Module 4:

PROPERTIES, COMPOSITION AND INDUSTRIAL APPLICATIONS OF ENGG. MATERIALS

Engineering materials

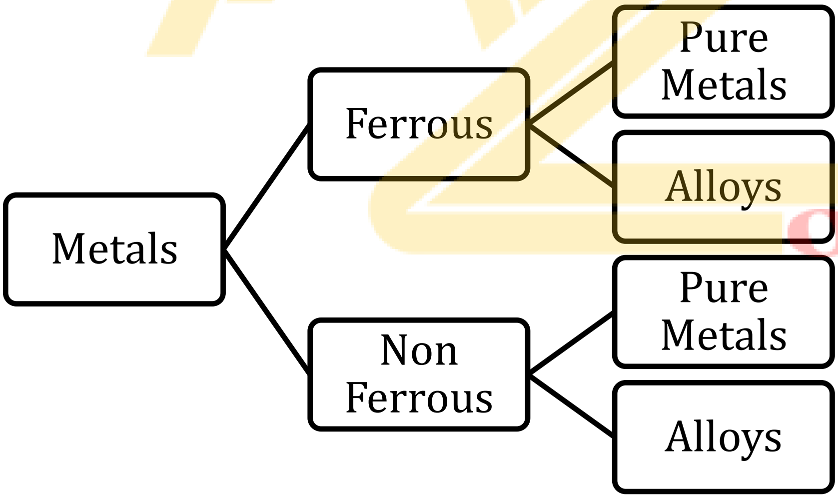
Metals

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

a) 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.

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.

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.

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

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

*Application :*Cutlery, kitchen equipment, surgical equipment, chemical handling equipments and cutlery etc.,

High speed 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

Application: Cutting tools for machines

Type of Non Ferrous metal

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

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.

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.,

Bronze

*Composition:*Alloy of copper and tin

*Properties and characteristics:*Fairly strong, malleable and ductile when soft

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.*

Composites

Definition of Composite Materials

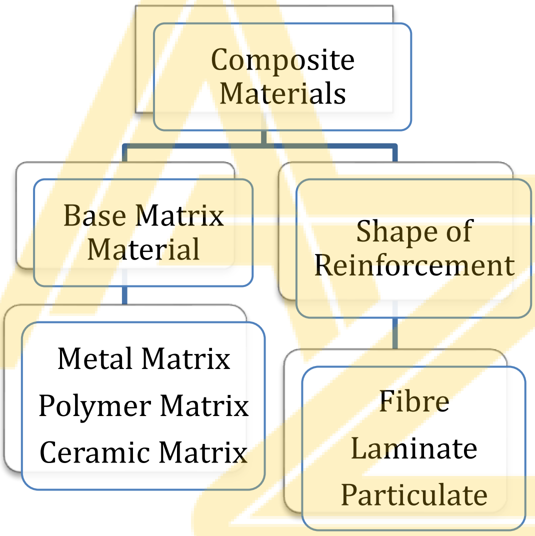
A composite is combination of two materials in on a Macroscopic level and are not soluble in each other in which one of the materials, called the reinforcing phase, is in the form of Fibres, sheets, or particles,and is embedded in the other materials called the matrix phase.

The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a Fibre or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members.

The matrix acts as a load transfer medium between Fibres, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the Fibre axis. The matrix also serves to protect the Fibres from environmental damage before, during and after composite processing.

When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological and environmental applications.

Classification of composite material



Metal Matrix composite

These contain at least two component parts one of which is metal. The other material may be a ceramic or an organic compound. It is made by dispersing a ceramic (oxides, carbides) or metallic (lead, tungsten and molybdenum) phase into metal matrix (aluminium, magnesium, iron, cobalt)

Properties of MMCs:

- Higher specific strength, stiffness, higher operating temperature, low coefficient of thermal expansion and greater wear resistance.
- MMC’s have lower ductility and the cost of fabricating is high.

Applications of MMCs:

- Used in piston for diesel engine.
- Used in automotive engine and brake parts.
- Used in spacecraft structures, missiles structures, fighter aircraft engines and structures.

Polymer Matrix composite

These comprises of a variety of short or continuous fibres that are bound together in an organic polymer matrix.

Properties of PMCs:

- The reinforcement in a PMC provides high strength and stiffness along the direction of reinforcement.
- Superior corrosion and fatigue resistance when compared to metals.

Applications of PMCs:

- Aerospace application
- Marine application
- Automotive application
- Sports industry applications

Ceramic Matrix composite

These consists of ceramic fibres embedded in a matrix made from ceramic materials such as C, SiC, Al_2O_3, etc. Ex: C/SiC

Properties of CMCs:

- Good corrosion resistance, high compressive strength and high thermal shock resistance.

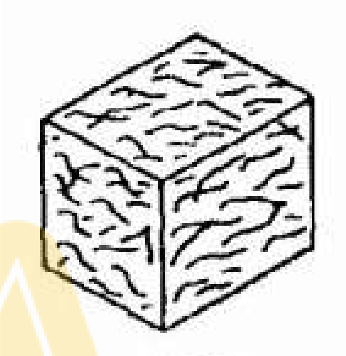
Applications of CMCs:

- Automotive applications: it is used in disc brakes of race cars and airplanes.
- Space applications: it can withstand high temperature of nose, landing edge and lower surface of wing
- Gas turbine application: it is used in combustor liner and blades in aircraft engine
- Cutting tool application : cutting tools for machining of materials that are generally hard to machine.

Composites can also be classified as follows

Fibre reinforced composite

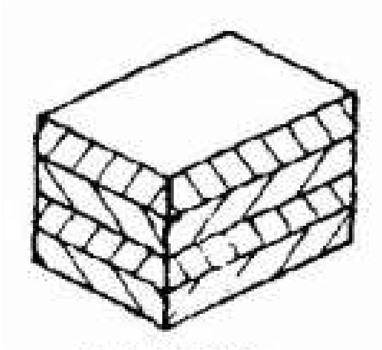
Fibre reinforced composite are those where the reinforcement in form of fibre. A natural example for fibre reinforce composite is wood in which strong cellulose fibre are aligned in a base matrix of lignin which bind the fibres.



A Fibre is characterized by its length being much greater compared to its cross- sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Technologically the most important type of composites is fibre reinforced ones because of their wide range of application. The characteristics of fibre reinforced composite are expressed in terms of specific strength and specific modulus parameters. Specific strength is nothing but the ratio of tensile strength to specific gravity whereas specific modulus is the ratio of young's modulus to specific gravity. Fibre reinforced composites with exceptionally high specific strength and moduli have been successfully produced using fibres of different material.

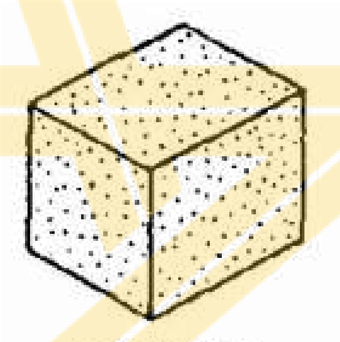
Laminated composites

In fibre –reinforced composites, if the fibres are of uniform alignment, the composites show anisotropicproperties i.e., different properties along different direction. But if layers of such composites are stackedand bonded together in such a way that successive layers have their fibres aligned in different direction,the composite on the whole will have high strength and uniform properties in all direction.The best example for a laminated for laminated composites is plywood where successive layers of wood having different orientation of grains are cemented together and composite on the whole has betterstrength in all direction.



Particulate composites

In particulate composites the reinforcement is of particle nature. It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape. In this type of composites, particles of varying shape and size of one material is dispersed in a matrix of second material. Particulate composites are similar in construction to dispersion strengthened alloys but differ in particle size and percentage by volume.



Polymers:

The word polymer comes from the Greek ***poly-***, which means "many", and the ***mer,*** which means **"parts".**

- A polymer is a large molecule made up of chains or rings of linked repeating subunits, which are called monomers.
- Polymers usually have high melting and boiling points. Because the molecules consist of many monomers, polymers tend to have high molecular masses.

Types of Polymers:

1. Thermoplastic Polymer
2. Thermosetting Polymer

1. Thermoplastic Polymer:

"Capable of softening or fusing when heated and of hardening again when cooled."

1. They have long chain molecules held by secondary bonds
2. Polymerization is linear
3. *They soften when heated harden when cooled i.e. reversible*
4. At higher temperatures these polymers liquify due to breaking of secondary bonds
5. They are relatively soft and ductile
6. Suitable for only at low temperature

2. Thermosetting Polymer:

"A thermosetting plastic is a polymer that irreversibly becomes rigid when heated."

1. They have 3-D network of primary bonds
2. Polymerization is in all direction
3. *They become permanently hard when heated.*
4. At higher temperatures the strong cross linked bonds are broken and leads to polymer degradation
5. They are harder, stronger and brittle
6. Suitable at both low and high temp.

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 aluminum and oxygen (alumina), silicone and nitrogen (silicon nitride) and silicon and carbon (silicon carbide).

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."
- 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.

OPTICAL FIBER:

- **Optical fiber** is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair.
- Optical fibre are used most often as a means to transmit light between the two ends of the fibre and find wide usage in fiber-optic communications.

CERMETS

"Cermet is compose of ***metals and ceramics****. Cermets are used instead of metals and ceramics to avoid corrosion. Cermet is used for better conductivity."*

- Cermet has a high **thermal conductivity** and a good electrical conductivity compared to ceramic.
- Cermet has a very **high melting point** because of its elements which is metals and ceramics. Its **boiling point** is also very high.

SMART MATERIALS:

- Smart materials are a group of new and state-of-the-art materials developed in recent times and which have a tremendous influence on many of our latest technologies.
- The word "smart" implies that these materials are able to sense changes in their environment and then respond to these changes in a pre-determined manner.
- Smart materials, also called intelligent materials, are a concept that extends to both newer and traditional materials which form a part of modem sophisticated systems.

Two major categories of smart materials are discussed they are:

1. Piezo-electries
2. Shape memory alloys

Piezo-electric:

- Certain materials posses a property by which they experience a dimensional change when an electrical voltage is applied to them. Such materials are known as *piezoelectric* because of converse effect; that is they generate electricity when pressure is applied.
- Common among those which are used as piczo-electric materials are — Barium titanate (BaTiO3), lead titanate ($PbTiO_3$), lead zirconate (PbZr03), potassium niobate (KNb03) etc.

Shape Memory Alloys:

- Shape memory alloys are those materials, even after being deformed, have the ability to remember and return to their original shape and size, upon appropriate heat treatment.
- Deformation is normally carried out at relatively low temperature, whereas, shape memory effect happens due to heating.
- Among materials that arc capable of recovering significant amounts of deformation, the best known are Nickel-Titanium (NITINOL) alloys; and some Copper based alloys (Cu-Zn-Al and Cu-Al-Ni).

Semiconductor

- A semiconductor material has an electrical conductivity value falling between that of a metal, like copper, gold, etc. and an insulator, such as glass.
- Their resistance decreases as their temperature increases, which is behaviour opposite to that of a metal.
- Their conducting properties may be altered in useful ways by the deliberate, controlled introduction of impurities ("doping") into the crystal structure
- some examples of semiconductors are

silicon,

germanium, and

gallium arsenide

Insulator

- An electrical insulator is a material whose internal electric charges do not flow freely; very little electric current will flow through it under the influence of an electric field.
- This contrasts with other materials, semiconductors and conductors, which conduct electric current more easily.
- The property that distinguishes an insulator is its resistivity; insulators have higher resistivity than semiconductors or conductors.
- A perfect insulator does not exist, because even insulators contain small numbers of mobile charges (charge carriers) which can carry current.

JOINING PROCESSES.

Welding

Welding may be defined as the metallurgical joining of two metal pieces together to produce essentially a single piece of metal. Welding is extensively used in the fabrication work in which metal plates, rolled steel sections, casting of ferrous materials are joined together. It is also used for repairing broken, worn out, or defective metal part.

Principle of welding

A welding is a metallurgical process in which the junction of the two parts to be joined are heated and then fused together with or without the application of pressure to produce a continuity of the homogenous material of the same composition and characteristics of the part which are being joined.

Types of welding

Welding are classified in to two type

• Pressure welding

• Fusion welding

In Pressure welding the parts to be joined are heated only up to the plastic state and then fused together by applying the external pressure.

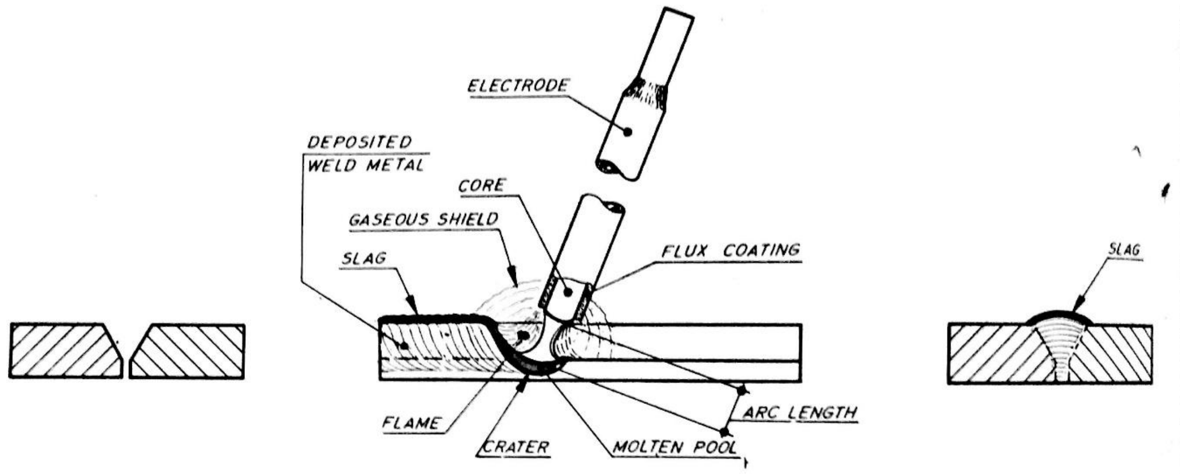
Ex: Forgewelding, resistance welding

In Fusion welding which also known as non-pressure is welding, joints of the two parts are heated to the molten state and allowed to solidify.

Ex: Arc welding, gas welding.

Arc welding

The arc welding operates under the principle that when two conductor of an electric circuit are touched together momentarily and then instantaneously separated slightly, assuming that there is sufficient voltage in the circuit to maintain the flow of current, an electric arc is formed. Concentrated heat is produced throughout the length of the arc at a temperature of about 5000 to 6000°C. in arc welding, usually theparts to be welded are wired as one pole of the circuit, and the electrode held by the operator forms the other pole. When the arc is produced, the intense heat quickly melts the work piece metal which is directly under the arc, forming a small molten metal of the electrode. The molten metal in the pool is agitated by the action of the arc, thoroughly mixing the base and the filler metal. A solid joint will be formed when the molten metal cools and solidifies. The flux coating over the electrode produces an inert gaseous shield surrounding the arc and protects the molten metal from oxidizing by coming in contact with atmosphere.



Plates Before Welding
A

Welding Process
B
Arc Welding

Welded Joint
C

Arc welding electrodes

There are two types of electrodes that are used in arc welding

(A) Consumable electrodes

(B) Non- consumable electrodes

Consumable electrodes

Consumable electrodes are the electrodes which also melts along with the work piece and fill the joint. Consumable electrodes could be either bare or coated. When bare electrodes are used globules of the molten metal while passing from the electrodes absorb oxygen and nitrogen from atmosphere. Which gets trapped in the solidifying weld metal and thereby decreases the strength of the joint Electrodes are madeup of soft steel or alloy steel The coating consists of chalk, starch, ferro manganese and binding agents.

Coated electrode facilitates:

(a) Protection of molten metal from oxygen and nitrogen by providing a gaseous shield around the arc

(b) To establish and maintain the arc throughout the welding

(c) The formation of the slag over the joint thus prevents from rapid cooling

(d) Addition of alloying element

Non- consumable electrodes

When these are used, an additional filler material is also required Advantage in using this electrode is that amount of metal deposited can be controlled which is not possible in other type of electrode.

Resistance welding

This type of welding employs the principles of both the pressure and fusion welding methods. It consistsof heating of the Parts to be welded are heated up to the plastic state and joined by applying mechanical pressure. Heating is done by passage of heavy localized electric current, the current flowing from one part of joint to other encounters a high resistance and temp increases. This method is employed for fastening thin metal sheets and wires.

General welding procedure

1. Cleaning: The surfaces of the parts to be welded need to be thoroughly cleaned for removal of dirt, oil, grease, etc.

2. Edge preparation: The process of preparing a contour at the edges of the pieces to be joined is called as edge preparation. This involves bevelling or grooving. The idea of doing this is to get fusion or penetration through the entire thickness of the member.

3. Clamping: Next, the parts to be welded are clamped suitably through jigs and fixtures to that there are no undesirable movements during welding.

4. Check for safety devices: safety devices like goggles and shield to protect the eyes, protective clothing to prevent the sparks and flying globules of molten metal, safety shoes, gloves,apron and other safety devices must be ensured

5. The initial weld: Initial tack welds are done at opposite corner of the joints to secure the pieces together. Any cracks at this stage must be chipped off as the presence of these cracks causes residual stresses. The length and spacing of the tack weld varies with the thickness of the metal and length of the joint.

6. Intermediate and final welding: The weld joint is formed through various weaving movement. During the process, filler metal and a suitable flux are used. After the intermediate run of welding, the final run is taken

7. Excess material removal: Extra material on the weld surface can be removed using tongs and chipper. The final weld is now allowed to cool and finally cleaned.

Gas welding

It is a fusion welding, in which a strong gas flame is used to raise the temperature of the work piece to melt them. As in the arc welding, a filler metal is used to fill the joint. The gases that can be used for heating are

(i) Oxygen and acetylene

(ii) Oxygen and hydrogen.

Oxy-acetylene gas mixture is most commonly used in gas welding

Oxy-acetylene welding

When Right proportions of oxygen and acetylene are mixed in the welding torch and then ignited. The flame produced is called as the oxy-acetylene flame. The temperature attained n this welding is around 3200ºC hence has an ability to melt all commercial metals.

Working:

- The typical oxy-acetylene welding process is shown in fig.
- After the initial equipment preparation, the to-be welded component setup and safety checks are completed, the pressure regulators fitted to the oxygen and oxyacetylene cylinders are adjusted to draw the oxygen and acetylene gas in the required proportions from the cylinders respectively.
- The pressure regulator in each of the cylinders is fitted with two gauges.
- One gauge indicates the gas pressure inside the cylinder and the other gauge indicates the reduced pressure at which the gas goes out.
- The respective gases from the cylinders are carried from the pressure regulator to the welding torch using the rubber hose pipe.
- Upon reaching the welding torch, these gases are allowed to mix in a mixing chamber and then are led out of the torch through the orifice of the blow pipe.
- The resultant flame at 3200^{o}C is used to melt the work pieces. To fill up the gap between work pieces and to add strength to the joint, filler rods are added to the molten metal pool.
- The molten metal pool that contains molten metal of the filler rod and the work pieces solidifies to form a welded joint.

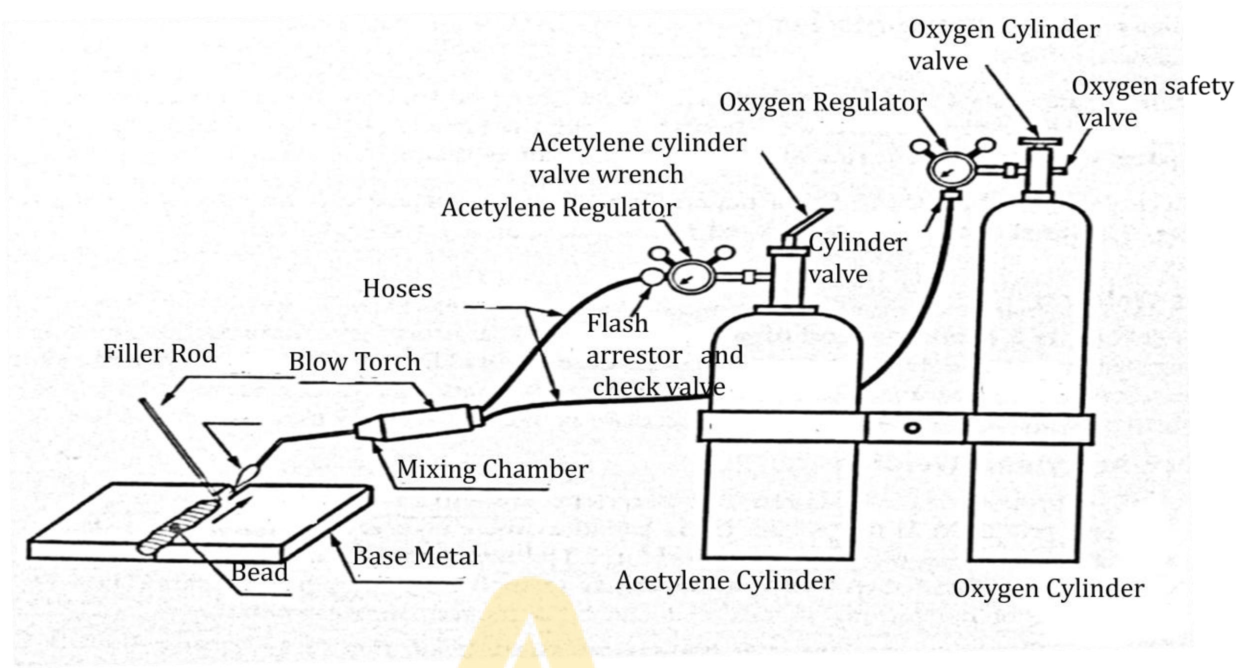


Fig. Oxy-Acetylene Welding

Types of oxy-acetylene flames

The types of flames depend on the gas ratio i.e. ratio of the parts of oxygen to the parts of the acetylene Depending on the gas ratio following flames are obtained

(i) Neutral flame

(ii) Oxidizing flame

(iii) Reducing flame (carburising flame)

(i) Neutral flame

• A neutral flame is obtained by supplying equal volume of oxygen and acetylene

• It consists of a small whitish inner cone surrounded by sharply defined blue flame

• Most of the gas welding is done using the neutral flame

(ii) Oxidizing flame

• This is obtained when there is excess of oxygen, gas ratio

• It appears to be similar to that of neutral flame but the inner white cone flame is shorter than that of neutral flame

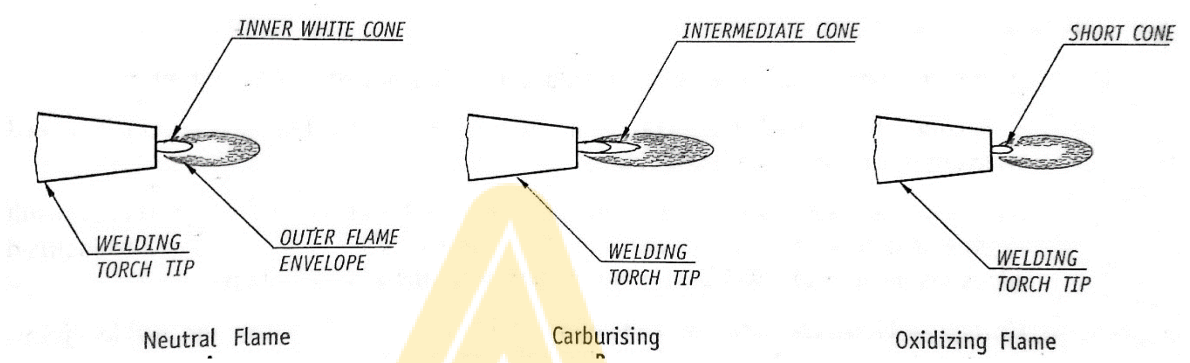
• This flame is generally used in metal cutting rather than welding since weld metal gets oxidized

(iii) Reducing flame

• This is obtained by supplying excess of acetylene in the gas ratio

• It has 3 cones, an inner white cone, surrounded by an intermediate whitish cone known as "intermediate flame feather" and a bluish envelope flame

• This flame is used for welding alloy steels, cast iron, aluminium



Advantages of oxy-acetylene welding

1. Most versatile process of welding with wide use in various manufacturing process

2. Low cost of the equipment and low cost of maintenance of the equipment

3. Because of separate heat source and filler metal the control can be exercised on the rate at which the filler metal deposits.

4. The rate of heating and cooling is slow. This help in retaining the structural homogeneity.

5. The equipment is portable and multi-functional because, apart from gas welding, it can also be used in torch brazing, braze welding, preheating and post heating.

Disadvantages

1. Difficult to attain low cost target while joining heavy section.

2. Handling and storage of gases not an easy job.

3. It takes long time for the flame to heat up the metal piece than compared to the arc welding.

4. Possible hazards due to explosion of gases.

Soldering

Soldering is a method of uniting two thin metal pieces using a dissimilar metal or alloy by the application of heat. The alloy of lead and tin is called soft solder, is used in varying proposition for sheet metal work, plumbing work and electrical junctions. The melting temp of the soft solder will be between 150̊ to 350̊ C. To clean the joint surfaces and to prevent oxidation a suitable flux is used while soldering. Zinc chloride is the flux that is commonly used in soft soldering. A soldering iron is used to apply the heat produced from the electrical source.

An alloy of copper, tin, and silver known as hard solder is used for stronger joint. The soldering temp of hard solder ranges from 600̊ to 900̊ C

Method of soldering

(i) Cleaning of joining surfaces

(ii) Application of flux

(iii) Tinning of surface to be soldered

(iv) Heating

(v) Final clean-up

(i) Cleaning of joining surfaces: Firstly, the joining surface are cleaned mechanically to make free from dust, oil scale etc. and ensure that the molten filler metal wets the surfaces.

(ii) Application of flux: Then the joining surfaces are coated with a flux usually rosin or borax. This cleans the surfaces chemically and helps the solder in making bond.

(iii) Tinning of surface to be soldered: before carrying out the soldering operation, the soldering iron must be tinned. This is to remove a thin film of oxide that forms on the copper bit, which in turns does not allow the job to be heated and thus it becomes difficult to solder. In tinning the copper bit is heated andthen rubbed with a file to clean it properly and then rotating with solder using resin. This causes the formation of a thin film of solder over the copper bit. This whole process is called tinning

(iv) Heating: the soldering iron is then heated and flowing molten filler metals fills the joints interface. Allow the soldered area to cool and then solidify thus making the joint.

(v) Final clean-up: after completing the soldering and joints are formed, clean it with steel wool or solvent to remove left over flux. After this clean the soldering iron using a damp sponge

Advantages of soldering

1. Low cost and easy to use

2. Soldered joints are easy to repair or do rework

3. The soldered joint can last for many years

4. Low energy is required to solder

5. An experienced person can exercise a high degree of control over the soldering process

Disadvantages of soldering

1. Not suitable for heavy sections

2. Temperature is limited

3. Strength is limited.

Brazing

Brazing is the method of joining two similar or dissimilar metals using a special fusible alloy. Joints formed by brazing are stronger than that of soldering. During the brazing, the base metal of the two pieces to be joined is not melted. The filler metal must have ability to wet the surfaces of the base metal to which it is applied. Some diffusion or alloying of the filler metal with base metal takes place even though the base metal does not reach its melting temperature. The materials used in brazing are copper base and silver base alloy. These two can be classified under the name spelters.

Method of brazing

1. Cleaning the surface of the parts.

2. Application of flux at the place of joint.

3. Common borax and mixture of borax and boric acid is used as flux.

4. The joint and the filler material are heated by gas welding torch above the melting temperature of the filler material.

5. It flows into the joint space and a solid joint is formed after cooling.

Advantages of Brazing

1. It is easy to learn.

2. It is possible to join virtually any dissimilar metals.

3. The bond line is very neat aesthetically.

4. Joint strength is strong enough for most non-heavy-duty type of application.

Disadvantages of Brazing

1. Brazed joints can be damaged under high temp.

2. Brazed joint require a high degree of cleanliness.

3. The joint colour is often different from that of the base metal.

Difference between Brazing, Soldering and Welding

Brazing	Soldering	Welding
In brazing filler metal is having the melting point greater than 450ºC	Soldering using the filler metal having the melting point less than 450ºC	Welding using the filler metal having the melting point nearly equal to the base metal
Joints takes place due to capillary actionbetween the base metaland the filler metal	Capillary action is also present in soldering between the base metal and filler metal.	No capillary action is present. Joint takes place due to fusion.
Base metal does not melt	Base metal does not melt.	Base metal melts in welding
Filler metal is having the melting point less than the base metal.	Filler metal is having the melting point less than the base metal.	In welding filler metal is not having the melting point less than the base metal.
Filler metal is uniformly distributedbecause of capillaryaction.	Filler metal is uniformly distributed because of capillary action	Filler metal melts and gets mixed with the base metal
Joints are stronger than soldering but weaker than welding	Joints are weaker than brazing	Joints are stronger as compared to brazing, soldering

It was uses filler metal which contains copper and zinc etc.	It uses the filler metal which contains lead and tin.	It uses the filler metal mostly having the same composition as that of base metal.

Tungsten Inert Gas(TIG) Welding:

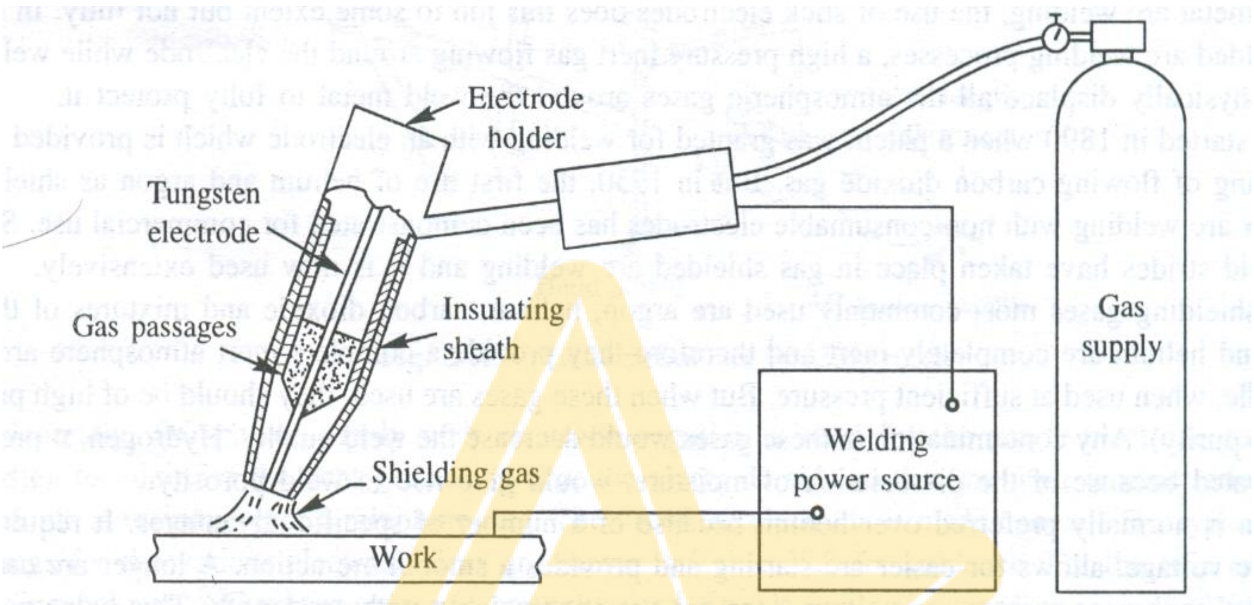


Fig. 25.19 A typical tungsten inert gas (TIG) welding setup

- In this operation, the work pieces to be joined are cleaned to remove dirt, grease and other oxides chemically or mechanically to obtain a sound weld.
- The welding current and inert gas supply are turned ON.
- An arc is struck by touching the tip of the tungsten electrode with the work piece, and instantaneously the electrode is separated from the work piece by a small distance of 1.5-3 mm such that the arc still remains between the electrode and the work piece.
- The high intensity of the arc melts the work piece metal forming a small molten metal pool. filler metal in the form of a rod is added manually to the front end of the weld pool.
- The deposited filler metal fills and bonds the joint to form a single piece of metal.
- The arc is extinguished by widening the gap between the workpiece and the electrode.
- The shielding gas is allowed to imping on the solidifying weld pool for a few seconds even after the arc is extinguished.
- This will avoid atmospheric contamination of the solidifying metal thereby increasing the strength of the joint.

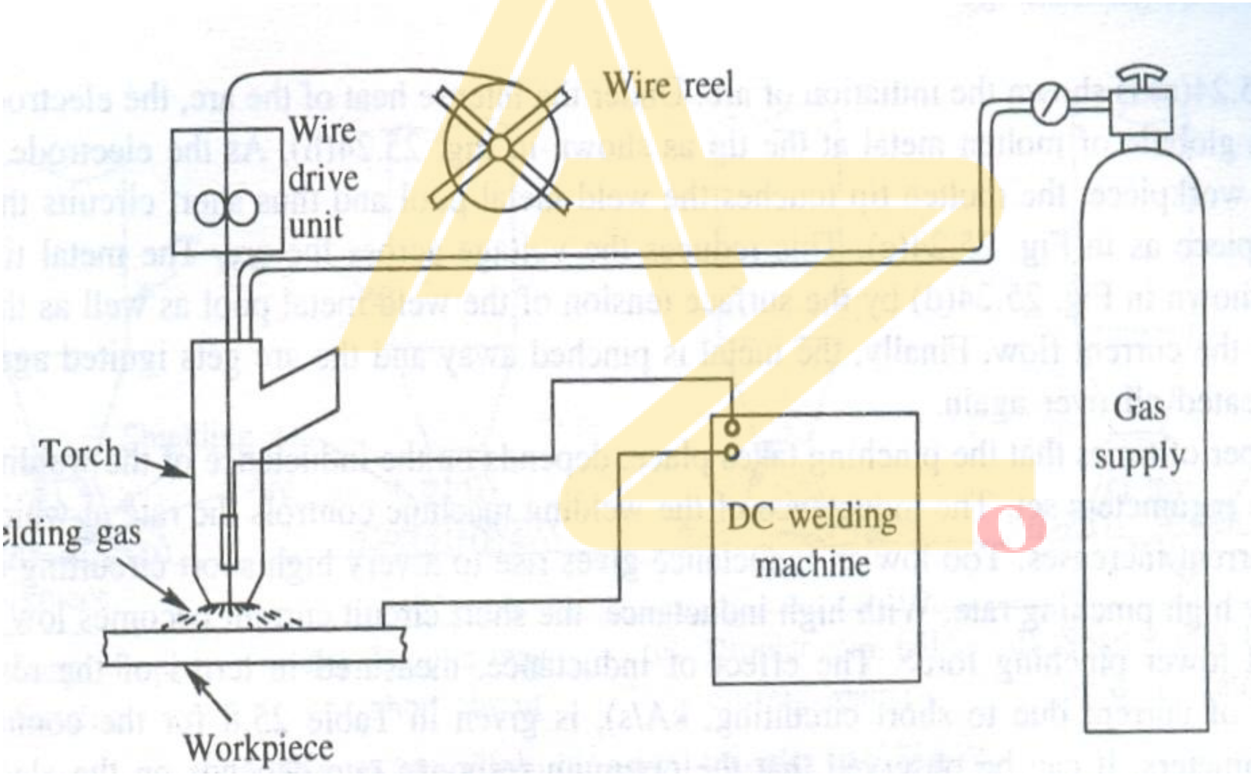
Advantages:

- Suitable for the thin metals
- Clear visibility of the arc provides the operator to have a greater control over the weld
- Strong and high quality joints are obtained
- No flux is used. Hence, no slag formation. This results in clean weld joints.

Disadvantages:

- TIG is the most difficult process compared to all the other welding processes.
- Skilled operator is required
- Process is slower
- Not suitable for thick metals.

Metal Inert Gas (MIG) Welding:



- In this operation, the workpieces to be joined are cleaned to remove dust, gease and other oxides, chemically or mechanically to obtain a sound weld. The tip of the electrode is also cleaned with a wire brush.
- The control switch provided in the welding torch is switched ON to initiate the electric power, shielding gas and the wire (electrode) feed.

- An arc is struck by touching the tip of the electrode with the work piece, and instantaneously the electrode is separated from the work piece by a small distance of 1.5-3 mm such that the arc still remains between the electrode and the work piece.
- The high intensity of the arc melts the work piece metal forming a small molten pool.
- At the same time, the tip of the electrode also melts and combines with the molten metal of the work pieces there by filling the gap between the two work pieces.
- The deposited metal upon solidification bonds the joint to form a single piece of metal.

Advantages:

- MIG welding is fast and economical
- The electrode and inert gas are automatically fed. This reduces the burden on the operator, and also helps him to concentrate on the arc.
- Weld deposition rate is high due to the continuous wire feed.
- No flux is used. Hence, no slag formation. This results in clean welds
- Thin and thick metals can be welded.
- Process can be automated.

Disadvantages:

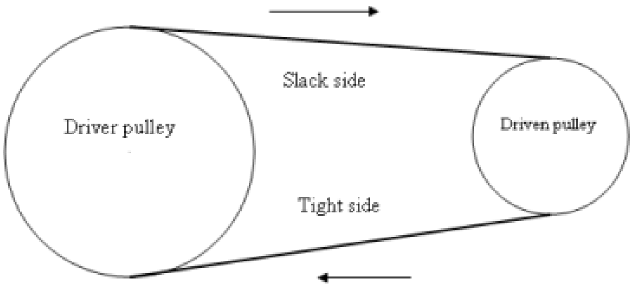
- Equipment is costlier
- Dross and porosity are the most prevalent quality problems in this process. However, extensive edge preparation can be eliminate this defect.

BELT DRIVES

Belt drives are one of the common methods generally employed whenever power or rotary motion is to be transmitted between two parallel shafts.

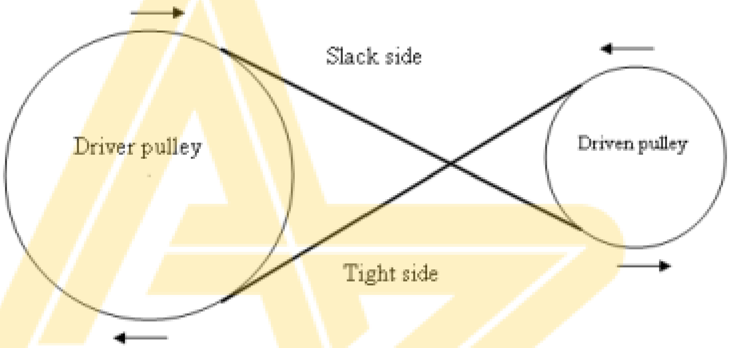
Open Belt Drive

- This type of belt drive shown in fig. is employed when the two parallel shafts have to rotate in the same direction.
- When the shafts are placed far apart, the lower side of the belt should be the tight side and the upper side must be the slack side.
- This is because, when the upper side becomes the slack side, it will sag due to its own weight and thus increases the arc of contact which in turn increases the capacity of the drive.



Crossed Belt Drive

- This type of belt drive shown in fig. is employed when two parallel shafts have to rotate in the opposite direction.
- At the junction where the belt crosses, it rubs against itself and wears off.
- To avoid excessive wear the shaft must be placed at a maximum distance from each other and operated at very low speeds.



Definitions:

Slip: It is defined as the difference between the tensions in the tight and slack sides of the belt is equal to the force of friction.

Creep: In the belt drive, the straight portions of the belt will be alternately subjected to higher and lower tensions. The slack side of the belt, having the lower tension T_2 as soon as it enters the driven pulley, will be subjected to a gradual increasing tension from T_2 to T_1.

Velocity ratio: It is defined as the ratio of the speed of the driving pulley to the speed of the driven pulley.

$$\text{Velocity ratio}=\frac{N1}{N2}$$

Open Belt System.

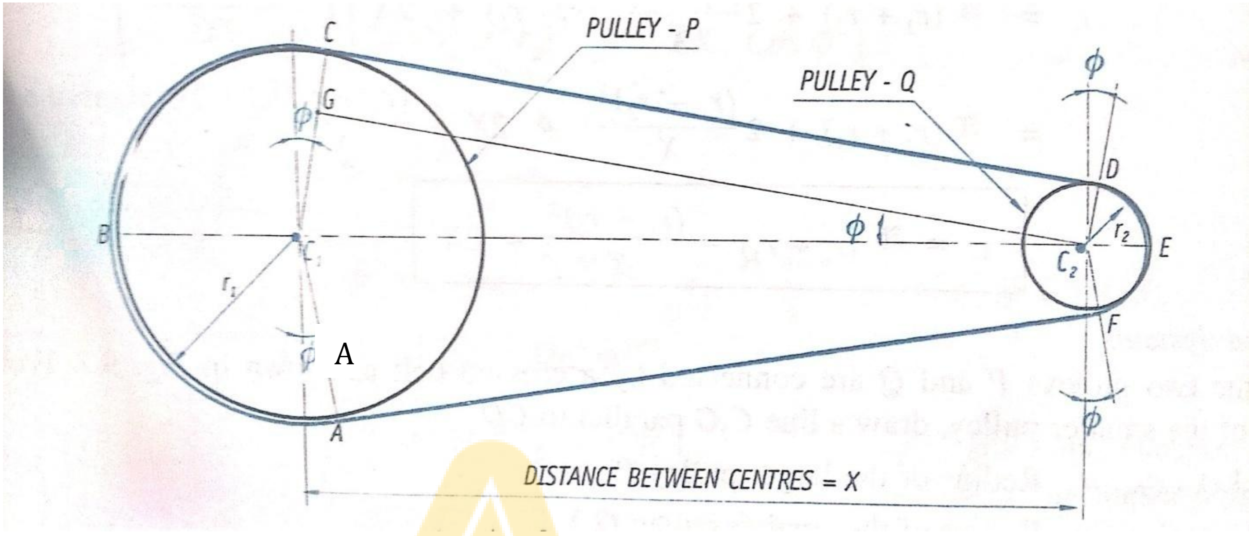
Let the two pulleys P and Q be connected by an open belt as shown in Fig. from the centre O, of the smaller pulley draw a line O_2G parallel to CD.

Let, r_1 = radius of the large pulley *P*

r_2 = Radius of the smaller pulley Q

X = Distance between the centers of the pulleys

From the geometry of the belt drive shown in fig. the length of the belt is given by,



L = Arc Length ABC + Length CD + Arc Length DEF + Length FA

= 2[Arc length BC + Length CD + Arc length DE]

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)r_1 + length\ CD + \left(\frac{\Pi}{2}-\phi\right)r_2\right]$$

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)r_1 + length\ GC_2 + \left(\frac{\Pi}{2}-\phi\right)r_2\right] \qquad (\because CD = GC_2)$$

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)r_1 + X\,Cos\,\phi + \left(\frac{\Pi}{2}-\phi\right)r_2\right] \qquad \left(\because \frac{GC_2}{X} = Cos\phi\right)$$

$$= 2\left[\frac{\Pi}{2}(r_1+r_2)+\phi(r_1-r_2)+X\,Cos\phi\right] \qquad 1$$

$$= \Pi(r_1+r_2)+2\phi(r_1-r_2)+2X\,Cos\phi$$

From the triangle GC_1C_2

$$Sin\phi = \frac{r_1-r_2}{X}$$

$$\phi = Sin^{-1}\frac{r_1-r_2}{X} = \frac{r_1-r_2}{X} \qquad \because (\phi \text{ is small}) \ldots\ldots\ldots\ldots\ldots 2$$

$$Cos\phi = \left[1 - Sin^2\phi\right]^{1/2}$$

$$= \left[1 - \frac{1}{2}\text{Sin}^2\phi\right] \qquad \text{(By Binomial Theorem and neglecting higher power)}$$

$$= \left[1 - \frac{1}{2}\left(\frac{r_1 - r_2}{X}\right)^2\right] \qquad 3$$

Substituting equ^n. (2) and (3) in (1)

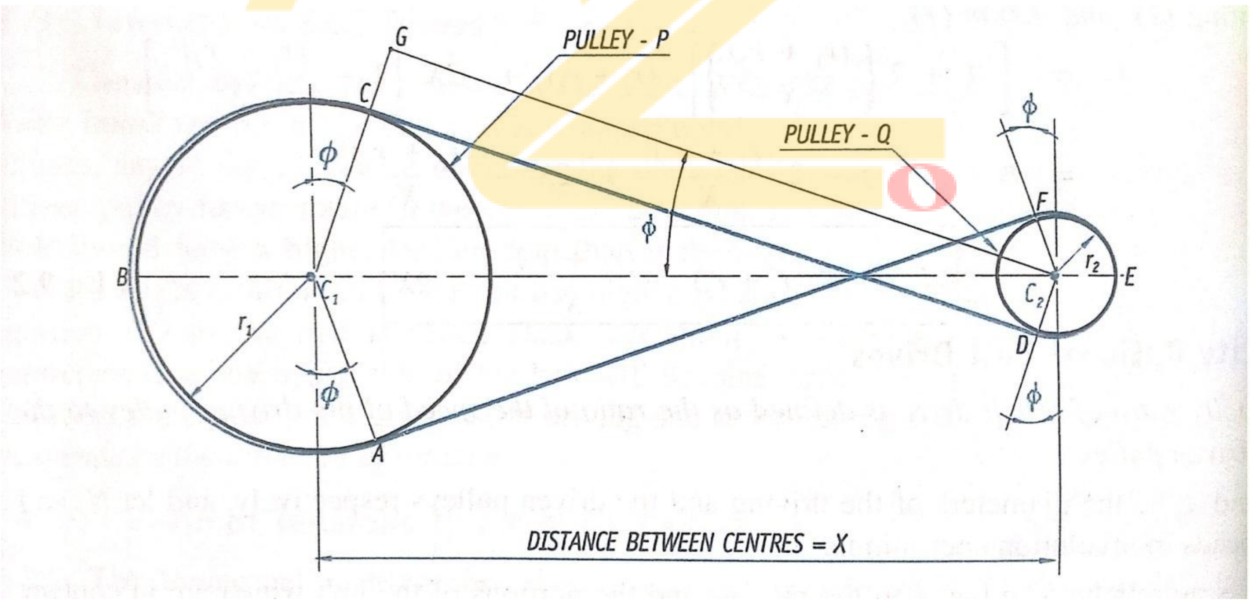
$$L = \Pi(r_1 + r_2) + 2\frac{(r_1 - r_2)}{X}(r_1 - r_2) + 2X\left[1 - \frac{(r_1 - r_2)^2}{2X^2}\right]$$

$$= \Pi(r_1 + r_2) + 2\frac{(r_1 - r_2)^2}{X} + 2X - \frac{(r_1 - r_2)^2}{X}$$

$$\boxed{L = \Pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X}$$

Crossed Belt Systems

Let the two pulleys P and Q are connected by a crossed belt as shown in Fig. from the centre C_2 of the smaller pulley, draw a line C_2G parallel to CD.



Let,

r_1 = radius of the larger pulley P

r_2 = Radius of the smaller pulley Q

X = Distance between the centres of the two pulley

From the geometry of the belt drive shown in Fig., the length of belt is given by.

L = Arc length ABC + Length CD + Arc length DEF + Length FA

= 2[Arc length BC + length CD + Arc length DE]

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)r_1 + \text{Length CD} + \left(\frac{\Pi}{2}+\phi\right)r_2\right]$$

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)(r_1+r_2) + \text{Length CD}\right]$$

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)(r_1+r_2) + \text{Length GC}_2\right] \qquad (\because \text{CD} = \text{GC}_2)$$

$$= 2\left[\left(\frac{\Pi}{2}+\phi\right)(r_1+r_2) + \text{X Cos}\phi\right] \qquad \left(\because \frac{GC_2}{2} = Cos\phi\right)$$

$$= [(\Pi+2\phi)(r_1+r_2) + 2\text{X Cos}\phi] \qquad \text{Equ}^{n}.(1)$$

From the triangle GC_1C_2,

$$Sin\phi = \frac{r_1+r_2}{X}$$

$$\phi = \text{Sin}^{-1}\frac{r_1+r_2}{X} = \frac{r_1+r_2}{X} \qquad (\because \phi \text{ is small}) \qquad \text{Equ}^{n}.(2)$$

$$Cos\phi = [1-Sin^2\phi]^{1/2}$$

$$= \left[1-\frac{1}{2}Sin^2\phi\right]$$ (By Binomial Theorem and neglecting higher powers)

$$= \left[1-\frac{1}{2}\left(\frac{r_1+r}{X}\right)^2\right]$$

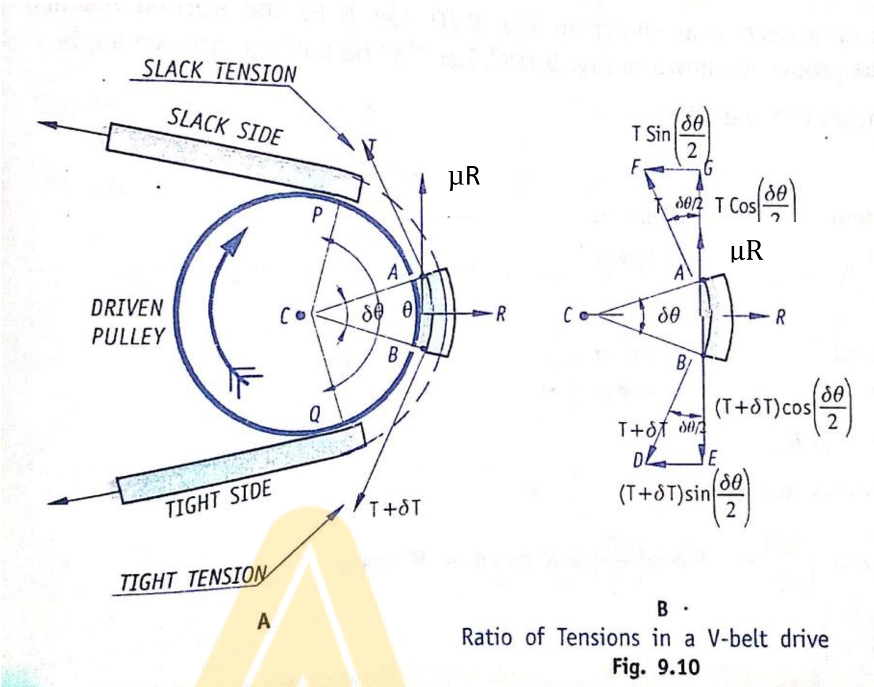
Substituting (2) and (3) in (1)

$$\text{L} = \left[\Pi+2\left(\frac{r_1+r_2}{X}\right)\right](r_1+r\ ) + 2X\left[1-\frac{(r_1+r_2)^2}{2X^2}\right]$$

$$\text{L} = \Pi(r_1+r_2) + 2\left[\frac{(r_1+r_2)^2}{X^2}\right] + 2X - \left[\frac{(r_1+r_2)^2}{X}\right]$$

$$\boxed{\text{L} = \Pi(r_1+r_2) + \left[\frac{(r_1+r_2)^2}{X}\right] + 2X}$$

RATIO OF TENSIONS IN BELT DRIVES:



Ratio of Tensions in a V-belt drive

Fig. 9.10

The ratio of tensions on the tight side to that of the slack side is called the ratio of tensions.

Let upper side be the tight side and lower side be the slack side.
Let,
T_1 = Tension on the tight side
T_2 = Tension on the slack side
ɵ = Angle of contact in ratios

Consider an elemental length CD of the belt as shown in fig. Let the angle of contact of this element be δɵ. Let T and δT be the tensions on slack side and tight sides respectively.

Let μ = coefficient of traction between the belt surface and the pulley surface. The acting on the element are:

i) Tension on the slack side = T
ii) Tension on the tight side = T + δT
iii) Normal reaction force existed by pulley on the belt = R
iv) the force of friction μR acting perpendicular to R

For the equilibrium of the element, the resultant force along horizontal and vertical directions must be equal to zero.

i.e., $\sum F_H = 0$ and $\sum F_v = 0$

$$\sum F_H = R - T\sin\frac{\delta\theta}{2} - (T+\delta T)\sin\frac{\delta\theta}{2}$$

i.e.,

$$R = T\sin\frac{\delta\theta}{2} + (T+\delta T)\sin\frac{\delta\theta}{2}$$

$$= 2T\sin\frac{\delta\theta}{2} + (\delta T)\sin\frac{\delta\theta}{2}$$

Since the angle δɵ is very small.

$\text{Sin}\,\frac{\delta\theta}{2} \approx \frac{\delta\theta}{2}$ and the product $\delta T \sin\frac{\delta\theta}{2}$ can be neglected

$\therefore$
$$R = 2T\,\frac{\delta\theta}{2}$$
$$R = T\delta\theta \qquad \textbf{Equ. (1)}$$

Now $\sum F_v = 0$

i.e.
$$\mu R + TCos\frac{\delta\theta}{2} - (T + \delta T)Cos\frac{\delta\theta}{2} = 0$$

i.e.,
$$\mu R - (\delta T)Cos\frac{\delta\theta}{2} = 0$$

or,
$$\mu R = (\delta T)Cos\frac{\delta\theta}{2}$$

$\because$ *angle* $\frac{\delta\theta}{2}$ *is* small

$$\text{Cos}\,\frac{\delta\theta}{2} = 1$$

$\therefore$
$$\mu R = \delta T \qquad \text{Equ. (2)}$$

From Equ. (1) and (2)
$$\mu T\delta\theta = \delta T \qquad \text{Equ. (3)}$$

For the total length of contact AB, of the belt for which the angle of contact varies from 0 to θ and the tension varies from T_2 to T_1, integrating the equation (3).

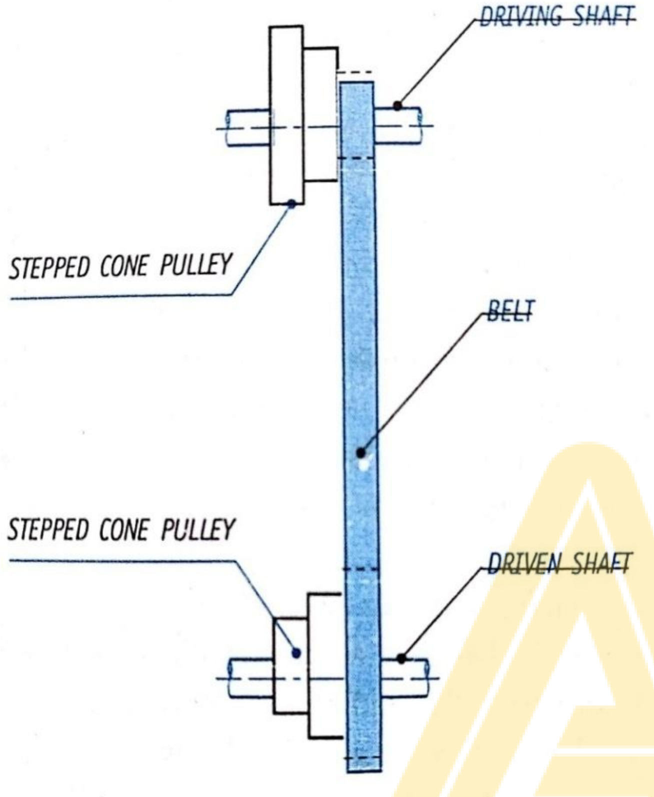
$$\int_{T_2}^{T_1} \frac{\delta T}{T} = \int_0^{\theta} \mu\delta\theta$$

i.e.,
$$\ln\left(\frac{T_1}{T_2}\right) = \mu\theta$$
$$\boxed{\left(\frac{T_1}{T_2}\right) = e^{\mu\theta}}$$

Taking logarithm on both sides,

$$\log\left(\frac{T_1}{T_2}\right) = \mu\theta \log e$$
$$\log\left(\frac{T_1}{T_2}\right) = \mu\theta \log 2.718\,281$$
$$\log\left(\frac{T_1}{T_2}\right) = \mu\theta * 0.4343$$
$$\boxed{\log\left(\frac{T_1}{T_2}\right) = 0.4343 * \mu\theta}$$

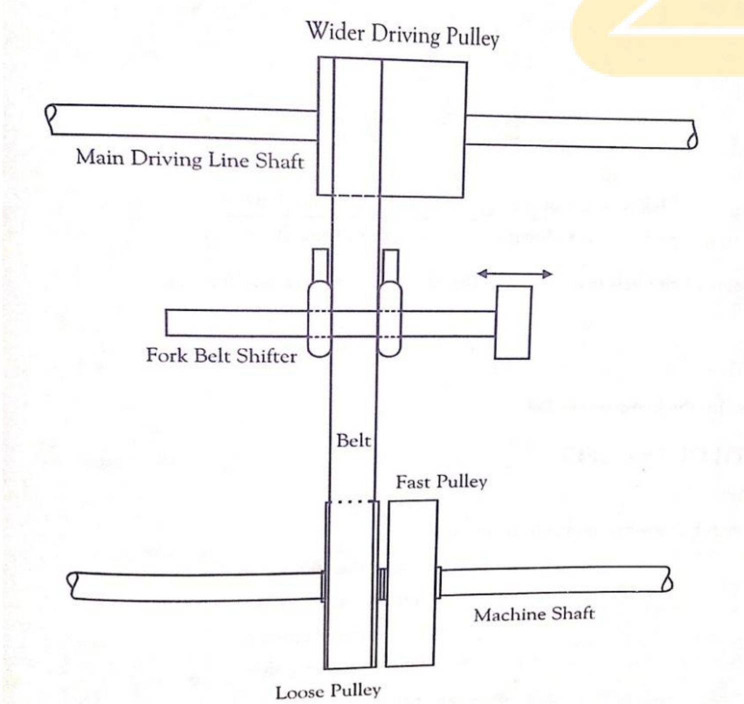
Stepped Cone Pulley or Speed Cone Pulley:



Stepped Cone Pulley

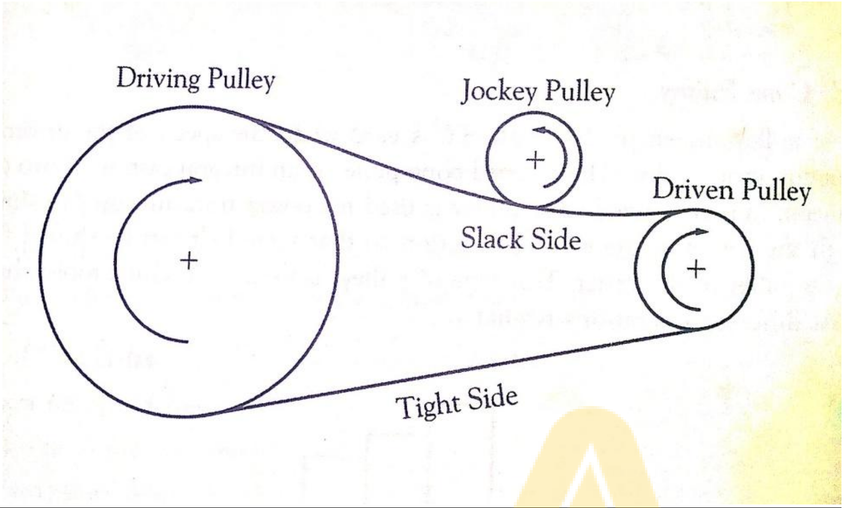
- A stepped cone pulley also called a speed cone, shown in fig.
- It is used when the speed of the driven shaft is to be changed very frequently as in the case of machine tools such as lathe, drilling machine etc.,
- A stepped cone pulley is an integral casting having three or more number of pulleys of different sizes one adjacent o the other as shown in fig.
- One set of stepped cone pulleys is mounted in reverse on the driven shaft.
- An endless belt will be wrapped around one pair of pulleys.
- By shifting the belt from one pair of pulley to the other, the speed of the driven shaft can be varied.
- The diameters of the driving and driven pulleys are such that same belt will operate when shifted on different pairs of pulleys.

Fast and Loose Pulley:



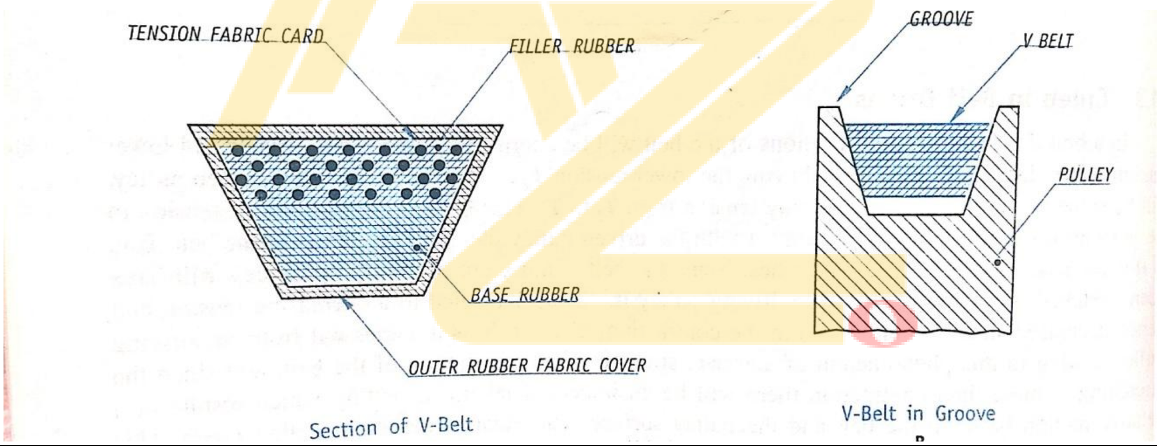
- When a number of machines obtain the drive from a main driving shaft, often it may require to run some of the' machines intermittently without having to *start and stop*" the main driving shaft every time.
- This can be accomplished by mounting two pulleys known as fast and loose pulley.
- When the belt is on the fast pulley, the power is transmitted to the machine shaft.
- When the machine shaft is to be brought to the rest, the belt is shifted from the fast pulley to the loose pulley.
- The axial movement of the loose pulley towards the fast pulley is prevented by adjacent to its boss that of the fast pulley.

Jockey Pulley:



In an open belt drive arrangement, if the centre distance is small, or if driven pulley is very small, then the arc of contact of the belt with the driven pulley will be very small, which reduces the tensions in the belt, or if the required tension of the belt cannot be obtained by other means, an idler pulley, called jockey pulley is placed on the slack side of the belt as shown in fig. This increases the arc of contact and thus the tensions which results in increases power transmission

V-Belts:



- ➢ These appear trapezoidal in cross section. These are moulded as endless loops from rubber, reinforced with fibrous material.
- ➢ These belts run in the V-grooved pulleys or sheaves.
- ➢ Multiple V-belts are used when the power transmitted is too great for a single belt.
- ➢ Power from 0.5 to 150 kW can be transmitted using V-belts
- ➢ It is used for general engineering applications, from domestic appliances to heavy duty rolling machines.

ADVANTAGES and DISADVANTAGES OF V BELTS

1. It can transmit higher power
2. It can be used for smaller centre distances
3. It can permit large speed ratios
4. There is no slipping of the belt from the pulley
5. In an emergency it is possible to continue the drive temporarily even if one of the belts snap
6. It is possible to operate with the shaft axes in any position
7. Several machines can be driven from a single driving shaft

DISADVANTAGES

1. The pulley construction is more complex in a V-belt drive when compared to flat belt drive
2. Durability of V-belts is less compared to flat belts
3. Not suitable for large center distances
4. It is a costlier system than flat belt drive.

NUMERICALS

1. Power is to be transmitted from a shaft to another by means of a belt drive. The diameter of the larger pulley is 600 mm and that of the smaller pulley is 300 mm. The distance between the centres of the two pulleys is 3 meter. If the axes of the two shafts are in the same plane and parallel to each other, find the length of the belt required for: (i) open belt drive and (ii) crossed belt drive.

Sol.

Radius of Larger pulley $r_1 = \frac{600}{2} = 300mm$

Radius of Smaller pulley $r_2 = \frac{300}{2} = 150mm$

$\left.\begin{array}{l}\text{Distance between the axes of the}\\ \text{Driving and driven shafts}\end{array}\right\}$ X = 3 m = 3000 mm

Length of belt in the open System:

$$L = \prod(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X$$

$$L = \prod(300 + 150) + \frac{(300 - 150)^2}{3000} + 2\,x\,3000$$

L = 7421.2 mm

Length of belt in the crossed system:

$$L = \prod(r_1 + r_2) + \left[\frac{(r_1 + r_2)^2}{X}\right] + 2X$$

$$L = \Pi(300+150) + \left[\frac{(300+150)^2}{3000}\right] + 2\,x\,3000$$

$$\boxed{L = 7481.2 \text{ mm}}$$

2. An engine is driving a generator by means of a belt. The pulley on the driving shaft has a diameter of 55 cm and runs at 276 rpm. If the radius of the pulley on the generator is 15 cm. find its speed in rpm.

Sol. *Engine*: Driving System

$d_1 = 55$ cm

$N_1 = 276$ rpm

Generator: Driving system

$d_2 = 2r_2$ $N_2 = ?$

$= 2 \text{ x } 15 = 30$ cm

Velocity ratio $\frac{N_1}{N_2} = \frac{d_2}{d_1}$

$$N_2 = \frac{d_1}{d_2} x N_1$$

$$N_2 = \frac{55}{30} x 276$$

$$N_2 = 506 \text{ rpm}$$

3. A motor running at 1750 rpm drivers a line shaft at 800 rpm. If the diameter of the pulley on the motor shaft is 160 mm. find that of the pulley on the line shaft.

Sol.

Motor: <u>**Driving system**</u>

$N_1 = 1750$ rpm

$d_1 = 160$ mm

Line shaft: <u>**Driven System**</u>

$N_2 = 800$ rpm

$d_2 = ?$

Velocity Ratio $\frac{N_1}{N_2} = \frac{d_2}{d_1}$

$$d_2 = d_1 x \frac{N_1}{N_2}$$

$$d_2 = 160 \text{ x } \frac{1750}{800}$$

$$d_2 = 350 mm$$

4. A shaft running at 100 rpm is to drive a parallel shaft at 150 rpm. The pulley on the driving shaft is 35 cm in diameter. Find the diameter of the driven pulley. Calculate the linear velocity of the belt and also the velocity ratio.

Sol.

<u>**Driving shaft**</u>**:**

$N_1 = 100$ rpm

$d_1 = 35$ cm

<u>**Driven Shaft**</u>

$N_2 = 150$ rpm

$d_2 = ?$

<u>**To find:**</u>

Linear velocity of the belt=?

Velocity ratio = ?

a) Velocity Ratio $= \frac{N_1}{N_2}$

$$= \frac{100}{150}$$

$$= \frac{100}{150}$$

$$= \frac{2}{3}$$

Velocity Ratio = 2 : 3

b) *Now,*

$$\frac{N_1}{N_2} = \frac{d_2}{d_1}$$

$$d_2 = \frac{N_1}{N_2} x d_1$$

$$d_2 = \frac{100}{150} x35$$

$$d_2 = 23.33\,\text{cm}$$

c) Linear velocity of the belt = $\pi\ d_1\ N_1$

$= \pi$ x (35/100) x 100

= 109.95 m/min.

5. The sum of the diameters of two pulleys A and B connected by a belt is 900 mm, if they run at 700 and 1400 rpm respectively, determine the diameter of each pulley.

Sol.

$d_A + d_B = 900$ mm $\quad N_A = 700$ rpm $\quad N_B = 1400$rpm

Velocity ratio $\frac{N_{A1}}{N_B} = \frac{d_A}{d_B}$

$$\frac{700}{1400} = \frac{d_A}{d_B}$$

$$d_A = 2d_B$$

But,

$$d_A + d_B = 900$$

Substituting d_A from equation 1 in equation 2

i.e., $2d_B + d_B = 900$

$d_B = 300$ mm

$d_A = 2d_B$

$d_A = 2$ x 300

$d_A = 600$ mm

6. A flat open belt drive consists of pulleys of diameter 1000 mm and 500 mm with the centre distance of 1500 mm. The coefficient of friction between the pulley and the belt is 0.3. when the maximum tension in the belt is 700N, find the effective pull of the belt drive.

Sol:

$D_1 = 1000$ mm $\quad$ $D_2 = 500$ mm $\quad$ $X = 1500$ mm

$r_1 = 500$ mm $\quad$ $r_2 = 250$ mm $\quad$ $\mu = 0.3$

$T_1 = 700$ N

For an open belt drive,

$\therefore$

$$Sin\phi = \frac{r_1 - r_2}{X}$$

$$\phi = Sin^{-1}\frac{r_1 - r_2}{X}$$

$$\phi = \text{Sin}^{-1}\frac{500 - 250}{1500}$$

$$\phi = \text{Sin}^{-1}\frac{1}{6}$$

$$\phi = 9.59^{\circ}$$

The angle of lap is always considered for the smaller pulley,

$$\theta = 180 - 2\phi$$

$$\therefore \quad = 180 - (2x9.59)$$

$$= 160.82^{\circ}$$

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$\log\left(\frac{T_1}{T_2}\right) = 0.4343\mu\theta$$

$$= \frac{0.4343x0.3x160.82x\Pi}{180}$$

$$= 0.3657$$

Taking antilogarithms,

$$\frac{T_1}{T_2} = 2.321$$

$$T_2 = \frac{T_1}{2.321}$$

$$= \frac{700}{2.321}$$

$$= 301.6N$$

$\therefore$ Effective pull in the belt drive $= T_1 - T_2$

$= 700 - 310.6$

$= 398.4$ N

GEAR DRIVES

- Gear drives find a very prominent place in mechanical power transmission.
- Gear drives are preferred when considerable power has to be transmitted over a short centre distance positively with a constant velocity ratio.

Types of Gears

There are various types of gears to suit various applications. They differ in the shape of the gear wheel like cylindrical or conical or elliptical, the orientation of their axes and the angle at which the teeth mesh, Gear drives transmit power between the shafts when their axes are: 1) parallel or 2) intersecting or 3) neither parallel nor intersecting. The different types of Gears used in these cases are:

1. *Spur Gears* - For parallel axes shafts
2. *Helical Gears* - For both parallel and Non-parallel and Non-intersecting Axes shafts
3. *Bevel Gears* – For Intersecting Axes shafts
4. *Worm Gears* – For Non-Parallel and Non-co-planar Axes shafts.
5. *Rack and pinion* – For converting Rotary motion into linear motion.

1. Spur Gears:

- When the axes of the driving and driven shafts are parallel and co-planar as shown in Fig. 1. and the teeth of the gear wheels are parallel to the axes, the gears are called Spur Gears.
- Teeth of the spur gears are cut on the circumference of the cylindrical discs.
- The contact between the mating gears will be along a line, hence spur gears can transmit higher power.
- Because of the instantaneous line contact when the teeth mesh, noise will be very high.
- They are widely used in machine tools, automobile gear boxes and in all general cases of power transmission where gear drives are preferred.

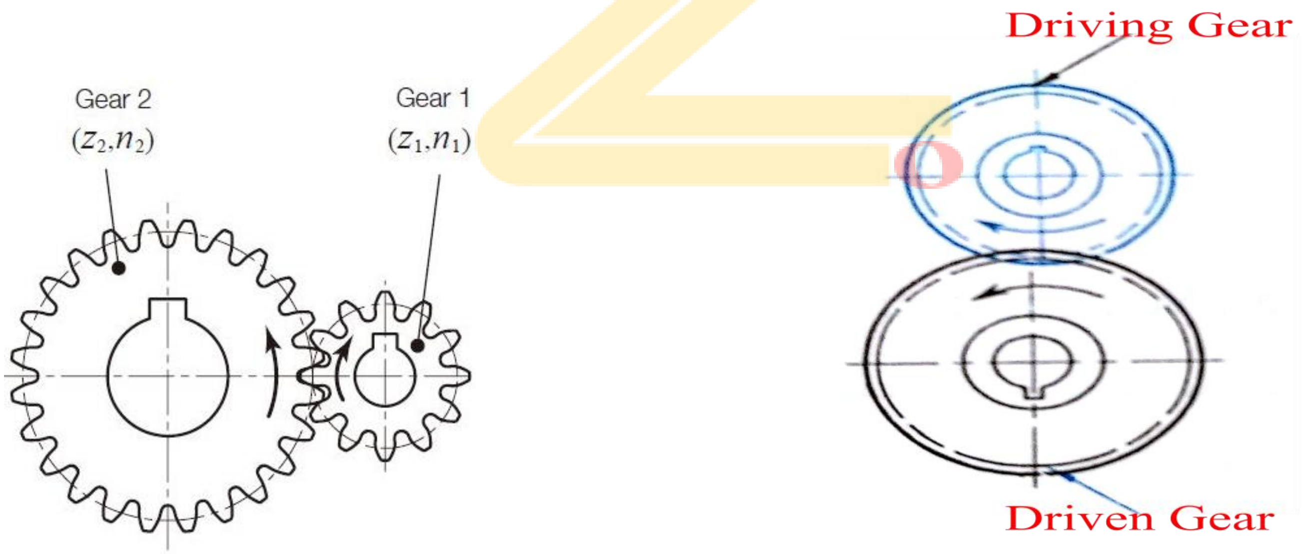
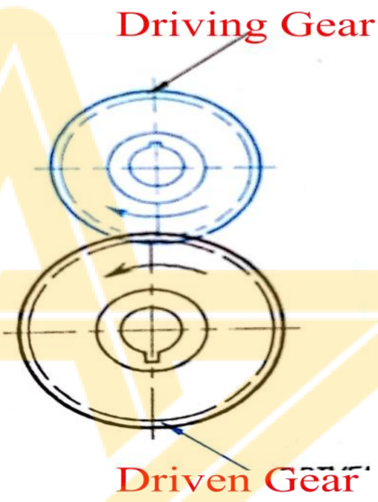


Fig. Spur gear

2. Helical Gears:

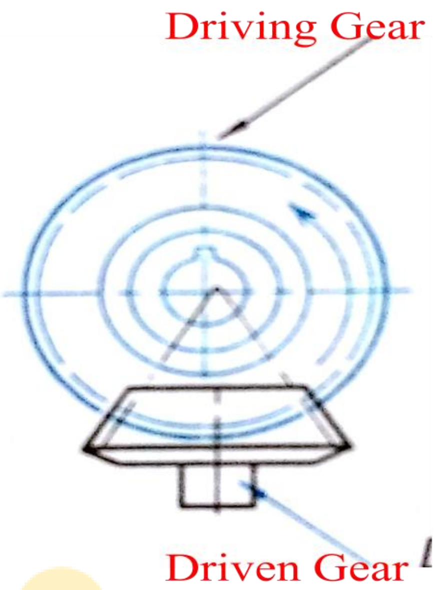
- Helical gears are similar to the spur gears except that the teeth are cut in the form of the helix around the gears as shown in Fig. 2.

- Helical gears are used for transmitting power between two parallel shafts and also between non-parallel, non-intersecting shafts.
- The curvilinear tooth contact is progressive, i.e., it extends diagonally across the meshing teeth starting first at one end of a pair of engaging teeth, then, a little further along and so on, progressively to the end of the particular tooth.
- Helical gears are preferred to spur gears when smooth and quite running at higher speeds are necessary.
- The main disadvantages of the helical gears are that it produces and thrusts on the driving and driven shafts.
- Generally they are used in automobile power transmission.



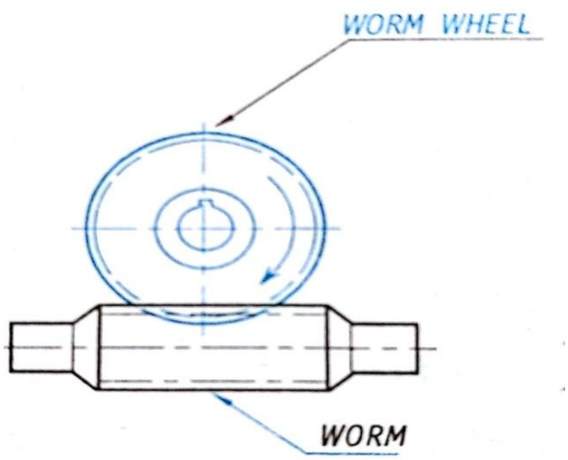
3. Bevel gears

- When the axes of the two shafts are inclined to one another, and interest when produced, bevel gears shown in Fig. 4.
- Teeth of the bevel gears are cut on the conical surfaces.
- The most common examples of power transmission by bevel gears are those in which the axes of two shafts are at right angles to each other.
- When two bevel gears have their axes at right angles and are of equal sizes, they are called miter gears.



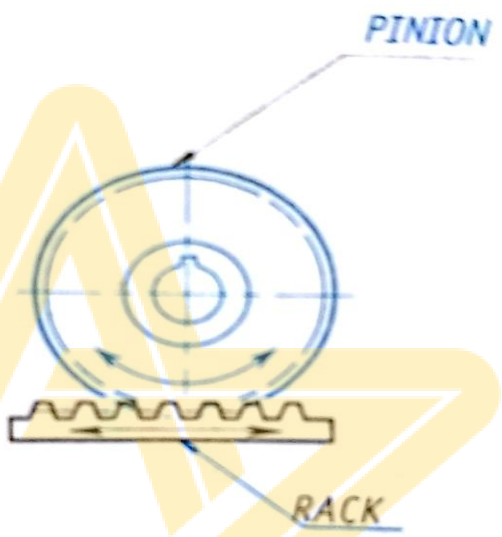
4. Worm and Worm Wheel

- Worm gears are used to transmit power between the driving and driven shafts having their axes at right angles and non-coplanar as shown in fig. 4.
- A worm drive consists of a worm (essentially a screw) which may have one or more number of helical threads of trapezoidal shape cut on it and a worm wheel ---a gear wheel with the tooth profile consisting of a small segment of a helix which engages with the worm.
- Worm gears are suitable for transmission of power when a high velocity ratio as high as 60:1 is required.
- They are generally employed in machine tools, like lathe, milling, drilling machines etc. to get large speed reduction.
- Another important characteristic of the worm and worm wheel drive is that it offers itself locking facility between the driven and the driving units when the direction of the drive is reversed.



5. Rack and Pinion

- When a rotary motion is to be converted into a linear motion, rack and pinion arrangement is used.
- Rack is a rectangular bar with a series of straight teeth cut on it as shown in fig.5.
- Theoretically rack is considered to be a spur gear of infinite diameter.
- Rack and pinion arrangement finds their application in machine tools, such as, lathe, drilling, planning machines, and on some steep rail tracks.
- Where the teeth of the locomotive wheel mesh with a rack embedded in the ground, offering the locomotive improved traction.



Velocity Ratio of Gear Drives

The velocity ratio of a gear drive is defined as the ratio of the speed of the driven gear to the speed of the driving gear. Let d_1 and d_2 be the pitch circle diameters of the driving gear respectively. Let T_1 and T_2 be the number of teeth on the driving and driven gears respectively. Let N_1 and N_2 be their speed in revolutions per minute.

Since there is no slip between the pitch cylinders of the two gear wheels, the linear speed of the two pitch cylinders must be equal.

$$\therefore \begin{bmatrix} \text{Linear Speed of the pitch cylinder} \\ \text{representing the Driving Gear} \end{bmatrix} = \begin{bmatrix} \text{Linear Speed of the pitch cylinder} \\ \text{representing the Driven Gear} \end{bmatrix}$$

i.e.,
$$\prod d_1 N_1 = \prod d_2 N_2$$

i.e.,
$$\frac{N_1}{N_2} = \frac{d_2}{d_1} \qquad \text{Equ}^n. (1)$$

The circular pitch for both the meshing gears remains same.

i.e., $$p_c = \frac{\prod d_1}{T_1} = \frac{\prod d_2}{T_2}$$

i.e., $$\frac{d_2}{d_1} = \frac{T_2}{T_1}$$ Equ^n. (2)

From equations 1 and 2,

Velocity Ratio of a gear Drive = $$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1}$$ Equ^n. (3)

Velocity ratio of the worm and worm wheel is expressed as:

$$[Velocity\ Ratio] = \frac{RPM\ of\ the\ worm}{RPM\ of\ the\ Worm\ wheel} = \frac{Number\ of\ Teeth\ on\ Worm\ wheel}{Number\ of\ Teeth\ on\ the\ Worm}$$

Numerical:

1. Two gear wheels having 80 teeth and 30 teeth mesh with each other. If the smaller gear wheel runs at 480 rpm, find the speed of the larger wheel.

Sol.

Larger Gear wheel: $T_1 = 80$, N_1=?

Smaller Gear Wheel: T_2, N_2 =480

Velocity ratio of simple gear train,

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

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

$$N_1 = \frac{30}{80} x 480$$

$$N_1 = 180 rpm$$

2. A gear wheel of 20 teeth drives another gear wheel having 36 teeth running at 200rpm. Find the speed of the driving wheel and the velocity ratio.

Sol.

Driving wheel:	***Driven Wheel:***	***Velocity ratio=?***
T_1=20 N	T_2=36N	
N_1=?	N_2=200	

Velocity ratio of simple gear trains,

$$\frac{N_1}{N_2} = \frac{T_2}{T_1}$$
$$N_1 = \frac{T_2}{T_1} x N_2$$
$$N_1 = \frac{36}{20} x200$$
$$N_1 = 360 rpm$$

$$Velocity\ \text{ratio} = \frac{N_1}{N_2}$$
$$= \frac{360}{200}$$
$$Velocity\ \text{ratio} = 1.8:1$$

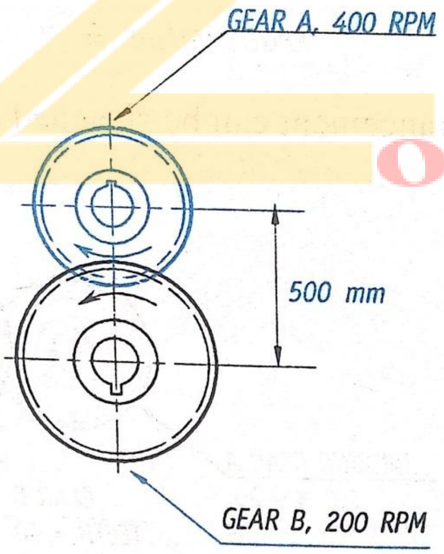
3. Two spur gears A and B connect two parallel shafts that are 500 mm apart. Gear A runs at 400rpm and gear B at 200 rpm. If the circular pitch is given to be 30mm, calculate the number of teeth on gears A and B.

Sol.

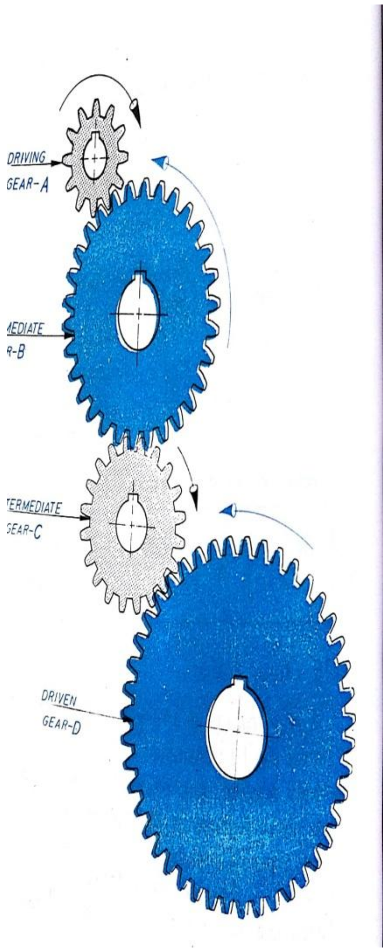
N_A = 400rpm, N_B = 200rpm P_c = 30mm T_A=? T_B=?

Let, d_A and d_B represent the diameters of gears A and B

$$\text{Velocity ratio} = \frac{N_A}{N_B} = \frac{d_B}{d_A}$$
$$= \frac{400}{200} = \frac{d_B}{d_A}$$
$$= d_B = 2d_A$$
$$\text{Center distance} = 500 = \frac{1}{2}(d_B + d_A)$$
$$= 1000 = (d_B + d_A)$$
from equation 1 and 2, we get
$$d_A = 333.34 \text{ mm}$$
$$d_B = 666.66 \text{ mm}$$



Simple Gear Train



Compound Gear Train