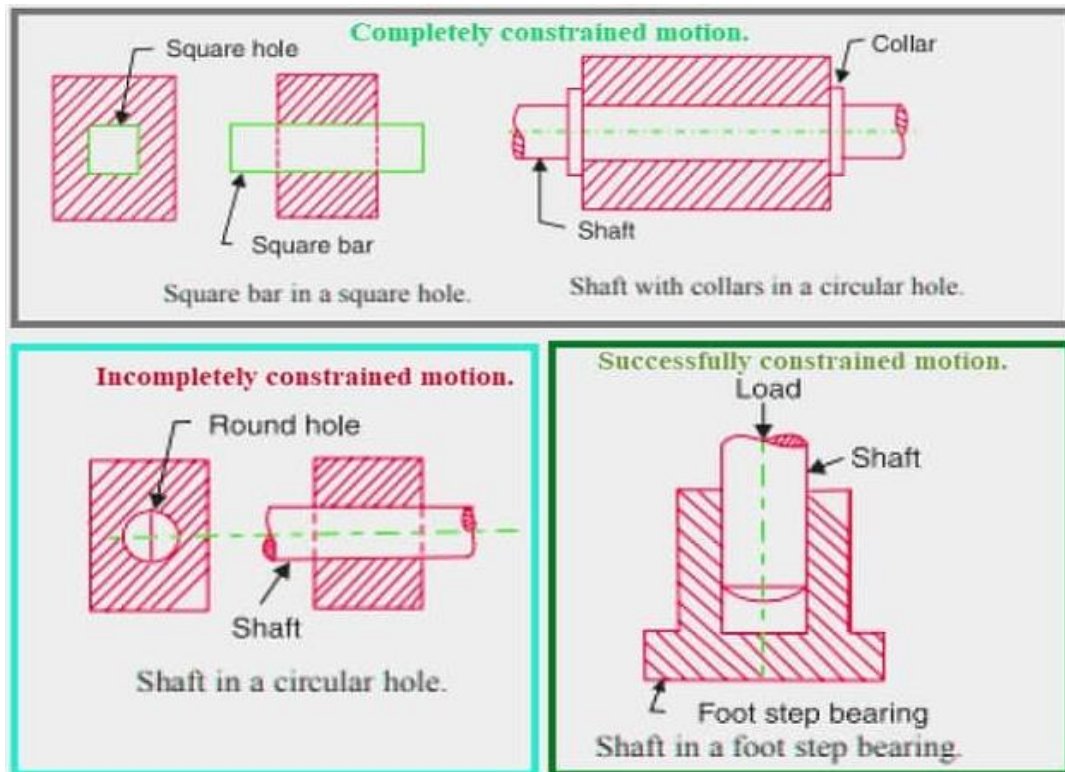
When the two elements of a pair are not connected mechanically but are kept in contact by the action of external forces, then the pair is known as force closed pair.

For example: Cam and follower pair as shown in fig.

8.5 Types of Constrained Motion:

There are three types of constrained motion:

1. Completely constrained motion
2. Incompletely constrained motion
3. Successfully constrained motion.



1. Completely Constrained Motion:

When the motion between two elements of a pair is in a definite direction irrespective of the direction of force applied, then the motion is known as **completely constrained motion**.

The constrained may be linear or rotary.

For example:

- i) The motion of square bar in a square hole as shown in fig. 8.9 i.e. sliding pair. In this case, the inner square bar can only slide inside the square hole.
 - ii) The motion of a shaft with collars at each end in a circular hole as shown in fig. 8.10 i.e., turning pair. In this case the inner shaft can have only rotary motion due to collars at the ends.
- In each case the force has to be applied in a particular direction for the required motion.

2. Incompletely Constrained Motion:

When the motion between two elements of a pair can takes place in more than one direction and depends upon the direction of the force applied, then the motion is called as an incompletely constrained motion. The change in the direction of applied force can change the direction of relative motion between the pair.

For example: A circular bar or shaft in a circular hole without collars as shown in fig. 8.11. In this case, the shaft may rotate or slide in a hole depending upon the direction of the force applied. Each motion is independent of the other.

3. Successfully Constrained Motion:

When the motion between two elements of a pair is possible in more than one direction but is made to have motion only in one direction by using some external means, then the motion is said to be successfully constrained motion.

For example: A shaft in a footstep bearing may have vertical motion apart from rotary motion as shown in fig. 8.12. But due to the applied load on the shaft it is constrained to move in that direction and thus it is successfully constrained motion. Similarly, a piston in a cylinder of an IC engine is made to have only reciprocating motion and no rotary motion due to constraint of the piston pin.

8.6 Kinematic Chain and its Relation:

Definition: Kinematic chain can be defined as an assembly of kinematic pairs, joined in such a way that each link forms a part of two pairs and the relative motion between the links or elements is completely or successfully constrained.

If each link is assumed to form the two pairs with two adjacent links, then the relation between the number of pairs (P) forming a kinematic chain and the number of links (l) can be expressed in the form of an equation

$$l = 2P - 4 \dots \dots \dots (1)$$

Since in a kinematic chain each link forms a part of two pair, therefore, there will be as many as links as the number of pairs.

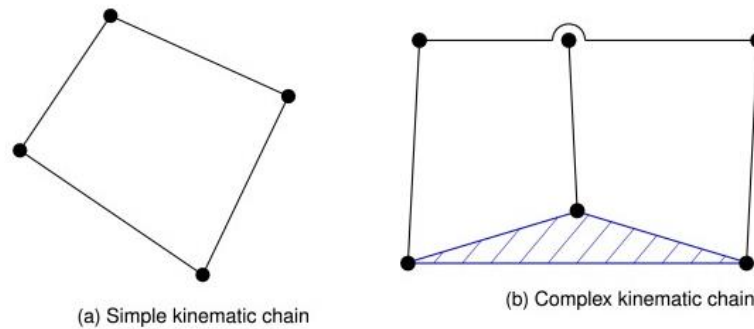
Another relation between the number of links (l) and the number of joints (j) which constitute a kinematic chain is given by the equation:

$$j = 3/2(l - 2) \dots \dots \dots (2)$$

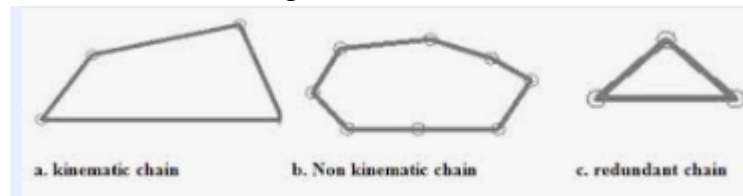
Equation (1) and (2) are applicable to only kinematic chains, in which lower pairs are used.

These equation can also be applied to kinematic chains, in which higher pairs are used. In such case each higher pair may be taken as equivalent to two lower pairs with an additional link or element.

Example: Crank shaft of an engine forms a kinematic pair with the bearings which are fixed in a pair, the connecting rod with the crank forms a second kinematic pair, the piston with the connecting rod forms the third pair and the piston with the cylinder forms a fourth pair. The total combination of these links is a kinematic chain.



In case the motion of a link results in indefinite motions of other links, then the chain is known as **non-kinematic chain** as shown in fig.



A **redundant chain** does not allow any motion of a link relative to the other as shown in fig.

8.7 Machine and Structure:

Machine: Machine is a mechanism or combination of mechanisms which, apart from imparting definite motions to the parts, also transmits and modifies the available mechanical energy into some kind of desired work.

It is neither a source of energy nor a producer of work but helps in proper utilization of the same. The motive power for the machine have to derived from external sources.

Structure: Structure is an assembly of a number of resistant bodies known as members with no relative motion between them. They are meant for carrying loads having straining action.

Ex: A railway bridge, a roof truss, machine frames, etc.

8.7.1 Difference between Machine and Structure:

Machine	Structure
1) The parts of a machine move relative to one another.	1) The members of a structure do not move relative to one another.
2) It transforms the available energy into useful work.	2) No energy is transformed into useful work.
3) Links may transmit both power and motion.	3) Members of structure transmit forces only.
4) Not meant for carrying the loads.	4) These are meant for carrying the loads.

8.8 Mechanisms:

When one of the links of a kinematic chain is fixed, the chain is known as mechanism.

The mechanism can be used for transmitting the motion. **Ex:** Typewriter, engine indicator, etc.

A mechanism with four links is known as simple mechanism and the mechanism with more than four links is known as compound mechanism. When the mechanism is required to transmit the power or to do some particular type of work, then it becomes the machine. When mechanism may be regarded as a machine, then each part is reduced to its simplest form to transmit the required motion.

8.8.1 Inversion of Mechanism:

In a mechanism one of the links of a kinematic chain is always fixed, therefore, we can obtain as many mechanisms as the number of links in a kinematic chain by fixing the different links in a kinematic chain. This method of obtaining different mechanism by fixing different links in a kinematic chain is known as inversion of mechanism.

The relative motions between the various links is not changed in any manner through the process of inversion, but their absolute motions i.e. those measured with respect to the fixed link may be changed drastically.

8.9 Types of Kinematic Chains:

Following are the different types of kinematic chains:

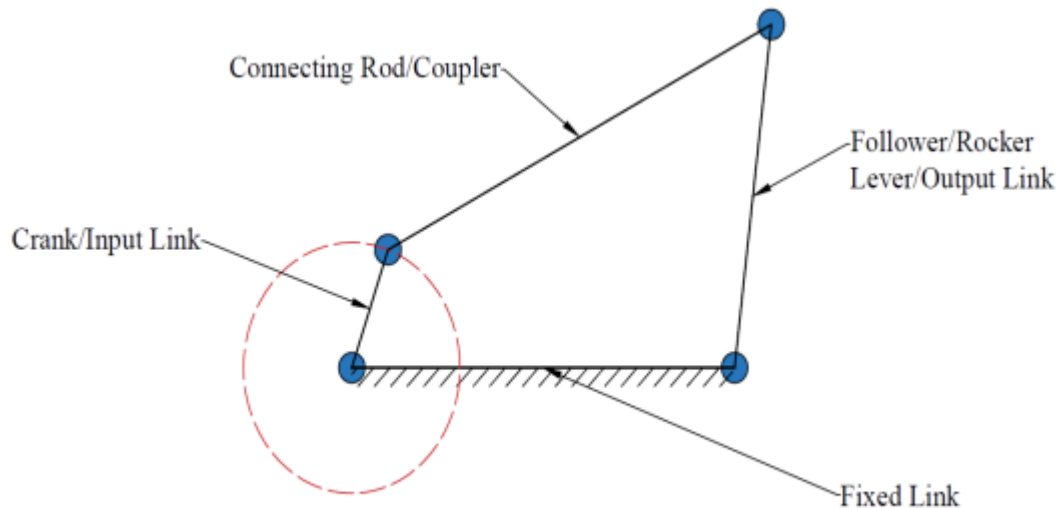
1. Four bar chain or quadric cyclic chain
2. Single slider crank chain
3. Double slider crank chain.

The most important kinematic chains are those consists of four lower pairs, each pair being a sliding pair or a turning pair.

8.10 Four Bar Chain or Quadric Cycle Chain:

A simple form of four bar chain as shown in fig. 8.16. It consists of four links, each of them forms a turning pair at A, B, C and D. These four links may be of different lengths.

According to the Grashof's law for a four bar mechanism, the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths, if there is to be continuous relative motion between the two links,



Four Bar Chain

In this four bar chain, the shortest link will make a complete revolution relative to the other three links, if it satisfies the Grashof's law, such a link is known as crank or driver i.e. link 4 (AD). The link 2 (BC) makes a partial rotation is known as lever or rocker or follower and the link 3 (CD) connects the crank and lever is called connecting rod or coupler. The fixed link 1 (AB) is known as frame of the mechanism.

When the crank i.e. link 4 is the driver, the mechanism is transforming rotary motion into oscillating motion.

8.10.1 Inversion of Four bar Chain:

Following are the some important inversions of four bar chain:

1. Beam engine (crank and lever mechanism)
2. Coupling rod of a locomotive (double crank mechanism)
3. Watt's indicator mechanism (double lever mechanism)

Beam Engine (Crank and Lever Mechanism):

The beam engine consists of a four links as shown in fig. 8.17 and it is also known as crank and lever mechanism. In this mechanism, when crank 'AB' rotates about the fixed centre 'A', the lever 'CDE', oscillates about a fixed centre 'D'. The end E of the lever CDE is connected to a piston rod which reciprocates in the cylinder due to the crank rotation. The main purpose of this mechanism is to convert the rotary motion into the reciprocating motion.

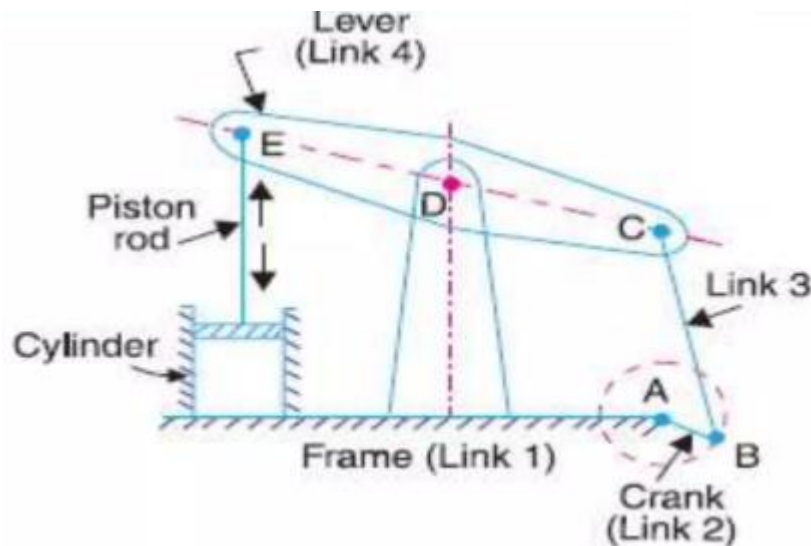


Fig: Beam engine

WEEK 08 Review Questions

1. List the types of links. Explain any two.
2. Define kinematic link. Briefly explain its types.
3. Define following terms:
 - a) Structure
 - b) Mechanism.
4. Define kinematic chain. Name different types of kinematic chains.
5. Define inversion of mechanism.
6. Explain kinematic chain. Give its relation.
7. Explain the following terms:
 - a) Sliding pair
 - b) Turning pair
 - c) Screw pair
 - d) Spherical pair
 - e) Rolling pair.
8. Explain lower pair and higher pairs.
9. Explain self-closed pair and force closed pair.
10. Differentiate between machine and structure.
11. Classify different kinematic pairs.
12. Differentiate between self-closed pair and force closed pair.
13. Explain with neat sketch completely constrained motion.
14. Explain with sketch four bar chain and mention its inversions.
15. Explain with a neat sketch beam engine.
16. Explain with a neat sketch four bar chain.
17. Explain with a sketch successfully constrained motion with example.

WEEK 09

INVERSIONS OF KINEMATICS CHAINS

Inversions and Kinematic Chains

- ❖ Single Slider Crank Chain, Crank and Slotted Lever.
- ❖ Quick Return Motion Mechanism
- ❖ Double Slider Crank Chain, Scotch yoke mechanism
- ❖ Pantograph



9.1 Single Slider Crank Chain:

A simple single slider crank chain as shown in fig 9.1 and it is a modification of basic four bar chain. It consists of one sliding pair and three turning pairs. Such mechanisms are usually found in a reciprocating steam engine and it converts the rotary motion into reciprocating motion and vice-versa.

It consists of link 1, and 2, link 2 and 3 and links 3 and 4 are the three turning pairs whereas the links 4 and 1 is a sliding pair. Link 1 is the frame of the engine, link 2 is the crank, link 3 is the connecting rod and link 4 is of cross-head. When the crank rotates, the cross-head reciprocates in the guides and thus the piston reciprocates in the cylinder.

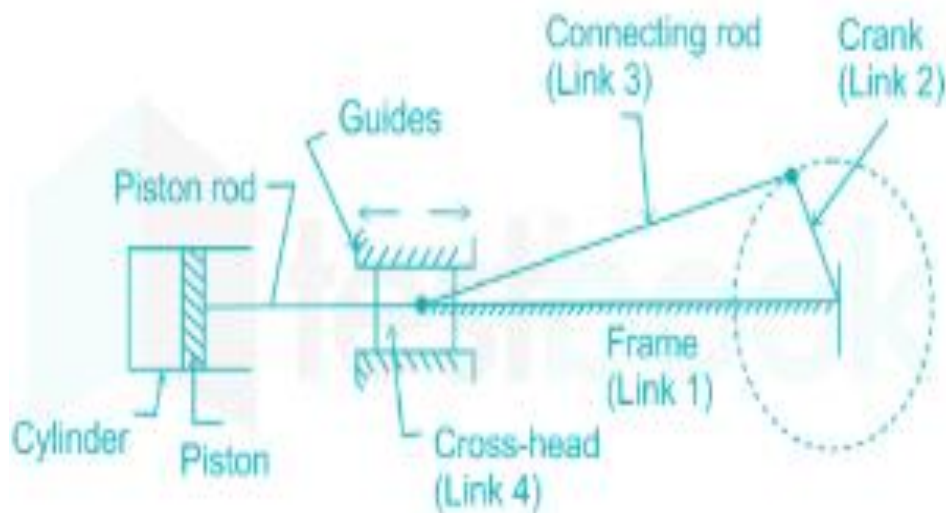


Fig: Single Slider Crank Chain

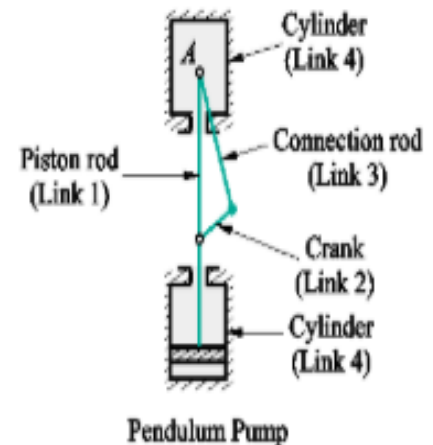
9.1.1 Inversions of Single Slider Crank Chain:

There are four inversions of single slider crank chain are possible and these are:

1. Pendulum pump or bull engine
2. Oscillating cylinder engine.
3. Rotary internal combustion engine or Gnome engine.
4. Crank and slotted lever quick return motion mechanism.
5. Whitworth quick return motion mechanism.

Pendulum Pump or Bull Engine Mechanism:

The pendulum pump or bull engine inversion can be obtained by fixing the link 4 i.e. cylinder (sliding pair) as shown in fig. 9.2. In this mechanism when the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 (cylinder) at A and the piston attached to the piston rod (link 1) reciprocates. In this case, the duplex pump is used to supply the feed water to the boilers, therefore two pistons are attached to the link I as shown in fig.



Crank and Slotted Lever Quick Return Motion Mechanism:

These mechanisms are generally used in shaping machines, slotting machines and in rotary internal combustion engines.

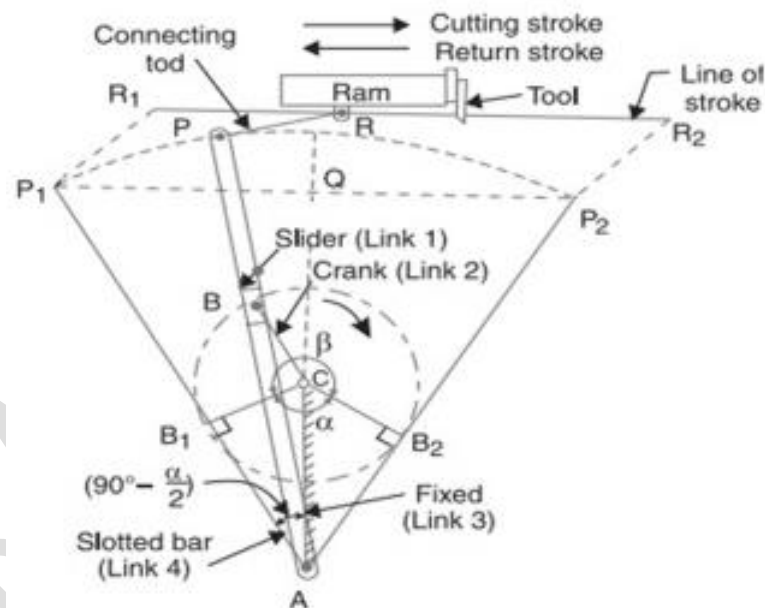


Fig: Crank and Slotted Lever Quick Return Motion Mechanism

A simple form of crank and slotted lever quick return mechanism as shown in fig. The link 3 (AC) corresponds to the connecting rod, which is fixed forming a turning pair. The driving link 2 i.e. the crank BC revolves with uniform angular speed about the fixed centre at C. A sliding block attached to the crank pin at B slides along the slotted bar AP and causing the AP to oscillate about the pivoted pin A. The short link PR transmits the oscillatory motion from AP to the ram which carries the tool and reciprocates along the line of stroke R_1R_2 . The line of stroke of the ram (i.e. R_1R_2) is perpendicular to AC produced.

AP_1 and AP_2 are the two tangents to the circle in the extreme positions of a cutting tool at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB_1 to CB_2 (or through an angle β) in a clockwise direction. The return stroke occurs when the crank rotates from the position CB_2 to CB_1 (or through an angle α) in a clockwise direction.

Since the crank has a uniform angular speed.

$$\text{Therefore, } = \frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360 - \beta}$$

$$\text{OR} \quad = \frac{360 - \alpha}{\alpha}$$

Since the tool travels a distance of R_1R_2 during the cutting and return stroke, therefore, the

$$\text{length of stroke} = 2AP \times \frac{CB}{AC}$$

9.2 Double Slider Crank Chain:

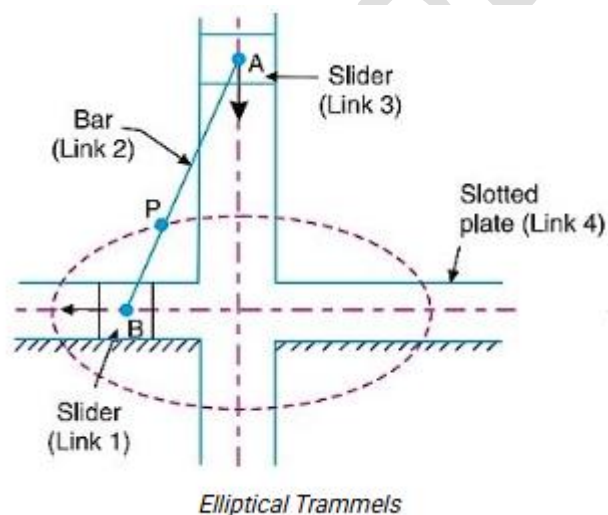


Fig: Double Slider Crank Mechanism

The kinematic chain which consists of two sliding pairs and two turning pairs is known as double slider crank chain. A simple form of double slider crank chain as shown in fig. 9.4. In this mechanism link 1 and link 2 form one turning pair and link 2 and link 3 form the second turning pair. The link 3 and link 4 becomes one sliding pair and link 1 and link 4 becomes the second sliding pair.

9.2.1 Inversion of Double Slider Crank Chain:

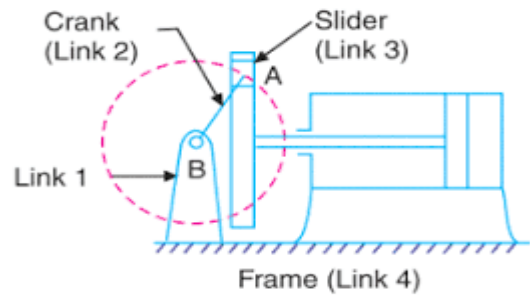
There are three main important inversions of double slider crank chain and these are:

1. Elliptical trammels
2. Scotch yoke mechanism
3. Oldham's coupling.

1. Skotch Yoke Mechanism:

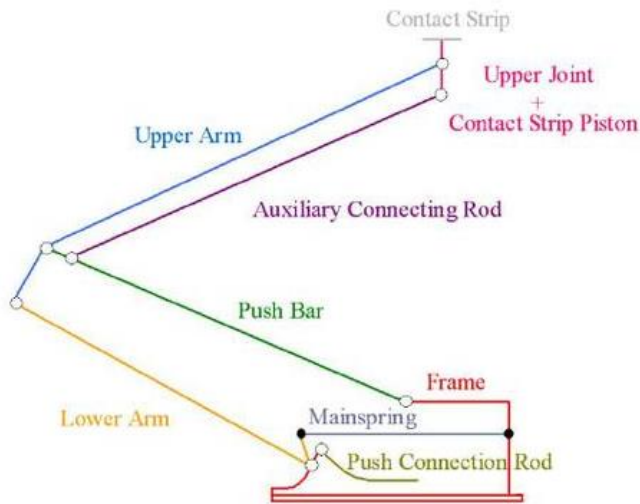
The skotch yoke mechanism is used for converting the rotary motion into the reciprocating motion. This inversion can be obtained by fixing the link 1 or link 3.

Fig. shows the skotch yoke mechanism in which link 1 is fixed and which guides the frame. When the link 2 i.e. the crank rotates about B as centre, the link 4 corresponds to the frame reciprocates.



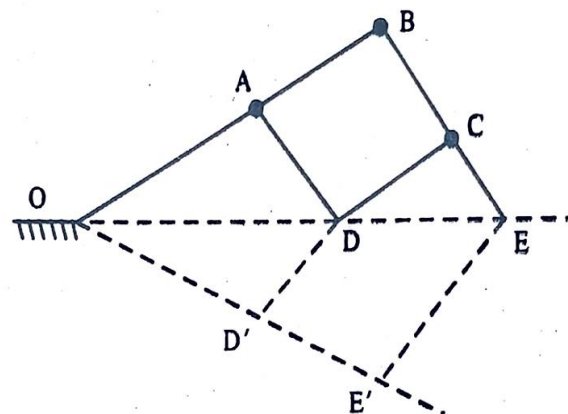
scotch yoke mechanism

9.3 Pentograph:



A Pentograph is a mechanism of mechanical linkages used to reproduce to an enlarged or a reduced scale and as exactly as possible the path described by a given point.

Pentograph consists of a jointed parallelogram like structure ABCD as shown in fig. It is made up of bars connected by a turning pairs. The bars BA and BC are extended to O and E respectively.



So that

$$\frac{OA}{OB} = \frac{AD}{BE}$$

Hence, for all relative positions of a bars, the triangles OAD and OBE are similar and the points O, D and E are in one straight line. Therefore, it is proved that point E traces out the same path as described by point D.

From the similar triangle OAD and OBE in the fig. we find

$$\frac{OD}{OE} = \frac{AD}{BE}$$

Let the point O be fixed and the points D and E move to some new positions D' and E', then

$$\frac{OD}{OE} = \frac{OD'}{OE'}$$

Therefore, straight line DD' is parallel to the straight line EE. Hence, if 'O' is fixed to the frame of a machine by means of a turning pair and D is attached to a point in the machine which has rectilinear motion relative to the frame, then E will also trace out a straight line patch. Similarly, if E is constrained to move in a straight out line, then D' will trace out a straight line parallel to the former.

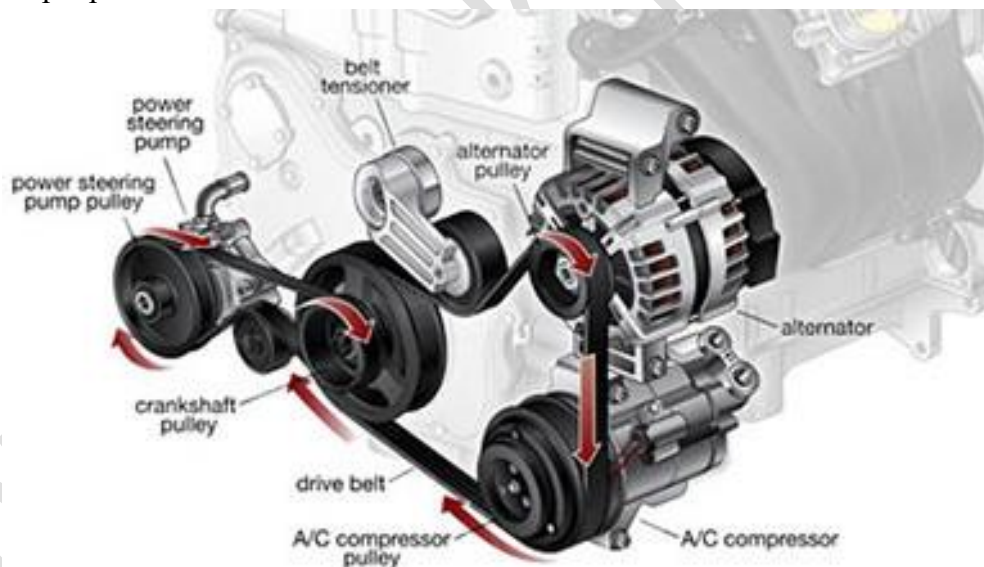
A Pentagraph is mostly used for the production of plane areas and figures such as maps, plans etc., on enlarged or reduced scales. It is also used as an indicator rig in order to reproduce to a small scale the displacement of the cross head and therefore, of the position of a reciprocating steam engine. It is also used to guide cutting tools.

WEEK 09 Review Questions

1. List the inversions of single slider crank chain
2. Explain with a sketch single slider crank chain and mention its inversions.
3. Explain bull engine mechanisms or pendulum pump.
4. Explain crank and slotted quick return motion mechanism and state its uses.
5. Explain with a neat sketch double slider crank mechanism.
6. What is double slider crank mechanism?
7. Explain with a sketch double slider crank mechanism and mention its inversions.
8. Explain with a neat sketch scotch yoke mechanism.
9. What is Pentagraph?
10. Explain with a neat sketch Pentagraph.
11. How to reproduce the plane into enlarge and reduce scale by using Pentagraph? Explain.

WEEK 10
TRANSMISSION SYSTEM

- ❖ Classification of Transmission system
- ❖ Belt drives, Rope Drives, Chain drives
- ❖ Types of Belt Drives.
- ❖ Length of belt drive in open and cross belt drive.
- ❖ Concept of Velocity Ratio, Slip and Creep.
- ❖ Material used for Belts.
- ❖ Applications of Rope drives.
- ❖ Applications of chain drives.
- ❖ Simple problems



10.1 Classification of Transmission System:

- **Belt Drives:** Employ belts running over pulleys to transmit power, common in applications where flexibility and speed variation are needed.
- **Chain Drives:** Use chains and sprockets to transmit power, often in applications requiring a high level of precision or high power transmission.
- **Gear Drives:** Utilize gears to transmit torque and change speed ratios, common in various machines and vehicles.
- **Friction Wheel Drives:** Rely on the friction between wheels to transmit motion, often used in situations where a simple and inexpensive drive is needed.

10.2 Belt or Rope Drives:

The belt or rope drives are used to transmit the power from one shaft to another by means of pulleys which may rotate at the same speed or at different speeds.

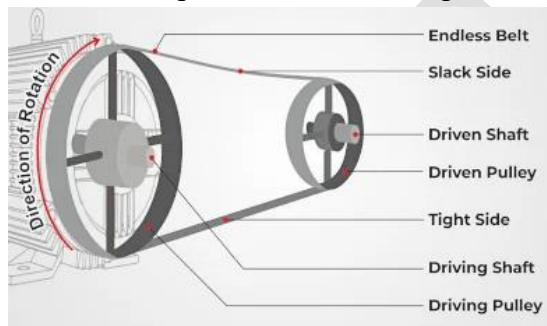


Fig. Belt or rope drives

To transmit power from one shaft to another, pulleys are mounted on the two shafts, the pulleys are then connected by an endless belt or rope passing over the pulleys as shown in fig. The connecting belt is kept in tension so that motion of one pulley is transferred to the other without slip. The speed of the driven shaft can be varied by varying the diameters of the two pulleys. The mechanical power or rotary motion is transmitted from the driving pulley to the driven pulley because of the frictional grip that exists between the belt and the pulley surface.

10.2.1 Types of Belts:

Normally belts can be classified into three types and these are:

1. Flat belt
2. V-belt
3. Rope or circular belt.



Fig: Types of belts

1. **Flat belt:** A belt having a rectangular cross-section is known as flat belt as shown in fig. 10.2(a) and these are used where the moderate amount of power is to be transmitted from one pulley to another pulley, when these two pulleys are not more than 8 m apart.
2. **V-belt:** A belt having a trapezoidal cross section is known as V-belt as shown in fig. 10.2(b), and these are used where moderate amount of power is to be transmitted from one pulley to another pulley, when these two pulleys are very nearer to each other.
3. **Rope or Circular belt:** A belt having a circular cross-section is known as rope or circular belt as shown in fig. 10.2(c), and these are used where a large amount of power is to be transmitted, from one pulley to the another pulley, when these two pulleys are more than 8 m apart.

10.2.2 Advantages and Disadvantages of Flat Belt:

The following are the advantages and disadvantages of flat belt

Advantages:

1. It is flexible and simple in construction.
2. Efficient at high speeds.
3. Protects against over load.
4. Its running and maintenance cost is low
5. It has relatively long life and easy to work with.
6. Smooth in operation.

Disadvantages:

1. Power loss due to slip.
2. The creep results in low efficiency.
3. It is not a positive drive.
4. Not preferred for short-centre distances.
5. Larger in size.
6. Because of the endlessness of the belt, joints reduce the life of the belt.

10.2.3 Advantages of Flat Belt over V-Belt:

Following are the advantages of flat belt over the V-belt:

1. Flat belt can be used for large centre distances even up to 15 m
2. Construction of pulley is simpler.
3. Durable than the V-belt.
4. Cheaper than V-belt.
5. Flat belts are very simple in design.
6. Periodic adjustment of the belt tension and belt replacement, when it is worn out, is easier.
7. Flat belts are very flexible, they have the ability to bend and twist on pulleys and follow very tortuous paths.
8. Precise alignments of shafts and pulleys are not critical with flat belt.
9. Better protection of machine against knocks and overloading.
10. Variable output speed is possible with flat belt drives.

10.2.4 Advantages and Disadvantages of V-belt Drive over Flat Belt Drive:

Following are the advantages and disadvantages of the V-belt drive over flat belt drive.

Advantages:

1. This drive gives compactness due to the small distance between the centres of pulleys.
2. This drive is positive, because the slip between the belt and the pulley groove is negligible.
3. The V-belts are made endless and there is no joint trouble, therefore the drive is smooth.
4. This drive provides longer life, 3 to 5 years.
5. The V-belt drive can be easily installed and removed.
6. The operation of the belt and pulley is quiet.
7. The belt has the ability to cushion the shock when machines are started.
8. The high velocity ratio (maximum 10) may be obtained in V-belt drive.
9. The power transmitted by V-belts is more than flat belts.
10. The V-belt can be operated in either direction with tight side of the belt at the top or bottom. The centre line may be horizontal, vertical or inclined.

Disadvantages:

1. This drive cannot be used with large centre distances.
2. The V-belts are not durable as compared to flat belts.
3. The pulleys construction for V-belts is more complicated than pulleys for flat belts.
4. V-belts are subjected to certain amount of creep, hence there are not suitable for constant speed application.
5. The V-belt life is greatly influenced by temperature changes, improper belt tension.
6. The centrifugal tension prevents the use of V-belts at speeds below 5 m/s and above 50 m/s.

10.2.5 Advantages and Disadvantages of Belt Drive Over Rope Drive:**Advantages:**

Following are the advantages of belt drive over rope drive

1. They are simple and economical.
2. Parallel shafts are not required.
3. Noise and vibration are damped out.
4. Power can be effectively transmitted for small and moderate centre distances.
5. They are lubrication free and require low maintenance.
6. They are highly efficient.
7. Some misalignment is tolerable.

Disadvantages:

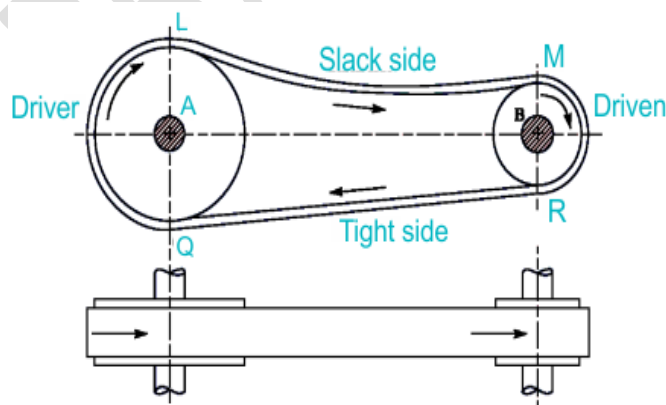
Following are the disadvantages of belt drive over rope drive:

1. These are not preferred for longer centre distances between the shafts.
2. They are not suitable for larger amount of power transmission.
3. Angular velocity ratio is not constant due to belt slip and stretch.
4. Operating temperatures are usually restricted to -35 to 85 °C.
5. Belts are costlier than the ropes.

10.3 Types of Flat Belt Drives:

Generally, the flat belt drives can be classified into two types, these are:

1. Open belt drive
2. Cross belt drive
3. Quarter turn belt drive
4. Belt drive with idler pulleys
5. Compound belt drive
6. Stepped or cone pulley drive
7. Fast and loose pulley drive.

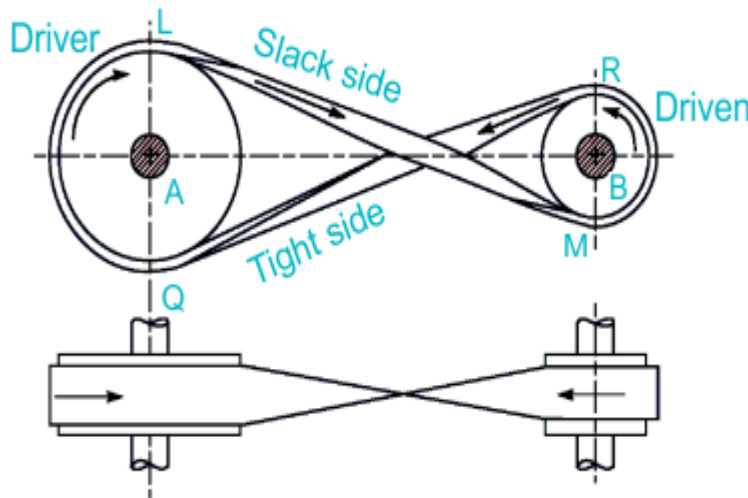
1. Open Belt Drive :

An open belt drive is used when the shafts are arranged parallel and required to rotate in the same direction as shown in fig. In this drive, when the driver pulley A rotates, it pulls the belt from lower side QR and delivers it to the upper side LM. Therefore, the tension in the lower side of the belt will be more than the upper side belt. Thus,

the lower side belt is known as tight side and the upper side belt is known as slack side.

Generally, the centre distance for an open belt drive is 14 m to 16 m. In case of horizontal drives, it is always desired that the tight side is at the lower side of the two pulleys. This is because the sag of the belt will be more on upper side than the lower side to increase the angle of contact between the belt and two pulleys to reduce the slip of belt over, the pulley.

2. Crossed Belt Drive:



The crossed belt drive is used when the shafts are arranged parallel and required to rotate in the opposite direction as shown in fig.

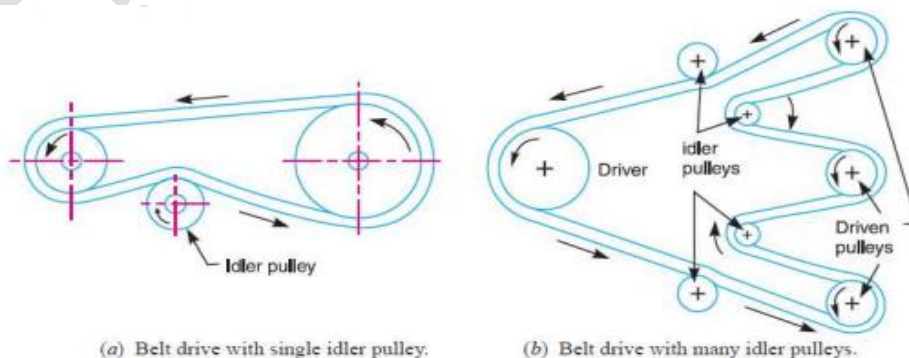
In this drive, the driver pulley 'A' pulls the belt from one side (i.e. QR) and delivers it to another side (i.e. LM). Therefore, the tension in the belt QR is more than that in the belt

LM. Thus, the belt QR is known as tight side and the belt 'LM' is known as slack side. A crossed belt drive can transmit more power than an open belt drive as the angle of contact is more in this drive, but the belt have to bend in two different planes and it wears out more.

3. Idler Pulleys:

A simple belt drive with an idler pulley as shown in fig. The idler pulley is used when the shafts are arranged parallel and an open belt drive cannot be used due to the small angle of contact on the smaller pulley as shown in fig. 10.6. This type of drive is generally provided to obtain the high velocity ratio and when the belt tension cannot be obtained by any other means.

In case, when it is required to transmit the motion from one shaft to number of shafts which are arranged in parallel, a belt drive with many number of idler pulleys can be used as shown in fig. 10.6.



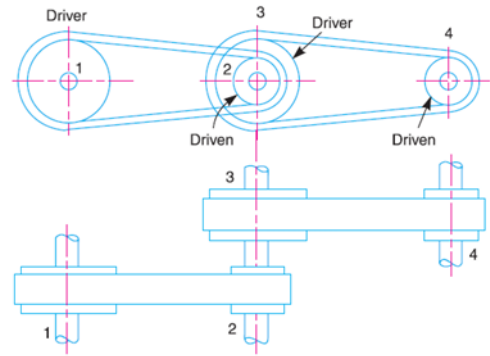
(a) Belt drive with single idler pulley.

(b) Belt drive with many idler pulleys.

4. Compound Belt Drive:

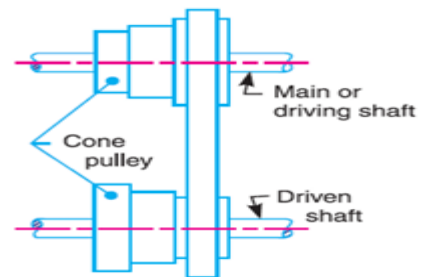
A compound belt drive is used when power is to be transmitted from one shaft to another shaft through a number of pulleys and it is required to have large velocity ratios as shown in fig.

Generally, the size of the larger pulley will be quite big, however by using an intermediate pulley, the size can be reduced, and this type of drive is known as compound belt drive.



5. Stepped or Cone Pulley Drive:

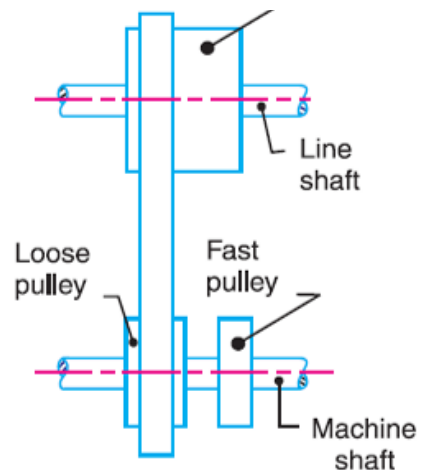
A stepped or cone pulley drive can be used when it is required to change the speed of driven shaft while the driving shaft runs at constant speed as shown in fig. This can be achieved by shifting the belt from one part of the stepped cone pulley to another part.



Stepped or cone pulley drive.

6. Fast and Loose Pulley Drive:

A fast and loose pulley drive can be used when the driven or machine shaft is to be started or stopped whenever required without interfering with the driving shaft as shown in fig. 10.9. The pulley which is keyed to the machine shaft is known as fast pulley and runs at the same speed as that of the machine shaft. When the driven shaft is required to be stopped, the belt is pushed on to the loose pulley by means of sliding Bar with belt forks as shown in fig.



Fast and loose pulley drive.

10.12 Materials Used for Belts:

Following materials can be used for belts:

1. Leather
2. Cotton or Fabric
3. Rubber
4. Balata.

1. **Leather Belts:** The leather may be either oak-tanned or mineral salt tanned e.g. chrome tanned. In order to increase the thickness of belt strips are cemented together.

2. **Cotton or Fabric Belts:** Most of the fabric belts are made by folding canvass or cotton duck to three or more layers and stitching together. These belts are impregnated with some filler like linseed oil in order to make the belts water proof and to prevent injury to the fibres.
3. **Rubber Belts:** These are made from layers of fabric impregnated with rubber composition and have a thin layer of rubber on the faces.
4. **Balata Belts:** These belts are similar to rubber belts except that balata gum is used in place of rubber.

10.13 Applications of Rope Drives:

Following are the uses of rope drives:

1. For transmitting the power over longer distances and where high power transfer is needed.
2. Used in mills and factories.
3. Elevators: Rope drives are used in elevators to lift and lower the elevator car.
4. Cranes and Hosts: Wire ropes are a primary component in cranes and hoists or lifting heavy objects.
5. Overhead Hoists: These systems use rope drives to move objects vertically and horizontally.
6. Conveyors: Ropes can be used in some conveyor systems to move materials.
7. Marine Applications: Ropes are used for a variety to tasks in marine settings, including winches, rigging and navigation.
8. Mining Wire ropes are used in mining operations for hoisting and conveying materials.

10.14 Applications of Chain Drives:

Following are the uses of chain drives:

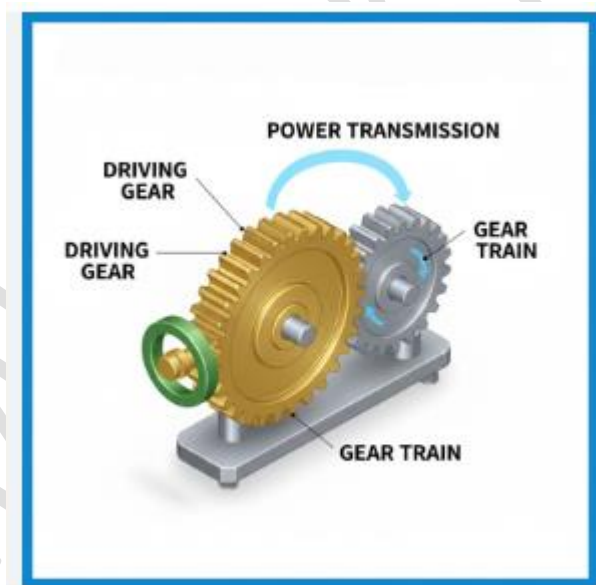
1. Used in Bicycles and Motorcycles.
2. Used in Automobiles (Timing Systems): In some vehicles, chain drives are used for timing systems.
3. Conveyors Chain drives are widely used in conveyor systems to move materials along production lines.
4. Printing Presses: Chain drives are used in paper feeding mechanisms.
5. Industrial Hoists and Cranes: They are used for lifting and Hoisting loads.
6. Used in material handling equipment.
7. Used in mining equipment.
8. Used in wood working machinery.

Week 10 Review Questions

1. State the classification of transmission systems.
2. List the types of flat belt drives.
3. List the advantages of flat belt over v-belt drive.
4. List the advantages and disadvantages of belt drive over rope drive.
5. Explain open belt and cross belt drive.
6. Explain the following:
7. Define the following terms:
 - a) Velocity Ratio
 - b) Slip
 - c) Creep
8. List the advantages and disadvantages of flat belt.
9. Explain belt drive with idler pulleys.
10. Explain compound belt drive.
11. Explain stepped or cone pulley drive.
12. Explain fast and loose pulley drive.
13. Explain length of the belt in open belt drive.
14. Plain velocity ratio of compound belt drive.
15. Explain with neat diagram belt drive with idler pulley.
16. Explain with neat diagram stepped or cone pulley drive.
17. Explain with neat diagram fast and loose pulley drive.
18. Explain with neat diagram compound belt drive and write its Velocity ratio.
19. Explain briefly compound belt drive with neat diagram.
20. State the applications of rope belt drives.
21. State the applications of chain drives
22. List the applications of rope belt drives and chain belt drives.
23. List the materials used for belts.
24. Explain materials used for belts.

WEEK 11
GEARS AND GEAR TRAINS

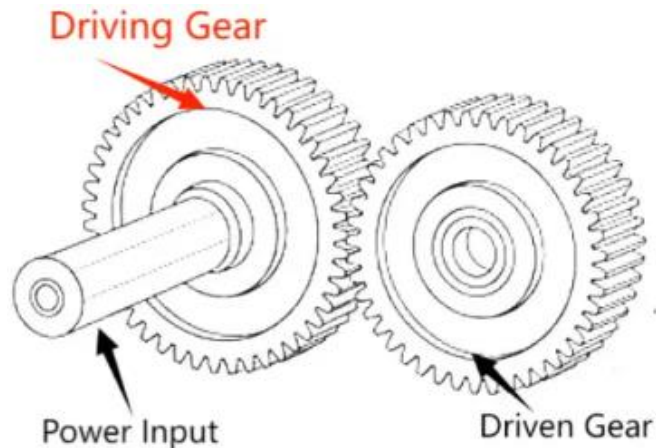
- ❖ Gears Drives– Introduction, Classification, Gear Terminology.
- ❖ Gear Trains – Introduction, Types, Simple & Compound Gear Trains.
- ❖ Reverted and Epicyclic Gear trains
- ❖ Simple Problems.



11.1 Introduction to Gear Drive:

A gear drive is a mechanical system that transmits the power and motion between rotating shafts using gears. It can be used to increase or decrease the speed, change torque and even reverse the direction of rotation.

The gears are the toothed wheels used for the transmission of motion from one shaft to another or between a shaft and a slide. This is accomplished by a successively engaging the teeth. Gears use no intermediate link or connector and transmit the motion by direct contact.



While transmitting the motion or power between the two shafts, the effect of slipping is to reduce the velocity ratio of the system. In precision machines, where a definite velocity ratio is very essential, in such case the transmission of motion or power is carried out by means of gears.

Gear drives are generally used where the centre between the driver and the follower is very small and requires positive drive. A simple gear drive is shown in fig.

11.1.1 Advantages and Disadvantages of Gear Drives:**Advantages:**

1. Positive velocity ratio.
2. Used for transmitting large power.
3. High efficiency.
4. Reliable service.
5. Compact in layout.
6. Transmission of power between shafts of small centre distance.

Disadvantages:

1. Gear manufacturing requires special tools-and equipment's.
2. Error in tooth cutting may create vibrations and noise during operation.
3. High production cost.

10.4 Classification of Gears :

Gears can be classified into the following:

I] According to the position of axis of the shafts:

1. Parallel gears:
 - i) Spur gear
 - ii) Helical gears
2. Intersecting gears:
 - i) Bevel gears
 - ii) Helical bevel gears
3. Non-intersecting and non-parallel gears:
 - i) Spiral gear

II] According to the peripheral velocity of the gears:

1. Low velocity gears
2. Medium velocity gears
3. High velocity gears.

III] According to the type of gearing:

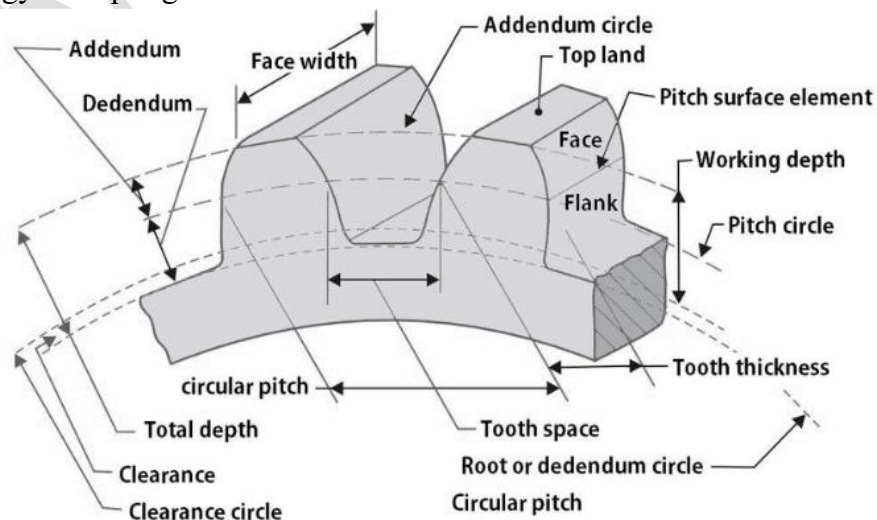
1. External gearing
2. Internal gearing
3. Rack and pinion.

IV] According to the position of teeth on the gear surface:

1. Straight teeth gear: Spur gears
2. Inclined teeth gear: Helical gears
3. Curved teeth gear: Spiral gears.

10.5 Spur Gear Terminology:

A simple terminology of a spur gear is shown in fig. and following terms can be used to specify the terminology of a spur gear.



1. **Pitch circle:** It is an imaginary circle which by rolling action, would give the same motion as the actual gear.
2. **Pitch circle diameter:** It is the diameter of the pitch circle, usually the size of the gear is specified by the pitch circle diameter.
3. **Pitch surface:** It is the surface of the rolling discs which the meshing gears have replaced at the pitch circle.
4. **Pitch point:** It is a common point of contact between two pitch circles.
5. **Addendum:** It is the radial distance of a tooth from the pitch circle to the top of the tooth.
6. **Dedendum:** It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.
7. **Addendum circle:** It is the circle drawn through the top of the teeth and is eccentric with the pitch circle.
8. **Dedendum circle:** It is the circle drawn through the bottom of the teeth. It is also called as root circle.

$$\text{Root circle diameter} = \text{Pitch circle dia.} \cdot \cos \Phi$$

Where Φ = is the pressure angle.

9. **Pressure angle or angle of obliquity (Φ):** It is the angle between the common normal to two gear teeth at the point of contact and the common tangent at the pitch point.
10. **Circular pitch:** It is the distance measured on the circumference of the pitch circle from a point of one teeth to the corresponding point on the next tooth.
It is denoted by ' P_c ',

$$\text{Pitch circle} = P_c = \frac{\pi D}{T}$$

Where, D = Dia. Of pitch circle
 T = No. of teeth on the gear.

11. **Diametral pitch:** It is the ratio of number of teeth to the pitch circle diameter in mm.
It is denoted by P_d .

$$\text{Diametral pitch} = P_d = \frac{T}{D}$$

Where T = No. Of teeth on the gear
 D = Pitch circle diameter.

12. **Clearance:** It is the radial distance from the top of the tooth to the bottom of the tooth, in a meshing gear.
13. **Clearance circle:** A circle passing through the top of the meshing gear is known as clearance circle.
14. **Total depth:** It is the radial distance between the addendum and the Dedendum circles of a gear. It is equal to the sum of the addendum and Dedendum.
15. **Module:** It is the ratio of pitch circle diameter in mm to the number of teeth. It is denoted by ' m '.

$$\text{Module} = \frac{D}{T}$$

16. **Working depth:** It is the radial distance from the addendum circle to the clearance circle.
17. **Tooth space:** It is the width of space between the two adjacent teeth measured along the pitch circle.
18. **Tooth thickness:** It is the width of the tooth measured along the pitch circle.
19. **Face of tooth:** It is the surface of the gear tooth above the pitch surface.
20. **Flank of tooth:** It is the surface of the gear tooth below the pitch surface.
21. **Face width:** It is the width of the gear tooth measured parallel to its axis.
22. **Top land:** It is the surface of the top of the tooth.
23. **Backlash:** It is the difference between the tooth space and tooth thickness, as measured along the pitch circle. The backlash should be zero, but in actual practice some backlash must be provided to prevent the jamming of the teeth due to tooth errors and thermal expansion.
24. **Profile:** It is the curve formed by the face and flank of the tooth.
25. **Pitch of contact:** It is the pitch traced by the point of contact of two teeth from the beginning to the end of engagement.
26. **Length of the path of contact:** It is the length of the common normal cut-off by the addendum circles of the wheel and pinion.
27. **Arc of contact:** It is the path traced by a point on the pitch circle from the beginning to the end of the engagement of a given pair of teeth.
The arc of contact consists of two parts –
 - ii) **Angle of approach:** It is the portion of the path of contact from the beginning of the engagement to the pitch point.
 - iii) **Arc of recess:** It is the portion of the path of contact from the pitch point to the end of the engagement of a pair of teeth.

11.4 Gear Trains:

4. When the two or more gears are made to mesh with each other to transmit power from one shaft to another, then such combination is known as gear train. The type of gear train used depends upon the velocity ratio required and the relative position of the axis of the shaft.

11.4.1 Types of Gear Trains:

Following are the different types of gear trains:

1. Simple gear train
2. Compound gear train
3. Reverted gear train
4. Epicyclic gear train.

1. Simple Gear Train:

In a gear train, when there is only one gear on each shaft, such a gear train is known as simple gear train. OR A series of gears capable of receiving and transmitting motion from one gear to another is known as simple gear train.

A simple form of simple gear train as shown in fig. All the gears may be arranged in a straight line or arranged in a zig-zag manner



When the distance between the two shafts is small, then the two gears 1 and 2 are used to mesh with each other to transmit the motion from one shaft to another. If the distance between the two gears is large, the motion from one gear to another gear may be transmitted either by providing large gear or by providing one or more intermediate gears.

Let N_1 = Speed of gear 1 in rpm

N_2 = Speed of gear 2 in rpm

T_1 = Number of teeth on gear 1

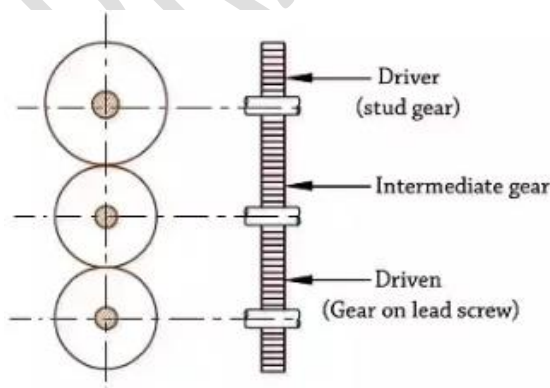
T_2 = Number of teeth on gear 2

Now, the velocity ratio or speed ratio of gear train is the ratio of the speed of the driver gear to the speed of the driven gear i.e.

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

The ratio of the speed of the driven gear to the speed of the driver gear is known as train value of the gear, i.e.

$$\text{Train value} = \frac{N_2}{N_1} = \frac{T_1}{T_2}$$



Simple gear train

For a simple gear train with one or more intermediate gear as shown in fig. 11.4. Then the speed ratio of the gear train is obtained as follows:

$$\frac{N_1}{N_2} \times \frac{N_2}{N_3} = \frac{T_2}{T_1} \times \frac{T_3}{T_2}$$

$$\text{Speed ratio} = \frac{N_1}{N_3} = \frac{T_3}{T_1}$$

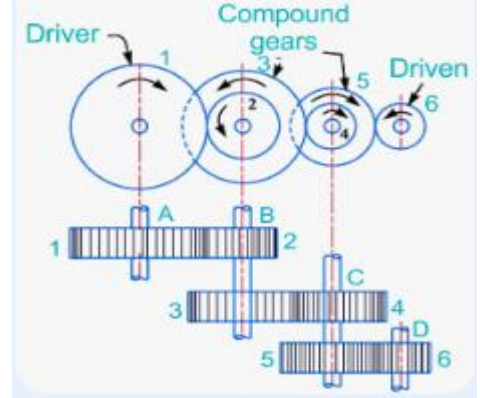
$$\text{Speed ratio} = \frac{1}{\text{Train value}}$$

2. Compound Gear Train:

In a gear train, when there are more than one gear on a shaft, the gear train is known as compound gear train.

A simple form of compound gear train is as shown in fig.

Whenever the distance between the driver gear and the driven gear has to be bridged over by the intermediate gears and at the same time a great speed ratio is required, then the compound gears on intermediate shafts are used. Each intermediate shaft has two gears so that, they may have the same speed, one of these two gears meshes with the driver gear and another one is with driven gear.



In fig. gear 1 is driving gear mounted on shaft A, gear 2, 3, 4, and 5 are the compound gears mounted on intermediate shafts B and C and the gear 6 is the driven gear mounted on shaft D.

Let $N_1, N_2, \text{ and } N_3 \dots \dots N_6$ = Speeds of gear 1, 2, 3, 4, 5 and 6 respectively in rpm.

$T_1, T_2, T_3 \dots \dots T_6$ = Number of teeth on gear 1, 2, 3, 4, 5 and 6 respectively.

We know that,

$$N_2 = N_3 \text{ and } N_4 = N_5$$

For gear 1 and 2:

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

For gear 3 and 4:

$$\text{Gear ratio} = \frac{N_3}{N_4} = \frac{T_4}{T_3}$$

For gear 5 and 6;

$$\frac{N_5}{N_6} = \frac{T_6}{T_5}$$

Speed ratio of the compound gear train is given by:

$$\frac{N_1}{N_2} \times \frac{N_3}{N_4} \times \frac{N_5}{N_6} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} \times \frac{T_6}{T_5}$$

$$\frac{N_1}{N_6} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} \times \frac{T_6}{T_5}$$

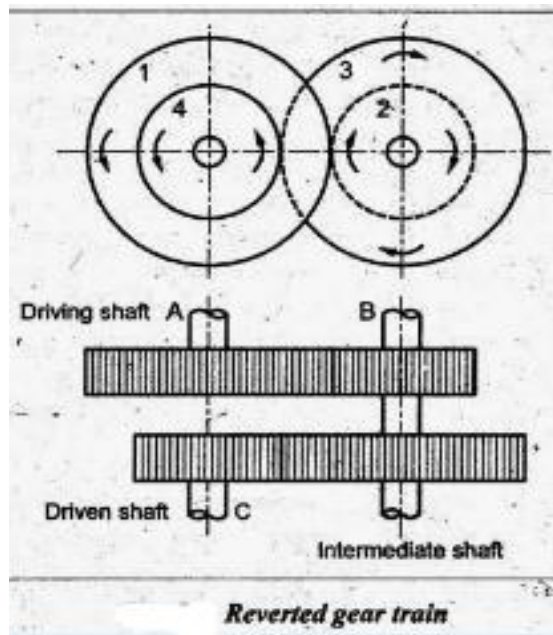
$$\text{Speed ratio} = \frac{\text{Speed of the first driver}}{\text{Speed of the last driven}}$$

$$\text{Train value} = \frac{\text{Speed of the last driven}}{\text{Speed of the first driver}}$$

The main advantage of compound train over a simple gear train is that a much larger speed reduction from the first shaft to the last shaft can be obtained with small gears.

3. Reverted Gear Train:

In a gear train, when the axes of the first gear and the last gear are co-axial, then the gear train is known as reverted gear train.



A simple form of reverted gear train as shown in fig. Gear 1 drives the gear 2 in opposite direction. Since gear 2 and gear 3 are mounted on same shaft, therefore, they form a compound gear and gear 3 rotates in the same direction as that gear 2. Gear 3 drives gear 4 in the same direction as that of gear 1. Therefore, in reverted gear train, the motion of the first gear and the last gear is same.

Let N_1, N_2, N_3 , and N_4 , Speeds of gear 1, 2, 3 and 4 respectively in rpm.

T_1, T_2, T_3 and T_4 , Number of teeth on gear 1, 2, 3, and 4 respectively

r_1, r_2, r_3 , and r_4 Pitch circle radii of gear 1, 2, 3 and 4 respectively

Since, the distance between the centres of the shafts of gears 1 and 2 as well as gear 3 and 4 is same, therefore,

$$r_1 + r_2 = r_3 + r_4$$

Also

$$T_1 + T_2 = T_3 + T_4$$

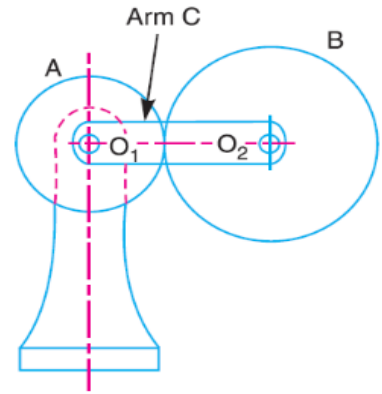
$$\text{Speed ratio} = \frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3}$$

$$\text{Speed ratio} = \frac{\text{Product of no. of teeth on driven}}{\text{Product of no. of teeth on drivers}}$$

4. Epicyclic Gear Train:

The gear train in which axes of the shafts, over which the gears are mounted move relative to the fixed axes is known as epicyclic gear train. It is also known as planetary gear train.

A simple form of epicyclic gear train as shown in fig. Gear A and the arm C have a common axes at O_1 about which they can rotate. The gear B meshes with gear A and has its axes on the arm at O_2 , about which the gear B can rotate. When the arm is fixed, the gear train becomes simple gear train i.e. gear A drives gear B, but if the gear A is fixed and the arm C is made to rotate about the axes of gear A i.e. about O_1 , then the gear B is forced to rotate upon and around gear A. Such type of motion is known as epicyclic.



The epicyclic gear train may be a simple or compound and these gear trains are useful for transmitting high velocity ratios with moderate sized gears in comparatively lesser space. The epicyclic gear trains are generally used in differential of the automobiles, back gear of lathe, pulley blocks, hoists, wrist watches, etc.

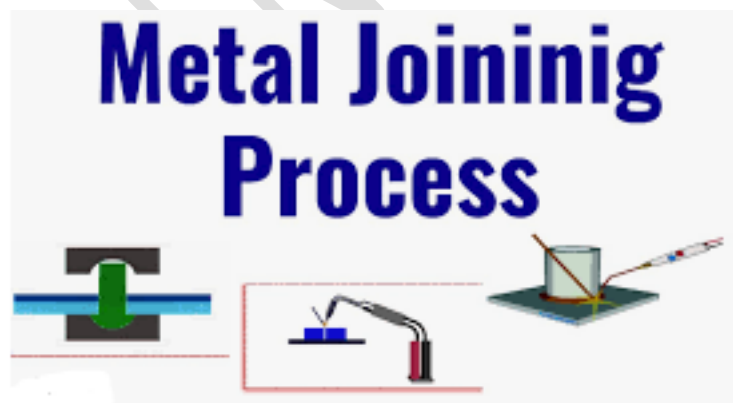
Fig: Epicyclic gear train

Week 11 Review Questions

1. What is gear drive? State its advantages.
2. List the advantages of gear drive.
3. List the advantages and disadvantages of gear drive.
4. Define the following term:
 - a) Pitch circle
 - b) Addendum
 - c) Dedendum
 - d) Circular pitch
 - e) Module
5. State the classification of gears.
6. Define:
 - a) Flank of tooth
 - b) Profile
 - c) Arc of contact
 - d) Angle of approach
 - e) Arc of recess.
7. What is gear train? State the types of gear train.
8. Explain simple gear train.
9. Explain with a neat diagram of simple gear train.
10. Explain with a neat diagram of compound gear train.
11. Explain with a neat diagram of reverted gear train.
12. Explain with a neat diagram of epicyclic gear train.

WEEK 12
METAL JOINING PROCESSES

- ❖ Metal Joining processes Classification of Joining Process
- ❖ Temporary and Permanent joining processes.
- ❖ Fasteners - Rivets, Bolts and Nuts and types.
- ❖ Welding - Classification of welding process
- ❖ Arc welding process- Arc welding electrodes, Arc welding equipment's. TIG (GTAW) and MIG (GMAW) welding, Defects in arc welding process.



12.1 Metal Joining Process:

The process of joining together two or more parts by a fastener which results in a mechanical joint is called metal joining process, it may also called as fastening.

The parts may be joined together by various types of mechanical joints. The choice of a particular type of a joint depends upon factors such as degree of permanency desired, the size and shape of the parts and the nature of the materials suitable etc.

Classification of Joining Process:**1. Temporary Joining Process**

- i. Threaded joining process
- ii. Non-threaded joining process

2. Permanent Joining Process**1. Temporary Joining Process:**

In temporary joining process the parts are held together by means of removable fasteners like, bolts and nuts, studs and nuts, screws, cotters, pins etc.

In this joint it is possible to separate the fastened parts without destruction and then they can be re-joined.

2. Permanent Joining Process:

In this process, the parts may be held by means of press fit, shrink fit, rivets, welding, brazing or soldering and adhesives.

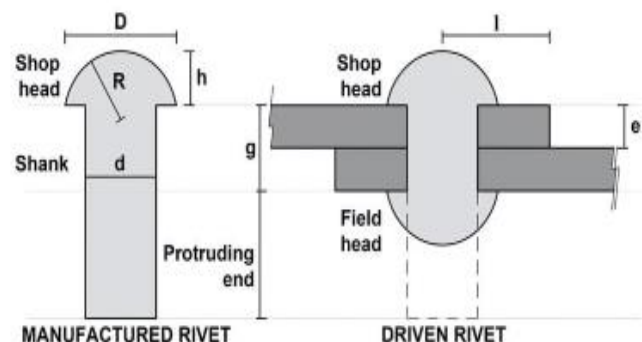
In this joint it is not possible to separate the fastened part without destruction.

12.2 Fasteners

A mechanical element which holds two or more parts of a machine or a structure is known as fastener. Some important fasteners are:

- Rivets
- Bolts and nuts.

Rivets: A rivet is a permanent mechanical fastener and is a round rod made from either mild steel or non-ferrous material such as copper, aluminium etc., with a head on one end and used to join two or more pieces of material permanently as shown in fig.



Bolts and Nuts:

Bolt: Bolt is a mechanical element used for fastening the objects together. It has a head at one end and a screw thread at the other end as shown in fig. It is a male threaded fastener.

Nut: Nut is a female threaded fastener, i.e. it is an internally threaded fastener which is then screwed into the bolts threaded end to hold the parts temporarily called temporary joint.

**12.3 Welding:****Introduction:**

Welding is a process of joining two similar or dissimilar metals by the application of heat with or without the application of pressure and with or without the use of filler metal. The welding results in a continuity of homogeneous material of the composition and characteristics of two parts which are being joined together.

Welding can also be defined as a metal joining process in which two similar or dissimilar metals are joined by heating the metals to a suitable temperature with or without the application of pressure with or without the use of filler metal and then allowed to solidify on cooling. During welding the metals to be joined are heated to a liquid state and the filler metal is added to fill the gap between the materials to be welded and then allowed to cool it. Generally the filler metal is the metal electrode having same material as that of materials to be welded.

Applications of Welding:

1. Fabrication and erection of steel structures.
2. Bridges and buildings.
3. Rail tracks.
4. Pipelines.
5. Pressure vessel tanks.
6. Steel reservoirs.
7. Machine manufacturing.
8. Automobile, ship and aircraft building.
9. Boilers.
10. Agricultural implements etc.

Advantages of Welding:

1. It is a permanent and strong joining process.
2. Good saving of material.

3. Less labours are required.
4. Low manufacturing cost.
5. Useful method for repairing broken and worn metal parts.
6. It can be mechanised and automated.

Disadvantages of Welding:

1. Development of Residual stresses in a weld area.
2. Distortion and changes in the microstructure in a weld area.
3. Poor fatigue resistance due to stress concentration.
4. It requires proper protections to the labour.

Types of Welding:

Welding may be classified into two types:

- i. Plastic welding or pressure welding.
- ii. Fusion welding or non-pressure welding.

i) Plastic welding: In plastic welding or pressure welding, the pieces of metal to be welded are heated to a plastic state and then pressed together to make the joint. For example, forge welding, resistance welding etc.

ii) Fusion welding: In fusion welding or non-pressure welding, the materials at the joint are heated to a molten state and allowed to solidify. For example, gas welding, arc welding etc.

12.4 Classification of Welding Processes:

Welding processes can be classified as;

1. Arc Welding:

- 1) Carbon arc welding
- 2) Metal arc welding
- 3) Plasma arc welding
- 4) Submerged arc welding
- 5) Electro-slag arc welding
- 6) Flux-cored arc welding
- 7) Metal inert gas (MIG) welding
- 8) Tungsten inert gas (TIG) welding
- 9) Atomic hydrogen arc welding.

2. Gas Welding:

- 1) Oxy-acetylene welding
- 2) Air-acetylene welding
- 3) Oxyhydrogen welding
- 4) Pressure gas welding.

3. Resistance Welding

- 1) Butt welding

- 2) Spot welding
- 3) Seam welding
- 4) Projection welding
- 5) Percussion welding.

4. Solid State Welding:

- 1) Friction welding
- 2) Forge welding
- 3) Ultrasonic welding
- 4) Explosive welding
- 5) Cold welding
- 6) Diffusion welding
- 7) Thermit welding
- 8) Laser welding
- 9) Electron-beam welding.

12.5 Arc Welding:

Definition:

Arc welding is the fusion welding process in which welding heat is produced by heating the workpiece with an electric arc setup between flux coated electrode and the workpiece.

Principle of Arc Welding:

A principle of arc welding is shown in fig. 12.2. The metals to be welded are brought together after cleaning properly and making contact of the electrode with the workpiece and then separating the electrode for a proper distance to produce an arc. The heat required for welding is obtained from the arc struck between a coated electrode and the workpiece. The arc temperature may be maintained between 3600 °C to 4000 °C. The arc melts the electrode and the job. The material droplets are transferred from the electrode to the job, through the arc and thoroughly mixed with the parent metal and refined, then deposited along the joint to be welded after cooling. The flux coating melts during this process and produces a gaseous shield and slag to prevent atmospheric contamination of the molten weld metal.

On cooling, the residue of the flux in the form of slag is chipped away. The power source may be AC or DC supply.

Arc Welding Electrodes:

In arc welding, two main types of electrodes are used:

1. Consumable
2. Non-consumable.

1. Consumable Electrodes: These are metal rods or wires that melts and become the part of the weld. These are used in shielded metal arc welding or gas metal arc welding and in MIG welding process.

2. Non-consumable Electrodes: These are electrodes do not melts and do not become the part of the weld such as tungsten electrodes in Gas Tungsten Arc welding or TIG welding.

Equipments for Arc Welding:

1. AC or DC power source.
2. Electrode holder.
3. Cables which connects the power source, electrode and workpiece.
4. Metal table.
5. Workpiece to be joined and electrode.
6. Handshields.
7. Ground connection.
8. Protective clothing, and gloves.
9. Chipping hammer, wire brush, eye protecting glasses, etc.

Preparation for Arc Welding:

Before welding, edges of the workpieces should be cleaned from dust, scale, rust, paints, grease, etc., either chemically or mechanically.

- Workpieces to be welded arc positioned and spaced with respect to each other and held in fixture in a flat position.
- Properly connecting the power source with current.
- Gripping the electrode in electrode holder properly.
- Now the operator is ready for welding.

Precautions to be followed in Arc Welding:

- 1) Before starting arc welding, the machines should be carefully inspected, cleaned and oiled.
- 2) All connections should be tight.
- 3) One should never look at arc, till eyes are protected with face shield and lenses.
- 4) Welder should wear helmet, hand gloves, cloths, shoes to protect from UV and infrared rays.
- 5) Removing flammable material around the place of welding.
- 6) Floor should be dry.
- 7) Electrode holders should be insulated.
- 8) Proper ventilation should be provided.

Advantages of Arc Welding:

1. It is the simple process of welding.
2. Portable equipment with less cost.
3. This process finds variety of applications.
4. A wide range of metals and their alloys can be welded.
5. Welding can be carried out in any position with good quality.

6. Low accuracy in welding setup is required.
7. Excellent joining properties can be obtained.
8. Less buckling and wrapping of the workpieces.

Disadvantages or Limitations of Arc Welding:

1. Skilled operator is required.
2. Electrodes have to be changed frequently.
3. Multirun welds requires often chipping takes a long time.
4. Not suitable for thin sheets.
5. Chances of slag entrapment and other defects are more.

Uses of Arc Welding:

1. Used for fabrication work.
2. Used for production of chassis of trucks, cars, etc.
3. Used for bicycle.
4. Used in industrial works, building factories etc.
5. Used for welding vehicle chassis.
6. Used for structural works.
7. Used for manufacturing of tractor trollies.

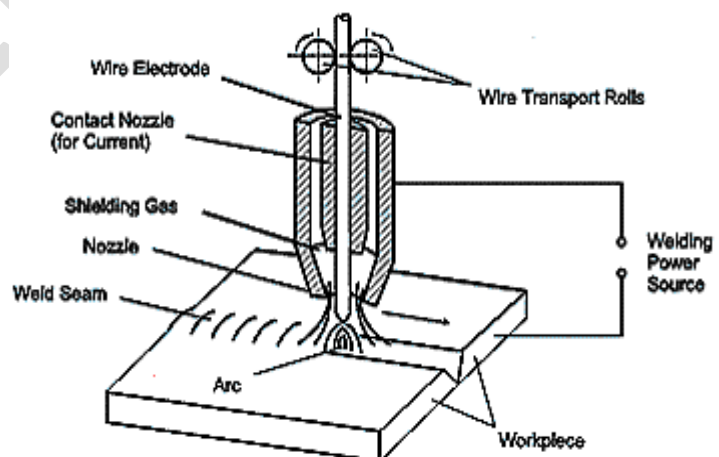
12.6 Types of Arc Welding:

12.6.1 MIG Welding (Metal Inert Gas Welding):

This process is also known as Gas Metal Arc Welding (GMAW). This method uses a consumable electrode which is fed into the arc in the form of wire and helium or argon may be used as inert gas. The working principle of MIG welding is shown in fig.

An electric arc is produced between workpieces and consumable electrode, which melts the electrode and deposited in the joint. The inert or shielding gas surrounds the arc and protects the weld from atmospheric effects to produce defect free weld. The electrode wire is automatically fed from the reel by a variable speed motor depending upon the arc voltage.

MIG welding may be semiautomatic in which the welder guides the gun and adjusts process parameters and in Automatic Welding all functions are taken care of by welding machine or robot. MIG welding may be used for stainless steel, magnesium, aluminium etc.



Advantages:

1. Much greater penetration and higher welding speed.
2. No possibility of cracks.
3. There is no slag to clean off after the welding.
4. It can be readily automated.
5. There is no weld spatter.
6. Produce very high quality of weld.
7. It is fast and economical.

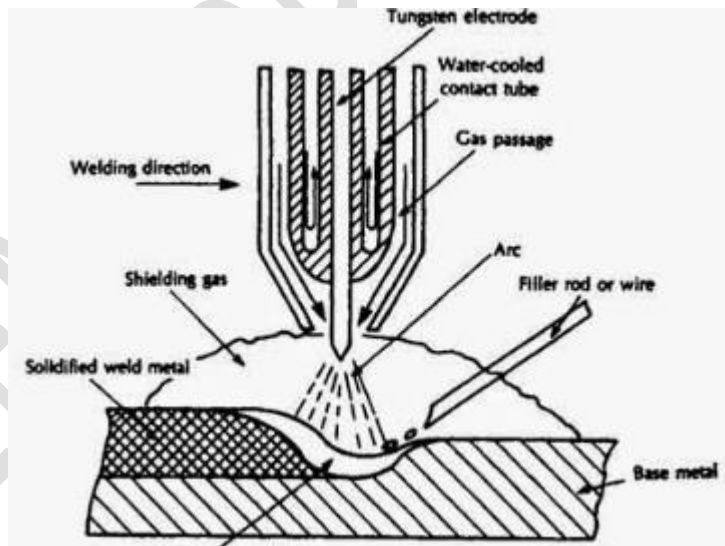
Disadvantages:

1. Difficult to weld in small corners.
2. Welding equipment is costly and more complex.

12.7 TIG Welding (Tungsten Inert Gas Welding):

It is also called as Gas Tungsten Arc Welding (GTAW). The arc is maintained between the workpiece and a tungsten electrode protected by an inert gas such as helium or argon or mixture of the two. The electrode is non-consumable since its melting point is about 3400 °C which is higher than the arc temperature.

The working principle of TIG as shown in fig. It consists of welding gun with handle. The stationary tungsten electrode is firmly held in a welding gun with shielding gas flow along the electrode through a nozzle at the end of the gun into the arc zone. An electric arc is produced between the workpiece and the non-consumable electrode, which melts the metals to be joined in that area and forms the molten pool. An inert or shielding gas surrounds the arc and protects the weld from atmospheric effects and welds are made without defects. A filler metal may or may not be used. Water is used to cool the welding gun.



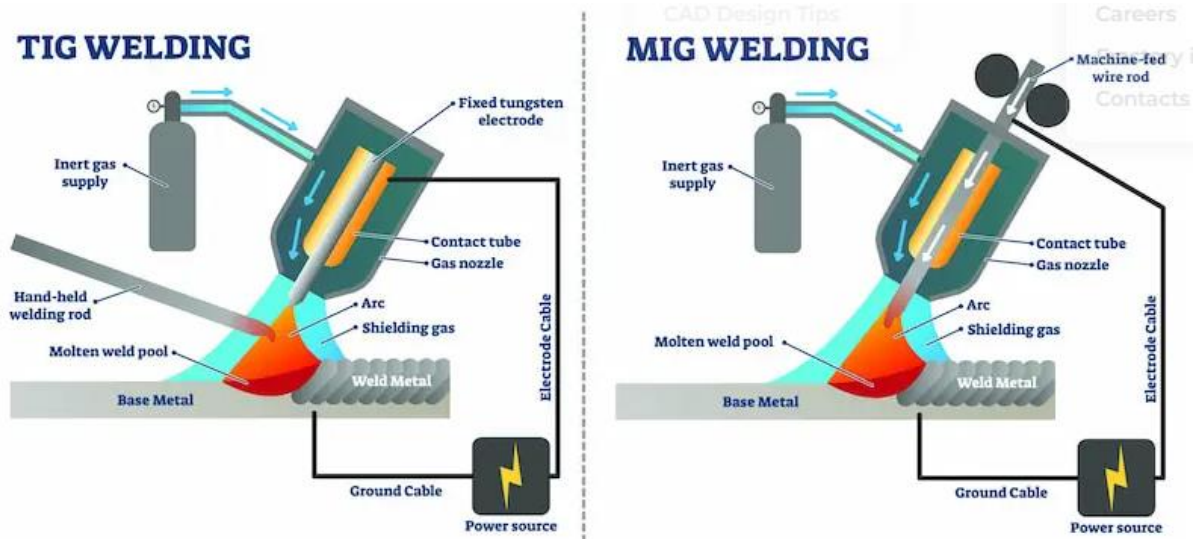
This process may be used for welding Aluminium and its alloys, Stainless steel, Cast iron, Silicon bronze, Titanium, Nickel, etc. This process may be carried out by AC or DC source.

Advantages:

1. It is faster process.
2. Produces a clean weld.
3. Flux is not required.

4. Unlike metals can be welded like brass to copper.
5. Heat affected zone is very low.
6. Requires no clean-up due to absence of slag or spatter.
7. No possibility of cracks.
8. Weld zone is visible.

12.8 Difference between MIG and TIG Welding:



MIG Welding	TIG Welding
1) It uses consumable electrode (metal).	1) It uses non-consumable electrode (tungsten).
2) Metal electrode works as a filler metal.	2) Tungsten electrode works as a non-filler metal.
3) Less stable arc.	3) More stable arc.
4) Low quality of weld with low precision.	4) High quality of weld with high precision.
5) Welding may have high contamination.	5) Welding has less contamination
6) More sparks, fumes and smoke.	6) Very less spark, fumes and smoke.
7) Requires less setup time and user friendly.	7) Requires high setup time and not user friendly.

12.9 Welding Defects and Remedies:

<i>Welding Defects</i>	<i>Remedies</i>
1) Poor fusion: An incomplete union between the deposited and parent metal due to faulty welding techniques and conditions.	Provide sufficient heat and slow travel of electrode
2) Under cut a groove melted into the base metal adjacent to the toe of the weld due to non-uniform feeding of the welding rod or excessive heat.	Establish the uniform feeding of the electrode and required amount of heat.

3) Porosity: The formation of blow holes or gas pockets, on the surface of the weld due to the presence of gases in the metal or moisture in the flux.	• Using proper weld technique to avoid absorption of gases by weld pool. • Cleaning the metal surface from rust, dirt, grease etc. before welding. • Using proper current with slow welding speed.
4) Slag inclusions: The presence of non-metallic substances in the metal or contamination of weld metal by atmosphere.	• Avoid contamination of the weld metal by atmosphere. • Proper removal of slag between layers of metal, • Using proper arc length, electrode angle with proper speed.
5) Cracks in the weld: Cracks may arise from locked up stresses setup due to non-uniform heating and cooling, excessive sulphur or phosphorus in the weld metal.	• Providing uniform heating and cooling to avoid locking of stresses. • Steady welding speed.
6) Spatter: Spatter refers to small particles or globules of metal scattered around the vicinity of the weld along its length.	• Low arc voltage, • Using appropriate current. • Avoid trapping of gases, weld along its length.

12.10 Brazing:

It is the process of joining the two pieces of similar or dissimilar metals in which a non-ferrous alloy is introduced in a liquid state between the pieces of metals to be joined and allowed to solidify. The melting point of the filler metal is above 420 °C, but should be lower than the melting temperature of parent metals to be joined.

During this process no forging action is present and also the parts do not melt. The strength of the joint is provided by metallic bonding. Following metals are used for brazing process. (Applications): copper and copper alloys, silver and silver alloys, aluminium alloys, nickel alloy, magnesium alloys, etc.

Steps in Brazing Operation:

1. The parts to be joined by brazing are cleaned from oil, dirt or oxides.
2. Adjust the gap between metals i.e., it should be very small:
3. All mating surfaces must be coated with flux.
4. They are then heated above 420 °C by any one of the methods namely dipping, furnace heating, torch heating, or electric heating.
5. Allowing the molten metal to flow by capillary action into the space between the parts and then cooled slowly to solidify.
6. Parts are then cleaned by hot water or steam which removes the residual flux.

Advantages of Brazing:

1. Dissimilar metals can be joined.
2. Assemblies can be brazed in a short time.
3. Complex assemblies can be brazed in several steps.
4. Materials of different thickness can be joined easily.
5. Non-metals can be joined to metals, when the non-metal is coated.
6. Brazed joints requires little or no finishing.
7. Metallurgical properties of base metal will not seriously disturbed.

12.11 Soldering:

It is a method of joining two or more similar or dissimilar metal-sheets by means of a fusible alloy or metal called solder, applied in the molten state. The melting point of the filler metal is below 420 °C and lower than the melting point of the parent metals to be joined.

Generally lead and tin alloys are used as a solder. The strength of the soldering joint depends on the strength of the alloys and its adhesive qualities. Soldering may be divided into two types:

1. Soft soldering
2. Hard soldering.

Soft soldering is widely used in sheet metal work for joining parts that are not exposed to the action of high temperature and excessive loads or forces. Hard soldering is used when a stronger joint is required. Silver alloyed with tin is used as a hard solder, the melting point of which is 300 to 450 °C. The steps of soldering are same as that of the brazing.

In soldering butt joints are avoided and lap joints are preferred. Electric connections, wire-terminals, computer processor boards, TV mother boards, electron boards, etc., are the applications of soldering. Soldering of lead pipe is known as wiping.

12.12 Difference between Welding and Soldering:

Welding	Soldering
1) Metals to be joined are heated to liquid state.	1) Filler metal is heated to its liquid state (below 420 °C).
2) High heat is required up to 4000 °C.	2) It requires temperature of the heat below 420 °C.
3) High strength of bonding.	3) Lower strength of bonding than brazing.
4) Suitable for high thick plates.	4) Suitable for thin sheets.
5) Flux coated electrode is melted at once when arc is struck.	5) Flux is applied over the surface of metals to be joined and then filler metal is heated and applied.
6) Used in wide engineering applications.	6) Used in wide electronic and less in mechanical applications.

12.13 Difference between Soldering and Brazing:

Soldering	Brazing
1) Filler metal is heated to its liquid state below 420 °C.	1) Filler metal is heated to its liquid state above 420 °C.
2) It requires temperature of the heat below 420 °C.	2) It requires temperature of the heat above 420 °C.
3) Lower strength of bonding.	3) Higher strength of bonding.
4) Suitable for thin sheets.	4) Suitable for thin plates.
5) Preferred for electric applications.	5) Preferred for engineering applications

Fillers of Brazing and Soldering:

In both Brazing and Soldering, filler metals are used to join the materials, but they differ in their melting points and applications.

- Brazing uses filler metals with melting point above 420°C.
- Soldering uses the filler metals with melting points below 420°C.

Brazing Filler Metals:

Alluminium-silicon alloys, copper, copper-silver alloys and copper-zinc alloys (Brass).

Soldering Filler Metals:

Lead-tin alloys, non-lead versions with antimony, bismuth, and copper, indium, tin or silver are used.

Applications of Brazing:

1. Brazing is used in aerospace industries.
2. Automotive industries.
3. In electronic equipment's.
4. Joining component in jet engines.
5. Used for fuel lines, radiators.
6. Used in air conditions system.
7. Used in manufacture of tools.
8. Used in jewellery manufacturing.

Applications of Soldering:

1. Used in electronic circuit boards, wires etc.
2. Used in assembly and repair of PCBs.
3. Used for joining pipes of water lines.
4. Used in assembly and repair of refrigeration components.
5. Used in heating systems such as radiators and fuel tanks.
6. Joining jewellery and sheet metal objects.
7. Used in repair of musical instruments etc.

WEEK 12 Review Questions

- 1) State the classification of joining process.
- 2) Define temporary and permanent joining processes.
- 3) Write the classification of welding process.
- 4) Define the welding process and state its applications.
- 5) What are the advantages and disadvantages of welding process?
- 6) What are the different arc welding processes?
- 7) Define arc welding and state the precautions to be followed in arc welding.
- 8) Write the equipment's required for arc welding.
- 9) What are the preparations required for arc welding?
- 10) Explain the welding electrodes.
- 11) Explain with neat diagram arc welding process.
- 12) Define MIG and TIG welding processes.
- 13) State the advantages of MIG process.
- 14) Write the advantages of TIG process.
- 15) Explain with neat diagram TIG welding process.
- 16) Explain with neat diagram MIG welding process.
- 17) Differentiate MIG and TIG welding process.
- 18) Write the defects of welding.
- 19) Explain the defects of welding and its remedies.
- 20) What is brazing and soldering?
- 21) State the steps in brazing operation.
- 22) Explain brazing with its advantages.
- 23) State the applications of brazing.
- 24) Explain fillers of brazing and soldering.
- 25) What is soldering? State the applications of soldering.
- 26) Differentiate welding and solder process.
- 27) Differentiate brazing and soldering process.

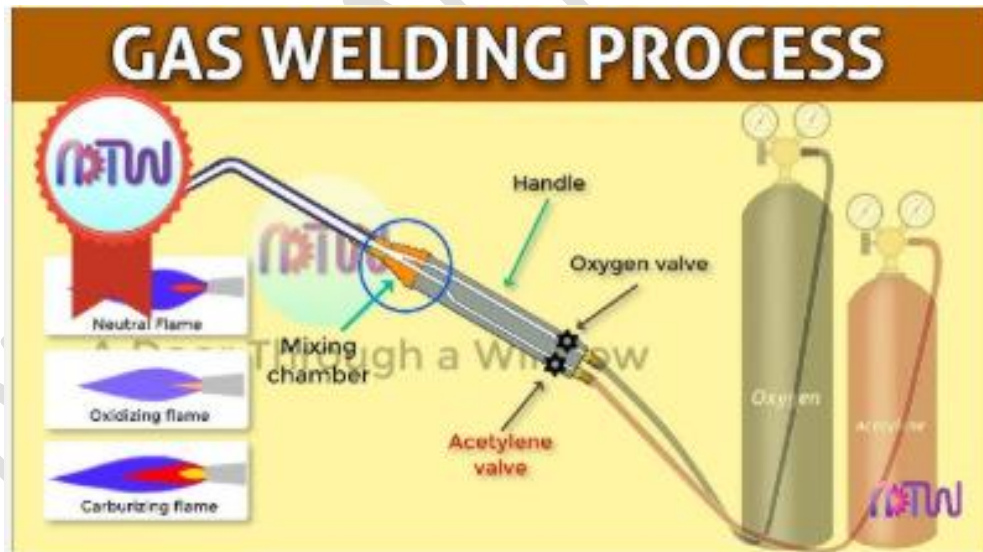
WEEK 13
GAS WELDING

Gas welding Process

- ❖ CO₂ and Oxy-Acetylene gas welding process
- ❖ Different types of gas welding flames.

Welding Positions – 1G, 2G, 3G, 5G. Soldering and Brazing

- ❖ Principles of Soldering and Brazing Processes,
- ❖ Fillers, heating methods Applications



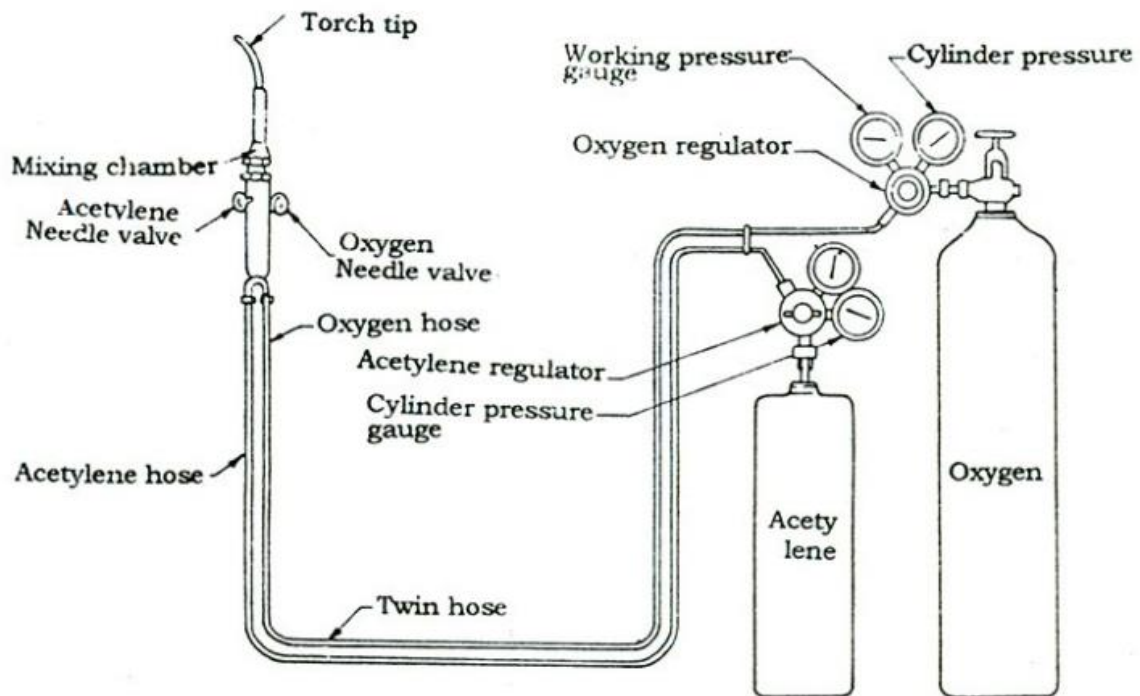
13.1 Gas Welding:

Definition:

Gas welding is a fusion welding process in which metals are joined by using the heat of combustion of an oxygen/air and fuel gas mixture. The high heat flame melts the base metal and filler metal, thus molten metal is mixed and allowed to flow together to form solid continuous joint on cooling.

The fuel gas may be acetylene, hydrogen, propane or butane. The material of the filler metal is same as that of the material to be welded.

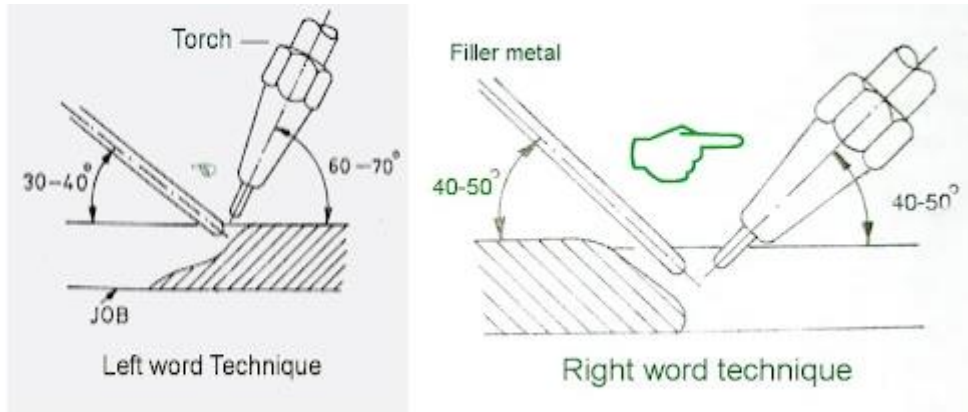
Principle of Gas Welding:



Oxy-Acetylene Gas Welding Setup

A principle of gas welding is shown in fig. The metals to be welded are brought together after cleaning properly. When acetylene is mixed with oxygen in correct proportions in the welding torch and ignited, the flame resulting at the tip of the torch is sufficiently hot about a temperature of 3200°C and melts the parent metal and filler metal to form a homogeneous mixture, which flows together to form a complete bond after solidification by cooling.

This oxyacetylene process does not require the components to be forced together under pressure until the weld forms and solidifies. Only the correct adjustment of the flame is very important for reliable work.



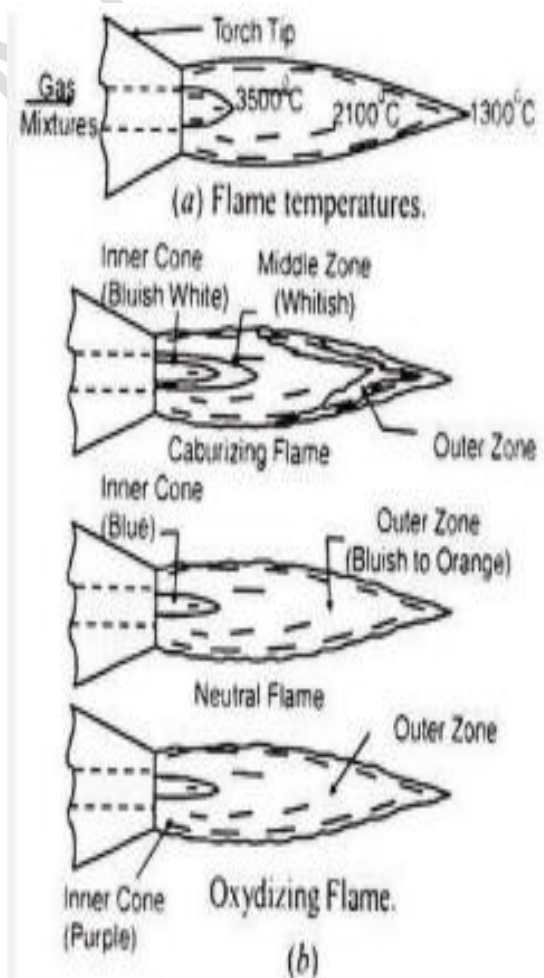
Types of Welding Flames:

The different types of welding flames are as follows:

1. Acetylene flame (full of acetylene)
2. Reducing flame (excess of acetylene with small quality of oxygen)
3. Neutral flame (equal proportions of acetylene and oxygen)
4. Oxidising flame (excess of oxygen).

These flames are as shown in fig.

1. **Acetylene flame:** It is the initial flame produced when you light the torch.
2. **Reducing flame:** This flame is produced from small quality oxygen is supplied to the acetylene flame i.e., rich in acetylene called carburising flame. The approximate temperature of about 3040 °C. It is used in welding lead and carburizing purposes.
3. **Neutral flame:** This flame is produced when equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. The approximate temperature of about 3260 °C. This flame is used for welding of mild steel, stainless steel, CI, copper, aluminium.
4. **Oxidizing flame:** This flame is produced from supplying excess quantity of oxygen to acetylene flame. The approximate temperature is about 3300 °F. This flame is used for welding copper-base metals, zinc-base metals and other few ferrous metals such as manganese steel and cast iron.



Equipments for Gas Welding:

- 1) 1 Welding torch or blow pipe
- 2) Hoses and fittings
- 3) Goggles
- 4) Apron
- 5) Welding rod (Filler metal)
- 6) Pressure regulator
- 7) Cylinders (oxygen and acetylene)
- 8) Spark lighters
- 9) Gloves
- 10) Flux.

Advantages of Gas Welding:

- 1) It can be used for wide variety of manufacturing.
- 2) Welder can have control over welding temperature.
- 3) Rate of heating and cooling relatively slow.
- 4) Welder can have full control over filler metal feeding as it is separate.
- 5) Equipment is versatile and inexpensive and usually portable.
- 6) Low maintenance cost.

Disadvantages

- 1) Flame temperature is less than the arc temperature.
- 2) Some fluxes used in this case may cause irritation to eyes, noses, throats, etc.
- 3) Gas flame takes long time to heat up the metal than the arc.
- 4) More safety problems associated with handling and storage of gases.
- 5) Oxygen and acetylene are expensive.
- 6) Heavy sections cannot be joined economically.

Applications of Gas Welding:

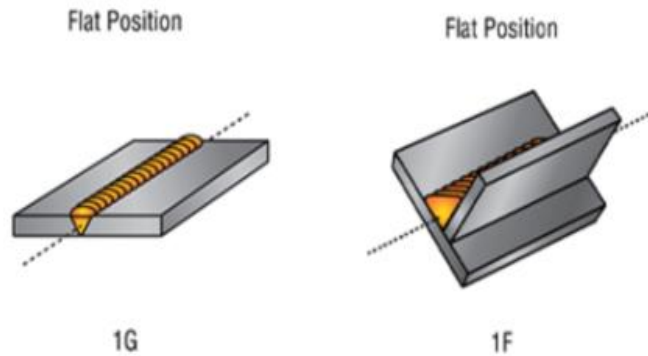
- 1) Used for gas cylinder welding.
- 2) Used for tankers.
- 3) Used for automobile industry.
- 4) Used in fabrication works.
- 5) Used in ship building.
- 6) Used in power plants.
- 7) Used in pipeline works.

13.2 Welding Positions:

A welding position is a technique of joining metals from different angles. Typically, welders use five welding positions: horizontal, flat, vertical, overhead, and inclined. The most frequently-used welds are grooves and fillets, which welders can perform in all five positions, while other welds might use only one or two positions.

The letter associated with the number listed below is G. As mentioned, G is groove.

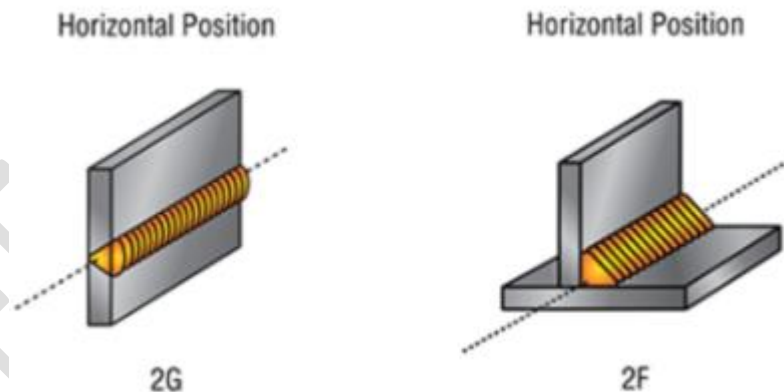
1) 1G Flat Welding Position: When the welder locates the workpiece on the floor or workbench, the position is called the flat position. It is considered the most accessible position because you are not welding against gravity. When using the flat position, it's best to maintain the tip angle, flame position, and consistent motion. The tip should be at a 45-degree angle with the plate surface.



In the flat position, the weld puddle goes into the joint evenly in a fluid state. The molten metal might be hotter than usual, and the deposition rate will be higher because gravity draws the metal downward at the joint. You can do every welding process in a flat position.

A 1G welding position indicates a flat welding position (1) with a Groove weld (G).

2) 2G Horizontal Welding Position: In this case, the welding axis becomes horizontal during this process. For a 2G groove weld, the welding is done on the vertical plane, and the face of the weld lies on the plane.

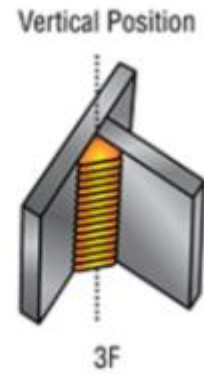
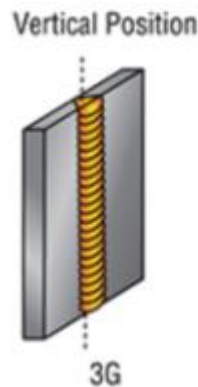


A 2G weld is slightly more challenging since, the weld puddle can sag. Gravity will take over if you run the molten metal too hot horizontally, so ensure the weld puddle is not too fluid. Compared to the flat position, the horizontal position needs more practice to perfect and is considered an out-of-position weld.

The 2G is a groove weld position involving the weld axis in a horizontal plane and the weld face in a perpendicular plane.

3) 3G Vertical Welding

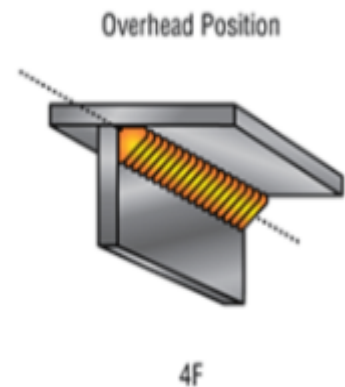
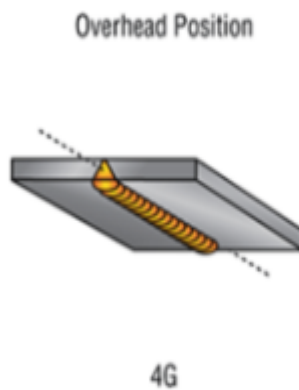
Position: In this process, the axis of the weld remains vertical-it can be vertically up or down. You can change the flame's angle to control the metal flow, with the 90-degree angle suitable for 3G welding. The primary consideration in the vertical position is puddle manipulation, and you can use a zigzag, upside-down, or triangular motion to do this.



The workpiece and the weld are perpendicular or almost perpendicular in this welding position. 3G is the vertical groove. One issue when performing this weld is the molten metal flowing downward and accumulating.

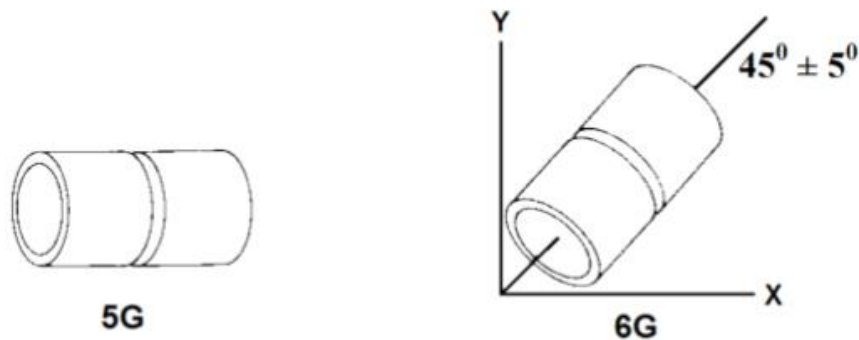
4) 4G Overhead Welding Position: When the welding is done from the lower surface of a joint, it is called the overhead position. The metal you deposit can sag, and the beads have higher crowns. Overhead welding is required when the workpiece is fixed and cannot be moved.

The flame should be regulated, so the metal gets enough time to freeze quickly. The techniques of the vertical positions are also valid with overhead, but it is critical to be aware of the falling sparks as you weld.



The challenging overhead position is performed with the torch at a 45-degree angle, and the 4G welding position is appropriate for groove weld. Remember, the metal can sag from the plate, causing a crown, so keep the molten metal puddle small to avoid this.

5) 5G Inclined Welding Position: The workpiece is placed in an inclined plane, and gravity causes the molten metal to flow downward in a flat position. A small arc produces the proper beads in the inclined position.



5G Welding Position: The 5G pipe welding position is used when the pipe's axis is stable horizontally and cannot be turned or rotated. Two methods exist to complete these welds: 5G uphill and 5G downhill. In the former, welders start from the overhead position, go to the horizontal, and finally to the flat position. In contrast, with the downhill position, welders start from the flat position, progress to the horizontal position, and end with the overhead position.

6) 6G Welding Position: One of the most challenging welding positions, 6G is similar to 5G, but the pipe is positioned at 45° to the other. The 6G position requires three welds: horizontal, flat, and vertical.

The difficulty comes from filling metal flowing downward and the fact that in the vertical position, it is overhead welding. The 6G weld position is primarily used for fabricating and installing pipes and pipelines in oil and gas plants, industrial plants, and any industry using pipes and pipelines.

Principles of Soldering and Brazing Processes:

Principles of Soldering Process:

Soldering joins metal pieces by melting and flowing a filler metal (solder) into the joint, creating a strong, electrically conductive connection. The solder, which has a lower melting point than the base metals, is heated until it melts, the melting point of the filler metal is below 420°C , then cools to solidify and bond the parts together. Capillary action draws the molten solder into the narrow gap between the metal surfaces, ensuring a strong and uniform bond.

Heating Method:

1. **Heat Application:** A heat source, like a soldering iron, is used to raise the temperature of the metal parts to be joined and the solder.
2. **Melting the Solder:** The solder, an alloy with a melting point lower than the base metals, melts when the desired temperature is reached, the melting point of the filler metal is below 420°C .
3. **Capillary Action:** Molten solder is drawn into the space between the metal parts through capillary action, filling the gaps and creating a strong bond.
4. **Solidification:** As the solder cools and solidifies, it creates a permanent, electrically conductive connection between the metal pieces. PRA

5. **Flux:** Flux, a substance that cleans the metal surfaces and prevents oxidation during soldering, is often used to enhance the bonding process.

Fillers Used in Soldering:

- Tin-lead alloys
- Tin-silver alloys and
- Tin-bismuth alloys chosen based on the application requirements.

Applications:

1. Used in computer processor board.
2. Used in Electric connections.
3. Used in TV Mother assembly.
4. Used in automotive repairs.
5. Used in aerospace and medical devices,
6. Used in jewellery making etc.

Principles of Brazing Process:

The principle of the brazing process involves joining metal components by melting and flowing a filler metal into the joint, with the filler metal having a lower melting point than the base metals being joined. The melting point of the filler metal is above 420 °C. In this process the molten filler metal is drawn into the narrow space between the base metals by means of capillary action.

Heating Method:

- 1) The parts to be joined by brazing are cleaned from oil, dirt or oxides.
- 2) Adjust the gap between metals i.e., it should be very small.
- 3) All melting surfaces must be coated with flux.
- 4) They are then heated above 420 °C by any one of the methods namely Dipping, Furnace Heating, Torch Heating or Electric heating.
- 5) Allowing the molten metal to flow by capillary action in to the space between the parts and then slowly cooled to solidify.

Fillers Used in Soldering:

Base Steel	Brazing Filler Metal
Aluminium	BAISi, aluminium silicon
Carbon steel	BCuZn, brass (copper-zinc) BCu, copper alloy BAg, silver alloy
Alloy steel	BAg, silver alloy BNi, nickel alloy
Stainless steel	BAg, silver alloy BAu, gold base alloy BNi, nickel alloy
Cast iron	BCuZn, brass (copper-zinc)
Galvanized iron	BCuZn, brass (copper-zinc)

Nickel	BAu, gold base alloy BAg, silver alloy BNi, nickel alloy
Nickel-copper alloy	BNi, nickel alloy BAg, silver alloy BCuZn, brass (copper-zinc)
Copper	BCuZn, brass (copper-zinc) BAg, silver alloy BCuP, copper-phosphorus
Silicon bronze	BCuZn, brass (copper-zinc) BAg, silver alloy BCuP, copper-phosphorus
Tungsten	BCuP, copper-phosphorus

Applications:

- 1) Used for assemblies like turbine blades and heat exchangers.
- 2) Used for manufacturing the fuel lines.
- 3) Used for manufacturing of radiators.
- 4) Used for manufacturing of HVAC systems, where leak-proof and robust joints are needed.
- 5) Used for precise bonding of electronic components and circuits.
- 6) Used for precise bonding of electronic components and circuits.
- 7) Used in the manufacturing of some medical devices and equipment.
- 8) Used for joining refrigerant tubing in air conditioners and refrigerators etc.

WEEK 13 REVIEW QUESTIONS

1. Define gas welding and list its advantages.
2. List the equipment's required for gas welding process.
3. Explain with its neat diagram CO₂ oxyacetylene gas welding process.
4. Explain different types of gas welding flames.
5. State the applications of gas welding process.
6. State the safety precautions to be followed in gas welding.
7. Explain principle of gas welding.
8. Define gas welding and list the different types of gas welding flames.
9. Explain with neat sketch the different type of gas welding flames.