21GES06 MECHANICAL AND BUILDING SCIENCES

MECHANICAL SCIENCES

SYLLABUS

CO1.-Summarise the basic infrastructure services MEP, HVAC, elevators, escalators and ramps
CO2.-Differentiate Materials for engineering applications
CO3- Demonstrate the metal joining, removing and addition process.

Course outcomes:

After successful completion of this course students will able to

1) Summarize the basic infrastructure services of Refrigeration,pumps and basic drives
2) Select appropriate materials for engineering applications
3) Perform welding,machining and 3D printing operations

Refrigeration: Unit of refrigeration, reversed Carnot cycle, COP, vapour compression cycle (only description and no problems); Definitions of dry, wet & dew point temperatures, specific humidity and relative humidity, Cooling and dehumidification, Layout of unit and central air conditioners. Description about working with sketches of: Reciprocating pump, Centrifugal pump, Pelton turbine, Francis turbine and Kaplan turbine. Description about working with sketches of: Belt and Chain drives, Gear and Gear trains, Single plate clutches.

Basics of Engineering Materials: Metals-Stainless steel,Magnesium, Titanium-properties, applications ceramics-Alunima,SiO_2,PZT-properties,applications, and polymeric materials-PMMA,PEEK,PTFE-properties,applications, metal matrix composites-types, fabrication methods,properties and applications.

Metal Joining Processes: List types of welding, Description with sketches of Arc Welding, Soldering and Brazing and their applications. Basic Machining operations: Turning, Drilling, Milling and Grinding. Principle of CAD/CAM, and 3 D printing.

Reference:

1. Clifford, M., Simmons, K. and Shipway, P., An Introduction to Mechanical Engineering Part I - CRC Press Roy and Choudhary, Elements of Mechanical Engineering, Media Promoters &Publishers Pvt. Ltd., Mumbai.
2. Sawhney, G. S., Fundamentals of Mechanical Engineering, PHI
3. G Shanmugam, M S Palanichamy, Basic Civil and Mechanical Engineering, McGraw Hill Education; First edition, 2018
4. Benjamin,J.,Basic Mechanical Engineering,Pentex Books,9th Edition,2018
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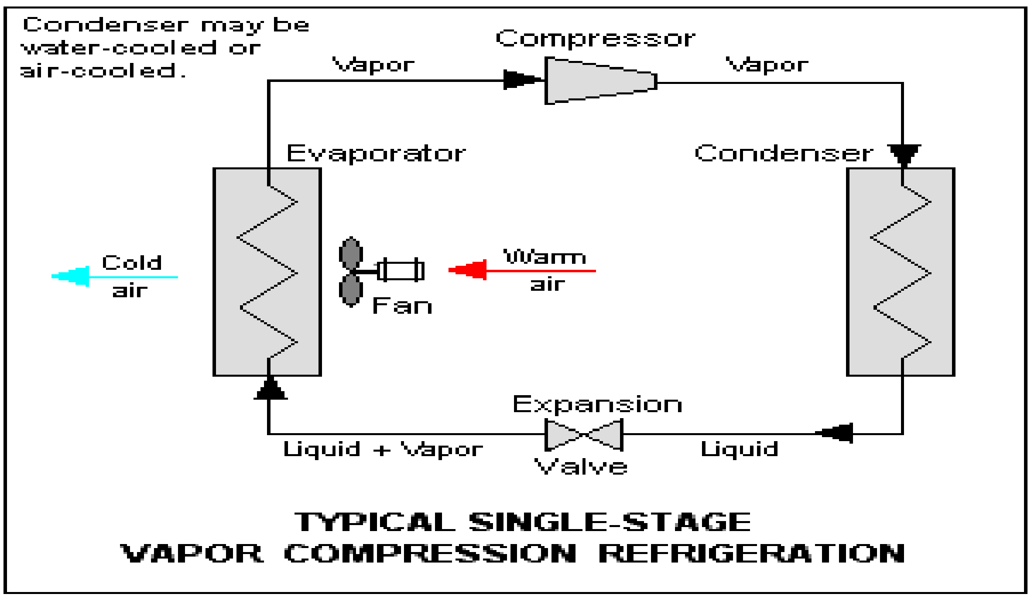
UNIT – I

REFRIGERATION

Unit of Refrigeration : The unit of refrigeration is expressed in terms of **ton of refrigeration (TR)**. One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

COP: is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor.

Vapour compression cycle:



STEP 1: COMPRESSION

The refrigerant (for example R-717) enters the compressor at low temperature and low pressure. It is in a gaseous state. Here, compression takes place to raise the temperature and refrigerant pressure. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

STEP 2: CONDENSATION

The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure. One cannot afford to ignore condenser safety and performance. Specifically, pressure control is paramount for safety and efficiency reasons.

STEP 3: THROTTLING AND EXPANSION

When the refrigerant enters the throttling valve, it expands and releases pressure. **Consequently, the temperature drops at this stage.** Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively. Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

STEP 4: EVAPORATION

At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, **it evaporates and absorbs latent heat of vaporization**. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure. There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

Dry-Bulb Temperature: The **dry-bulb temperature** (DBT) is the **temperature** of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture.

Wet-Bulb Temperature : is **defined** as the **temperature** of a parcel of air cooled to saturation (100% relative humidity) by the evaporation of water into it,

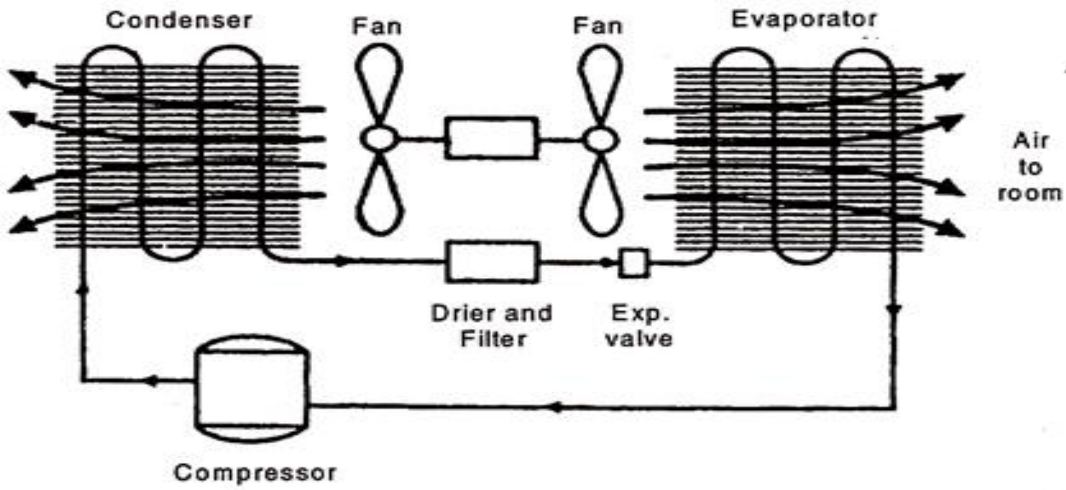
Dew Point Temperature: The dew point is **the temperature below which the water vapour in a volume of air at a constant pressure will condense into liquid water**. It is the temperature at which the air is saturated with moisture.

Specific Humidity: mass of water vapour in a unit mass of moist air, usually expressed as grams of vapour per kilogram of air, or, in air conditioning,

RELATIVE HUMIDITY : refers to the moisture content (i.e., water vapor) of the atmosphere, expressed as **a percentage of the amount of moisture that can be retained by the atmosphere** (moisture-holding capacity) at a given temperature and pressure without condensation.

Cooling And Dehumidification: **The process in which the air is cooled sensibly and at the same time the moisture is removed from it** is called as cooling and dehumidification process.

LAYOUT OF UNIT AIR CONDITIONERS



(a) Schematic diagram of refrigeration unit for room air conditioner

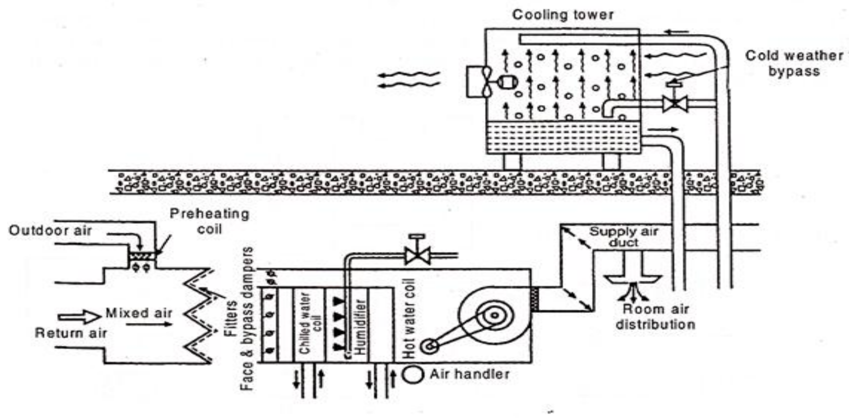
The schematic diagram of a typical room air conditioner or window air conditioner. Working or operation of this air conditioner is illustrated in above Fig

Warm room air (for recirculation) passes over the cooling or evaporator coil and in the process, gives up its sensible and latent heat also (in case of dehumidification is required). This conditioned air along with the fresh air (ventilation air) is then re-circulated in the room by a fan or blower.

The heat from the warm air-vaporises the cold liquid refrigerant flowing through the evaporator. The vapour then carries heat to the compressor, which compresses the vapour and increase its temperature to a value higher than temperature of the outdoor air. In the condenser, the hot refrigerant vapour liquefies and gives up the heat from the room air to the outdoor air.

The high pressure liquid refrigerant then passes through a restrictor—thermostatic expansion valve or capillary tube—which reduces its pressure and temperature. The cold and low pressure liquid refrigerant then re-enters the evaporator to repeat this refrigeration cycle.

Central Air Conditioning System:



The water chiller will produce 4°C – 7°C cold water, and by means of a pump, circulate it to the cold water coil in the air handler. Water off the coil will generally return at a 6°C rise.
Similarly, in winter, the boiler will produce hot water at 80°C to 90°C and pump it to the hot water coil. Note that it is possible to have the boiler and chiller operating at the same time, because in large buildings, there may be need for cooling and heating in different zones.
Condenser water off the chiller (36 – 37°C) is pumped to cooling tower spray nozzles where it is cooled within the tower to around 30°C and then is returned to the condenser.

The air handling unit or units, depending on the number of floors or zones, generally contain:

(a) Chilled water coils
(b) Main hot water coils (can be steam)
(c) Humidifier
(d) Filters
(e) Dampers for mixing return air and outside air
(f) Blower and motor.

A pre-heat coil is frequently required where large amounts of outside air at or below 0°C are needed.
The face and by-pass dampers either permit all the air to go through the humidifiers and the heating and cooling coils or allow some of it to be by-passed, depending on the particular situation. All air to be conditioned is always filtered and cleaned.

Water Chilling Equipment may be:

1. Packaged chillers – Lower capacity.
2. Centrifugal chillers (Hermetic) – Very large capacities upto 1300 tonnes.
3. Screw compressor chillers.
4. Absorption chillers.

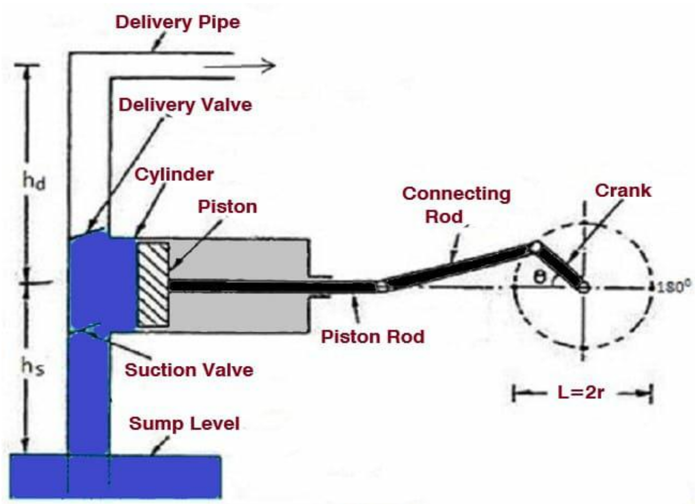
Cooling coils in central air conditioning station may use either chilled water circulating through the coils or there may be chilled water evaporators (chilled water sprays) or air-washers. In this case, chilled water works as a secondary refrigerant.

DX System (Direct Expansion) for Central Air Conditioning Plant:

The process of heat removal from the substance to be cooled or refrigerated is done in the evaporator. The liquid refrigerant is vapourised inside the evaporator (coil and shell) in order to

remove heat from a fluid such as air, water or brine. The fluid to be cooled can be made to pass over the evaporator surface inside which the refrigerant is boiling, such a system is called the Direct Expansion System (DX System).
In certain cases, such as in large air conditioning systems or in industrial processing, water or brine is chilled in the evaporator and the chilled fluid is circulated through copper or steel coils over which the air is passed. Such a system is called the indirect system. The coil, generally called cooling coil, acts as heat exchangers.

Reciprocating Pump



Reciprocating Pump is a Positive Displacement type pump that works on the principle of movement of the piston in forwarding and backward directions whereas the Centrifugal pump uses the kinetic energy of the impeller to supply the liquid from one place to another place.

The Parts of Reciprocating Pump are as follows.:

- Water Sump
- Strainer
- Suction Pipe
- Suction Valve
- Cylinder
- Piston and Piston rod
- Crank and Connecting rod
- Delivery valve
- Delivery pipe

Working Principle of Reciprocating Pump:

When the power supply is given to the reciprocating pump, the crank rotates through an electric motor.

The angle made by the crank is responsible for the movement of the piston inside the cylinder. By referring to the above diagram, the piston moves towards the extreme left of the cylinder when the crank meets position **A** i.e. **θ=0**.

Similarly, the piston moves towards the extreme right of the cylinder when the crank meets the position **C** i.e. **θ=180**.

A partial vacuum in the cylinder takes place when the piston movement is towards the right extreme position i.e. (**θ=0 to θ=180**.) and that makes the liquid enter into the suction pipe.

This is due to the presence of atmospheric pressure on the sump liquid which is quite less than the pressure inside the cylinder. Therefore, due to the difference in pressure, the water enters into the cylinder through a non-return valve.

The water which stays in the volume of the cylinder has to be sent to the discharge pipe via discharge valve and this can be done when the crank is rotating from **C** to **A** i.e. (**θ=180 to θ=360**) which moves the piston in the forward direction.

Due to the movement of the piston in a forward direction, the pressure increases inside the cylinder which is greater than the atmospheric pressure.

This results in the opening of the delivery valve and closing of the suction valve.

Once the water comes into the delivery valve, it cannot move back to the cylinder because it is a unidirectional valve or non-return valve.

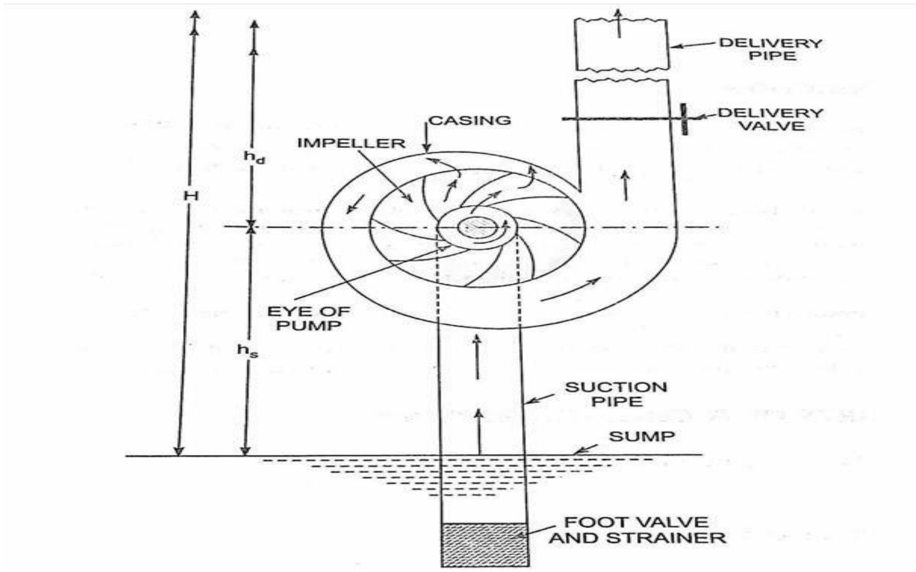
From there, it enters into the delivery pipe so that it can be sent to the required position.

Therefore, in this way, the water is sucked and discharged from the sump to the desired location through the piston inside the cylinder.

The applications of Reciprocating Pump are as follows.

- Gas industries
- Petrochemical industries
- Oil refineries
- Vehicle water servicing centers etc.

Centrifugal pump:



The centrifugal pump defines as a hydraulic machine which converts the mechanical energy into hydraulic energy by means of a centrifugal force acting on the fluid.

The different **parts of the centrifugal pump** are listed below.

1. Shaft
2. Impeller
3. Casing
4. Suction Pipe
5. Delivery Pipe

Types of Casings in Centrifugal Pump

1. Volute casing.
2. Vortex casing.
3. Casing with guide blades.

1. Volute casing (Spiral casing)

It is surrounded by the impeller. Such a casing provides a gradual increase in the area of a flow thus decreasing the velocity of water and correspondingly increasing the pressure.

2. Vortex casing

Vortex casing is a circular chamber in which introduce between the impeller and casing. here the fluid from the impeller has to first pass through the vortex chamber and then through the volute casing. In such a case, there is better conversion has done that is velocity energy into pressure and it has good efficiency than the volute casing.

3. Casing with Guide Blades

In casing with guide blades, the blades surrounding the impeller. these blades are designed and arranged in such a way that, the water from the impeller enters the guide vane s without shock and creates a passage of increasing area, through which the water passes and reaches the delivery to leave with pressure.

Working Principle of Centrifugal Pump

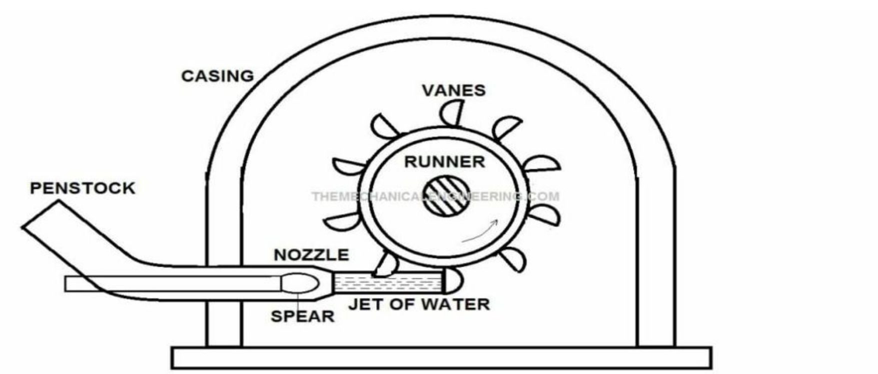
The pump works on the principle of the forced vortex flow. it means when a mass of liquid is rotating by an external torque, the rise in pressure head of the rotating liquid takes places. The rises in pressure head at any point is directly proportional to the velocity of the liquid at that point.

Therefore the rise in pressure head is more at the outlet of the impeller and the liquid will discharge with a high-pressure head at the outlet. Due to this, the high-pressure head of the liquid can be lifted to a high level. This pump is suitable for low head discharge. It develops normally at the head of 50m.

Priming In A Centrifugal Pump

Priming is the operation in which the suction pipe, casing of the pump and a portion of the pipe up to the delivery valve is completely filled up from an outside source with the liquid to be raised by the pump before starting the pump.

Pelton wheel turbine:



PELTON WHEEL TURBINE LINE DIAGRAM

Pelton Wheel Turbine is the type of impulse or hydraulic turbine which is used for high heads for the generation of power. In this, the jet after leaving the nozzle runs in the open air and strikes the bucket or vane.

Parts of Pelton wheel Turbine:

- **Casing**
- **Spear**
- **Break Nozzle**
- **Runner or Rotor**
- **Penstock**
- **Governing Mechanism**

Pelton Wheel Turbine Working Principle:

The working principle is water is coming from the storage reservoir through a penstock to the Inlet of the nozzle which is the inlet of the turbine so the hydraulic energy of the water is mainly converted into kinetic energy.

The water releases in the form of a jet from the nozzle and strikes on the vanes for a very small time duration.

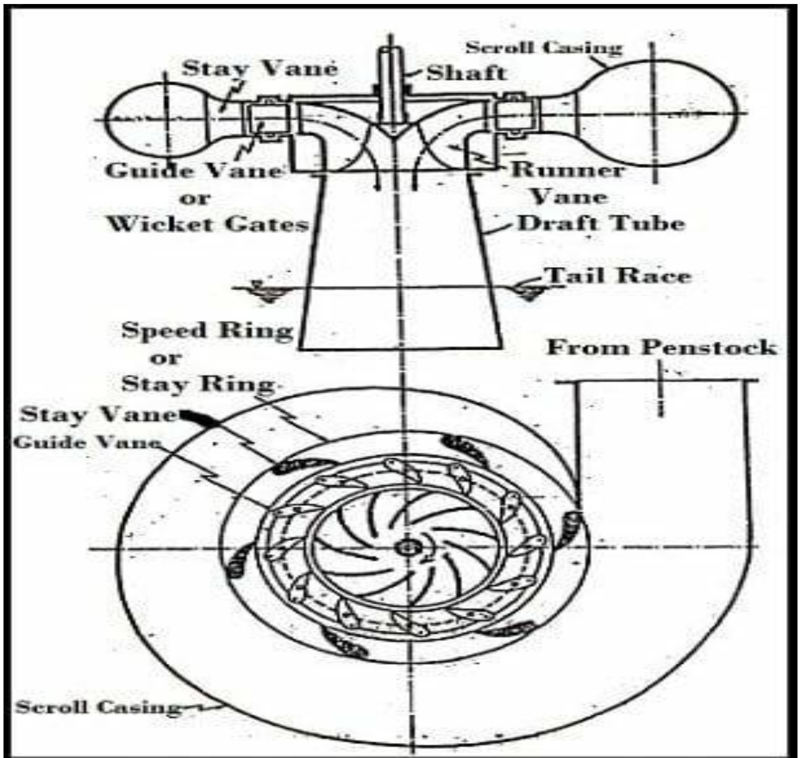
Since a very high force is exerted on the vanes by the jet of water for a very small time duration so these turbines are known as Impulse turbines.

Bucket changes the direction of run/flow of water jet and momentum transfer takes place.

All events happen in open air i.e at atmospheric pressure. The nozzle is used to convert the head available with water into a dynamic head and the water comes out from the nozzle in the form of a jet.

As the jet strikes over the runner vane, it will apply a large magnitude force for a small amount of time over the runner called Pelton force the Pelton force will rotate the runner.

Francis turbine:

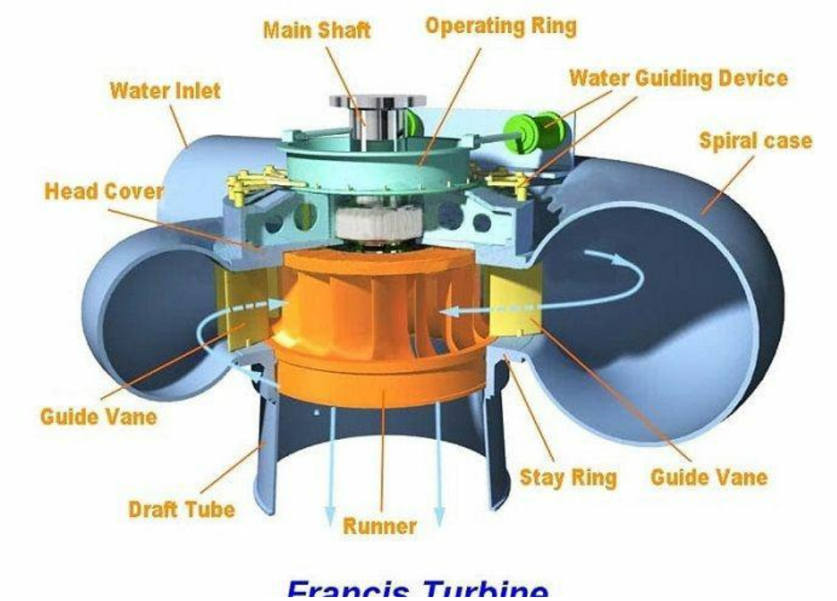


FRANCIS TURBINE SKETCH

Francis turbine definition is a combination of both impulse and reaction turbine, where the blades rotate using both reaction and impulse force of water flowing through them producing electricity more efficiently. Francis turbine is used for the production of electricity most frequently in medium or large-scale hydropower stations.

Major Components of Francis Turbines With Diagram

- **Spiral Casing**
- **Stay Vanes**
- **Guide Vanes**
- **Runner Blades**
- **Draft Tube**



Francis Turbine Working Principle

Francis turbines are employed regularly in hydroelectric power plants. In these power plants, high-pressure water enters the turbine through the snail-shell casing (the volute). This movement decreases the water pressure as it curls through the tube; however, the water's speed remains unchanged. Following the passing through the volute, the water flows through the guide vanes and is directed towards the runner's blades at optimum angles. Since the water crosses the precisely curved blades of the runner, the water is diverted somewhat sideways. This makes the water lose some part of its "whirl" motion. The water is also deflected in the axial direction to exit a draft tube to the tail race.

The mentioned tube reduces the water's output velocity to gain the maximum amount of energy from the input water. The process of water being diverted through the runner blades results in a force that propels the blades to the opposite side as the water is deflected. That reaction force (as we know from Newton's third law) is what makes power to be carried from the water to the turbine's shaft, continuing rotation. Since the turbine moves due to that reaction force, Francis turbines are identified as reaction turbines. The process of altering the direction of the water flow also decreases the pressure within the turbine itself.

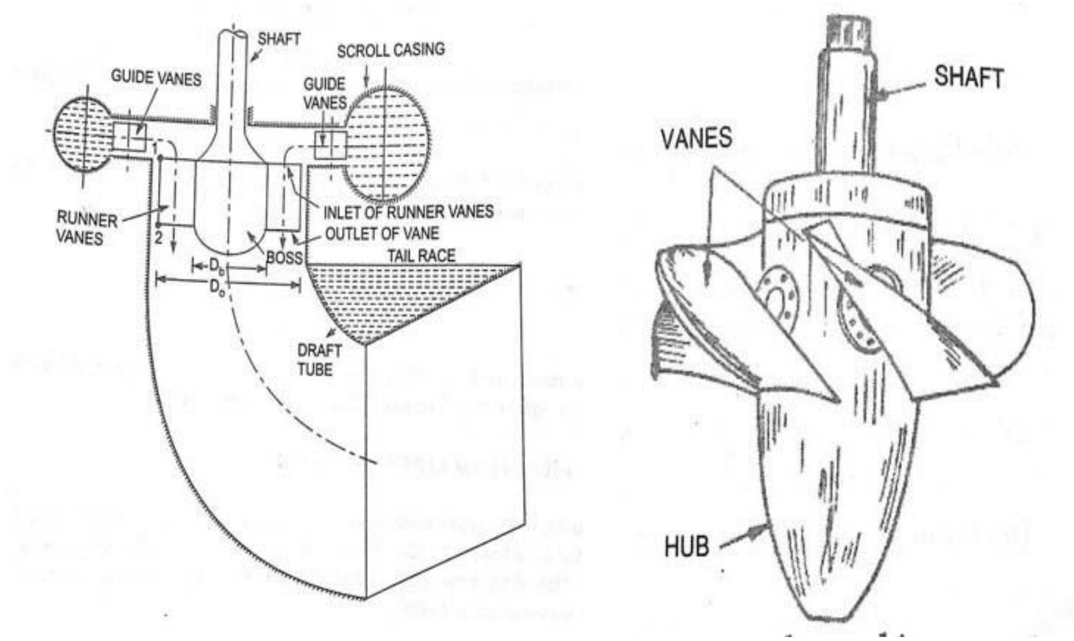
Applications of Francis Turbine:

Francis Turbine, as the most effective hydraulic turbine, can be applied in many fields:

- Large Francis turbine is distinctively designed for the site to operate at the highest achievable efficiency, typically more than 90%.

- Rather than electrical products, they may also be employed in pumped storage. In pumped storage, the reservoir is filled with the turbine (acting as a pump) during low to moderate power demand; then, it can be reversed and utilized to generate power while peak demand.
- Francis turbines can be designed for a broad range of heads and flows.
- Francis turbine covers a wide range of heads, from 20 to 700 m, and its output varies from a few kilowatts to 200 megawatts. This possibility, in addition to its high efficiency, has made the Francis turbine the most widely used turbine in the world

Kaplan turbine:



A Kaplan turbine is one kind of a propeller hydro turbine (particularly a reaction turbine) used in hydroelectric plants. Waterflow both in and out of Kaplan turbines through its rotational axis, which is called axial flow. The point that makes Kaplan turbines special is that the blades can change their demand to preserve maximum efficiency for various water flow rates. Kaplan turbine, similar to Francis turbine, is a reaction turbine. Water running through a Kaplan turbine loses its pressure.

Main Parts of a Kaplan Turbine

- **Scroll casing,**
- **Guide vane mechanism,**
- **Draft tube, and**
- **Runner blades**

Working Principle of the Kaplan Turbine With Diagram

This turbine is one sort of axial flow reaction turbines. In this way, the working fluid, which is often water, changes the pressure while moving within the turbine and produces energy.

The power is the combination of both the kinetic energy of the flowing water and hydrostatic head.

In order to understand the way it produces power, the water from the pen-stock enters the scroll casing. After that, the water passes through the scroll casing, and the guide vanes guide the water from the casing to the runner's blades. The critical point is that the vanes are flexible and can adjust themselves based on the required flow rate.

While the water moves across the blades, it begins rotating because of the water's reaction force. Besides, the blades in the Kaplan turbine are also adjustable. The water goes through the draft tube, where its kinetic energy and pressure energy decrease from the runner blades.

Actually, the kinetic energy converts into pressure energy here and results in enhanced pressure of the water. Eventually, the water is discharged to the trail race. The turbine's rotation is utilized to rotate the shaft of a generator to produce electricity and some extra mechanical work. Below is the diagram of Kaplan Turbine:

belt drive

The **belt** is a flexible element of a mechanical system. It is used to transfer the power from one System to another System.

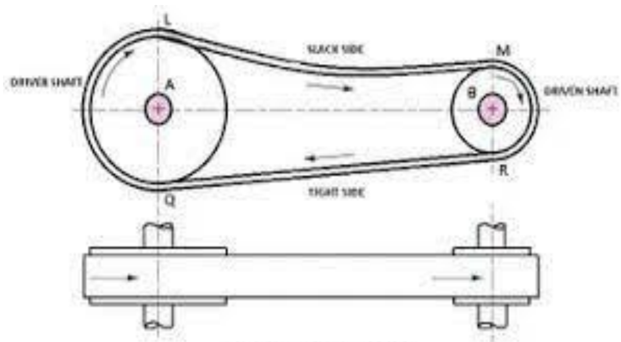
There are five different kinds of belt drive can be found and those are:

- Open belt drive
- Closed or crossed belt drive
- Fast and loose cone pulley
- Stepped cone pulley
- Jockey pulley drive

1. Open Belt Drive

The open belt drive is used with shafts arranged parallel and rotating in the same direction. In that case, the driver pulls the belt from one side and delivers it to the other side.

Thus, the tension in the lower side belt will be higher than the upper side belt. The lower side belt is known as the tight side belt while the upper side belt is known as the slack side belt.

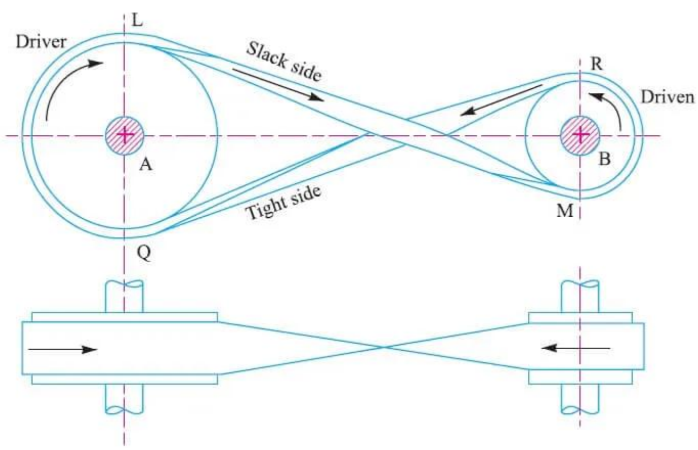


OPEN BELT DRIVE

2. CLOSED OR CROSSED BELT DRIVE

Cross or twisted belt drives are used with rotating shafts in parallel and opposite directions. In this case, the driver pulls the belt from one side and delivers it to the other side.

Thus, the tension at the Bottom Side of the belt will be higher than at the upper side of the belt. The belt is known as the tight side due to high tension, while the belt due to low tension is known as the slack side.



UNIT II

BASICS OF ENGINEERING MATERIALS

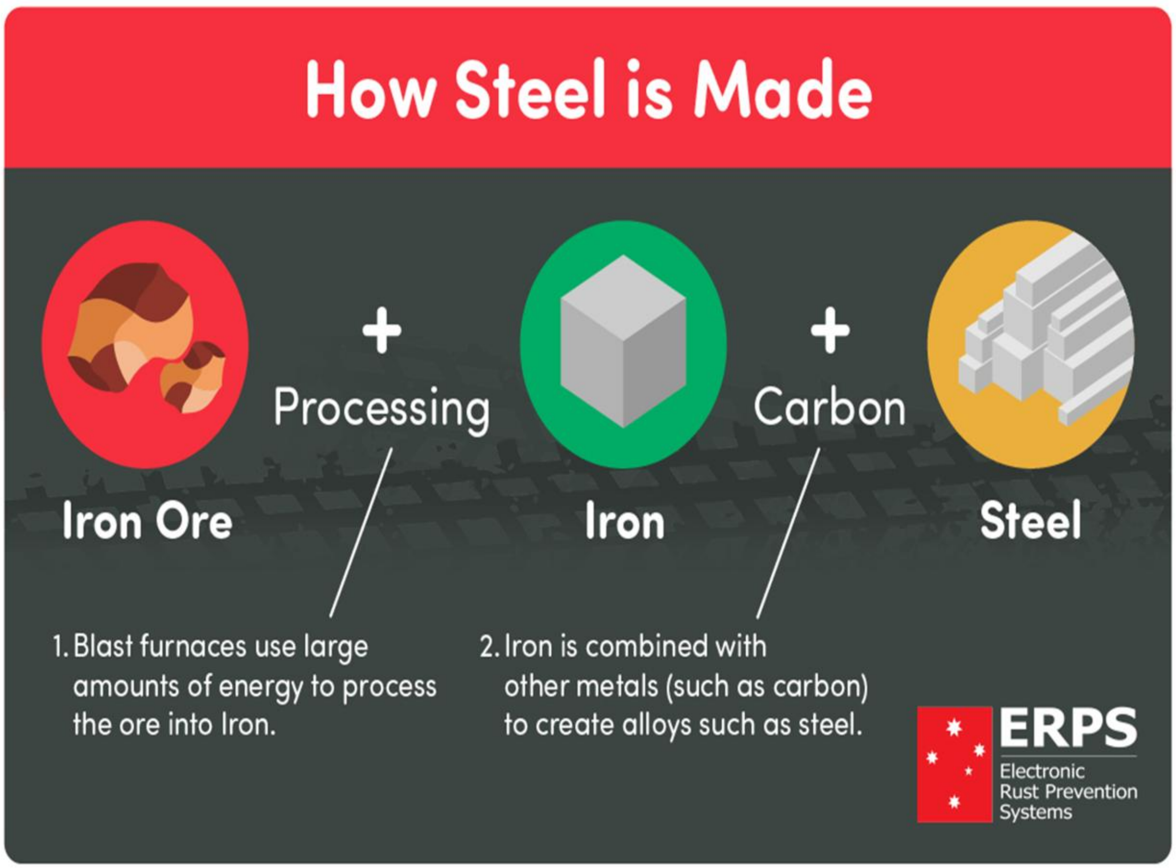
STEEL

- Steel is the world's most important engineering and construction material.
- It is used in every aspect of our lives; in cars and construction products, refrigerators and washing machines, cargo ships and surgical scalpels.
- It can be recycled over and over again without loss of property.

What is steel?

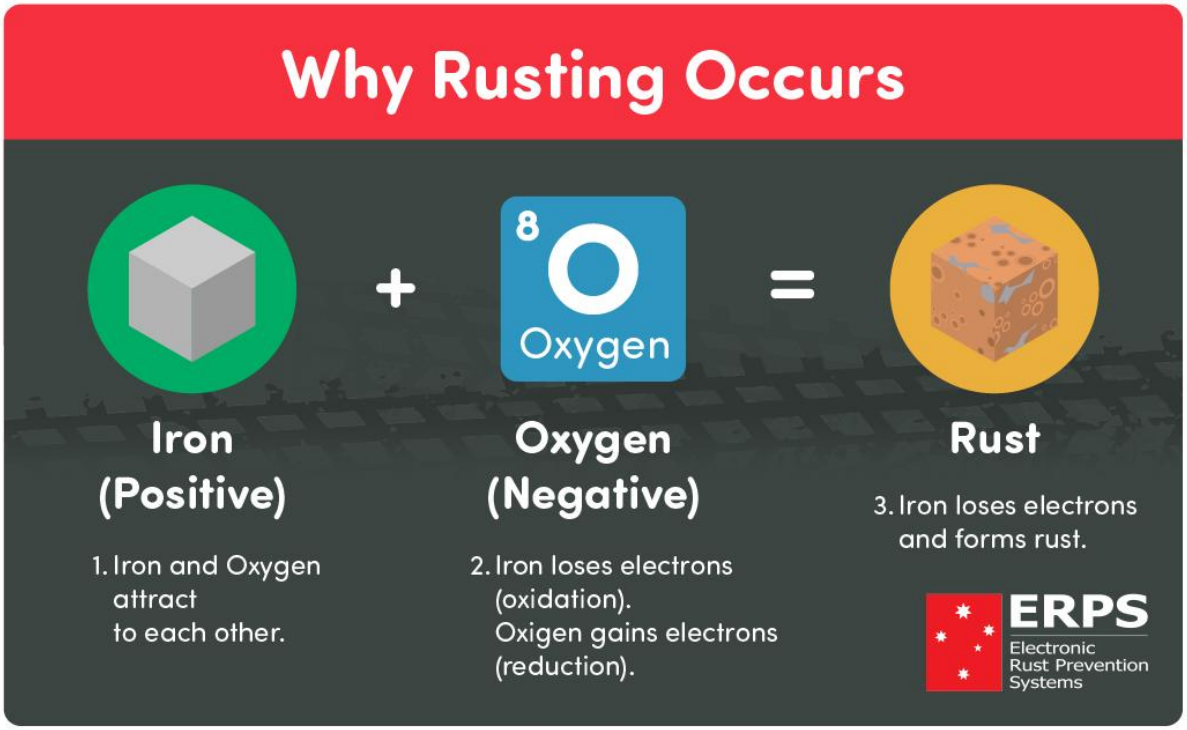
- Iron is made by removing oxygen and other impurities from iron ore.
- When iron is combined with carbon, recycled steel and small amounts of other elements it becomes steel.

- Steel is an alloy of iron and carbon containing less than 2% carbon and 1% manganese and small amounts of silicon, phosphorus, sulphur and oxygen.



Why does steel rust?

- Many elements and materials go through chemical reactions with other elements.
- When steel comes into contact with water and oxygen there is a chemical reaction and the steel begins to revert to its original form - iron oxide.



How to prevent rust?

- In most modern steel applications this problem is easily overcome by coating.
- Many different coating materials can be applied to steel.
- Paint is used to coat cars and enamel is used on refrigerators and other domestic appliances.
- In other cases, elements such as nickel and chromium are added to make stainless steel, which can help prevent rust.

What is Stainless Steel?

- Stainless steel is a corrosion-resistant alloy of iron, chromium and, in some cases, nickel and other metals.

What is Stainless Steel?

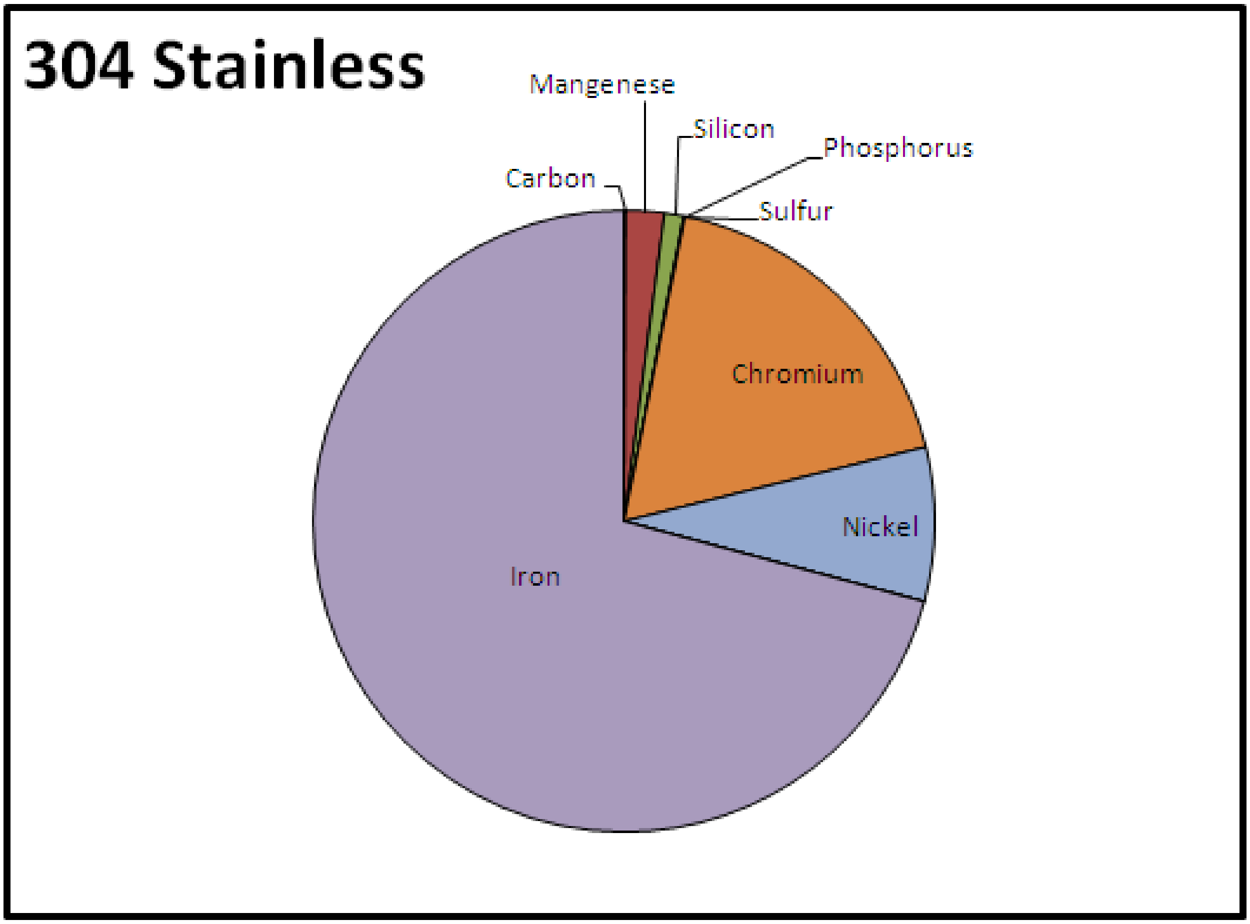
- Stainless steel is a corrosion-resistant alloy of iron, chromium and, in some cases, nickel and other metals.

- Completely and infinitely recyclable
- It is the “green material” par excellence.
- Within the construction sector, its actual recovery rate is close to 100%.
- Also environmentally neutral and inert.
- It does not leach compounds that could modify its composition when in contact with elements like water.

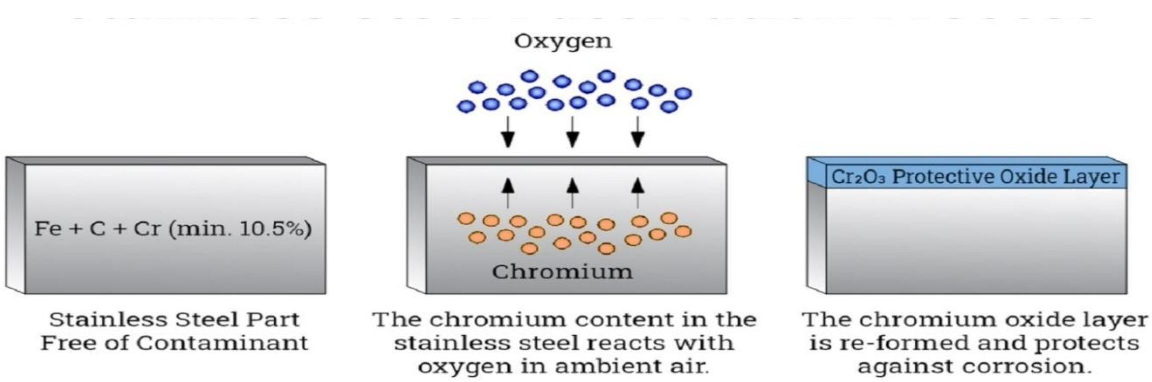
Composition of Stainless Steel

- Steel is an alloy of iron and carbon. Stainless steels are steels containing at least 10.5% chromium, less than 1.2% carbon and other alloying elements.

- Stainless steel's corrosion resistance and mechanical properties can be further enhanced by adding other elements, such as nickel, molybdenum, titanium, niobium, manganese, etc.



- On contact with oxygen, a chromium oxide layer is formed on the surface of the material. This passive layer protects it and has the unique ability to repair itself.



Mechanical Properties

- It combines ductility, elasticity and hardness, enabling it to be used in difficult metal forming modes (deep stamping, flat bending, extrusion, etc.) while offering resistance to heavy wear (friction, abrasion, impact, elasticity, etc.).
- It offers good mechanical behaviour at both low and high temperatures.

Resistance to Fire

- Stainless steel has the best fire resistance of all metallic materials when used in structural applications, having a critical temperature above 800°C.

Corrosion Resistance

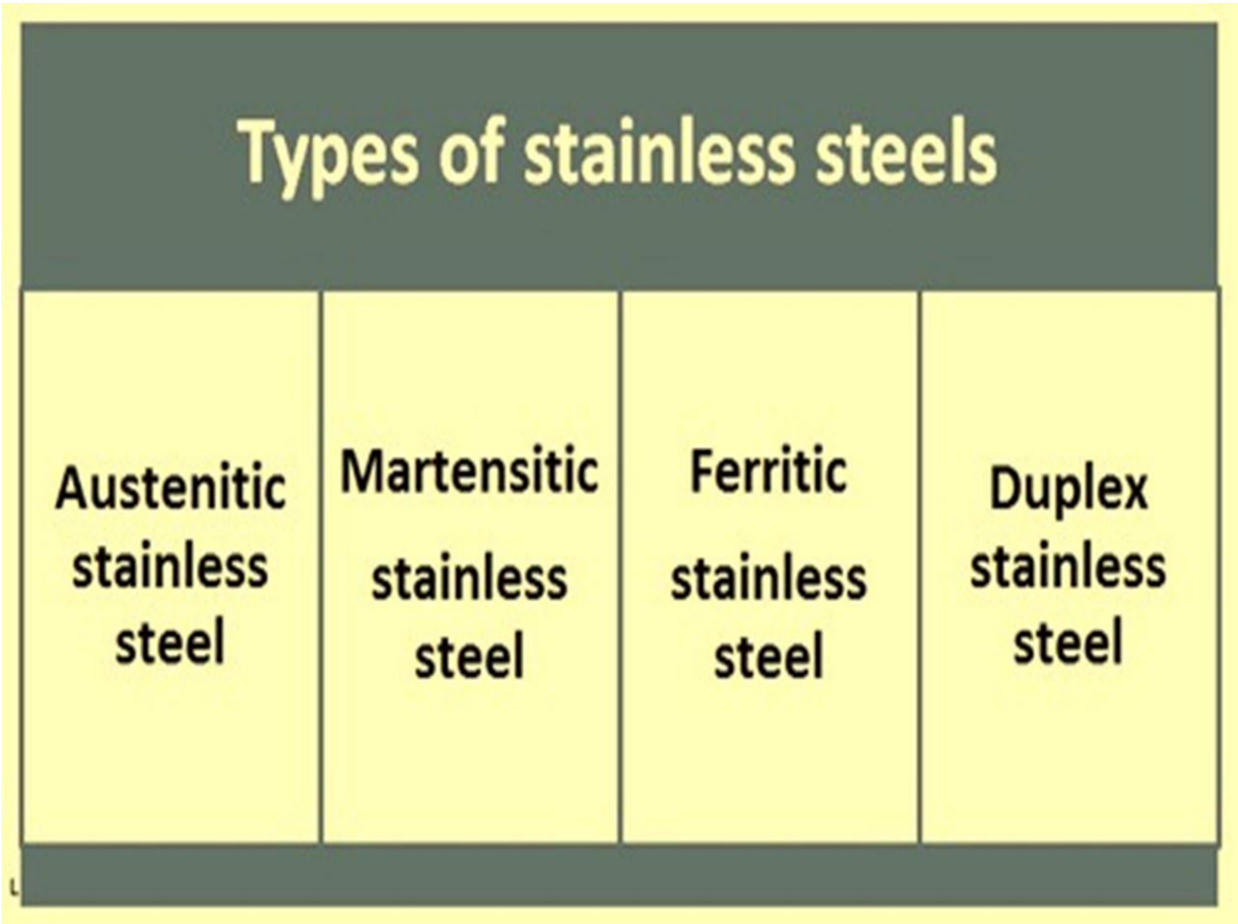
- If the surface is scratched, it regenerates itself. This particularity give stainless steels their corrosion resistance.

Cleanability

- Stainless steel items are easy to clean, usual cleaning products (detergents, soap powders) are sufficient and do not damage the surface.

Recycling

- Stainless steel ideally suited to building applications exposed to adverse weather, such as roofs, facades, rainwater recovery systems and domestic water pipes.



Magnesium

Magnesium is the lightest of all metal elements and is primarily used in structural alloys due to its lightweight, strength, and resistance to corrosion.

Magnesium alloys

- Magnesium alloys are well-known for being the lightest structural alloys .
- They are made of magnesium, the lightest structural metal, mixed with other metal elements to improve the physical properties. These elements include manganese, aluminium, zinc, silicon, copper, zirconium, and rare-earth metals .
- Some of magnesium's favourable properties include low specific gravity and a high strength-to-weight ratio.

Magnesium alloys – properties

- Lightweight
- Low density (two thirds that of aluminum)
- Good high-temperature mechanical properties
- Good to excellent corrosion resistance

Magnesium alloys – Applications

- From automotive and aerospace applications to electronic and biomedical uses.

Structural applications

- Automotive, aerospace, industrial, and commercial applications

Automotive applications

- support brackets for brakes and clutch, housing for transmission

Aerospace applications

- landing wheels, helicopter rotor fittings, gearbox housings

Industrial applications

- high-speed operating machinery, such as textile machines

Commercial applications

- luggage, hand tools, computer housings, ladders

Electronic applications

- electronic packaging, hard drive arms, cell phone and portable media device housings.

Medical applications

- Portable medical equipment and wheelchairs.
- Cardiovascular stents and orthopaedic devices

Titanium

- Titanium in its pure form is a silvery metal known for its strength and low density compared to other similarly hard metals
- Because of its physical and chemical properties, the metal has become useful in a wide variety of industries and applications such as medical equipment, chemical plants, military installations, and sports gear.

Titanium properties

- High strength, low density
- Its fatigue strength is about half of its tensile strength, and does not decline when exposed to welding or when submerged in seawater.
- Taitanium is a suitable component for applications that require a unique mixture of strength and material lightness.

Corrosion resistance

- Because pure titanium readily reacts with oxygen, it naturally produces an oxide film that gives itself protection against corrosive materials and environments. Its corrosion resistant against chlorine compounds, seawater, common acids, and extreme temperatures.

Refractory properties

- Titanium is also characterized by its refractory metal properties. Its melting point goes beyond 1650°C, significantly higher than aluminium and steel. Meanwhile, its coefficient of thermal expansion is 8.6 µm/(m·K), lower than steel and copper.

Aerospace industry

- Due to titanium alloy's temperature and corrosion resistance, the material is used in the manufacturing of aircraft parts (airframe and fastening components), hydraulic system components, and landing gear.

Marine equipment

- Titanium has a high level of corrosion resistance against seawater, making it a suitable component for ship rigs, propeller blades and shafts, and other parts submerged in water.

Sports applications

- The high strength-to-weight ratio of titanium lends itself to a range of applications in the sports industry. The material is used as components of sporting goods such as tennis rackets, baseball bats, golf clubs, bike frames, and ski equipment.

Medical industry

- Due to its inertness and non-toxicity, titanium is used in a wide array of medical applications including surgical implants, dental implants, surgical tools, and accessibility equipment.

Pyrotechnics

- Powdered Titanium produces bright white sparks that are used in fireworks.

Jewellery

- The biocompatibility, high strength-to-weight ratio, and corrosion-resistant properties of titanium is useful in the jewellery industry for bracelets, rings, and necklace chains.

Pigment

- Titanium dioxide – the natural oxide form of the metal – has found its use as a whitening agent in paints, plastics, and toothpaste.

CERAMICS

- A ceramic is an inorganic non-metallic solid made up of either metal or non-metal compounds that have been shaped and then hardened by heating to high temperatures.
- In general, they are hard, corrosion-resistant and brittle.

ADVANCED CERAMICS

- Advanced ceramics – new materials
- Advanced ceramics are not generally clay-based. Instead, they are either based on oxides or non-oxides or combinations of the two:
- Typical oxides used are alumina (Al_2O_3) and zirconia (ZrO_2).
- Non-oxides are often carbides, borides, nitrides and silicides, for example, boron carbide (B_4C), silicon carbide (SiC) and molybdenum disilicide ($MoSi_2$).

ALUMINA

- A chemical compound primarily comprising of oxygen and aluminium molecules.
- Colourless crystalline substance (sapphire & ruby)
- The most common naturally occurring crystalline form

is corundum.

- Aluminium oxide particles are separated by the heating or calcination of $Al(OH)_3$ at around 1100°C.
- When refined from bauxite, alumina has an appearance of a white powder just like table salt or granular sugar.

ALUMINA – PROPERTIES

- Alumina possesses good or high thermal conductivity. At elevated temperatures, it can withstand alkali attacks and strong acid.
- It consists of excellent dielectric properties.
- Metallic Aluminium is highly reactive with atmospheric oxygen.
- It exhibits high stiffness and strength.
- It is available at a purity range from 94%.

ALUMINA – APPLICATIONS

- Alumina is the primary material in the production of aluminium.
- 90% aluminium oxide is used in the manufacture of aluminium metal mostly by the electrolysis process.
- They are widely used in Electronic Substrates, Thread and Wire Guides, Seal Rings, Ballistic Armour, Thermometry Sensors, Grinding Media, Furnace Liner Tubes, High Voltage Insulators, Laboratory Instrumentary Tubes.
- Various formulation of glass consists of aluminium oxide as an ingredient.
- Alumina is often used extensively in engineered ceramics which is also called advanced or technical ceramics.

SILICA

- Group of minerals composed of silicon and oxygen
- Found commonly in the crystalline state
- Composed of one atom of silicon and two atoms of oxygen resulting in the chemical formula SiO_2.
- Most commonly found in nature as quartz and in various living organisms.
- In many parts of the world, silica is the major constituent of sand

SILICA- properties

- The melting point of silica is 1610 C, which is higher than iron, copper and aluminium, and is one reason why it is used to produce moulds and cores for the production of metal castings.
- Quartz is usually colourless or white
- Quartz may be transparent to translucent
- It is also relatively inert and does not react with dilute acid.
- They are nonconductors of electricity and are diamagnetic.
- Hard and strong and fail by brittle fracture under an imposed stress.

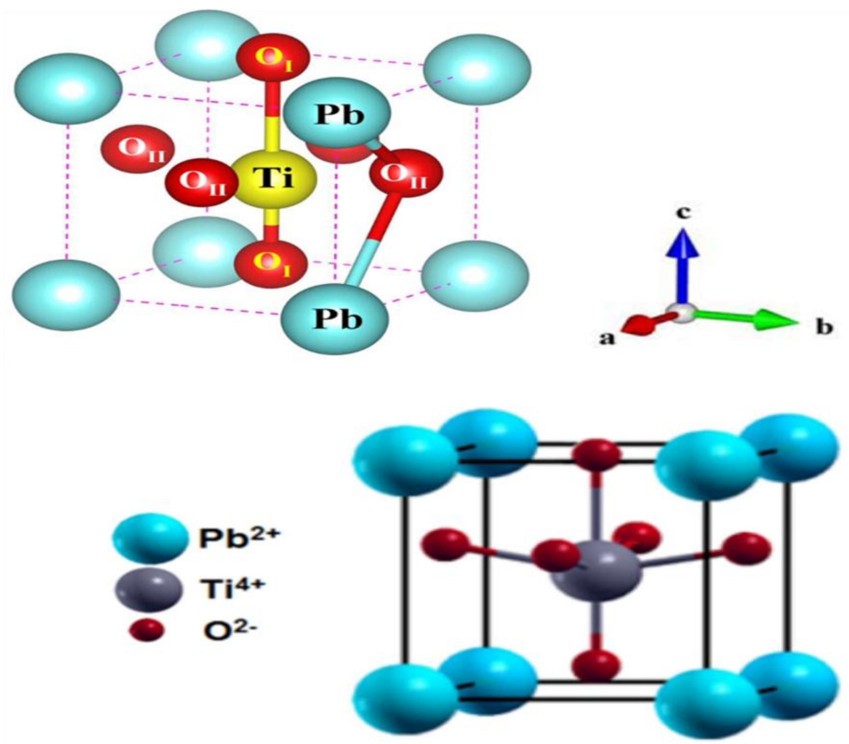
SILICA- Applications

- Silica has played a continuous part in man's development and been one of the basic raw materials supporting the industrial revolution (as refractory, flux, and moulding sand) and today's information technology revolution (providing the raw material for silicon chips).
- Industrial silica is used in a vast array of industries, the main ones being the glass,foundries, construction, ceramics, and the chemical industry.
- Silica in its finest form is also used as functional filler for paints, plastics, rubber, and silica sand is used in water filtration and agriculture.
- Construction and maintenance of an extensive range of sports and leisure facilities.
- Crystalline silica is also irreplaceable in a series of high-tech applications, for example in optical data transmission fibres and precision casting.
- In the metallurgical industry as the raw material for silicon metal and ferrosilicon production.
- Another specialized application is in the oil production.

- This led a socio-economic survey of crystalline silica usage to conclude that "if man wishes to live in silica free environment he must move to another planet"(B. Coope, 1998).

PZT (Lead Zirconate Titanate)

PZT (Lead Zirconate Titanate)



PZT – properties

- Piezoelectric ceramics are hard, chemically inert and completely insensitive to humidity or other atmospheric influences.
- Piezoelectric components are ideal for all kinds of electromechanical transducers.

PZT – applications

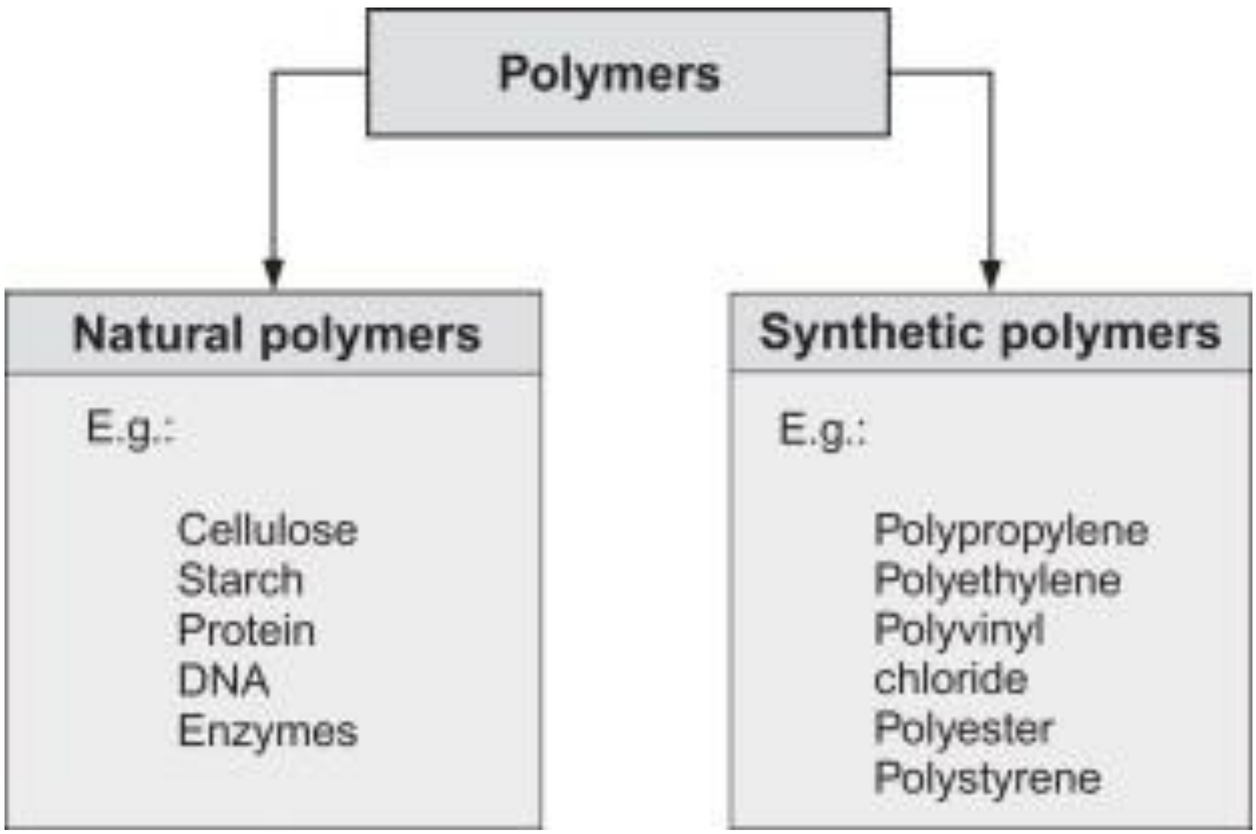
- Generators (conversion of mechanical into electrical energy)
  - spark igniters
  - solid-state batteries
- Sonic and ultrasonic transducers (conversion of electrical into mechanical energy)
- sonic (< 20 kHz)
  - buzzers
  - telephone microphones
  - high-frequency loudspeakers
- ultrasonic
  - echo-sounders
- measurement of distance in air
  - materials-testing equipment
  - atomizers
  - welding equipment
  - cleaning processes
- higher-frequency ultrasonic
  - medical applications
  - delay lines
- Sensors (conversion of mechanical force or movement into a (proportional) electric signal)
  - acceleration sensor

– pressure sensor

– knock sensor (internal-combustion engines)

Polymeric materials

- Polymers are substances composed of macromolecules, very large molecules with molecular weights ranging from a few thousand to as highas millions of grams/mole.



Natural polymers

Cotton from plants is a natural polymer and is used to make clothing

Natural latex from rubber tree is a polymer

Crustacean shells are made of chitin, a natural polymer

Silk from silk worms is used to make cloth

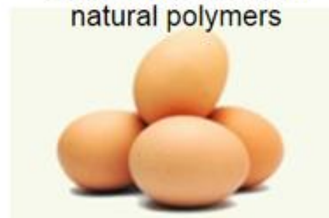
Rubber can be used to make tires

"Carbs" like spaghetti are natural polymers

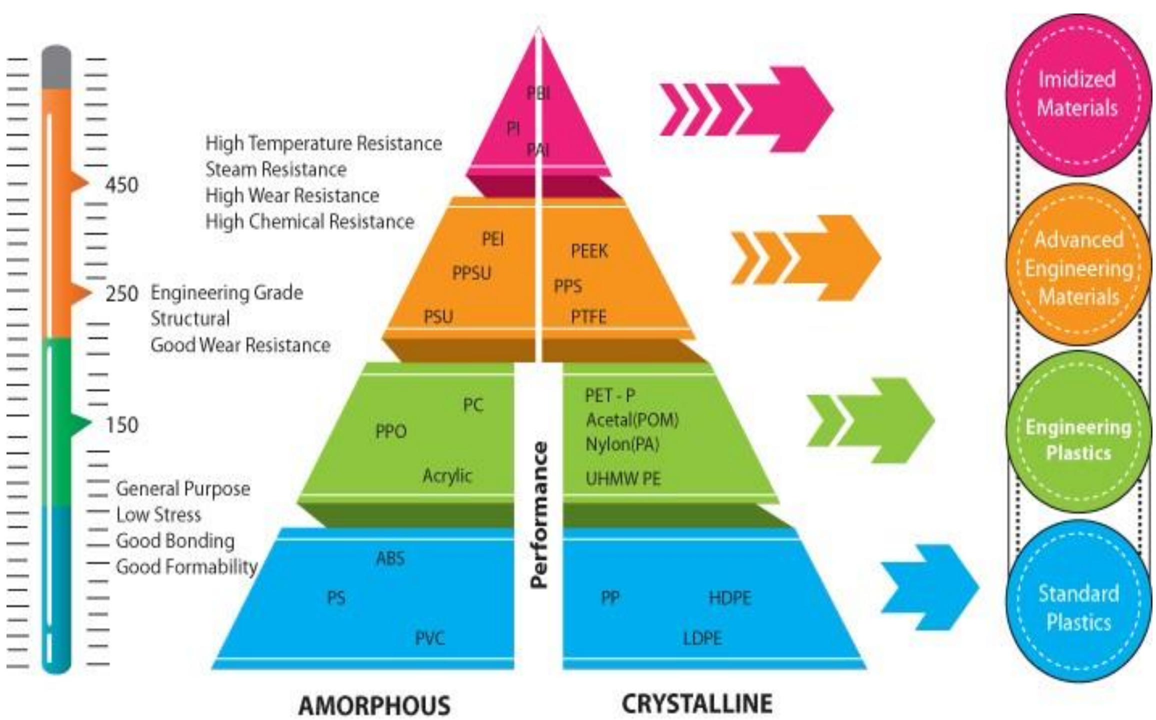
Wood is a natural polymer used for paper

or rubber bands!

Proteins from eggs and other foods are also natural polymers



Synthetic polymers



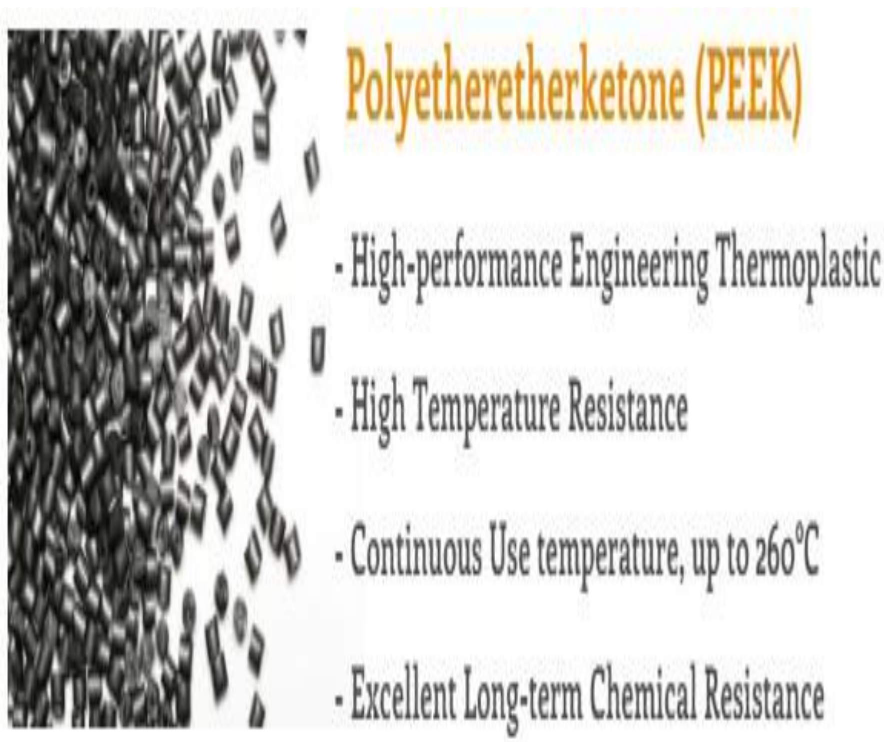
450
250
150
High Temperature Resistance
Steam Resistance
High Wear Resistance
High Chemical Resistance
Engineering Grade
Structural
Good Wear Resistance
General Purpose
Low Stress
Good Bonding
Good Formability
PBI
PI
PAI
PEI
PPSU
PSU
PEEK
PPS
PTFE
PC
PPO
Acrylic
PET - P
Acetal(POM)
Nylon(PA)
UHMW PE
ABS
PS
PVC
PP
HDPE
LDPE
Performance
AMORPHOUS
CRYSTALLINE
Imidized Materials
Advanced Engineering Materials
Engineering Plastics
Standard Plastics

Engineering polymers

Polyetheretherketone (PEEK)

Polymethyl methacrylate (PMMA)

Polytetrafluoroethylene (PTFE)



PEEK – properties

- Exceptional tensile properties
- Excellent creep resistance
- Maintain good insulating properties in a broad temperature range and environmental changes
- Its smoke and toxic gas generation are extremely low

- Insoluble in all common solvents.
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- Excellent creep resistance
- Maintain good insulating properties in a broad temperature range and environmental changes
- Its smoke and toxic gas generation are extremely low
- Insoluble in all common solvents.

Automotive applications

- Under-the-hood piston units
- Seals
- Washers
- Bearings
- Various active

  components

  used in transmission,

  braking and

  air-conditioning systems

Aerospace applications

- In Critical engine parts
- In aircraft exterior parts
- In interior components

- fiber optic filaments for aircraft electrical systems

Medical and Healthcare applications

- Handles on dental syringes
- Sterile boxes that hold root canal files
- dental instruments
- Endoscopes
- Dialyzers

Electrical / electronic applications

- Coaxial connector jacks used in hands-free telephone kits
- Surface-mounted trimming potentiometers
- As insulators

  for connector pins

  on under-sea

  environment

  control equipment.

Polymethyl methacrylate (PMMA)

- Also known as acrylic or acrylic glass, is a transparent and rigid thermoplastic material widely used as a shatterproof replacement for glass.
- High resistance to UV light and weathering,
- Excellent light transmission
- Unlimited coloring options

PMMA – properties

- Offers high light transmittance more than glass
- Tough, durable and lightweight
- Has excellent **scratch resistance**
- Has high resistance to UV light and weathering
- unaffected by detergents, cleaners, dilute inorganic acids, alkalies, and aliphatic hydrocarbons.

PMMA – Applications

- In window and door profiles
- Canopies
- Panels
- façade design
- Suitable choice

  of building green houses
- To build aquariums

  and marine centers

Lighting Applications

- Used for designing LED lights
- Used for construction of lamps

Automotive and Transportation Applications

- car windows
- motorcycle windshields

- interior and exterior panels
- Fenders
- car indicator light covers
- interior light covers
- Used for windows of a ship
  (Salt resistance) and
  aviation purposes.

Electronics Applications

- LCD/LED TV screens
- Laptops
- smartphones display
- electronic equipment displays
- solar panels as cover materials

Medical and Healthcare Applications

- To fabricate incubators
- drug testing devices
- storage cabinets in hospitals
  and research labs.
- As dental cavity fillings
  and bone cement.

Furniture Applications

- Chairs

- Tables
- kitchen cabinets
- Bowls
- table mats

Polytetrafluoroethylene (PTFE)

- Polytetrafluoroethylene or PTFE is the commonly used versatile, high-performance fluoropolymer made up of carbon and fluorine atoms

PTFE – properties

- Exception chemical resistance
- Good resistance to heat and low temperature
- Good electrical insulating power in hot and wet environments
- Good resistance to light, UV and weathering
- Low coefficient of friction

PTFE – Applications

Automotive Applications

- O-rings
- Gaskets
- valve stem seals
- shaft seals
- linings for fuel hoses
- power steering

  and transmission etc

Chemical Industry Applications

- Coatings for heat exchangers
- Pumps
- diaphragms
- impellers
- tanks
- reaction vessels
- autoclaves
- containers etc.

Electrical & Electronics Applications

- Electrical insulation
- flexible printed circuit boards
- semiconductor parts

Engineering Applications

- Seats and plugs
- bearing
- non-stick surfaces
- coatings for pipes
- fittings
- valve and pump parts.

Medical Applications

- Cardiovascular grafts

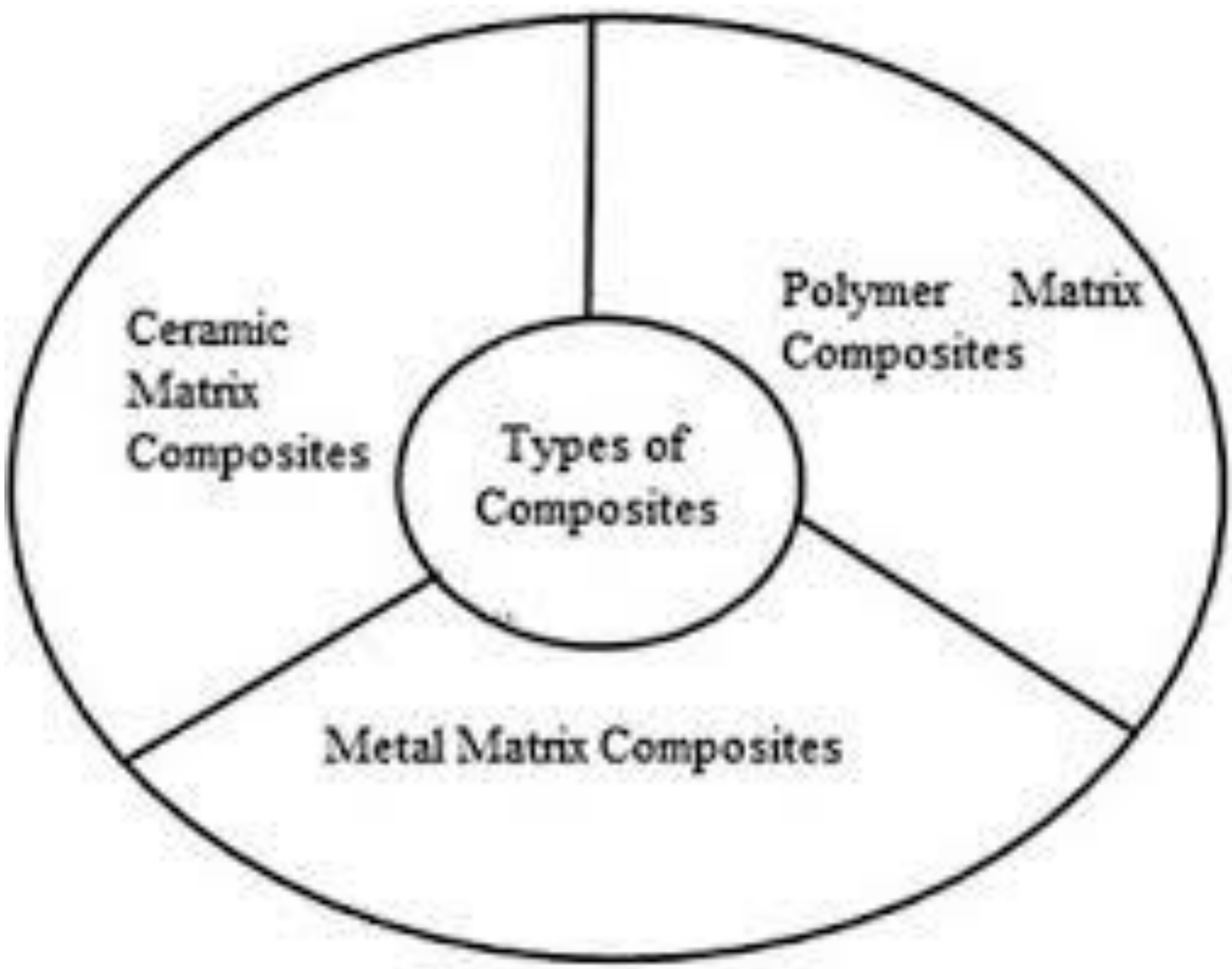
- ligament replacement
- heart patches

Metal matrix composites

What is a composite material?

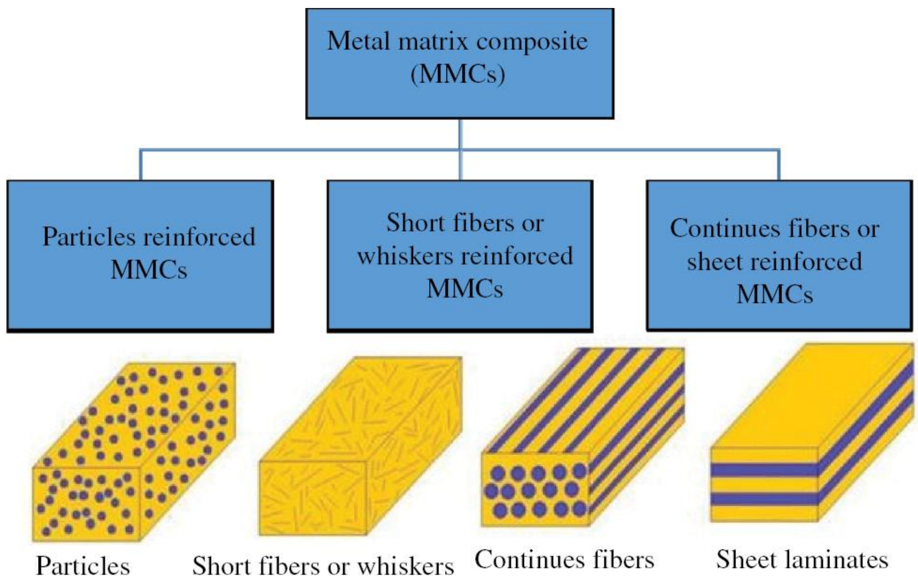
- A composite is a material made from two or more different materials that, when combined, are stronger than those individual materials by themselves.

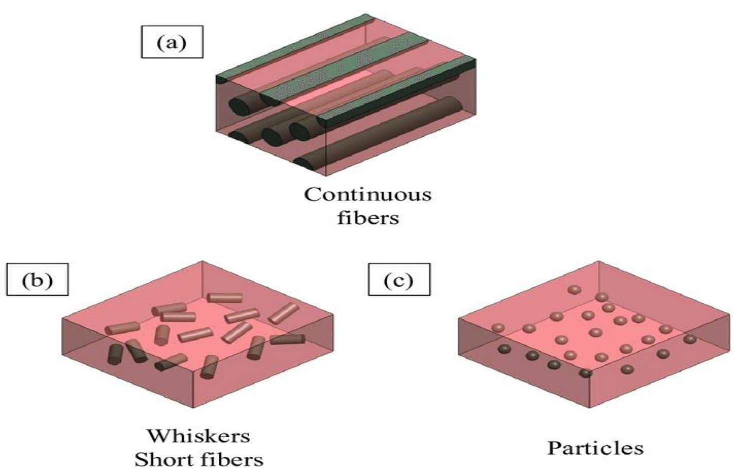
Classification of composites

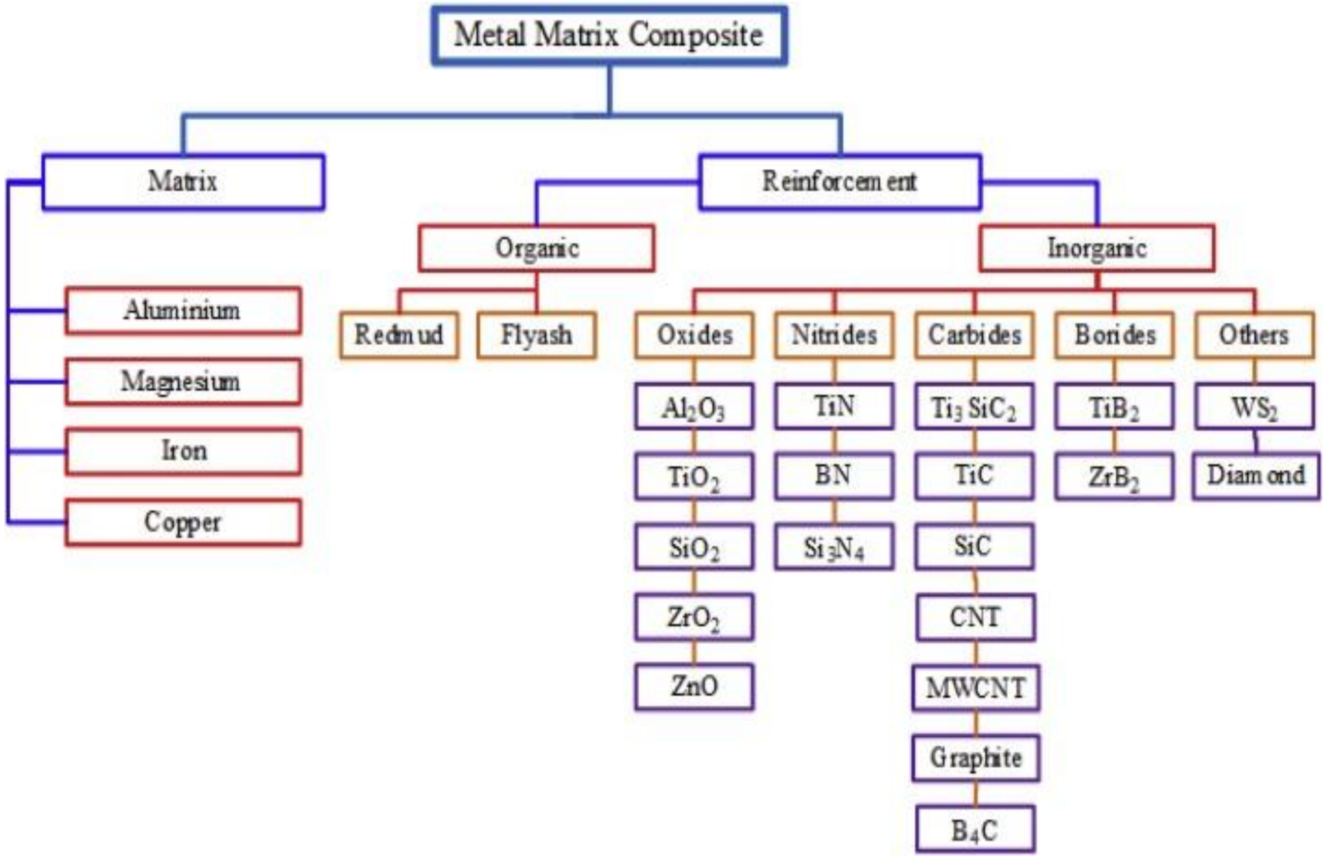


Metal matrix composites

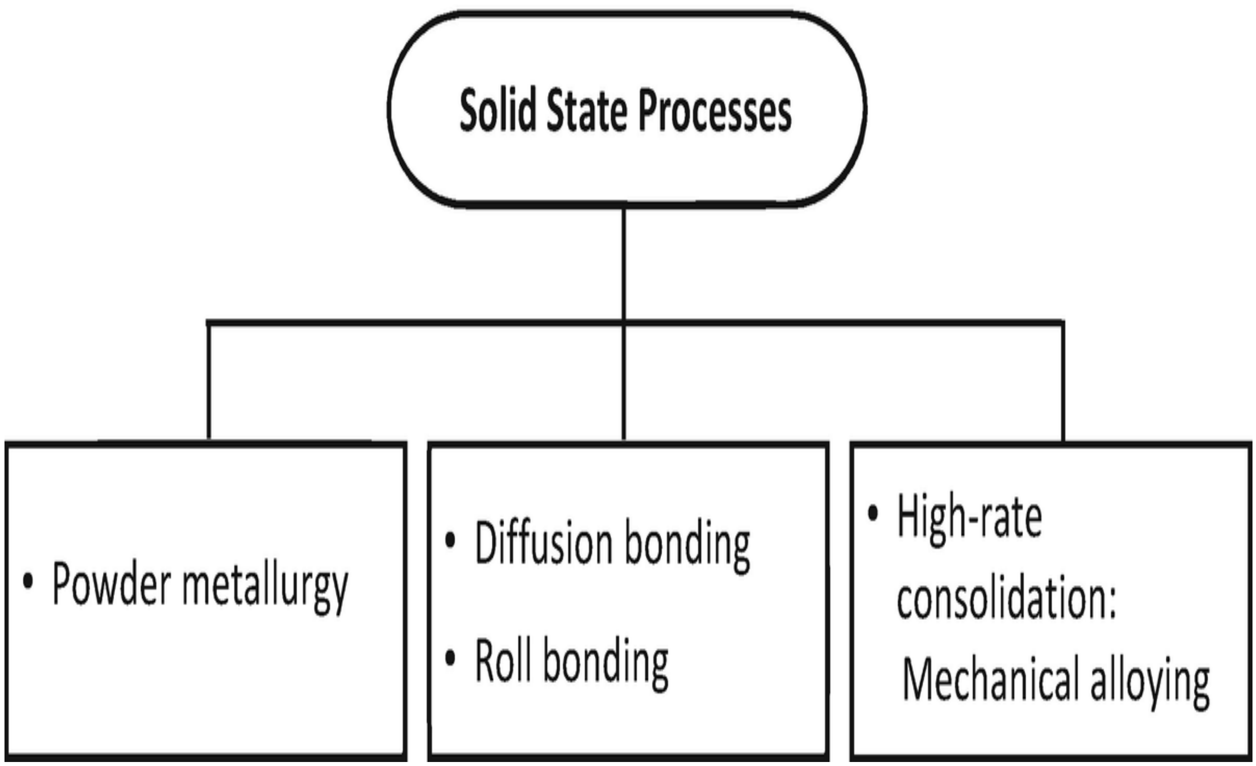
- Metal matrix composites (MMCs) are composite materials containing at least two constituent parts – a metal part and a material or a different metal part.
- The metal matrix is reinforced with the other material to improve strength and wear.
- Most metals and alloys make good matrices.
-

- 





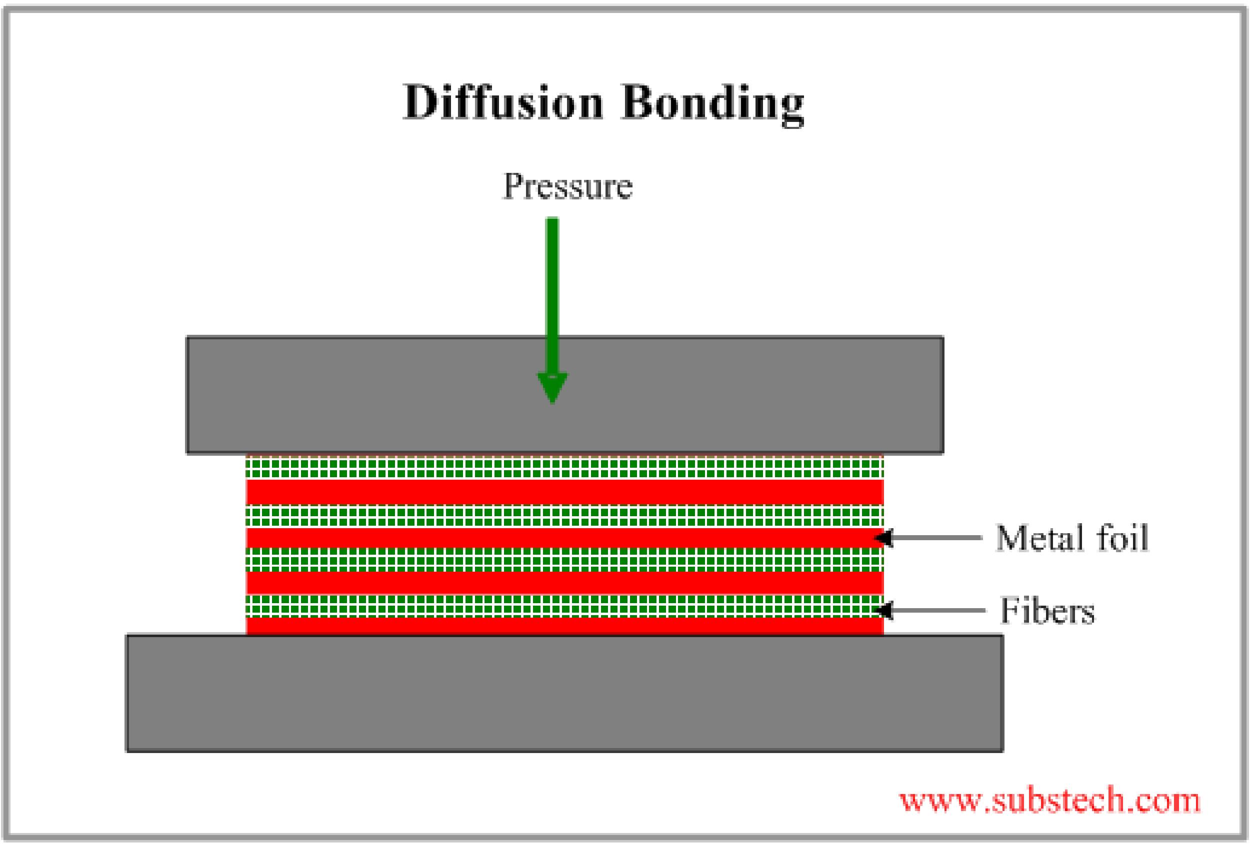
Metal Matrix Composite
Matrix
Reinforcement
Organic
Inorganic
Aluminium
Magnesium
Iron
Copper
Redmud
Flyash
Oxides
Nitrides
Carbides
Borides
Others
Al_2O_3
TiO_2
SiO_2
ZrO_2
ZnO
TiN
BN
Si_3N_4
Ti_3SiC_2
TiC
SiC
CNT
MWCNT
Graphite
B_4C
TiB_2
ZrB_2
WS_2
Diamond



Solid State Processes
• Powder metallurgy
• Diffusion bonding
• Roll bonding
• High-rate consolidation:
Mechanical alloying

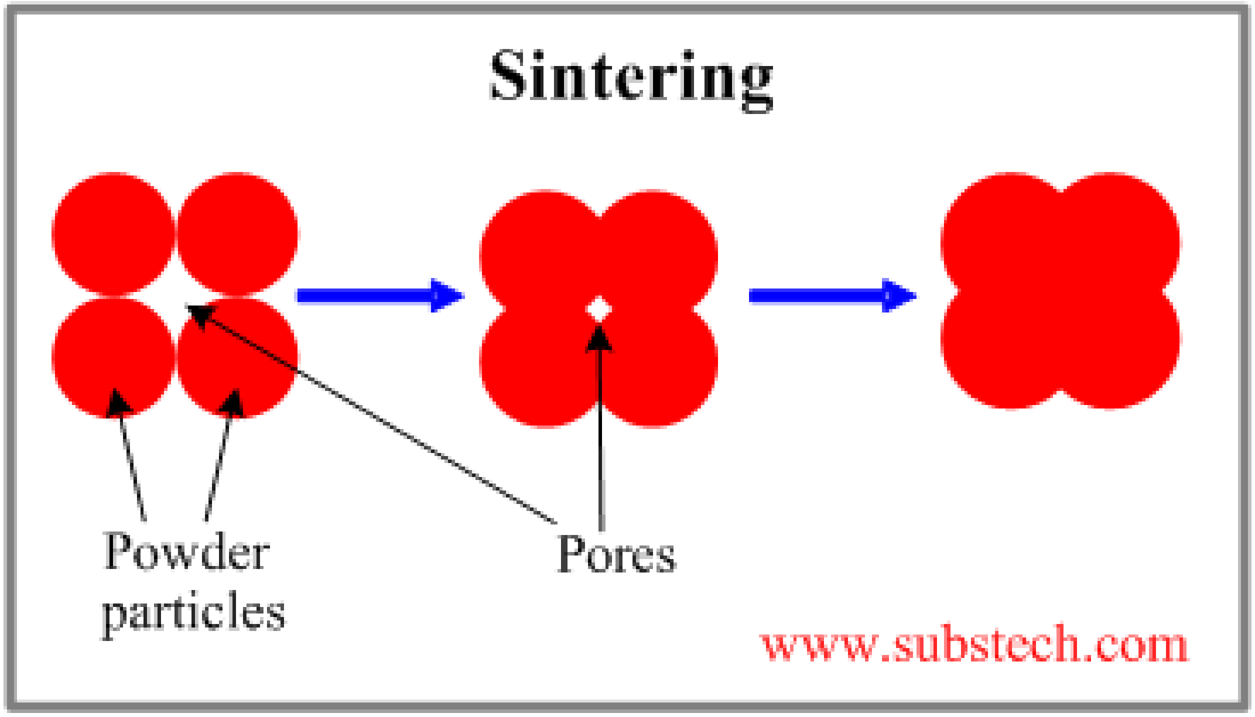
Solid state fabrication

- Metal Matrix Composites are formed as a result of bonding matrix metal and dispersed phase due to mutual diffusion occurring between them in solid states at elevated temperature and under pressure.
- There are two principal groups of solid state fabrication of Metal Matrix Composites:
- **Diffusion bonding**
- **Sintering**



Sintering

- A process, in which a powder of a matrix metal is mixed with a powder of dispersed phase in form of particles or short fibers for subsequent compacting and sintering in solid state (sometimes with some presence of liquid).



MMCs – properties

- Fire resistant
- Operate in wider range of temperatures
- Do not absorb moisture
- Better electrical and thermal conductivity
- Resistant to radiation damage
- Do not display out gassing
- Low CTE and light weight
- Good damping and high compression strength
- High specific stiffness and strength.

Applications of Metal Matrix Composites

Aerospace and Aircraft Industry

- Metal matrix composites work well as components in
- transmission systems,
- gearboxes,
- engine parts and accessories, and
- other internal elements.

Sports

- for tennis rackets,
- bicycle frames,
- and other sports

that involve

speed and strength.

Automotive Applications

- Car and motor racing make use of metal matrix composites for engine and vehicle body parts due to the lightweight nature of the material.

Unit III
Metal Joining Processes

1. Manufacturing Technology

- Involves sizing, shaping and imparting desired combination of the properties to perform indented function for design life.
- There are four chief manufacturing processes
  - Casting: zero process
  - Forming: zero process
  - Machining: negative process
  - Joining: positive process

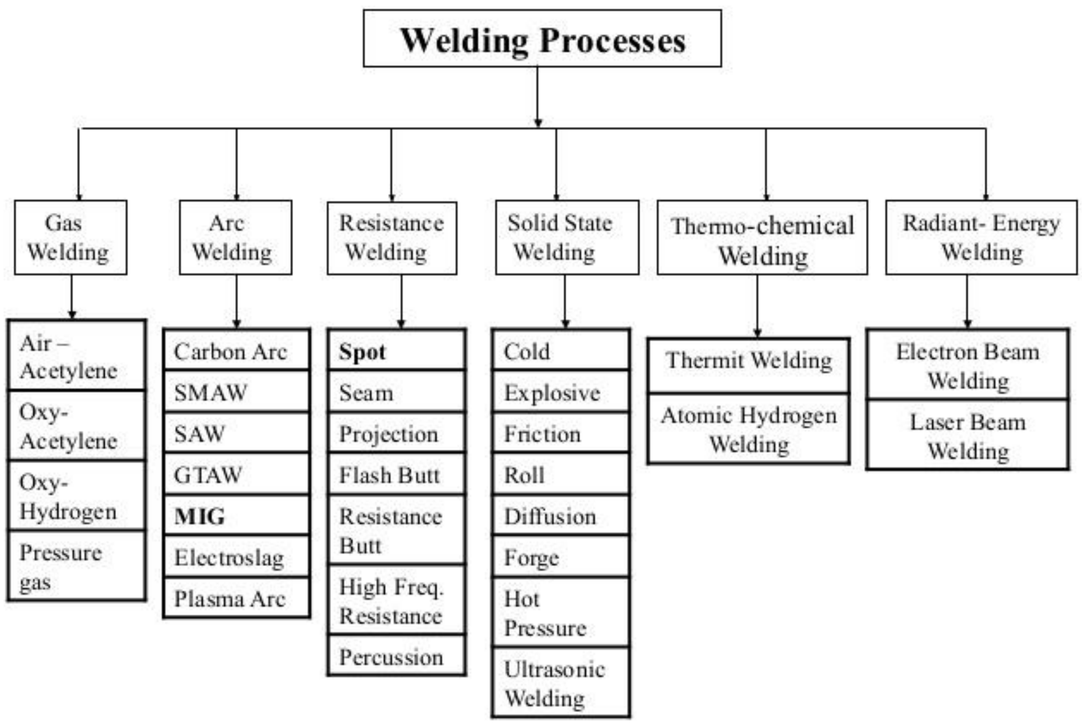
1.1. Joining

- The fabrication of engineering systems frequently needs joining of simple components and parts.
- Three types of joining methods namely
  - ✓ Mechanical joining(nuts & bolts, clamps, rivets),
  - ✓ Adhesive joining (epoxy resins, fevicol),
  - ✓ Welding(welding, brazing and soldering)

1.2. Welding

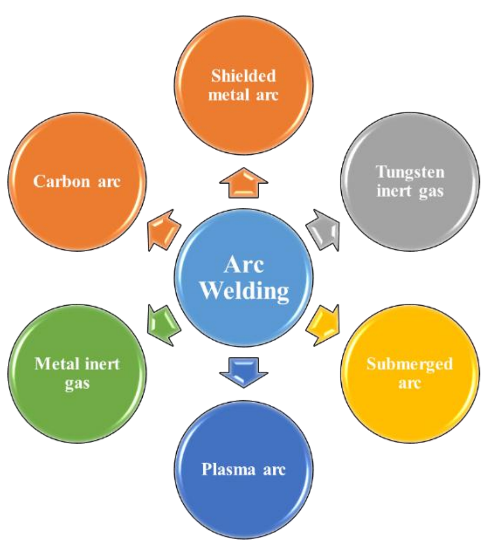
- Welding is a process in which two or more parts are joined permanently.
- Welding is a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone.
- It is used in the manufacture of automobile bodies, aircraft frames, railway wagons, machine frames, structural works, tanks, furniture, boilers, general repair work and ship building.

Classification of Welding Processes



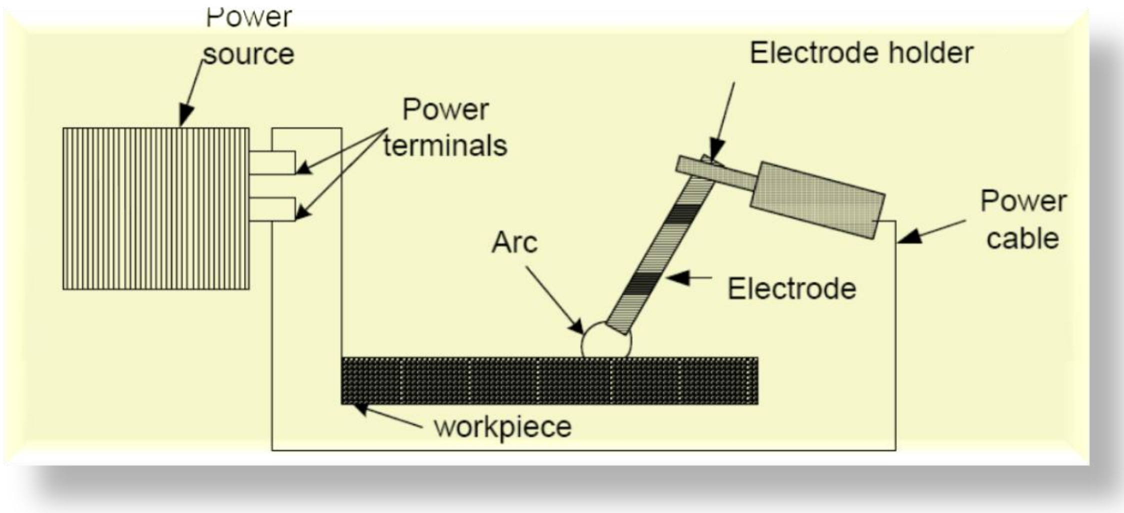
2. Arc welding processes

- All arc welding processes apply heat generated by an electric arc for melting the faying surfaces of the base metal to develop a weld joint



2.1. Arc Welding

The arc is started by bringing the tip of the electrode into contact with the base metal (work piece) by a very light touch, hence this arc is maintained by keeping the electrode at a relatively close distance from the base metal. This arc length is usually 3mm - 4mm



The heat is generated by an electric arc between base metal and a consumable electrode.

- A temperature of 5500°C is generated by this arc.
- Electrode movement is manually controlled, hence it is termed as manual metal arc welding
- It may or may not need separate shielding, The flux burns to form the protective layer/cover for the weld
- Process can use both AC and DC. DC power source is invariably used with all types of electrode irrespective of base metal (ferrous and non-ferrous).
- AC can be unsuitable for certain types of electrodes and base materials

2.1.1. Heat Generation in Arc Welding

- The amount of heat generated at the anode and cathode may differ appreciably depending upon the flux composition of coating, base metal, polarity and the nature of arc plasma.

$$Q = VIt$$

Q= Heat generated by a welding arc (J)

V= Arc voltage (V)

I= Arc current (A)

t= Welding time (s)

2.1.2. Electrodes

- Two types of electrodes are used:
    - Consumable Electrode and
    - Non-consumable Electrode

Consumable electrodes

- 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.

2.1.3. Flux:

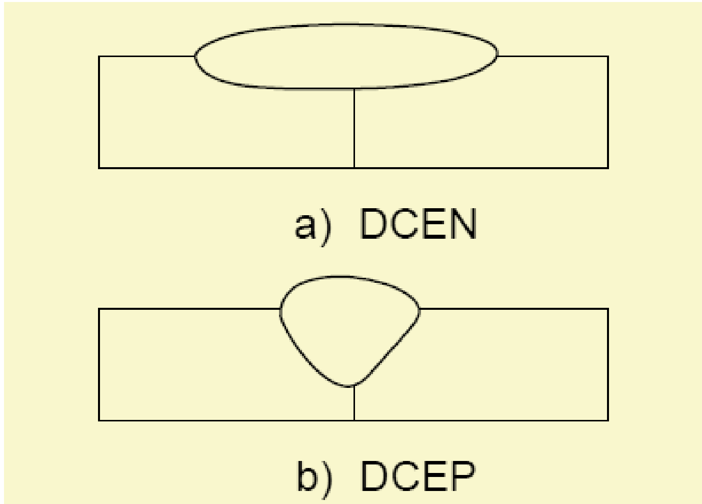
- The flux melts and covers the weld region giving protection and it should be removed by brushing as it is hardened.

2.1.4. Power Source in Arc Welding

- In direct current, electricity always flows from negative to positive.
- In alternating current, the electricity flows back and forth from negative to positive and positive to negative on a sine wave

2.1.5. Polarity in DC Arc Welding

- ***Straight Polarity ➔ Electrode –ve; Work +ve***
    - ➢ (DCEN)
        - ❖ more heat is produced at electrode.
        - ❖ higher burn off rate, therefore a higher deposition of electrode.
        - ❖ DCEN polarity is generally used for welding of all types of steel.
- ***Reverse Polarity ➔Electrode +ve; Work –ve***
    - ➢ (DCEP)
        - ❖ more heat is generated at the workpiece
        - ❖ deeper penetration of the weld bead,
        - ❖ DCEP is commonly used for welding of non-ferrous metal besides other metal systems.



Weld Bead Appearance

2.2. Advantages

- Shielded Metal Arc Welding (SMAW) can be carried out in any position with highest weld quality.
- Big range of metals and their alloys can be welded easily.
- The SMAW welding equipment is portable and the cost is fairly low.

2.3. Disadvantages

- Due to flux coated electrodes, the chances of slag entrapment and other related defects are more.
- Due to limited length of each electrode and brittle flux coating on it, mechanization is difficult.

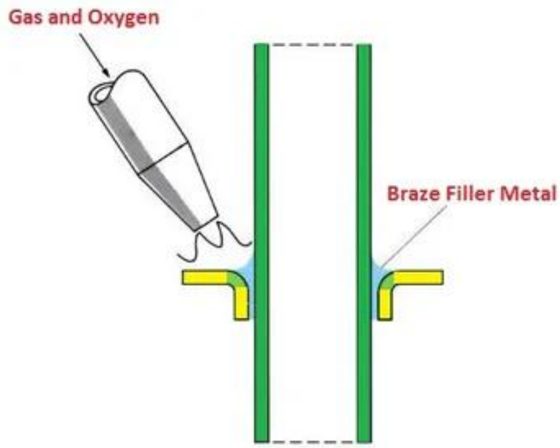
2.4. Applications of arc welding

- Shipbuilding
- Automotive industries
- Construction industries
- Mechanical industries

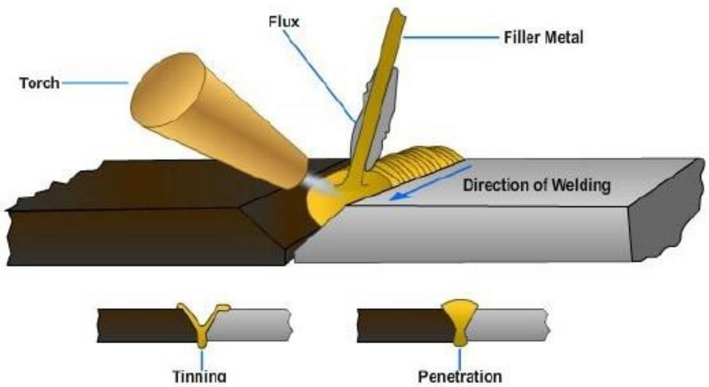
3. Brazing

- It is a joining process in which a filler metal is melted and distributed by capillary action between the faying (contact) surfaces of the metal parts being joined.
- Base material does not melt in brazing, only the filler melts.
- The filler material is called Spelter and the filler material is made up of Copper alloy

- In brazing, the filler metal has a melting temperature (liquidus) above 450°C, but below the melting point (solidus) of base metals to be joined.



Brazing Process



Braze welding cast iron and nickel alloy using the backhand method.

- To achieve a perfect joint, the filler and the parent materials should be metallurgically compatible and the design of the joint should incorporate a minimum gap into which the braze filler metal will be drawn.
- The joints must be properly cleaned and protected by the flux or protective atmosphere during the heating process to prevent excessive oxidation.

3.1. Types of Brazing

- torch brazing,
- furnace brazing,
- induction brazing,
- dip brazing, and
- resistance brazing

3.2. Filler materials used for brazing

Filler Metal	Typical Composition	Approximate Brazing Temperature °C	°F	Base Metals
Aluminum and silicon	90 Al, 10 Si	600	1100	Aluminum
Copper	99.9 Cu	1120	2050	Nickel copper
Copper and phosphorous	95 Cu, 5 P	850	1550	Copper
Copper and zinc	60 Cu, 40 Zn	925	1700	Steels, cast irons, nickel
Gold and silver	80 Au, 20 Ag	950	1750	Stainless steel, nickel alloys
Nickel alloys	Ni, Cr, others	1120	2050	Stainless steel, nickel alloys
Silver alloys	Ag, Cu, Zn, Cd	730	1350	Titanium, Monel, Inconel, tool steel, nickel

3.3. Characteristics of a good flux include,

- low melting temperature,
- low viscosity so that it can be displaced by the filler metal,
- facilitates wetting, and
- protects the joint until solidification of the filler metal.

Spelter + Borax + Water = Paste

3.4. Advantages of brazing

- Brazing can be used to join a large variety of dissimilar metals.
- Pieces of different thickness can be easily joined by brazing
- Thin-walled tubes & light gauge sheet metal assemblies not joinable by welding can be joined by brazing.
- Complex & multi-component assemblies can be economically fabricated with the help of brazing.
- Inaccessible joint areas which could not be welded by gas metal or gas tungsten arc spot or seam welding can be formed by brazing.

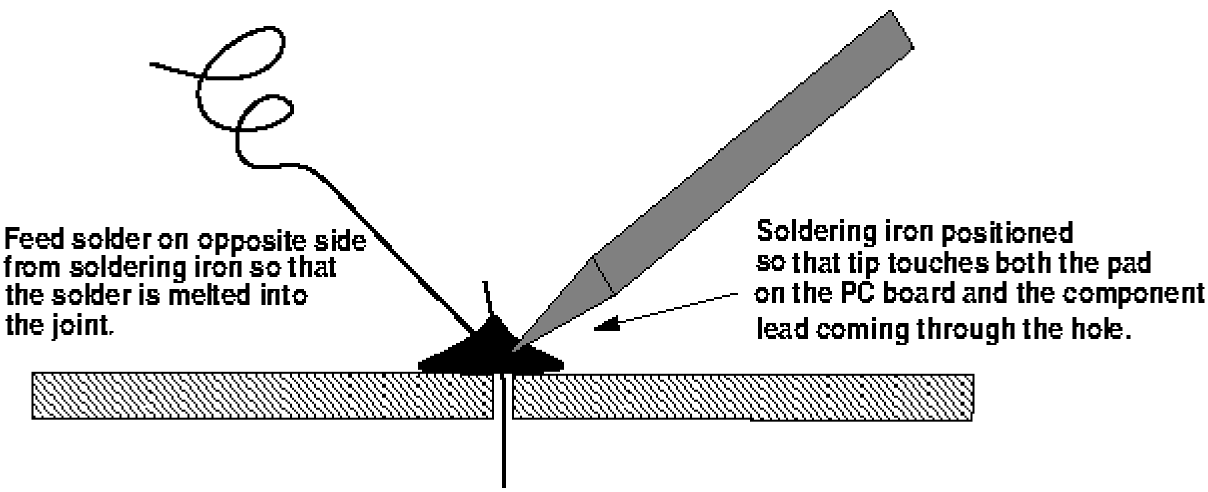
3.5. Applications of brazing

- Brazing is used for the fastening of pipe fittings, carbide tips on tools, heat exchangers, electrical parts, radiators, axles, etc.
- It can join cast metals to wrought metals, dissimilar metals, porous metal components, etc.

- It is used to join parts of the bicycle such as frame and rims.

4. Soldering

- Soldering is similar to brazing and can be defined as a joining process in which a filler metal with melting point (liquidus) not exceeding 450°C is melted and distributed by capillary action between the faying surfaces of the metal parts being joined.
- As in brazing, no melting of the base metals occurs, but the filler metal wets and combines with the base metal to form a metallurgical bond.
- Filler metal, called Solder, is added to the joint, which distributes itself between the closely fitting parts.



4.1. SOLDER

- Alloys of Tin and Lead.
- Tin is chemically active at soldering temperatures and promotes the wetting action required for successful joining.

Filler Metal	Approximate Composition	Approximate Melting Temperature °C	°F	Principal Applications
Lead–silver	96 Pb, 4 Ag	305	580	Elevated temperature joints
Tin–antimony	95 Sn, 5 Sb	238	460	Plumbing and heating
Tin–lead	63 Sn, 37 Pb	183[a]	361[a]	Electrical/electronics
	60 Sn, 40 Pb	188	370	Electrical/electronics
	50 Sn, 50 Pb	199	390	General purpose
	40 Sn, 60 Pb	207	405	Automobile radiators
Tin–silver	96 Sn, 4 Ag	221	430	Food containers
Tin–zinc	91 Sn, 9 Zn	199	390	Aluminum joining
Tin–silver–copper	95.5 Sn, 3.9 Ag, 0.6 Cu	217	423	Electronics: surface mount technology

4.2. Advantages of Soldering Process:

- Joints prepared using the soldering process will be dismantled easily.
- Soldering can be done at a low temperature of less than Brazing operation.
- The soldering cost is very less.
- It's simple in design and economical.

4.3. Disadvantages of Soldering Process:

- Skiller worker is required to make a perfect and stronger joint.
- Solders are costlier.
- Soldering can be applied only for small joints but it cannot be applied for heavy parts.

5. Comparison between Welding, Soldering and Brazing

Sl. No.	Welding	Soldering	Brazing
1.	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.
2.	Temperature required is upto 3800°C of welding zone.	Temperature requirement is upto 450°C.	It may go to 600°C in brazing.
3.	Workpiece to be joined need to be heated till their melting point.	No need to heat the workpieces.	Workpieces are heated but below their melting point.

4.	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost negligible.
5.	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.	Cost involved and sill required are in between others two.
6.	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.	No heat treatment is required after brazing.
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.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.

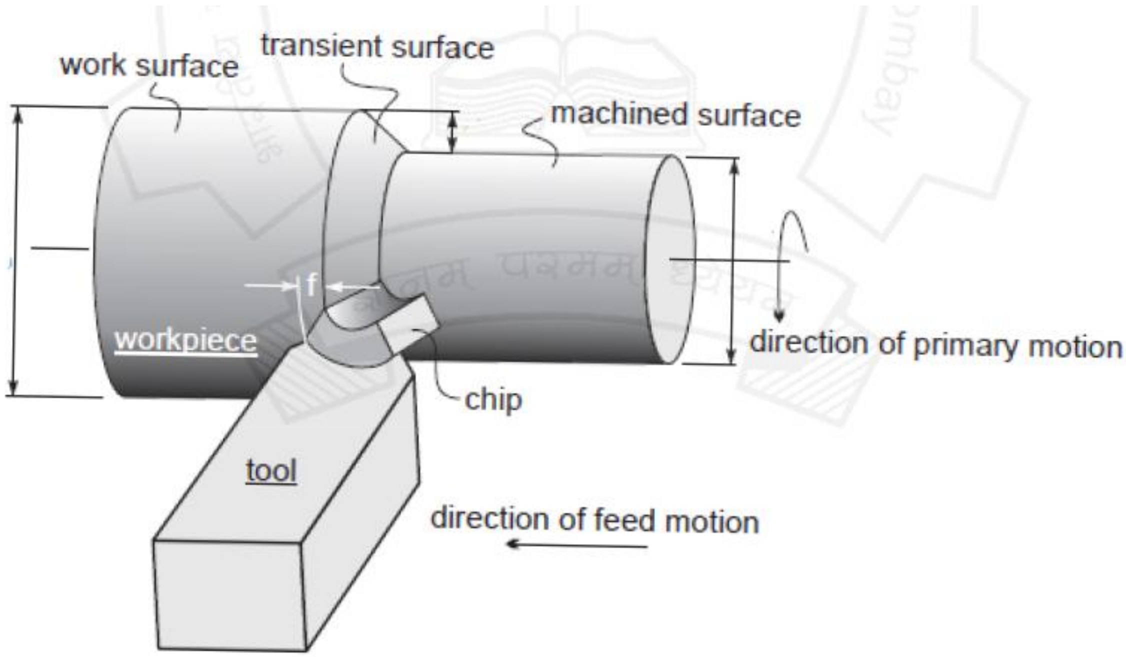
6. Basic Machining Operations

6.1. Machining

- Machining is the manufacturing process by which parts can be produced to the desired dimensions and surface finish from a blank by gradual removal of the excess material in the form of chips with the help of a sharp cutting tool.
- Almost 90% of the all engineering components are subjected to some kind of machining during manufacture

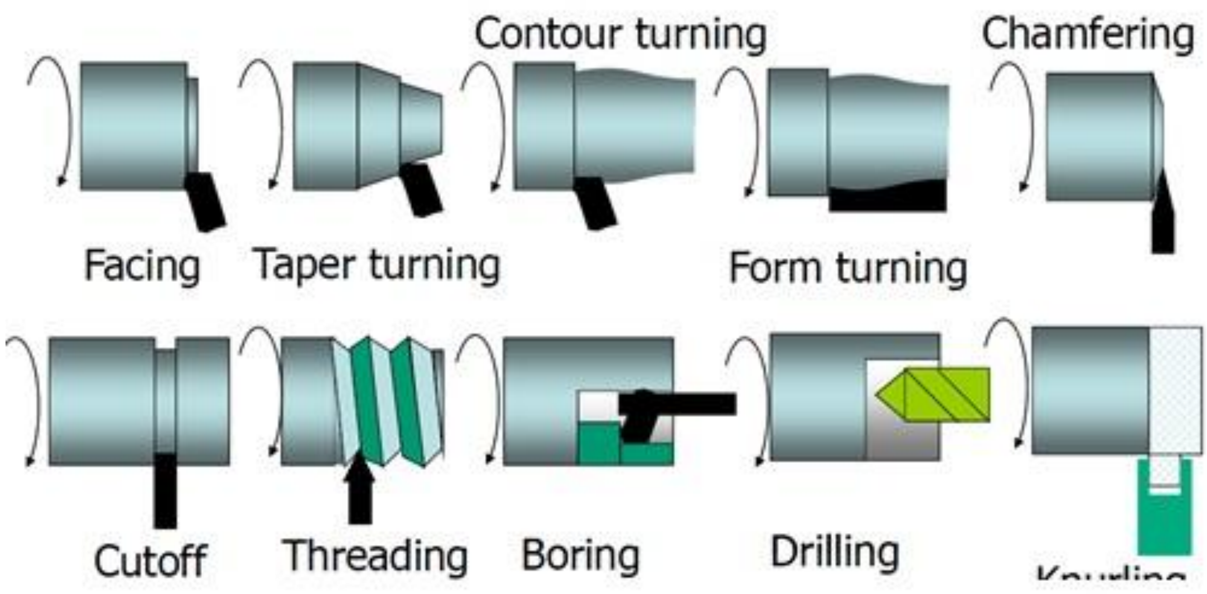
6.2. Turning

- Turning is used to produce parts cylindrical in shape by a single point cutting tool on lathes
- The cutting tool is fed either linearly in the direction parallel or perpendicular to the axis of rotation of the workpiece, or along a specified path to produce complex rotational shapes.
- The primary motion of cutting in turning is the rotation of the workpiece, and the secondary motion of cutting is the feed motion



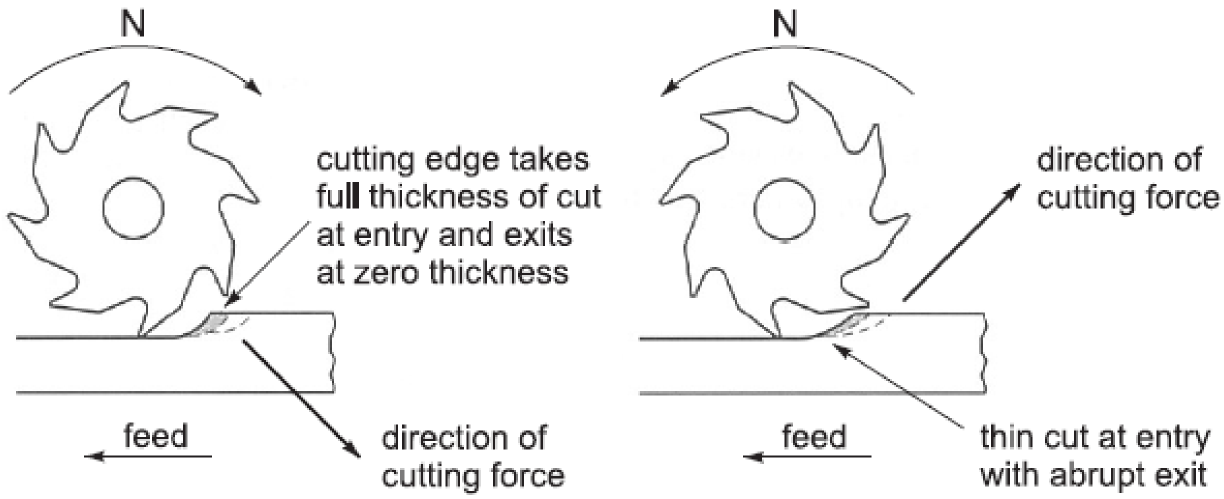
6.2.1. Turning Operations

- *Straight turning* is used to reduce the diameter of a part to a desired dimension
- *Contour turning and Taper turning*are performed by employing a complex feed motion using special attachments to a *single point turning tool* thus creating a contoured shape on the workpiece
- *Facing*is done to create a smooth, flat face perpendicular to the axis of a cylindrical part. The tool is fed radially or axially to create a flat machined surface.
- *Thread cutting*is possible in *lathe* by advancing the cutting tool at a feed exactly equal to the *thread pitch*
- *Boring*is similar to *straight turning* operation but differs in the fact that it can produce internal surface of revolution, which is often considered to be difficult due to overhanging condition of the tool.
- In *form turning* the shape of the cutting tool is imparted to the workpiece by plunging the tool into the workpiece. In *form turning*, the cutting tool can be very complex and expensive but the feed will remain linear and will not require special machine tools or devices.



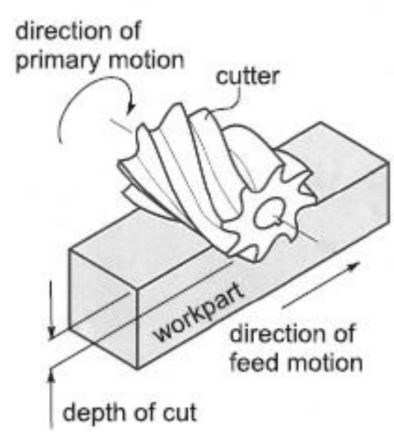
6.3. Milling

- *Milling* is a process of producing flat and complex shapes with the use of multi-point (or multi-tooth) cutting tool.
- The axis of rotation of the cutting tool is perpendicular to the direction of feed, either parallel or perpendicular to the machined surface.
- Milling is usually an interrupted cutting operation since the teeth of the milling cutter enter and exit the workpiece during each revolution.
- This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation.
- The tool material and cutter geometry must be designed to withstand these conditions.
- Two basic types of milling operations:
    - *down milling*
    - *up milling*
- *Down milling*, when the cutter rotation is in the same direction as the motion of the workpiece being fed, and
- *Up milling* in which the workpiece is moving towards the cutter, opposing the cutter direction of rotation



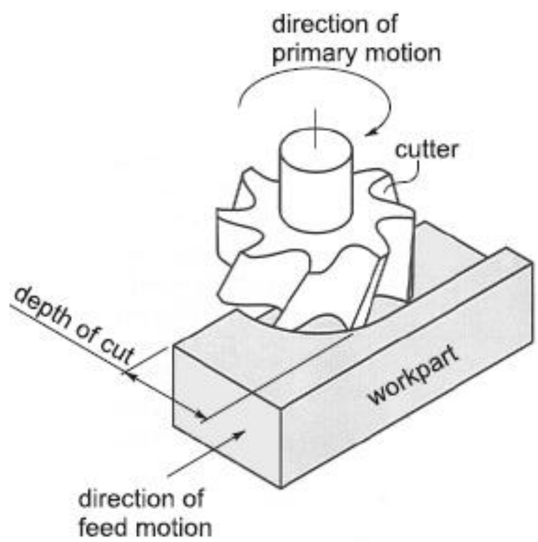
6.3.1. Milling Operations

- In ***peripheral milling***also referred to as *plain milling*, the axis of the cutter is parallel to the surface being machined, and the operation is performed by the cutting edges on the outside periphery of the tool.
- The primary motion is the rotation of the tool. The feed is imparted to the workpiece



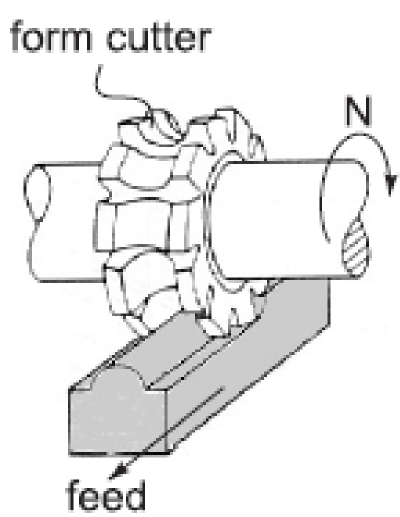
peripheral milling

- In ***face milling***, the tool is perpendicular to the machined surface.
- The tool axis is vertical, and machining is performed by the teeth on both the end and the periphery of the face-milling tool.
- Also, up and down types of milling are available, depending on directions of the tool rotation and feed.
- *End milling* is used to produce pockets, key holes by using a tool referred to as the *end mill*, has a diameter less than the workpiece width.



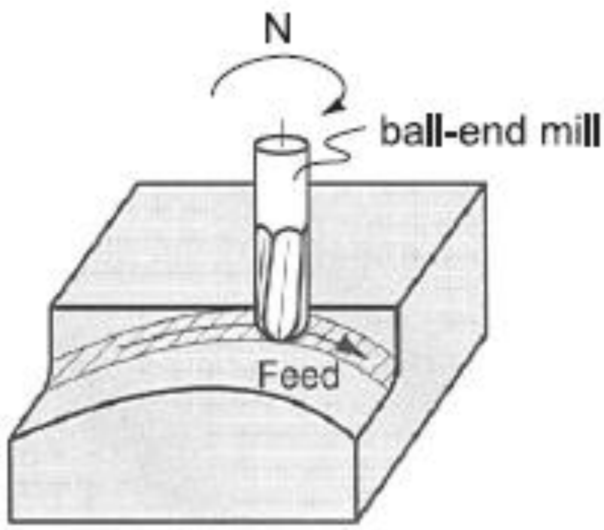
face milling

- In ***form milling***, the cutting edges of the peripheral tool (also referred to as *form cutter*) have a special profile that is imparted to the workpiece.
- Tools with various profiles are also available to cut different two-dimensional surfaces.
- One important application of form milling is in gear manufacturing.



face milling

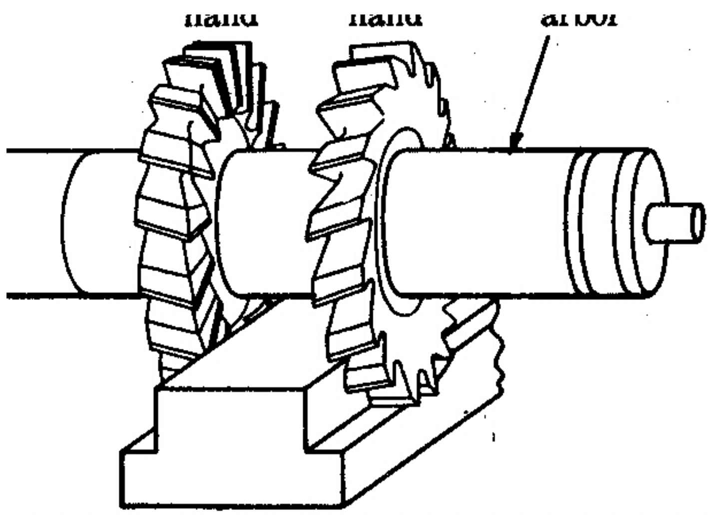
Surface contouring, is an operation performed by computer controlled milling machines in which a ball-end mill is fed back and forth across the workpiece along a curvilinear path at close intervals to produce complex three-dimensional surfaces.



Surface contouring,

Straddle Milling

- For faster and accurate machining two parallel vertical surface at a definite distance, two separate side milling cutters are mounted at appropriate distance on the horizontal milling arbour



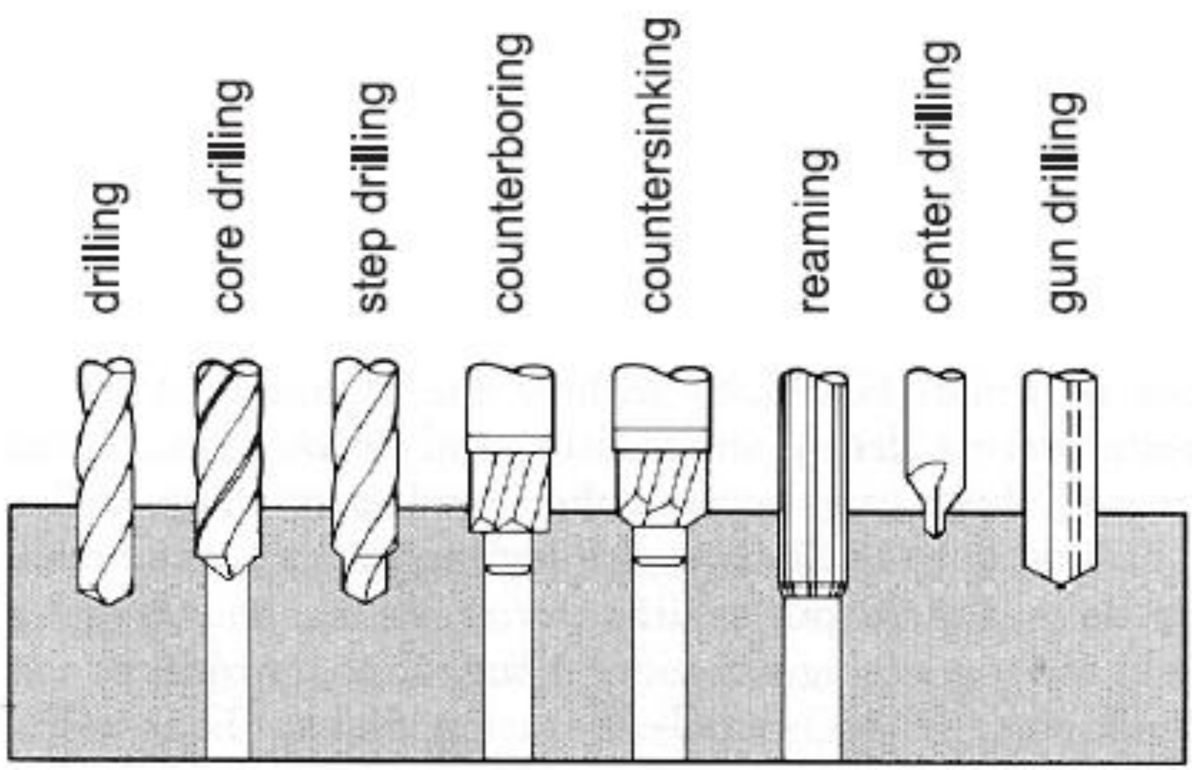
Straddle Milling

6.4. Drilling

- *Drilling* is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called *drills* or *drill bits*.
- Various cutting tools are available for drilling, but the most common is the *twist drill*.

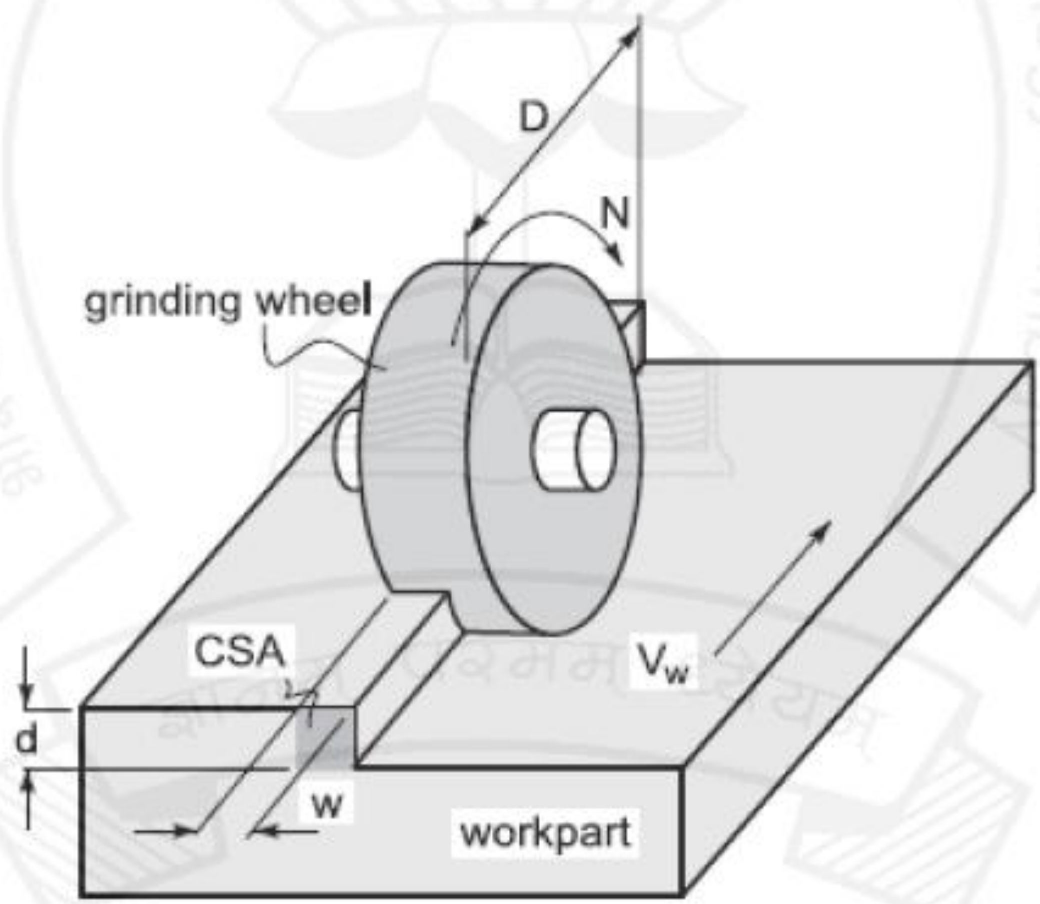
A variety of drilling processes are available to serve different purposes.

- ***Drilling***is used to drill a round blind or through hole in a solid material. If the hole is larger than ~30 mm, a smaller pilot hole is drilled before *core drilling* the final one.
- For holes larger than ~50 mm, three-step drilling is recommended.
- ***Core drilling*** is used to increase the diameter of an existing hole.
- ***Step drilling*** is used to drill a stepped (multi-diameter) hole in a solid material.
- ***Counter boring***provides a stepped hole again but with flat and perpendicular relative to hole axis face. The hole is used to seat internal hexagonal bolt heads.
- ***Countersinking***is similar to counter boring, except that the step is conical for flat head screws.
- **Reaming** operation is usually meant to slightly increase the size and to provide a better tolerance, surface finish and improved shape of an initially drilled hole. The tool is called reamer.
- ***Center drilling*** is used to drill a starting hole to precisely define the location for subsequent drilling operation and to provide centre support in lathe or turning centre. The tool is called *center drill* that has a thick shaft and very short flutes.
- ***Gun drilling*** is a specific operation to drill holes with very large *length-to-diameter* ratio up to 300.



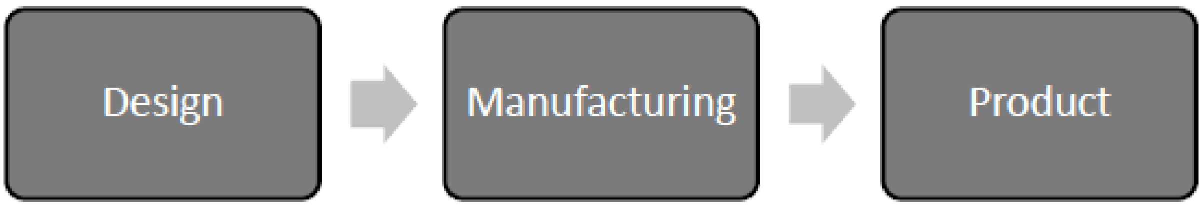
6.5. Grinding

- *Grinding* is the most popular form of abrasive machining. It involves an abrasive tools consisting of grain of hard materials which are forced to rub against the workpiece removing a very small amount of material.
- Grinding can be performed to produce flat as well as cylindrical (both external and internal) surface efficiently.
- Grinding is applied when the material is too hard to be machined economically or when tolerances required are very tight.
- *Grinding* can produce flatness tolerances of less than ±0.0025 mm on a 127 x 127 mm steel surface if the surface is adequately supported.
- The major advantages of grinding process include dimensional accuracy, good surface finish, good form and locational accuracy applicable to both hardened and unhardened material.



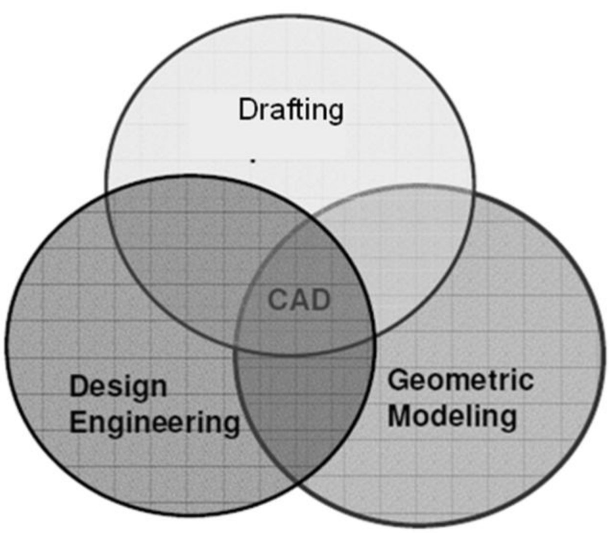
6.6. Principle of CAD/CAM

How to make a Product?



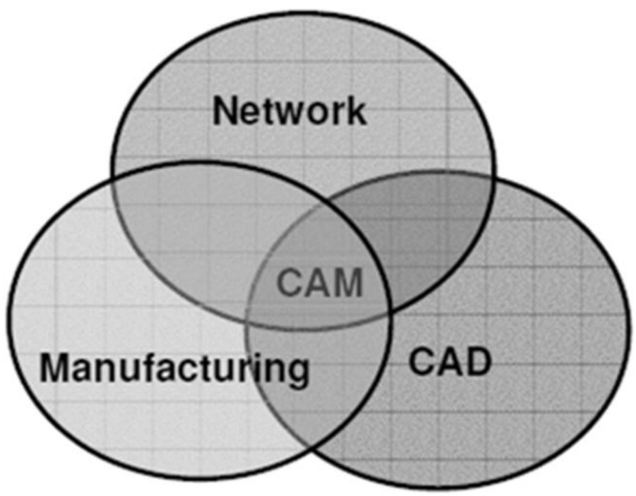
CAD

- Design + Computer = CAD
- CAD if often defined in a variety of ways and includes a large range of activities. Very broadly it can be said to be the integration of computer science (or software) techniques in engineering design.
- At one end when we talk of modeling, iIt encompasses the following:
    - Use of computers (hardware & software) for designing products
    - Numerical method, optimizations etc.
    - 2D/3D drafting
    - 3D modeling for visualization
    - Modeling curves, surfaces, solids, mechanism, assemblies, etc.

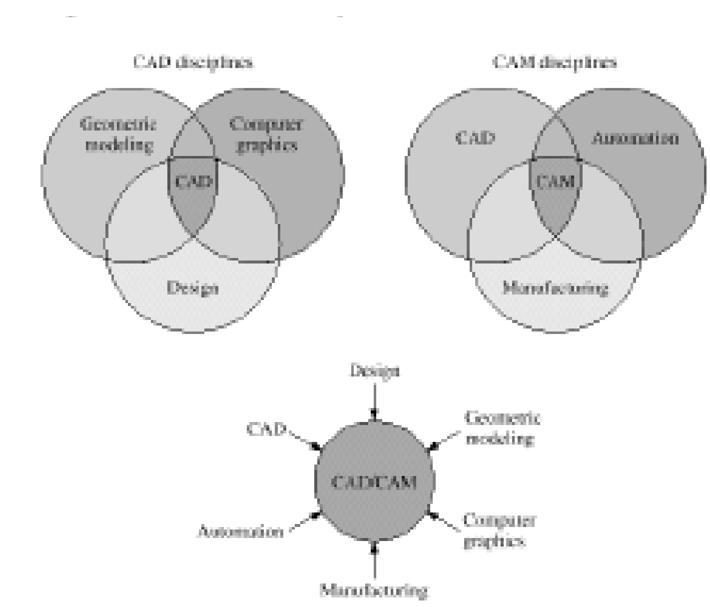


CAM

- Manufacturing + Computer = CAM
- Computer Aided Manufacturing (CAM) is the use of software and computer-controlled machinery to automate a manufacturing process.
- three components for a CAM system to function
- Software that tells a machine how to make a product by generating toolpaths.
- Machinery that can turn raw material into a finished product.
- Post Processing converts toolpaths into a language machines can understand.



CAD/CAM



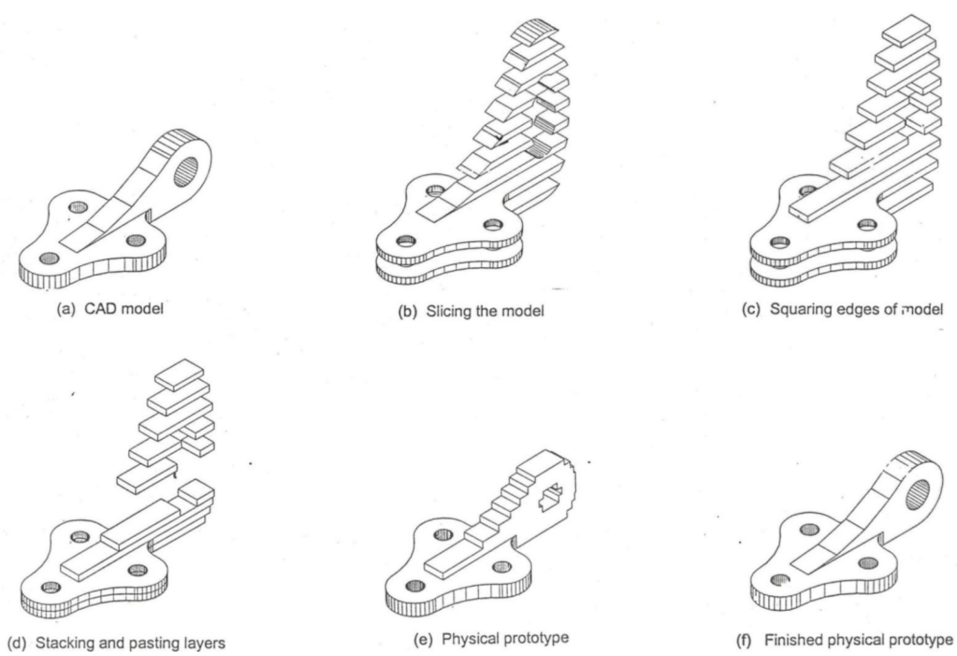
6.7. 3D Printing

- 3D printing or additive manufacturing is a process of making three dimensional solid objects from a digital file.
- An object is created by laying down materials layer by layer until the whole object is created.
- It simply stacks and fuses layers of material.
- Each of these layers can be seen as a thinly sliced cross-section of the object.
- 3D printing enables you to produce complex shapes using less material than traditional manufacturing methods.

6.7.1. Various names of 3D Printing

- Rapid Prototyping
- Stereo-Lithography
- 3D Printing
- Additive Manufacturing
- Layered Manufacturing
- Solid Freeform Fabrication
- Direct Digital Mfg…

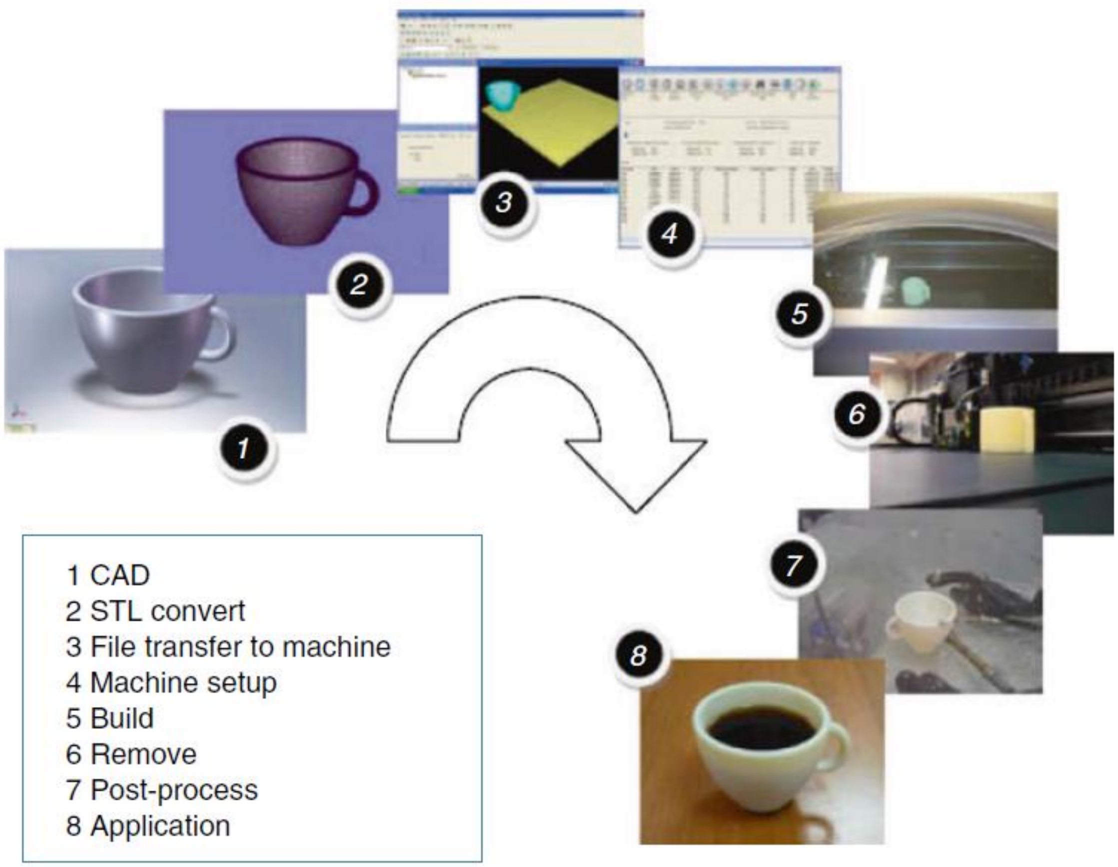
6.7.2. Divide (or slice) and conquer



(a) CAD model
(b) Slicing the model
(c) Squaring edges of model
(d) Stacking and pasting layers
(e) Physical prototype
(f) Finished physical prototype

6.7.3. **AM Process Flow**

- CAD model
- STL file Conversion
- Part Orientation
- Support Generation
- Model Slicing
- Tool Path Generation
- Printing
- Post Processing (if applicable)



6.7.4. **Benefits**

- Mass Customization
- Very low start-up costs

- Design freedom at no extra cost
- Each and every part can easily be customized

6.7.5. Limitation

- Less cost-competitive at higher volumes
- Limited accuracy & tolerances
- Lower strength & anisotropic material properties
- Requires post-processing & support removal

6.7.6. APPLICATIONS OF AM

Aerospace & Defence

- Functional prototypes
- Tooling
- Lightweight components