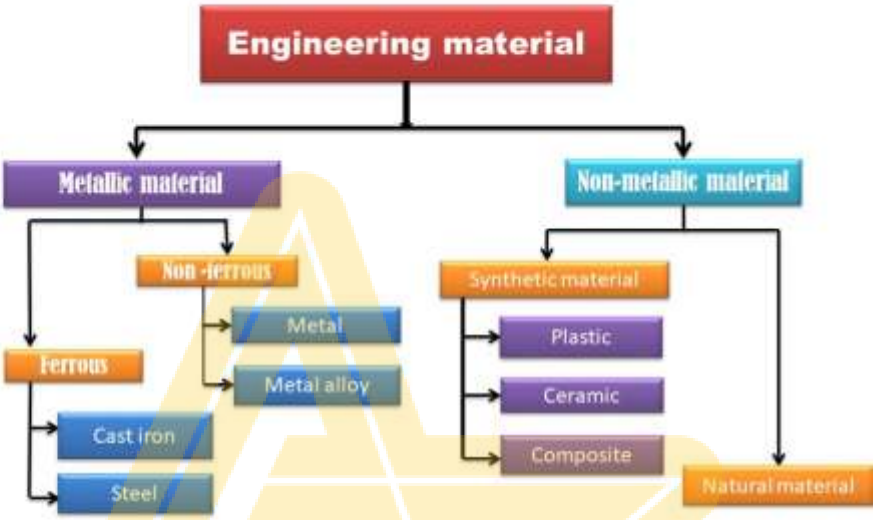
Module-4

Module-4 (8 hours)
Engineering Materials: Types and applications of Ferrous & Nonferrous Metals, silica, ceramics, glass, graphite, diamond and polymer. Shape Memory Alloys. **Joining Processes:** Soldering, Brazing and Welding, Definitions, classification of welding process, Arc welding, Gas welding and types of flames.

Engineering materials



Metals

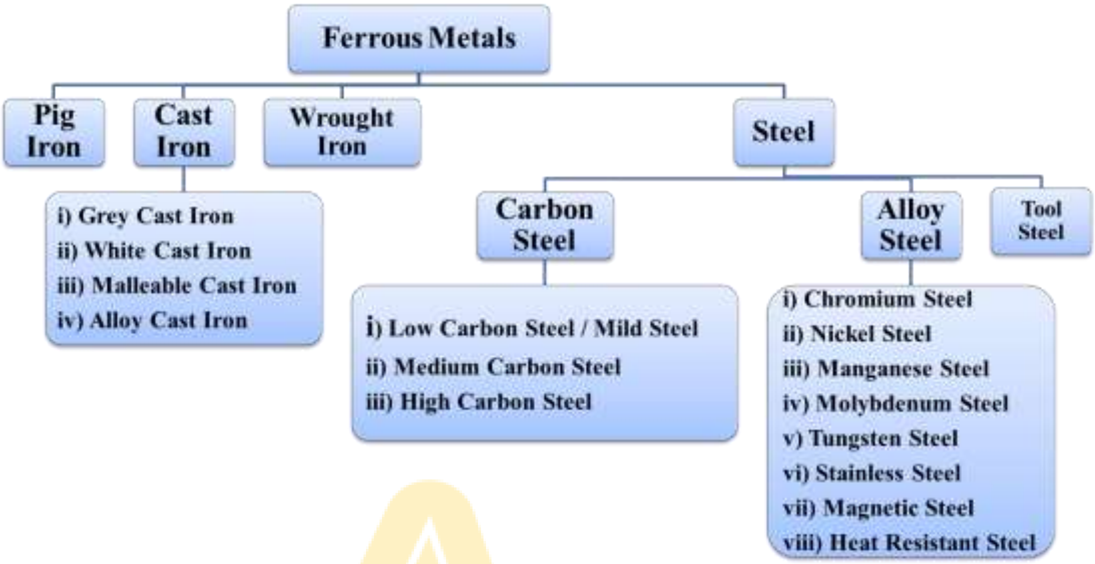
A metal is a material that is typically hard, opaque, shiny, and features good electrical and thermal conductivity. Metals are generally malleable: they can be hammered or pressed permanently out of shape without breaking or cracking well as fusible and ductile

Metals can be either ferrous or non-ferrous. Ferrous metals contain iron while non-ferrous metals do not. Both ferrous and non-ferrous metals are divided into pure metals and alloys.
A pure metal is an element – Ex: iron, copper, gold - unalloyed (not mixed) with another substance.

An alloy is a mixture of two or more elements (Ex: iron and carbon) to make another metal with particular properties (Ex: steel).

Ferrous metals
Ferrous metals contain iron. Examples are cast iron, mild steel, medium carbon steel, high carbon steel, stainless steel, and high speed steel.

Non-ferrous metals
Non-ferrous metals do not contain iron. Some common non-ferrous metals are aluminium, copper, zinc,tin, brass (copper + zinc), and bronze (copper + tin).



Type of Ferrous metal

Cast iron

Composition:Alloy of iron and 2-5% carbon, 1-3% silicon and traces of magnesium, sulphur and phosphorus
Properties and characteristics: it is very strong but brittle. Cast iron has relatively low melting point, is wear resistant, possesses good fluidity, has admirable machinability and is resistant to deformation

Application: It is used to manufacture machine frames, columns, beds and plates, housing flywheel, manhole cover, automotive parts such as engine block, cylinder head, gear box case and machine parts which are not subjected to tension and shocks.
Cast Iron is divided into following types:

- **Grey Cast Iron**
- **White Cast Iron**
- **Malleable Cast Iron**
- **Ductile Cast Iron**
- **Wrought Iron**


Steel

Steel is an alloy of iron and carbon which is produced either by basic oxygen steelmaking process or by electric arc furnace.
Steels are broadly classified into

a) **Carbon Steels**
b) **Alloy Steels**
c) **Tool Steels**

Carbon steels: carbon steels are types of steel containing primarily iron and carbon. Other elements present in small proportions are sulphur, phosphorous, manganese and magnesium. The following types of carbon steel are.

a) Mild steel or Low carbon steel

Composition: It has a carbon content of 0.05 to 0.3%. The balance is iron. The most popularly used carbon steel is mild steel.
Properties and characteristics: Tough, ductile and malleable. Good tensile strength, poor resistance to corrosion
Application: General-purpose engineering material like rivets, bolts, keys plain washer boiler plate's shaft, camshafts and gear.

b) Medium carbon steel

Composition: It has a carbon content of 0.3 - 0.6% carbon. The remainder is iron content.

Properties and characteristics: Strong, hard and tough, with a high tensile strength, but less ductile than mild steel.
Application: It finds application in transmission shafts, springs, spring washers, crane hooks and hand tools etc.

c) High carbon steel

Composition: It has a carbon content of 0.6 - 1.5%. it has an iron content of 96% to 97%

Properties and characteristics: Even harder than medium carbon steel, and more brittle. Can be heat treated to make it harder and tougher
Application: Cutting tools, hammers, chisels, screw, punches, drills lathe tools, leaf springs and milling cutter

d) Stainless steel

Composition:Alloy of iron and carbon with 16-26% chromium, 8-22% nickel and 8% magnesium

Properties and characteristics:Hard and tough, resists wear and corrosion
Composition:Alloy of iron and 0.8 - 1.2% carbon (medium carbon steel) with tungsten, chromium, vanadium, and sometimes cobalt

- It is a type of steel that do not get stained and is resistant to rusting and corrosion.
- It mainly consists of 18% chromium , 8% nickel , 0.03% carbon.
- The rest is majorly iron and in small amounts of manganese, silicon, molybdenum, phosphorous, sulphur, nitrogen etc. stainless steel will not readily corrode, rust or stain with water unlike the ordinary steel.

Applications: Buildings, kitchen equipments, springs, surgical equipments, chemical handling equipments, shaving blades, Cutlery, kitchen equipment, surgical equipment, chemical handling equipments and cutlery etc.

e) High speed steel -High speed steel(HSS)- Tool Steel

Composition:Alloy of iron and 0.8 - 1.2% carbon (medium carbon steel) with tungsten, chromium, vanadium, and sometimes cobalt

Properties and characteristics: Very hard, high abrasion- and heat resistance

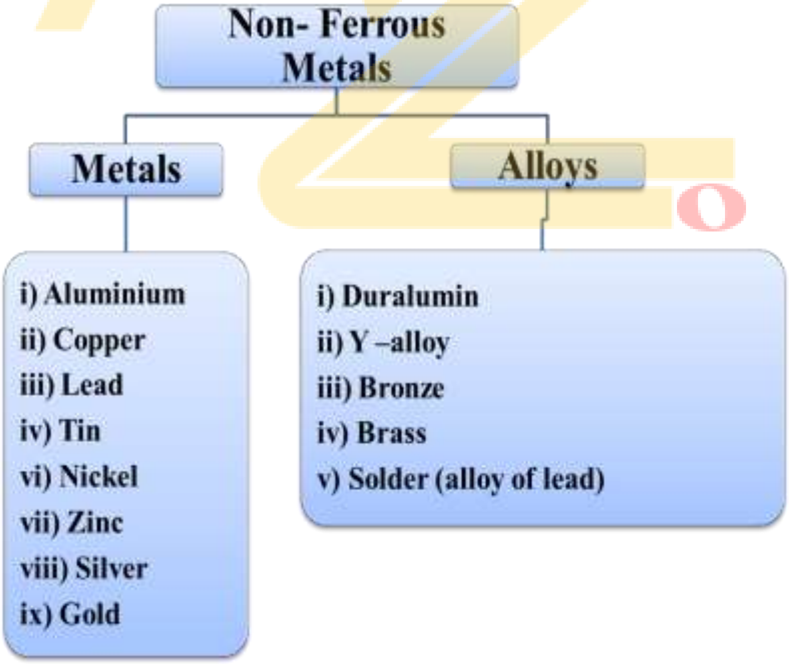
- Tool steels are Special steels with Carbon content is in the range of 0.8 to1.2%
- They are very hard and exhibit good wear and abrasion resistance, they withstand hardness at elevated temperatures.
- The alloying elements added to realize this property are tungsten, vanadium, cobalt, chromium and molybdenum
- Example of tool steel is HSS (High Speed Steel)
  - It contains Carbon (0.7-0.8%), tungsten (12– 20%), Chromium (3-5%), vanadium (1-2%), cobalt (5-10%), it is used to make drill bits, lathe tools, milling cutters etc. HSS tools can operate at cutting at cutting speeds which are 2 to3 times higher than high of high carbon steel tools and also retain their red hardness up to a temperature of 620^{o}C

Applications:-Tool steels are used in machining operations that are capable of cutting at high speeds without any loss in the hardness.

Type of Non Ferrous metal

Non- Ferrous Metals are engineering materials that do not contain iron.
The various reasons non ferrous materials are preferred

- Good strength to weight ratio
- Good resistance to corrosion
- Light weight
- High electrical and thermal conductivity



Aluminium

Composition: Pure aluminium (an element)

Properties and characteristics: Good strength-to-weight ratio, light, soft, ductile, good conductor of heat and electricity Application: Kitchen equipment, window frames, general cast components The alloys of Aluminium are Duralumin and Y-Alloy

- Aluminium is a silvery white, Soft and ductile material.
- In its ore form , aluminium is found as hydrated aluminium oxide or Bauxite.

Properties :

- Light weight and easy workability
- It has the ability to resist corrosion
- Highly ductile
- Good electrical and thermal conductivity

APPLICATIONS OF ALUMINIUM

- Since it is ductile, it can be used to protect pure metals by Al foil.
- As it is good conductor of electricity & cheap so it is used for making electrical wires.
- Aluminum has no aroma, hence it is widely used in food packing and cooking pots.
- It is used in mirrors and other decorative architectural components. In the packaging industry, it is used to make foils and drinking cans

Limitations

- The chief limitation of aluminum is its low melting temperature (660^{o}C), which restricts the maximum temperature at which it can be used.
- • Moreover it is very soft, which restricts their application in automobile and aircrafts (where lightweight and stronger materials are required).

Aluminium alloys

However the application of pure aluminum is very rare as compared to that of it's alloys.

Addition of other alloying elements like copper, magnesium, manganese, silicon, nickel etc.

Aluminium alloys

1) Al-Cu-Mg-alloys (duraluminium)
2) Al-Cu-Mg-Si-alloys (forgable)
3) Al-Mg-Si-alloys (corrosion resistance)
4) Al-Zn-Mg-Cu-alloys (high strength)
5) Al-Cu-Mg-Ni-Fe-alloys (heat resistance)

Two important Aluminium alloy

Duralumin (Aluminium- 92 %), Copper – (3.5 to 4.5%), Magnesium- 0.4 to 0.7%, iron and silicon (0.7%), Manganese (0.4 to 7%) Duralumin can be highly strengthen by heat treatment . It is as strong as steel but weighs only one third of the weight of steel. Duralumin can be spun, pressed, riveted, machined, etc.

Applications



Y-alloy

Y- alloy consists of (Aluminium- 93%, Copper – 2%, Nickel- 2%, Magnesium- 1%,) Y- alloy is good conductor of heat and is available in both wrought and cast forms.

Applications:- since y-alloy maintains strength at elevated temperatures, it is used to make piston, cylinder head of I.C engine, it is also used to make connecting rods and blades of propeller.



Copper

Composition: Pure copper (an element)

Properties and characteristics: Malleable and ductile, good conductor of heat and electricity, good corrosion resistance and light weight.

Application: copper tubes used in refrigerator and air conditioners and radiators due to high thermal conductivity, electrical wires and cables, used to make door knobs.

Alloys of copper are Brass and Bronze.

Alloys of Copper

- **Brass** (Alloy of Copper- 51 to 81% and Zinc- 19 to 49%)
- **Bronze** [Alloy of Copper and tin(5-10%)]

Brass

Composition: Alloy of copper (51% to 81%) and zinc (19% to 49%), small amount of aluminium, tin, manganese and lead give special properties to brass.

Properties and characteristics: Resistant to corrosion, fairly hard, good conductor of heat and electricity

Application: electrical fuses and fittings, brazing solder, musical instruments such as horns, trumpets and bugles etc.,

Applications of Brasses

- Pump parts, Marine fittings, valves, condenser tubes, fuses, taps, etc.
- Electrical fittings
- As Brazing spelter

- Gears, pinions and other moving parts of a clock
- Brush holders

Bronze

Composition:Alloy of copper and tin
Properties and characteristics:Fairly strong, malleable and ductile when soft

Gun Metal
(Copper 88%, tin 10%, Zinc 2%)
Marine fittings, pumps , valves, bearings, bushes, fitting of steam pipe

Gunmetal, also known as **red brass.**
This is a type of bronze – an alloy of copper (88%), tin (10%), and zinc (2%).
Originally used a chiefly for making guns. Gunmetal casts and machines well, is resistant to corrosion from steam and salt water, and is used to make steam and hydraulic castings, valves, and gears.

Bell Metal
(Copper 75 to 80%, and tin 20%)
Used in bells (due to its ringing and damping qualities)
Bell metal is a hard alloy used for making bells and related instruments, such as cymbals, cannon. It is a form of bronze, usually in approximately a 4:1 ratio of copper to tin (e.g., 78% copper, 22% tin by mass)

Application: Decorative goods, architectural fittings

Zinc

Composition: - Zinc is a heavy, bluish white metal which can be extracted from zinc sulphide.
Properties:

- It is a fair conductor of electricity
- It has relatively low melting and boiling point
- It is resistant to corrosion

Application; - Usually used for coating steel to make galvanised items

Tin

Composition: - it is a silvery-white metal obtained from an oxide called tin stone by refining in a reverberatory furnace.
Properties:

- Soft, malleable and ductile
- It is corrosion resistant from water but is not resistant for acids and alkalies.
- It has low melting point (232ºC)

Application:
- It is coated for storing food and water
- Used in perforated lanters, candle shields and mirror frames.
- Used as roofing material due to its light weight and corrosion resistance.

Lead

Lead is a soft and malleable metal obtained from its ores (mainly the galena ore) and found as oxides or sulphides.
Properties:

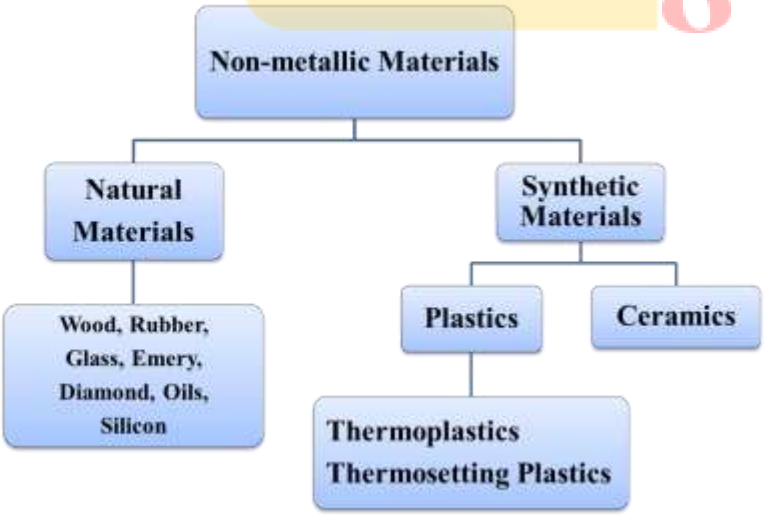
Soft metal and malleable and ductile.

- It has poor tensile strength
- High thermal expansion

Application

- Solders since it has a low melting point.
- Water pipes due to its corrosion resistance.
- In making Bullets and shots for fire arms.

Non Metals



CERAMICS:

The word "ceramic" is derived from the Greek word keramikos meaning pottery.

"Ceramics can be defined as inorganic, non-metallic materials that are typically produced using clay and other minerals from the earth or chemically processed powders."
Ceramics may be crystalline in nature and are compounds of metallic and non-metallic elements such as aluminumand oxygen (alumina), silicone and nitrogen (silicon nitride) and silicon and carbon (silicon carbide).

- Ceramic is an inorganic, non-metallic solid manufactured by baking naturally occurring clays at high temperatures after moulding to shape.
- Ceramics are used manufacture of Tiles, dies, engine parts, structural and refractory bricks, as high-voltage insulators, high-temperature resistant cutting tool.
- Advanced ceramics, on the other hand, are typically made from synthetic raw materials such as **alumina, silicon carbide, and zirconia, and are engineered for specific applications**.
- They can have **high strength, toughness, and hardness, as well as excellent resistance to wear, corrosion, and high temperatures.**
- Advanced ceramics are commonly used in applications such as **cutting tools, automotive components, electronic substrates, and biomedical implants.**
-

GLASS:

"Glass may also be defined as a hard, brittle, transparent or translucent material mainly compound of silica, combined with varying proportions of oxides of sodium, potassium, calcium, magnesia, iron and other minerals."

Glass is a transparent, amorphous solid material that is made by melting silica (silicon dioxide) and other ingredients at high temperatures and then rapidly cooling the molten

The term "glass" as ordinarily used refers to material which is made by the fusion of mixture of silica, basic oxides and a few other compounds that react either with silica or with the basic oxides.

The composition of glass can vary depending on its intended use and properties, but most glasses are composed primarily of silica (silicon dioxide, SiO_2) which is the main source of its strength and durability.

Properties

- **Transparency:** Glass is highly transparent, which makes it ideal for use in optical applications, such as eyeglasses, camera lenses, and telescopes.
- **Durability:** Glass is a very hard and brittle material that is resistant to physical damage, making it ideal for applications such as windows, mirrors, and table tops.
- **Chemical resistance:** Glass is highly resistant to chemical attack, which makes it ideal for use in containers for corrosive liquids and gases.
- **Versatility:** Glass can be molded, shaped, and colored to suit a wide range of applications, and it is a popular choice for use in art, architecture, and interior design.
- **Environmental sustainability:** Glass is a 100% recyclable material and can be melted down and reused many times over, making it an environmentally friendly choice for many applications

GRAPHITE

- Graphite is a naturally occurring form of carbon with a unique structure that gives it special properties.
- It is a mineral that is found in metamorphic rocks such as schist and gneiss, as well as in some igneous rocks

like lava.

Graphite is known for being soft and brittle, and it has a metallic luster.

Application

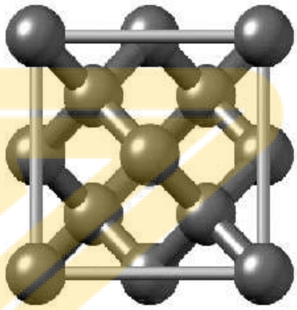
- Graphite is also an excellent conductor of electricity due to its unique structure.
- The delocalized electrons in the hexagonal lattice are free to move throughout the structure, allowing for the conduction of electricity.
- This property makes graphite useful in many applications, including as an electrode material in batteries and fuel cells, and in electrical contacts and switches.

Application

- Pencils
- Lubricants
- Batteries and fuel cells
- Thermal management
- Industrial applications
- Aerospace
- Nuclear industry

Diamond

- Diamond is a naturally occurring mineral that is composed of carbon atoms arranged in a unique crystal structure.
- It is the hardest known natural material, with a Mohs hardness rating of 10, and is prized for its beauty and durability.



Properties

- **Hardness:** Diamond is the hardest naturally occurring material, with a rating of 10 on the Mohs scale of mineral hardness.
- **Thermal conductivity:** Diamond has the highest thermal conductivity of any material, meaning it can quickly transfer heat away from its source
- **Optical properties:** Diamond has a high refractive index and can produce a brilliant sparkle due to its ability to refract and reflect light.
- **Chemical resistance:** Diamond is highly resistant to chemical corrosion, making it a valuable material in harsh environments.
- **Electrical insulator:** Diamond is an excellent electrical insulator, meaning it does not conduct electricity well.
- **High melting point:** Diamond has a very high melting point, making it extremely resistant to heat.
- **High stiffness:** Diamond is an extremely stiff material, meaning it is difficult to deform or bend.

Application

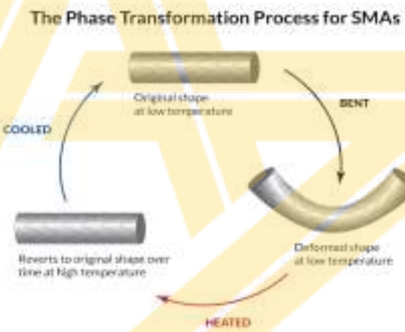
- **Jewelry:** Diamonds are prized for their beauty and are commonly used in engagement rings, necklaces, and other types of jewelry.
- **Cutting tools:** The extreme hardness of diamonds makes them useful as cutting tools in industrial applications such as cutting and polishing other hard materials like metal, stone, and glass.
- **Semiconductors:** Diamonds have unique electrical properties, such as high carrier mobility and low dielectric constant, which makes them useful as semiconductors in high-performance electronic devices.

Application

- **Heat sinks:** Diamond's high thermal conductivity makes it useful in heat sinks, which are used to dissipate heat in electronic devices.
- **Medical equipment:** Diamond-tipped surgical tools are used in some medical procedures because of their hardness and durability.
- **Abrasives:** Diamonds are used as abrasives in a variety of applications, such as sandpaper and grinding wheels.
- **Electronics:** Diamond's optical transparency and high refractive index make it useful in optical components such as windows for lasers and infrared detectors.

Shape Memory Alloys

- Shape memory alloys (SMA) are a class of metallic materials that can "remember" their original shape and return to it after being deformed.
- SMAs are typically made from a combination of nickel, titanium, and copper, although other metals can also be used.



- The unique properties of SMAs are due to a solid-state phase transformation that occurs when the material is heated or cooled.
- When an SMA is in its "martensitic" phase (at a lower temperature), it can be easily deformed into a new shape.
- However, when the material is heated above a certain temperature (known as the "austenitic" phase), it returns to its original shape.

Applications

- **Biomedical implants:** SMAs can be used in biomedical implants, such as stents, because they can be compressed and inserted into a small space, then return to their original shape once in place.
- **Aerospace and defense:** SMAs can be used in aerospace and defense applications, such as shape-changing wings or actuators, because they can change shape in response to changes in temperature or other stimuli.
- **Automotive Industry:** SMAs can be used in automotive applications, such as sensors or engine components, because they can respond to changes in temperature or other stimuli to optimize performance.
- **Consumer goods:** SMAs can be used in consumer goods, such as eyeglass frames, because they can be easily

adjusted to fit the user's face and then return to their original shape.

- **Robotics:** SMAs are used in robotics for actuation and sensing because of their high force-to-weight ratio and the ability to return to their original shape after deformation.
- **Textiles:** SMAs are used in textiles for shape memory and self-healing applications, such as smart clothing that can change shape and repair itself.
- **Construction:** SMAs are used in construction for earthquake-resistant structures and smart windows that can change their optical properties based on external conditions

Plastics

- The name of Plastics originated from Greek word called ‘ Plasticos’ meaning to be able to be shaped or moulded by heat.
- **Plastics are categorized as**
  - **Thermoplastics**
  - **Thermosetting plastics**

Thermoplastics

- These are plastics that can be soften and get formed by the application of heat, and when cooled, takes up the shape of the form.
- In case heat is applied again, they will soften again,
- Examples of thermoplastics are acrylic and styrene

Thermosetting plastics

- These are plastics that can be soften by the application of heat, and upon cooling gets moulded into the mould shape
- But in case heat is applied again, Softening does not happen and gets permanently moulded in the mould shape.
- Examples of thermosetting plastics are polyester resins that are used in glass reinforced plastics work

Silica

- Silica is a naturally occurring mineral compound that is composed of silicon and oxygen atoms (SiO_2).
- It is one of the most abundant minerals in the earth's crust and can be found in rocks, sand, and soil.
- Silica has many different forms, including quartz, cristobalite, tridymite, and amorphous silica.
- Silica is typically hard, brittle, and resistant to chemical reactions.


- Prolonged inhalation of silica dust can lead to a number of **respiratory diseases, including silicosis, lung cancer, and chronic obstructive pulmonary disease (COPD).**

For this reason, it is important to take precautions to limit exposure to silica dust in occupational settings and during certain industrial processes

Application

- Production of glass, ceramics, semiconductors, and other electronic components.
- It is also used in the construction industry as a component of concrete, and in the manufacturing of abrasives, coatings, and refractory materials.

Rubber

- **Rubber:** rough, elastic material, unaffected by water, attacked by oil and steam, electrical resistance.
- Pure crude rubber is a white or colorless hydrocarbon. The simplest unit of rubber is *isoprene.*
- **Uses:** The flexibility of rubber is often used in hose, tires, and rollers for a wide variety of devices ranging from domestic clothes wringers to printing presses; its elasticity makes it suitable for various kinds of shock absorbers and for specialized machinery mountings designed to reduce vibration.


Applications Of Rubber:

1. Tires: One of the most common applications of rubber is in the manufacturing of tires for cars, trucks, buses, and bicycles.
2. Seals and Gaskets: Rubber is used to make seals and gaskets that prevent air, water, or other fluids from leaking from one part of a machine to another.
3. Industrial Belts: Rubber belts are used in various industries to transmit power from one machine to another, such as in conveyor belts for material handling.
4. Footwear: Rubber is used in the manufacturing of footwear such as shoes, boots, and sandals.
5. Insulation: Rubber is a good electrical insulator and is used in the manufacturing of cables, wires, and other electrical components.
6. Sports Equipment: Rubber is used in the manufacturing of sports equipment such as balls, mats, and protective gear.
7. Medical Products: Rubber is used in the manufacturing of medical products such as gloves, tubing, and catheters.
8. Consumer Goods: Rubber is used in the manufacturing of consumer goods such as erasers, rubber bands, and toys.
9. Adhesives: Rubber-based adhesives are used in various industries such as construction, automotive, and packaging.

Metal Joining Processes

Metal joining processes refer to various methods used to connect two or more metal components or parts to create a larger structure or to repair damaged metal parts. Some common metal joining processes include:

1. **Welding:** Welding is the most common metal joining process. It involves melting the metal components to be joined and then cooling them, causing the parts to fuse together. Some common types of welding include arc welding, MIG welding, TIG welding, and spot welding.

2. **Brazing**: Brazing is a process that uses a filler metal to join two metal components. The filler metal has a lower melting point than the base metal, so it can be melted and flowed into the joint between the two parts.

3. **Soldering:** Soldering is similar to brazing, but it uses a filler metal with an even lower melting point. The filler metal is melted and flowed into the joint between the two parts, creating a strong bond.

4. Adhesive bonding: Adhesive bonding involves using an adhesive to join two metal components. The adhesive is applied to one or both parts, and then the parts are pressed together and allowed to cure.

5. Mechanical joining: Mechanical joining methods include using **bolts, screws, rivets, or other fasteners to connect two metal components.** This method does not require heat or electricity, but it may not be as strong as welding, brazing, or soldering.

6. Explosion welding: Explosion welding involves using explosives to create **a high-speed collision between two metal components**. The impact causes the metals to fuse together, creating a strong bond.

Soldering

Soldering is a joining process in which two or more metal items are joined together by melting and then flowing a filler metal into the joint—the filler metal having a relatively low melting point.

Soldering is a metal joining process that involves melting a low-melting-point metal alloy (called solder) and using it to join two metal parts together. Soldering is often used to create electrical connections, such as joining electronic components to a printed circuit board, or to repair or replace metal parts in plumbing or HVAC systems.

The basic process of soldering involves cleaning and preparing the metal surfaces to be joined, applying flux (a chemical cleaning agent) to the joint area to help the solder flow and prevent oxidation, heating the joint area with a soldering iron or torch, and then applying the molten solder to the joint. As the solder cools, it solidifies and forms a strong, permanent bond between the metal parts.Soldering requires a relatively low temperature, typically between 200-400 degrees Celsius, depending on the type of solder and the metal being joined. It is important to use the correct type of solder for the job, as different solders have different melting points and compositions, and may be better suited for specific applications.

Soldering can be done by hand with a soldering iron or torch, or it can be automated using soldering machines or robotic systems. It is a relatively simple and inexpensive method of metal joining, and it is often preferred over welding or brazing for delicate or precision applications, or for joining dissimilar metals that cannot be welded.

Steps To Follow When Soldering

1. **Clean the surfaces:** Before soldering, it is important to clean the surfaces that will be joined to remove any dirt, grease, or oxidation. Use a fine abrasive pad or sandpaper to remove any corrosion, and wipe the surfaces with a clean cloth or alcohol to remove any residue.

2. **Apply flux:** Apply a small amount of flux to the joint area to help the solder flow and to prevent oxidation during the soldering process. The flux can be applied with a brush or a small applicator, or it may be included in the solder wire.

3. **Heat the joint**: Use a soldering iron or torch to heat the joint area until the metal reaches the correct temperature for the solder to melt. The temperature will depend on the type of solder being used and the metal being joined.

4. **Apply solder:** Once the metal is heated, touch the solder wire to the joint and allow it to melt and flow into the joint area. Apply only enough solder to fill the joint, and avoid applying too much, which can result in a weak joint or a short circuit.

5. **Remove the heat:** Once the solder has flowed into the joint, remove the heat source and allow the joint to cool. Do not move or disturb the joint until it has cooled completely, as this can cause the joint to weaken or break.

6. **Clean the joint:** After the joint has cooled, clean any excess flux or residue from the joint with a clean cloth or brush. Avoid touching the joint with bare hands, as the heat may cause burns.

These are the basic steps for soldering, but the exact process may vary depending on the specific application and the tools being used. Always follow the manufacturer's instructions for the solder and flux being used, and wear appropriate safety gear, such as eye protection and heat-resistant gloves, when soldering.

Important Points

Solder : Alloy of Lead and Tin .

Melting temp: 150 -350^{0}C.

Flux: To clean the joint surfaces and to prevent the oxidation.

Eg. Zinc chloride.

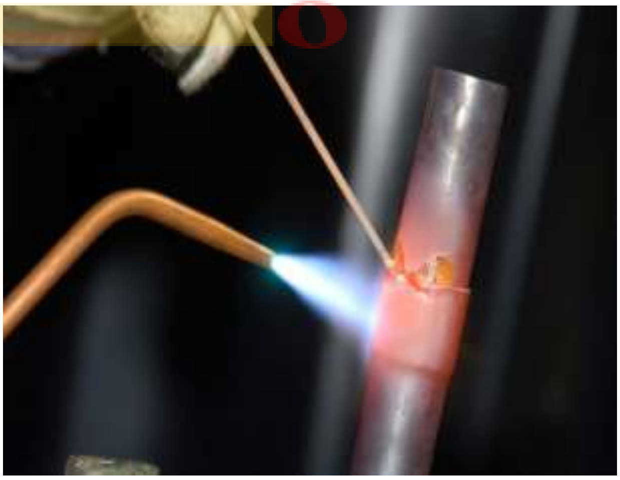
Soldering iron: is used to apply heat from electrical source.

For strong joint an alloy of copper Tin and silver known as hard solder with melting temp 600- 900^{0}C is used.

Advantages	Disadvantages
• Soldering is a relatively simple and inexpensive method of metal joining that requires only basic tools and equipment. • It can be used to join dissimilar metals that cannot be welded or brazed, such as copper and aluminum. • Soldering can be used for delicate or precision applications, such as electronics or jewelry making, where welding or brazing may be too strong or damaging. • It creates a strong, permanent bond between the metal parts being joined. • Soldering can be used to make electrical connections that are reliable and resistant to corrosion. • It can be done quickly and efficiently, especially when using automated soldering machines or robotic systems.	• Soldered joints may not be as strong as welded or brazed joints, especially when subjected to high stress or vibration. • Soldered joints may be more prone to failure in high-temperature applications, as solder can melt or become brittle at high temperatures. • Soldering requires the use of flux, which can be messy and difficult to clean up if not used properly. • Soldering can produce toxic fumes and smoke, especially when using lead-based solders, and appropriate ventilation and safety measures must be taken. • Soldering may not be suitable for all types of metal joining applications, especially those that require a high degree of precision or strength. • Soldering may not be as visually appealing as other metal joining methods, such as welding or brazing, as it may leave visible solder marks or discoloration.

Brazing

Brazing is a metal joining process that involves melting a filler metal into the joint between two metal parts using heat, typically with a torch or furnace. The filler metal is drawn into the joint by capillary action, creating a strong bond between the two parts.



- Method of joining two similar or dissimilar metals using a special fusible alloy.
- This produces joints stronger than soldering.
- Base material does not melt in brazing, only the filler melts.
- In brazing, the filler metal has a melting temperature above 450°C, but below the melting point of metals to be joined.
- Flux used is usually Borax.

Difference between Soldering and brazing

Brazing	*Soldering*
Filler metal has the melting point above 400⁰C.	Filler metal has the melting point below 400⁰C.
More stable joints can be made.	Less stable joints can be made.
High pressure and temperature do not affect the joint.	Joints are affected by high temperature and pressure.
Equipment cost is more.	Equipment cost is very low.

Here are some advantages and disadvantages of brazing

Advantages

- Brazing creates strong, permanent joints that are often stronger than the base metal itself.
- Brazing can be used to join dissimilar metals, such as copper and steel, which may not be weldable due to their different melting points or other properties.
- Brazing can be used to join thin or delicate parts without damaging them, making it useful in applications such as electronics or jewelry making.
- Brazing can be used to create a hermetic seal, preventing air or other contaminants from entering the joint.
- Brazing can be done with a variety of filler metals, including silver, copper, brass, and nickel, allowing for flexibility in material selection and performance characteristics.
- Brazing can be done quickly and efficiently, especially when using automated brazing machines or robotic systems.

Disadvantages

- Brazing requires higher temperatures than soldering, which can be a limitation for some materials or applications.
- Brazing can cause distortion or warping of the base metal, particularly with thin or heat-sensitive parts.
- Brazing requires the use of flux, which can be messy and difficult to clean up if not used properly.
- Brazing may not be suitable for all types of metal joining applications, particularly those requiring a high degree of precision or surface finish.
- Brazing can be more expensive than other metal joining methods, particularly if specialized equipment or materials are required.
- Brazing can produce toxic fumes and smoke, particularly when using cadmium or other hazardous filler metals, and appropriate ventilation and safety measures must be taken.

Difference between Soldering and brazing and welding

Welding	Brazing	Soldering
Base metal fused	Base metal doesn't fused	Base metal doesn't fused
High Temp , High power	Low Temp , Low power	Low Temp , Low power
High distortion	Low distortion	No distortion
High stresses in joints	Low stresses in joints	Low stresses in joints
Mictrostucture of base metal change	Base Metal Microstructure no change	Base Metal Microstructure no change
Dissimilar metals difficult to join	Dissimilar metal easy to join	Dissimilar metal easy to join
Thin sheet difficult to weld	Thin sheet can be joined	Thin sheet can be joined
High strength of joints	Low strength of joints	Low strength of joints
Tensile strength > 200 MPa	Tensile strength 100~150 Mpa	Tensile strength <75MPa

Difference between Soldering and welding

S.No	Welding	Soldering
1	Welding joints are strongest joints used to bear the load. Strength of the welded portion of joint is usually more than the strength of base metal	Soldering joints are weakest joints out of three. Not meant to bear the load. Use to make electrical contacts generally.
2	Temperature required is 3800°C in welding joints.	Temperature requirement is up to 450°C in soldering joints.
3	To join work pieces need to be heated till their melting point.	Heating of the work pieces is not required.
4	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.
5	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.
6	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.
7	No preheating of workpiece is required before welding as it is carried out at high temperature.	Preheating of workpieces before soldering is good for making good quality joint.

Welding

Welding is a metal joining process in which two or more parts are joined at their contacting surfaces by the application of heat or/and pressure, with or without the use of filler material.

OR

Welding is a metal joining process that involves melting the base metals being joined along with a filler material to form a strong, permanent bond between them.

Advantages of welding:

1. Welding produces strong, permanent joints that are often stronger than the base metal itself.
2. Welding can be used to join a wide range of materials, including steel, aluminum, and stainless steel.
3. Welding can be used to join thick sections of metal, making it suitable for structural applications.
4. Welding can be used to create smooth, visually appealing joints that blend in with the surrounding metal.
5. Welding can be done quickly and efficiently, especially when using automated welding machines or robotic systems.
6. Welding can be used to create hermetic seals or other specialized joint configurations, such as T-joints or lap joints.

Disadvantages of welding:

1. Welding requires high temperatures and specialized equipment, which can be expensive and may require skilled operators.
2. Welding can cause distortion or warping of the base metal, particularly with thin or heat-sensitive parts.
3. Welding may produce weld spatter or other surface irregularities that require additional finishing or clean-up.
4. Welding may not be suitable for all types of metal joining applications, particularly those requiring a high degree of precision or surface finish.
5. Welding can produce toxic fumes and smoke, particularly when using certain filler materials or working with certain metals, and appropriate ventilation and safety measures must be taken.
6. Welding may introduce heat-affected zones (HAZ) in the metal around the weld, which can alter the material properties and affect its performance.

Types of welding

Welding processes can be broadly classified into

(i) Fusion welding, (ii) Pressure welding

Fusion welding

- Heat is applied to melt the base metals.
- In many fusion welding processes, a filler metal is used to provide strength to the welded joint.
- Types:
  - Arc welding,
  - Resistance welding,
  - Gas welding,
  - Electron beam welding,
  - laser welding

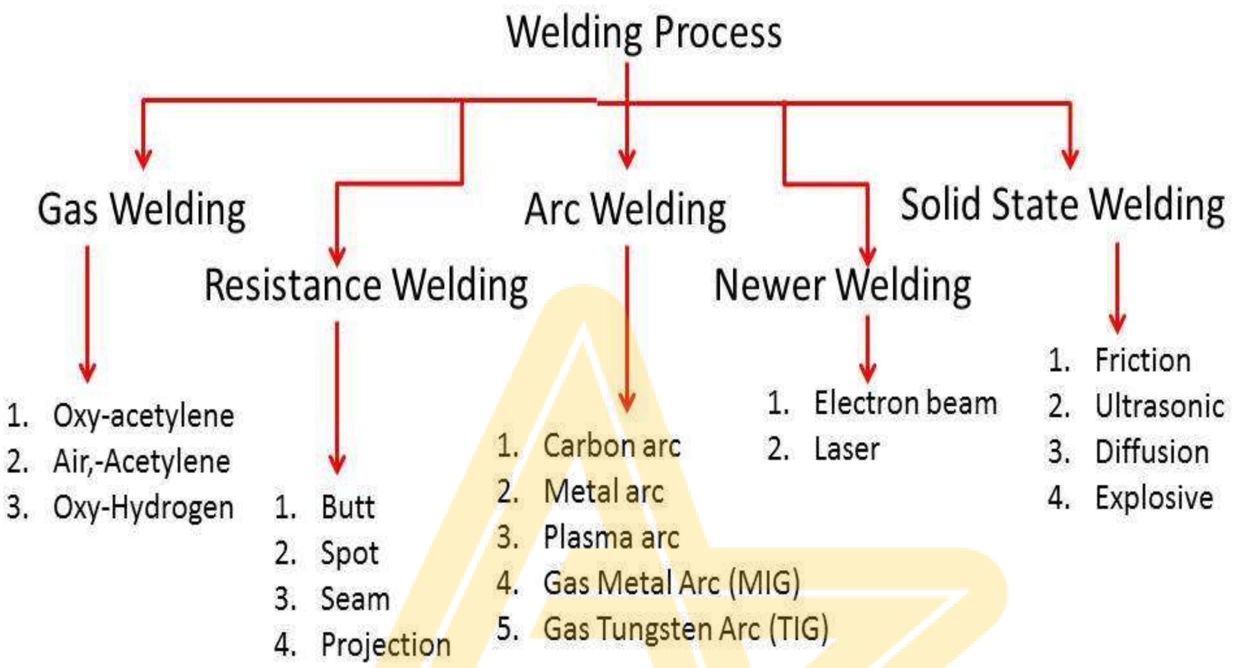
Pressure welding

In this method, joining is done by application of pressure only or a combination of heat and pressure.

Even if heat is used, the temperature in the process is less than the melting point of the metals being welded.

No filler metal is utilized.

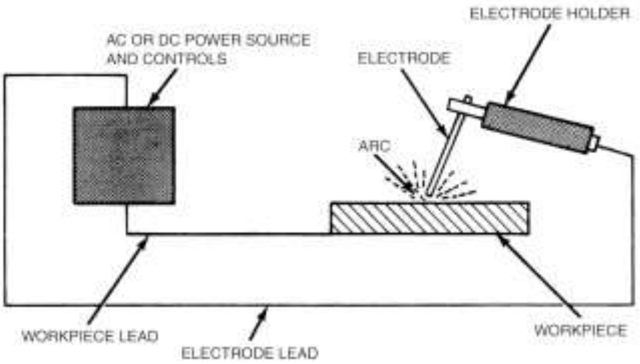
Classification of Welding

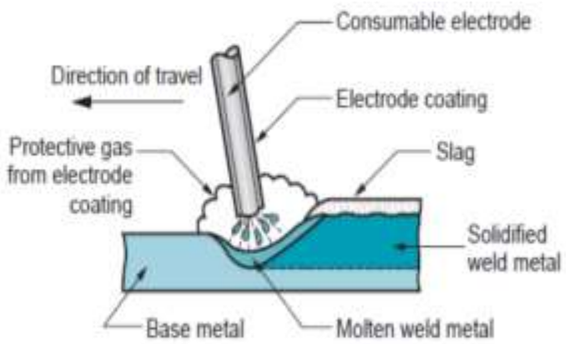


Electric Arc welding

Electric arc welding is a type of arc welding that uses a power supply to create an electric arc between an electrode and the base metal being welded.

- It is a fusion welding process in which the melting and joining of metals is done by the heat energy generated by the arc between the work and electrode.
- An electric arc is generated between the electrode and the work.
- Temperature of 5500°C is generated by this arc.





Electric arc welding is a welding process that uses an electric arc to melt and join two pieces of metal together. The process involves creating an electric arc between an electrode and the metal being welded. The heat generated by the arc melts the metal and a filler material, which is added to the joint to create a strong, permanent bond.

- Preparation: The metal pieces to be welded are cleaned and prepared to ensure a clean and secure weld. This may involve removing rust, dirt, or other contaminants from the metal surfaces.

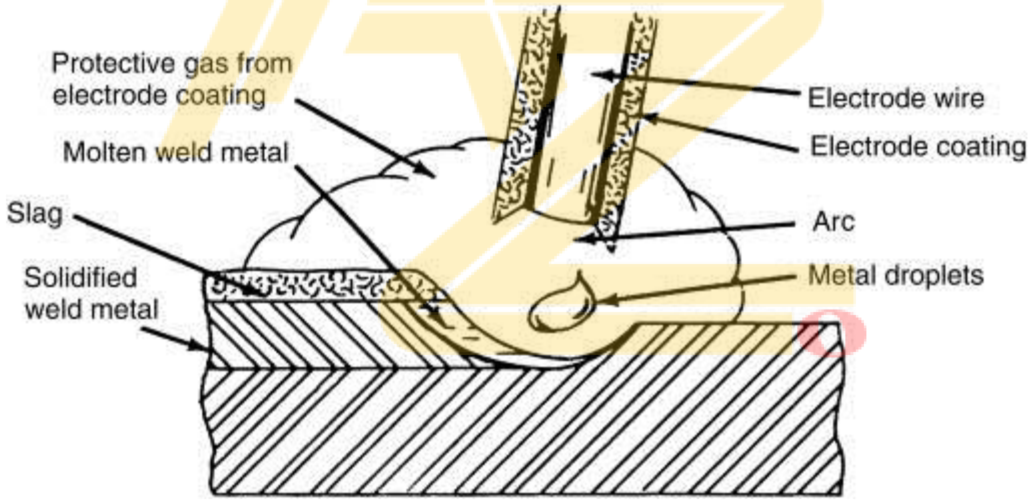
- Set up: The welding machine is set up with the appropriate settings for the metal being welded, including the type and thickness of the metal, the welding position, and the type of electrode and filler material being used.

- Arc initiation: The electrode is brought into contact with the metal and an electric arc is created. This generates intense heat, which melts the metal and the filler material.

- Welding: The electrode is moved along the joint, melting the metal and depositing the filler material as needed. The operator must control the heat and speed of the electrode to ensure a strong, smooth weld.

- Finishing: After the welding is complete, the weld is inspected and any excess weld material is removed. The weld may also be ground or sanded to create a smooth finish.

Arc shielding



Shielding gas

- This covers the arc, electrode tip and weld pool from external atmosphere.
- The metals being joined are chemically reactive to oxygen, nitrogen, and hydrogen in the atmosphere.
- So the shielding is done with a blanket of gas or flux, or both, which prevent exposure of the weld metal to air.
- Common shielding gas: Argon, Helium

Electric arc welding can be performed using a variety of electrode types, including stick electrodes, metal-cored electrodes, and flux-cored electrodes. The process can be performed manually or with the use of automated welding machines or robotic systems.

Electrodes Types

Two types of electrodes are used:

- **Consumable**
- **non-consumable**

Consumable electrodes: Present in rod or wire form with 200 to 450 mm length and less than 10 mm diameter.

The electrode is consumed by the arc during the welding process and added to the weld joint as filler metal.

Non-Consumable electrodes:

The electrodes are not consumed during arc welding.

Filler metal is supplied by means of a separate wire that is fed into the weld pool.

Advantages of arc welding

1. Arc welding produces strong, permanent joints that are often stronger than the base metal itself.
2. Arc welding can be used to join a wide range of materials, including steel, aluminum, and stainless steel.
3. Arc welding can be done quickly and efficiently, especially when using automated welding machines or robotic systems.
4. Arc welding can be used to create smooth, visually appealing joints that blend in with the surrounding metal.
5. Arc welding can be used in a variety of positions, including flat, horizontal, vertical, and overhead.
6. Arc welding can be performed in outdoor or remote locations, as long as there is a source of electricity.

Disadvantages of arc welding:

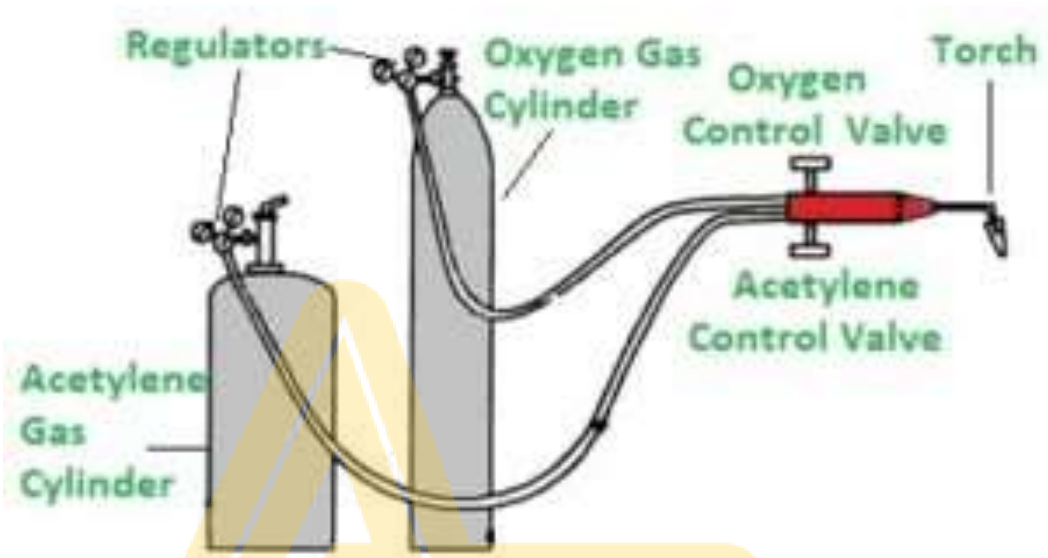
1. Arc welding requires specialized equipment and safety precautions, such as protective clothing and welding helmets, which can be expensive and may require skilled operators.
2. Arc welding can cause distortion or warping of the base metal, particularly with thin or heat-sensitive parts.
3. Arc welding may produce weld spatter or other surface irregularities that require additional finishing or clean-up.
4. Arc welding may not be suitable for all types of metal joining applications, particularly those requiring a high degree of precision or surface finish.
5. Arc welding can produce toxic fumes and

Applications of arc welding:

1. Construction and infrastructure projects (bridges, buildings, highways, etc.)
2. Manufacturing of metal products (including cars, planes, ships, and heavy equipment)
3. Repair and maintenance of machinery and equipment
4. Welding of pipes and pipelines (including for oil and gas industry)
5. Fabrication and installation of metal artwork and sculptures
6. Maintenance and repair of industrial plants and facilities
7. Welding of pressure vessels, boilers, and other large containers
8. Fabrication and installation of metal stairways, handrails, and other architectural features
9. Welding of fences, gates, and other metal structures

Gas Welding(Oxy Acetylene Welding)

Gas welding is a welding process that uses a fuel gas, such as acetylene, and oxygen to create a flame that melts and joins two pieces of metal together



Gas welding is a welding process that uses a fuel gas, such as acetylene, and oxygen to create a flame that melts and joins two pieces of metal together. Here are the basic steps involved in gas welding:

Process of gas welding

1. Preparation: The metal pieces to be welded are cleaned and prepared to ensure a clean and secure weld. This may involve removing rust, dirt, or other contaminants from the metal surfaces.

2. Set up: The welding equipment is set up with the appropriate settings for the metal being welded, including the type and thickness of the metal, the welding position, and the gas flow rate.

3. Flame creation: The fuel gas and oxygen are mixed in the welding torch and ignited to create a flame. The size and intensity of the flame can be adjusted to control the heat input and ensure a high-quality weld.

4. Welding: The operator uses the welding torch to heat the metal and melt a filler rod or wire, which is added to the joint to create a strong, permanent bond. The operator must control the heat and speed of the torch to ensure a strong, smooth weld.

5. Finishing: After the welding is complete, the weld is inspected and any excess weld material is removed. The weld may also be ground or sanded to create a smooth finish.

6. Gas welding can be performed using a variety of fuel gases, including acetylene, propane, and natural gas, as well as a variety of filler metals, including steel, copper, and aluminum. The process can be performed

manually or with the use of automated welding machines or robotic systems.

Gas welding has some advantages over other welding processes, such as its ability to be used in remote locations and its precise heat control. However, it can be slower and less efficient than other welding processes and may require more skill and experience to perform effectively.

Advantages of gas welding:

1. Gas welding can be used to join a wide range of materials, including steel, copper, and aluminum.
2. Gas welding produces a high-quality weld with good strength and toughness.
3. Gas welding allows for precise control over the heat input and allows for fine-tuned adjustments during the welding process.
4. Gas welding can be performed in remote locations, as long as there is a source of fuel gas and oxygen.
5. Gas welding equipment is relatively portable and can be used for both indoor and outdoor welding applications.

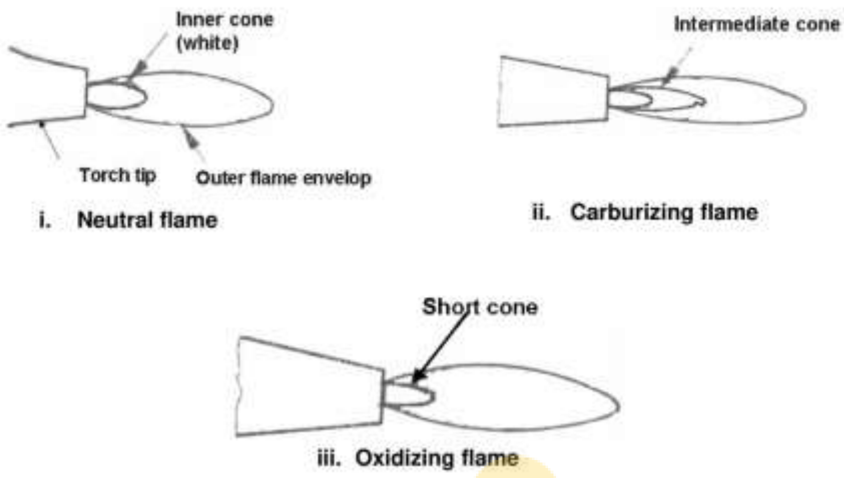
Disadvantages of gas welding:

1. Gas welding can be slower and less efficient than other welding processes, particularly for large or complex welds.
2. Gas welding can be more difficult to learn and may require more skill and experience than other welding processes.
3. Gas welding can produce more heat distortion and warping of the base metal than other welding processes, particularly with thin or heat-sensitive parts.
4. Gas welding requires specialized equipment and safety precautions, such as protective clothing, welding goggles, and proper ventilation, which can be expensive and may require skilled operators.
5. Gas welding may not be suitable for all types of metal joining applications, particularly those requiring a high degree of precision or surface finish.

Applications of Gas Welding

1. Metal Fabrication: Gas welding is commonly used in metal fabrication, where it is used to join metal pieces together to create structures such as railings, gates, and fences.
2. Automotive Repair: Gas welding is used in the automotive industry to repair damaged metal parts, such as body panels, frames, and exhaust systems
3. Aircraft Maintenance: Gas welding is also used in aircraft maintenance and repair, where it is used to repair damaged parts and perform maintenance on the aircraft's structure
4. Pipe Welding: Gas welding is commonly used to weld pipes made of various metals, including steel, copper, and aluminum.
5. Jewelry Making: Gas welding is used in the jewelry industry to join small metal pieces together, such as in the creation of rings, necklaces, and bracelets.
6. Sculpture: Gas welding is used in sculpture to join metal pieces together and create intricate designs.
7. Artistic Welding: Gas welding is also used in artistic welding, where welders create sculptures and other artistic pieces using metal as their medium.
8. Construction: Gas welding is used in construction for welding steel structures such as bridges, high-rise buildings, and other large structures.

Gas welding flames



Neutral Flame

- The neutral flame has a one-to-one ratio of acetylene and oxygen.
- Neutral flame has a temperature of 3250^0C
- The neutral flame is so called because it is chemically balanced and has no tendencies to react with any material used for welding.
- It has a well-defined inner or white cone and outer envelope and it produce a temperature capable of melting all commercial metals.
- This flame is mainly used for steel, stainless steel, copper, and aluminium, etc.

Carburizing Flame

- The carburizing flame or reducing fleme shows the inner cone (bluish white), the intermediate cone(white), the outer envelope flame is light blue.
- Reducing flame has a temperature of 3150^0C
- High Carburizing flames are not used in cutting low-carbon steels because the additional carbon they add embrittlement and hardness. These flames are ideal for cutting cast iron because the additional carbon poses no problems

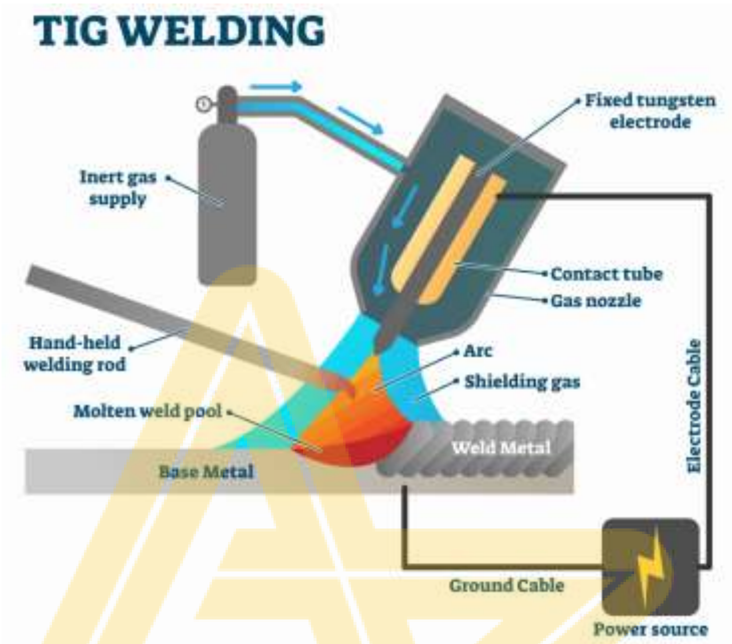
Oxidising Flame

- An oxidising flame has an excess of oxygen.
- This type of flame is used where the maximum temperature is desired.
- This flame has a temperature of 3480^0C. This type of flame is used in following cases
- To weld copper, brass, bronze and zinc alloys.
- For gas cutting

Types of ARC Welding

TIG- Tungsten Inert Gas welding

TIG stands for Tungsten Inert Gas welding, also known as Gas Tungsten Arc Welding (GTAW). It is a welding process that uses a non-consumable tungsten electrode to create an electric arc that melts the metal being welded and forms a strong bond between the two pieces. The process uses a shielding gas, typically argon, to protect the weld from contamination and oxidation.



Advantages of TIG welding:

- TIG welding can be used to weld a wide range of metals, including stainless steel, aluminum, and titanium.
- TIG welding produces a high-quality weld with excellent strength and appearance, and minimal spatter or distortion.
- TIG welding allows for precise control over the heat input, and the ability to weld thin materials.
- TIG welding produces a small, concentrated heat source that minimizes heat-affected zones and reduces the risk of warping or distortion.
- TIG welding can be used for both manual and automated welding applications.

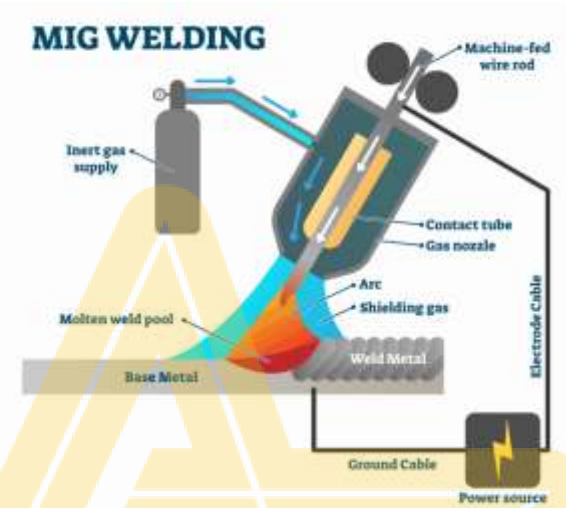
Disadvantages of TIG welding:

- TIG welding can be slower and more complex than other welding processes, particularly for thicker materials or complex joints.
- TIG welding requires a high level of skill and experience to perform effectively, particularly in controlling the torch, electrode, and filler material.
- TIG welding can be more expensive than other welding processes, particularly in terms of equipment and shielding gas costs.
- TIG welding may not be suitable for all types of metal joining applications, particularly those requiring high speed or high volume production.

TIG welding is commonly used in the aerospace, automotive, and high-tech industries, as well as for artistic and decorative welding applications. It can be performed manually or with the use of automated welding machines or robotic systems.

MIG- Metal Inert Gas welding

MIG stands for Metal Inert Gas welding, also known as Gas Metal Arc Welding (GMAW). It is a welding process that uses a continuously fed metal wire as the electrode and a shielding gas, typically a mixture of argon and carbon dioxide, to protect the weld from contamination and oxidation.



Advantages of MIG welding:

- MIG welding is a fast and efficient welding process that can be used to weld a variety of metals, including stainless steel, aluminum, and mild steel.
- MIG welding produces a high-quality weld with good strength and appearance, and minimal spatter or slag.
- MIG welding is easy to learn and can be performed with a semi-automatic or fully automatic welding machine.
- MIG welding can be used for both thin and thick materials, and is suitable for high-speed production welding applications.

Disadvantages of MIG welding:

- MIG welding produces a larger, more diffused heat source compared to TIG welding, which can result in larger heat-affected zones and greater distortion or warping of the metal being welded.
- MIG welding requires a clean welding surface and may produce more smoke and fumes compared to other welding processes, which can be a health hazard if proper ventilation is not used.
- MIG welding may require the use of a shielding gas, which can add to the cost of the welding process and require additional equipment for gas storage and delivery.
- MIG welding may require frequent replacement of the wire spool and contact tip, which can increase maintenance costs.
- MIG welding is commonly used in the automotive, construction, and manufacturing industries, as well as for repair and maintenance applications. It can be performed with a semi-automatic or fully automatic welding machine, and requires less skill and experience compared to TIG welding.