Induction Motor

INTRODUCTION

- One of the most common electrical motor used in most applications which is known as **induction motor**.
- This motor is also called as asynchronous motor because it runs at a speed less than synchronous speed. [Synchronous speed is the speed of rotation of the magnetic field in a rotary machine and it depends upon the frequency and number poles of the machine].
- An **induction motor** always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux current in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed i.e. the synchronous speed.
- There are basically two **types of induction motor** that depend upon the input supply - single phase induction motor and three phase induction motor.
- Single phase induction motor is not a self starting motor and three phase induction motor is a self-starting motor.
- In general we need to give two supply i.e. double excitation to make a machine to rotate. [For example if we consider a DC motor, we will give one supply to the stator and another to the rotor through brush arrangement].

Working Principle of Induction Motor

- But in induction motor we give only one supply, so it is really interesting to know that how it works.
- From the name itself we can understand that there is induction process occurred.
- Actually when we are giving the supply to the stator winding, flux will generate in the coil due to flow of current in the coil. Now the rotor winding is arranged in such a way that it becomes short circuited in the rotor itself. The flux from the stator will cut the coil in the rotor and since the rotor coils are short circuited, according to Faraday's law of electromagnetic induction, current will start flowing in the coil of the rotor.
- When the current will flow, another flux will get generated in the rotor.
- Now there will be two flux, one is stator flux and another is rotor flux and the rotor flux will be lagging to the stator flux.
- Due to this, the rotor will feel a torque which will make the rotor to rotate in the direction of rotating magnetic flux. So the speed of the rotor will be depending upon the ac supply and the speed can be controlled by varying the input supply.
- This is the **working principle of an induction motor** of either type.

Types Induction Motor

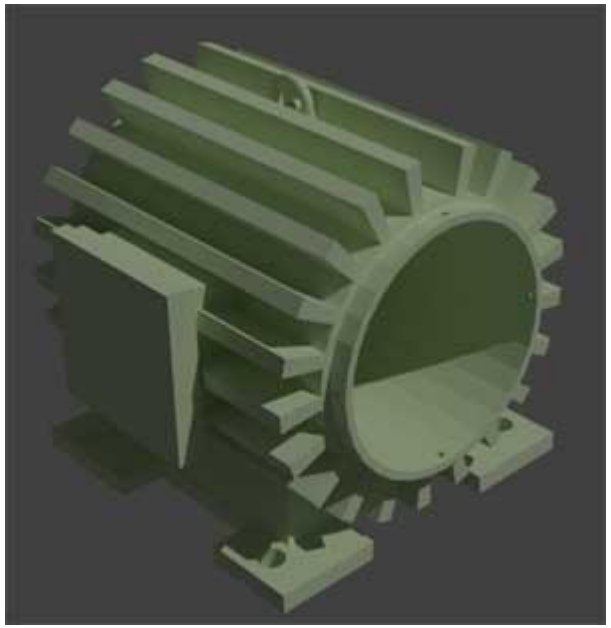
- SINGLE PHASE INDUCTION MOTOR
  - Split phase induction motor
  - Capacitor start induction motor
  - Capacitor start capacitor run induction motor
  - Shaded pole induction motor

- THREE PHASE INDUCTION MOTOR
  - Squirrel cage induction motor
  - Slip ring induction motor

Construction of Three Phase Induction Motor

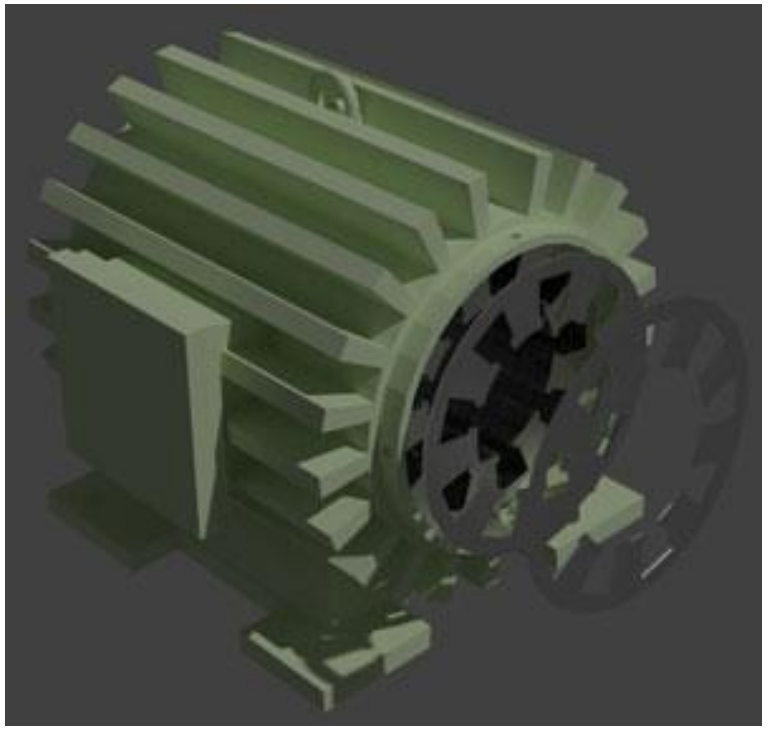
- The three phase induction motor is the most widely used electrical motor.
- Almost 80% of the mechanical power used by industries is provided by three phase induction motors because of its simple and rugged construction, low cost, good operating characteristics, absence of commutator and good speed regulation.
- In three phase induction motor the power is transferred from stator to rotor winding through induction. The Induction motor is also called asynchronous motor as it runs at a speed other than the synchronous speed.
- Like any other electrical motor induction motor also have two main parts namely rotor and stator
- Stator: As its name indicates stator is a stationary part of induction motor. A stator winding is placed in the stator of induction motor and the three phase supply is given to it.
- Rotor: The rotor is a rotating part of induction motor. The rotor is connected to the mechanical load through the shaft.
- The rotor of the three phase induction motor are further classified as Squirrel cage rotor, Slip ring rotor or wound rotor or phase wound rotor.
- Depending upon the type of rotor construction used the three phase induction motor are classified as: Squirrel cage induction motor,Slip ring induction motor or wound induction motor or phase wound induction motor.

- The construction of stator for both the kinds of three phase induction motor remains the same. The other parts, which are required to complete the induction motor are: Shaft for transmitting the torque to the load. This shaft is made up of steel.
- Bearings for supporting the rotating shaft.
- One of the problems with electrical motor is the production of heat during its rotation. In order to overcome this problem we need fan for cooling.
- For receiving external electrical connection Terminal box is needed.
- There is a small distance between rotor and stator which usually varies from 0.4 mm to 4 mm. Such a distance is called air gap.
- **Stator of Three Phase Induction Motor**
- The stator of the three phase induction motor consists of three main parts : Stator frame , Stator core ,Stator winding or field winding.
- **Stator Frame**



It is the outer most part of the three phase induction motor.

Its main function is to support the stator core and the field winding. It acts as a covering and it provide protection and mechanical strength to all the inner parts of the induction motor.
The frame is either made up of die cast or fabricated steel.
The frame of three phase induction motor should be very strong and rigid as the air gap length of three phase induction motor is very small, otherwise rotor will not remain concentric with stator, which will give rise to unbalanced magnetic pull.

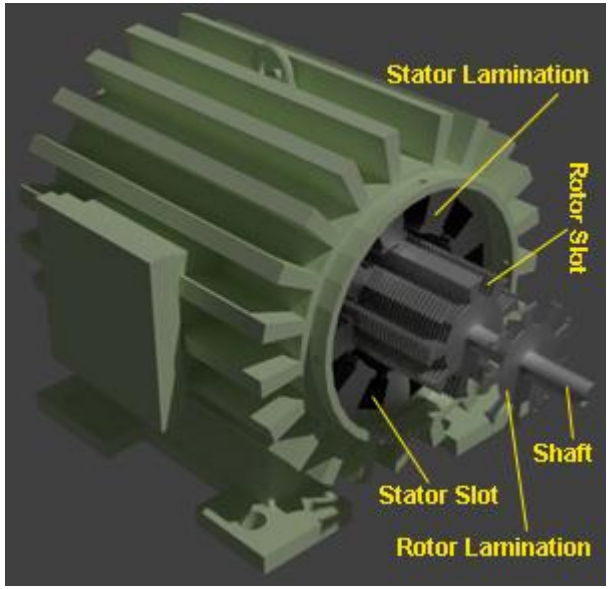


Stator Core

- The main function of the stator core is to carry the alternating flux.
- In order to reduce the eddy current loss, the stator core is laminated.
- These laminated types of structure are made up of stamping which is about 0.4 to 0.5 mm thick.
- All the stamping are stamped together to form stator core, which is then housed in stator frame. The stamping is generally made up of silicon steel, which helps to reduce the hysteresis loss occurring in motor.

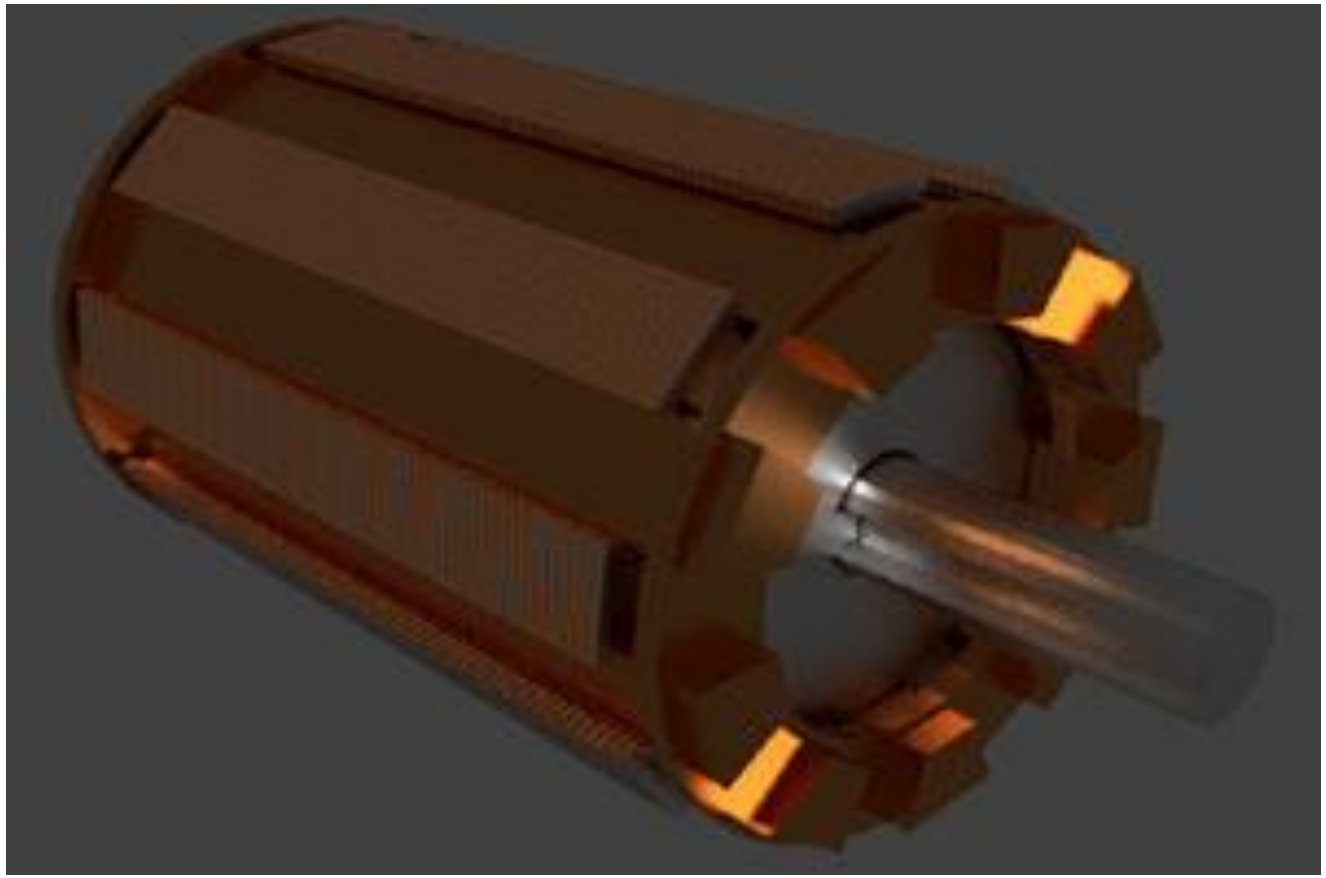
Stator Winding or Field Winding

- The slots on the periphery of stator core of the three phase induction motor carries three phase windings.
- This three phase winding is supplied by three phase ac supply. The three phases of the winding are connected either in star or delta depending upon which type of starting method is used.
- The squirrel cage motor is mostly started by star – delta starter and hence the stator of squirrel cage motor is delta connected.
- The slip ring three phase induction motor are started by inserting resistances so, the stator winding of slip ring induction motor can be connected either in star or delta.
- The winding wound on the stator of three phase induction motor is also called field winding and when this winding is excited by three phase ac supply it produces a rotating magnetic field.



Types of Three Phase Induction Motor

- **Squirrel cage three phase induction motor:** The rotor of the squirrel cage three phase induction motor is cylindrical in shape and have slots on its periphery.
- The slots are not made parallel to each other but are bit skewed (skewing is not shown in the figure of squirrel cadge rotor beside) as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of motor more smooth and quieter.
- The squirrel cage rotor consists of aluminum, brass or copper bars (copper bras rotor is shown in the figure beside). These aluminum, brass or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor.
- The rotor conductors are permanently shorted by the copper or aluminum rings called the end rings.
- In order to provide mechanical strength these rotor conductor are braced to the end ring and hence form a complete closed circuit resembling like a cage and hence got its name as "squirrel cage induction motor".
- The squirrel cage rotor winding is made symmetrical. As the bars are permanently shorted by end rings, the rotor resistance is very small and it is not possible to add external resistance as the bars are permanently shorted. The absence of slip ring and brushes make the construction of Squirrel cage three phase induction motor very simple and robust and hence widely used three phase induction motor. These motors have the advantage of adapting any number of pole pairs. The below diagram shows squirrel cage induction rotor having aluminum bars short circuit by aluminum end rings.



Advantages of squirrel cage induction rotor-

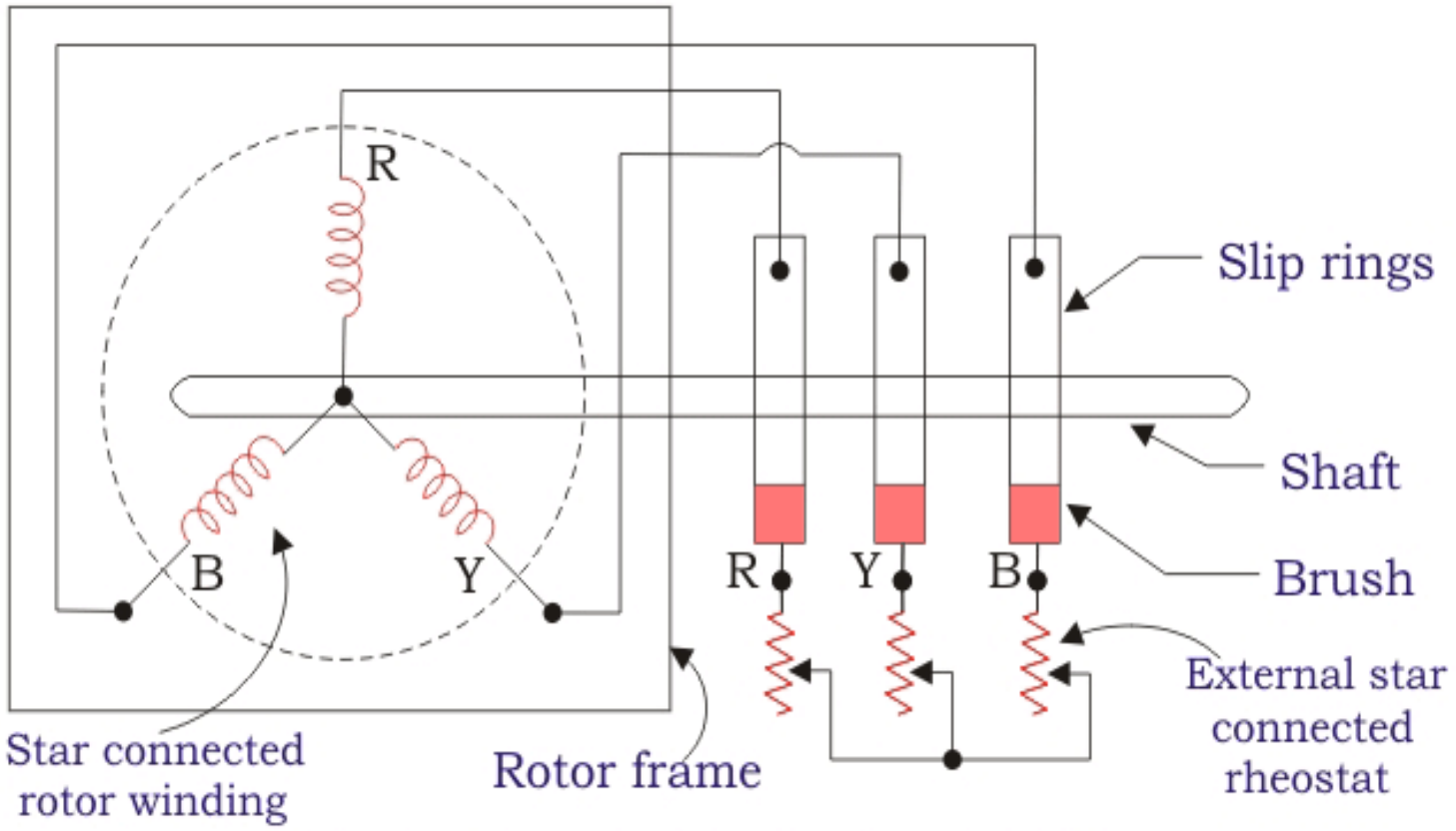
1.Its construction is very simple and rugged.

2.As there are no brushes and slip ring, these motors requires less maintenance.

Applications: Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc.

Slip ring or wound three phase induction motor :

- In this type of three phase induction motor the rotor is wound for the same number of poles as that of stator but it has less number of slots and has less turns per phase of a heavier conductor.
- The rotor also carries star or delta winding similar to that of stator winding. The rotor consists of numbers of slots and rotor winding are placed inside these slots.
- The three end terminals are connected together to form star connection.
- As its name indicates three phase slip ring induction motor consists of slip rings connected on same shaft as that of rotor.
- The three ends of three phase windings are permanently connected to these slip rings.
- The external resistance can be easily connected through the brushes and slip rings and hence used for speed control and improving the starting torque of three phase induction motor.
- The brushes are used to carry current to and from the rotor winding. These brushes are further connected to three phase star connected resistances.
- At starting, the resistance are connected in rotor circuit and is gradually cut out as the rotor pick up its speed.
- When the motor is running the slip ring are shorted by connecting a metal collar, which connect all slip ring together and the brushes are also removed. This reduces wear and tear of the brushes. Due to presence of slip rings and brushes the rotor construction becomes somewhat complicated therefore it is less used as compare to squirrel cage induction motor.



Slip Ring Three Phase Induction Motor

1.Advantages of slip ring induction motor - It has high starting torque and low starting current.

2.Possibility of adding additional resistance to control speed.

Application:

Slip ring induction motor are used where high starting torque is required i.e in hoists, cranes, elevator etc.

Difference between Slip Ring and Squirrel Cage Induction Motor

Slip ring or phase wound Induction motor	Squirrel cage induction motor
Construction is complicated due to presence of slip ring and brushes	Construction is very simple
The rotor winding is similar to the stator winding	The rotor consists of rotor bars which are permanently shorted with the help of end rings
We can easily add rotor resistance by using slip ring and brushes	Since the rotor bars are permanently shorted, its not possible to add external resistance
Due to presence of external resistance high starting torque can be obtained	Staring torque is low and cannot be improved
Slip ring and brushes are present	Slip ring and brushes are absent
Frequent maintenance is required due to presence of brushes	Less maintenance is required
The construction is complicated and the presence of brushes and slip ring makes the motor more costly	The construction is simple and robust and it is cheap as compared to slip ring induction motor
This motor is rarely used only 10 % industry uses slip ring induction motor	Due to its simple construction and low cost. The squirrel cage induction motor is widely used
Rotor copper losses are high and hence less efficiency	Less rotor copper losses and hence high efficiency
Speed control by rotor resistance method is possible	Speed control by rotor resistance method is not possible
Slip ring induction motor are used where high starting torque is required i.e in hoists, cranes, elevator etc	Squirrel cage induction motor is used in lathes, drilling machine, fan, blower printing machines etc

Problem

- The important characteristics normally shown by a squirrel cage induction motors are **crawling and cogging**.
- These characteristics are the result of improper functioning of the motor that means either motor is running at very slow speed or it is not taking the load.

Crawling of Induction Motor

- It has been observed that squirrel cage type induction motor has a tendency to run at very low speed compared to its synchronous speed, this phenomenon is known as crawling. The resultant speed is nearly $1/7^{th}$ of its synchronous speed. Now the question arises why this happens? This action is due to the fact that harmonics fluxes produced in the gap of the stator winding of odd harmonics like 3^{rd}, 5^{th}, 7^{th} etc. These harmonics create additional torque fields in addition to the synchronous torque. The torque produced by these harmonics rotates in the forward or backward direction at $N_s/3$, $N_s/5$, $N_s/7$ speed respectively. Here we consider only 5^{th} and 7^{th} harmonics and rest are neglected. The torque produced by the 5^{th} harmonic rotates in the backward direction. This torque produced by fifth harmonic which works as a braking action is small in quantity, so it can be neglected. Now the seventh harmonic produces a forward rotating torque at synchronous speed $N_s/7$.

Problem

- Hence, the net forward torque is equal to the sum of the torque produced by 7^{th} harmonic and fundamental torque. The torque produced by 7^{th} harmonic reaches its maximum positive value just below 1/7 of N_s and at this point slip is high. At this stage motor does not reach up to its normal speed and continue to rotate at a speed which is much lower than its normal speed. This causes crawling of the motor at just below 1/7 synchronous speed and creates the racket. The other speed at which motor crawls is 1/13 of synchronous speed.

Cogging of Induction Motor

- This characteristic of induction motor comes into picture when motor refuses to start at all. Sometimes it happens because of low supply voltage. But the main reason for starting problem in the motor is because of cogging in which the slots of the stator get locked up with the rotor slots. As we know that there is series of slots in the stator and rotor of the induction motor. When the slots of the rotor are equal in number with slots in the stator, they align themselves in such way that both face to each other and at this stage the reluctance of the magnetic path is minimum and motor refuse to start.
- This **characteristic of the induction motor** is called cogging. Apart from this, there is one more reason for cogging. If the harmonic frequencies coincide with the slot frequency due to the harmonics present in the supply voltage then it causes torque modulation. As a result, of it cogging occurs. This characteristic is also known as magnetic teeth locking of the induction motor.