UTILIZATION OF ELECTRICAL ENERGY AND TRACTION

CONTENTS

S.S Mana

Electrolysis Process

Electrolysis

It is a chemical process in which direct electric current is passed through an electrolyte containing ionic compounds, which can be either in molten state or in aquoes phase.

During electrolysis the anion moves towards the anode & the cation moves towards the cathode, the experimental set up in which electrolysis take place is called an electrolytic cell.

Electrolytic cell

The electrolysis reaction is occuring in an electrolytic cell. The cell occuring in the electrolytic cell is always non-spontaneous. External electronics energy is used to drive this non-spontaneous reaction. In this cell, the anode is located at the right side & the cathode is located at the right side. At anode, oxidation reduction occur & at cathode, reduction reaction occur

Anion migrate towards the anode & get liberated, cation migrade towards cathode & get deposited.

Oxidation.

The gain of oxygen or loss of hydrogen or the loss of an electron in a species during a redox reaction is called oxidation. During electrolysis oxidation take place at the anode.

Reduction

The loss of oxygen or gain of hydrogen or the gain of electron in a species during a redox reaction is called reduction. During electrolysis reduction take place at the cathode.

Electrodeposition

The process of depositing a coating of one metal over another metal or non-metal, electrically is called the electrodeposition. It is used for protective decorative and functional purpose & includes such processes as electroplating/electroforming/electrotyping etc.

Factor on which quality of electrodeposition depends

→ **Nature of electrolyte** - The electrolyte from which complex ion can be obtained provide a smooth deposit.

→ **Current density** - The deposit of metal will be uniform and fine grained if the current density is used at the rate higher than is used.

→ **Temperature** - A low temp of the solution favours formation of small crystal of metal & high temp ~~larger~~ large crystal.

→ **Conductivity** - The solution of good conductivity provides economy in power consumption & also reduce the tendency to form creats & rock deposits.

→ **Electrolytic Concentration** - By increasing the concentration of the electrolyte, higher current density can be achieved.

→ **Addition Agent**

→ **Throwing Power** - It is defined as the ability of the electrolyte to produce, even irregular surface.

It can be improved by 2 ways
→ by increasing the distance between anode & cathode.
→ By reducing the voltage drop at the cathode surface.
→ Polarisation.

Faraday's law of electrolysis

1st law - It states that, the mass of element deposited at an electrode is directly proportional to the charge(Q) in coulumbs

$m \propto Q$, Z = electrochemical equivalent
$m \propto (It)$ I = steady current in Amps
$m = ZIt$ t = time for which 'I' flows through the electrolyte.

If $I = 1$ & $t = 1$, then
$m = Z$.

→ Electrochemical equivalent 'Z' can be defined as the mass of the substance deposited or liberated per unit charge, unit Z = $\frac{kg}{Coulomb}$

2nd law

It states when the same quantity of electricity is passed through different electrolyte, the mass of different ion, that are liberated at the electrode are directly proportional to their chemical equivalent weight.

$$\frac{\omega_1}{\omega_2} = \frac{E_1}{E_2}$$

ω = mass of the substances in gram
E = chemical equivalent weight.

Chemical Equivalent (E) - It is defined as the weight of that substance which will combine or displace the unit weight of hydrogen.

$$\text{chemical equivalent} = \frac{\text{Atomic weight}}{\text{valency}}$$

Current efficiency - It is defined as the ratio of actual quantity of substance deposited or liberated to the theoretical quantity as calculated from the actual law.

$$\text{current efficiency} = \frac{\text{actual quantity of substance deposited/liberated}}{\text{theoritical} \quad '' \quad '' \quad ''}$$

→ The value of current efficiency lies b/w 90-98%. In certain case the 'η' is very low. Ex- Chromium plating (15-18%)

Energy efficiency

It is defined as the ratio of ~~theortl~~ theoritical energy reqd to the actual energy reqd for deposting a given quantity of metal.

$$\text{energy } \eta = \frac{\text{theoritical energy reqd}}{\text{actual} \quad '' \quad ''}$$

Electro extraction

Extraction of metal is an electro chemical process employed for production of metal with commercially acceptable purity.

There are 2 method for extraction of metals.

1st - The ore is treated with a strong acid to obtain a salt & the solution of such a salt is electrolysed to liberate the metal.

2nd - It is used when the ore is available in molten state or can diffuse and in this method the ore which is in a molten state is electrolysed in a furnace.

Example of extraction of metal.

Extraction of zinc - The ore consisting of zinc is treated with conc. sulphuric acid, roasted and passes through other processes to get rid of impurity by precipitation - The zinc sulphate solution is then electrolysed. The cell consist of large lid line wooden boxes having Al cathode & Pb anode.

The current density is 1000 amp/sq. unit.

Zinc is deposited on cathode.

Extraction of Aluminium - Ore of Al, bauxite & cryolite. Bauxite is treated chemically & reduced to Al oxide & then dissolve in cryolite & electrolyte.

The furnace is lined with carbon the temp of furnace is about 1000°C to keep the electrolyte in a fused state. Al deposited at the cathode.

Application of Electrolysis :

1. Electro deposition, Electroplating, electrodeposition of rubber etc electrometalisation, electrofacing, electro forming, electrotyping
2. Manufacture of chemicals.
3. Anodising
4. Electro polishing
5. Electro cleaning
6. Electrostriping
7. Electrometallurgy
8. Electro extraction & electro refining

Electroplating -

It is the process of appling a metal coating on another conducting surface through an electrodeposition process. It is defined as the electrodeposition of metal upon metallic surface.

There are 2 operation involve in electroplating

① Cleaning ② Deposition.

Electrodeposition of Rubber

Rubber latex obtain from the tree consist of very fine collidal particles, of rubber suspended in water, like other collidal solutions, particles of rubber are -vely charged. On electrolysis of the solution, the rubber particles migrate towards the anode and deposit on cathode. Current density is $100\ A/m^2$ is used.

Electrometalisation

It is the process of depositing metal on conducting base for decoration and protective purpose. Non conductive base is made conductive by coating of graphite at cathode.

Electrofacing

It is a process of coating of metallic surface with a harder metal by electrodeposition in order to increase its durability.

Electroforming

It is a metal forming process, in which parts are fabricated through electrodeposition on a model.

Application

① Manufacture of gramophone papers

② Production of Seamless tube.

Electrotyping

It is a chemical method for forming metal parts that exactly reproduce a model. It is a special application of electroforming & it is used to reproduce printing, set up type models etc. The process is same as electroforming.

Anodyzing

Anodyze is a coat with a protective oxide layer by a electrolytic process in which the metal form an anode.

An anodic coating means an oxide film deposited or created on a metal surface with the help of an anode and oxidation. The process of providing an oxide film is known as anodyzing.

Electropolishing

It is a electrochemical finishing process that removes a thin layer from metal bar.

Electro cleaning

It is a cleaning process using metal surface filtration before they undergo procession.

Electroparting

2 or more metal may be separated electrolytically.

Electrometallurgy

It include electro extraction and electrorefining process. It is a method in metallurgy that produces metal.

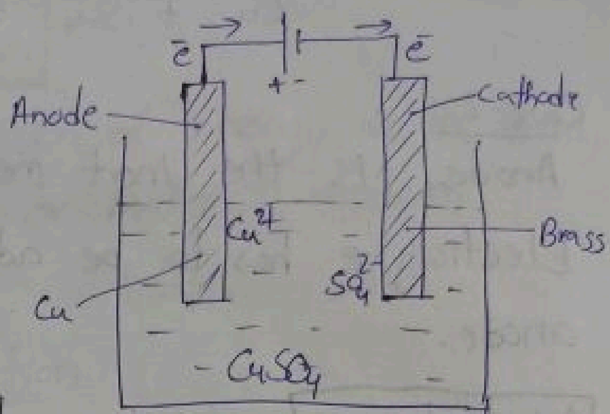
Electrorefining

It is a process in which materials usually metals are purified by means of an electrolytic cell.

Here the anode is impure metal and cathode is pure metal

By electrorefining it is possible to get atmost 100% purity.

Principle of Electrodeposition



This process contain electrolyte, 2 electrode and battery. The electrolyte should contain positive ions (cations) of metal to be deposited. These cations are reduced at the cathode to the metal in zero valence state. The electrolyte for copperplating can be solution of $CuSO_4$ which dissociate in Cu^{2+} cation, and SO_4^{2-} anion.

At the cathode, the Cu^{2+} is reduced to metallic copper by gaining two electrones. When the anode is made of the coating metal, the opposite reaction may occar there turning it into dissolve.

Here Cu would be oxidized at the anode to Cu^{2+} by loosing 2 electrons. In this case the rate at which anode is dissolve = the rate at which cathode is plated.

The net result is effective transfer of metal from anode to cathode.

when dc is passed through electrolyte ($CuSO_4$), it decompose to its ions, $CuSO_4 \rightarrow Cu^{2+} + SO_4^{2-}$

At Cathode,

Cu^{2+} ion get reduced to Cu and get deposited on the article.

At Anode (Case-1)

Anode is the coating ~~meat~~ metal (Cu)

Cu get oxidized to form Cu^{2+} ion and react with SO_4^{2-}.

$$Cu + SO_4^{2-} \rightarrow CuSO_4 + 2\bar{e}$$

Case-2

Anode is the inert metal.

Electrolyte has to be added to maintain the concentration of anode.

Advantages

- To protect the metal against corrasion
- To give reflecting properties.
- To give shining appearance to article
- To increase the thermal conductivity of metal.
- To increase the tensile strength of metal.
- To replace wornout material

Disadvantages

- Expensive
- Reqd electricity, time consuming, coating may be uniform, electroplating both solution has to be disposed carefully. As it is prone to water pollution.

ILLUMINATION

Nature of radiation and its spectrum

→ Radiation is the emission ~~or~~ transmission of energy in the form of wave or particles through space or material medium.

→ Radiation is a form of energy.

→ Light and heat are types of radiation.

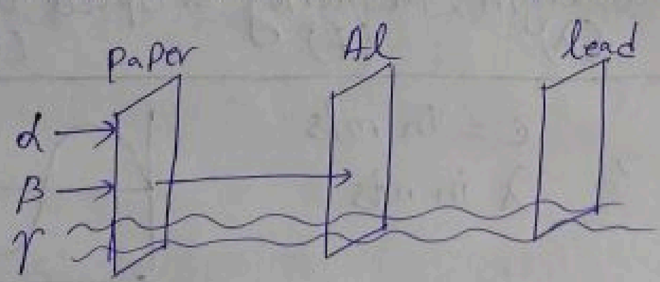
2 basic type of radiation are

1. Particulate radiation - α particles & β particles.
2. Electromagnetic radiation - radiowaves, microwaves, infrared waves, UV light, gamma radiation, X-radiation.

Particulate radiation involve tiny fast moving particle, that have both energy & mass.

Electromagnetic (EM) waves are produced by vibrating electric charge and they consist of both electric & magnetic waves.

EMR is a kind of radiation is pure energy with no mass.



→ α-particles are high energy large subatomic structure of Proton and neutron, they can travel only short distance and are stop by paper or skin.

→ β are fast moving electron, they are fraction of the size of α-particles, but can travel further and are more penetrating.

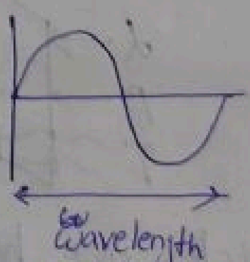
Electro Magnetic Spectrum

The EM Spectrum is the range of frequency of EM radiation and their respective wavelength and photon energy. It covers EM wave with frequency range from belao 1 Hz to above 10^{25} Hz wavelength from 1000 Km down to a fraction of the size of an atomic neucleus.

frequency (Hz)	wavelength (m)	Nature of wave
3×10^{27}	10^{-14}	cosmic
3×10^{20}	10^{-12}	γ-rays
3×10^{18}	10^{-10}	X-rays
3×10^{16}	10^{-8}	UV rays
3×10^{14}	10^{-6}	visible light
3×10^{12}	10^{-4}	Infrared ray
3×10^{10}	10^{-2}	short wave radio wave
3×10^{8}	1	—
3×10^{6}	10^{2}	Long wave radio wave

Relation between wavelength (λ), frequency (f) & speed of light (c)

$$f = \frac{c}{\lambda}$$, c = in m/s, λ in mts



Lumen

It is the SI unit of luminious flux. It is a measure of total quantity of visible light emitted by source per unit of time.

Luminous Intensity

The Luminous Intensity in a given direction is the limited flux emitted by the source of per unit solid angle. It is the quantity of visible light that is emitted in unit time per unit solid angle. It is denoted by symbol I, unit is candela (Cd) or lumens/steradian.

$I = \frac{F}{\omega}$ — F → Flux, ω → solid angle

Intensity of Illumination (E)

It is defined as the energy of light striking a surface of specific unit area per unit time.

MHCP (Mean Horizontal Candel Power)

It is defined as the mean of candel power in all direction in the horizontal plane, containing source of light.

MSCP (Mean Sperical Candel Power)

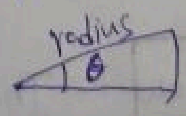
It is defined as the candel power in all direction and in all plane, from the source of light.

MHSCP (Mean Hemisperical Candel Power)

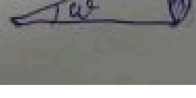
It is defined as the mean of all candel power in all direction above or below the horizontal plane passing through the source of light.

Solid angle

Plane angle is subtended at a point in a plane by two converging straight line in the same plane. And its magnitude is given by → $\theta = \frac{Arc}{radius}$ = radian



→ $\omega = \frac{Area}{(Radius)^2}$ = steradian



Brightness

Brightness of a surface is defined as the luminous intensity per unit projected area of the surface in the given direction. It is denoted by symbol 'L'

$$L = \frac{I}{A \cos\theta}$$ unit = candela/sq.mt = Cd/m^2.

Relation between I, L, E

Considering uniform diffuse spherical source with radius 'r' meters & luminous intensity 'I' candela.

$$L = \frac{I}{\pi r^2}, \quad E = \frac{I}{4\pi r^2} \times 4\pi = \frac{I}{r^2} \Rightarrow E = \frac{I}{r^2}$$

$$\therefore E = \pi L$$

Luminious Flux

The total quantity of light energy emitted per second from a luminous body is called luminious flux.

Luminious efficiency

It is the ratio of total luminious flux radiated by any source, to the total radian flux from that source. It is expressed in lumen/watt.

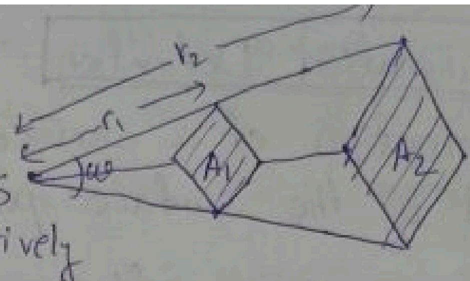
* Law of Illumination

There are 2 types of law.

① Inverse square law ② Lambert cosine law

① **Inverse square law** - The illumination of a surface is inversely proportial to the square of the distance of the surface from the source.

$$E \propto \frac{1}{r^2}$$



In this diagram consider surface area A_1 & A_2 at a distance R_1 & R_2 respectively from the source point S. of luminous intensity 'I' & normal to the ray.

Here solid angle 'ω' is subtended.

Total luminous flux radiated = Iω lumen

Illumination of surface area A_1.

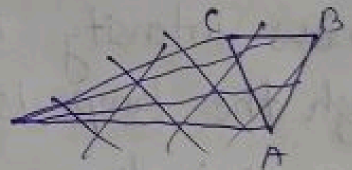
$$E_1 = \frac{I\omega}{A_1} = \frac{I\omega}{\omega r_1^2} = \frac{I}{r_1^2}$$

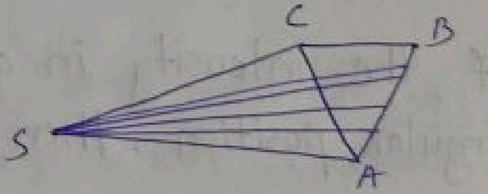
Similarly for surface area A_2,

$$E_2 = \frac{I\omega}{A_2} = \frac{I\omega}{\omega r_2^2} = \frac{I}{r_2^2}$$

② Lambert Cosine Law

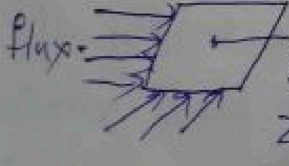
This law state that the illumination at any point on a surface is directly proportional to the cosine of the angle between the normal at that point and the direction of luminious flux.





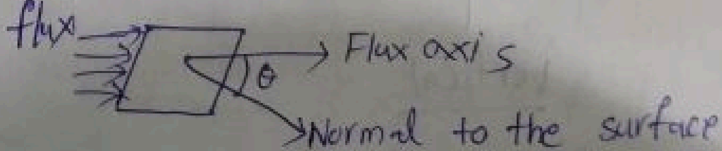
$$E \propto \cos\theta$$

In normal surface,



Normal to the surface make zero angle to the flux axis.

$$E = \frac{\phi}{Area}$$



$$E = \frac{\phi}{Area} \times \cos\theta$$

Illumination Defination:

Illumination of a surface is defined as the luminious flux received by the surface per unit area.

$$(E) = \frac{flux}{Area} = \frac{C.P.\,\omega}{A}\ lux \qquad \because lux = \frac{lumen}{metre}$$

Reduction factor $= \frac{MSCP}{MHCP}$

Polar Curve

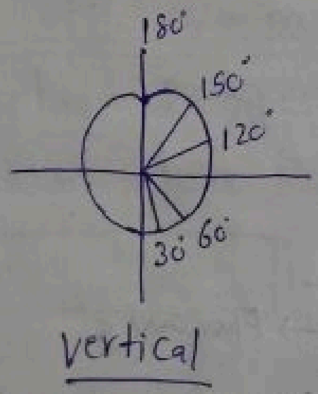
→ They are the plot drawn b/w candle power and angular position.

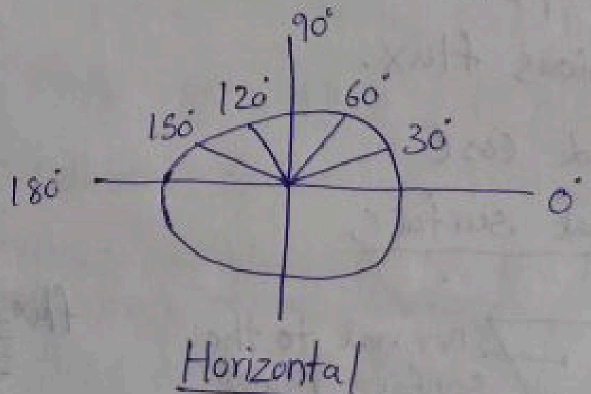
→ The light intensity is not same in all direction, in most of the lamp, because of their unsymmetrical shape.

→ The luminious intensity in all direction can be represented by polar curve. They help to find out the distribution of candel power or light.

→ If the luminious intensity is measured in a horizontal plane passing through the lamp is plotted against angular position, then this curve is known as horizontal polar curve.

→ If the intensity in a vertical plane is plotted against the angular position, then the curve is known as vertical polar curve.





→ Slight depression at 180° in case of vertical polar curve due to the position of lamp holder, whereas at 0° in the horizontal polar curve is due to collide coil filament.

→ The Polar curve are used to determine the MHCP and MSCP. These are used to determine the actual illumination of a surface by applying the candel power in a particular direction.

Maintenance factor

The ratio of illumination under normal working condition to the illumination when the things are perfectly clean.

$$\text{Maintenance factor} = \frac{\text{illumination under normal working condition}}{\text{illumination when everything is clean}}$$

Depreciation factor

$$\text{Depreciation factor (D.P)} = \frac{1}{\text{Maintenance factor}}$$

$\therefore D.P > 1.$

* Types of lightning scheme

The distribution of the light emitted by lamp controlled by means of reflector. The interior lightning scheme is divided into 4 types. ① Direct lightning ② Semi Direct lightning ③ Indirect lightning ④ Semi Indirect lightning

① Direct lightning

It is the most commonly used type of lightning scheme. In this scheme more than 90% of total light flux is made to fall directly on the working plane with the help of deep reflector.

It is mainly used for industrial and general outdoor lightning.

② Semi Direct lightning -

In this lightning scheme 60-90% of the total light flux is to fall downwards directly with the help of semi direct reflector. This remaining light is used to illuminate the ceiling & wall. This light scheme is used in room with high ceiling where a high level of uniformly distributed illumination is desirable.

③ Indirect lightning -

In this lightning scheme more than 90% of total flux is thrown upwards to the ceiling for diffuse reflection by using inverted reflector. It is used for decoration purpose in cinema, theatre, hotel etc. And in workshop where large machine would causes troublesome shadow is where indirect lightning is employed.

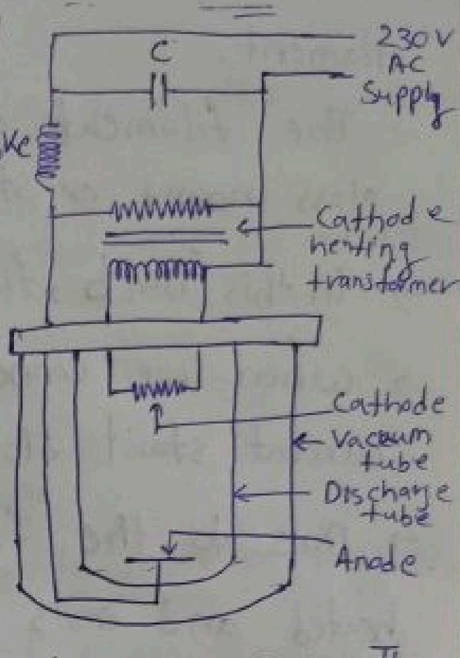
④ Semi Indirect lightning

In this lightning scheme 60-90% of total flux is thrown upward to the ceiling for diffuse reflection. And rest reaches the working plane & directly aspect for some absorption by inverted reflector. It is mainly used for indoor light decoration purpose.

Local lightning - If the light is confined to illuminate a particular object, it is called local lightning, ex- lamp mounted in a deep deflector & fitted on a machine tool like leth, planar etc or an ordinary table lamp in a study room gives local lightning.

General lightning - It refers to the background level of light in a particular space. It may provide slowly by artificial lightning or a combination of artificial or another light. In Industry it is compulsary to minimize accidents.

* The ratio of general to local lightning level should not be more than 1 to 3.



* Sodium Vapour lamp

A Sodium lamp consist of an inner bulb of special glass containing the sodium & the inert gas either neon / argon and it is fitted with two filament. The discharge tube is surrounded by outer tube as shown in figure. For heating the cathode, a transformer is included. Sodium below 60°C in its solid state. For starting the lamp the electric discharge is allow to take place in neon gas. The temp inside the discharge tube rises and vaporise sodium. Operating temp is around 300°C. It takes about 10 mins for the sodium vapour to displace the red colour of neon by its brown yellow colour. The lamp takes about half an hour to reach full output. A choke is provided for stabilizing the electric discharge and capacitor is used for improvement of powerfactor. The light output is about 10-50 lumen/watt. Sodium Vapour has the highest theoritical luminious intensity & it gives monochramatic orange yellow light. The monochromatic light makes the object appear grey. This lamp is used only for streed lightning.

* Incandescent lamp

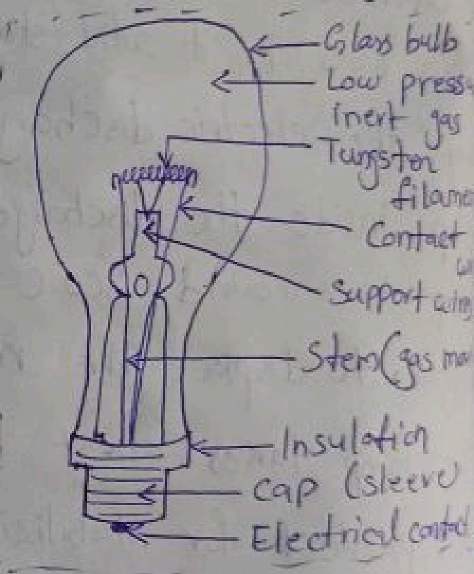
They are also Known as filament lamp. These lamps work on the principle of incandesce or heating effect of electric current. The glass bulb is filled with an inert gas as nitrogen or argon. Light bulb have two metal contacts, which connect to the end of electric circuit. The metal contact are attache to two stiff wire, which are attached to a thin metal filament.

→ The filament sit in the middle of the bulb held up by a glass mount or stem.

→ In this bulb, filament is connected between two copper wire

→ when we connect this bulb with electric power supply, current start flowing through the copper wire and filament.

→ Due to the flow of electric current, the filament get heated and emits light.



→ The bulb glow due to the heating effect of filament. So this type of bulb is called incadescent lamp.

→ Tungsten is the most common material used for filament, because of its high melting point.

→ Sometimes due to heat, the filament gets oxidise, which may create problem.

→ To prevent the oxidation of filament, we use argon.

→ when wire became red hot, it emit more heat as compared to light.

→ when wire became white hot, light radiation is more than heat.

Properties of filament

① High melting point ② High resistivity ③ Low temp. coefficiant ④ Low vapour pressure ⑤ Sufficient mechanical strength to with-stand vibration during use (6) Ductility

Function of Parts

① **Contact wire** - Electric conductor carrying the current to the filament.

② **Inert gas** - Gas inserted in the bulb, to slow down the evaporation of the filament.

③ **Base** - Metal end of our light bulb inserted into a socket to connect it to the electrical circuit.

④ **Stem** - Bottom support

⑤ **Support wire** - Metal wire holding the filament.

⑥ **Tungsten filament** - Very thin metal wire usually made of tungsten, emitting light ray when an electric current passes through it.

⑦ **Glass bulb** - Gas sealed in glass, enveloped into the luminious body of lamp is inserted.

Application

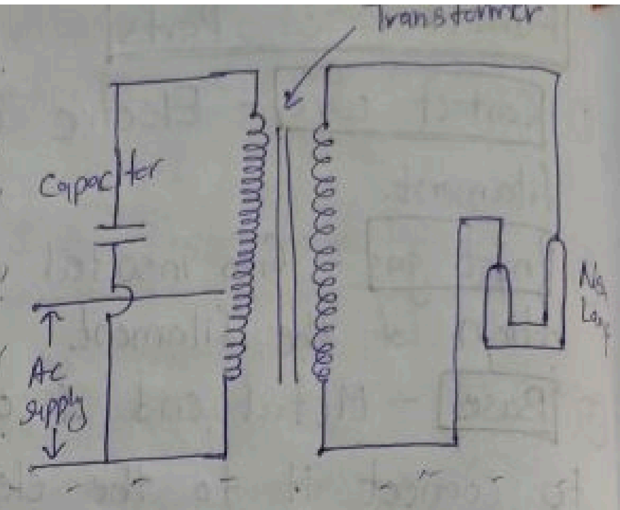
widely used in household and commercial lightning for portable lightning such as table lamp, flask light & for decorative light.

Effect of Voltage variation on working of Filament lamp

The filament lamp are under operation of constant supply voltage. But a variation of ±6% voltage at consumers terminals is permitted under the indian electricity rule. Further drop of voltage in the electrical wiring may occur, thus a voltage variation from +6 to -8.5% may result. Hence the operating voltage varies from 212-224 V on a 230V supply main.

*Neon lamp

It consist of a glass bulb filled with neon gas with a small % of Helium. The electrode are in the form of iron cell and are coated on the inside.



→ The colour of the light emitted is red & this lamps are mostly used for electrical advertising. (If Helium gas is used in place of neon, pinkish white light is obtained.)

→ Figure shows the circuit of a neon lamp. The transformer has high leakage reactance, which stabilize the arc in the lamp, a capacitor is used for improvement of power factor.

→ These lamps are operated on 110V a.c of 150V dc supply.

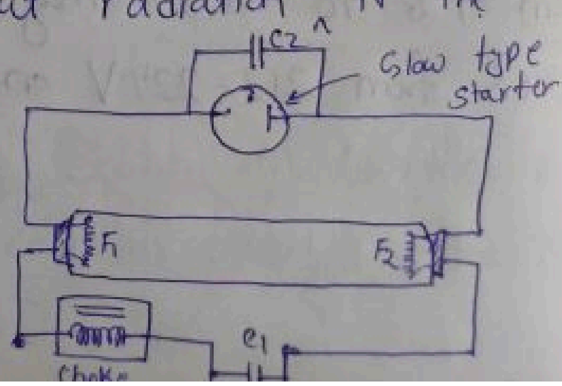
→ Its luminous efficiency is 15-40 lumen/watt.

→ Power consumption is about 5W.

→ These lamps are used as indicator lamps & night lamp.

*Fluorescent lamp

Principle of Operation - When fluorescent material are subjects to electromagnetic radiation of particular wavelength they get excited and in turns give out radiation. at some other length & give out radiation even if the exciting radiation is removed.



F_1 & F_2 are filament of tube

C_1 → Capacitor across the tube

C_2 → Capacitor across the stater

Construction

The fig shows the construction detail of fluorescent lamp.

- It consist of a long glass tube which is internally coated with a little quantity of argon gas.
- There are two electrode F_1 & F_2 made up of collide tungsten filament, coated with an electron emitting material.
- The control circuit of the tube contains glow type starter, choke & two capacitor C_1 & C_2.
- There are two electrode of which one is fixed while other is 'U' shape bimetallic strip, made of two different metal.
- These electrodes are sealed in a glass bulb, which is filled with a mixture of helium & hydrogen.
- The contact are normally open.
- The coating effect use, depends upon the colour effect desire & may consist of zinc silicate (green light), cadmium, silicate (Pink light); ~~com~~ they are known as phosphorus.

Tube

Glass tube which is sealed with two filament at two end. It is coated with fluorescent powder and filled with mercury and argon

Choke

- Supply large potential for starting arc. Limit the arc current to safe value

Starter

It is provided to limit the starting current.

Capacitor - Improve power factor

Working

When supply is on, current flow through the choke to filament 1 (F_1) to starter to Filament 2 (F_2) to neutral

→ At that time choke include high voltage which is applied to two filaments & ionize gas.
→ Due to this there will be high voltage ionization, so that light will be emitted through the tube.

Advantages

→ Efficiency is high about 90%.
→ Life is more. (Average life- 4000 working hour)
→ Less glare → Luminous efficiency - 40 lumen/watt.

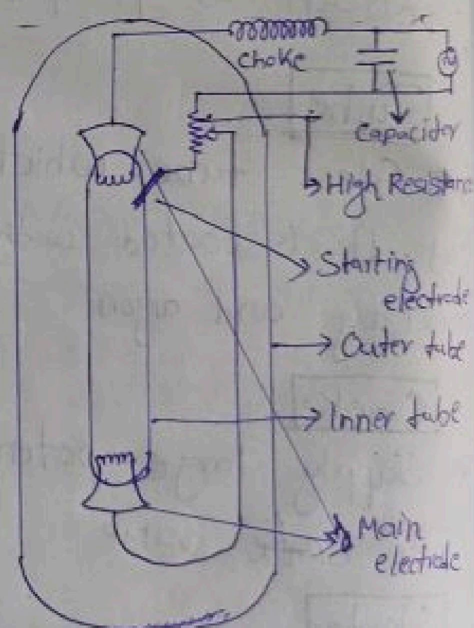
Disadvantages

→ High initial cost, due to use of choke & starter

~~Mercur~~ High Pressure Mercury Vapour Lamp (MVL)

Principle

When mercury discharge under low pressure gives mainly UV radiation. If pressure is increased to 1-2 atmospheric pressure its proportion of radiation in visible spectrum is increase & we get a light of bluish colour.



It consist of:-

Choke

The choke is acting ballast. At the time of supply voltage variation the current flowing through the inert tube, ~~voltage variation~~ is mainted constant, to ~~give~~ keep uniform light intensity.

Starting resistance / Limiting resistance

When ever current flow through the starting resistance, there is a I^2R loss, which is converted into heat. If the temperature of this heat goes near about 600°C. Then inert gases ionization start.

Auxilliary electrode & Main electrode

The ionization is take place through the inert gases whenever current flow from auxilliary electrode to main electrode.

Inner tube

The various inert gases (argon, nitrogen etc). with mercury powder are filmed in the inner tube at 5-7 times of the atmospheric pressure.

Outer tube

Its function is to make the vaccum surrounding the inner tube to avoid thermal dissipation.

Capacitance

The function of capacitor is to improve the power factor.

Working

→ whenever 1ø 230V a.c supply is ~~supplied~~ provided to the discharge tube of MVL, Initially the current flow from phase to the choke to the starting electrode to neutral.

→ The starting electrode or resistance is made of tungsten filament, having more resistance (5-10KΩ) so that, whenever current flow from tungsten filament as per the thermal emission, the light is emitted through the filament.

→ At the same time, the rated voltage is applied, in between the two main electrode. Due to this voltage, there will be collision of neon gas particles & current will start to flow through the discharge tube

→ Whenever temp. surrounding the inner tube increases upto 600°C, the mercury powder will start vaporising and the continuous collision process of all inert gases take place, so that full light is emitted through the discharge tube.

Advantages

→ Its efficiency is high & output is more.

→ It has long life (3000 working hour), Luminous eη = 40 lumens/watt

Disadvantages

→ The initial time reqd for warming up is more than 5 mins.

→ If lamp goes out, while in service, cooling is reqd for restarting. This cooling reduce the vapour pressure.

→ Each lamp contain mercury, which can be harmful for both human & wildlife.

Application

→ Street & parking lots.

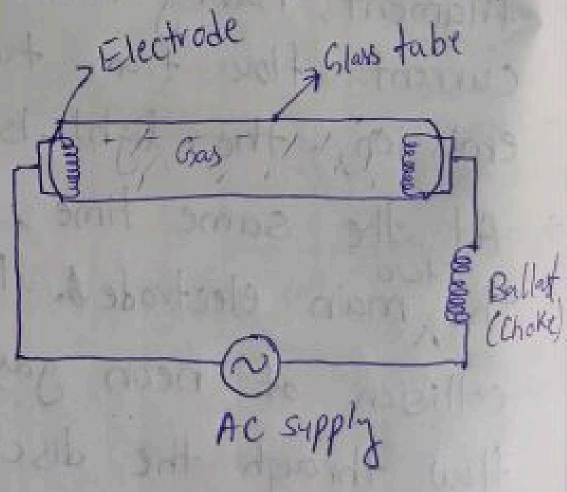
→ Factory

→ Photolithography

* Discharge Lamp

In electric discharge lamp also called vapour lamp.

Discharge lamp are family of artificial light sources, that generate light by sending an electric discharge through an ionize gas.



→ Typically such lamp use a noble gas (argon, neon, krypton, zenon) or a mixture of these gases.

→ Most lamp are ~~additiona~~ filled with additional material like mercury, sodium.

→ It consist of a glass tube

→ Both the side of this lamp have 2 electrode

→ when high voltage is applied (or) current passes through the electrode, then it emit electrons.

→ Inside the tube, gas is filled.

→ when electron is passes through the gas, discharge is created there. So atom in gas or gas molecule are excited. It means they get high energy

→ They release the energy in the form of light.

→ The colour of light depends on gas filled inside the ~~gas~~ tube.

→ Their are 3 group of discharge lamp,

① Low pressure discharge lamp ② High pressure discharge lamp

③ High intensity discharge lamp

→ It offer long life & high efficiency but are complicated to manufacture

Excitation

→ If the electron has kinetic energy above a certain critical value in the process of passing through a certain potential /voltage which is termed as the excitation potential.

→ The collison may occur one of the electron to jump from its normal orbit into another one.

→ This happen when the colliding electron has a kinetic energy of 2.1 eV

→ The colliding electron imparts its kinetic energy to the atom that it strike & this atom is said to be in a excited state. In this way the atom can be placed in the 1st, 2nd, 3rd, 4th or higher excited state depending upon the K.E of the colliding electron.

~~Kinetic energy of the colliding electron.~~

Electrical Heating.

→ Electrical heating is any process in which electrical energy is converted into heat energy.

→ Electrical heating works on the principle of joule heating (An electric current through a resistance convert electrical energy into heat energy)

→ Let us take the case of solid material, which has resistance 'R' ohm & current flowing through it is 'I' amphere for 't' sec, then heat produced in the material will be '$H = I^2Rt$'

Advantages of Electrical Heating

① Clean & neat atmosphere
② No pollution / no fuel - gas is produced.
③ ~~Contro~~ Accurate control temp can made easily
④ Response quickly
⑤ Localize application
⑥ Uniform heating
⑦ Comparatively set
⑧ Overall efficiency is much higher.
⑨ Cheap furnace
⑩ Low ambient temperature
⑪ Mobility of job
⑫ Highest efficiency of utilization
⑬ Heating of bad conductor of heat & electricity

Mode of heat transfer

There are 3 mode of transfer of heat.

① Conduction. ② Convection ③ Radiation

① Conduction

→ This phenomenon take place in solid, liquid & gas.

→ Heat transfer is proportional to the differance of temp between two faces.

→ No actual motion of molecule.

② Convection

→ This phenomenon take place in liquid & gas

→ Heat is transfer due to actual motion of molecule

③ Radiation

→ This phenomenon is confined to surface

→ Radiate energy emitted or absorbed is dependent on the nature of the surface

* Stephen's Law

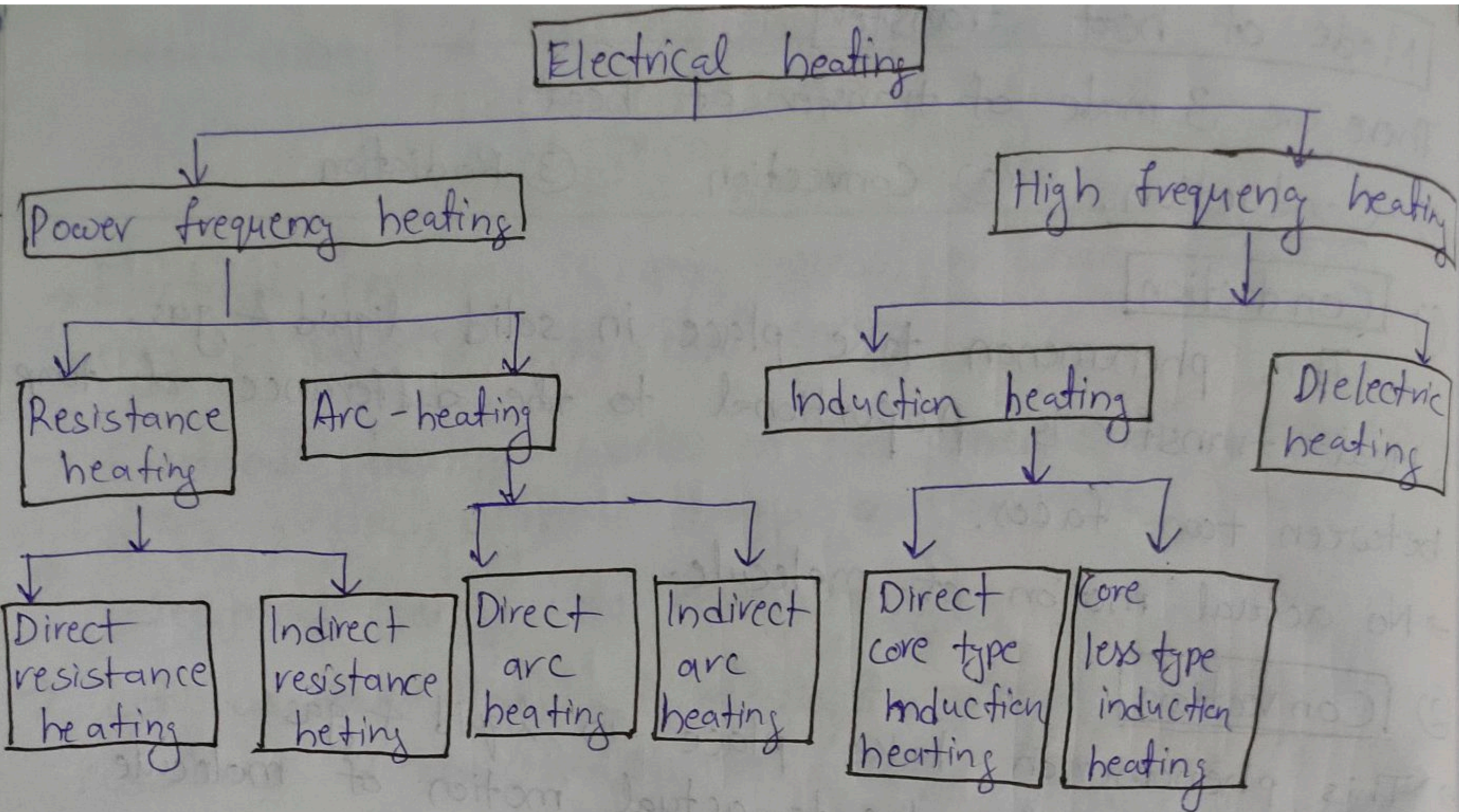
It state that the radiated power density (of a black body is proportional to its absolute temperature 'E' rise to the fourth power i.e $E = e\sigma T^4$

Classification of Heating method

① Low temperature upto 400°C

② Medium temperature heating from 400 - 1150°C

③ High temperature heating above 1150°C



Principle of Resistance heating

→ This method is based upon the I^2R loss.

→ Whenever current is passed through a resistive material, heat is produed because of I^2R losses.

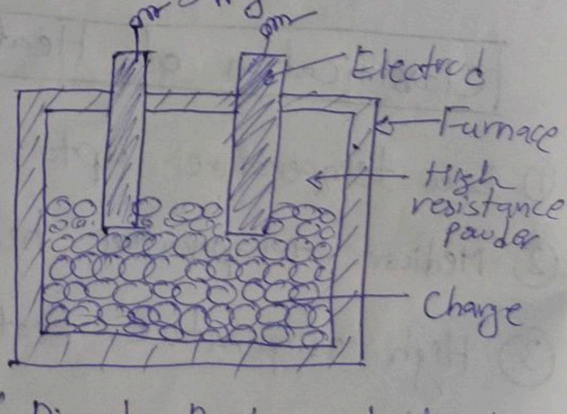
→ The generation of heat is done by electric resistor carring current.

→ There are two method of resistance heating ① Direct resistance heating ② Indirect resistance heating.

① Direct Resistance heating

→ In this method of heating, the material is taken as a resistance & current is passes through it.

→ The charge may be in the form of powder pieces or liquid.



(Direct Resitance heating)

→ Two electrodes are immersed in the charge & connected to the supply.

→ In case of dc or 1 ϕ ac, two electrode are required

→ In case of 3 ϕ supply, three electrodes are required.

→ when metal pieces are to be heated, a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.

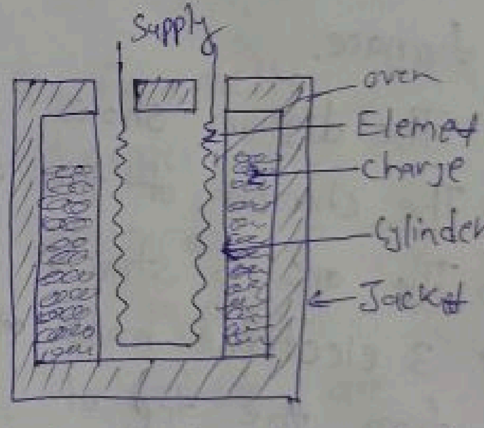
→ But it gives uniform heat & high temperature.

→ One of the major application of the process is salt bath furnace having an operating temperature b/w 500C - 1400°C

Advantages

① High efficiency
② Gives uniform heat & high temperature
③ Mainly used in salt-bath furnace & water heater.

② **Indirect Resistance Heating**



Indirect Resistance Heating.

→ In this method the current is passes through a highly resistive element which is either placed above or below the oven, depending upon the nature of the job to be performed.

→ The heat is proportional to I^2R losses produced in heating element. delivered to the charge, either by radiation or by convection.

→ Sometime in case of industrial heating. The resistance is placed in a cylinder, which is surrounded by the charge placed in the jacket.

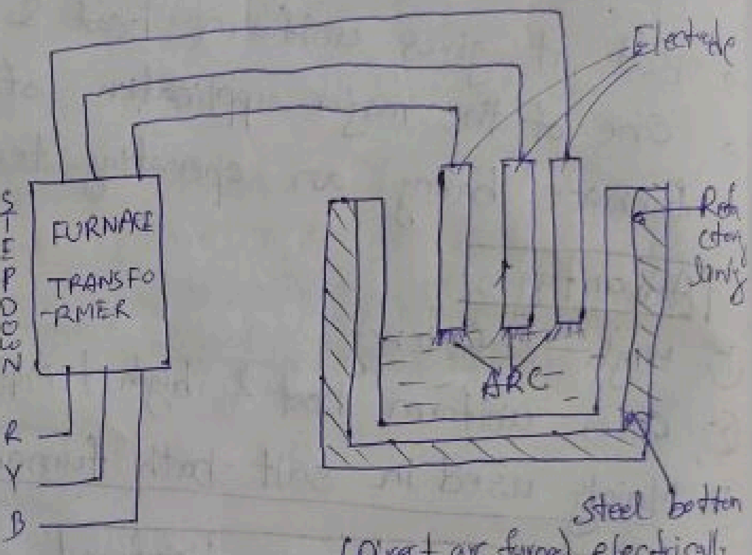
→ The arrangement provides as uniform temperature.

→ Automatic temperature control can be provided in this place.

→ This method is used in room heater, in bimetallic strip using starter, immersion water heater & various type of resistance oven, used in domestic & commercial cooking.

Direct Arc Furnace

By striking the arc b/w the charge & electrode, the heat is directly conducted & taken by the charge. The furnace operating on this principle is known as direct arc furnace.

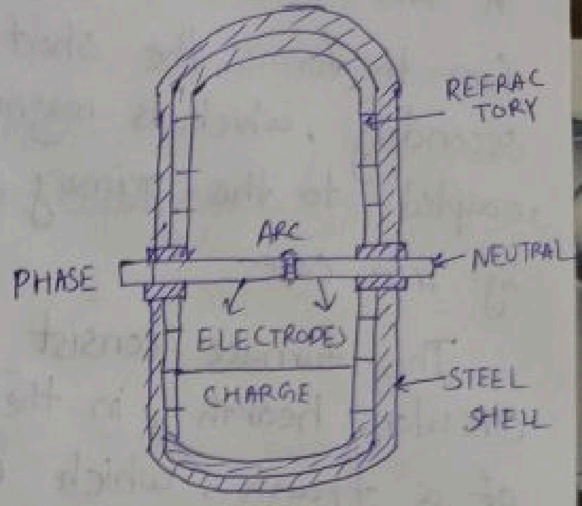


(Direct arc furnace)

→ The diagram shows a direct electric arc furnace.
→ The chamber of the furnace is lying with refactory material
→ The arc is struck between electrode & charge.
→ 3 electrode made of carbon or graphite are projected from the top of the furnace & 3ϕ supply is given
→ The current passes through them by the charge.
→ Since the arc is in direct contact with the charge so it is possible to produce highest temperature by direct electric arc furnace
→ As the arc passes through the charge, it will produce automatic stirring/mix action
→ The arc has a negative resistance characteristics (resistance decreases & temp increases)
→ Thus some current limiting device is required in the circuit to prevent short circuit

→ The direct arc furnace is very commonly used for the production of steel.

Indirect Arc Furnace



By striking the arc between two electrode, the heat is transferred to the charge by radiation. The furnace operating on this principle is known as indirect arc furnace.

→ The figure shows an indirect arc furnace, in this furnace, the arc is formed b/w two electrode & heat is produced.

→ Heat is transmited to the charge by radiation.

→ The temperature is lower than direct arc furnace

→ So indirect arc furnace are suitable for melting metal having lower melting point. Ex- Brass, copper, zinc etc.

→ The arc is struck b/w the ~~two~~ electrode, so only two electrode are required. Therefore 1 ϕ supply is given.

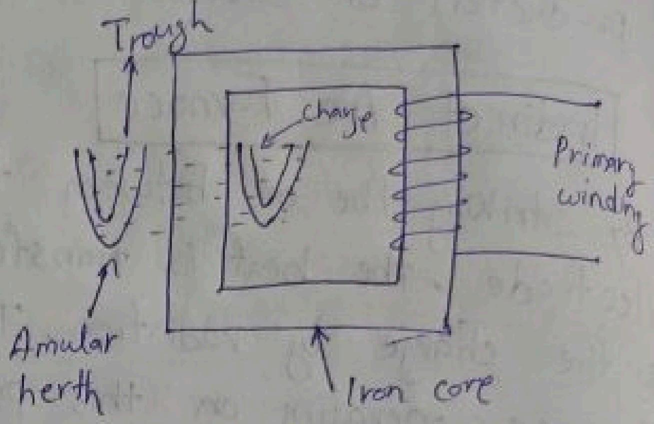
→ During the process of heating the electrode are consumed, so the feeding of electrode to the indirect arc furnace is automatic.

→ The furnace is cylindrical. since the arc does not come in contact with the charge, so the automatic stirring ~~function~~ action is absent.

→ The furnace may be equipped with automatic rocking equipment.

→ The power factor varies from 0.7 to 0.8.

Direct Core type Induction Heating



In this furnace, the charge ~~from th~~ forms the short circuited secondary, which is magnetically coupled to the primary winding by iron core.

The furnace consist of a circular hearth, in the form of a trough, which contain the charge to be melted in the form of an amular ring. The metal ring is quite large diameter, is magnetically interlink with electrical winding. The ring is energised from a.c source.

The furnace is like a transformer in which the charge to be heated form a single turn short circuited secondary And is magnetically coupled to the primary by an iron core, so to start the furnace, molten metal has to be poured in the amular.

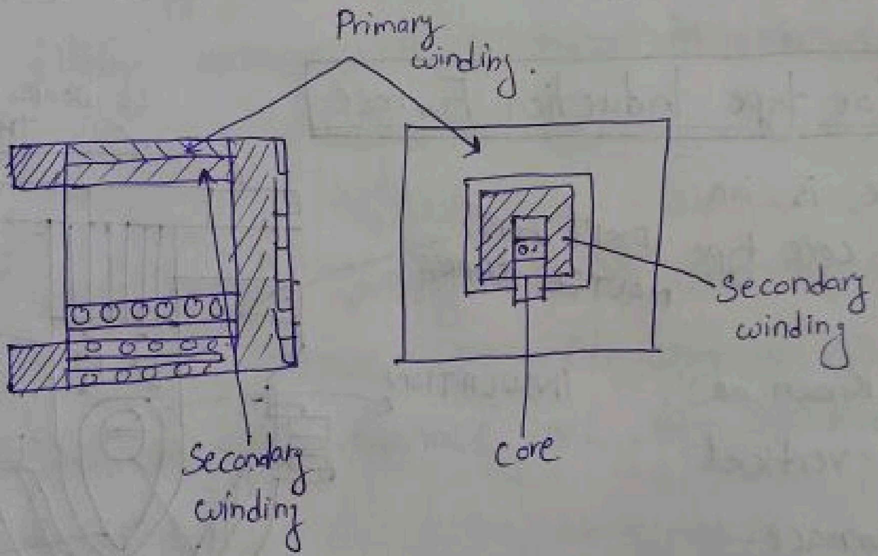
The magnetic coupling between primary & secondary winding is very poor. Its result in high leakage reactance & low power factor. To minimize the leakage reactance & low power factor, frequency of the order 10Hz is used.

~~Are producing low frequency~~. A special motor-generator set is reqd for producing arc at low frequency. If the current density increases beyond the limit, it produces pitch effect, which causes temporary interuptions of secondary circuit.

Drawback/Disadvantages

① It cannot function, if the secondary circuit is not close.
② Not suitable for ~~interpmittent~~ intermittent service.
③ Odd shape of crusible are not convinient from metalogical point of view.

Indirect Core type Induction Furnace



→ In this type of furnace, a suitable element is heated by induction, which in turn transfer the heat to the charge by radiation.
→ The secondary winding is formed by the wall of a metal cylinder.
→ An iron core link the primary winding & secondary winding.
→ when primary winding is connected to ac supply, secondary current is induced in the metal contain by transformer action which heat up the container.

→ The part of the magnetic circuit, place inside the ~~open~~ oven chamber, consist of a special alloy which losses its magnetic properties at a particular temp.

→ If the chamber attain critical temperature, the reluctance of the magnetic circuit increases highly.

→ Its operating power factor about 0.7 & temperature is 1000°C.

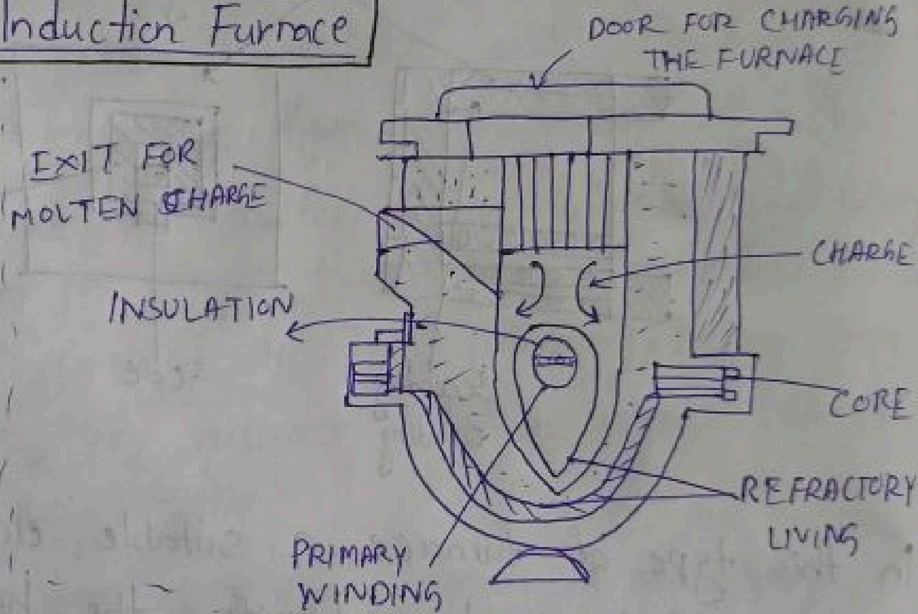
→ The temperature can be controlled easily.

Vertical Core type Induction Furnace

→ This furnace is an improve over core type furnace

→ It is also known as ajaxwyatt vertical core type furnace.

→ Crusiable use is vertical, which is suitable for metalogical point of view.



→ The magnetic coupling in this furnace is better than core type.

→ Hence leakage reactance is comparatively low & p.f is high.

→ This furnace is very suitable for continous operation & can be operated on normal frequency.

→ The core is made of laminated steel & the secondary ckt is formed by single turn of molten metal

→ The stirring action is produced by the pinch effect.

→ The secondary ckt is ~~als~~ only complete, when there is sufficient molten metal, in the 'V' portion.

→ It is necessary to keep the 'V' full of metal in order to maintain the continuity of the secondary ckt, so this furnace is suitable for ~~continous operation~~ continous operation.

→ The top is covered with insulated cover which can be removed for charging.

→ Hydraulic tilting arrangement is there to take the molten metal out.

Uses

→ The furnace is used for melting & refining non ferious metal like brass, copper & zinc. Its efficiency is about 75%.

→ Standard size of this furnace are 60 - 300 KW, 1ϕ 50 Hz working ~~at 600V~~.

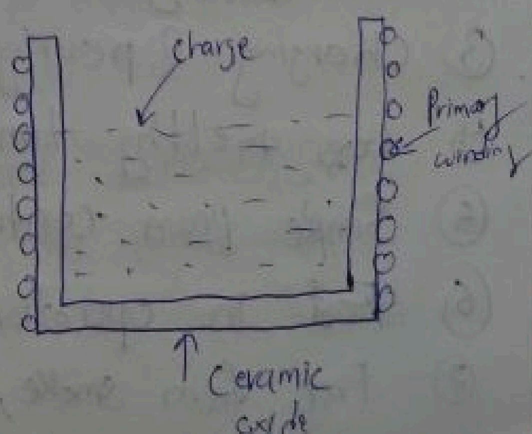
Advantages

→ Control is simple.

→ High pf 0.8 - 0.85 comparatively.

Core less Induction Furnace

→ This furnace mainly consist of primary coil, a cermanic crusable with charge which form secondary winding.



→ A frame which include the support ~~mechanism~~ tilting mechanism which is not shown in figure.

→ The primary winding coil are made of hollow tubes & are cooled by circulation of water through them.

→ This furnace mainly operated at high frequency.

→ The primary winding not made of copper wire, inplace of hollow copper tube.

→ Convinient shape of crusable is used.

→ Generally frequency in the range of 500-1000 Hz is employed for large furnace of 5 turn.

→ In this furnace when the primary winding is connected to a high frequency ac supply. The flux produce by set up eddy current in the charge. This eddy current heat up the charge.

→ Because of high frequency supply, the skin effect is existing the primary winding.

→ For efficient operation of the furnace, the ratio between diameter & the depth should be nearly 8. $\left(\frac{D}{T}=8\right)$.

Advantages

① Low erection cost

② Low operating & maintenance cost.

③ Charging & pouring is simple

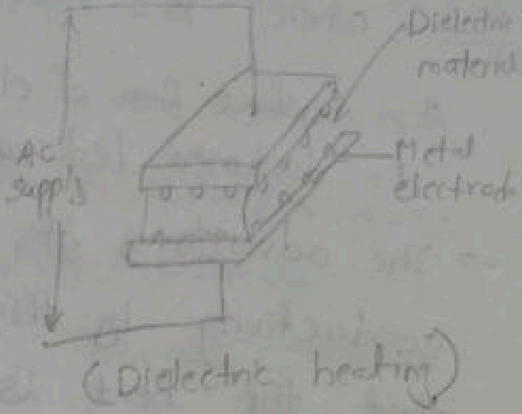
④ less melting time.

⑤ Simple power control device can be employed.

⑥ Fast in operation.

⑦ Free from smoke, dust & noise

Dielectric Heating



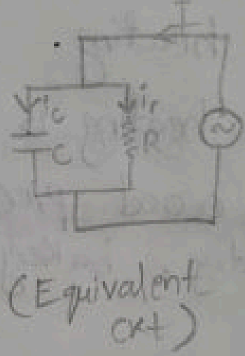
→ It is also known as high frequency capacitive heating.

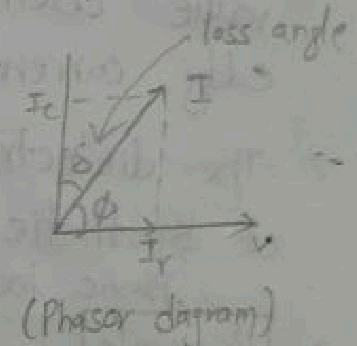
→ Employed for heating of insulating material like wood, plastic, ceramic.

→ The supply frequency applied for this type of heating is b/w 10-30 Mega cycle per second.

→ Applied voltage is upto 20 KV.

→ The principle of operation of dielectric heating is that, when a capacitor is subjected to a sinusoidal voltage, the current drawn by it is never leading the voltage by exact 90°.





→ The angle between voltage & current is slightly less than 90°, by angle delta known as loss angle (δ)

$$\delta = \frac{1}{2\pi}\frac{\sqrt{\rho \times 10^7}}{\mu_r f} \text{ metre}$$

where 'ρ' is resistivity, 'μ_r' - relative permeability. 'f' - frequency.

→ There is a small component of current, which is in phase with the applied voltage & produce power loss in dielectric.

→ The material to be heated is placed between two sheet type electrode, which form the capacitor.

→ Value of capacitor is given by

$$C = K K_0 \frac{A}{d} \text{ Farad}$$

where K = relative permeability & K_0 = permitivity of vaccum $= 8.854 \times 10^{-12}$

A = Surface Area of electrode

d = distance between two electrode.

→ The advantages of heating material of poor thermal conductivity by this method, result from the fact that, the heat is produced ~~from the~~ within the material itself.

→ The necessary high frequency supply is obtain from a value oscillator as in the case of high frequency eddy current heating.

→ The dielectric heating is used in welding in manufacture of synthetic, wood processing industry, food processing, Plastic industry, bakery, book binding.

→ **Principle**

Used to heat non conducting material, the material to be heated is placed between two conducting electrode across which alternating voltage of high frequency is applied.

→ Two electrode separated by a dielectric medium & across which some potential difference is applied from a capacitor. The resistance 'r' is very high, so that the current 'i' flowing through is very small, so current 'i_c' can be considered to be the same as the total current 'i'.

So 'P' = power consume, $I = I_c + I_r$

$$P = VI \cos\phi$$

→ But I_R is so small, that it can be neglected, so $I = I_C$

$$I = \frac{V}{X_C}, \quad X_C = \frac{1}{2\pi f C}$$

$$I = V \cdot 2\pi f C$$

$$\therefore P = V \cdot (V \cdot 2\pi f C) \cos\phi = V^2 \cdot 2\pi f C \cos\phi \qquad \because \phi = 90 - \delta$$

$$\therefore \cos\phi = \cos(90 - \delta) = \sin\delta$$

where δ is small & it should be in radian

$$\therefore P = V^2 \, 2\pi f C \sin\delta$$

MICROWAVE HEATING

→ In this system, electricity is converted into electromagnetic wave, which generate energy & this energy is used to cook the food.

→ These waves are nothing but high frequency radio wave similar to those radio & tv.

→ The wavelength of this wave is very short of very high frequency also known as microwave.

→ In the oven, microwave are confined inside the open cavity & reflected of to its ~~will~~ wall & door. Once the door is open, all microwaves are automatically switch off.

→ These microwaves vibrate million of times per second (2400 - 2500) MHz

→ The microwave are attracted to water & sugar molecule, they cause these molecule to vibrate at 2400 MHz / second

→ Leading to friction within the food which generate the heat ~~with~~ which began the cooking process.

→ The microwave heating is used in the microwave oven for baking purpose, the frequency used is from 900 MHz – 2400 MHz.

Application of microwave heating

- → Baking manufacture of bread & toast.
- → Dry of paper & textile.
- → Treatment of disease like cancer.
- → Manufacture of plastic
- → Processing of cement & timber etc.

Advantages of microwave heating

- → It has neat & clean system
- → It provide uniform heating to the substances
- → The system provide quick heating
- → The depth of penetration of heat into the material is much more.
- → within the material, the heat is generated directly which gives much faster temperature rise.

ELECTRIC WELDING

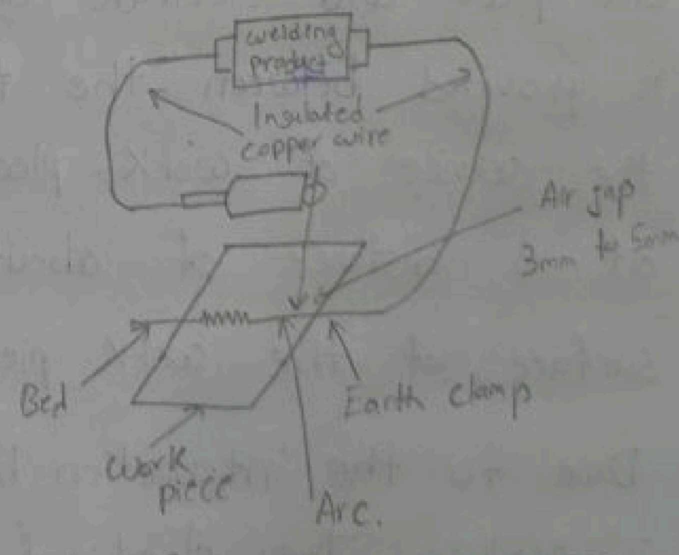
→ Welding is a process in which two metal parts are joined with heating

→ Electric welding is defined as that branch of welding in which electric current is used to produce the large heat reqd for joining together into ~~firm~~ firm union two pieces of metal.

- Electric welding
  - Resistance welding
    - Butt welding
    - Flash welding
    - Spot welding
    - Projection welding
    - Seam welding
  - arc welding
    - Metal arc welding
    - Carbon arc welding
    - Atomic hydrogen ~~welding~~
    - Helium Argon welding

~~Principle of~~ Arc welding

The welding in which the electric arc is produce to give heat for the purpose of joining two surface is called electric arc welding. The joining by fusion of two or more pieces of metal together by



using the heat produce ~~from~~ form an electric Arc. The arc is flam reflection of intense heat ie generated as the electric current passes through a highly resistance air gap.

Arc welding is divided into 4 type.

(1) Carbon arc welding
(2) Metal Arc welding
(3) Atomic hydrogen arc welding
(4) Helium or argon arc welding

Here in arc welding, pressure is not use, filter metal is obtained from the electrode. Arc welding is also Known as stip welding.

Principle of Arc welding

A high current is passed through the circuit (both ac & dc), one terminal is connected to the electrode & other to work piece. A suitable gap is gap between one piece and electrode and shown in fig. The gap is provided between the ~~team~~ terminal of the electrode and the service of work piece by Keeping the electrode at a distance of about 3mm to 6mm, from the surface of the work piece.

Due to the interaction by the air gap or gas heat is produce. The electrical energy is converted into heat energy producing a temp of 3000°c to 4000°c.

This heat is meant for the edges to be melted & molten coil is form.

. On Solidification the welding joint is obtain.

Advantages :-

(1) Simple welding equipment.

(2) Process is fast and relable

(3) welders use Standard domestic current.

(4) Use for maintance repair & field construction

Disadvantages

(1) Not clean

(2) the deposition made is limited.

Resistance welding

These process are the pressure welding process. in which heavy current passes through the area of interface of metal to be join.

Heat produce by resistance welding is $H = I^2RT$.

I = Current in Ampere, R = Resistance of welded area

T = Time for flow of current.

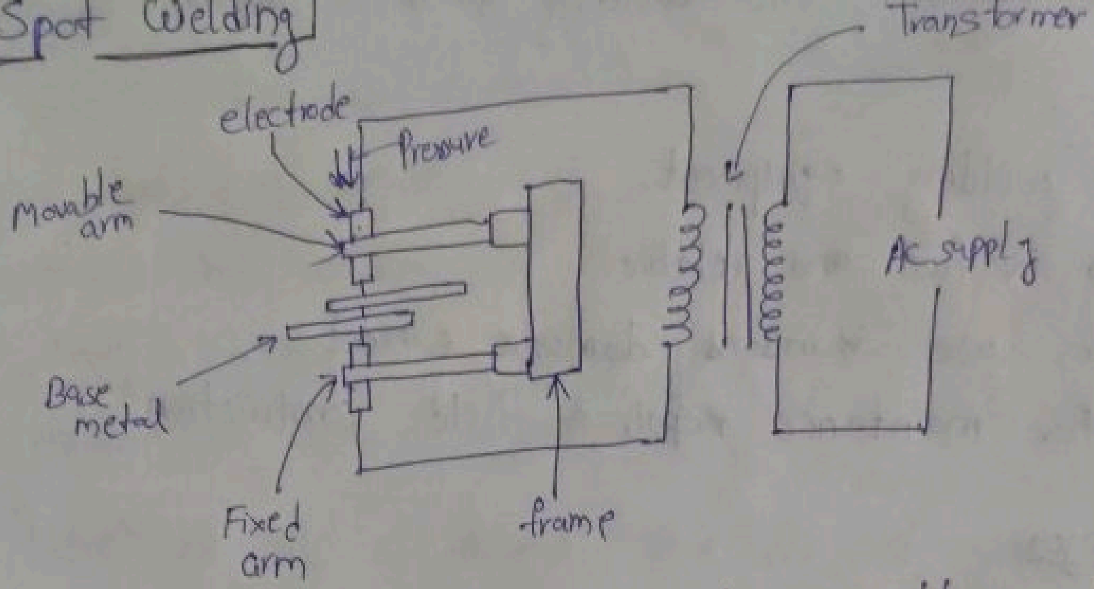
→ Current is provided for few Kilo Ampere.

→ voltage range from 2-12 volt.

→ Necessary pressure is varied from 30-60 N/m^2

→ Major type of resistance welding are (i) spot welding. (ii) Projection welding (iii) Seam welding (iv) Butt joint welding

Spot Welding



Spot welding is one form of resistance welding which is a method of welding two or more metal sheet together without using any filter material by applying pressure & heat to the area to be welded.

The process is used for joining sheet material & uses copper alloy electrode to apply pressure & convey the electric current through the workpiece.

The material between the electrode is squeeze together. It then melt destroying the interface between the path. The current is switch off & the nugget of molten material solidify forming the join. To create heat copper electrode pass an electric current through workpiece.

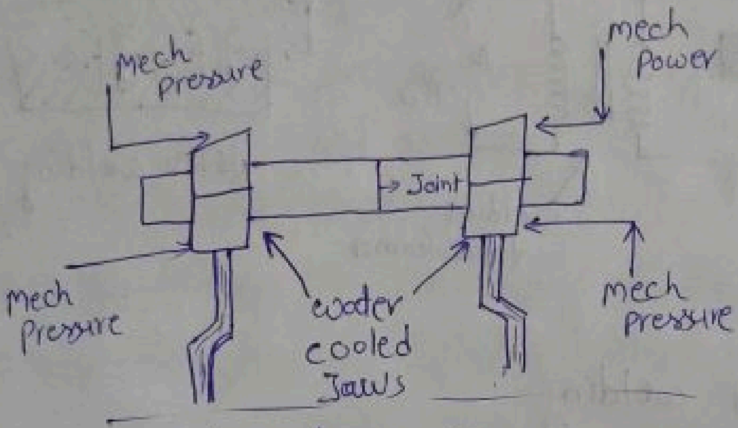
The heat generated depends on the electrical resistance & thermal conductivity of metal & the time that the current is applied. Here copper is used for electrode because it has low resistance & high thermal conductivity.

→ Current range 1000-5000A, depends on the base metal

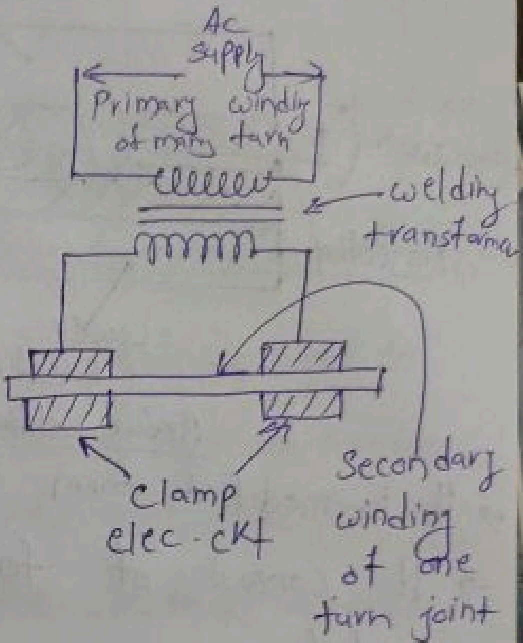
→ Voltage 2-12 volt.

→ It is primarily used for joining metal are normally upto 3mm thickness

Butt Joint welding



elementary ckt



elec. ckt

→ In this process heat is generated by the contact resistance between two component

→ The face of the component should be edge prepared as shown in fig.

→ The two parts are brought together & pressure is applied along the axial direction by spring.

→ A heavy current is passes from the welding transformer, which create the necessary heat at the joint.

→ Due to comparatively high resistance of the contact area,

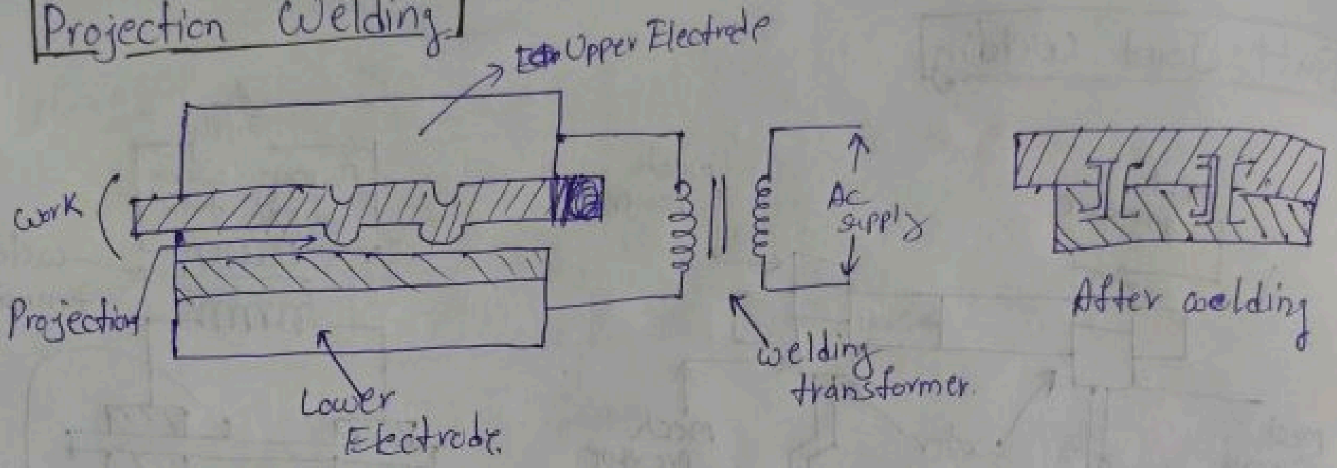
→ The metal at the joint melt into two parts, fused together & producing joint

Application

① where the parts are joint end-to-end

② For welding pipes, wires, rod

Projection Welding



Before welding

→ It is modified form of spot welding

→ It consist of forming slight projection on the sheet of metal

→ The projection are accurately formed in precise location of the metal by special set of dies.

→ After the projection are formed, the rise portion of one piece are ~~place~~ press into the contact with another piece.

→ At the same time, heavy current is passes through the two pieces.

→ when the rise portion touch the 2nd sheet of steel. as their clamp by electrode in a projection welder, then current is applied, current flow at the point, heat & fuse the two pieces together.

Advantages

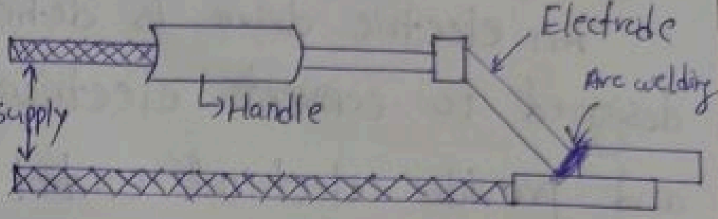
① More than one spot or weld are done at a time, so more output is obtained

② Due to low current density & low pressure, the electrode life is increased.

③ Good finish appearance.

④ It locates the weld automatically at certain desire point by the position of projection.

Metallic Arc Welding



→ In this metallic arc system, a metal rod is used as an electrode & workpiece.

→ Ac supply from the secondary of the welding transformer or dc supply from the dc welding generator depending upon whether ac or dc is used, which is connected across the job & electrode.

→ The work is then suddenly tauched by the electrode & then separated from it a little. This result in an arc between the job & electrode.

→ Due to heat generated by the arc, a little portion of work melt & also tips of the electrode.

→ The two pieces to be welded fused together & electrode is remove, the metal cools & solidifies giving a strongly welded joint.

→ The potential differance across the arc is 20-25V.

→ The arc drawn between the metal electrode & the work create a temp. of over 3500°C. In a small area concentrate at a point.

Carbon Arc Welding

This method is normally used for welding copper & its alloy. A carbon electrode is connected across the -ve terminal & work is connected across the +ve terminal. For this type of welding, only dc supply can be used

→ 2 method of carbon arc welding are used.

→ In one method, no flux is used & in other method, flux iron in the form of powder of paste is used to prevent the weld from oxidation.

→ Former method is limited to non-ferrous metal & the later method is usually applied for ferrous metal.

→ Carbon Arc welding is a welding process in which heat is generated by an electric arc struck between a carbon electrode & the workpiece. The arc heats & melt the workpiece edges, forming a joint.

Advantages

→ Low cost of equipment & welding operation

→ The process is easily automated.

Disadvantages

→ Unstable quality of the weld

Atomic Hydrogen Arc Welding

The atomic hydrogen arc welding process are

1. Electrode energy is supplied to an arc between two tungsten electrode, where it is transfered into heat.

→ Molecular hydrogen is blown through this arc & transfer into the atomic form which act as a vehicle for the transfer of energy from the arc to the work.

→ In the direction away from the arc, sudden decrease of temp. causes the rapid decrease in the concentration of atomic hydrogen & a release of the heat of recombination

→ Required voltage is 300 volt & current range upto 50 Ampere

→ In this type of welding arc is struck between two tungsten electrode & hydrogen is passes through the arc.

→ Due to high temp about 4000°C of the arc, hydrogen changes to its atomic form.

→ When the atomic hydrogen travel to cooler region of the arc it rejects its molecule.

→ Then heat is generated which is used to melt the job to be melted.

→ This method is used for melting stainless steel & most non-ferrous metal.

→ Both Ac & dc supply are used.

Helium or Argon Arc Welding

→ This method is used for welding Aluminium & Aluminium alloy, Magnesium & Magnesium alloy.

→ An arc is struck between electrode of tungsten & the work.

→ Helium or argon is used to give an inert atmosphere, so that oxidation of the welded joint does not take place

→ Sta
the

→ standard dc or ac equipment may be used, provided the open circuit voltage araund 100V for ac & 70V for dc.

INDUSTRIAL DRIVE

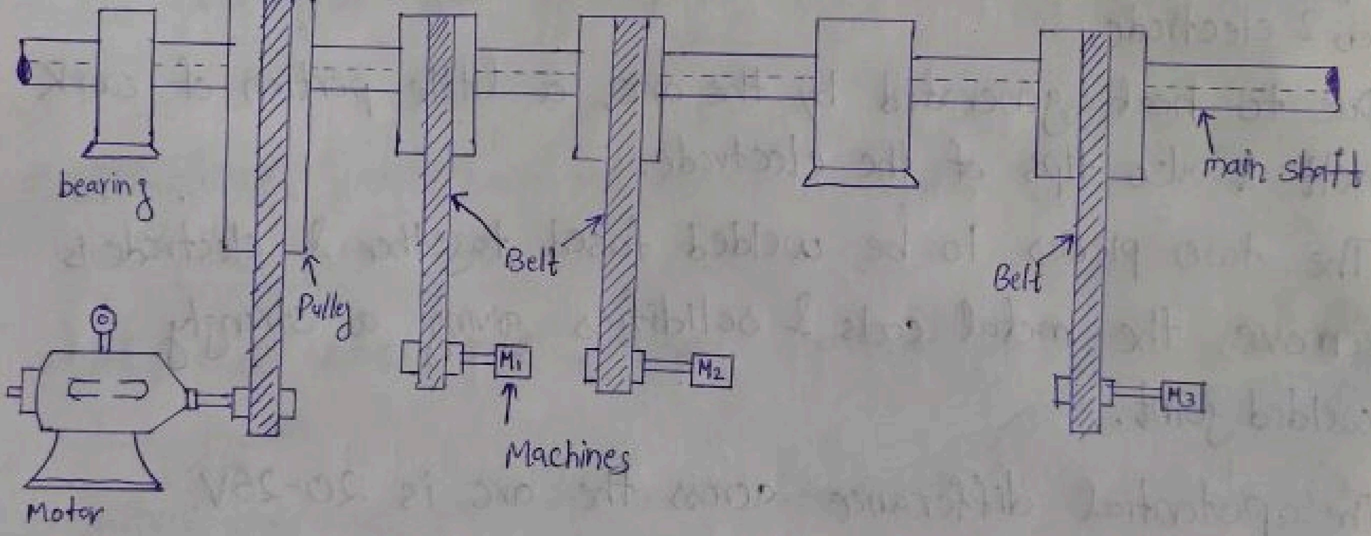
Electric Drive

An electric drive is defined as a form of machine equipment designed to convert electrical energy into mechanical energy and provide electrical control of these processes.

→ It is divided into 3 types
  * Group drive * Individual drive * Multimotor drive.

Group drive

In group drive, one motor is used as a drive for two or more than two machines.



→ The motor is connected to a long shaft, on which belt & pulleys are connected to run other machines.

→ It is also called line shaft drives

→ This type of electric drive is economical

→ It is not possible to install a new machine at a far away distance

Advantages

→ Initial cost of Group drive is less as compared to that of the individual drive.

→ Group drive system is useful because all the operations are stopped simultaneously.

→ Less space is required.

→ It require little maintenance (low maintenance cost)

Disadvantages

→ It has low power factor.

→ It does not provide constant speed.

→ It is not suitable for driving heavy machines, such as cranes, lift & hoists etc.

→ In G.D, if the main motor fails, then whole industry will come to stand still

→ Efficiency is low

Individual Drive

→ In this type of electric drive a single electric motor is use to drive one individual machine.

→ machine can be located at convinient place

→ If there is a fault, in one motor, this will not effect the production of the industry appreciably.

Advantages

→ Individual drive give desired operation as each machine is driven by its own individual motor

→ Individual motor works at good p.f

→ Efficiency of the system is high

→ Individual drive is more reliable

→ Machine may be fitted wherever convinient.

→ More useful where constant speed is required

→ Most suitable for driving heavy machines such as lifts, hoists & cranes etc

Disadvantages

→ Initial cost is high

→ All operations are not stopped at once.

→ More space is required

→ More maintenance is required

Application of DC Motor

1) Separately excited DC motor - Paper machine, steel rolling unit, Diesel electric propulsion of ship.

2) Shunt Motor - Lathe, Fan & blowers, Printing press etc.

3) Series Motor - Crane, Hoists, Trolley cars, conveyors, electric locomotive

4) Compound Motor
   (a) Cumulative Compound wound - Shears, punches, heavy plane etc.
   (b) Differentially Compound wound - Employed for experimental & Research

3-ϕ Induction Motor

1) Squirrel cage induction motor - Lathe, Drilling machines, Industrial drives.

2) Slip ring Induction motor - Lift, Cranes, conveyors, elevators, food processing factory machines.

3-ϕ Synchronous Motors

Operating speed is less (around 500 rpm) & high power is reqd (35KW to 2500KW). Ex - Reciprocating pump, compressor, rolling mills

1-ϕ Induction Motor

Small fans, mixer, toys, high speed vacuum cleaners, electric shavers, drilling machines.

Universal Motor

Portable drill machine, hair dryers, grinders, table fans, blowers, polishers, kitchen appliances.

Repulsion Motor

It is used for loads requiring high starting torque such as hoists, lift, electraic train etc.

Choice of Electrical Drives :-

Some of the important factors to choose an electrical drive are:-

1) Requirements related to the source:

Type of source & its capacity, magnitude of voltage, voltage fluctuations, power factor, harmonics & their effect on other loads & ability to accept regenerated power.

2) Steady state operation requirements :-

Nature of speed torque characteristics, speed regulation, speed range, efficiency, duty cycle, quadrants of operation, speed fluctuation & ratings.

3) Transient requirements:-

Starting, breaking, values of acceleration & deacceleration, reversing performance

4) Capital & running cost, maintenance

5) Environment & location.

6) Reliability

7) Space & weight restrictions.

Characteristics of DC Motor :-

→ Speed armature current ($N - I_a$)

→ Torque armature current ($T_a - I_a$) (electrical Characteristics)

→ Speed Torque Characteristics ($N - T_a$) (mechanical Characteristics)

$$P = VI \cos\theta$$

$$\cos\theta = \frac{VI\cos\theta}{VI} = \frac{\text{Real Power}}{\text{Apparent Power}}$$

Shunt Motor

Speed armature current :-

Speed equation

$$\boxed{N = \frac{V_t - I_a R_a}{K_a \phi}}$$

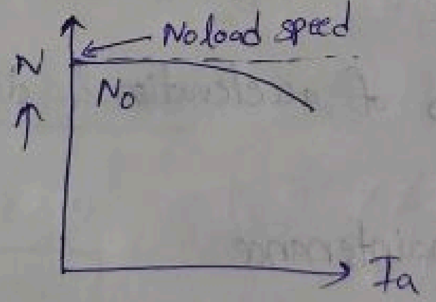
$$E_b = V_t - I_a R_a$$

$$\Rightarrow K_a \phi N = V_t - I_a R_a$$

For a shunt motor ϕ is constant (independent of I_a)

$$N = \frac{V_t}{K'} - \frac{I_a R_a}{K'}$$

when the armature current Increases (load Increases), the speed f



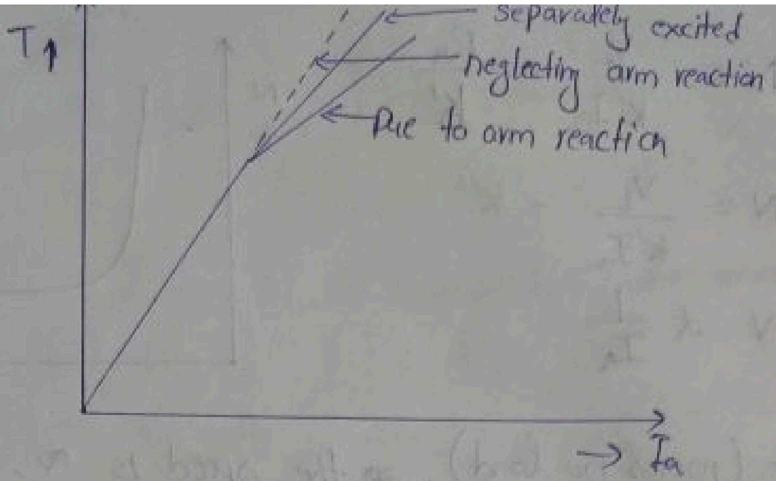
Torque armature current :- ($T_a - I_a$)

Torque equation , $T_a = K_a \phi I_a$

For shunt motor at small load ϕ is constant

$$T_a = K' I_a$$

$$T_a \propto I_a$$



Speed Torque Characteristics :- (N-T_a)

Speed torque:

$$N = \frac{V_t - I_a R_a}{K_a \phi} = \frac{V_t}{K'} - \frac{I_a R_a}{K'}$$

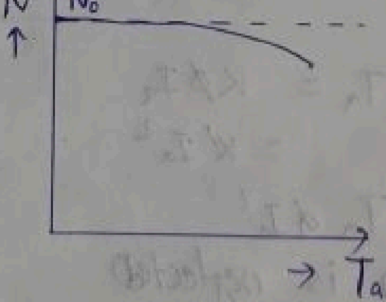
torque equation = $T_a = K_a \phi I_a$

$$\Rightarrow I_a = \frac{T_a}{K''}$$

Putting value of I_a in speed eqn we get,

$$N = \frac{V_t}{K'} - \frac{T_a R_a}{K' K''} = \frac{V_t}{K'} - \frac{T_a}{K''}$$

Torque Increases means load Increases, when the torque Increases the speed falls.



Series Motor

N - I_a Characteristics :-

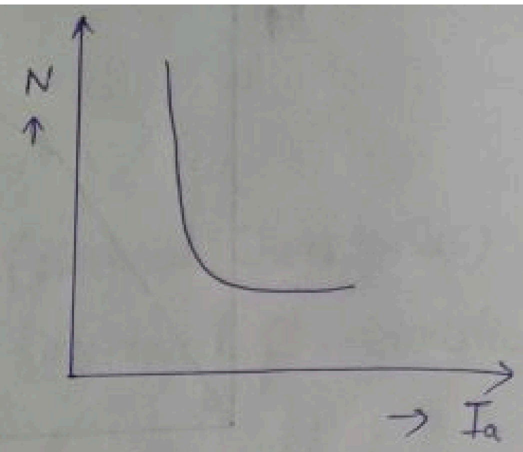
$$N = \frac{V_t - I_a R_a}{K_a \phi}$$, for series motor, $\phi \propto I_a$

$$\Rightarrow N = \frac{V_t - I_a R_a}{K' I_a}$$

$\Rightarrow N = \frac{V_t}{K' I_a} - \frac{R_a}{K'}$

$\Rightarrow N = \frac{V_t}{K' I_a} - K''$

$\Rightarrow N \propto \frac{1}{I_a}$



when $I_a = 0$ (means no load), the speed is ∞.

when I_a increases, the speed decreases.

2mark Imp Q/ Why series motor can't be started without a load? (or) G/

Why series motor is always started with load?

Ans → At no load $I_a = 0$, so flux is zero, the speed is infinitely high.

→ If the series motor is started without any load it may come out from the base due to very high speed.

→ So always a series motor is started with a mechanical load (by belt & pully arrangement)

T–I_a Characteristics

Torque equation $T_a = K \phi I_a$

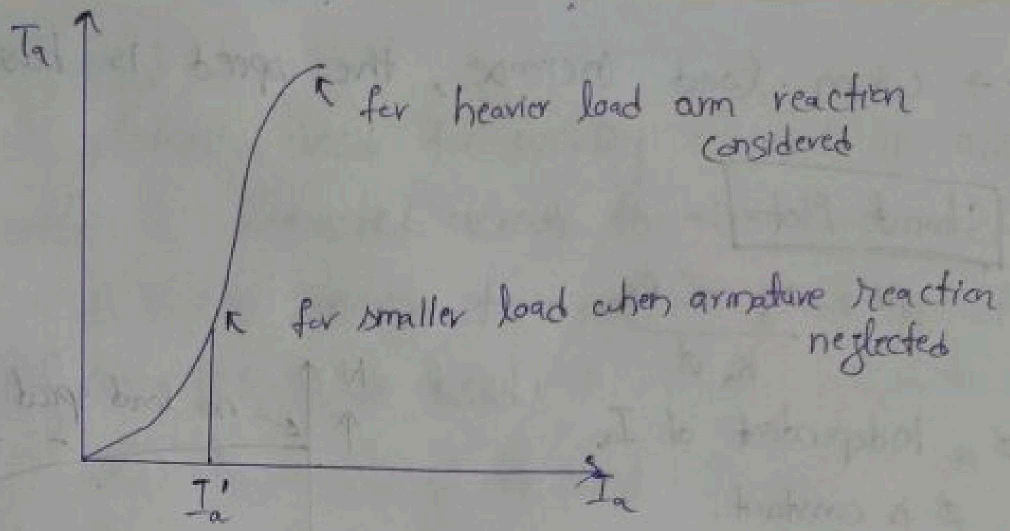
$= K' I_a^2$

$T_a \propto I_a^2$

(when armature reaction is neglected)

For higher load armature reaction cannot be neglected, so flux reduces.

So for heavier load $T_a \propto I_a$



Q/ In traction what type of motor is used & why?

Ans DC series motor is used because in series motor at the time of starting $T_a \propto I_a^2$, So very high torque is produced at the time of starting.

Ex- Traction means locomotive train, Hoist, crane.

N-Ia Characteristics

Speed equation

$$N = \frac{V_t - I_a R_a}{K_a \phi} = \frac{V_t}{K_a \phi} - K''$$

torque equation $T = K \phi I_a$

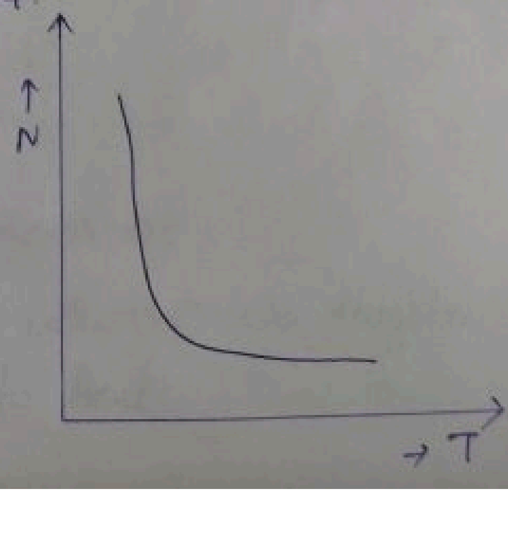
$$= K''' I_a^2$$

$$I_a = \sqrt{\frac{T}{K'''}}$$

Putting the value of Ia in speed eq^n we get.

$$N = \frac{V_t}{K' \sqrt{\frac{T}{K'''}}} - K''$$

$$N \propto \frac{1}{\sqrt{T}}$$



→ Pully is used to transmit the mechanical power.

→ when load increase, the speed is basically decrease

Shunt Motor :-

$$N = \frac{V_t - I_a R_a}{K_a \phi}$$

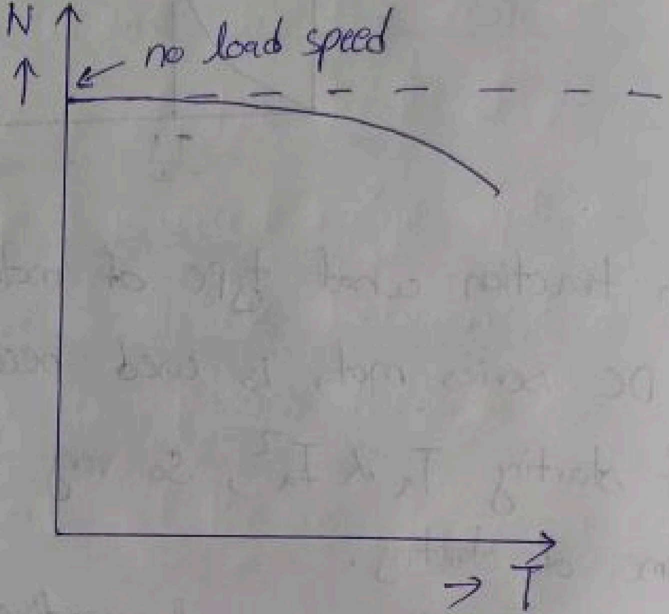
ϕ is independent of I_a

ϕ is constant.

$$N = \frac{V_t}{K'} - I_a R_a$$

$$T = K\phi I_a$$

$$\Rightarrow I_a = \frac{T}{K'}$$



Putting the value of I_a

$$N = \frac{V_t}{K'} - K''T$$

Compound Motor

Compound motor is either shunt field dominated or series field dominated, the characteristics takes the shape of either series or shunt motor depending up sent of this respective thing.

Electric Traction

System of Track Electrification :-

→ In India electrification of the track has been confined to the urban and suburban lines in the vicinity of large cities.

→ Two types of vehicles are used for electric traction.

→ The 1st type of vehicles receive power from a distribution network while the 2nd type of vehicles generate their own power.

1. DC System

→ The d.c traction in India exists only in Bombay region & some parts of Madras.

→ In this system the electric motor use are dc series motor.

→ The operating voltage is generally about 600 volts for sub-urban railways and tram cars.

→ For main line railways the operating voltage is from 1500 V to 3000V.

→ The motor receive power from an overhead line with the help of a pantograph and the railway steel track is the return conductor.

→ For sub urban service the distance between the sub-station is 3 to 5 Km & for main line service it is about 40 to 50 Km.

2. AC System

→ The AC system in India is being employed from Howrah to Tundla & from Madras to Tambram.

→ The modern development in electric traction is to use 1-ϕ ac supply.

→ The AC system are 4 types:-

3ϕ AC system

→ This system employs 3ϕ slip ring induction motors, speed control being obtained by a combination of pole changing and rotor resistance method.

→ Advantages
Regenerative breaking is obtained immediately as the speed exceeds the synchronous speed.

→ Disadvantage - Use two overhead conductors

1ϕ Standard frequency system

→ This system is also known as composite system of traction.

→ This system is employed in India on South-Eastern & Eastern Railways.

→ The System has a single overhead wire supplied at 25KV, 50 c/s.

→ A transformer is mounted on the locomotive and it step-down the voltage which is further rectified and supplied to the traction motor.

→ The sub-station are supplied at a high voltage of upto 152 KV which is step down to 25KV by transformer.

1ϕ low frequency system

→ 1ϕ. 15KV, 16 2/3 cycle/sec system is use in West Germany, Sweden & Australia for the main line service.

→ In some urban area, of USA 11 KV at 25 cycle/sec is employed.
→ 400V is use of traction motors.
→ Series motor is employed for traction.
→ The main disadvantages of this system is that a special low frequency power distribution network is required.

1ϕ to 3ϕ System

→ In this system, 1ϕ high voltage ac system is use for distribution network.
→ The locomotives carry a phase converter which convert 1ϕ ac in 3ϕ.
→ The voltage use for distribution bet is 16,000V at 50 cycle/s
→ This system is adapted in Hungary.
→ Advantages
Low cost distribution and cheap and robust ~~cost~~ construction of Induction motor.

System of Traction

The various system of traction are:-

1. **Direct Steam Engine**

→ Reciprocating steam engine is most widely employed for rail road operation.
→ The locomotive & train unit is self-contained, therefore it is not tied to a route.

Advantage
→ It has simple control.
→ Initial investment required is low.

→ It is cheap for low density traffic area and in initial stages of communication by rail.

Disadvantages

→ Low efficiency (6-8%)

→ Higher cost of maintenance.

→ Limited overload capacity.

2. Direct Internal Combustion Engine

→ The characteristics of an IC engine is that it produces almost constant torque at all speed.

→ To increase the starting torque and speed, a gear box has to be provided.

→ The η of internal combustion engine at its normal speed is about 25%.

Advantage

→ Speed control & braking system employed is very simple.

→ It is cheap drive for country districts.

Disadvantage

→ Speed control is possible only by employing a gear box.

→ The maintenance & running cost are higher.

3. Internal Combustion Engine Electric Drive

→ In this system the reduction gear & gear box are eliminated as a diesel engine drives.

→ The locomotives of this type of drive are becoming widely used because these have been found considerable favour for railway work.

Advantages

→ Low capital cost.

→ Absence of smoke & dirt and hence convenience of passengers.

→ overall η is greater than that of Steam locomotives.

→ Better riding qualities.

Disadvantages

→ Maintenance and operating cost is high.

→ Life of diesel engine is comparatively short.

→ Special cooling system is required.

4. Battery Electric Drive

→ In this drive the locomotive carries the secondary batteries which supply power to DC motor employed for driving the vehicle.

→ The capacity being small.

→ It is use for shunting in railway yards. for traction in mines, for local delivery of goods in large town and large industrial plant.

→ Advantages are low maintenance cost & absence of furnace.

5. Electric Drive

→ This is the most extensively developed and widely use system of traction.

→ In this system the vehicle draw electrical energy from the distribution system fed at suitable point from substation.

Advantages

→ Maintenance & repair cost is about 50% of steam locomotive.

→ Due to absence of smoke & dust. It is very clean.

Disadvantages

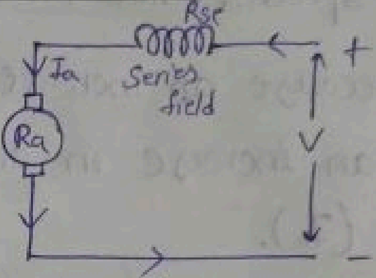
→ In vicinity it causes interference to the telephone line.

→ whole system become standstill in case of power failure.

→ A very high capital cost.

Running Characteristics of DC & AC traction Motor

Series Wound Motor



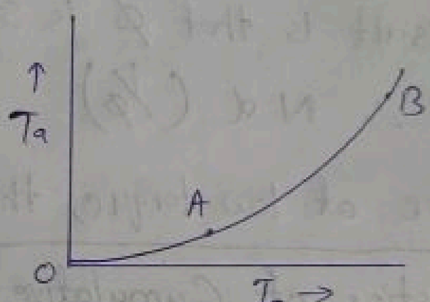
(a) T_a/I_a Characteristics :-

Here $T_a \propto \phi I_a$

upto magnetic saturation

$\phi \propto I_a$

$\therefore T_a \propto I_a^2$



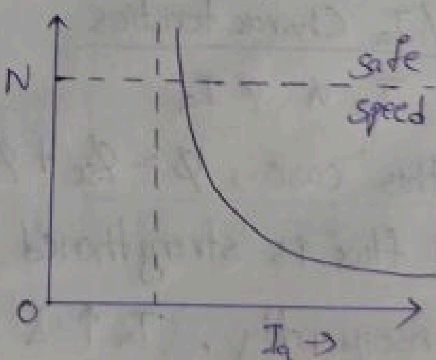
→ If I_a is doubled, T_a is almost quadrupled. So, T_a/I_a curve is a parabola.

→ $T_a \propto I_a^2$, Hence series motor are used where high starting torque is required. Ex- hoists, electric traction etc.

(b) N/I_a Characteristics :-

Here $N \propto \frac{E_b}{\phi}$

where $E_b = V - I_a(R_a + R_{se})$



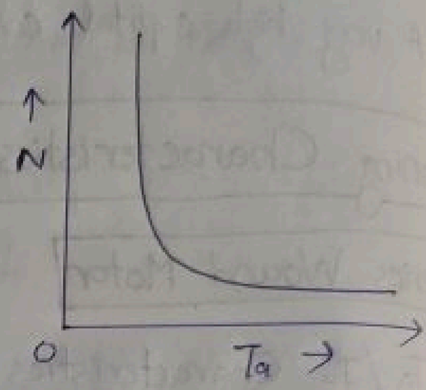
when I_a increases the back emf E_b decreases due to $I_a(R_a + R_{se})$ drop whereas flux ϕ increases.

→ $I_a(R_a + R_{se})$ drop is quite small under normal condition & may be neglected.

$\therefore N \propto \frac{1}{\phi} \propto \frac{1}{I_a}$ upto magnetic saturation.

→ upto magnetic saturation, the N/I_a follows the hyperbolic path. After saturation the flux become constant & so does the speed.

(c) T_a/N characteristics :-



→ Series motor develop a high torque at low speed & vice-versa.

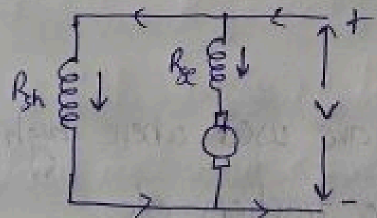
→ It is because an increase in torque requires an increase in armature current (I_a).

→ The result is that ϕ is strengthened & hence the speed drops.

$$\therefore N \propto (1/\phi)$$

→ Therefore at low torque, the motor speed is high.

Characteristics of Cumulative Compound Motor :-

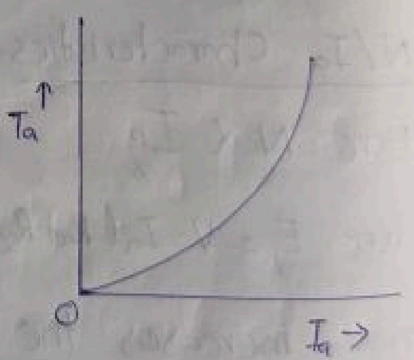


$$\phi = \phi_{se} + \phi_{sh}$$

1. T_a/I_a Characteristics

$$T_a \propto \phi I_a$$

In this case, $\phi = \phi_{se} + \phi_{sh}$. so that total flux is strengthened

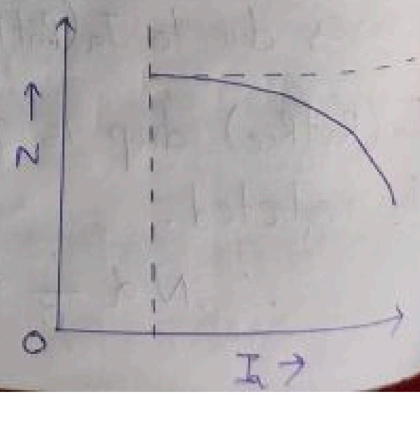


→ Consequently, $T_a \uparrow$ & $I_a \uparrow$

2. N/I_a Characteristics

$$N \propto \frac{E_b}{\phi}, \text{ where } \phi = \phi_{se} + \phi_{sh}$$

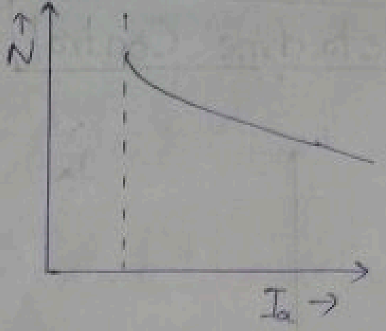
when load increases, the series field strengthens the shunt field, so that total flux increases.



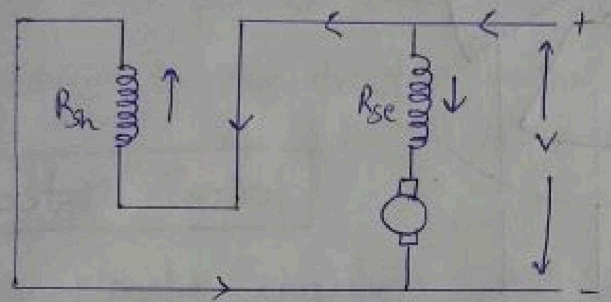
→ Hence the speed of motor falls.

3. N/Ia Characteristics

It links between that of shunt motor & a series motor.



Characteristics of Differential Compound Motor

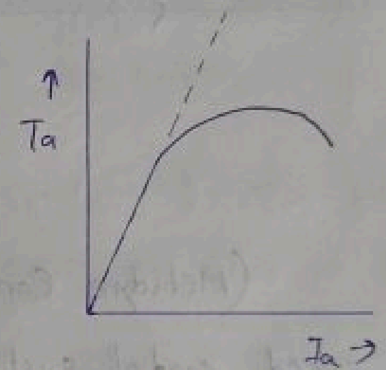


$\phi_t = \phi_{sh} - \phi_{se}$

1. Ta/Ia Characteristics

→ Series winding oppose the shunt, therefore, the resultant flux decreases as the armature current increases.

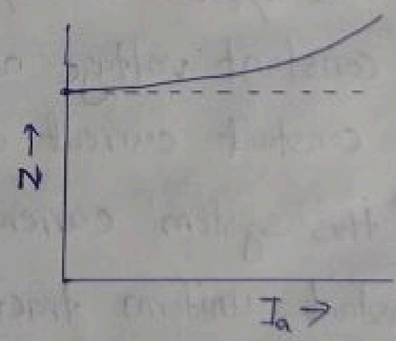
→ Consequently Ta increase with Ia.



2. N/Ia Characteristics

With increase in load, the resultant flux decreases and hence the motor speed increases.

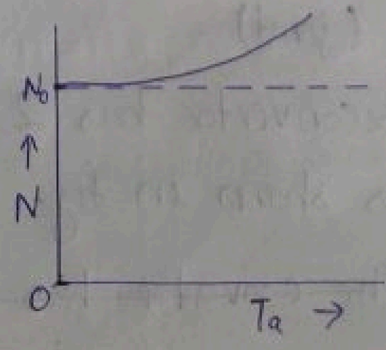
$\therefore N \propto \frac{E_b}{\phi}$



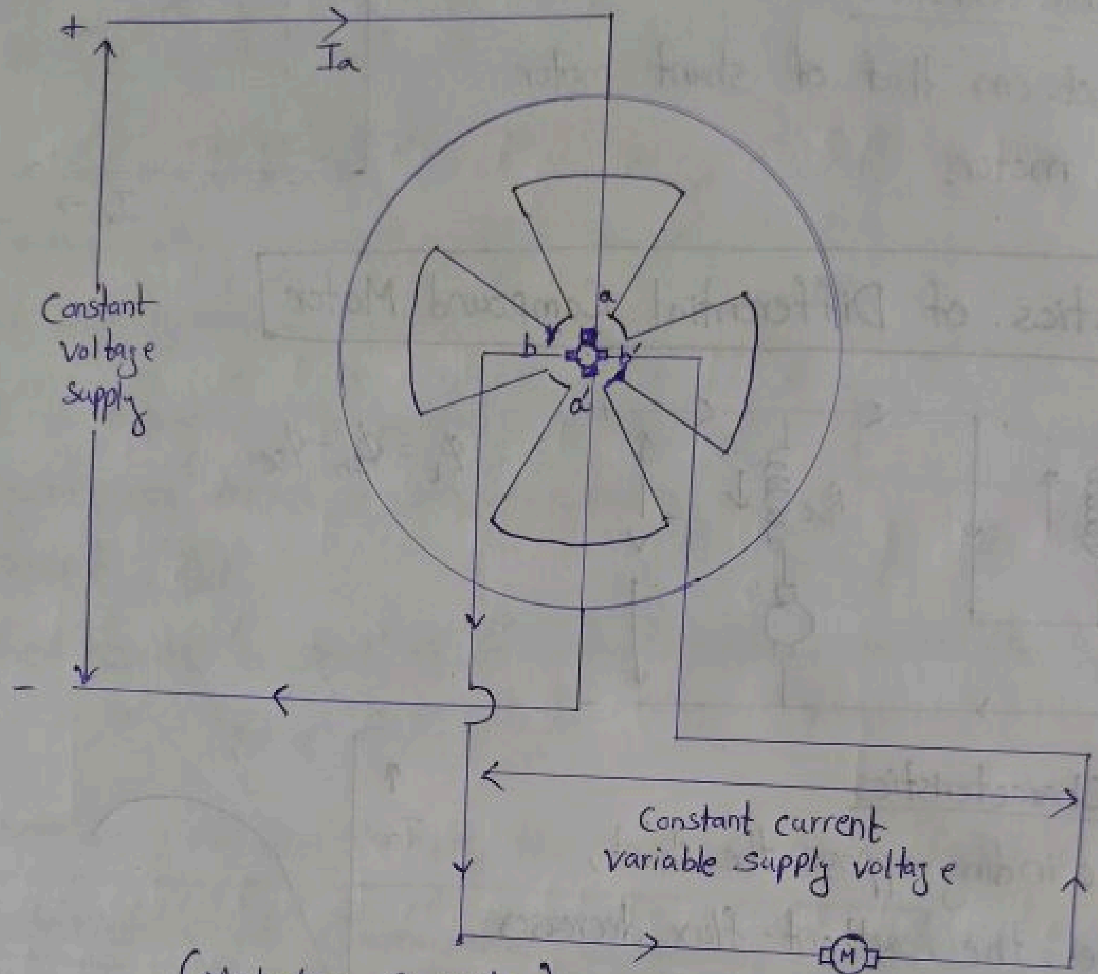
3. N/Ta Characteristics

→ It is clear from the curve that as the Ta increases, the motor speed also increases.

→ If torque increases too much, the machine may tend to attain dangerously high speed with serious consequences.



Metadyne Control



(Metadyne Converter)

→ This speed control system is based on constant current system.

→ In this system metadyne converter is used which takes power at constant voltage and variable current & delivers the same at constant current and variable voltage.

→ In this system current throughout - the starting period remain constant, uniform tractive effort is developed.

→ This give very smooth drive & high coefficient of adhesion (joint)

→ The converter has 2 pole dc armature & 4 pole field magnet as shown in fig.

~~→ The converter has 2~~

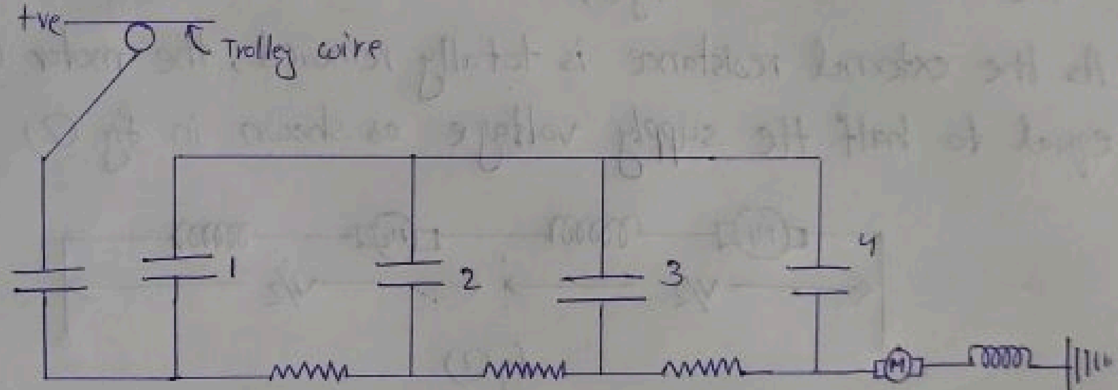
→ There are two set of brushes, one set connected to a constant voltage supply main & other is connected to the load or traction motor.

→ During operation the metadyne converter draws current I_a from the mains.

→ The other set of brush will feed constant current at varying voltage to the traction motor.

Rheostatic Control

→ Series motor can be started by connecting an external resistance in series with the main circuit of the motor.



(Basic Traction Motor CKt)

→ At the time of start of dc series motor, the back emf develop by the motor is zero.

→ when back emf is zero, full or max^{m} resistance is connected in series with armature.

→ Then full load rated current is equal to the line voltage.

→ At the time when the motor picks up the speed, the back emf develop by the motor increases and external resistance is gradually cut off in order to maintain the constant current through out the accelerating period.

→ Fig shows a traction motor circuit with rheostatic starting.

→ In this method, a lot of power is wasted in the external circ

Series - Parallel Control

→ When we use two motors then these are connected in series through starting resistance 'R'.

→ The starting resistance 'R' is gradually cut off to zero value, as the motor speeds up.

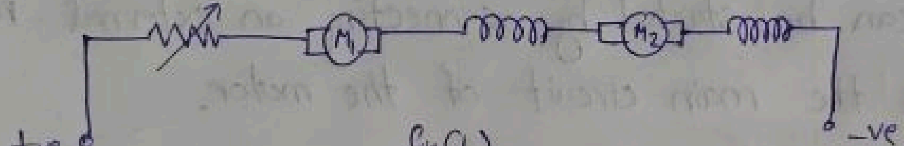


fig (1)

→ As the external resistance is totally removed, the motor will be equal to half the supply voltage as shown in fig (2)

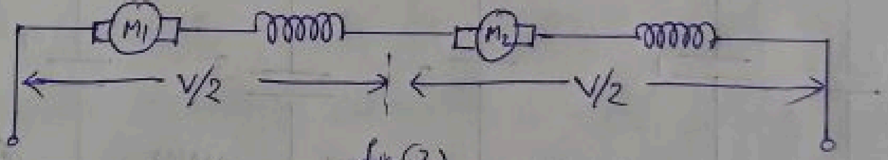


fig (2)

→ This is the first running position.

→ In this position, each motor will run at 1/2 of its normal speed.

→ Since no external resistance lies in the circuit, therefore there is no loss of energy and motor will run at their maximum efficiently.

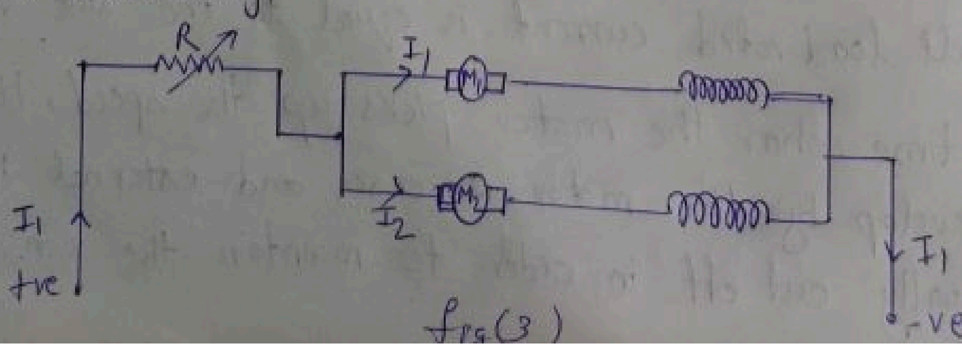


fig (3)

→ In the second running position, the two motors are connected in parallel and in series with an external resistance 'R' as shown in Fig (3)

→ The external resistance is gradually cut off as the motor speed up.

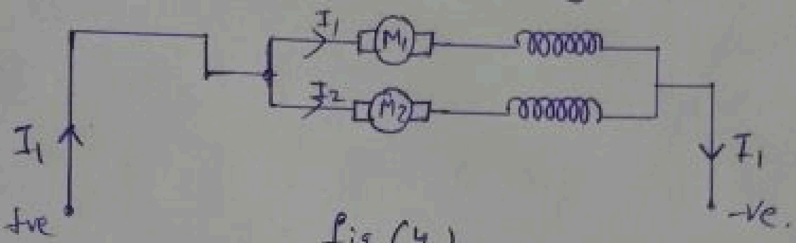


fig (4)

→ when the external resistance is totally removed from the circuit as shown in fig (4), the second running position is obtained.

→ In this position, the voltage across each motor is equal to the full line voltage.