LECTURE NOTES
ON

Utilization of Electrical Energy & Traction
For 5th sem, Electrical engineering (Diploma)

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Electrolysis

The process of decomposition of electrolyte by the passage of electric current through them is called electrolysis.

Electroplating

The process of depositing a metal on the surface of some other metal by electrolysis is called electroplating.

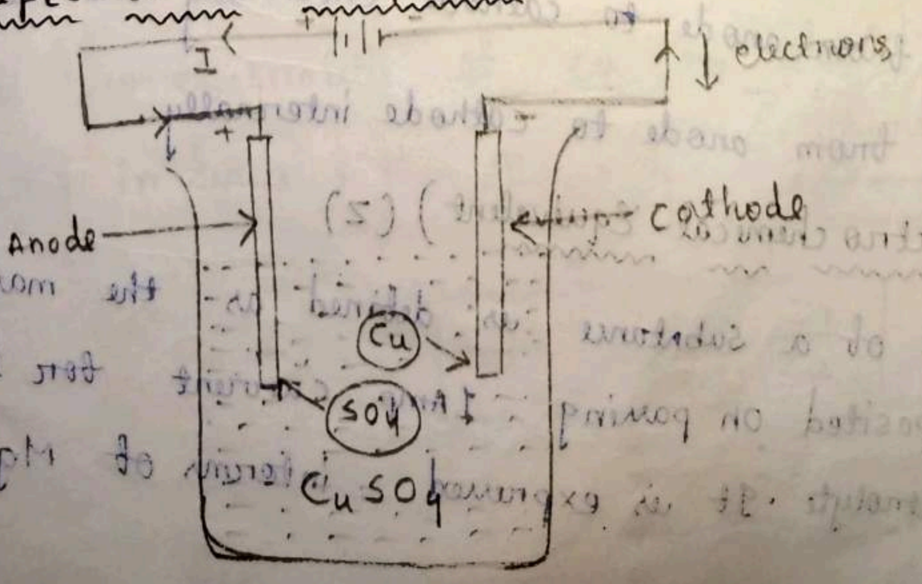
Electro deposition

It is the process of depositing a metal over another metal or non-metal by electrolysis. An electroplating is a very common example of electrodeposition.

Electro cleaning

Before electroplating the metal should have a surface free from oil, grease, etc. They are cleaned by electro-cleaning method. A solution of sodium phosphate is used as an electrolyte in the tank. Then the tank is ~~collected to~~ connected ~~to~~ +ve terminal and the plate to be cleaned is connected to -ve terminal.

Principle of Electro deposition



when $CuSO_4$ (copper sulphate) is disslowed in water, it ~~imedi~~ immediately dissociates in to +ve charge ions (Cu^{++}) & -ve charge ions (SO_4^{--}).

If two electrodes are immersed in the electrolyte and a potential difference is applied between them, then (Cu^{++}) ions will move towards the cathode and SO_4^{--} ions will move towards the anode.

The Cu^{++} is deposited at the cathode as metal. The SO_4^{--} ions are collected at the anode and react with water giving out oxygen.

$$2SO_4 + 2H_2O \longrightarrow 2H_2SO_4 + O_2$$

The oxygen is libarated as gas and H_2SO_4 is formed in the electrolyte. If the anode is made up copper, the H_2SO_4 reacts with it forming copper sulphate ($CuSO_4$) and libarating hydrogen.

$$H_2SO_4 + Cu \longrightarrow CuSO_4 + H_2$$

The $CuSO_4$ is diposited on the cathode. The electrons will move from anode to cathode externally and the current ~~eto~~ follows from anode to cathode internally.

~~ECE~~ (Electro chemical Equivalent) (Z)

The ECE of a substance is defined as the mass of the ion deposited on passing 1Amp current for 1 second through electrolyte. It is expressed interms of Mg/culomb imp Faraday's laws of Electrolysis

1st Law

The mass of a substance libarated from an electrolyte is directly proponnal to the quantity of electricity passed through the electrolyte in a particular time.

$m \propto Q$

or, $m \propto it$

or, $m = zit$

where z = A constant known as ECE of the substance in kg/C.

2nd Law

This law states that when the same quantity of electricity is passed through several electrolites, The mass of irons libareted are propotional to their chemical equivalents or equivalent weights (E).

$m \propto E$

where E = chemical equivalent

$= \frac{\text{Atomic weight}}{\text{Valency}}$

Ex:- If two electrolites of $CuSO_4$ & $NiSO_4$ are connected in series, then $\frac{m_1}{m_2} = \frac{E_1}{E_2} = \frac{\text{chemical equivalent of Cu}}{\text{chemical equivalent of Ni}}$

$$\therefore \frac{m_1}{m_2} = \frac{E_1}{E_2} = \frac{Z_1}{Z_2}$$

Current Efficiency

It is defined as the ratio of actual quantity of substance libarated to the theoritical quantity.

$$\text{Current efficiency} = \frac{\text{Actual quantity of substance libarated}}{\text{Theoretical quantity}}$$

The value of current efficiency is always less than 1. That is lies between 90 to 98 %.

Energy Efficiency

~~On account~~ It is defined as the ratio of theoritical energy required to the actual energy required for the libaration of metal.

$$\Rightarrow \frac{\text{Theoritical energy required}}{\text{Actual energy required}}$$

The value of energy efficiency is always more than 1.

Q) If 110 mg of silver is deposited on the cathode in 3 min 20 s by a DC current of 0.5 A, calculate the ECE of silver.

A) Given

$m = 110\,mg$

$t = 3\text{ min } 20\text{ sec}$

$= 200\text{ sec}$

$I = 0.5\,A$

$m = ZIt$

$Z = \frac{m}{It} = \frac{110}{0.5 \times 200} = 1.1\ mg/C$

Q) It is required to deposite copper (Cu) on the both surfaces of an iron plate 200 cm^2 in area. what thickness of Cu will be deposited if 1 Amp of current is passed through the solⁿ for $1\frac{1}{2}$ hrs. The density of copper is 8.9 g/cc and ECE of Cu is 0.329 mg/c

A) Given

$A = 200 cm^2$ (Area of the plate)

$T = 1\frac{1}{2}$ hrs

$= 1.5 \times 60 \times 60$

$= 5400$ sec

$i = 1$ Amp

density of Cu = 8.9 g/cc

$Z = 0.329$ mg/c

$m = zit = 0.329 \times 1 \times 5400$

$z = \frac{m}{It}$ $= 1776.6$ mg

$= 1.7769$

volume of the Cu $= 2 \times$ Area $\times$ Thickness

$= 2 \times 200 \times x$

$= 400x \ cm^3$

mass = volume × density

$1.776 = 400x \times 8.9$

$x = \frac{1.776}{400 \times 8.9}$

$x = 0.00049 89$ cm

Thickness of Cu deposited = 0.000499 cm

Q) A 20 cm long portion of a circular shaft 10 cm dia is to be coated with a layer of 1.5 mm Nickel. determine the quantity of electricity in Amphr (Ah) & the time taken for the process. Assume current density of 195 A/m^2, current efficiency of 92%, specific gravity of Nickel is 8.9 and ECE of Ni is 1.0954 kg per 1000 Ah.

A) Given

$l = 20cm$

$d = 10cm$

thickness = 1.5mm

current density = 195 A/m^2

current efficiency = 92% = 0.92

specific gravity of Ni = 8.9 ⟶ density

$z = 1.0954$ kg / 1000 Ah

Q = ?

t = ?

volume = Area of the outer circumference × thickness

= $2\pi d l$ × thickness

= $\pi \times 10 \times 20 \times 0.15$

= 94.24 cm^3

m = volume × density

= 94.24×8.9

= 838.736 gm

= 0.838 ~~kg~~ 736

$Q = \frac{m}{z}$

$= \frac{0.838736 \times 1000}{1.0954}$

$= 765.689\ Ah$

Theoritical quantity of electricity required:

$= \frac{\text{Actual quantity of electricity}}{\text{current efficiency}}$

$= \frac{765.69}{0.92} = 832.27\ Ah$

~~Area =~~ I = current density × Area of the cylinder

$= 195\ A/m^2 \times \pi d l\ cm^2$

$= 195\ A/m^2 \times \pi \times 10 \times 20$

$= 195\ A/m^2 \times 628.31\ cm^2$

$= 195\ A/m^2 \times 0.062831\ m^2$

$= 195 \times 0.062831\ A$

$= 12.252\ A$

$Q = it$

$t = \frac{Q}{i} = \frac{832.27}{12.252} = 68\ hrs$

Q) How much Al will be produced from AlO_2 (Aluminium oxide) in 24 hr, if the average current 3500 Amp and current efficiency is 90%. ? Al is trivalent & its atomic weight is 27. The chemical equivalent of silver is 107.018 and 0.00111 gm of silver is deposited by 1 culomb.

A) Given

current (i) = ~~3000A~~ 3500 A

current efficiency = 90% = 0.9

volume of Al = 3

At wt. of Al = 27

E_{Ag} = chemical equivalent of Ag = 107.98

t = 24 hrs

Z_{Ag} = 0.00111 gm/C

$$E_{Aluminium} = \frac{\text{Atomic weight}}{\text{valency}}$$

$$= \frac{27}{3}$$

$$= 9$$

$$\frac{Z_{Al}}{Z_{Ag}} = \frac{E_{Al}}{E_{Ag}}$$

$$Z_{Al} = \frac{E_{Al} \times Z_{Ag}}{E_{Ag}}$$

$$Z_{Al} = \frac{9 \times 0.00111}{107.98} = 0.0000925 \text{ gm/C}$$

Actual quantity of Al liberated

= Current efficiency × Theoretical quantity

= 0.9 × (3500 × 24 × 3600)

Q = 272160000

m = Z_{Al} i t

= 0.000925 × 272160000

= 251748 gm = 251.748 kg

Q) Find the thickness of copper deposited on a plate of 2.25 cm^2 during electrolysis if a current of 1A is passed for 100 minutes. Density of copper is 8.9 gm per cc and ECE of copper is 0.0003295 g/c.

A) Given

Area of the plate = 2.25 cm^2

Current (i) = 1A

t = 100 min = 6000 sec

density of copper = 8.9 g/cc

ECE of copper = 0.0003295 g/c (Z)

∴ Mass = ZIt

= 0.0003295 × 1 × 6000

= 1.977 g

∴ volume of copper

2 Area × thickness

= 2 × 2.25 × x

= 4.5x cm^3

we know that

Mass = volume × density

⇒ 1.977 = 4.5x × 8.9

$$\Rightarrow x = \frac{1.977}{4.5 \times 8.9} = 0.049363\,cm$$

Ex:- 72

If a current of 10A deposits 13.42g of silver from a Silver nitrate solution in 20 min calculate electrochemical equivalent of silver.

A) Given data

I = 10A

M = 13.42g

$t = 20\,min = 20 \times 60 = 1200\,sec$

$M = ZIt$

$Z = \frac{m}{D} = \frac{13.42}{10 \times 1200}$

$= 0.0011883$ gm/coulumb

Ex: 7.3

calculate the quantity of electricity and the steady current Required to deposite 5g. copper from copper sulphate solution in 1 hour. ECE of copper is 0.3294 mg/coloumb

A) Given data

$M = 5g$

$t = 1\,hour = 3600\,sec$

ECE copper $= 0.3294 \times 10^{-3}$ g/columb

we know that

$M = ZIt$

$\therefore Q = It$

$M = ZQ$

$\therefore Q = \frac{m}{Z}$

$= \frac{5}{0.3294 \times 10^{-3}} = 15179.11$ coulumb

$\therefore$ current

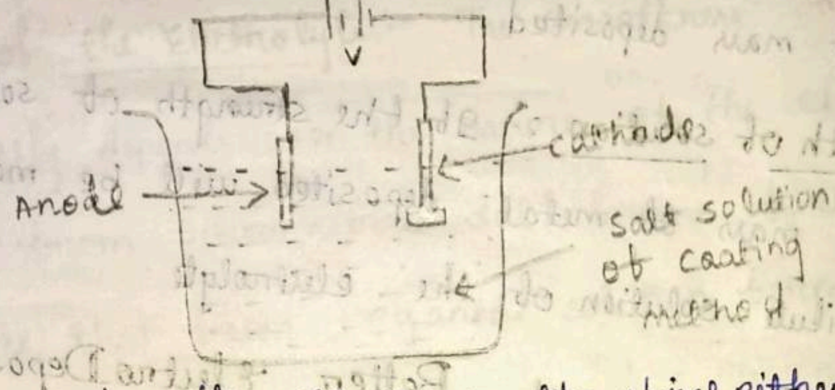
$Q = It$

$I = \frac{Q}{t} = \frac{15179.11}{3600}$

$= 4.216A$

Electroplating

The object to be electroplated is thoroughly cleaned, polished, degreased & arranged as cathode in a voltmeter, containing anode & electrolyte of the metal to be deposited.



To give even deposits all over the object either the cathode must be surrounded by anode or cathode must be rotated at uniform speed.

For gold or silver plating the electrolyte is always alkaline.

For Ni or Cu plating the electrolyte is usually acids.

The p.d. for this purpose is from 1 to 16 V. If the current density is high, the deposite will be crystalline or powdery. By regulating the current, we can get the depositated metal smooth & adhorent (being attached).

Factors affecting the amount of Electrodeposition

(i) Time :- Time is directly proposnal to the quantity of electrodeposition. So more mass will be deposited if time is more and less mass deposited if time is less.

ii) Ebbiciency :- Greater the Ebbiciency, greater is the quantity of metal deposited for a given time.

iii) Current :- The value of current is directly proposnal to the marks deposited. Greater is the current, Greater is the quantity of mass deposited.

iv) Strength of solution :- If the strength of sol^n is more then the mass of metal deposited will be more as compared to the dilute solution of the electrolyte.

Factors Abbecting the Better Electro Deposition :-

The factors which ebbect the appearance of the deposited metal are :-

(i) current density :- At higher values of current density, the quality of deposite become more uniborm & bine ground.

ii) Electrolyte Concentration :- By increasing the concentration of electrolyte, higher current density can be archieved. Increase of concentration of electrolyte gives better deposite of metal.

iii) Temperature :- The temp. of the electrolyte is dibberent for dibberent metals to have better deposite.

chromium plating ⟶ 35°C
copper " ⟶ 50°C
Nickel " ⟶ 50°C to 60°C.

iv) Addition of Agents :- The quality of a deposite is improved by the presence of an additional agent which may be an organic compound. Ex:- Such as gums, rubber, alkalies sugar etc.

v) Nature of the Electrolyte :- The smoothness of the deposite largely depends upon the nature of the electrolyte. Ex:- silver from silver nitrate sol^n ~~froms~~ forms a rough deposite while that from cyanide solution forms a smooth deposite.

Application of electrolysis :—

The electrolysis process has many applications such as

i) Extraction of metal from their ores → extraction of zinc, → Extraction of Al

ii) Refining of metals

iii) production of chemicals

iv) electro-deposition

v) electrocleaning

Extraction of zinc :- Zinc oxide is the ore of zinc. which is treated with concentrated sulphuric acid and passed through various chemical processes. The zinc sulphate sol^n is obtained. Electrolysis process is carried out in a wooden box with inner lining of lead. The anodes are lining of lead & cathodes are of alluminium, so zinc is deposited on the cathode.

The current density is about 1000 A/m^2 and voltage drop per cell is about 3.5 V.

Extraction of Al :- The ores of Al are bauxite, cryolite, baruite are treated chemically and reduced to alluminium oxide and then dissolved in fused cryolite to form as electrolyte.

Here the anode is carbon and cathode is the bottom of the steal bath. Aluminium metals gets deposited at the cathode of steel bath.

The current density is about 45000 Ampere and 8 V per cell is required.

Refining of Metals :- The metal extracted from its ~~od~~ ore is not pure. The purity of Cu. is about 98%. This purity of cu. should have 99.95%. ~~fro~~ for electrical application.

This purity of cupper can be improved by depositing cu. at regular interval in the cathode.

Production of chemicals :- Many chemical such as :- caustic sode (KOH), chlorinegas, Amonium sulphate, H_2O, Oxygen are produced by electrolysis on a large scale.

<u>Electrocleaning</u> :- Before electroplating the metal should have a surface free form grease, oil etc. and they are cleaned by electrocleaning method. A solⁿ of sodium phosphate is used as an electrolyte for this method

— × —

Electric Heating

Electric heating is based on the principle that when electric current passes through a medium that may be (solid, liquid, gas) heat is produced. Let us take the case of solid material which has a resistance (R) and current flowing through it is I ampere for t seconds. Then heat produced in the material will be $H = I^2Rt$ joules

or, $H = \frac{I^2Rt}{J} = \frac{I^2Rt}{4.2}$ kelvin → Formula for heat

This is the Joule's law.

Advantages of Electric Heating

i) Clean and neat atmosphere :- There is no coal dust or smoke

ii) No pollution :- There is no flue gases.

iii) The temperature can be control with in ± 5°C.

iv) Ease of control :- started instantenously or stopped at a required time.

v) Localised application :- A workpiece can be heated up to a particular depth for heat treatment.

vi) uniform heating :- The work piece can be heated uniformly through induction heating.

vii) Highest Efficiency :- Heat produced electrically doesnot go waste through chimney and other by-products.

viii) Economical :- It is the cheapest heating method as well as low maintenance cost.

ix) Safety :- It is quite safe and respond quickly

x) Automatic protection :- It can be provided with suitable switchgears.

xi) Better working condition :- It does not produce any irritating noise and low radiating losses

gmp

Methods of Heat Transfer

There are three modes of transmission of Heat transfer.

i) conduction

ii) convection

iii) Radiation

Conduction :- solids are heated by conduction method. In this method one molecule of the substance gets heated & transfers the heat to the adjecent one & so on.

The quantity of heat passed is given by $Q = \frac{kA}{t}(T_1 - T_2)T$ J/m²

where, k = coefficient of thermal conductivity in MJ/m²/m/°c/hr

A = cross sectional area of the plates in m².

t = thickness of the plate in m.

T_1 & T_2 = Temperature of the two faces in °c absolute

T = Time in hours.

Convection :- Liquids are heated by convection method

Ex :- water is heated by an immersion heater.

Heat dissipation is given by, $H = a(T_1 - T_2)^b$ w/m²

where, T_1 & T_2 = Temp. of ~~the two faces in °c absolute~~. heater & water.

a & b = are the constants which depends upon the heating surface facilities for heating.

For vertical surface in air $H = 3.875 (T_1 - T_2)^{1.25}$ w/m²

iii) Radiation :- Distant objects are heated from the source of heat by radiation. The heat of son reaches to us by radiation.

Rate of heat radiation is given by stefan's law

$$H = 5.72 \times 10^4 ke \left[\left(\frac{T_1}{1000}\right)^4 - \left(\frac{T_2}{1000}\right)^4\right] \text{ w/m}^2$$

where, T_1 = Temp. of the source in °c absolute

T_2 = Temp of the object in °c absolute

k = constant known as radient efficiency.

= 1 (for single elements)

= 0.5 to 0.8 (for several elements placed side by side)

e = emissivity = 1 (for black body)

= 0.9 (for heating element)

Application of Electric Heating

Domestic Application

i) Electric iron

ii) Imersion heater

iii) Room heater

iv) oven

v) gyser

Industrial Application

i) Melting of metals
ii) Making of plywood
iii) Electric welding
iv) moulding of glass, plastic
v) Enamelling of copper conductor

Methods of Electric Heating

Basically heat will be produced due to circulation of current through a resistance.

In magnetic materials hystreries loss can cause heating

→ Inter molecular friction can also be the source of heat.

→ production of an arc between an electrode and the material can be also be a method of heating.

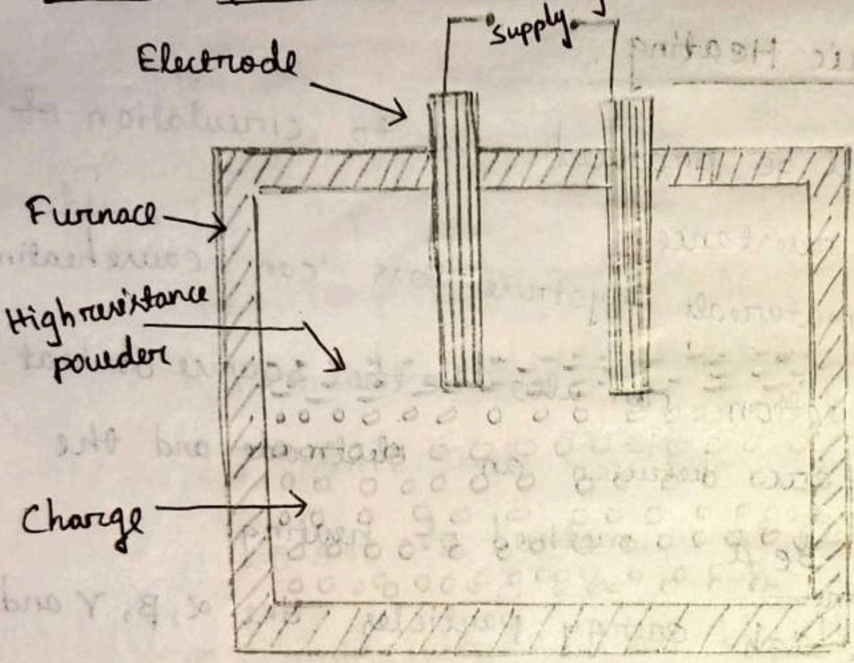
→ Bombardment of some high energy particles like α, β, γ and X-ray can produce heating on a surface.

Electric Heating
- Power frequency heating
  - Resistance Heating
    - Direct Resistance heating
    - indirect Resistance heating
  - Arc heating
    - Direct Arc heating
    - indirect Arc heating
- High frequency heating
  - Induction Heating
    - Direct core type Induction Heating
    - coreless type induction heating
  - Dielectric Heating

Resistance Heating

This method is based upon the I^2R loss whenever current is passed through a resistive material heat is produced because of I^2R loss. There are two methods of resistance heating.

Direct Resistance Heating



In this method of heating the material or charge to be heated is taken as a resistance and current is passed through it. The charge may be in the form of powder, pieces or liquid. The 2 electrodes are immersed in the charge and connected to the supply.

When metal pieces or charges are to be heated a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit. The current flows through the charge and heat is produced.

This method has high efficiency since heat is produced in the charge itself.

→ This method gives uniform heat and high temp. between 300°C to 1400°C.

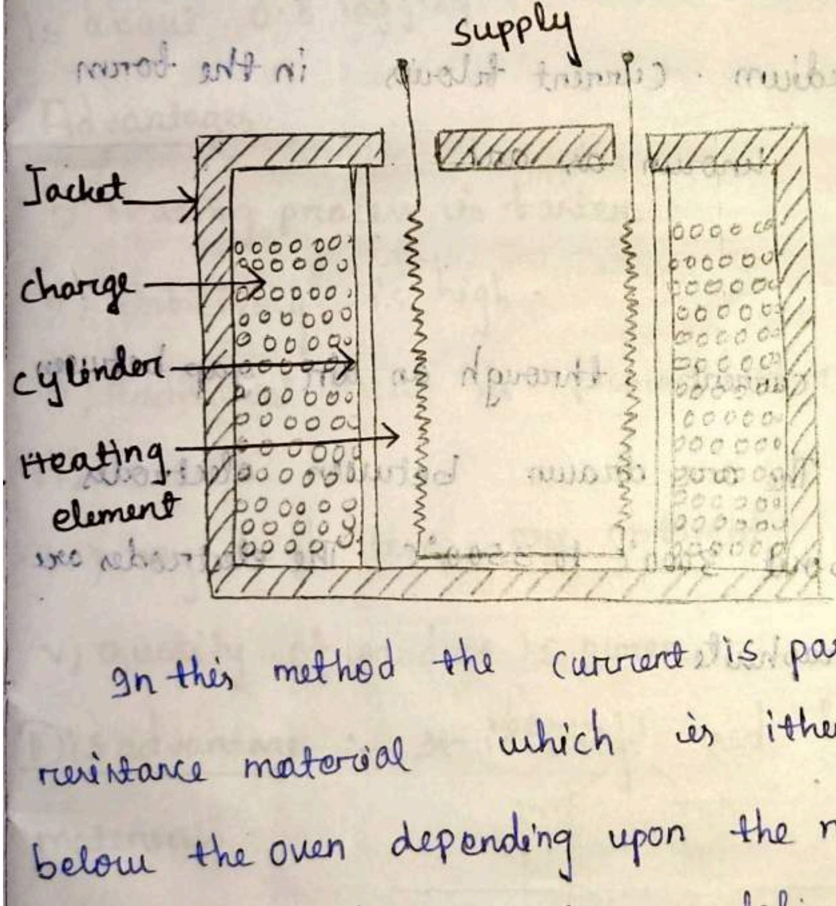
automatic temperature control is not possible in this method.

Application

i) Resistance welding

ii) electro boiler for heating water

Indirect Resistance Heating



In this method the current is passed through a highly resistance material which is either placed above or below the oven depending upon the nature of Job. The heat produced in heating element delivered to the charge either by radiation or by convection.

Sometimes in case of industrial heating the resistance is placed in a cylinder which is surrounded by the charge placed in the jacket as shown in fig.

Automatic temp. control can be provided, in this case.

Application

i) Resistance oven

ii) Immersion heater

iii) Domestic and comercial cooking

iv) Heat treatment of metals

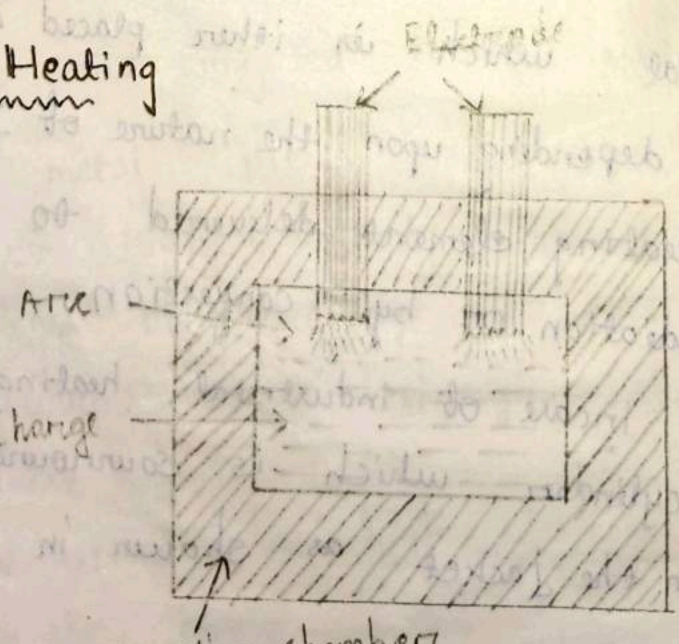
Arc

when high voltage is applied across an air-gap, the air gates ionised under the influence of electrostatic forces and becomes conducting medium. Current flows in the form of a continuous spark known as arc.

Arc heating

Arc is the flow of current through an air gap between 2 conducting bodies. The arc drawn between electrodes develops high temp. about 3000°C to 3500°C. The electrodes are made of carbon or graphaite.

Direct Arc Heating



In this method the arc is struck between electrodes & the charge. The current flows through the charge & there is a direct contact between the arc and the charge so the heat is directly conducted.

→ The usual size is 5 to 10 tonnes.

→ In case of 3-phase supply 3 electrodes are use and the charge it self forming the star (Neutral) point. The power in the furnace is controlled by wearing voltage length of the arc and its resistance. The power factor is about 0.8 lagging.

Advantages

i) Heating process is faster.

ii) Efficiency is high.

iii) Additional heat is produced due to current through the charge.

iv) very high temp. are obtained

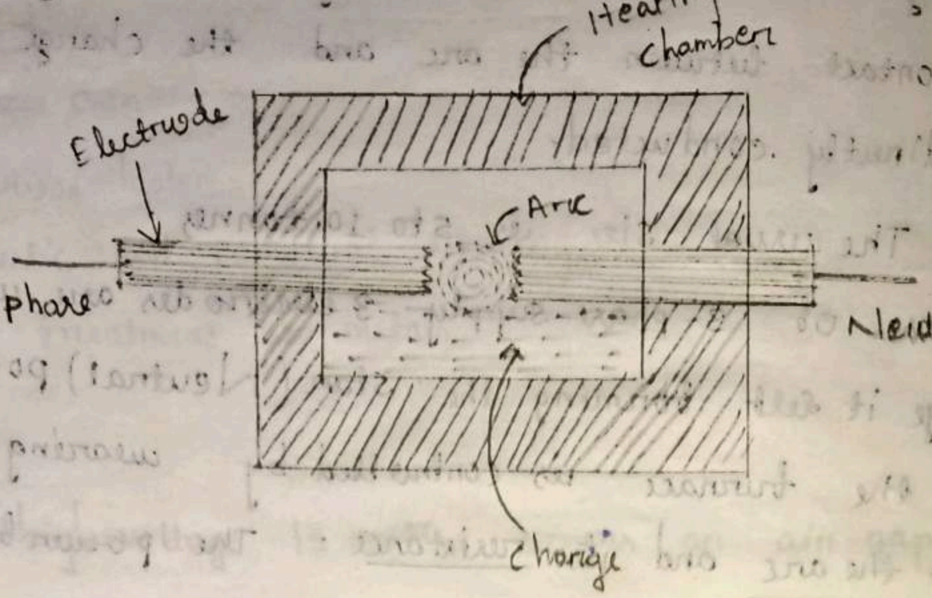
v) Quality of product is purer

Disadvantages :- It is only used for electrical conducting materials.

uses

i) It is use in production of stell

Indirect Arc Heating



In this method the arc is formed between electrodes & heat is transmitted to the charge by radiation. The temp. of the charge is lower than indirect arc heating as current doesn't flow through the charge so there is no stirring action

→ The power factor is about 0.85 ~~and~~ (lagging) and the capacity of the furnace very strong 0.25 to 3 tonnes. Here the electrodes are horizontally placed and its construction limits two electrodes so single phase supply is required.

Uses :- It is use for non-ferrous metals and that is in iron foundaries.

Induction Heating :-

In induction heating effect of currents induced by electromagnetic acting in the charge is used. Induction heating is based on the principle of transformer. The eddy current loss in the transformer core is dissipated in the form of heat and this heat is utilized in heating metals or charge.

i. The primary coil is magnetically coupled with the charge to be heated when an <u>AC voltage</u> is applied to the coil, an emf is induced in the charge and so eddy current flows in the charge.

There are two types of induction heating or induction furnace :

i) core type induction furnace

(a) direct core type induction furnace

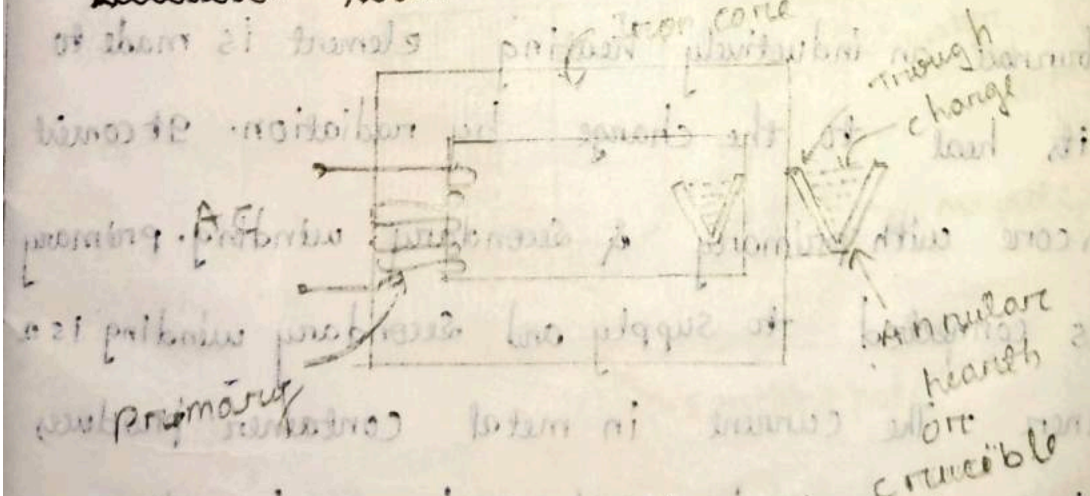
(b) indirect " " " "

ii) core less type induction furnace

Core type induction furnace

It is just like a T/F having primary connected to the supply and the charge to be heated as secondary.

1) Direct Core Type Induction Furnace



The charge forms the secondary winding and consist of 1 turn only. The current in the charge is very high (around several 1000 Ampers).

Electromagnetic forces are set up by the high current in the molten metal such furnaces are operated at low frequency (around 25 hz) The charge is kept in the crucible which forms are single turn such ct short circuited secondary coil.

There are some draw backs.

i) leakage reactance is high and p.f. is low., so poor magnetic coupling.

ii) The crucible is of odd shape and not convenient form metallurgical point of view.

iii) For low frequency, a frequency converter is required.

iv) such furnaces are not suitable for intermittent services.

Due to above drawbacks such furnaces were absolute now a days.

<u>Indirect core type Induction furnace</u>

In this furnace an inductively heating element is made to transfer its heat to the charge by radiation. It consist of an iron core with primary & secondary winding. primary winding is connected to supply and secondary winding is a metal container. The current in metal container produces heat which is transmitted to the charge by radiation.

Here temp. can be controlled without any external control equipment. It consist of a small part of the magnetic circuit situated in the oven chamber and made of a special alloy. which loses its magnetic properties at a particular temp and regains them when cooled. As the furnace attens a critical temperature, the reluctance of the circuit increases and so inductive effect decreases thereby cutting off the heat supply.

That small part of the magnetic circuit is detachable type and can be replaced to get critical temp between 400°C - 1000°C

Coreless type Induction furnace

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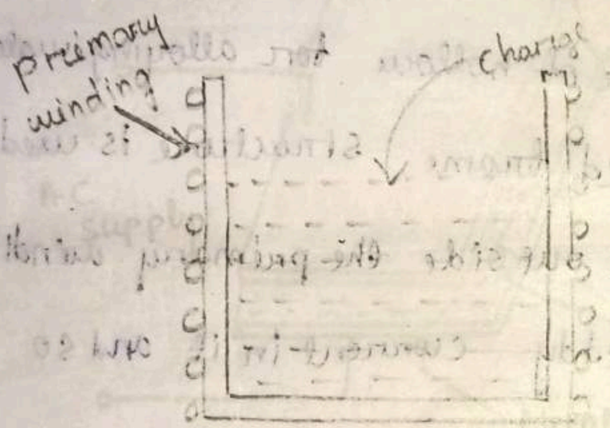
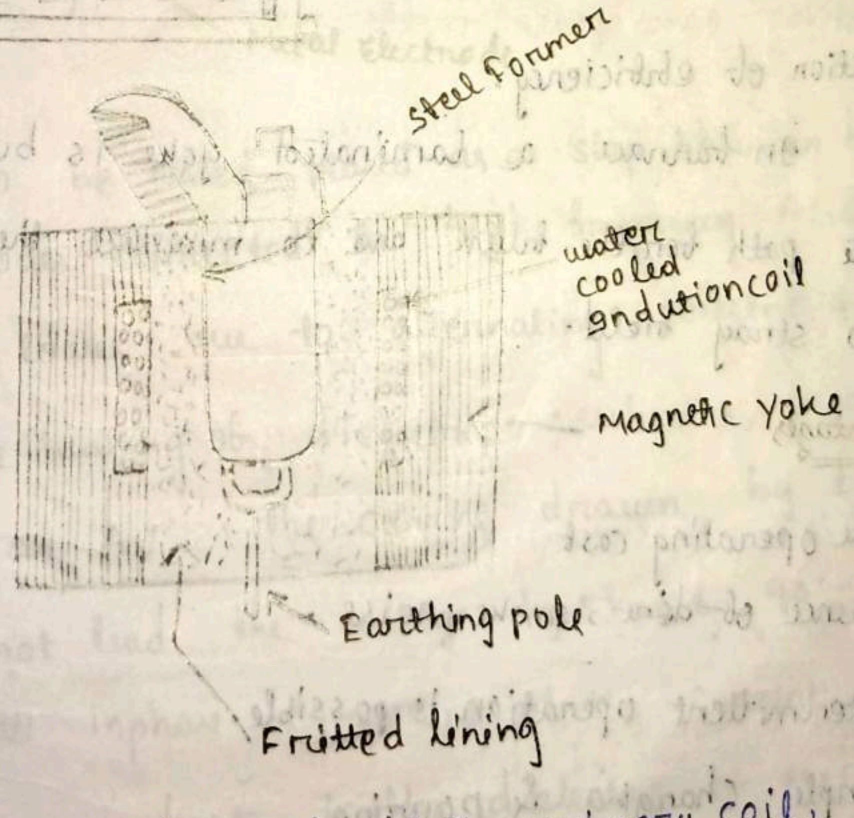




It consist of 3 main parts. i) The primary coil,
ii) The refractory container (crucible)
iii) The frame.

The charge is put into the crucible and primary coil is connected to high frequency AC supply.

The flux produced by the primary winding sets up eddy current in the charge. The heat produced by the eddy current melts the charge. These eddy current sets up electromagnetic forces which produce stirring or striking action of the metal.

The skin effect produces heat in the primary winding. Therefore the windings are made of hollow for alloying water for cooling purposes. Insulated frame structure is used, otherwise stray magnetic field out side the primary winding will result in circulation of eddy current in it and so reduction of efficiency.

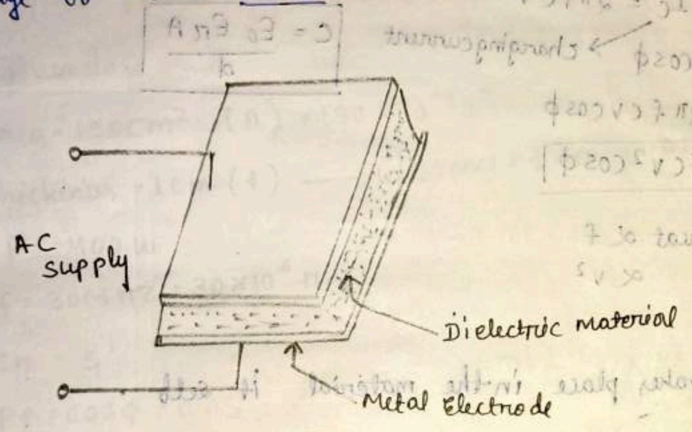
In furnace a laminated yoke is built to provide a definite path for the flux and to minimize the eddy current loss due to stray field.

Advantages

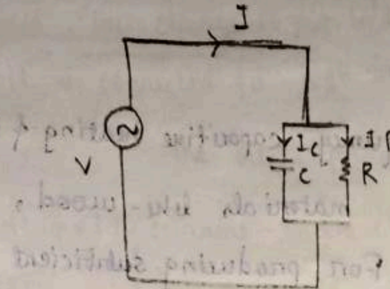
i) Low operating cost
ii) Absence of dirt, smoke, noise.
iii) Intermittent operation is possible.
iv) simple charging & pouring
v) precise controll of power.
vi) crucible of any shape

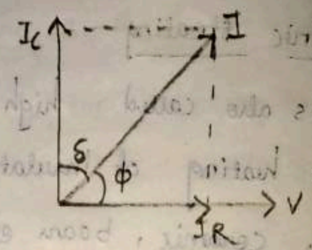
Dielectric Heating

This is also called high frequency capacitive heating & is used for heating of insulating materials like- wood, plastic, ceramic, boars etc. For producing sufficient heat frequency between 10 MHZ to 30 MHZ and the voltage of about 20KV must be use.



The material to be heated placed as a slap between metallic plates or electrodes connected to high frequency AC supply. The dielectric losses due to alternating electro static field cause the heating of dielectric. When a capacitor is subjected to an AC, the current drawn by the capacitor does not lead the voltage by exactly 90°. There is always a small inphase component of the current which produces power loss or heat in the dielectric of the capacitor





δ = dielectric loss angle

$I_C = \frac{V}{X_C} = 2\pi f C V$

As, $I \simeq I_C = 2\pi f C V$ → charging current

$C = \frac{\epsilon_0 \epsilon_r A}{d}$

$P = VI\cos\phi$

$= V\, 2\pi f C V \cos\phi$

$P = 2\pi f C V^2 \cos\phi$

∴ Dielectric heat $\propto f$

$\propto V^2$

Advantages

i) heating takes place in the material it self.

ii) Heat generation is uniform.

iii) poor thermal conductivity materials can be heated.

Disadvantages

i) For high frequency, frequency converter is required.

ii) Efficiency is very low about 50%.

Application

i) **wood** :- For drying and glueing

ii) Rubber :- For vulcanising

iii) heating of bones

iv) dehydration of food and tobaco

v) Drying of explosives.

vi) gluing of laminated glass.

vii) Drying of boundary cores.

Q) A slab of insulating material $150\ cm^2$ in area and 1 cm thick is to be heated by dielectric heating. The power required is 400 W at 30 MHz. Material has permittivity of 5 & p.f. 0.05. Determine the voltage.

Absolute permittivity $= 8.854 \times 10^{-12}\ F/m$

A) Given data

area $= 150\ cm^2$ (A) $= 150 \times 10^{-4}\ m^2$

thickness $= 1\ cm$ (t) $\longrightarrow$ distance $= 1\ cm = 0.01\ cm$

$P = 400\ W$

$f = 30\ MHz = 30 \times 10^6\ Hz$

$\varepsilon_r = 5$

$Pf = \cos\phi = 0.05$

$\varepsilon_0 = 8.854 \times 10^{-12}\ F/m$

$P = 2\pi f C V^2 \cos\phi$

$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$

$= \frac{8.854 \times 10^{-12} \times 5 \times 150 \times 10^{-4}}{0.01}$

$= 66.375 \times 10^{-12}\ F$

$P = 2\pi f C V^2 \cos\phi$

$V = \sqrt{\frac{P}{2\pi f C \cdot \cos\phi}} = \sqrt{\frac{400}{2 \times \pi \times 30 \times 10^6 \times 66.375 \times 10^{-12} \times 0.05}}$

$= 799.635 \simeq 800\ V$

Q) A Insulating material 2 cm thick and 200 cm^2 in area is to be heated by dielectric heating. The material has permittivity of 5 of p.f. 0.05. power required is 400w and frequency of 40MHz, is to be used. Determine the voltage and current

A) Given data

$t = 2cm \longrightarrow d = 0.02m$

$A = 200cm^2 = 200 \times 10^{-4} m^2$

$\cos\phi = 0.05$

$\varepsilon_r = 5$

$f = 40MHz = 40 \times 10^6 Hz$

$P = 400V$

$\varepsilon_0 = 8.854 \times 10^{-12} F/m$

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d}$$

$$= \frac{8.854 \times 10^{-12} \times 5 \times 200 \times 10^{-4}}{0.02}$$

$$= 44.27 \times 10^{-12}$$

$$V = \sqrt{\frac{P}{2\pi f C \cos\phi}}$$

$$= \sqrt{\frac{400}{2 \times \pi \times 40 \times 10^6 \times 44.27 \times 10^{-12} \times 0.05}}$$

$$= 848 V$$

$$\boxed{I = \frac{P}{V \cos\phi}} = \frac{400}{848 \times 0.05} = 9.43 A$$

25/11/21

Principle of Arc Welding

3rd chapter

Welding :-

welding is a process of joining metals of similar composition by heating to a suitable temp. with or without application of pressure and addition of filler material.

Electric welding

It is define as that branch of welding in which electric current is used to produce the large heat require for joining two pieces of metal.

Electric welding is used for construction of ship, bridges, steel frames, structure, tank, pipe lines etc.

→ Broadly electric welding are of 2 types

i) Resistance welding

ii) Arc welding

~~Electri~~

Electric welding
- Resistance welding
  - Butt welding
    - upset Butt welding
    - Flash welding
  - spot welding
  - Projection welding
  - seam welding
- Arc welding
  - Metal Arc welding
  - Carbon Arc welding
  - Automatic hydrogen Arc welding
  - Helium or Argon Arc weldin

Resistance Welding: cont

In resistance welding the heat is produced by passing a heavy current through the joint.

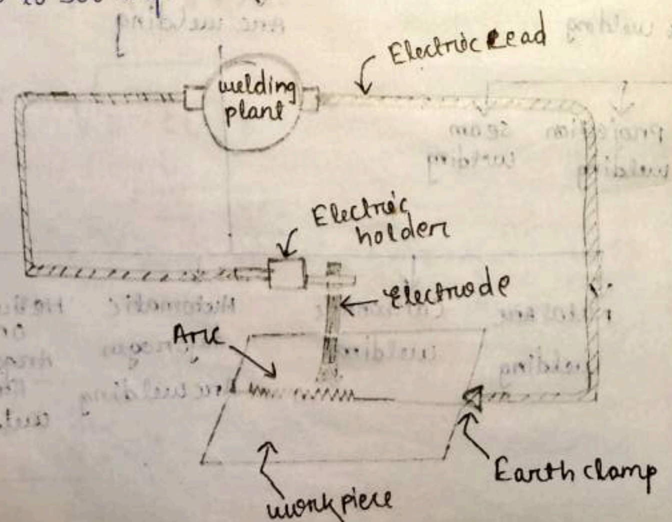
Arc welding

In Arc welding the heat is produced ~~either~~ by striking an arc between an electrode and the metalic joint.

Arc Welding

An ~~arc welding~~ electric arc is produced by bringing two conductors connected to a current source, In contact and then separating by a small distance. The current continous to flow across the small gap and gives heat. The heat developed is utilized to melt the workpiece and then the filler metal and thus for the joint.

The temperature Is about 3000°C. Minimum voltage for welding for about 100V and current ranges from 30 to 500 Amp



Principle

Current from a source either AC or DC can be obtained form a welding plant. one terminal is connected to the electrode and other is connected to the work piece. The gap is provided between electrode and work piece of about 3mm to 6mm.

Condition for succesful welding

i) Arc welding plant is provided to produced the required electrical condition at the arc.

ii) Either DC or AC may be used.

iii) The sparking voltage is usually 80 to 100 volt in case of AC and 60 to 80 volt in case of DC.

iv) The Arc voltage depends upon the type of metal and the flux of the electrode.

v) The current depends upon the type of metal and the gauge (distance) and the type of electrode.

Electric Arc welding Equipments

i) In DC welding the equipments are motor-generator (MG) set. The motor is squirrel cage induction motor & the generator is differentially compound generator give drooping characteristics.

ii) In AC welding a transformer is used to reduce the supply voltage to about 100V. To regulate the current a resistance is used and to produce drooping characteristic a reactance may be used.

Welding Accessories

i) one electrode holder

ii) one flexible cable

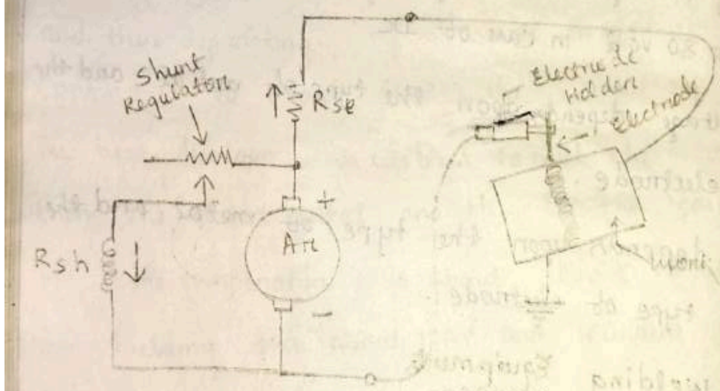
iii) one face ~~cream~~ screen with coloured glasses.

iv) one pair of leather gloves.

v) one chipping hammar to remove the slag from the weld.

vi) one wire brush to clean the weld after the chipping.

Dc Welding Plant ✓

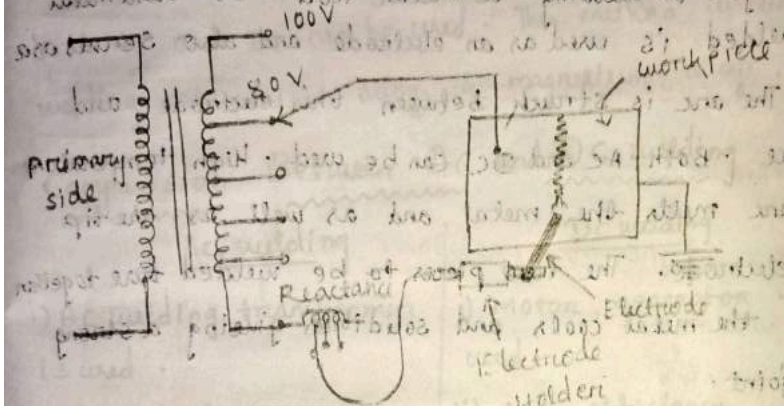


The high striking voltage and low arc voltage is obtained by a differential compound DC generator which given dropping characteristics high voltage is available to enable the arc to be struck but as current flows voltage reduce.

In this method the series coils (Rse) are wound in a reverse direction to the shunt coils (Rsh). on open circuit the shunt coil gives high voltage to strike the

Arc. when Arc is struck current flows through the series winding, thus the series field opposes the shunt field. Therefore the voltage drops. By means of a shunt Regulator, the open circuit voltage can be varied.

AC Arc Welding Plant



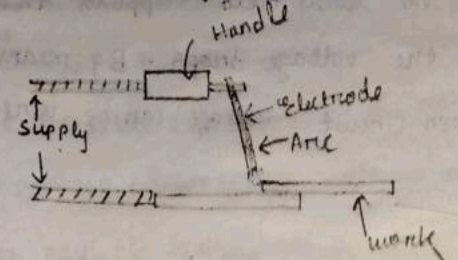
The dropping characteristics is obtained in case of AC welding by means of a reactance coil in series with the arc. The voltage at the secondary side of transformer remains constant. But as soon as current flows the voltage drop across the reactance coil reduces the voltage at the arc. The reactance coil also controls the flow of current.

Types of Arc Welding

There are 4 types of Arc welding

i) Metal Arc welding
ii) Carbon " "
iii) Automatic hydrog Arc welding
iv) Helium or argon arc welding

Metal Arc Welding



In this type of welding a metal rod of same metal to be welded is used as an electrode and also serves as a filler. The arc is struck between this electrode and work piece. Both AC and DC can be used. High temperature of the arc melts the metal and as well as the tip of the electrode. The two pieces to be welded fuse together and then the metal cools and solidifies giveing a strong welding joint.

Carbon Arc Welding

This method is normally used for welding Cu and its Alloys. the carbon electrode is kept -ve with respect to the work piece. In this type of welding only dc can be used. This method is applied to both ferrous & non-ferrous metals.

Automatic hydrogen Arc welding

In this method the arc is established between two tungsten electrodes and a stream of hydrogen gas is passed through the arc and arround the electrodes. In this type of welding both AC and DC can be used. This method is used for welding stainless steel carbon steel & Aluminium.

iv) Hilium OR Argon Arc Welding

In this method of welding the arc is struck between a tungsten electrode & the workpiece. Helium or argon is used to give an innert atmosphere so that oxidation of the welded joint doesn't take place. In this method both AC and DC can be used. This method is used for welding aluminium alloys & magnesium alloys.

Comparision Between AC and DC welding

AC welding	DC welding
i) AC welding transformer is used.	i) Motor, generator set is used.
ii) very high efficiency.	ii) Low efficiency.
iii) Arc is not at all stable.	iii) Arc is more stable.
iv) Heat produced is not uniform.	iv) Heat produced is uniform.
v) Energy consumption is low.	v) Energy consumption is more.
vi) Heat is equal in both poles → (polarity)	vi) 70% of heat on +ve pole and 30% of heat on -ve pole
vii) only flux coated electrodes can be used.	vii) Any type of electrode can be used.
viii) Equipment Required is cheap.	viii) Equipment required is costly.

Resistance Welding

imp

The principle of resistance welding is that generation of heat in the joint by passing heavy current & followed the application of mechanical pressure.

A heavy current is sent through the two metals to be welded. The heat generated is given by $H = I^2Rt$

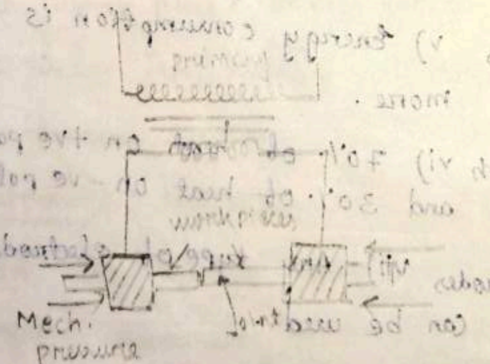
where, R = It is the resistance of the joint.

AC is ~~more~~ most suitable for resistance welding.

→ There are 5 types of Resistance welding.

i) Butt welding
ii) Flash welding
iii) spot welding
iv) seam welding
v) projection welding

Butt welding

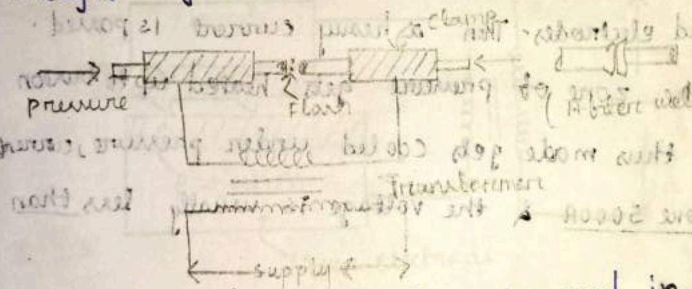


In this process heat is generated by the contact resistance between the two work piece. The two work pieces are brought together & the pressure is applied by a spring

A heavy current is passed from the welding T/F which creates the neccessary heat at the joint. The metal at the joint melts and the two parts fuse together.

Butt weldings are used to join end to end of the parts. It is used for welding pipes, wires and rodes.

Flash welding :- This is similar to butt welding except in this case current is applied before the parts brought together. So when they meet arcing or flashing takes place. As soon as the metal approches to meeting temp, the current is shut off and, the pieces are rapidly brought together under high pressure.



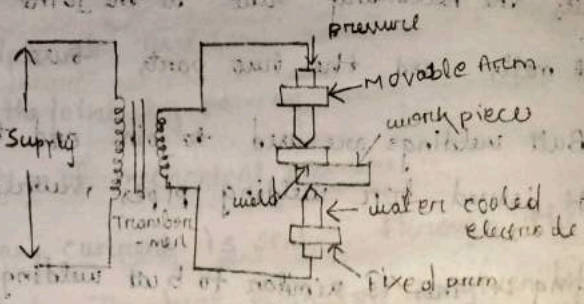
This method of welding is used in production work, particularly in welding rods & pipes, chains, rail ends, etc.

* when high pressure is applied, the squeezed molten metal gives off sparks or flash, hence the name flash welding.

* The voltage required is 2 to 8 V & current varries from 50 A to several hundred amperes.

* Flash welding is considered superior to butt welding.

Spot welding

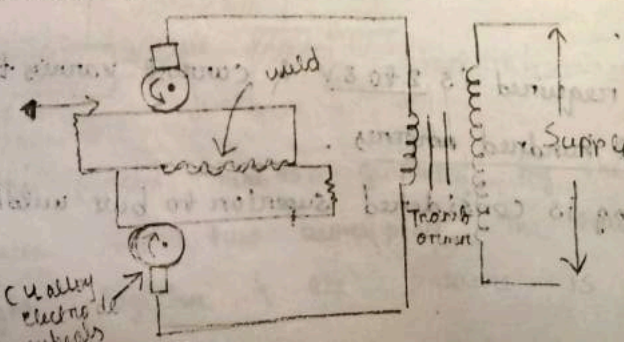


This is the simplest & most universally adopted method of making lap. It is usually used for joining or fabricating sheet metal structure, boxes, cores & enclosing cases, etc.

In this process the workpieces to be welded are over-lapped and pressed together by mechanical pressure between two water cooled electrodes. Then a heavy current is passed. The metals in the zone of pressure gets heated up to fusion and the joint thus made gets cooled under pressure, current required is above 5000A & the voltage is usually less than 3V.

The current, the time for the current flows and the pressure between the electrode tips are the main factors affecting the quality of the weld.

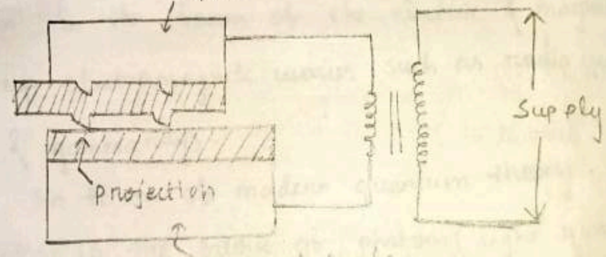
Seam welding



It can be defined as series of continuous spot welds. In this case, the metal sheets to be welded are pressed between knife edged wheels and are made to travel slowly. The current is passed between these wheels and a series of overlapping spot welds are obtained.

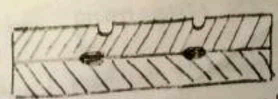
In order to localise the current & pressure to the welding point, the contact area of electrode should be small. This type of welding provides leak proof joint. Seam welding is used for welding tanks, transformers, refrigerators, gasoline tanks, air crafts etc.

Projection welding



It is a modified forms on the sheet are formed. After the projections are formed, the raised portions are pressed into contact with another piece. At the same time a heavy current is passed through the two pieces. The current flow at the projection points, heats & fuses the two pieces together.

This type of welding is employed on punched, formed or stamped parts where projection automatically exists.


(After projection welding)

Avantages over spot welding

i) More O/P is obtained (since more than one weld are done at a time)

ii) Life of electrode is increased (due to use of low current density & low pressure)

iii) welds are automatically located by the position of the projections.

iv) It is easy to weld certain parts which can not be welded by spot welding.

Illumination 4th

~~Light~~ :- Light is the cause & illumination is the result of the light on surfaces on which it falls. Illumination makes the surface look more or less bright with certain colours.

Light may be produced by passing current through filament through arcs between carbon & metal rods or through suitable gases (as in neon or other gases).

Nature of Radiation & its ~~specification~~ specification :-

Electromagnetic radiation is the flow of energy at the universal speed of light through free space or through a medium in the form of the electric & magnetic fields that make up electromagnetic waves such as radio wave, visible light & gamma rays.

In terms of modern quantum theory, electromagnetic radiation is the flow of photons (light quanta) through space; photons are packets of energy that always moves with the universal speed of light.

The band of colours, as seen in a rainbow, is the spectrum of light. A spectrum is the rainbow of colours in visible light after passing through a prism.

Radiant Energy

Light is a part of radiant energy that propagates or transmits as a wave motion through ether (medium through which light waves are transmitted through all spaces).

The velocity of propagation of this radiant energy = 3×10^8 m/sec

velocity of propagation, $\boxed{v = \lambda f}$ m/sec

where, λ = wave length of light in Angstrom unit (Au)

$1\,AU = 10^{-10} m$

The visible radiation lies between 4000 AU to 7500 AU.

Terms used in Illumination

i) Light

It is defined as the radiant energy form a hot body which produces the visual sensation upon the human eye. It is denoted by 'Q', expressed in lumen-hours.

2) Luminous flux (ϕ)

It is defined as the total quantity of light energy emitted per second from a luminous body. It is expressed in lumens

$\phi = \frac{Q}{t}$ lumens

It is also defined as the rate of luminous energy.

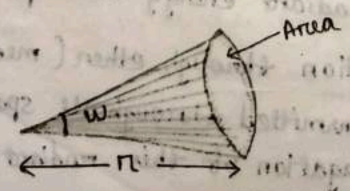
3) Lumen

It is defined as the amount of luminous flux emitted in a unit solid angle (ω) by a source of one candle power in all direction.

Lumen = candle power × solid angle

$\text{Lumen} = C.P \times \omega$

4) solid angle (ω)



It is the angle generated by the lines passing through the point in space and the periphery of the area. It is expressed in steradians.

Solid angle is given by the ratio of the area of the surface to the square of the radius.

$$\therefore \boxed{\omega = \frac{\text{Area}}{r^2}} \text{ steradians}$$

The largest solid angle is obtained by considering the point of the centre of sphere & the surface area of the sphere.

$$\text{Total solid angle, } \omega = \frac{\text{Area of the sphere}}{r^2}$$

$$= \frac{4\pi r^2}{r^2}$$

$$= 4\pi \text{ steradians}$$

5) Luminous Intensity

Luminous intensity in any given direction is the luminous flux emitted per unit solid angle. It is denoted by 'I' and expressed in lumens / steradian or candela (cd).

$$\therefore \boxed{I = \frac{\phi}{\omega}} \text{ candela (cd) or lm/steradians}$$

6) Intensity of Illumination (E)

It is defined as no of lumens falling on the surface of unit area. $\boxed{E = \frac{\phi}{A}}$ lm/ m^2 or Lux

Bigger unit of illumination is phot

$$\boxed{1 \text{ phot} = 10^4 \text{ lux}}$$

7) Mean Horizontal candle power (MHCP)

It is defined as the average of candle power in all directions in the horizontal plane containing the source of light.

8) Mean spherical candle power (MSCP)

It is defined as the average of candle powers in all directions and in all planes from the source of light.

$$M.S.C.P = \frac{\text{Total flux in lumens}}{4\pi}$$

9) Mean Hemi spherical candle power (MHSCP)

It is defined as the average candle power in all directions above or below the horizontal plane passing through the source of light.

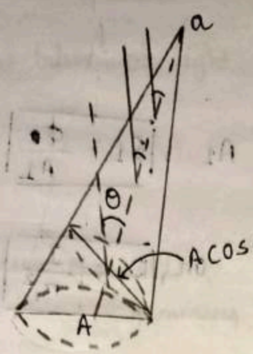
10) Luminous efficiency

It is defined as the output in lumens per watt of the power consumed by the source of light. It is measured in lumens per watt.

$$\text{Lamp or Luminous efficiency} = \frac{\text{Lumens emitted by source}}{\text{wattage of source of light}} \ \text{lumens/watt}$$

Brightness / Luminance

Brightness of a surface is defined as the luminous intensity per unit projected area in the given direction



If a surface of area "A" has luminous intensity "I" candelas in a direction θ to the normal then the brightness of the surface is $B = \frac{I}{A\cos\theta}$ candela/m^2 or nits

* Bigger unit of brightness is candela/cm^2 or stilb.
* Another unit of brightness is lumens/cm^2 or lambert.

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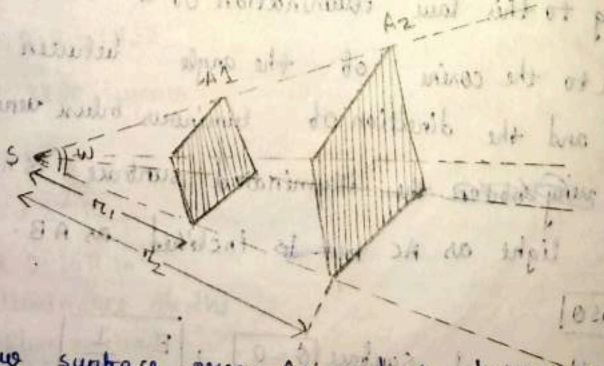
Laws of Illumination

There are two laws :-

i) Inverse Square Law



Let two surface areas A_1 and A_2 be placed at distances r_1 and r_2 meters from the source (S).

The source (S) having the intensity $\boxed{I = \frac{\phi}{\omega}}$ lumens/steradian

Thus flux on A_1 and A_2 = $\boxed{I\omega}$. The solid angle $\boxed{\omega = \frac{Area}{r^2}}$

$\therefore \phi\,(flux) = I\,\frac{Area}{r^2}$

Illumination on surface A_1, $\boxed{E_1 = \frac{\phi}{A_1}} = \frac{I\frac{A_1}{r_1^2}}{A_1}$

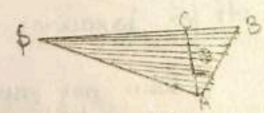
or, $\boxed{E_1 = \frac{I}{r_1^2}}$ lux or, lumen/m^2

Similarly, Illumination on surface A_2; $E_2 = \frac{\phi}{A_2} \Rightarrow \frac{I\frac{A_2}{r_2^2}}{A_2}$

or, $\boxed{E_2 = \frac{I}{r_2^2}}$ lux

Hence illumination of a surface is inversely proportional to the square of its distance from the source.

2) Lambert's cosine law (Imp)



According to this law illumination of a surface is proportional to the cosine of the angle between the normal and the direction of luminous flux very often. ~~very often~~ the illuminated surface is not normal to the light as AC but is inclined as AB.

$\therefore \boxed{E \propto \cos\theta}$

In the normal surface $\boxed{\theta = 0}$, $\boxed{E = \frac{I}{r^2}}$

* In the inclined surface $E = \frac{I}{r^2} \cos\theta$

Q) A lamp has a mean spherical candel power of 25, Calculate the total flux of light from the lamp.

A) Given

MSCP = 25

Total luminous flux = MSCP × 4π

= 314 lummens

Q) A 0.4 mtr diameter defusing sphere opal glass (20% absorption) encloses an incondescent lamp with a luminous flux 4850 lumens. calculate the average lumines or brightness of the sphere.

A) Given

d = 0.4 m

r = 0.2 m

φ = 4850

∴ Total flux emitted by the glass,

Flux = (100−20)% of φ

= 0.8 × 4850

= 3880 lumens

Area = $4\pi r^2$

= $4 \times 0.2^2 \pi$

= 0.16π m²

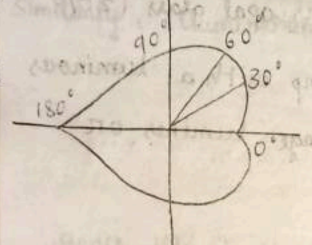
Average luminance of the sphere = $\frac{\text{flux emitted}}{\text{Area}}$

= $\frac{3880}{0.16\pi}$ = 7719 lumen/m² or Lux

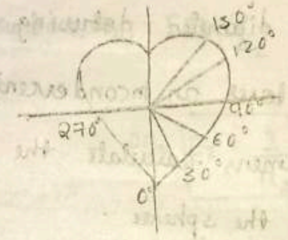
Polar curves

The luminous intensity or candle power of any lamp is not uniform in all directions due to its un-symmetrical shape. The luminous intensity in all the directions can be represented by polar curves.

If the luminous intensity in a horizontal plane passing through the lamp is plotted against angular position, a curve is obtained known as horizontal polar curve. Similarly, vertical polar curve.



(Horizontal polar curve)



(vertical polar curve)

(The polar curves are used to determine to MHCP & MSCP. The MHCP of a lamp can be determined from the horizontal polar curve. MSCP can be determined from vertical polar curve by Rousseau's construction)

Lighting schemes

As far as designing of lighting schem we have to see whether the sources thrown light directly over a working surface or it reaches the surface after reflection. The lighting schem can be classified as i) direct lighting

ii) Indirect lighting

iii) semidirect lighting

iv) semiindirect lighting

v) Local lighting

vi) General lighting

Direct lighting

In this case the light from the sources is thrown directly over the surface to be illuminated. Reflectors give additional help but this should not be too deep.

Indirect lighting

In this case no light reaches directly from the source on the surface to be illuminated. A reflector is mounted on a bulb and the entire light emitted by the bulb is thrown on the ceiling and after reflection from the ceiling like flare on the working plane.

Semidirect lighting

In this case 60% or more of light reaching the surface to be illuminated comes directly from the sources. The rest of it comes after reflection.

Semiindirect lighting

In this case more than 60% light is thrown on the surface reflecting the light. The rest comes on the surface to be illuminated directly from the sources this type of lighting is used for indoor domestic lighting.

Local lighting

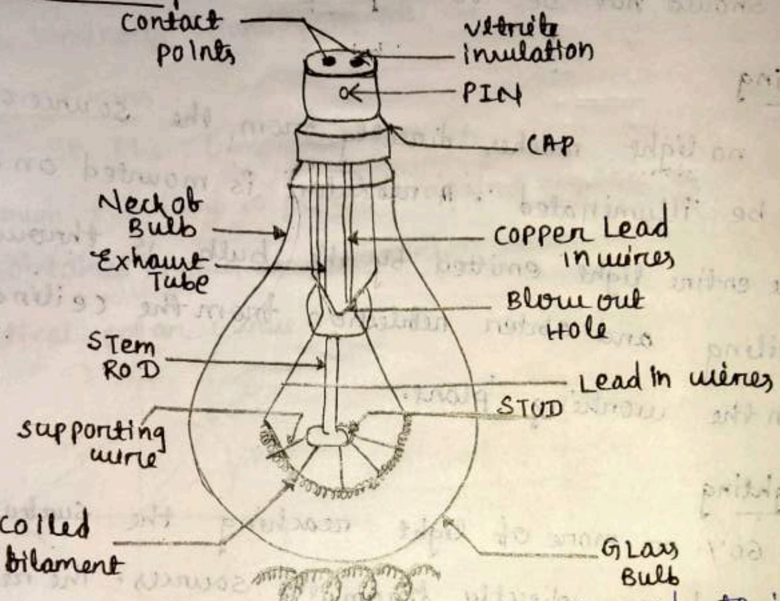
If the light is thrown to a particular object it is called local lighting for example an ordinary table lamp.

General lighting

It is a big no of lighting sources are fixed to give local lighting effect, there will be dark patches between bright spot scattered here & there. this will cause a bet of batigue on the eyes

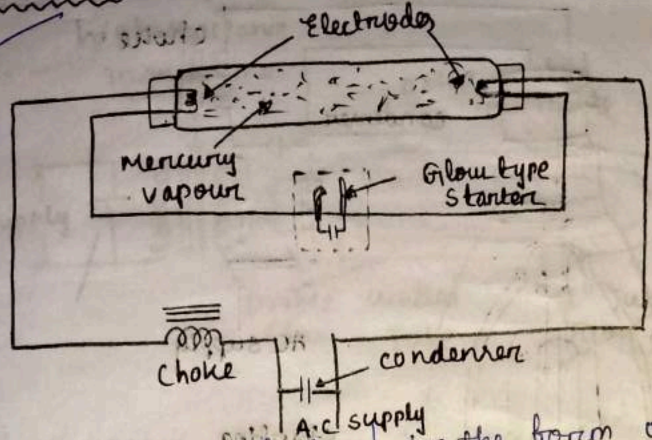
Electric Lamps

Filament lamp



In this lamp tungsten filament is used to increase the working temp. and efficiency the lamp is filled with nitrogen gas. the working temp. of gas filled lamp 2500°C the temp. of this lamp can be further increased by using coiled coiled filament. The efficiency of this bulb is 10-20 lumens per watt. The life of this lamp is 1000 working hours.

Fluorescent tube

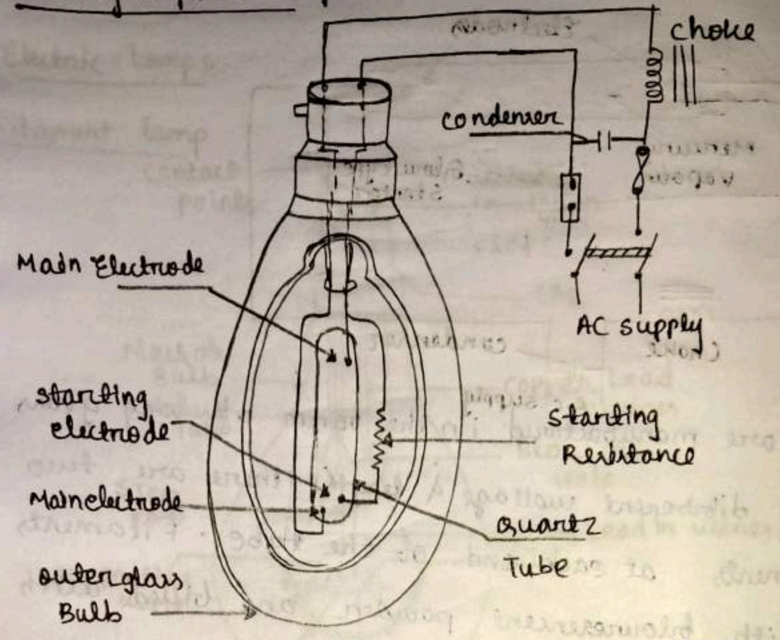


This lamps are manufactured in the form of long glass tube having different wattage & length. There are two tungsten filaments at each end of the tube. Filaments are coated with flourescent powder and filled with argon gas and some mercury.

The function of the choke is to provide high voltage of about 1000 volt for starting the tube.

A glow type starter used to perform the function of a switch. Initially it behaves like a short circuit and after some seconds it behaves like open circuit.

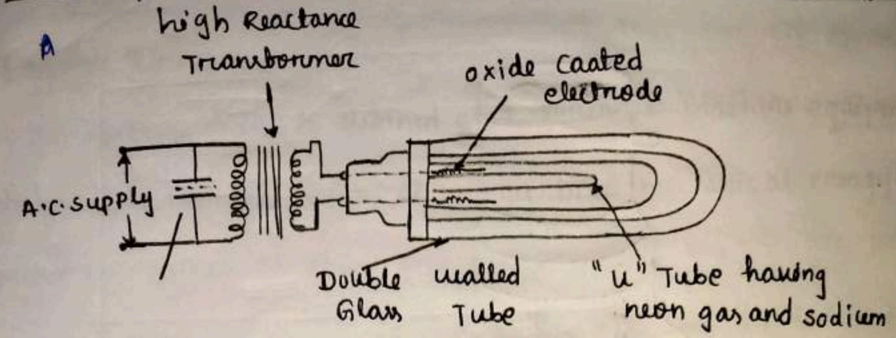
Mercury vapour lamp



It is a hot cathode gas discharge lamp. It consist of two main electrodes made of tungsten coated with berrium oxide and are enclosed in a hard glass or quartz tube. This tube contains argon gas at low pressure and some mercury.

A choke is connected in series with the lamp to be high starting voltage. When temp. of filament increases the mercury vapourises and give bluish colour light. This lamps are special used for highway lighting, park lighting and showrooms etc. The efficiency of the lamp is 35 to 40 lumens per watt

Sodium Vapour Lamp



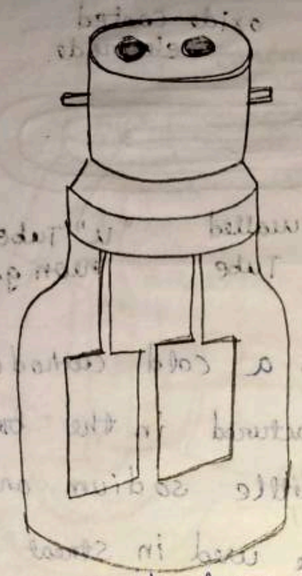
A sodium vapour lamp is a cold cathode low pressure lamp. This lamp is manufactured in the form of 'U' shape tube which contains a little sodium and neon gas.

Since this lamps are used in street light the tube is enclosed in an outer doubled walled glass tube in order to maintain the temp. of the filament or tube.

When cold sodium is in solid state and the lamp is started as a neon lamp. But after 10 to 15 minutes when temp. increases the solid sodium turns in to vapour giving yellowish light.

For starting the discharge high voltage is taken from a transformer. The efficiency of the lamp is 40-50 lumens/watt and it is used for street lighting.

Neon Lamp



Neon lamp

This a cold cathode lamp where neon gas is used at low pressure. In this lamp two flat or spiral electrodes are kept close together in a glass bulb. The lamp can be operated at low voltage such as 110 Volt AC or 1.5 volt DC. When supply is given to the electrodes the gas becomes ionized and emits light which is reddish in colour. A 2000Ω resistance is connected in series with the electrodes to minimize the fluctuation of current through the electrode.

A neon lamp is generally used as an indicator lamp and can also be used as night lamp.

Industrial Drives

Electric Drive

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

Electrical drives used in industry may be divided in to two type : (i) Group drive
(ii) Individual drive

Group drive

In this drive, one motor is used to drive two or more 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 drive.

This type of drive is economical, as a single motor of large capacity costs less than the costs of ano of small motors of the same total capacity. Less space is required.

Individual Drive

In this drive, a single motor is used to drive one individual machine. The operator has complete control on his machine. If there is a fault in one motor, this will not effect the production of the industry.

Such drive is most suitable for driving heavy machines such as lifts, hoists, cranes, etc. Efficiency is high & it is more reliable.

Choice of Electric Drives

Some of the important factors to choose an electric drive are:

1) Steady state operation requirements

Nature of speed-torque characteristics, speed regulation, Efficiency, Dutycycle, quadrant operation, speed fluctuations & ratings.

2) Transient requirements

Starting, Braking, Acceleration, Deacceleration & Reversing performance.

3) Requirements related to the source

Type of source & its capacity, magnitude of voltage, voltage fluctuations, p.f., harmonics & the ability to accept regenerated power.

4) Capital, running & maintenance cost, environment, Location, Reliability, space, weight restriction, etc.

Characteristics of DC Motor

i) Electrical cht (T_a/I_a)

ii) Electromechanical cht. (N/I_a)

iii) Mechanical cht (N/T_a)

Cht. of series motor

i) Electrical cht. (T_a/I_a) :-

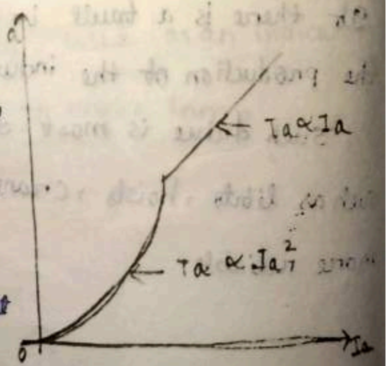
we know that $T_a \propto \phi I_a$ Before Saturation, $\phi \propto I_a$

$\therefore T_a \propto I_a^2$

Hence, the curve is a parable.

After saturation ϕ is almost constant

$\therefore T_a \propto I_a$

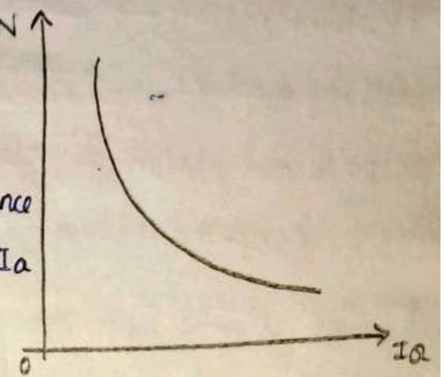


Hence the cht. becomes a st. line.

2) Electro mechanical cht. (N/ Ia)

we know that $N \propto \frac{E_b}{\phi}$

As $\phi \propto I_a$, $N \propto \frac{E_b}{I_a}$



when load is heavy, Ia is large. Hence speed is low. But when load is small Ia is very small. Hence speed becomes dangerously high.

Hence a series motor should never be started without load otherwise it may develop excessive speed and get damaged.

Application of DC Motor

i) shunt Motor → Lathe machine, Vaccum cleaner, blower, washing machine, priting press, etc.

ii) DC series motor → electric traction, Rolling meal, crane.

iii) DC compound motor → driving compressor, stamping machine, passanger elevator, door lift etc.

Application of 3ϕ induction motor

i) squirrel cage → Lathemachine, drilling machine, grinder, blower, etc.

ii) slipring induction motor → lift, pump, winding machine, Compressors, etc.

Application of 3ϕ synchronous Motor

Driving large fan, compressors, pumps, etc. It can also work on lagging and leading powerfactor and to improve power factor.

Application of 1-ϕ induction motor

i) R-split phase Induction motor → fan, blower, washing machine, domestic refrigerator, small machine tools, etc.

ii) L-split phase IM (shaded pole IM) → small fan, toys, hair drier, electric clock, coollers pump, etc.

iii) capacitor start Induction motor → grinder, large washing machine, refrigerator, pump, etc.

iv) capacitor run induction motor → sit ceiling fan, table fan.

v) capacitor start & rum IM → Blower, compressor, grinder, large size washing machine.

vi) single phase series motor → traction work for small matter on low frequency at $16\frac{3}{4}$ Hz = 16.75 Hz

vii) universal motor → It can be used in both A.C and DC, vaccum cleaner, mixer, domestic sewing machinge, hair drayer, electric shaver, etc.

viii) Repulsion motor → coil winding, machine tools

ix) Repulsion start ↔ Induction Run motor → commercial refrigerator, heavy blower, floor polishing, compressor,

x) Repulsion inductor motor → garage air pump, petrol pump, household refrigerator, mixing machine, etc.

Electric Traction

System of Traction

Electric traction means a locomotion in which the driving force is obtained from electric motors. The various systems of traction are :

i) Direct stem Engine System

ii) Direct Internal combustion Engine

iii) Internal combustion Engine with Electric drives

iv) Battery Electric drive

i) Direct ~~sys~~ steam Engine system

In this system the driving force is obtained by a reciprocating steam engine, mounted on the locomotive. It is most widely used for rail road operation.

Advantages

a) Intial cost is low.

b) The speed control is simple.

c) It doesnot intefere with tele communication system.

d) The locomotive is not tied to any particular track or route. It can be operated anywhere.

Disadvantages

a) The efficiency of the system is very low.

b) Maintenance cost is very high.

c) It pollutes the atmosphere.

d) Limited over load capacity.

2) Direct Internal combustion Engine

This engine drive is very common in road transport vehicles like trucks, buses, cars etc. It can not be used for heavy works like railways. To increases starting torque & also for speed control a gear box has to be provided.

Advantages

a) Initial investment is very low.

b) Speed control is ~~possib~~ & braking system is very simple.

c) It is a cheap drive.

Disadvantages

a) overload capacity is limited.

b) speed control is possible only by employing a gear box.

c) Maintenance & Running coil is high.

3) Internal combustion Engine with Electric Drive

In this system the gear box are eliminated as a direct engine drives as DC generator coupled in it at a constant speed which supplies power to electric motors fitted with the wheels.

Advantages

a) Low capital cost.

b) Absence of smoke & dirt.

c) overall efficiency is greater.

Disadvantages

a) Maintenance & operating cost is high.

b) overload capacity is limited.

c) Life of diesel engine is comparatively shorter.

d) special cooling system is required.

4) Battery electric Drive

In this drive the locomotive carries the secondary batteries which supply power to DC motors employed for driving the vehicle. The capacity being small, it is used for shunting in railway yards, for traction in mines, for local delivery of goods in large towns and large industrial plants.

Low maintenance cost & absence of fumes.

5) Electric drive

This is the most extensively developed & widely used system of traction. In this system the vehicle draws electrical energy from the distribution system fed at suitable points.

Advantages

a) It is very clean.

b) Maintenance & repair cost is about 50% of that of steam locomotive

c) It can withstand high over loads for short time. This is helpful on mountain grades.

Disadvantages

a) It causes interfere to the telephone lines.

b) whole system becomes standstill in case of power failure.

c) A very high capital cost is involved for power generation & associated transmission & distribution.

Systems of Track Electribriction

Two types of vehicles are used for electric traction;

a) vehicles recieves AC or DC power from a distribution over-head line.

b) vehicles generates their own power like diesel engine electric drives.

Accordingly there are two main systems of electric traction

i) DC system

In this system the electric motors used are DC series motors. The operating voltage is about 600 V for suburban railways & from tran cars. For main line railways the operating voltage is from 1500V to 3000V.

The motors recieve power from an overhead line with the help of a pantograph and the railway track is the return conductor.

2) AC system

The AC system in india is being employed from How to New Delhi and from Chennai to Tanbram. The modern development in electric traction is to use 1-ϕ AC supply.

The AC system used is further of 4-types.

3) 3ϕ AC system

This system employs 3-ϕ SRIM (Slip ring IM). The voltage & frequency at which the motor is made to operate are about 3600V & $16\frac{2}{3}$ HZ.

4) 1ϕ standard frequency system

This system is also known as composite system of traction. The system has a single overhead wire supplied at 25 kV, 50Hz which is the standard industrial frequency, transformer is mounted on the locomotive and its steps down the voltage which is further rectified and supplied to the traction motor. This system has become very popular.

3) 1ϕ low frequency system

In this system 15 kV, $16\frac{2}{3}$ Hz is used. A stepdown transformer is carried in the traction unit which steps down the voltage to about 400 V for the use of traction motors.

4) single phase to 3ϕ system

In this system single phase high voltage AC system is employed for distribution networks. The locomotive carry a phase converter which converts 1ϕ AC into 3ϕ. The 3ϕ supply is connected to 3ϕ induction motor for getting the necessary driving force. The voltage used for distribution network is 16000 V at 50 Hz

Characteristics of DC series motor

i) Electrical characteristics

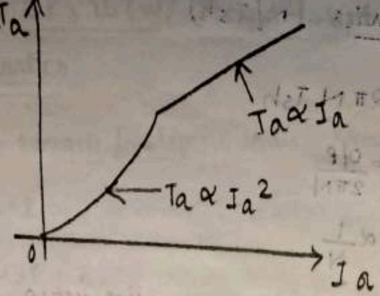
we know that $T_a = 0.159\,\phi Z I_a \frac{P}{A}$

$T_a \propto \phi I_a$

Before saturation $\phi \propto I_a$

$$\boxed{T_a \propto I_a^2}$$

Hence the cht. is a parabola.



Abter saturation ϕ is almost constant $\therefore \boxed{T_a \propto I_a}$

Hence the cht. is a straight line.

ii) Electro- Mechanical characteristics (N/I_a)

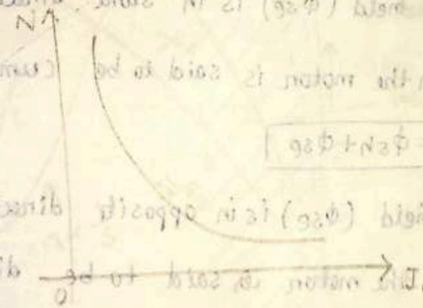
we know that $E_b = \frac{P\phi ZN}{60} \times \frac{P}{A}$

$$\text{or, } E_b \propto \phi N$$

$$\text{or, } N \propto \frac{E_b}{\phi}$$

But In series motor $\phi \propto I_a$

$\therefore \boxed{N \propto \frac{E_b}{I_a}}$



If load is high I_a is also high and also the speed becomes low.

If load is low I_a is also low and also the speed becomes very high.

If there is no load the armature current (I_a) is very low & that speed becomes dangerously high speed.

So, the series motor can not be started with out load.

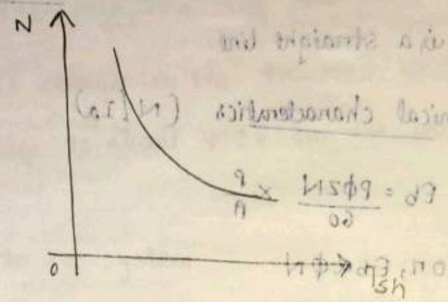
iii) <u>Mechanical characteristics (N/Tsh)</u>

we know that $O/p = 2\pi N T_{sh}$

$$or,\ T_{sh} = \frac{O/p}{2\pi N}$$

$$or,\ T_{sh} \propto \frac{1}{N}$$

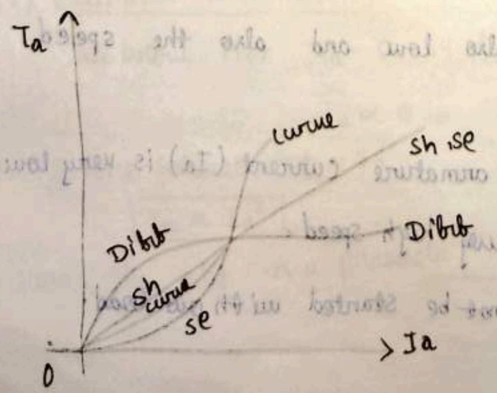
If speed increases torque is decreases vice versa

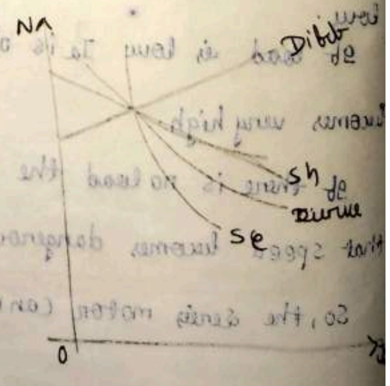


Characteristics of compound motor

If the series field (ϕ_{se}) is in same direction of shunt field (ϕ_{sh}), then the motor is said to be cummutatively compounded $\boxed{\phi = \phi_{sh} + \phi_{se}}$

If the series field (ϕ_{se}) is in opposite direction of shunt field (ϕ_{sh}) then the motor is said to be differentially compounded. $\boxed{\phi = \phi_{sh} - \phi_{se}}$



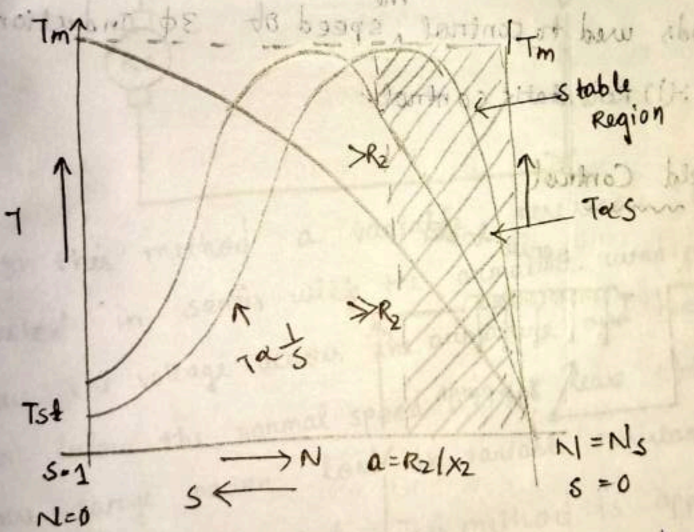


14 (w), 14 (S) BP, 15 (w) Torque–slip characteristics or Torque-speed characteristics

A family of torque / slip curves is shown in fig. for a range $s = 0$ to $s = 1$

We know $T = \frac{k s E_2^2 R_2}{R_2^2 + (s X_2)^2}$

Hence the torque / slip curve is a rectangular hyperbola so, beyond the maxm torque any further increase in load results in decrease of torque. The result is that the motor slows down and stop. The stable operation of the motor lies between the values $s = 0$ & $s = R_2 / X_2$



It is seen that the maxm torque doesnot depend on R_2. Greater the R_2 greater the slip & greater the starting torque (T_{st})

Control of Motors

The starting current taken by a DC motor during the starting period is limited by the resistance of the stator. There is a considerable loss of energy in the starting resistance. Speed of DC motor can be controlled by varying armature current, applied voltage and field flux.

The methods used to control the speed of DC series motor :- i) Tapped field control

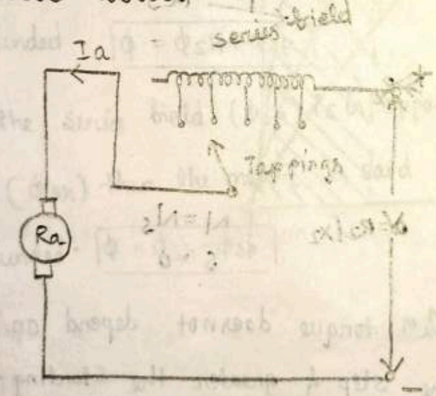
ii) Series parallel control

iii) Multi unit control

iv) Metadyne control

The methods used to control the speed of 3ϕ Induction motor are :- (i) Rehostatic control.

Tapped field Control

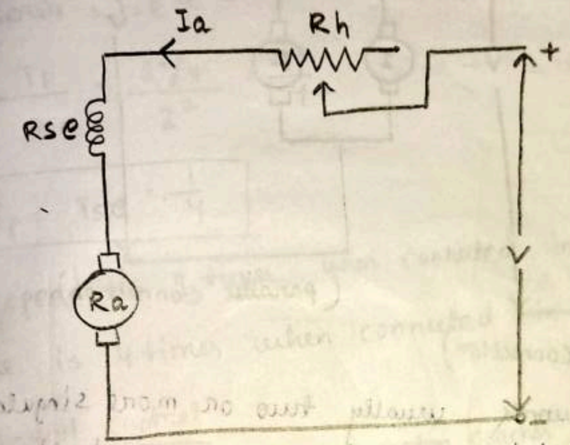


The speed of traction motor can be increased by weaking the field strength. For reducing the field strength either a field diverter or the field is tapped.

The no of series field terms in the circuit can be changed by tappings. with full field the motor runs at its minimum speed which can be raised in steps by cutting out some of the series terms.

The advantages of this system is to make the equipment very flexible, eliminate the necessary of changing the gear ratio and can operate various types of services at a reasonable energy consumption.

Rehostatic control

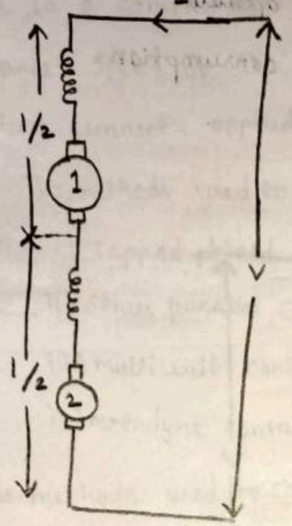


In this method a variable resistance (Rh) is connected in series with the armature winding. This reduces the voltage across the armature and hence speed falls below the normal speed it is least efficient method because large power loss in variable resistance. This is the simplest method of control. This method is applied to light locomotives and motor coaches where a single speed is sufficient and energy consumption is not taken into consideration.

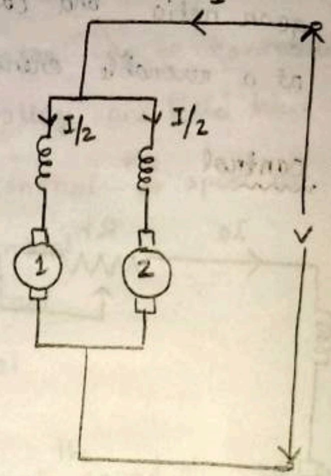
Speed control of 3ϕ IM can be archieved by adding Rehostat in either stator circuit or rotor circuit. The control of speed can be from rotor side possible for slipring induction motor.

In this case the speed of 3ϕ IM can be reduced but the starting torque is increased.

Series parallel control



(series connection)



(parallel connection)

In traction work usually two or more singular motors are employed or used at low speed the motors are joined in series and for high speed, they are joined in parallel.

when in series the two motors have the same current but voltage across each motor is $V/2$, so speed decreases.

when joined in parallel voltage across each machine is same but current through them is $I/2$, so the speed increases.

we know $N \propto \frac{E_b}{\phi} \propto \frac{V}{I}$

In parallel, $N_p \propto \frac{V}{I/2} = \frac{2V}{I}$

In series, $N_{se} \propto \frac{V/2}{I} \propto \frac{V}{2I}$

$$\frac{N_p}{N_{se}} = \frac{2V/I}{V/2I} = 4$$

$$\boxed{N_p = 4 \times N_{se}}$$

we know, $T \propto \phi I \propto I^2$

In parallel, $T_p \propto \left(\frac{I}{2}\right)^2 \propto \frac{I^2}{4}$

In series, $T_{se} \propto I^2$

$$\therefore \frac{T_p}{T_{se}} = \frac{I^2/4}{I^2} = \frac{1}{4}$$

$$\boxed{T_p = T_{se} \cdot \frac{1}{4}}$$

The speed is 4 times when connected in parallel and torque is 4 times when connected in series

Multi-unit control

For city or suburban services motor coaches are usually employed. Each motor coach may have ~~one~~ one or two trailer coaches. The length of a train depends upon the no of motor and trailer coaches. By the use of multiple unit control the motor coaches can be controlled from a single point.

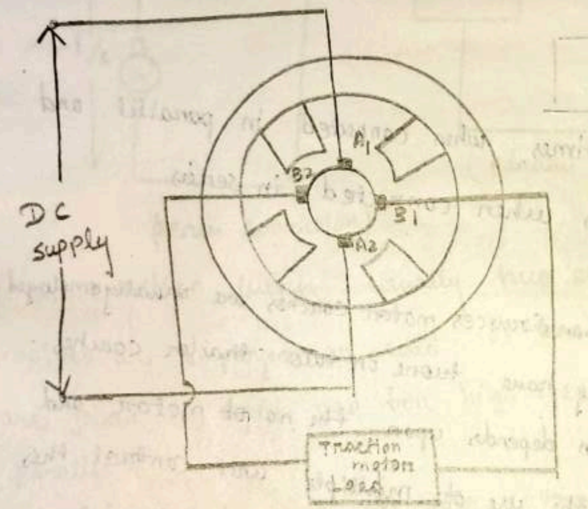
A unit of train equipment consist of a group of two or four motors in every motor coach and provided with a series parallel controller, reverser, starting Resistance & collector gear.

The controller and reversers are controlled by a master controller. The electric cables joining the various unit are called coupling cables.

The controller in any one unit may be operated that all motor starts simultaneously.

All the motors are started simultaneously with maximum starting resistance in series with each motor. Step by step all resistance are cut out and all the motors are in full running position. All the operations can be done by only one controller.

Metadyne Controller :-



In series parallel control of dc traction motor there is a loss of energy in the starting resistance. Metadyne system of control estimate the loss of energy and archieve a very smooth control during the accelaration period.

Consider a DC armature with 4 brushes and 4 poles. If current is supply to brushes A1 & A2, an emf is ...ed in the armature winding between brushes B1 & B2.

Since an emf is induced across B_1 and B_2, a current will flow in the load (traction motor) between them. This motor behaves like a DC transformer if the supply voltage remains constant the current also remains constant. There fore this system is very suitable for starting DC motors. The load current can be controlled by using a regulator winding in series with the traction motor.

Braking

In traction work both electrical and mechanical breaking are employed or we for bringing the vehicle to rest.

The main advantage of using electrical braking is that it reduces the wear on the mechanical breakes & gives a higher value of braking retardation thus bringing a vehicle quickly to rest. For electrical motor There are 3 methods employed for electric ~~break~~ braking

i) plugging

ii) Rehostatic or dynamic braking

iii) Regenerative braking

Regenerative Braking

Regenerative Braking with DC motor is employed when the terminal voltage (Eb) must be more that of the supply voltage V. During Regeneration the current through the armature reverses and the field connection must be reversed. During Re-generative Braking the auxiliary field winding are placed in parallel across the ar... and the main series field.

that
with
motor
motors
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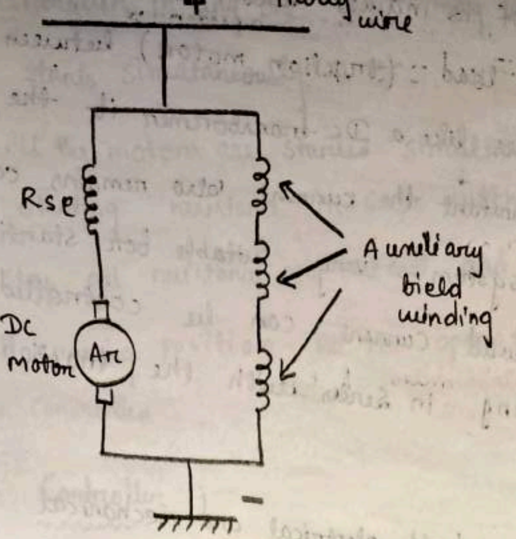
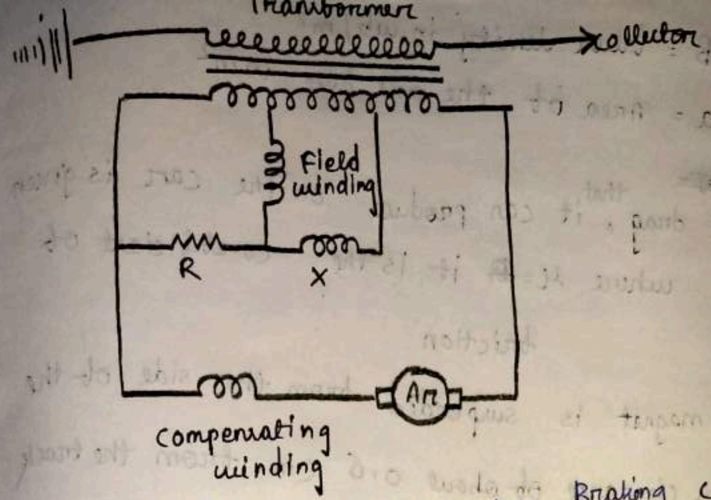
and 4 poles
emf is
B_1 & B_2



Regenerative Braking with 3ϕ induction motor occurs automatically when the motor runs at a speed slightly above synchronous speed. Then it works as an induction generator. The induction generator however must be connected to a ~~supply~~ system supplied from synchronous generator. By adding extra resistance in the rotor circuit the speed increases ~~with out any~~ for a particular braking torque. Therefore while braking without any extra resistance in the rotor circuit, the speed will be kept almost constant. This is a ~~good~~ great advantage with the induction motor when used for traction.

Braking with 1-ϕ Series Motor



In case of 1-ϕ Series motor Braking can be possible by both rehostatic and regenerative system.

In rehostatic breaking the motors add separately excited and the fields are excited from low voltage transformer.

In Regenerative Braking the regenerated power should be at supply frequency the regenerated current must be in phase opposition to the applied voltage and also the flux. So the power may be fed back in ~~to the~~ supply system.

Magnetic Braking

It is used in tramcars. The electromagnet is bipolar. The body is made of cast steel and the pole faces are made of soft steel. The exciting coil is enclosed in a water tight case (colling system). The magnetic flux is perpendicular to the pole faces and the trac. The force of attraction between the magnet & the trac is given by $F = \frac{B^2 a}{2 \times 4\pi \times 10^{-7}}$ N where, B = flux density in wb/m^2

a = Area of the pole face in m^2

The drag that it can produce on the car is given by μF where μ = it is the co-efficient of friction

The magnet is suspended from the side of the car with a clearance of about 0.6 cm from the track