GANESH INSTITUTE OF ENGINEERING AND TECHNOLOGY

Utilization of Electrical Energy & Traction

(Th- 04)

(As per the 2020-21 syllabus of the SCTE&VT, Bhubaneswar, Odisha)

Fifth Semester

Electrical Engg.

Prepared By: Er.P.K DASH

UTILISATION OF ELECTRICAL ENERGY AND TRACTION

CHAPTER-WISE DISTRIBUTION OF PERIODS & MARKS

Sl. No.	Chapter/ Unit No.	Name of The Chapter/ Unit	Periods as per Syllabus	Expected Marks
01	01	Electrolytic Process	08	20
02	02	Electrical Heating	08	15
03	03	Principles of arc welding	08	15
04	04	Illumination	12	10
05	05	Industrial Drives	10	20
06	06	Electric Traction	14	20
TOTAL			**60**	**110**

CHAPTER NO.- 01
ELECTROLYTIC PROCESS

Learning Objectives:

Definition and Basic principle of Electro Deposition.
Important terms regarding electrolysis.
Faradays Laws of Electrolysis.
Definitions of current efficiency, Energy efficiency.
Principle of Electro Deposition.
Factors affecting the amount of Electro Deposition.
Factors governing the electro deposition.
State simple example of extraction of metals.
Application of Electrolysis.

ELECTROLYTIC PROCESS

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

ELECTROLYTE:

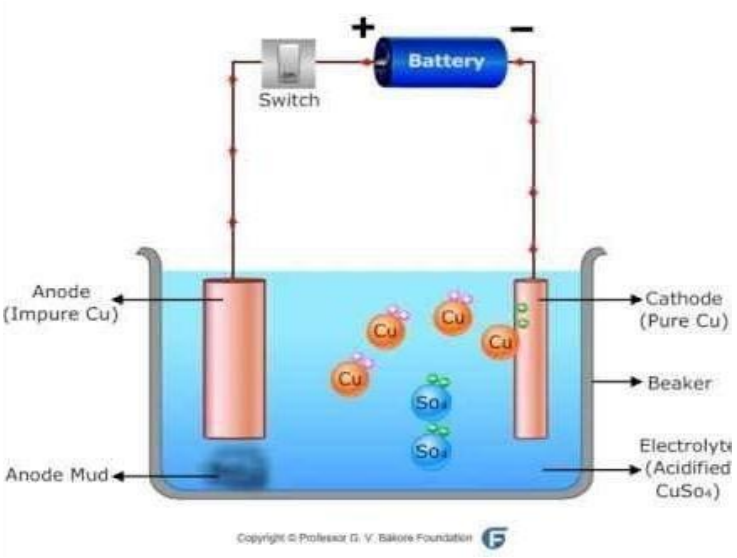
The substance which decomposes when an electric current is passed through them is called as electrolyte.

DEFINATION AND BASIC PRINCIPLE OF ELECTRODEPOSITION

ELECTRODEPOSITION :

It is the process of depositing a metal on the surface of some other metal by electrolysis is called as electroplating

BASIC PRINCIPLE:



- If two electrodes are dipped in an electrolyte and potential is applied across the electrodes are named as a node and cathode.
- The molecules of the substance dissolved dissociate i.e they are broken up into two types of ions positive and negative.

- Consider the case, copper sulphate dissolved in water. It dissolves positive charged copper ions and negative charged sulphate ions.
- If two electrodes are placed in the solution and one of them is connected to the positive terminal of the dc and other to the negative terminal, then the positively charged ions travel towards the cathode and negatively charged ions towards the anode.
- They give up their respective charge on reaching the electrodes and become ordinary molecule of respective radical. Therefore, copper is deposited at the cathode as metal and the sulphate ions are collected at the anode and react with water giving sulphuric acid and oxygen gas as shown in the following reaction.

  $2SO_4 + 2HO = 2H_2SO_4 + O_2$

IMPORTANT TERMS REGARDING ELECTROLYSIS

ELECTROLYTE

- The solution of the salt which is used for electrolysis is called electrolyte.

ELECTRODE

- The plates merged in an electrolyte and connected to dc supply are called electrode.

ANODE

- The electrode connected to the positive terminal of the supply is called anode.

CATHODE

- The electrode connected to the negative terminal of the supply is called cathode.

IONS

When a dc is passed through an electrolyte it gets chemically decomposed into two parts.

a) +ve ions b) -ve ions

FARADAYS LAWS OF ELECTROLYSIS:

Faraday was a scientist who deduced two laws on the phenomenon of electrolysis which are called as Faradays law of electrolysis.

FIRST LAW:

Faradays first law states that the weight of a substance liberated from an electrolyte in a given time is proportional to the total quantity of the electricity passed in that time.

Mathematically,

$W \alpha Q$

$W \alpha IT$, $W=ZIT$

Where, Q=Quantity of electricity passed.

W=Weight of substance. I=Current.

T=Time.

Z=Electro chemical equivalent.

- Electro chemical equivalent of a substance is the amount of weight liberated on passing a steady electric current of I ampere for 1 second through its solution.
- The unit of electro chemical equivalent is gm/coulomb.

SECOND LAW:

Faradays second law states that when the same current flows for a given time through several electrolytes, the weights of substance liberated are proportional to their chemical equivalent.

Chemical Equivalent=Atomic weight of substance (a) / Valency (V)

According to this law if we take two electrolytes of copper sulphate and nickel sulphate in which current flows for the same time, then weight of copper deposited by given quantity of electricity/weight of nickel deposited by same quantity of electricity.

Q1) Find the electro chemical equivalent of silver if a current of 10ampere deposit 13.42gm of silver from a silver nitrate solution in20 minutes.

Answer

Given data: I=10A, W=13.42gm

T=20min =1200sec

Required data- Electro chemical equivalent (W)

Solution:

We know that electro chemical equivalent, W=ZIT

Z=W/IT

=13.42/12000

$=1.118\times10^{-3}$gm/coulomb

Q 2) Calculate the weight of a substance, if a current of 15amper deposit in a silver nitrate solution having 25 min and electro chemical equivalent is 0.00123gm/coulomb.

Answer:

Given data : I=15amp

Z=0.00123gm/coulomb, T=25×60 =1500sec

Required data: W

Solution

We know that W=ZIT

=15×0.00123×1500

=27.675gm

DEFINATION OF CURRENT EFFICIENCY & ENERGYE FFICIENCY

CURRENT EFFICIENCY:

It is defined as the ratio of actual quantity of substance liberated to the theoretical quantity.

η_c=Actual quantity of the substance liberated / Theoretical quantity.

Its true value lies between 90% to 98%.

Weight of substance, $W=Z\ I\ T\ \eta_c$

ENERGY EFFICIENCY

On account of secondary reactions, the voltage required for decomposition or liberation of metal is higher than the theoretical value which increases the actual energy required.

It is defined as the ratio of theoretical energy required to the actual energy required.

Energy Efficiency=Theoretical energy/Actual energy required.

Q3) Find the thickness of the copper deposited on a plate of 2.25 cm^2during electrolysis, current of 1ampere passes for 100min.Density of copper is 8.9 and electro chemical equivalent is 0.0003295 gm/coulomb.

Answer:

Given data , $A=2.25cm^2$ I=1A

T=100min =6000sec
D=8
Z=0.000325gm/coulomb

Required data- Thickness(t)

Solution

Weight of substance, W=ZIT
=0.0003295×1×6000 =1.98gm

Density=Mass/Volume

Volume=Mass/Density
=1.98/8.9
=0.22cm^3

Thickness of cu=Volume/Area
=0.22÷2.25
=0.098cm

Q4) A rectangular plate 20×10 cm is to be coated with nickel with a layer of 0.2mm thickness. Determine the quantity of electricity in ampere hour and time taken for the process. Current density is190Amp/m^2 and current efficiency is 90% and specific gravity of nickel is 8.9 and electro chemical equivalent for nickel is 0.0003043gm/coul.

Answer

Given data :

A=200cm^2 =200÷10^4m^2

Current density=190A/m^2 , Thickness=0.02cm

Current efficiency=90%=0.9, Z=0.003043gm/coulomb

Specific gravity=8.9

Required data- Time, Q

Solution :

Volume=Area ×Thickness
=200×0.02 = 4cm^2

Weight=Specific gravity ×Volume
=8.9×4 =35.6cm

W=Z I T ηc

IT=W÷Zηc
=35.6÷(0.0003043×0.9)
=129988.68coulomb

Current density=Current/ Area

Current=Current density ×Area
=190×(200/10^4) =3.8A

IT=129988.68 coulomb

T=129988.68÷3.8
=34207.54sec.

PRINCIPLE OF ELECTRO DEPOSITION :

- It is the process of depositing a metal on the surface of some other metal or non metal by electrolysis is called electro deposition.

- Electroplating is a very common example of such process.
- If two electrodes are dipped in an electrolyte and potential is applied across them, the electrodes are named as anode and cathode.
- The molecules of the substance dissolved dissociate i.e they are broken up in to two types of ions positive and negative.

,FACTORS AFFECTING THE AMOUNT OF ELECTRO DEPOSITION :

TIME

Time is directly proportional to the quantity of electro deposition, more mass will be deposited in more time, similarly less time will be deposited in less time if other conditions remain constant.

EFFICIENCY

Efficiency is directly proportional to quantity of metal deposited ,greater is the efficiency greater is the quantity of metal deposited for a given time.

CURRENT

Current is directly proportional to the mass of metal deposited, if current is high the mass of the metal deposited is high, similarly if current is low the mass of the metal deposited is less.

STRENGTH OF SOLUTION

If the strength of the solution is more, then the mass of metal deposited will be more as compared to dilute solution of electrolyte if other conditions remain same.

FACTORS GOVERNING THE ELECTRO DEPOSITION :

CURRENT DENSITY

If current density is more, the quantity of metal deposited is more. At low value of current density the ions are released at slow rate.

ELECTROLYTIC CONCENTRATION

Electrolytic concentration is directly proportional to the current density, more the concentration of electrolyte then current density is more as a result mass deposition is more.

TEMPERATURE

The temperature of electrolyte is different for different metal to have better deposit.
Example-Chromium plating the temp is maintained at 35°c
Copper plating the temp is maintained at50°c
Nickel plating it is between 50°c to 60°c.

ADDITION OF AGENTS

The quality of metal deposition is improved by the presence of an additional agent, which may be organic compound such as rubber, sugar, salts etc

NATURE OF ELECTROLYTE

The smoothness of the deposit largely depends nature of electrolyte, for example silver from silver nitrate solution forms a rough deposit while that from cyanide solution forms a smooth deposit.

NATURE OF METAL UPON WHICH DEPOSIT IS TO BE MADE

This factor influences the growth of crystals since it is believed that the operation of crystals is in continuation of the same in the base metal.

THROWING POWER

The throwing power of an electrolyte may be regarded as the quality which produces a uniform deposit on a cathode having an irregular shape. In an electrolyte of low conductance, the current will concentrate on the parts of the cathode which are nearer the cathode resulting in poor throwing power. If the electrolyte has good conductance, the throwing power will also be good.

1.8. STATE SIMPLE EXAMPLES OF EXTRACTION OF METALS

Extraction of Zinc

The ore consisting of zinc is treated with concentrated sulphuric acid ,roasted and passed through other processes to get rid of impurities by precipitation. The zinc-sulphate solution is then electrolysed.

Extraction of Aluminium

Ores of aluminium are bauxite, cryolite. Bauxite is treated chemically and reduced to aluminium oxide and electrolyzed, thus Aluminium deposits at the cathode.

1.9 APPLIATION OF ELECTROLYSIS

The application of electrolysis are :

- Extraction of metal from their ores.
- Extraction of zinc.
- Extraction of Aluminium.
- Refining of metal.
- Production of metal.
- Production of chemical.
- Separation of metal from their compound.
- Electro deposition.
- Electro cleaning

Extraction of metal from their ores

This is done in two ways:

- The ore is treated with a strong acid to obtain a salt and the solution Of such a salt is electrolyzed to liberate the metal.
- When the ore in molten state is available it is electrolysed in a furnace.

Extraction of Zinc

The ore consisting of zinc is treated with concentrated sulphuric acid, roasted and passed through other processes to get rid of impurities by precipitation. The zinc sulphate solution is then electrolysed.

Extraction of Aluminium

Ores of aluminium are bauxite, cryolite. Bauxite is treated chemically and reduced to aluminium oxide and electrolysed, thus Aluminium deposits at the cathode.

Refining of Metals

Electrolytic extraction gives about 98 to 99 percent pure metal. Further refining is done by electrolysis. The anodes are made of the impure metal extracted from its ores and the electrolyte is a solution of the salt of the metal. Pure metal is deposited on the cathode.

Production of chemical

Many chemical such as caustic soda, chlorine gas are produced by electrolysis on an large scale.

Separating metal from their compound

Many metals are separated from their compound by electrolysis ,for example an ore of aluminium contains 70% of aluminium oxide silica and iron oxide.

Electro deposition

Electro deposition is the process of depositing a metal over another metal or non-metal by electrolysis. Electroplating is a very common example of such process.

Electro cleaning

The article before electroplating shall have a substance free from grease and they are cleaned by electro cleaning method.

SHORT QUESTIONS WITH ANSWER:

Q.1. State faradays 1st law of electrolysis? [S-16, W-20]

Ans -Faradays 1st law states that the weight of a substance liberated from an electrolyte is directly proportional to the total quantity of electricity passed in that time.

$W \alpha Q$

Where, Q=Quantity of electricity passed.

W=Weight of substance.

State faradays 2nd law of electrolysis? [S-16, W-20]

Ans- Faradays 2nd law states that if the same current flows for a given time through several electrolyte, weight of the substance liberated are proportional to their chemical equivalent.

What is electroplating? [S-14]

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

Define electrolysis?

Ans- The process of decomposition of an electrolyte by the passage of electric current through them is called electrolytic process or electrolysis.

Define electrochemical equivalent of a substance?

Ans-Electro chemical equivalent of a substance is the amount of weight liberated on passing a steady electric current of 1 ampere for 1 second through its solution.

The unit of electrochemical equivalent is gm/coulomb.

Define electroplating with example?

Ans- The process of depositing metal on the surface of some other metal or non-metal by electrolysis is known as electroplating.

Example- Electroplating, Electro cleaning.

What is current efficiency? [S-14, 17, W-18,S-19, W-20]

Ans-Current efficiency is defined as the ratio of actual quantity of substance liberated to theoretical quantity of substance liberated.

ηc=Actual quantity of the substance liberated / Theoretical quantity Its true value lies between 90 to 98%.

Weight of substance $W=Z\ I\ T\ \eta c$.

Define Energy Efficiency?

Ans-On account of secondary reactions , the voltage required for decomposition or liberation of metal is higher than the theoretical value which increases the actual energy required.

It is defined as the ratio of theoretical energy required to the actual energy required.

Energy Efficiency=Theoretical energy /Actual energy required.

Mention the need of electroplating?

Ans-The electroplating is used for to protect the metal against corrosion. To give shining appearance to the article.

10.What are the Factors affecting the amount of electro deposition?

Ans- Factors affecting the amount of electro deposition are Time , Efficiency , Current Strength of solution.

LONG QUESTIONS:

Explain factors affecting the amount of electro deposition? [W-17, 18, 20]

State and explain Faradays law of electrolysis? [S-18,W-19, S-19]

Explain the factors governing for better electro deposition? [W-20]

Briefly describe about the application of electrolysis?

Q.5.Write short note on electro deposition. [S-16]

ELECTRICAL HEATING:

Learning Objectives:

Advantages of electrical heating.
Mode of heat transfer and Stephen's Law.
Principle of Resistance heating. (Direct resistance and indirect resistance heating.)
Discuss working principle of direct arc furnace and indirect arc furnace.
Principle of Induction heating.
Working principle of direct core type, vertical core type and indirect core type Induction furnace.
Principle of coreless induction furnace and skin effect.
Principle of dielectric heating and its application.
Principle of Microwave heating and its application.

Introduction :

- Electrical heating is preferred over all other types of heating methods i.e by wood, coal, oil and gas.
- Electric heating is based on the principle that when electric current passes through a medium (solid, liquid, gas) heat is produced.

Let us consider the case of a solid material which has a resistance of R ohms and current I ampere flows through it for t seconds, then heat produced in the material will be,

$H=I^2Rt$ joules

$H=I^2Rt/4.2$calories $= 0.24I^2Rt$.

Advantages of electrical heating :

The various advantages of electric heating over other the types of heating are:

1. **Economical** : Electrical heating equipment is cheaper; they do not require much skilled persons; therefore, maintenance cost is less.
2. **Cleanliness :** Since dust and ash are completely eliminated in the electric heating, it keeps surrounding clean.
3. **Pollution free**: As there are no flue gases in the electric heating so atmosphere is pollution free.
4. **Ease of control** : In this heating, temperature can be controlled and regulated accurately either manually or automatically.
5. **Automatic protection** : Protection against over current and over heating can be provided by using fast control devices.
6. **Better working conditions**: No irritating noise is produced with electric heating and also radiating losses are low.
7. **Less floor area:** Due to the compactness of electric furnace, floor area required is less.

Mode of heat transfer and Stephen's Law:

There are three modes of transmission of heat:

1. Conduction
2. Convection
3. Radiation

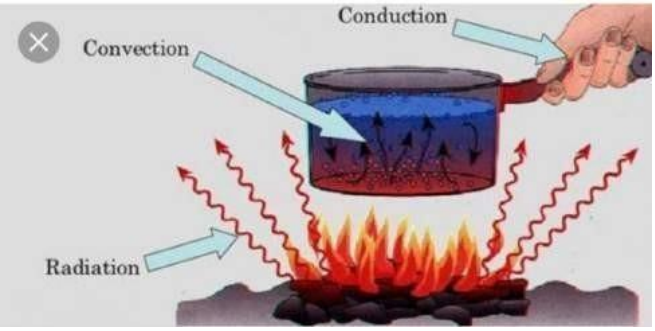


Fig:1

1. **CONDUCTION**:-The transfer of heat from one substance to another due to direct contact.
2. **CONVECTION**:-The transfer of heat through liquid is called convection .
3. **RADIATION**:-Energy transmitted in form of rays or waves is called radiation.

Stephen's Law:

The law states that; "The total energy emitted/ radiated per unit area of Black body across all wave lengths per unit time is directly proportional to the fourth power of it's absolute temperature"

$E \alpha T^4$, $E=\delta T^4$

Where, E= Energy Radiated.

T=Absolute Temperature. δ=Stephen's constant.

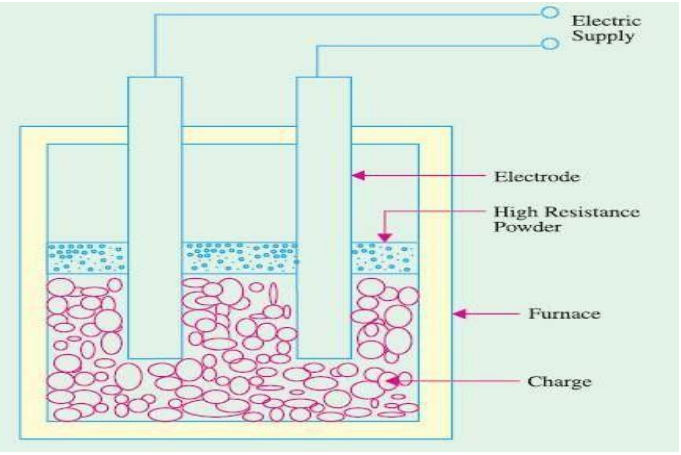
Principle of Resistance heating. (Direct resistance and indirect resistance heating.)

It is based on the I^2R effect.

When current is passed through a resistance element, I^2R loss takes place which produces heat. There are two methods of resistance heating.

1. Direct Resistance Heating.
2. In-Direct Resistance heating.

1. Direct Resistance Heating.

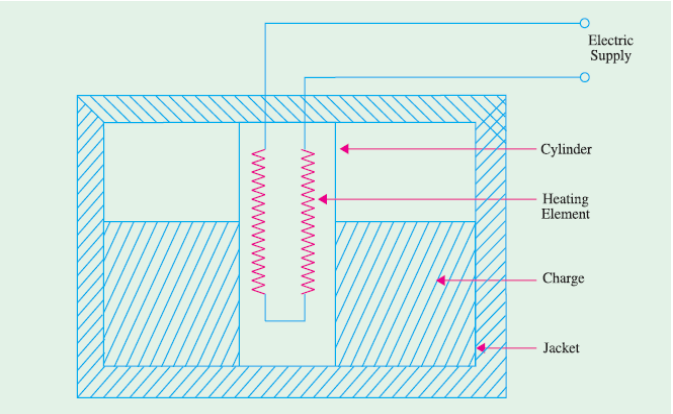


- In this method the material or charge to be heated is treated as a resistance and current is passed through it.

- The charge may be in the form of powder, small solid pieces or liquid. The two electrodes are inserted in the charge and connected to either a.c. or d.c. supply.

- The two electrodes will be required in the case of d.c. or single-phase a.c. supply but there would be three electrodes in the case of 3-phase supply.
- When the charge is in the form of small pieces, a powder of high resistivity material is sprinkled over the surface of the charge to avoid direct short circuit.
- Heat is produced when current passes through it.
- This method of heating has high efficiency because the heat is produced in the charge it self.

2. In-Direct Resistance heating.



- In this method of heating, electric current is passed through a resistance element which is placed in an electric oven.
- Heat produced is proportional to I^2R losses in the heating element. The heat so produced is delivered to the charge eitherby radiation or convection.
- Sometimes, resistance is placed in a cylinder which is surrounded by the charge placed in the jacket as shown in given fig. This arrangement provides uniform temperature. Moreover, automatic temperature control can also be provided.
- Both ac and dc can be used for this purpose at full main voltage depending upon the design of heating element

  Example-resistance oven.

Discuss working principle of direct arc furnace and indirect. arc furnace :

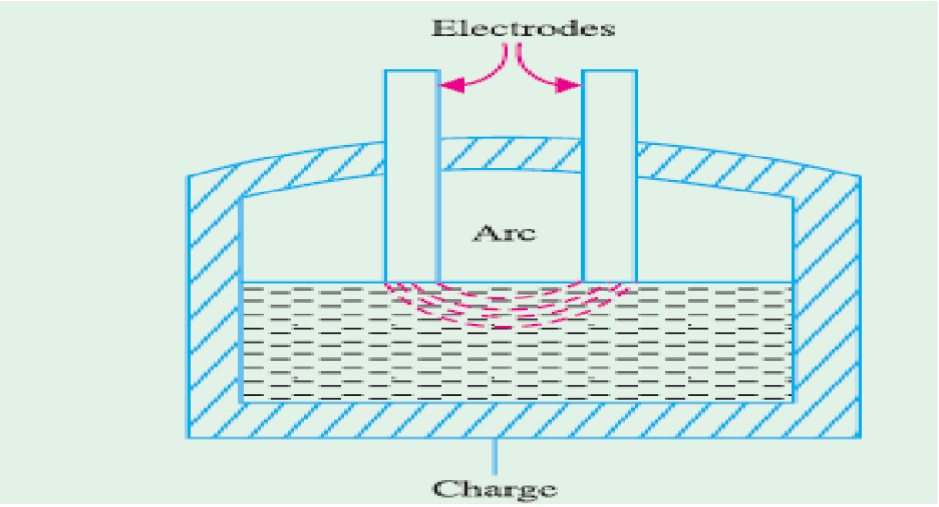
Arc furnace:

- The furnace used for melting or extraction of ferrous or non-ferrous metalsneed high temperature operation.
- If a sufficiently high voltage is applied across an air-gap, the air becomes ionized and starts conducting in form of a continuous spark or arc producingintense heat.
- When electrodes are made of carbon/graphite, the temperature obtained is in the range of 3000°C- 3500C.
- Arc is the flow of current through an air gap between two conducting bodies.

Arc furnace is divides in to two types:

1. Direct arc furnace.
2. Indirect arc furnace.

1. Direct arc furnace.



- When the arc is struck between electrodes and charge, the arc current flows through charge.
- There is a direct contact between the arc and charge.
- The electrodes used may be of carbon or graphite.
- For dc and ac supply two electrode are used and for three phase supply threeelectrodes.
- Their is a stirring action due to electromagnetic force.
- Heating process is much faster in this system and efficiency is too high.
- Electrically these furnace can be subdivided into two types:
  a)Conducting buttom .b)Non conducting buttom.

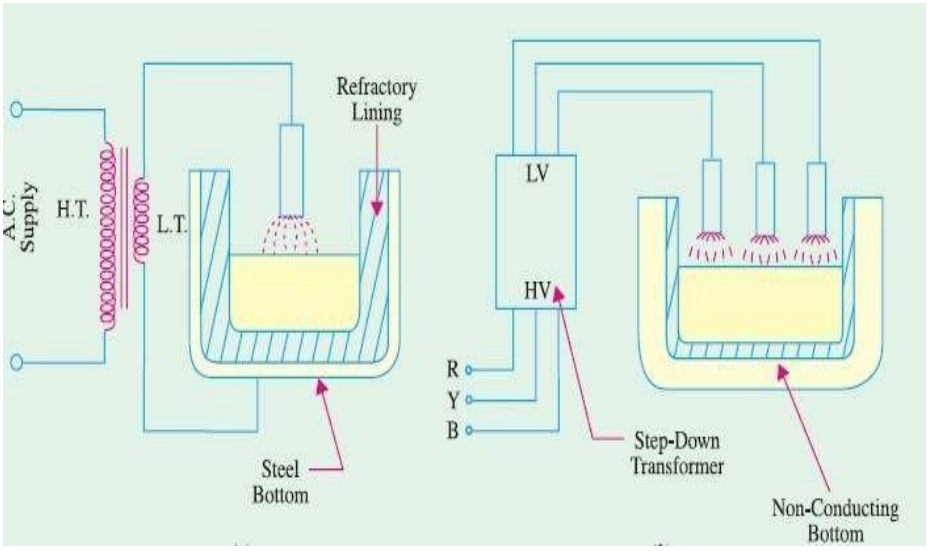
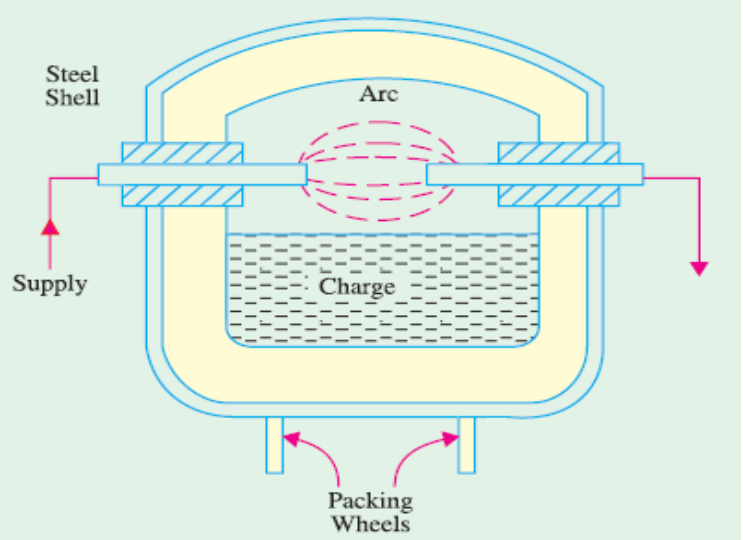


Fig-a Fig-b

- Fig(a) shows conducting buttom arc furnace in which the bottom of the furnace forms part of the electric circuit so that current passes through the body of the charge which offers very low resistance.
- It produces uniform heating of charge without stirring it mechanically.
- In Fig. (b), shows non conducting buttom arc furnace in which no current passesthrough the body of the furnace.
- Most of the furnaces are of non-conducting bottom type due to insulation problem faced in case of conducting bottom.

2. Indirect arc furnace.



- The above Fig. shows a single-phase indirect arc furnace which is cylindrical in shape.
- The arc is struck by short circuiting the electrodes manually or automatically for a moment and then withdrawing them apart, the heat from the arc and the hot refractory lining is transferred to the top layer of the charge by radiation, heat from the hot top layer of the charge is further transferred to other parts of the charge by conduction.

- Since no current passes through the body of the charge, there is no inherent stirring action due to electro-magnetic forces set up by current. Hence, such furnaces have to be rocked continuously in order to distribute heat uniformly.

- In this furnace charge is heated by radiation only so its temperature is lower than direct arc furnace. Such furnaces are mainly used for melting non-ferrous metals although can be used in iron foundries.

Principle of Induction heating :

This heating process makes use of the currents induced by the electro-magnetic action in the charge to be heated. In fact, induction heating is based on the principle of transformer working.

Eddy current :

- Whenever the flux linking to any conducting body changes an emf isinduced which is a function of rate of rate of change of current.
- Consider a coil of N turns wound on one limb of a magnetic core.Let the coil be supplied with alternating current from a source.
- The flux created by this current will be changing in magnitude as well asdirection.
- This changing flux links with the coil and magnetic core which results ininduced emf, and magnitude of the induced emf is given by $e=-N\, d\phi/dt$.
- Due to this emf a current is circulated through the core, this current iseddy current, the power dissipated is utilized in heating the core.

Hysteresis loss :

- If a piece of metal is magnetised and de- magnetised again and againsome energy is lost in this process.
- This losses occurring in any electromagnetic device is hysteresis loss.
- The energy lost is converted to heat and it is much more then the heatproduced by eddy current.

Classification of Induction Heating Furnace:

Induction heating furnace is classified into two types i.e

a) Core type
b) Coreless type.

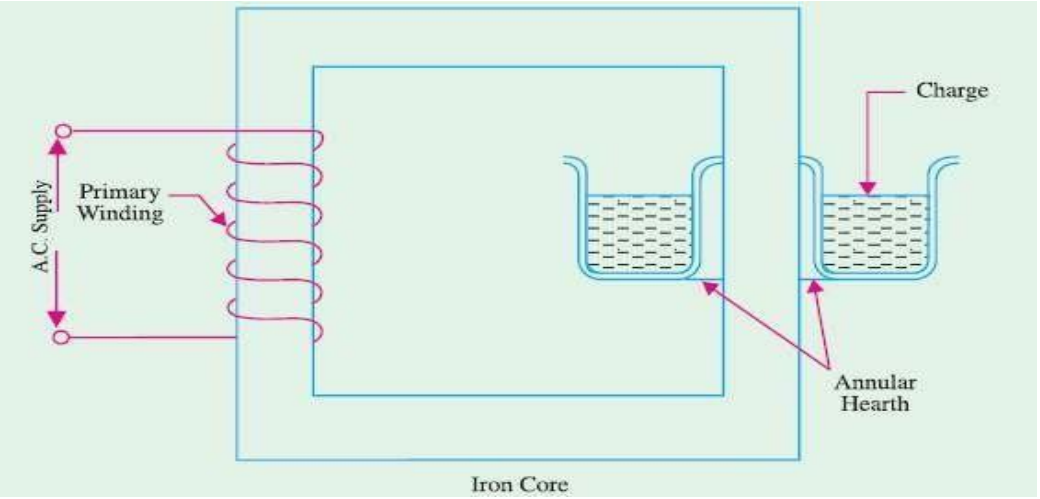
a)CORE TYPE : It operates just like a two winding transformer.

These can be further sub-divided into 3 types

I. Direct core-type furnaces.
II. Vertical core-type furnaces.
III. Indirect core-type furnaces.

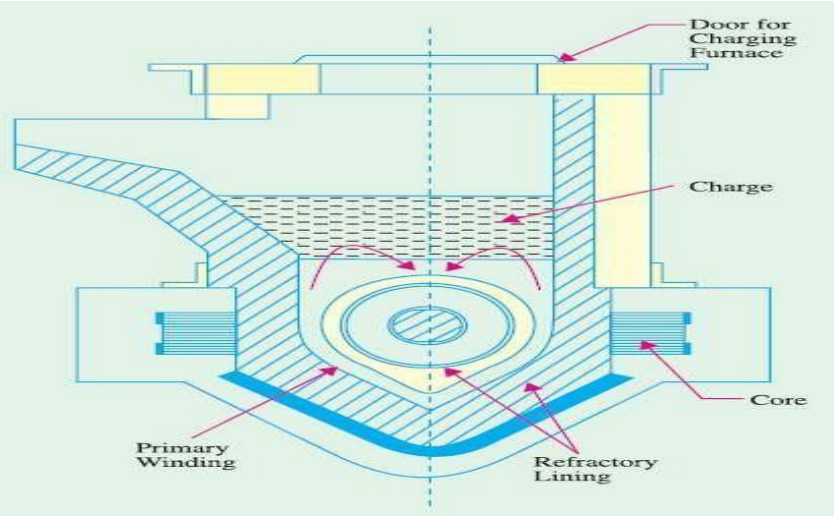
Working principle of direct core type, vertical core type and indirect core type Induction furnace:

i. Direct core-type induction furnaces :



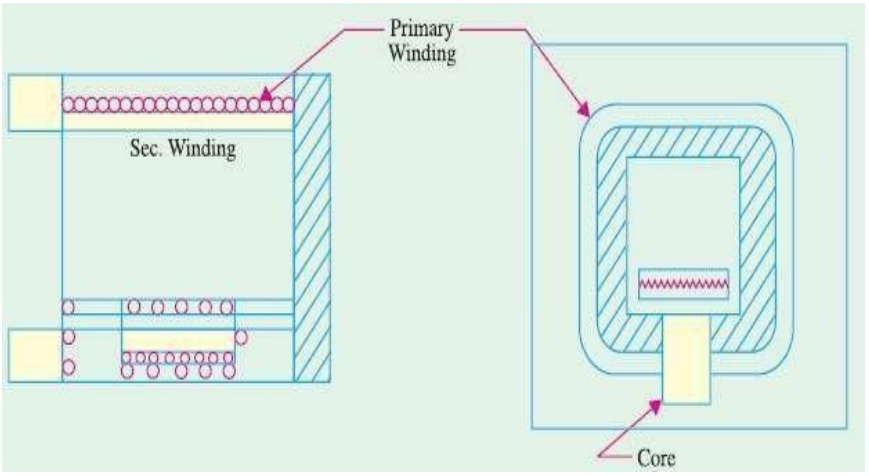
- It is shown direct core type induction furnace .
- It is like a transformer in which the charge to be heated forms secondary of single turn only and is magnetically coupled to theprimary by an iron core.
- The furnace consists of a circular hearth which contains the charge tobe melted .
- When there is no molten metal in the hearth, no current flows in thesecondary.
- To start the furnace, molten metal has to be poured in the annularhearth.
- Furnace can't function if the secondary circuit is open, it must beclosed.

II. Vertical core-type furnaces:



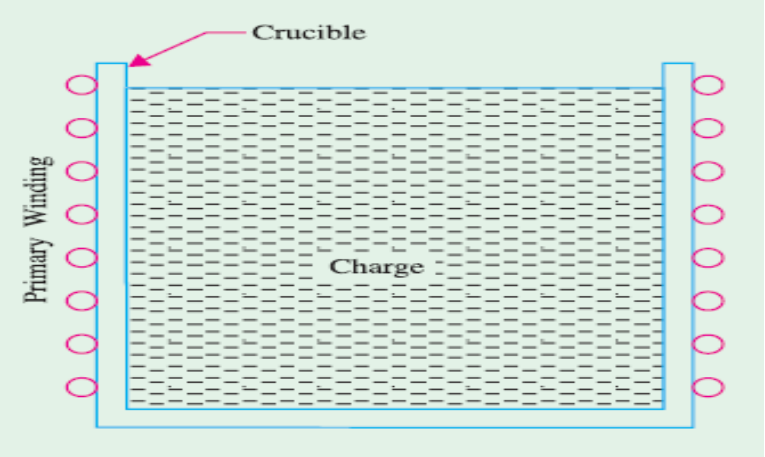
- It is also known as Ajax-Wyatt furnace and its an improvement over the core-type furnace .
- It has vertical channel for the charge. In this furnace magnetic coupling isbetter than direct core type induction furnace .
- It has a Vee channel which is narrow, a small quantity of charge is sufficient to keep the secondary circuit closed. Vee channel must be kept full of charge in order to maintain continuity of secondary circuit. .
- The top of the furnace is covered with an insulated cover which can beremoved for charging.
- It is used in industries for melting and refinery the brass and non ferrous-metals.

III.Indirect core-type furnaces.



- The fig shows an indirect core type furnace. In this furnace a suitable element is heated by induction which transfers the heat to the charge by radiation.
- The secondary consists of a metal container which forms the walls of the furnace . The primary winding is magnetically coupled to this secondary by aniron core.
- When primary winding is connected to a.c. supply, secondary current is induced in the metal container by transformer action heating the container .

Principle of coreless induction furnace and skin effect.

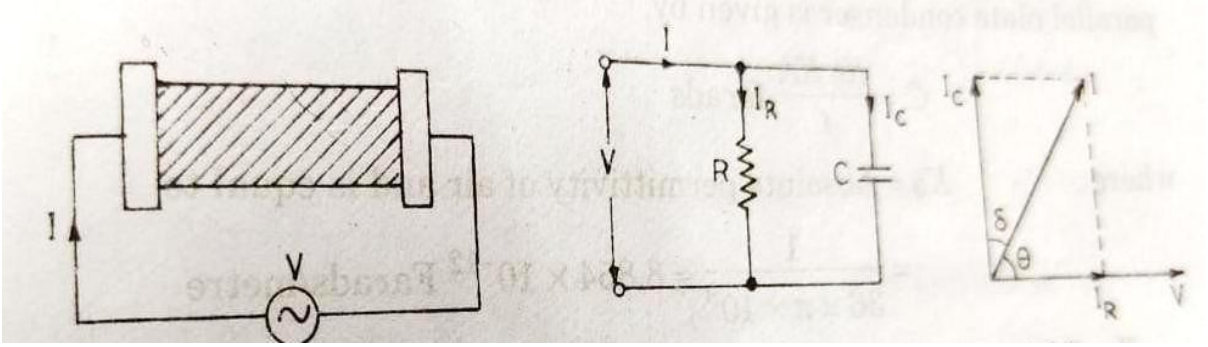


- The fig shows a coreless type induction furnace. It has three main parts
    1. primary coil
    2. A ceramic crucible containing charge .
    3. The frame supports and tilting mechanism.
- In this furnace the flux developed by the primary winding sets an eddy current in thecharge.
- The eddy current developed in any magnetic field is given byEddy current $\alpha B^2 * F^2$.
- These eddy current is sufficient to heat the metal to the melting point.
- Artificial cooling of primary winding is necessary due to high amount of heat.

Skin Effect :

- The steady direct current flowing through a conductor distributes itself over the whole section of the conductor.
- The alternating current tends to concentrate near the surface of the conductorand no current flows through the core of conductor this phenomenon is skineffect.
- Skin effect is very small in low frequencies and its effect is more in high frequencies.

Principle of dielectric heating and its application :



- It is also called high-frequency capacitive heating used for heatinginsulators like wood, plastics and ceramics etc.
- Principle of dielectric heating states that material to be heated isplaced between two conducting electrodes across which alternating current of high frequency is applied.

- Two electrodes separated by an dielectric medium and acrosswhich some potential difference is applied forms a capacitor.
- Since a capacitor is developed as a result of the above circuit ,it may not be pure. So a resistor of very high resistance is connectedso that the current flowing through it is very small.

Power consumed by the circuit is given by $P=2\pi fv^2c\cos\phi$

Capacitance of the capacitor is calculated by $C=K0KA/t$

Where K0=Absolute Permittivity of air , $8.854*10^{-12}$Farads/meter

K=Permittivity of material to be heated.

A=Surface area of plate in m^2.

t=Thickness of the material to be heated in meter.

APPLICATION OF DIELECTRIC HEATING:

1. Ply wood Industries.
2. Plastic Industries

Q) A piece of plywood is heated by dielectric heating. The area ofcross-section of the piece is $0.5m^2$ and thickness is 2.5cm.If thefrequency is2.5Hz and the power developed is 1000w. Find the voltage necessary for heating , if relative permittivity is 3.6 and power factor is 0.046.

Solution-

Given data$A=0.5m^2$

$t=2.5cm=0.025m$ $P=1000w$

$K=3.6$ $\cos\phi=0.046$

Required data- V

Answer

We know that

$C=K_0 KA/t$

C=8.854*10-12*3.6*0.5/0.025 C=6.374*10-10F

$P=2\pi fv2c\cos\phi$, $V^2=P/2\pi c\cos\phi$

$V^2=1000/(2*3.14*6.374*10-10*0.046)$

$$V=\sqrt[2]{2.17*10^{12}}$$

V=1473091.986v

Principle of Microwave heating and its application.

- In this system electricity is converted into electromagnetic waveswhich generate energy used to cook food.
- These waves are high frequency radio waves similar to that usedon radio and television
- When the wave length of these waves are very short at highfrequency is known as micro wave.
- If micro wave energy comes into contact of some substance it isreflected.
- These waves are reflected by metals and absorbed by food helps in cooking.

APPLICATION OF MICROWAVE HEATING

- Manufacturing of Plastic.
- Processing of Cement.
- Food processing and Kitchen work.

Short questions with answers:

What is Stephen's law? (S-11)

Ans-According to stephen's law energy radiated per second ,per unit areaby a perfect body is directly proportional to the 4^{th} power of its absolute temperature.

$E \alpha T^4$

$E = \delta T^4$

Where,

E=Energy Radiated.

T=Absolute Temperature.

δ= Stephen's constant.

State modes of heat transfer. (S-14)

Ans- There are three modes of transmission of heat :

I. Conduction
II. Convection
III. Radiation.

Define electrical heating.

Ans-Electrical heating is defined as that when electric current passesthrough a medium heat is produced.

What do you mean by conduction and write two examples oftransferring heat by conduction?

Ans- The transfer of heat from one substance to another due to directcontact is conduction.

- Heating of long rod.
- Heating of electric rod.

Define resistance heating?

Ans-Whenever a current is passed through a resistor material the heat isproduced because of I^2R loss this process is called resistance heating.

Define skin effect. (S-17,19)

Ans- The tendency of an alternating current to concentrate near thesurface of conductor is know as skin effect.

What is dielectric heating? (W-20)

Ans-Dielectric heating is defined as that process of heating in which thematerial to be heated is placed between two conducting electrodes across which alternating voltage of high frequency is applied.

Mention the application of dielectric heating. (S-16, W-18)

Ans-The following are the application of dielectric heating:

- Ply wood Industries.
- Plastic Industries.

Mention the methods used for resistance heating.

Ans-There are two methods used for resistance heating

- Direct resistance heating.
- Indirect resistance heating.

What are the advantages of electric heating?

Ans- Advantage of electric heating

- Economical
- Cleanliness
- Pollution Free
- Ease of control.

Long Questions :

Explain coreless type Induction Furnace? (S-11)

State advantages of electric heating? (S-11,12,14,15,16,18,19)

Write short note on resistance heating. (S-16,18)

With neat diagram explain the working of indirect core type inductionfurnace. (S-12)

State and explain principle of dielectric heating. (S-11.15)

Explain the function of direct arc furnace.

Differentiate between direct and indirect resistance heating.

CHAPTER-3
PRINCIPLES OF ARC WELDING

Learning Objectives:

Explain principle of arc welding.
Discuss D. C. & A. C. Arc phenomena.
D.C. & A. C. arc welding plants of single and multi-operation type.
Types of arc welding.
Explain principles of resistance welding.
Descriptive study of different resistance welding methods.

Welding:-

It is a process in which two metal parts are joined by heating.

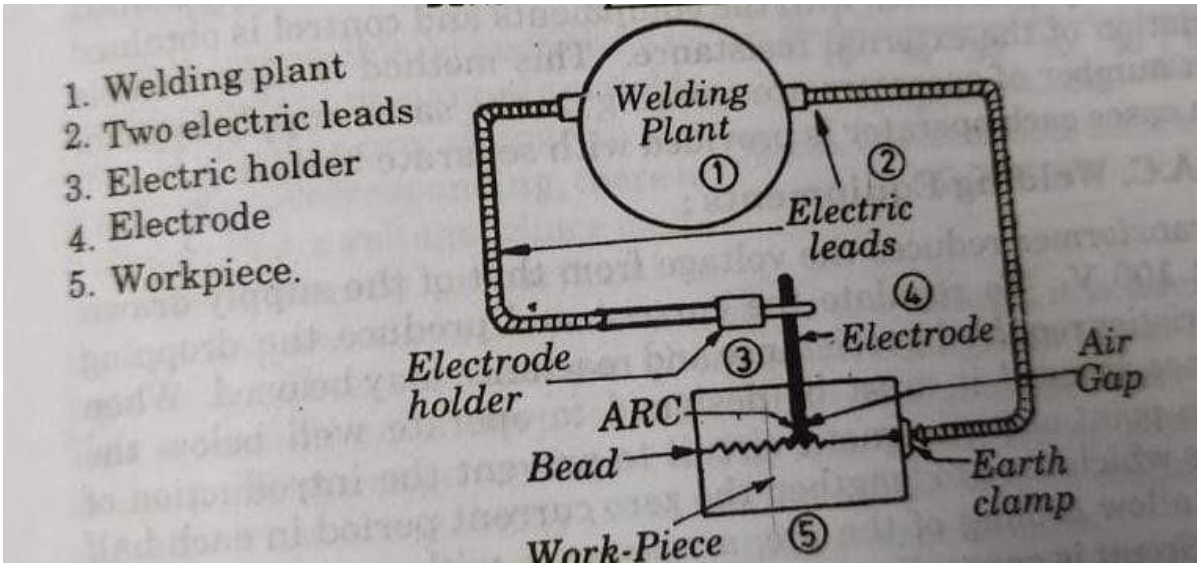
Electric welding:-

Electric welding is defined as the branch of welding in which electric current is used to developed a large heat required forjoining two metal pieces.

It is two types

1. Resistance Welding.
2. Arc Welding.

Explain principle of arc welding.



- An electric arc is produced by bringing two conductors connectedto a source of electric current momentarily in contact and then separated by small distance.
- The current continues to flow across the small gap that is called arc, the heat developed is utilized to melt the work piece and jointhem.
- Current from a source ac or dc is obtained, one terminal isconnected to electrode and other terminal to work piece.
- A gap is provided between tip of electrode and surface of workpiece by keeping a distance of about 3mm to 6mm.
- Due to the interruption by the air gap heat is produced oftemperature from 3700̊ c to 4000̊ c.
- In this process electrical energy is converted at the arc into heatenergy.

Discuss D. C. & A. C. Arc phenomena.

BASIC FEATURES OF ARC WELDING:

The basic feature of Arc welding are :

1. Good forceful arc is produced.
2. A good way to weld aluminum.
3. Arc welding is easy to hold once obtained.
4. Absence of arc blow.

PROPERTIES OF ARC WELDING:

The properties of Arc welding are :

- The source of supply can be ac or dc.
- No requirement of external high pressure.
- Heat developed is due to the arc between electrode and surface ofwork piece.
- Striking voltage must be high.
- Temperature of arc voltage must be high.

ACCESSORIES FOR ARC WELDING :

The accessories for arc welding are:

- Electrode Holder
- Electrode
- Flexible Copper Wire
- Leather Gloves
- Welding transformer or motor generator set
- Wire brass
- Chipping Hammer
- Earthing clamp
- Face screen

DC ARC WELDING :

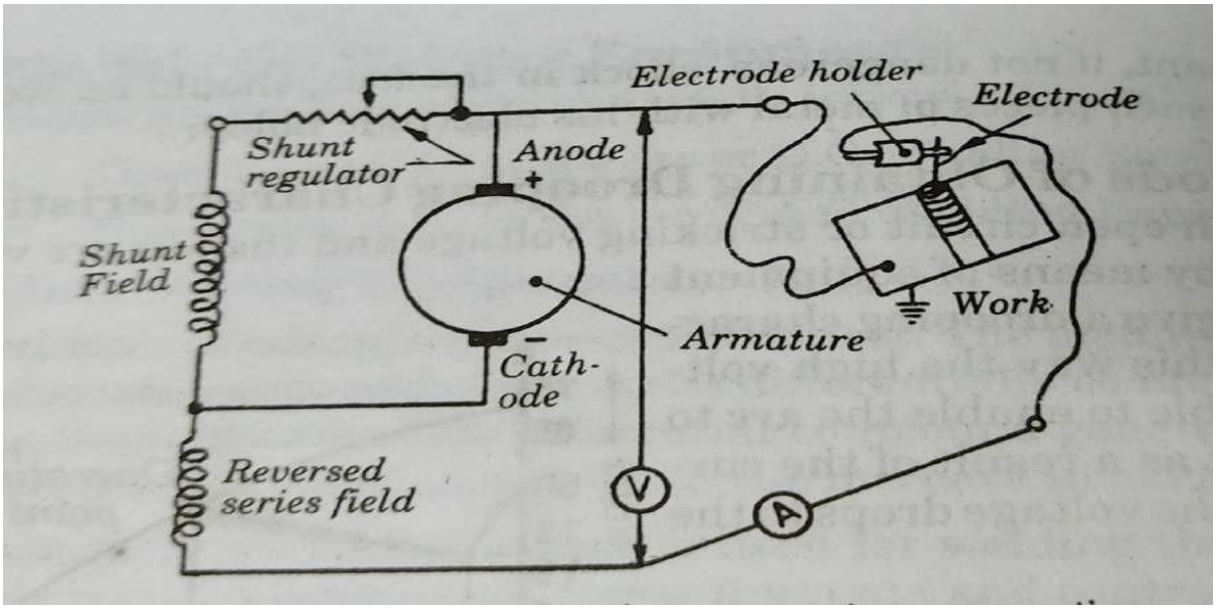
- It consists of a motor generator set. The motor is a squirrel cage induction motor, and generator is differentially compound to give adrooping characteristics.
- In differential compound generator the terminal voltage falls automatically with increase in load current.
- If supply from existing system is used for welding ,then a ballastresistance is put in series with the equipment.
- This method is also suitable when a number of operators areworking on the same supply system.

AC ARC WELDING :

- There is no rotating part in case of ac welding.
- Ac welding transformer has high efficiency.
- Ac is not at all stable.
- Energy consumption is low.
- Heat developed is not uniform.
- There is always danger of electric shock to operator due to lowoperating voltage.

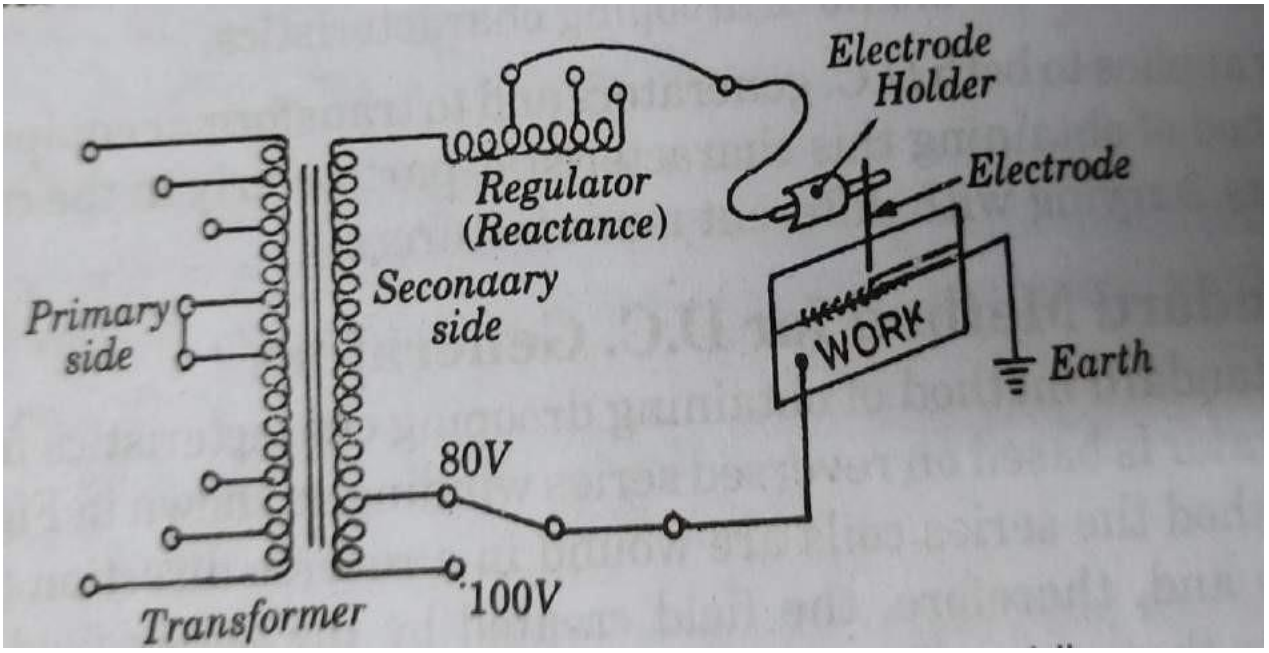
D.C. & A. C.arc welding plants of single and multi-operation type

1. Dc arc welding plant of multi operation type :



- In this method the series coil is wound in reverse direction to shuntcoil so the field created by series field is in opposition to that created by shunt field. on open circuit the shunt field is only operative and maximum voltage is available to strike arc.
- When arc is struck current flows through the series winding set upopposition to shunt field, the resultant field strength is less than open circuit.
- By inserting a shunt regulator in series with shunt field the opencircuit voltage can set to such position that voltage drops automatically to appropriate arc voltage.
- This method is utilized with variation by several manufacturer insome case the shunt field being self excited while in other it is separately excited.

Ac arc welding plant of multioperation type :



- Figure shows the connection diagram for ac welding. The droppingcharacteristics is obtained in AC by a reactance coil in series with the arc.
- Voltage at secondary side of transformer remains constant and is available for striking the arc, as soon as the current flows voltage drop across the reactance coil reduces the voltage at the arc to therequired value.
- Reactance coil also controls the flow of current.
- As the reactance is in series with the arc ,the current can becontrolled by adjusting the amount of reactance in a circuit achieved by tapping the coil.

Types of arc welding.

There are different types of arc welding.

1. Metallic arc welding.
2. Carbon arc welding.
3. Atomic Hydrogen arc welding.
4. Helium or Argon arc welding.

1. METALLIC ARC WELDING :

- In this arc system a metal rod is used as electrode and arc is struck between electrode and work piece. The work is touched byelectrode then separated from it a very small distance as a resultarc and heat is produced.
- Due to the heat generated a little portion of work and tip of the arc melts. Two pieces to be welded fuses together and when electrodeis removed the metal cools and it gives strongly welding joint.

2. CARBON ARC WELDING:

- This method is normally used for welding copper and its alloy. Thecarbon electrode is kept negative with respect to work if dc is used.
- If carbon electrode is made positive , the carbon particles have atendency to go into the welded joint and cause brittleness so electrode should be kept negative.

3. ATOMIC HYDROGEN ARC WELDING :

The essential of atomic hydrogen arc welding process are:

- Electrode energy is supplied to an arc between two tungstenelectrodes where it is transferred into heat.
- Molecular hydrogen is blown through this arc and transformedcatalytically and transfer of energy from arc to the wor
- In this welding hydrogen gas is used to protect the welding pointfrom brittleness.

4. HELIUM OR ARGON ARC WELDING :

- This method is used for welding aluminium alloys, magnesium andits alloys.
- An arc is struck between electrode and work piece , helium orargon is used to give an inert atmosphere so that oxidation ofwelded joint doesn’t take place.

Explain principles of resistance welding.

- The principle of resistance welding is that the generation of heat inthe joint is by passing heavy current through the parts.
- This is followed by application of mechanical pressure whichwelds the plastic metal and refines and grain structure.

Heat is generated due to the resistance, $H=I^2Rt$

Where I=current in amperes

R=Electrical resistance of joints, where weld is to take place

t =time in seconds.

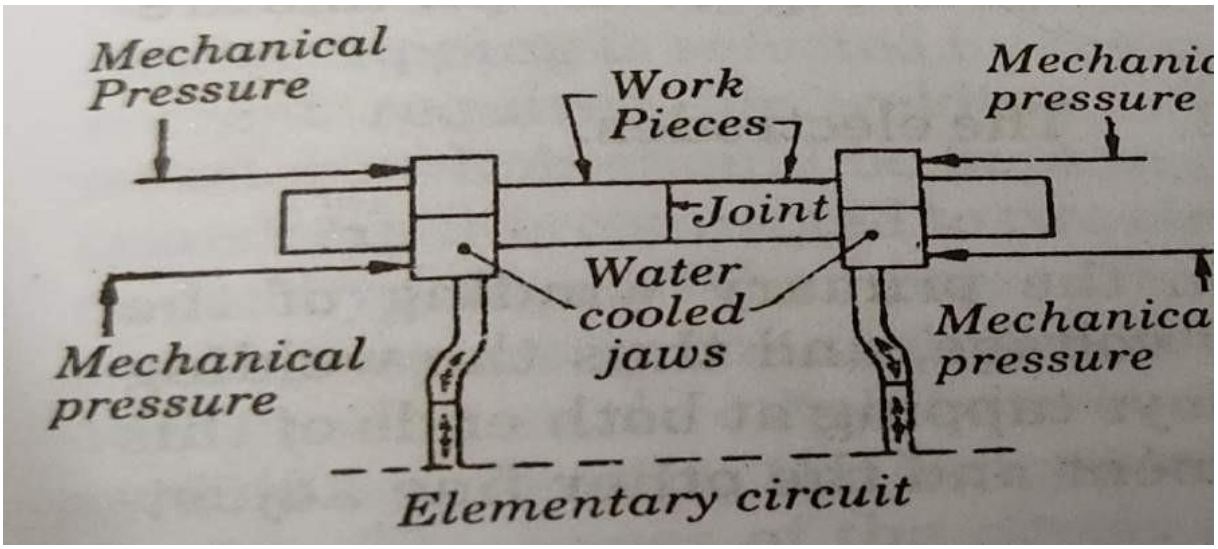
ADVANTAGES OF RESISTANCE WELDING:

- Quick method of joining two pieces.
- Very little wastage of metal.
- Process can be accurately controlled.
- Welding are uniform.

Descriptive study of different resistance welding methods.

1. Butt welding.
2. Flash welding.
3. Spot welding.
4. Scam welding.
5. Projection welding.

1. BUTT WELDING:



- In this process heat is generated by the contact resistancebetween two component, the faces component should be machined or edge prepared.
- The two parts are brought together and pressure is applied alongthe axial direction. A heavy current is passed from welding transformer which creates necessary heat at the joint due to comparatively high resistance at the contact area.
- The metal at the joints melts and two parts fuse togetherproducing bulged joint.

APPLICATION:-

- For welding pipes ,wires and rods.
- Where parts are joined end to end or edge to edge.

2. FLASH WELDING :

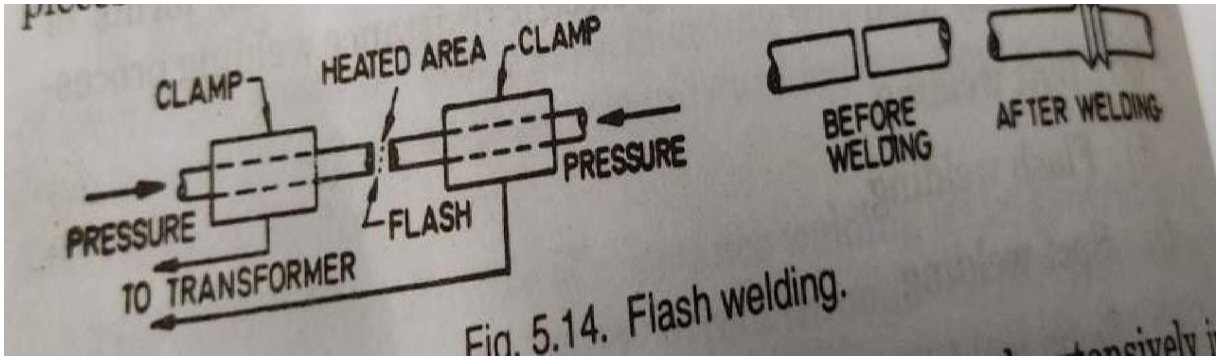


Fig. 5.14. Flash welding.

- This is similar to butt welding except for the difference that in thiscase current is applied to the parts before they are brought together.
- So that when they meet arcing and flashing takes place andwelding occur. so it is called flash welding.

APPLICATION:-

- This method of welding is used extensively in productionwork.

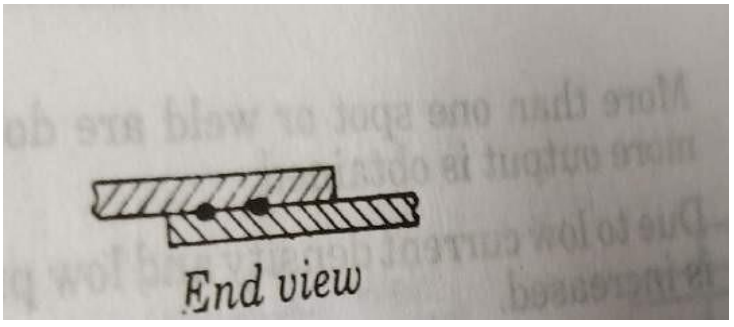
3. SPOT WELDING :

- This is simplest and most universally adopted method of making lap welds in thin sheets up to a maximum thicknessof 12.7mm

APPLICATION:-

- Applied to welding of sheets.
- It may be applied to all types of boxes, cores and enclosingcases etc.

4. SCAM WELDING:

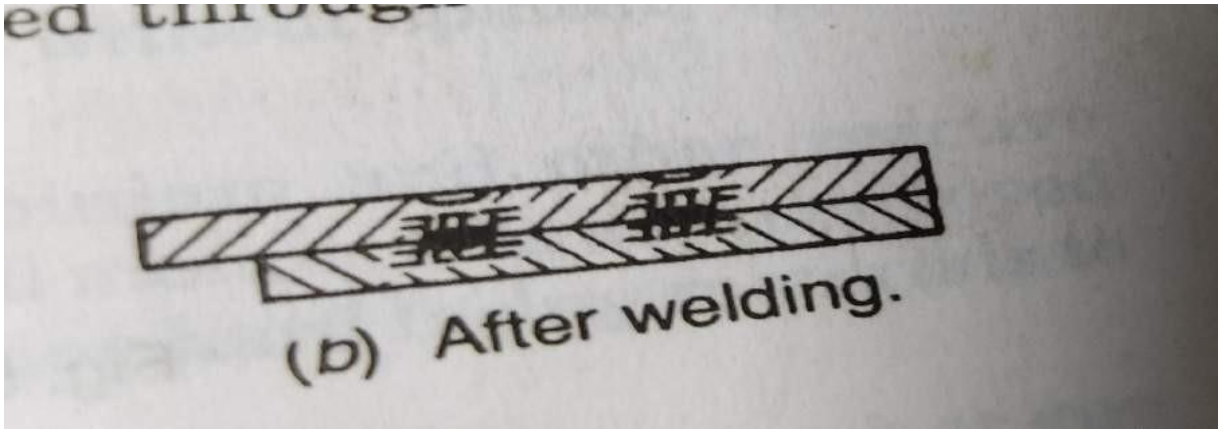


- It is similar to spot welding except that a series of spots areproduced by roller electrode instead of tipped electrode.

APPLICATION:-

- It is used for making lap and butt welds.

5. **PROJECTION WELDING :**



- It is a modified form of spot welding .projection welding consistsof forming slight projections on the sheet of metal.
- Projections are accurately formed in precise locations on themetal by a special set of dies.
- After the projection are formed, the raised portions on one pieceare pressed into contact with another piece at the same time a heavy current is passed through the two pieces then projection welding occurs.

APPLICATION:-

- It is advantageous in assembling parts made by punching orstamping and for welding studs nuts to plates.

ADVANTAGES OF PROJECTION WELDING OVER SPOT WELDING:-

- More than one spot or weld are done at a time, therefore moreoutput is obtained.
- Due to low current density and low pressure electrode life isincreased.

Short questions with answer:

Mention the types of arc welding. Ans-Arc welding are of 4 types these are

I. Metallic arc welding.
II. Carbon arc welding.
III. Atomic hydrogen welding.
IV. Helium or Argon welding.

Mention the types of resistance welding. Ans-
Resistance welding are of 5 types these are

I. Butt welding.
II. Flash welding.
III. Spot welding.
IV. Scam welding.
V. Projection welding.

Write the application of butt welding.
Ans- For welding pipes ,wires and rods. Where parts are joined end to end or edge to edge.

Write the application of spot welding.
Ans- Applied to welding of sheets.
It may be applied to all types of boxes, cores and enclosingcases etc.

Write the application of scam welding.
Ans-It is used in many types of pressure tight of leak tanks.
It is used to weld circular container ,car body etc.

Which type of gas is used in atomic hydrogen arc welding ?
Ans- In atomic hydrogen arc welding hydrogen gas is used to protectthe welding point from brittleness.

Mention the name of the accessories of arc welding.
Ans-

- Electrode holder.
- Electrode.
- Flexible Cable.
- Leather gloves.
- Welding transformer and motor generator set.
- Wire brass.
- Chipping hammer.
- Earthing clamping.
- Face screen.

Write the use face screen in arc welding.
Ans-Face screen is used to protect the workers eye from an unpleasantlight and infrared radiation, harmful gas ,slag, dust particle and smoke.

Define electric welding.

Ans-Electric welding is defined as the branch of welding in which theelectric current is used to produce large heat required for joining two metal piece.

Define arc welding?

Ans-Arc welding is that process of electrical welding in which two workpiece are joined together, when large amount of heat is produced by striking an arc between electrode and work piece .

Q.10 What is resistance welding? (W-20)

Ans: The principle of resistance welding is that the generation of heat inthe joint is by passing heavy current through the parts.

Long questions:

Explain the principle of arc welding. (S-15,W-18,S-19)

State the various resistance welding process with necessary sketch.

Write different electric arc welding and their function. (S-18)

Briefly describe about metal arc welding. (S-09,W-20)

Differentiate between A.C and D.C arc welding. (w-20)

CHAPTER -4
ILLUMINATION:

Learning Objectives:

Nature of Radiation and its spectrum.

Terms used in Illuminations. [Lumen, Luminous intensity, Intensity of illumination, MHCP, MSCP, MHSCP, Solid angle, Brightness, Luminous efficiency.]

Explain the inverse square law and the cosine law.

Explain polar curves.

Describe light distribution and control. Explain related definitions like maintenance factor and depreciation factors.

Design simple lighting schemes and depreciation factor.

Constructional feature and working of Filament lamps, effect of variation of voltage on working of filament lamps.

Explain Discharge lamps.

State Basic idea about excitation in gas discharge lamps.

State constructional factures and operation of Fluorescent lamp. (PL and PLL Lamps)

Sodium vapor lamps.

High pressure mercury vapor lamps.

Neon sign lamps.

High lumen output & low consumption fluorescent lamps.

Nature of Radiation and its spectrum :

- All objects above the temperature of absolute zero(-273.15° Celsius) radiate energy to their surroundingenvironment.
- Different types of radiation have been identified each of which is defined by its wavelength.

  $V = \lambda f$

  Where v = velocity.

  λ= wave length, f= frequency
- The visible light has a wavelength of 0.4micron to 0.75 micron.

ILLUMINATION :

- When light falls on any surface ,that phenomena is called illumination.
- Illumination is defined as the ratio of luminous flux (φ) falling onthe surface to the unit area is called Illumination.

  Mathematically, $E = \varphi / A$ LUX=lumen/M^2

  Where, E= Illumination (lux)

  φ =Luminous Flux (lumen).

  A=Surface area (M)

Terms used in Illuminations [Lumen, Luminous intensity, Intensity of illumination, MHCP, MSCP, MHSCP, Solid angle, Brightness, Luminous efficiency.]

1. LIGHT:

- It is defined as the radiant energy from a hot body causing visualsensation upon the human eye.

2. FLUX:

- It is also known as luminous flux. It is defined as the total quantityof light energy radiated or emitted per second from a luminous body is known as flux.

  Flux (φ)=Light energy(Q)/t,,,,,,φ = Q/t
- Its unit is lumen.

3. LIGHT ENERGY :

- It is the energy obtained in visual radiations in a given time and isdenoted by Q.

4. LUMINOUS EFFICIENCY :

- It is defined as the output in lumens per unit watt.

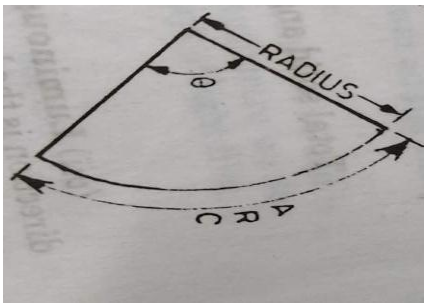
  Or
- It is defined as the total output luminous flux per unit watt.

5. PLANE ANGLE:

- Plane angle is subtended at a point in the same plane by twoconverging lines.

  $l=r\Theta$

  $\Theta=l/r$ = arc/radius
- Its unit is degree or radian.



6. SOLID ANGLE:

- Solid angle is defined as the angle generated by the line passingthrough the point in the space and the periphery of the area.

  Or
- It is the ratio of area of sphere surface to the square of radius of sphere.

  ω =area/(radius)^2 $\omega = 4\pi r^2/ r^2$

  $\omega = 4\pi$ steradians.

  Note-
- Plane angle produced by full circle $\Theta = l/r = 2\pi r/ r = 2\pi$ radian.
- Solid angle produced by full sphere. $\omega = 4\pi r^2/ r^2 = 4\pi$ steradians.

7. LUMINOUS INTENSITY :

- Luminous Intensity in any particular direction is the luminous fluxemitted by per unit solid angle by a point source.
- It is denoted by I

  Mathematically

  $I=F/\omega = \varphi/\omega$ Lumens/Steradian or candla,

  Candla= Lumens/Steradian
- One candle gives out luminous flux of 4π lumens in space.

***8.* LUMEN:**

- It is defined as the amount of luminous flux given out in space.

Lumen=candle power *solid angle

- Note-Total lumens given out by the source of one candla is 4Лlumens.

9. CANDLE POWER :

- It is defined as the lumens given out by the source in a unit solidangle in a given direction.
  CP=Lumen/steradian

10. MEAN SPHERICAL CANDLE POWER:

- It is defined as the average of candle power in all direction and inall planes from the source of light.
  MSCP=Total Lumen/ 4Л

11. MEAN HEMI SPHERICAL CANDLE POWER:

- It is the average of all candle powers in all directions above or below the horizontal plane passing through the same source of light.

12. MEAN HORIZONTAL CANDLE POWER:

- It is the average of all the candle power in all direction in thehorizontal plane containing the source of light.

13. REDUCTION FACTOR:

- Reduction factor of a source of light is defined as the ratio of itsmean spherical candle power to its mean horizontal candle power.
  RF=MSCP/MHCP

14. LAMP EFFICIENCY:

- It is defined as the ratio of luminous flux to the power input.It is expressed as lumens/watt or watts/candle power.
- Note- Lumen efficiency = Lamp efficiency

15. SPACE HEIGHT RATIO :

- It is defined as the ratio of horizontal distance between twoadjacent lamps from the working plane.

LAWS OF ILLUMINATION :

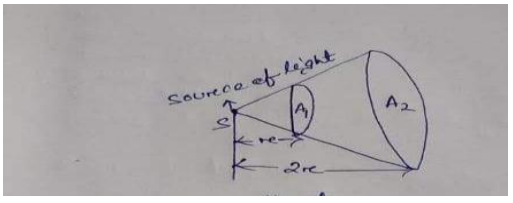
- Illumination has two laws
  a)Inverse square law. b)Lambert's cosine law.

Explain the inverse square law and the cosine law.

1. Inverse square law :

- According to this law illumination E. of a surface is inversely proportional to the square of distance between source and surfaceprovided distance between the surface and the source is sufficiently large so that source can be considered as a point source.

Explanation:



- Consider a point source having an intensity I.
- Let two surface having area A1 and A2 and placed at a distance rand 2r meters away respectively from the source.
- The two surface are enclosed by same solid angle ω.

In other words ,illumination at a surface is inversely proportionalto the square of its distance from source.

We know that,

$E = \frac{Q}{A}$

So $E_1 = \frac{Q_1}{A_1} = \frac{I\omega}{A_1} = \frac{I}{r^2}$ ----------(i) $\left(\text{as } \omega = \frac{A}{r^2}\right)$

Similarly

So $E_2 = \frac{Q_2}{A_2} = \frac{I\omega}{A_2} = \frac{I}{(2r)^2}$---------- (ii)

Dividing equation (i) to equation (ii) we get

$\frac{E_1}{E_2} = \frac{I}{r^2} * \frac{(2r)^2}{I}$

$\frac{E_1}{E_2} = \frac{4r^2}{r^2}$

$\frac{E_1}{E_2} = 4$

LAMBERT'S COSINE LAW

According to this law the illumination(E) of a surface is directly to the cosine of the angle between normal to thesurface and direction of incident light.

Explanation :

$E \alpha \cos\theta$

i. In the normal surface case, $E = \frac{\emptyset}{\text{Area}}$

ii. And in the inclined surface case, $E = \frac{\emptyset}{\text{Area}} * \cos\theta$

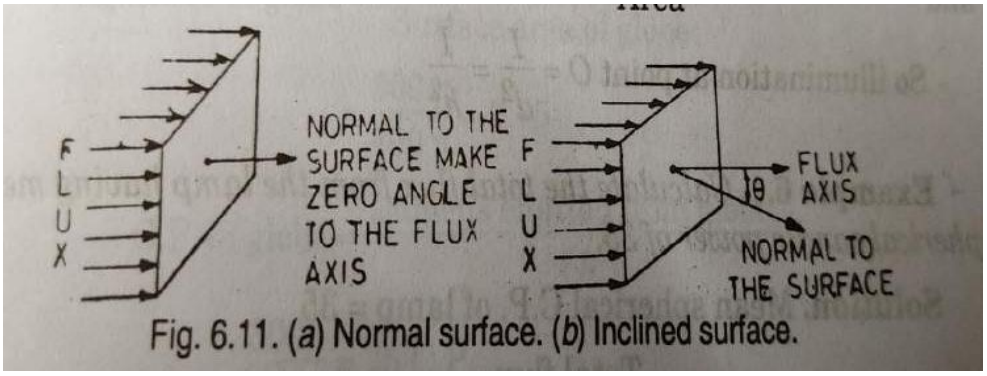
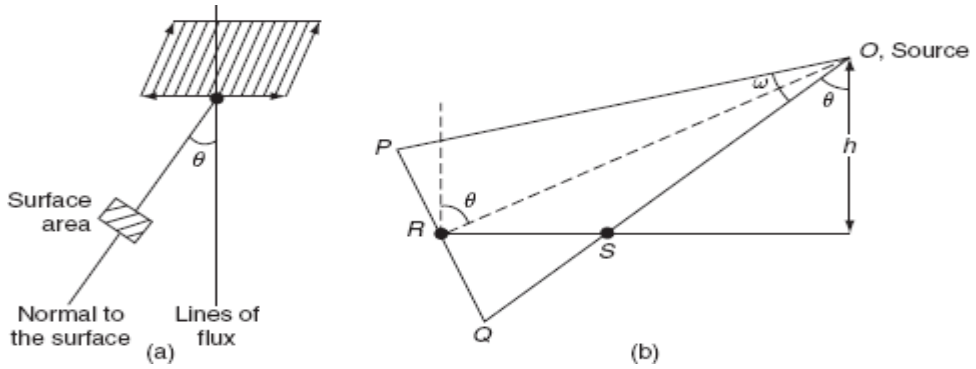


Fig. 6.11. (*a*) Normal surface. (*b*) Inclined surface.

Proof:

While discussing, the Lambert's cosine law, let us assume that the surface is inclined at an angle 'θ' to the lines of flux as shown in Fig.



Let

PQ = The surface area normal to the source and inclined at 'θ' to the vertical axis.

RS = The surface area normal to the vertical axis and inclined at an angle θ to the source 'O'

Therefore, from Fig.

$$PQ = RS\cos\theta.$$

$$\therefore \text{The illumination of the surface } PQ, E_{PQ} = \frac{\text{flux}}{\text{area of } PQ}$$

$$= \frac{I \times \omega}{\text{area of } PQ} = \frac{I}{\text{area of } PQ} \times \frac{\text{area of } PQ}{d^2} \quad \left[\because \omega = \text{area}/(\text{radius})^2\right]$$

$$= \frac{I}{d^2}.$$

$$\therefore \text{The illumination of the surface } RS, E_{RS} = \frac{\text{flux}}{\text{area of } RS} = \frac{\text{flux}}{\text{area of } PQ/\cos\theta}$$

$$[\because PQ = RS\cos\theta]$$

$$= \frac{I}{d^2}\cos\theta.$$

From the above Fig.

$$\cos\theta = \frac{h}{d}$$

$$\text{or } d = \frac{h}{\cos\theta}.$$

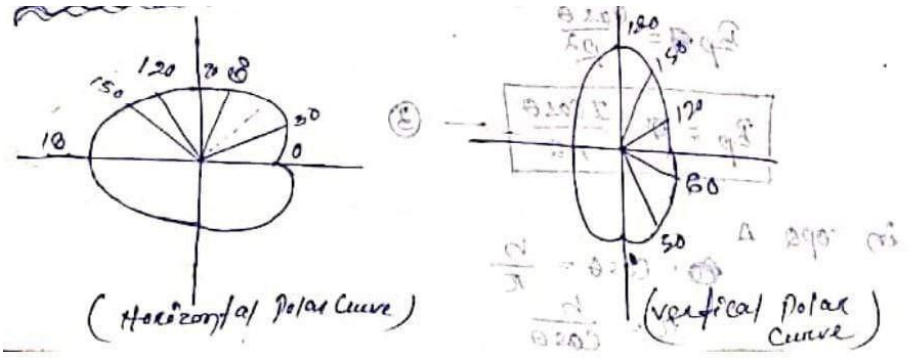
Substituting 'd' from the above equation in Equation we get

$$\therefore E_{RS} = \frac{I}{(h/\cos\theta)^2} \times \cos\theta = \frac{I}{h^2}\cos^3\theta$$

$$\therefore E_{RS} = \frac{I}{d^2}\cos\theta = \frac{I}{h^2}\cos^3\theta$$

where d is the distance between the source and the surface in m, h is the height of source from the surface in m, and I is the luminous intensity in candela.

Explain polar curves :



- The luminous intensity or candel power of any lamp is not practically uniform in all direction ,due to its unsymmetrical shape.
- The distribution of lamp is given by polar curve.
- By polar curve the luminous intensity in all direction can berepresented.
- The polar curve is used to find MSCP with help of vertical polarcurve.
- and MHSCP with the help of horizontal polar curve.
- Polar curve are also used to find the actual units of a surface byemploying the candel power.

Describe light distribution and control. Explain related definitionslike maintenance factor and depreciation factors.

- All the light emitted by the source doesn't reach the surface to be illuminated .some portion of light directly falls upon theworking plane and rest of light absorbed by wall and ceiling.
- Co-efficient of utilisation is the ratio of lumen's reaching theworking plane to the total lumen given out by the lamp.
- Co-efficient of utilisation=lumens reaching on workingplane/total output emitted by source of light.

DEPRECIATION FACTOR

- Due to accumulation of dirt , dust, and smoke on lamp theyemit less light as compare to new light.
- So it is defined as the ratio of illumination when everything isclean to the illumination under normal working condition.
- Depreciation Factor=illumination under clean / illuminationunder normal working condition.
- Itis always greater than unity.

MAINTENANCE FACTOR

- It is the total opposite or reverse of the depreciationfactor.It is always less than unity

SPECIFIC CONSUMPTION

- It is the ratio of power input to the source of light to itsluminous intensity.

ABSORPTION FACTOR

- It is the ratio of neat lumen available after absorptionto the total lumen emitted by source of light.

  Absorption Factor=neat lumen available after absorption / total lumen emitted by source of light.

Design simple lighting schemes and depreciation factor.

1. Types of lighting scheme :

I. Direct lighting.
II. Indirect lighting
III. Semi direct lighting
IV. Semi indirect lighting
V. Local lighting

Direct lighting

- In this case the light from the source is thrown directly over the surface to be illuminated. In this lightning the reflectors give additional help but should not be too deep otherwise ceiling andwalls will not be illuminated properly.

In Direct lighting

- In this case no light reaches directly from the source on thesurface to be illuminated.
- In case of indirect lighting a reflector is mounted on a bulb and theentire light emitted by the bulb is thrown on the ceiling and after reflection from the ceiling light falls on the working plane.
- Example-Halls, clubs, restaurant.

Semi Direct lighting

- In this case sixty percent or more of the light reaching the surfaceto be illuminated comes directly from the source. The rest of it comes after reflection.

Semi In Direct lighting

- More than sixty percent of light is thrown on the surface from thereflecting of light.
- In this lighting the height of lighting source is low.
- This scheme is used for indoor lighting

Local lighting

- If the light is confined to illuminate a particular object it is calledlocal lighting.
- Example-ordinary table lamp in a study room gives local light.

Problem-1 :The illumination at a point on a working plane directly below the lamp is to be 60 lumens/m2. The lamp gives 130 CP uniformly below the horizontal plane. Determine: 1. The height at which lamp is suspended. 2. The illumination at a point on the working plane 2.8 m away from the vertical axis of the lamp.

Solution:

Given data:

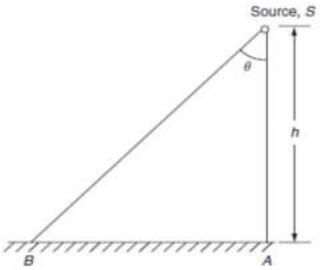
Candle power of the lamp = 130 CP.

The illumination just below the lamp, E = 60 lumen/m2.

1. From the given Fig. the illumination just below the lamp, i.e., at point A:

$$E_A = \frac{I}{h^2}$$

$$\therefore h = \sqrt{\frac{I}{EA}} = \sqrt{\frac{130}{60}} = 1.471 \text{ m}$$

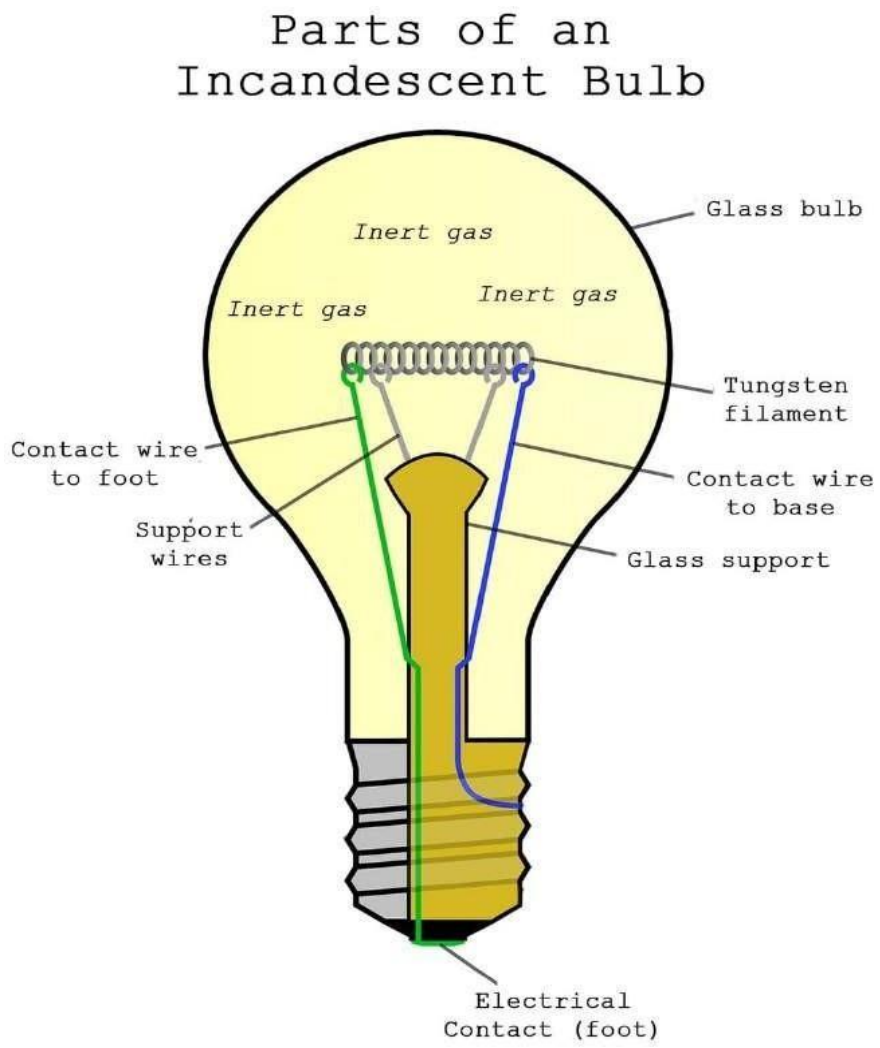


2. The illumination at point '*B*':

$$E_B = \frac{I}{h^2}\cos^3\theta$$

$$= \frac{130}{(2.8)^2}\left\{\frac{2.8}{\sqrt{2.8^2+1.471^2}}\right\}^3 = 11.504 \text{ lux}$$

Constructional feature and working of Filament lamps, effect of variation of voltage on working of filament lamps.



Construction :

- Incandescent lamp consists of an air-tight glass enclosure with afilament of tungsten wire inside.
- Contact wires and a base with two or more conductors provideelectrical connection to the filament.
- It contains a glass support which is attached to the bulb base, andsmall wires are embedded in the stem to support filament and its lead wire.
- The bulb is filled with a inert gas nitrogen or argon to reduce therate of evaporation.

Working:

- When current is passed through the filament wire both heat andlight are produced due to thermal effect of current.
- When wire is in red hot position it emits more heat as compared tolight.
- The material used for filament should have the followingproperties
  - It should have high melting point.
  - It should have high resistivity.
  - It should have high mechanical strength.
  - It should be ductile ,so that it can be drawn into very thin wires.
- Now a days filament wire is made of tungsten element, becausetungsten element full filled the above properties.

Effect of glass :

- White glass cover distributes uniformly light output.
- Blue glass cover gives moon light.
- Green ,red ,yellow glass used for signal purposing.

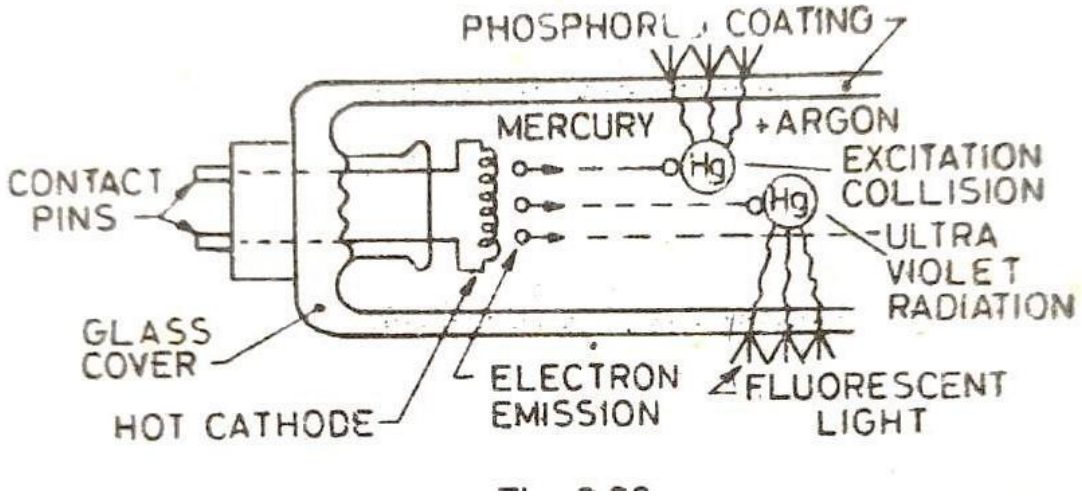
Effect of variation of voltage on filament lamp :

- The rating of bulb is specified in volt or wattage ex-100w,250v
- If the bulb of a given voltage rating are not operated at the ratedvoltage there is direct influence on
- Lumen output, Life, Efficiency.

Explain Discharge lamps.

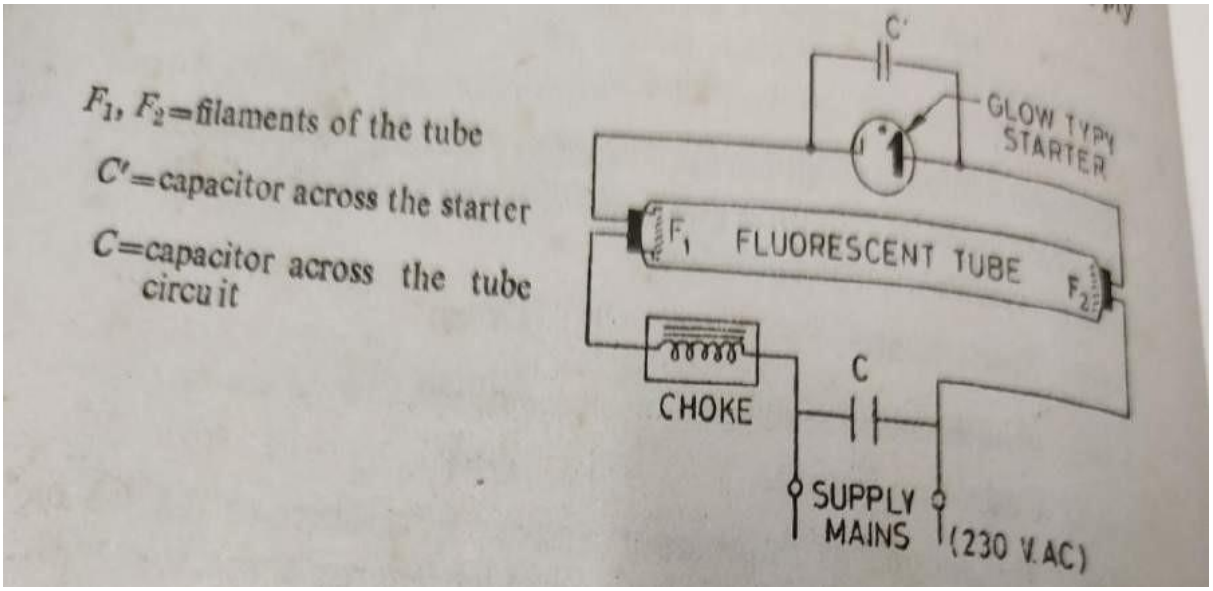
- Electric discharge lamp is also known as vapour lamp.
- Lighting device consisting of a transparent container within whicha gas is energized by an applied voltage and glows.
- Gas are normally poor conductors but on application of suitablevoltage called ignition voltage across the two electrodes result indischarge through the gas guided by electromagnetic waves.
- Wavelength of the radiation depends upon gas, its pressure, and the metal vapour used in lamp.
- Argon gas and sodium and mercury vapours are used by manufacture of gaseous discharge lamp.

State Basic idea about excitation in gas discharge lamps.



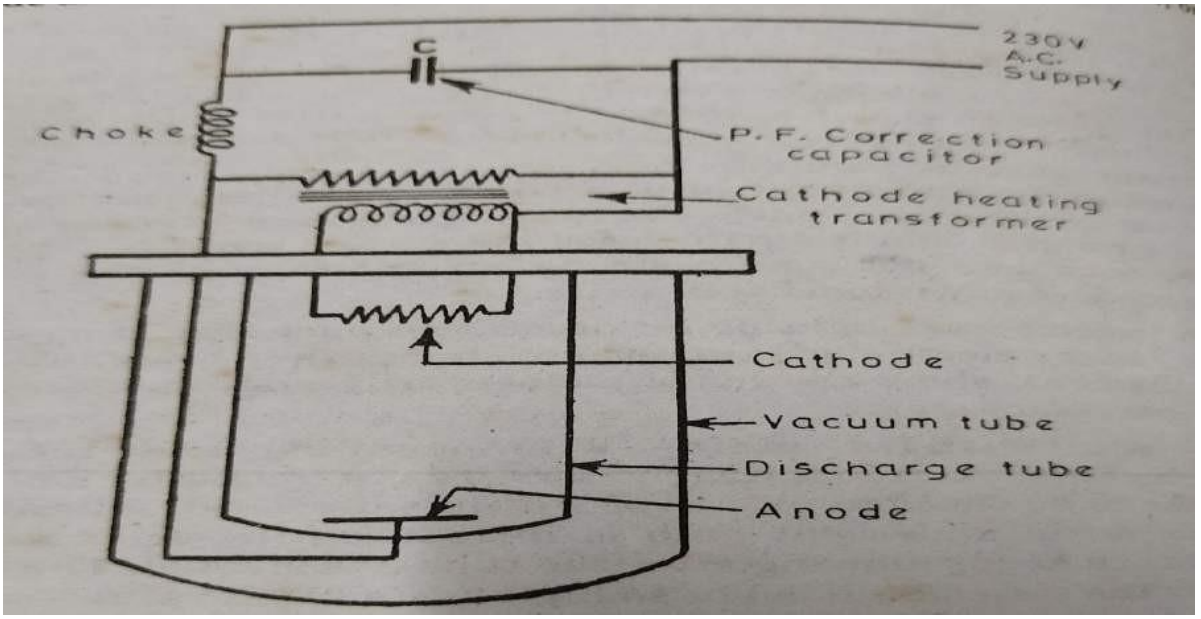
- According to Quantum theory any excited atom is capable of emitting light when it departs with extra energy gained by it duringcollision with some high energy particle.
- Consider a gas filled discharge tube filled with inert gas neon , argon at low pressure, when cathode filament is heated up , thermionic emission starts from cathode, the electrons emittedare attracted towards anode and starts accelerating.
- The accelerated electrons collide with gas atom due to obstruction created by gas molecules
- In this type of collision quantum energy given by striking electron is large enough to change level of gas atoms.

State constructional factures and operation of Fluorescent lamp.(PL and PLL Lamps) :



- When the circuit shown in the fig is energised, nearly full voltage appears across the starter terminals.
- The starter is filled with argon gas. This gas gets ionised and a glow appears inside the starter. This warms up the bimetallic stripcarrying the moving contact, soon after the strip bends and shortcircuits the starter terminals. This circulates a strong current through the filament F1,F2, and choke circuit .
- In the mean while the bimetallic strip of the starter cool down andbreaks open the starter circuit. A high voltage surge is induced inthe choke which makes one of the filament at very potential w.r.tanother filament.
- This momentary high potential difference is enough to ionise the gas medium i.e mercury and argon present inside the tube, this results in passage of current between two electrodes inside the tube.
- The current doesn't flow afterwards through the starter circuit due to the low potential difference across the tube.
- Choke also helps in keeping the current through the ionised medium within safe limit.

Sodium vapor lamps :



- It consists of an inner U- shaped glass tube made of highresistance glass and small amount of metallic sodium, neon gasand two electrodes one is anode and other is cathode.
- Inner tube is enclosed with an outer glass tube of U-shape and the space between them is evacuated to minimize the heat lossesfrom the inner tube.
- Presence of neon gas serves to vaporise sodium by producing sufficient heat.

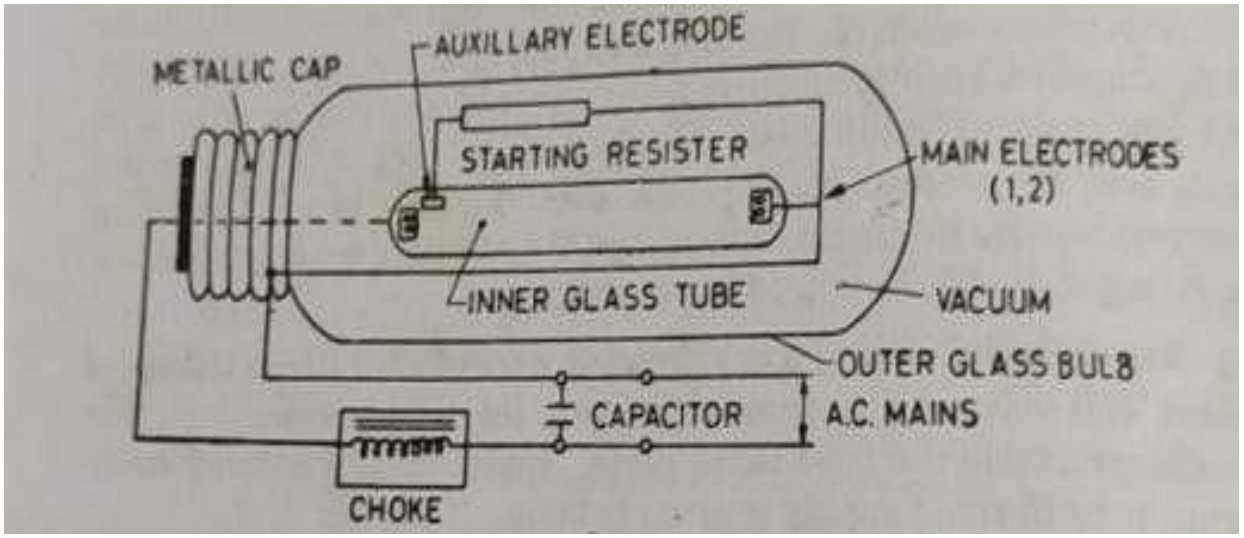
Operation :

- When supply is given to the lamp discharge takes place in the neon gas and red orange glow is produced. The metallic sodium gradually vaporizes and then ionizes producing yellow colour light.
- The cathode heating transformer is used to send a high voltage at the time of starting the lamp. So the luminous discharge inside the tube take place under normal running conditions, normal rated supply is given to the lamp.
- Function of choke is to limit the current at the time of starting.
- These lamps are suitable only ac operation.

Uses :

- It is used for general outdoor lighting, highway and street light
- These lamps are not suitable for indoor lighting.

High pressure mercury vapor lamps :



- The tube containing mercury vapour is made of hard glass, the outer cover protects the inner tube from coming into direct contactwith atmospheric temperature variation. It also absorbs the ultraviolet radiation emitted from the lamp during working.
- Besides mercury the inner tube consists of a percentage of argongas. There are two main electrodes made of tungsten wire and a starting electrode which is spaced quite close to one of main electrodes. During connection to the supply mains the auxiliary electrodes through a high series resistance along with main electrode.

Working principle :

- When the circuit is energised the supply voltage appears betweenmain electrodes and the auxiliary electrode.
- The argon coming between these two electrodes is immediately ionised because distance between the two electrodes is very smalland aglow appears between electrodes .A small current starts to flow through the starting resister.
- The function of capacitor is to improve the power factor of the circuit which will otherwise be quite low due to high inductancechoke present in circuit.

Neon sign lamps :

- Neon lamp consists of a glass tube field with a neon gas with asmall percentage of helium .
- The two electrodes in the glass tube are of pure iron spaced few millimeter apart.
- These lamps are operated on 110v AC or 150v DC supply.
- Neon lamp gives orange pink colour light.
- These lights are used as an indicator lamp and night lamp

High lumen output & low consumption fluorescent lamps :

- A compact florescent lamp (CFL) is also known as energy savinglamp.
- Compared to incandescent lamps giving the same amount of visible light cfl uses one-fourth to one-third power and last eight tofifteen times longer.
- The working principle remains same as in other fluorescent lamp.
- It has the following advantage over conventional lamp.
    a. More compact .
    b. Light weight.
    c. High lumen efficiency.
    d. Longer lamp life.

Short question with answer:

Define solid angle? (S-11,12,14,15,18)

Ans- Solid angle is defined as the angle generated by the line passing through the point in the space and the periphery of the area.

Define MSCP? (S-12,15,18)

Ans- It is defined as the average of candle power in all directionand in all planes from the source of light.

MSCP=Total Lumen/ 4Л.

Define intensity of illumination? (S-11,12,18)

Ans-Intensity of Illumination is defined as the ratio of luminous fluxto the unit area .

MathematicallyE= φ /A

Define luminous intensity ? (S-12,14,18,19)

Ans-Luminous Intensity is defined as the luminous flux emitted byper unit solid angle . It is denoted by II = φ/ ω .

Define Luminous efficiency or radian efficiency? (S-12,14,16,17)

Ans-It is defined as the output in lumen per unit watt

It is the ratio of energy radiated in form of light to total energy ofthe body.

Define mean spherical candle power?

Ans-It is defined as the average of candle power in all direction andin all planes from the source of light.

MSCP=Total Lumen/ 4Л

Define mean hemi spherical candle power? (W-20)

Ans-It is the average of all candle powers in all directions above or below the horizontal plane passing through the same source of light.

Define mean horizontal candle power?

Ans-It is the average of all the candle power in all direction in thehorizontal plane containing the source of light.

Define reduction factor?

Ans - Reduction factor of a source of light is defined as the ratio of itsmean spherical candle power to its mean horizontal candle power.

RF=MSCP/MHCP

Q.10-Define space height ratio .

Ans-It is defined as the ratio of horizontal distance between twoadjacent lamps from the working plane.

LONG QUESTIONS :

Write the working principle of filament lamp.

With a neat diagram describe the working principle of florescent lamp. (S-12.W-20)

Write the working principle of Sodium vapour lamp. (W-18)

Write the working principle of Mercury vapour lamp. (S-14, W-19)

State and explain inverse square law. (S-14,16,18)

State different types of lighting scheme. (W-20)

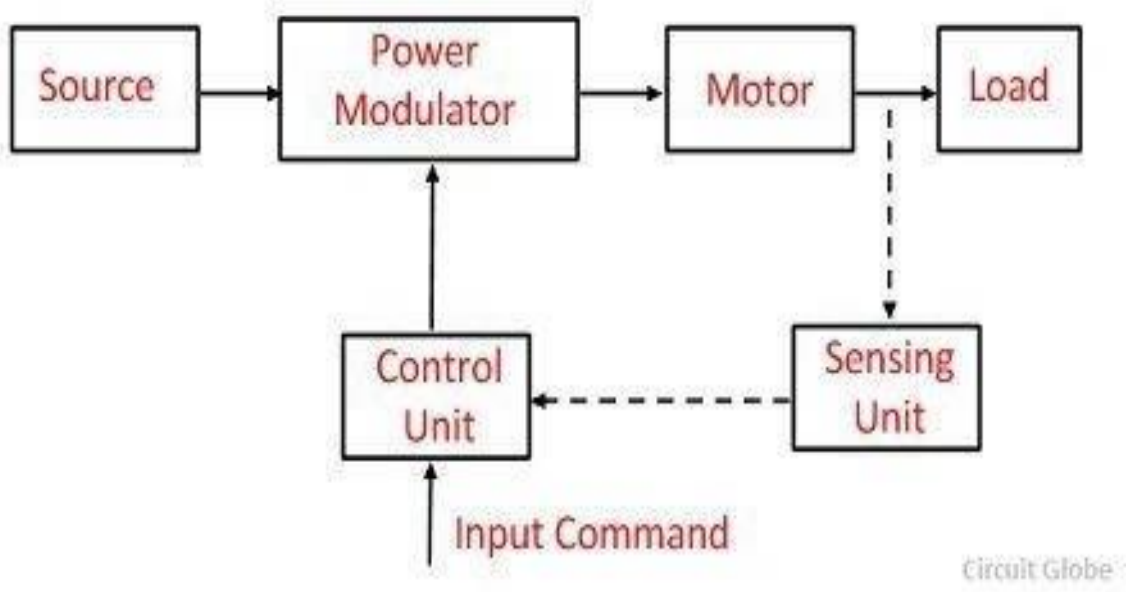
CHAPTER-5
INDUSTRIAL DRIVES

Learning Objectives:

State group and individual drive.
Method of choice of electric drives.
Explain starting and running characteristics of DC and AC motor.
State Application of:
DC motor.
3-phase induction motor.
3 phase synchronous motors.
Single phase induction, series motor, universal motor and repulsion motor.

Industrial drives :

- An electric drive is defined as a form of machine equipment designed toconvert electric energy into mechanical energy and provide electrical control of these processes.
- Block diagram of an electric drive as given below:



1. **Source:**-It is either type of electrical power dc or ac supply.
2. **Power Modulator**:-It converts electrical energy received from source in the suitable form to the motor. During transient operation such as starting, braking and speed reversal it restricts source and motor currents within permissible limits.
3. **Load:**- It is usually machinery designed to perform a given operation i.e fans, machine tools, domestic appliances, trains ,pumps, etc.
4. **Motor**:-Motors commonly used in electrical drives are d.c motors-shunt, series, compound and permanent magnet, induction motors –squirrel cage ,wound rotor and linear , synchronous motors- wound fieldand permanent magnet; brushless dc motor; stepper motor; and switched reluctance motors.
5. **Sensing Unit**:- It is employed for sensing the drive parameters ,such as speed , motor current etc. These signals are fed to control unit.
6. **Control Unit:**- It controls the power modulator besides generating commands for the protection of motor and power modulator. It usuallyoperates at much lower voltage and power levels.

State group and individual drive :

Types of electric drives

Electric drives used in industry may be divided into three types.

1. **Group Drives:-** In this one motor is used as drive for two or more thantwo machines. This type of electric drive is economical , as a single Motor of larger capacity costs less than the costs of a number of smallmotors of the same total capacity.
2. **Individual Drive:-** In this type of electric drive a single electric motor is used to drive one individual machine. If there is a fault in one motor ,thiswill not effect the production of the industrial appreciably.
3. **Multi-Motor Drives:-**It consists of several individual drives ,each perform different functions and are a part of big ,complicated machinery.This type of drive have their application in paper –making machines ,cable manufacturing units.

Advantages of electric drive :

- Cost is too low as compared to other system of drive.
- The system is more simple and clean.
- The control is very easy and smooth.
- Flexible in layout.
- Facility for remote control.

Disadvantages of electric drive:

- Electric drive system is tied only up to the electrified area.
- Failure in supply for a few minutes may paralyze the whole system.

Method of choice of electric drives :

1. Requirements related to the source : Type of source, and its capacity , magnitude of voltage, voltage fluctuations, power factor, harmonics and their effect on other loads,and ability to regenerate power.
2. Steady state operation requirements *:* Nature of speed torque characteristics, speed regulation, speed range ,efficiency, duty cycle, quadrants of operation, speed fluctuation andratings.
3. Transient requirements Starting, breaking values of acceleration and de acceleration , reverse performance.
4. Capital and running cost ,maintenance.
5. Environment and location.
6. Reliability.
7. Space and weight resistance.

Explain starting and running characteristics of DC and AC motor:

Generally, three characteristic curves are considered important for DC motors which are, (i) Torque vs. armature current, (ii) Speed vs. armature current and (iii) Speed vs. torque.

Characteristics Of DC Series Motors :

1.Torque Vs. Armature Current (T_a-I_a)

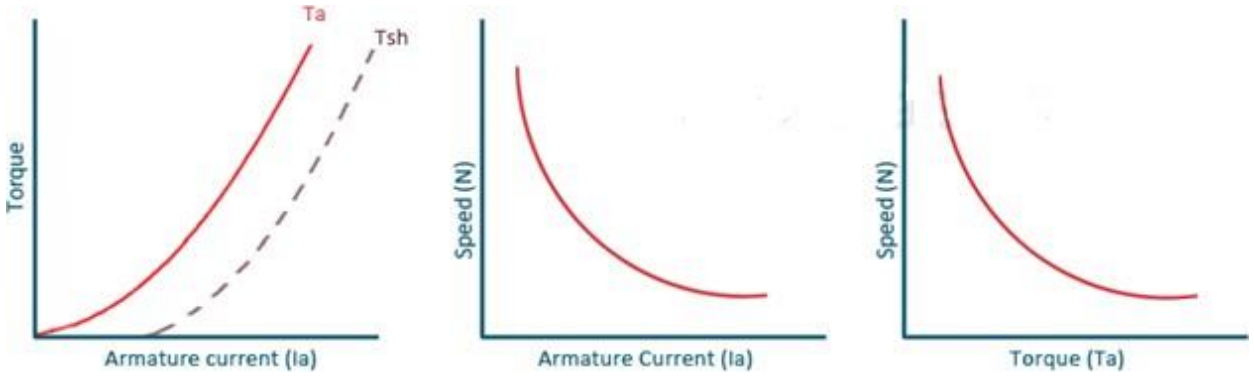
- This characteristic is also known as electrical characteristic.
- We know that torque is directly proportional to the product of armature current and field flux, T_a a $\phi.I_a$.
- In DC series motors, field winding is connected in series with the armature, i.e. $I_a = I_f$. Therefore, before magnetic saturation of the field, flux ϕ is directly proportional to Ia. Hence, before magnetic saturation Ta α Ia^2. Therefore, the Ta-Ia curve is parabola for smaller values of Ia.
- After magnetic saturation of the field poles, flux ϕ is independent of armature current Ia. Therefore, the torque varies proportionally to Ia only, T a Ia. Therefore, after magnetic saturation, Ta-Ia curve becomes a straight line.
- The shaft torque (Tsh) is less than armature torque (Ta) due to stray losses.
- Hence, the curve Tsh vs Ia lies slightly lower.
- In DC series motors, (prior to magnetic saturation) torque increases as the square of armature current, these motors are used where high starting torque is required.

2. Speed Vs. Armature Current (N-Ia):

- We know the relation, N a E_b/ϕ.
- For small load current (and hence for small armature current)change in back emf Eb is small and it may be neglected. Hence, for small currents speed is inversely proportional to ϕ.
- As we know, flux is directly proportional to Ia, speed is inversely proportional to Ia. Therefore, when armature current is very small the speed becomes dangerously high. That is why a series motor should never be started without some mechanical load. But, at heavy loads, armature current Ia is large. And hence, speed is low which results in decreased back emf Eb. Due to decreased Eb, more armature current is allowed.

3.Speed Vs. Torque (N-Ta) :

- This characteristic is also called as mechanical characteristic. From the above two characteristics of DC series motor, it can be found that when speed is high, torque is low and vice versa.



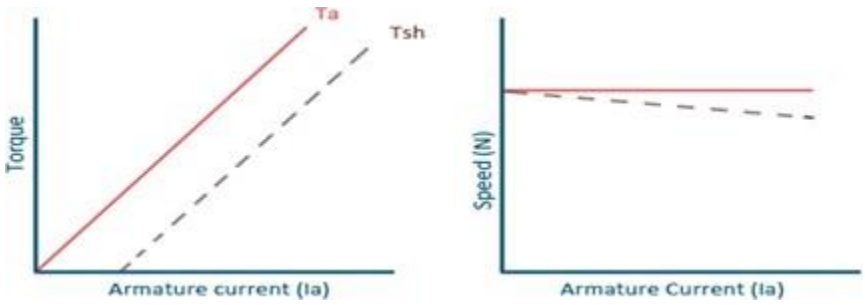
Characteristics Of DC Shunt Motors :

1. Torque Vs. Armature Current (Ta-Ia)

- In case of DC shunt motors, we can assume the field flux ϕ to be constant. Though at heavy loads, ϕ decreases in a small amount due to increased armature reaction.
- As we are neglecting the change in the flux ϕ, we can say that torque is proportional to armature current.
- Hence, the Ta-Ia characteristic for a dc shunt motor will be a straight line through the origin. Since heavy starting load needs heavy starting current, shunt motor should never be started on a heavy load.

2. Speed Vs. Armature Current (N-Ia)

- As flux ϕ is assumed to be constant, we can say N a Eb. But, as back emf is also almost constant, the speed should remain constant.
- But practically, ϕ as well as Eb decreases with increase in load. Back emf Eb decreases slightly more than ϕ, therefore, the speed decreases slightly.
- Generally, the speed decreases only by 5 to 15% of full load speed. Therefore, a shunt motor can be assumed as a constant speed motor.
- In speed vs. armature current characteristic in the following figure, the straight horizontal line represents the ideal characteristic and the actual characteristic is shown by the dotted line.



Characteristics Of Single phase Induction Motor:

Full Load Torque Expression

$$T = \frac{ksE_2^2 R_2}{R_2^2 + (sX_2)^2}$$

where $k = \frac{3}{2\pi N_s'}$

$N_s' = \frac{N_s}{60}$ Synchronous speed in RPS

X_2 = Rotor reactance at standstill

E_2 = Induced EMF in rotor at standstill

R_2 = Rotor resistance

s = slip

To draw the torque slip characteristics of induction motor (three phase) following points are considered:

At synchronous speed (N_s); slip, s = 0 and torque, T = 0.

When rotor speed is very near to synchronous speed i.e. when the slip is very low the value of the term $(sX_2)^2$ is very small in comparison to R_2^2 and is neglected.

Therefore, torque is given by the expression:

$T = ksE_2^2R_2 / R_2^2$

In the above expression, all quantities are constant except slip s.

Therefore, $T \alpha s$

Thus, at low values of slip, torque is approximately proportional to slip *s* and the torque slip characteristics of induction motor is a straight line as shown in the figure.

The region (from s = 0 to $s = s_m$) is called the stable region of operation and operating point of the motor should be in this region.

In the stable region, the value of slip is small. Hence this region is also called as the low slip region.

As the slip increases torque increases and attains its maximum value when $s = R_2/X_2$. This maximum value of torque is also known as break down or pull out torque.

When a further increase in slip occurs due to increase in load beyond the point maximum torque i.e. when slip is high, the value of term $(sX_2)^2$ is very large in comparison to R_2^2.

Therefore, R_2^2 is neglected as compare to $(sX_2)^2$ and torque is given by the expression:

$T = ksE_2^2R_2 / (sX_2)^2$

or $T = kE_2^2R_2 / (sX_2^2)$

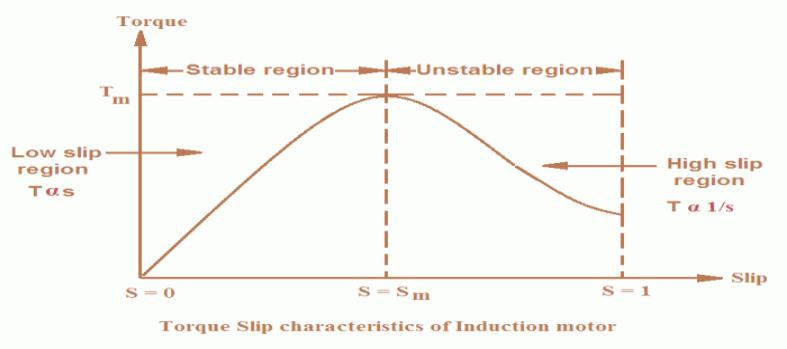
In the above expression, all quantities are constant except s.

Therefore, $T \alpha 1/s$

Thus at higher values of slip (i.e. the slip beyond that corresponding to maximum torque) torque is approximately inversely proportional to slip, s and the torque slip characteristics of induction motor is rectangular hyperbola as shown in the figure.

The region (extending from $s = s_m$ to s = 1) is called unstable region. In this region with the increase in load, slip increases but torque decreases.

The result is that the motor could not pick up the load and slows down and eventually stops. In the unstable region, the value of slip is large so this region is also called as the high-slip region.



Torque Slip characteristics of Induction motor

State Application of: DC motor.

Dc motors are used in

- conveyors, turntable and others for which adjustable speed and lowor constant torque are required.

5.4. State Application of:

3-phase induction motor.

3 phase induction motor are used in

- Lifts.
- Cranes.
- Hoists.
- Large capacity exhaust fans.
- Oil extracting mills.

5.4. State Application of:

3 phase synchronous motors.

Due to constant speed characteristics, it is used in

- Machine tools
- Motor generator set.
- Centrifugal pumps
- Pulp grinder
- Paper Mills

5.4. State Application of:

Single phase induction

As these motors are simple in construction, cheap in cost, so it finds its application in

- for conveyor belts.
- coal mining.
- fans
- washing machine

5.4. State Application of:

series motor

Due to its high starting torque, it is widely used in

- Hoist
- Cranes
- Conveyors
- Air compressor
- Sewing machines

State Application of:

5.4.4. universal motor

- Power drills
- Wash machine
- Blowers

State Application of:

5.4.4. repulsion motor

- High speed lift
- Electrical locomotives
- Fans and PumpPrinting Press
- Textile Machines

Short questions with answer:

What is electric drives?

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

What do you mean by group drive? Give example (W-2020)

Ans-In this type of electric drive one motor is used as a drive for two or more than two machines. Example of group drive is textile mill.

State individual drives? Give example (W-2020)

Ans: In this type of electric drive a single motor is used as a drive for one individual machines. Example of individual drive is used to rotate spindle, to move the feed with the help of gears.

What is the application of dc series motor ? (W-2017)

Ans-

- For traction work
- Cranes
- Hoists
- Conveyors

What is the application of three phase synchronous motor?(W-2020)

Ans: As these motors are simple in construction, cheap in cost, so it finds its application in

- for conveyor belts.
- Centrifugal pumps.
- Paper mills
- Rolling mills

Long questions:

1. State group drive and individual drive?(S-2018, 2014)
2. Explain about starting and running characteristics of dc motor?(S-2019,2017)
3. Explain the choice of electric drives.(S-2018,2017,2016)

CHAPTER-6
ELECTRIC TRACTION

Learning Objectives:

Explain system of
traction.
System of Track electrification.
Running Characteristics of DC and AC traction motor.
Explain control of motor:
Tapped field control.
Rheostatic control.
Series parallel control.
Multi-unit control.
Meta dyne control.
Explain Braking of the following types:
Regenerative Braking.
Braking with 1-phase series motor.
Magnetic Braking.

Explain system of traction :

The system of traction involving the use of electricity is known as the electric traction .
There are various systems of traction are commonly used such as

1. Direct steam engine drive
2. Direct internal combustion engine drive
3. Steam electric drive
4. Petrol electric traction
5. Battery electric drive
6. Electric Drive
7. Internal combustion engine electric drive

1.Direct Steam Engine Drive :

- The steam engine drive used to be widely employed for railway work.
- In this drive thereciprocating steam engine is invariably used for getting the necessary motive power because of its inherent simplicity, operational dependability, and simplified maintenance, the simplicity of connections between the cylinders and driving wheels and easy speed control.
- It causes no interference to the communication lines running along the track.
- It is cheap for low density traffic areas and initial stages of communication by rail.

2.Direct Internal Combustion Engine Drive:

- Direct internal combustion engine drive is widely employed for road transport.
- The efficiency of internal combustion engine at its normal speed is about 25 percent.
- It is self contained unit and it is not tied to any route.
- Initially the cost of vehicle and garage is very low.
- Speed control and braking system employed is very simple.
- It is cheap drive for the outer suburbs and country districts.

3.Steam Electric Drive:

- A few locomotives employing steam turbine for driving a generator used for supplying current to electric motors have been built for experimental purposes.

4.Petrol Electric Traction:

- This system has been used in heavy lorries and buses.
- Due to electric conversion it provides a very fine and continuous control which makes the vehicle capable of moving slowly at an imperceptible speed and creeping up the steepest slope without throttling the engine.

5.BatteryElectric Drive:

- In this drive the locomotive carries the secondary batteries which supply power to dc motor employed for driving the vehicle .
- Such a drive well suited for frequently operated service such as local delivery of goods in large towns with maximum daily run of 50 to 60 km, shunting and traction in industrial works and mines.
- The major limitation of this type of drive is the small capacity of the batteries and the necessity for frequent charging, speedrange is also limited.

6.Electric Drive:

- The drive of this type is mostly widely used.
- In this system of traction the vehicle draws electrical energy from the distribution system fed at suitable points from either a central power station or substations.

7.Internal Combustion Engine Electric Drive :

- In this drive the reduction gear and gear box are eliminated as the diesel engine is to drive the dc generator coupled to it at a constant speed.
- This type of drive has foundconsiderable favour for railway work and locomotives of this type are becoming widely used.

System of Track electrification:

- Two types of vehicles are in use for electric traction.
- In one type they receive power from a distribution network while in the other type they generate their own power.
- The former type vehicles may use both a.c. or d.c. ; the latter type will be the diesel-electric car or train, petrol-electric truck, lorry and battery driven vehicles.

Dc traction motor

Most suitable motors for dc system are the series and compound motors.

DC Series Motor:

- The series motor used for traction purposes have following requirements
- The dc series motor develops high torque at start which is essential for tractionservices.
- The series motor is simple speed control method.

- Power drawn from supply mains varies as the square root of the load torque.
- Series motor is not suitable for regenerative braking as these are not electrically stable.
- In case of dc series motor commutation is excellent up to twice full load so replacement of brushes in not required frequently.
- In cases of dc series motors the flux varies as the armature current, torque corresponding to a given armature current, therefore is independent of line voltage.
- In case of dc series motor up to magnetic saturation, torque developed is proportional to the square of the armature current. Thus dc series motor requires comparatively less increased power input with the increase in load torque.
- The series motor when operated in parallel to drive a vehicle by means of different axles, share load almost equally even there is unequal wear of different driving wheels.
- The dc series motor is simple and robust in construction.

Ac traction motor:

AC Series Motor:

- Many single phase ac motors have been developed for traction purposes but only compensated series type Commutator motor is best for traction.
- The construction of an ac series motor is similar to a dc series motor except that some modification such as whole magnetic circuit laminated, series field with as few turns as possible, large no of armature conductors, use of carbon brushes, numerous poles with lesser flux per pole.
- Compensating windings are provided to neutralize armature reaction andcommutating or inter poles are provided for better performance in terms of higher efficiency and a greater output from a given size of armature core.
- The speed –Torque characteristics and the speed-current characteristics of compensated series type Commutator motors are similar to those of D.C. series motor.
- The a.c. Series motor is not suitable to suburban services where stops are frequent.
- If a d.c. series motor is worked on a.c. it would not operate in a satisfactory manner.
- Though the torque on the armature would be unidirectional, it would be at double thefrequency since both the field current and the armature current reverse every half cycle.
- The alternating flux would cause heavy iron losses in the field and yoke.
- Heavy sparking would also take place at the brushes since the induced voltage and currents in the armature would beshort-circuited at the time of commutation.
- The overall performance of the motor would be poor.

Running Characteristics of DC and AC traction motor :

The difference between d.c. and a.c. operation can be understood by areference to figure shown below.

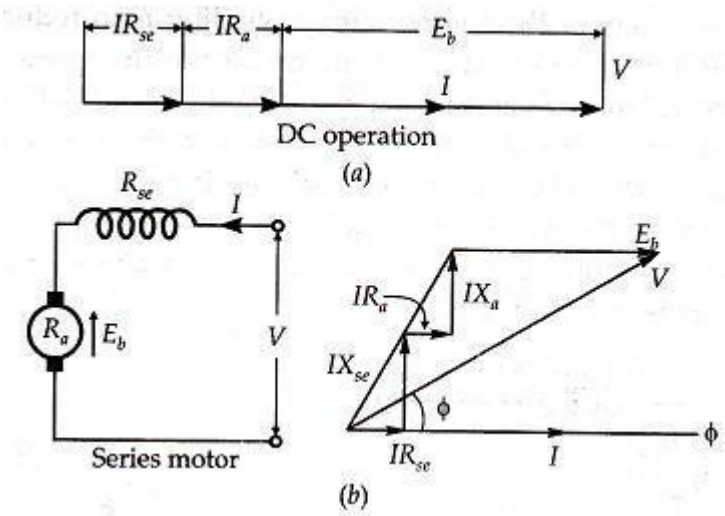


Fig. 1 Operation of series wound motor on dc and ac

- Operation on d.c. is simple enough. I is the current drawn by the motor, IR_{se} and$I$ R_a are the drops in the series field and the armature respectively. E_b is the back emf developed and equals kØN.

  Mathematically, we have $V = E_b + IR_{se} + IR_a$
- Since $I(R_{se} + R_a)$ drop is about 10 percent of the applied voltage,E_b is practicallyequal to V.
- On the a.c. the magnetizing component of the current and the flux are in time phase and the back emf E_b which is due to rotation of the armature is also in phase with the flux.
- If we neglect the loss component of the current we can assume the whole current to be in phase with the flux. The drops IR_{se} and IR_a are in phase with the current while the drops due to reactance, i.e. IX_{se} and IX_a are leading the current by 90^0.
- The a.c. operation is shown by the phasor diagram below. In this case E_b will be much less as compared to the d.c. operation. N is proportional to E_b and torque depends upon the product of E_b and I. Since, E_b in d.c. is larger than in a.c., for the same torque the speed for d.c. operation is higher than for a.c. operation as shown below.

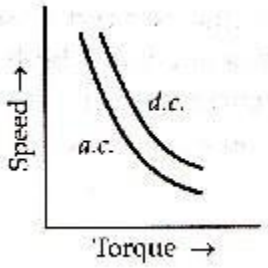


Fig.2 Speed – torque curves for d.c. and a.c. operation

- In order to improve the performance of the motor on a.c., a compensating winding either in series with the armature or short-circuited in it be provided.
- The effect of the compensating winding is to reduce the armature reactance of the motor which increases the value of E_b and provides better speed regulation.

- The armature and field mmfs are at right angles to each other. The compensating winding provides an mmf opposite to the armature mmf and therefore considerably reduces the armature reactance drop. This is shown below

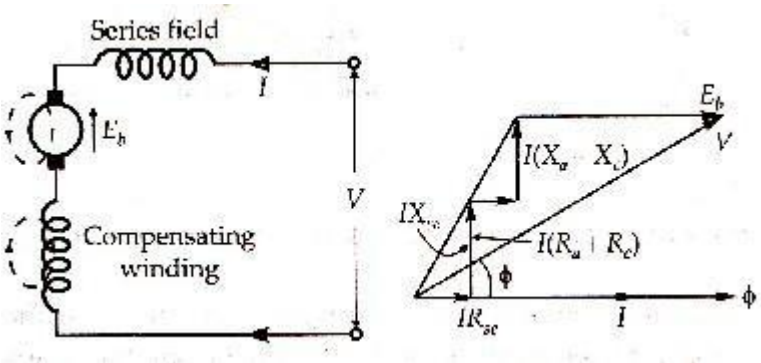


Fig. 3 Circuit diagram & phasor diagram of the series motor with compensating winding.

$R_a + R_c$ represent the resistances of the armature and compensating winding.
$X_a + X_c$ represent the reactances of the armature and compensating winding.

- Fig. below shows the case where the compensating winding is short-circuited on itself. It acts like the short-circuited secondary of a transformer and greatly reduces the effect of the armature reactance.
- In the phasor diagram R' and X' are the equivalent resistance and a reactance of the armature and compensating winding referred to the armature circuit.
- It is alsoseen that by using the compensating winding ,the power factor of the motor improves as shown in the figure below.

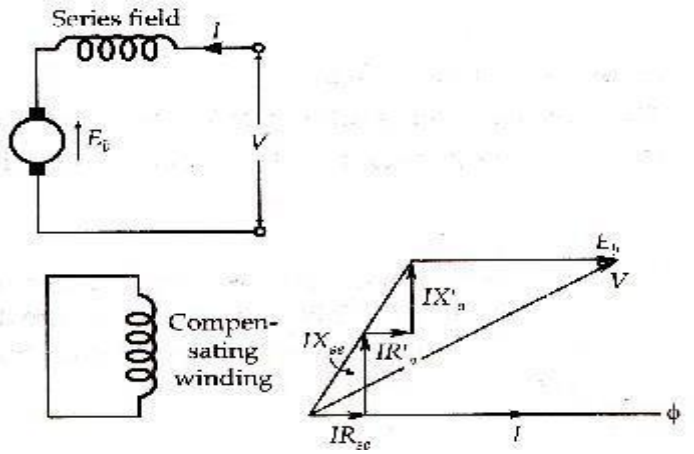


Fig.4. Circuit and phasor diagram for an inductively compensating series motor

Explain control of motor:

Control of d.c. motors :

- The starting current taken by a D.C. motor during its starting period is limited to a value approximately equal to the normal rated current by the resistance of the starter.
- There isa considerable loss of energy at the starting resistance.
- Consider the use of a single motor started by a resistance starter, the average value of the current during the starting period beinglimited to I, the normal full-load current.

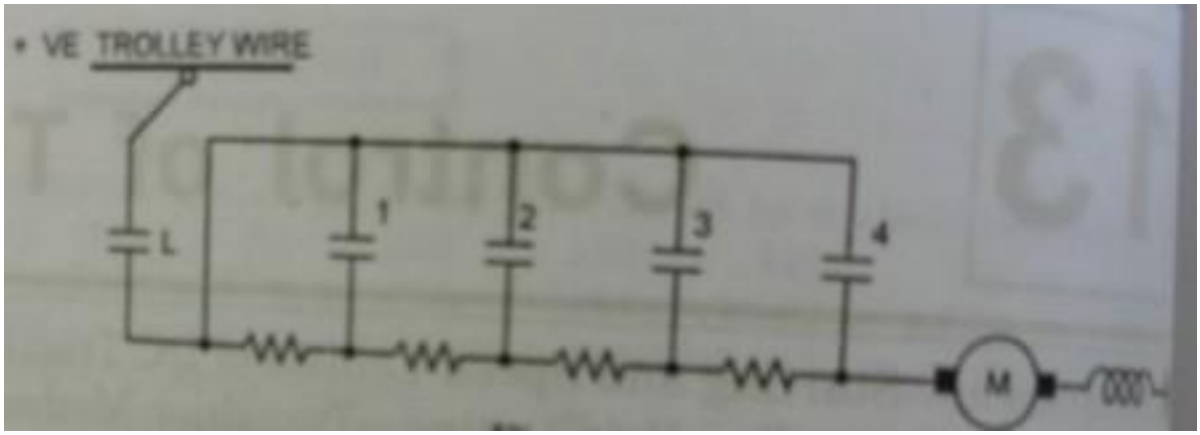
- The back emf of the motor starts to build up from zero magnitude. At the instant of switching on the supply,E_b=0, a current of I amperes is drawn from the supply and the supply voltage is the sum of the IR drop in the motor armature and the voltage drop across the starting resistance. At any other instant during starting, the supply voltage = (motor back emf)+(IR drop in the motor armature)+(voltage drop across starting resistance).
- At the end of the accelerating period, the back emf has developed to a full value and the supply voltage =(back emf)+(IR drop).

Tapped field control.

- As the speed of the motor is inversely proportional to the flux(assuming line voltage constant), therefore, the speed can be varied by varying the flux.
- In case of series motors the flux can be varied either (i) by connecting a variable resistance known as diverter in parallel with the series field winding or (ii) by cutting out some of the series field turns.
- Since in both the cases the flux can be only reduced, therefore, this method is known as field weakening method and speeds above normal can be obtained.
- By this method speed can be raised to the extent of 15 to 30 percent of normal speed owing to design difficulties arising with traction motors.
- The field weakening method is of no use for starting purpose.
- This method is used for increasing the speed of traction motors up to the extent of 10 to 15 percent when they have attained maximum possible sped by series-parallel control system.
- The advantage of this system is that it increases the flexibility of the train utility.

Rheostatic control :

- A series motor can be started by connecting an external resistance (starter) in series with the main circuit of the motor.
- At the starting instant, since the back emf developed by the motor is zero, therefore, the resistance connected in series with the motor is maximum and is of such a value that the voltage drop across it with full load rated current is equal to the line voltage.
- As the motor speeds up, the back emf developed by the motor increases, therefore, the external resistance is gradually reduced in order to maintain the current constant throughout the starting or accelerating period.
- Basic traction motor circuit with rheostatic starting is shown in figure. In this method there is a considerable loss of energy in the external circuit.



Series parallel control.

The series-parallel control is carried out as follows:

A) Shunt Transition: The various stages involved in this method of series- parallelcontrol are shown below.

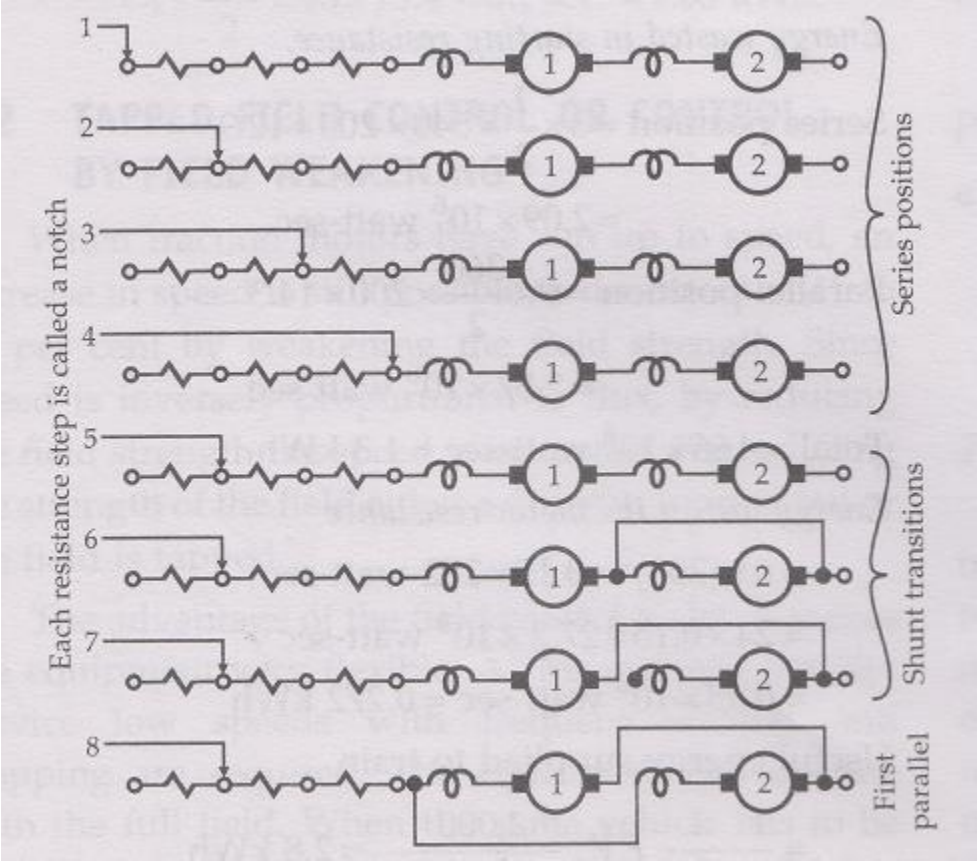
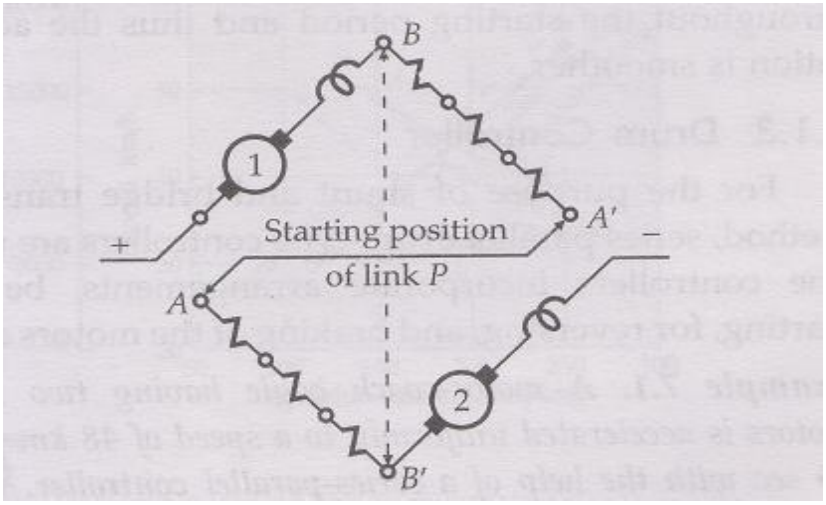


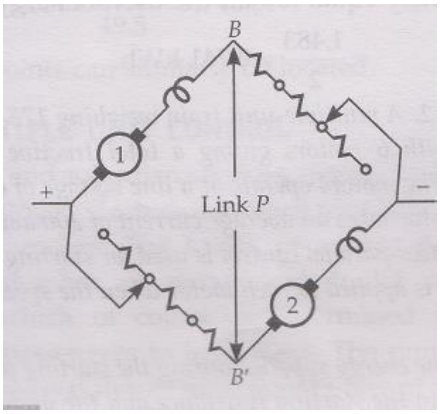
Fig..11 Series position

- In steps 1,2,3,4 the motors are in series and are accelerated by cutting out the starting resistance in steps.
- In step 4 , the motors are in full series. During transition fromseries to parallel, the resistance is re-inserted in the motor circuit (step-5).One of the motors is by-passed (step-6) and disconnected from the main circuit (step-7).
- It is then connected in parallel with the other motor (step-8) giving the first parallel position. The resistance is then cut out in steps completely and the motors are placed in parallel.
- This method is known as the shunt-transition method.

B) Bridge Transition:
   - The motor and the starting rheostats are connectedin the form of a Wheatstone bridge as shown below.
- At starting, motors are in series with link P in position AA‘
- Motors in full series with link P in position BB‘
- In the first starting position the motors are in series and the rheostats are completely in Circuit as indicated by the rheostats arm P at A A′. A and A′ are moved in the direction of the arrow heads and in position BB′ the motors are in full series.



- In the transition step, the rheostats are reinserted by connecting to positive andnegative of the supply as shown below.



- The advantage of the bridge transition method over the shunt transition method is that the normal accelerating torque is available from both the motors throughout the starting period and thus the acceleration is smoother.

Multi-unit control :

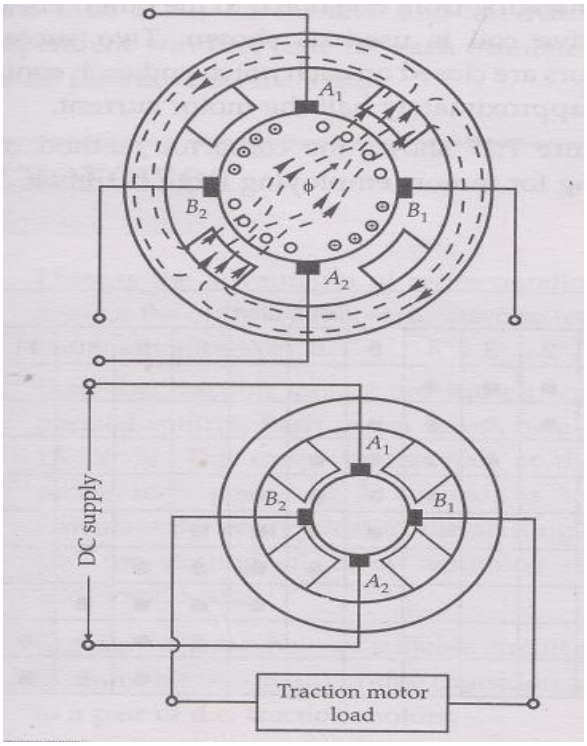
- Originally derived from lift operation over a hundred years ago, multiple unit (MU) control has become the most common form of train control in use around the world today.
- Electric locomotives were originally designed so that the motors were controlled directly by the driver.
- The traction power circuits passed through a large controller mounted in the driving cab. A handle was rotated by the driver as necessary to change the switches in the circuit to increase or reduce power as required. This arrangement meant that the driver had to remain close to the motors if long and heavy, power-carrying cables were to be avoided.
- While this arrangement worked well enough, the desire to get rapid turn rounds on city streetcar railways led to the adoption of remote control.
- It would not be necessary to have a locomotive added at the rear of an arriving train to allow it to make the return journey. A cab would be installed at each end of the train and the driver just had to change ends to change direction. Once this idea was established, it was realised that the

motors could be placed anywhere along the train, with as many or as few as required to provide the performance desired.

- Multiple unit trains, as these trains became known, were equipped with control cables called train lines, which connected the driver's controls with the motor controls and power switches on each motor car.
- The opening and closing of the power switches was achieved by electro-magnetic relays, using principles originally designed for lifts. While the idea was being established on passenger trains, it was also adopted on locomotives.
- It quickly became the standard method of control.

Meta dyne control :

- The meta dyne system of control estimates the energy loss and achieves a very smooth control during the acceleration period.
- Consider a D.C. armature with two brushes and two poles. If current is supplied to the two brushes A_1A_2 the armature cross-flux will be as shown mainly confined to the poles as shown in Figure.
- If there are four brushes, current is supplied to brushes A_1A_2 and the armature cross-flux will take up the path as shown below. If now the current is supplied to brushes B_1B_2 as shown the armature cross-flux takes up path as indicated.
- If the armature is rotated at a constant speed and a current I is fed into the bushes A_1A_2 , an emf is induced in the winding betweenB_1B_2 due to the flux produced by I.
- No emf is induced between A_1A_2 and the voltage between A_1A_2 is on account of the voltage drop due to I_1 .
- Since an emf is induced across B_1 ,B_2 a current I_2 will flow in a load connected between them. The resultant flux distribution on account of I_1 and I_2 is as shown below.



- The total flux may be assumed to be made up of two components $Ø_1$ and $Ø_2$ at right angles and directed along A_2A_1 and B_2B_1 .The rotation of the armature in $Ø_2$ induces an emf E_1 between A_1 and A_2 which opposes the supply voltage.
- Since the current is to be kept at its original value of I_1 ,the supply voltage must be induced to overcome E_2 . Under steady conditions

  $E_1 \text{ a } Ø_2 = KI_2$

  $E_2 \text{ a } Ø_1 = KI_1$

  $E_1I_1 = E_2I_2 = K\ I_1I_2$
- This shows that the machine behaves like a D.C. transformer. Only the rotational losses of the machine need be supplied by the driving motor.
- If the supply voltage E_1 remains constant , I_2 remains constant. Thearrangement therefore is quite suitable for starting D.C. motors.

Explain Braking of the following types:

Braking with 1-phase series motor.

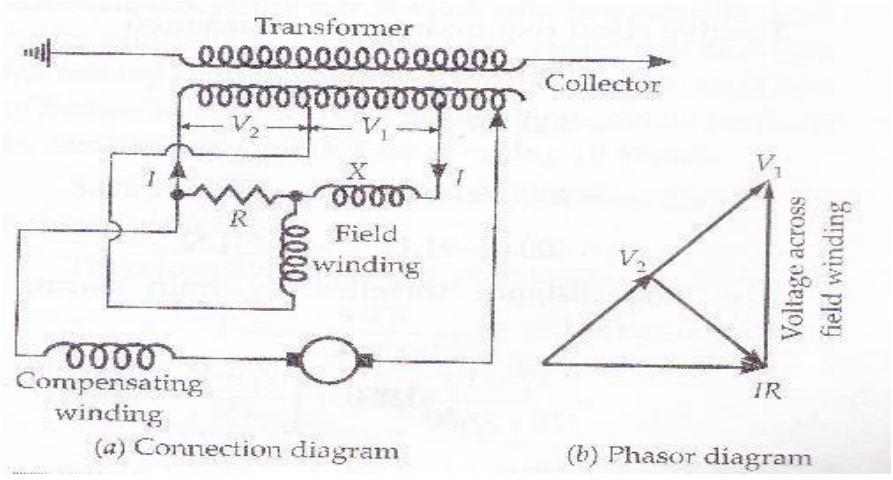
In this case both Rheostatic and regenerative braking are possible.

Rheostatic Braking:

- The motors are worked as separately excited generators supplying energy to resistance load.
- The fields are energized at low voltage from suitable tapings on the train transformer.
- The kinetic energy of the rotor is dissipated as electrical energy in the load resistance. Also, the fields of the motors may be excited from one of the motors acting as a series generator.
- In this case D.C. will be generated in the rotors of the motors and the kinetic energy of rotors will be dissipated as D.C. power in the loading resistors.

Regenerative Braking :

- For generative braking the regenerated power should be at the frequency of the main supply.
- This necessitates the energizing of the field winding from the main supply. Secondly, the regenerated current must be in phase opposition to the applied voltage and also the flux Ø so that the power may be feedback into the supply system.
- The voltage applied to the field winding must be 90^0 out of phase with respect to the supply voltage.
- An arrangement to obtain these conditions is shown below.

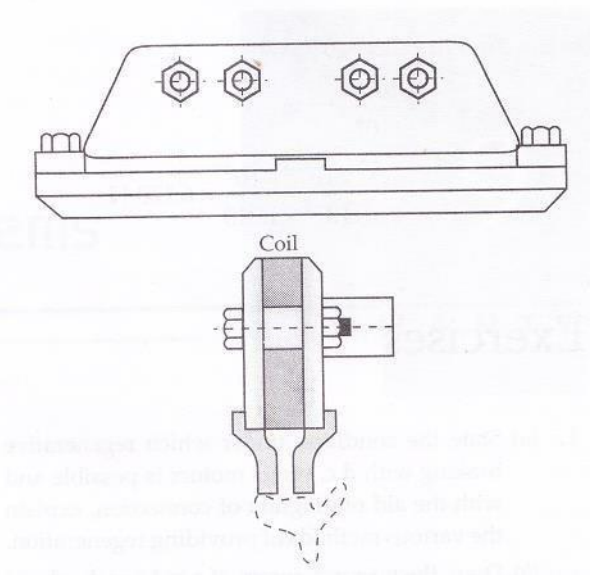


Magnetic Braking :

- It is used in tramcars. The electromagnet is bipolar. The body is made of cast steel andthe pole faces are made of soft steel and can be renewed. The exciting coil is enclosed in a water-tight case. The magnetic flux is perpendicular to the pole faces and the track. The forceof attraction between the magnet and the track is given by

$$\mathrm{F} = \frac{B^2 a}{2\pi * 10^{-7}} N,$$

where B is the flux density in weber/m^2 and a is the area in the pole face in sq.m.
The drag that it can produce on the car is given by micro farad, where t is the coefficient of friction.



Short questions with answer:

What is electric traction? (S-20160

Ans-An electric traction means a locomotive in which the driving force is obtained from electric motors

What is magnetic breaking (S-2016)

Ans- Magnetic breaking is a theory explaining the loss of stellar angular momentum due to material getting captured by stellar magnetic field..

State the group of systems of electric traction(W-2020)

Ans: There are three main types of electric traction.

i. Direct current electrification system- In this system three phase power is received from the power grids is de-escalated to low voltage and converted to DC by rectifiers.
ii. Alternating current electrification system-The supply system of ac electrification include single, three-phase and composite system.
iii. Composite system-These are used to provide continuous journeys along routes that are electrified using more than one system.

Which motor will you choose for traction? (W-2006)

Ans-

- For traction work the following motors are to be choosen
- DC series motor
- 3 Phase IM
- Repulsion motor
- Ac series motor single phase.

Long questions:

1. Describe about the magnetic breaking in electric traction briefly?(W-2020)
2. Explain the dc system of track electrification in electric traction briefly?(W-2020)
3. Explain briefly the meta dyne control of motor.(W-2018,S-2016).
4. Write short notes on Tapped field control of motor(W-2018)
5. Write short notes on Series parallel method of speed control of motor(W-2020)