

# AC Induction Motors

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# Objective

- To introduce the principle of operation of an AC induction motor and discuss the basic construction.

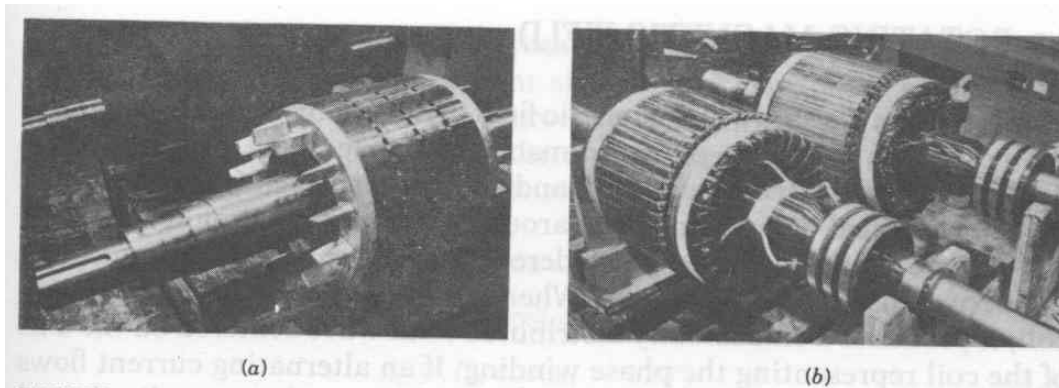
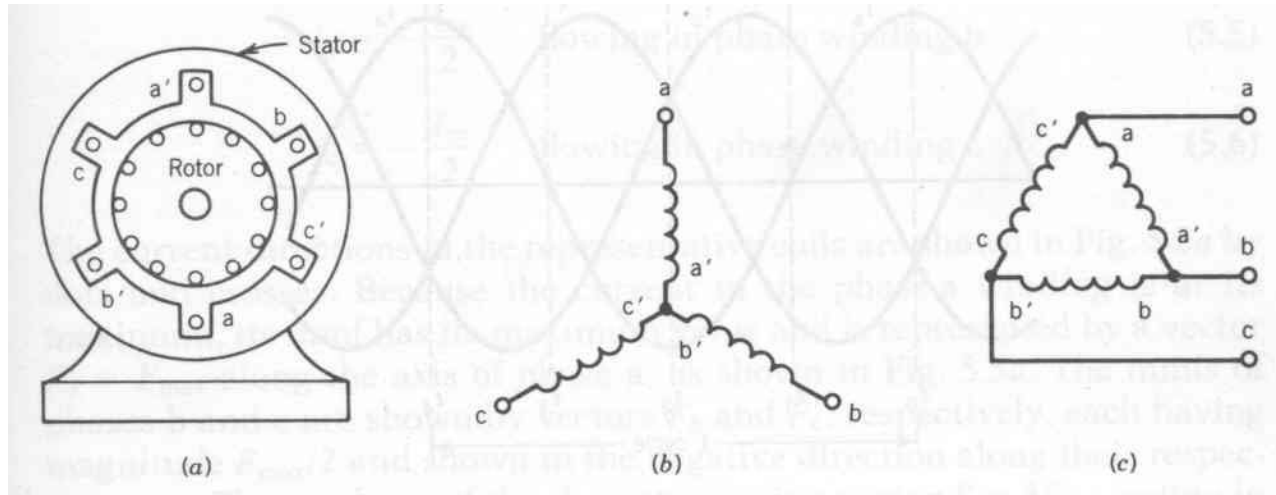
## Review

- The AC Synchronous motor has been discussed where a rotating magnetic field is established using a 3 phase supply and a rotor, fed by DC ‘excitation’, was introduced.
- The rotor, once up to synchronous speed, ‘locks’ on to the rotating magnetic field. The synchronous motor is a constant speed drive, turning at synchronous speed, it is expensive (due to the rotor and slip rings etc) and will not ‘self-start’.

# Induction motor rotor

- An induction motor is different from a synchronous motor in its rotor construction and the method of producing torque
- An induction motor rotor can either be a **wound rotor** or a **squirrel cage rotor**
- The squirrel cage rotor is far more common and will be the rotor type dealt with in this class
- A squirrel cage rotor is constructed using a number of short-circuited bars arranged in a ‘hamster-wheel’ or ‘squirrel-cage’ arrangement

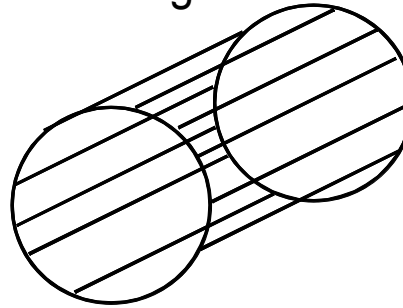
# Winding/Rotor Arrangements for 3 Phase Induction Machine



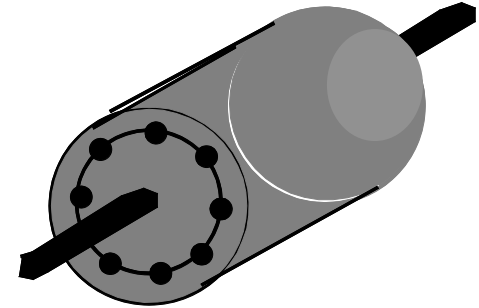
# Squirrel Cage Rotor - Construction

- A typical squirrel cage rotor construction is shown on the right
- The cage is constructed from rotor bars (generally copper), typically insulated from and embedded in the rotor body
- The bars are then shorted together with end rings at either end
- There are no slip rings nor any DC excitation supplied to the rotor
- It is a cylindrical not salient rotor

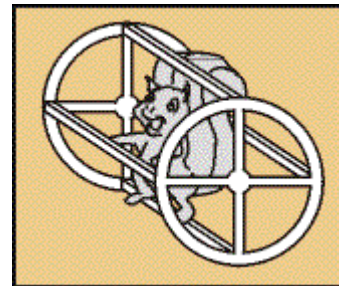
Electrical  
Diagram



Mechanical  
Diagram



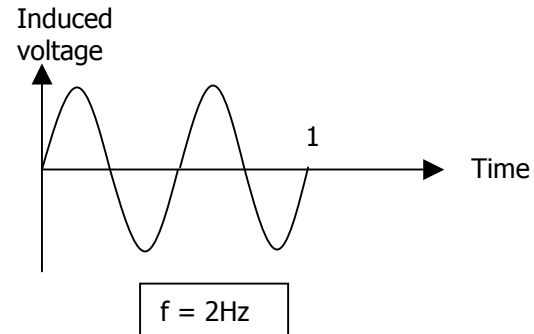
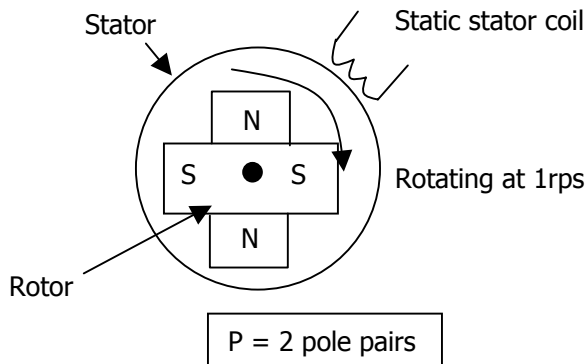
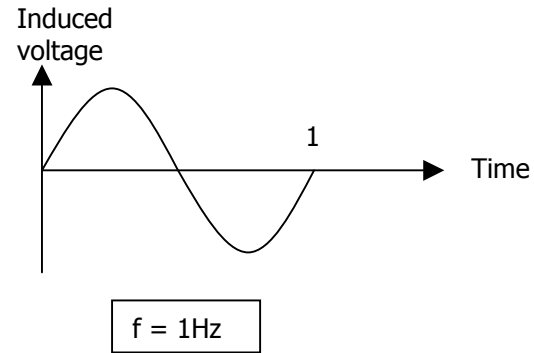
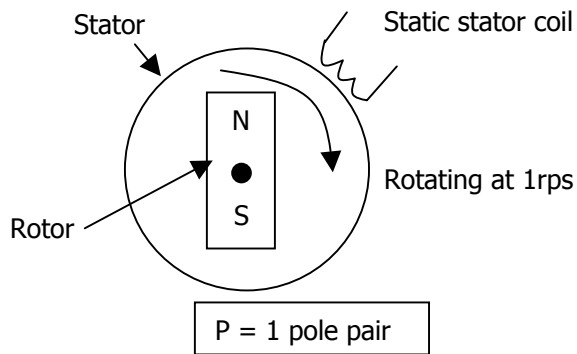
Squirrel Cage Induction Motor Rotor



# Induction Motor Action

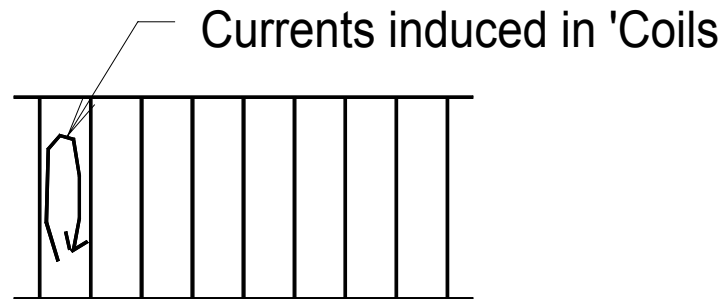
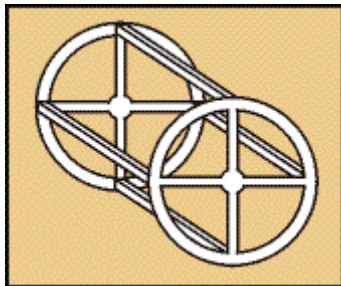
- How does an induction motor work? There is no electrical connections to the rotor to supply power to, therefore how is a rotor mmf to be established that will interact with the rotating field and produce torque?
- The answer is given in the name - by a process of inducing currents by transformer action in the rotor.
- Consider an induction motor if the rotor is locked and prevented from moving
  - At this time AC power is supplied to the stator which establishes a rotating magnetic field. This field will rotate past stationary coils which will experience a changing level of magnetic flux
  - From Faraday's Law (see electromagnetism notes) a voltage will be induced in the coils, causing rotor currents to circulate

# Synchronous Speed



# Induction Motor Action - contd

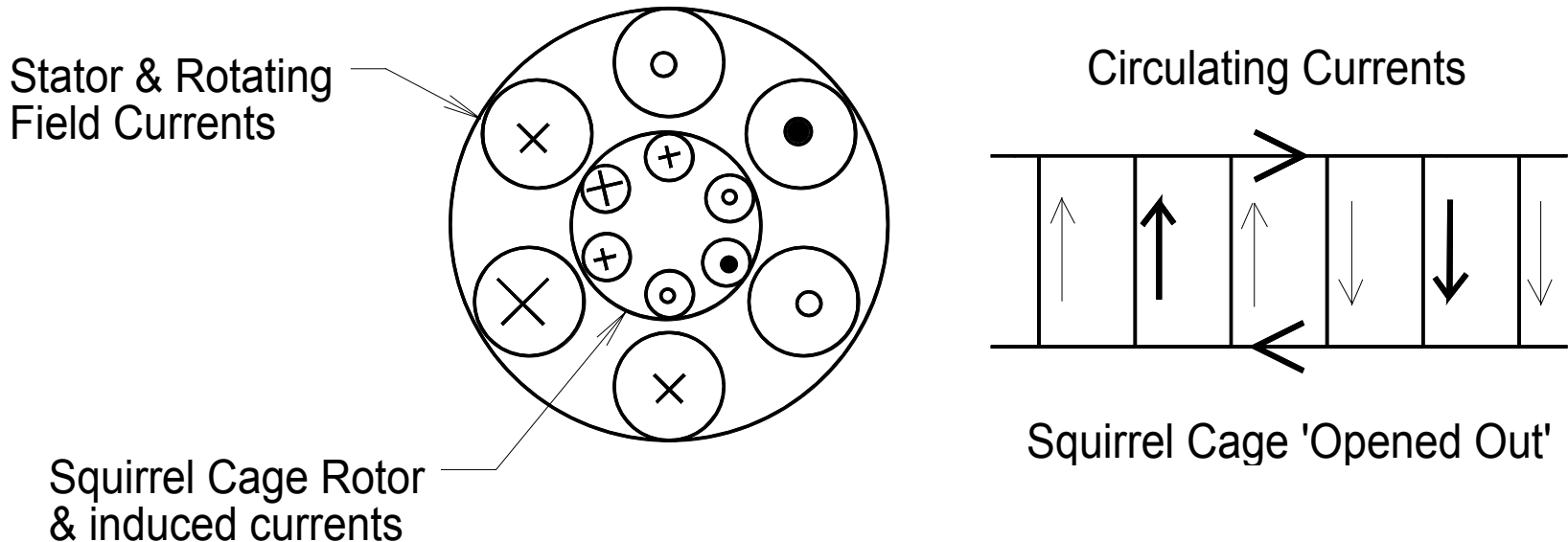
- For example at standstill, with a 50Hz stator supply, 50Hz emfs will be induced in the rotor. For a short-circuited squirrel cage rotor, corresponding currents will then flow
- These currents will establish a rotor mmf, and a similar analysis of the interaction between the stator rotating mmf and the rotor mmf can be performed as for the synchronous motor case. However we are considering that the rotor remains stationary for the moment
- Take a 'snap-shot' in time of the rotating magnetic field and stator currents and the induced rotor currents for a typical squirrel cage rotor.



Squirrel Cage 'Opened Out'

# Squirrel Cage Currents

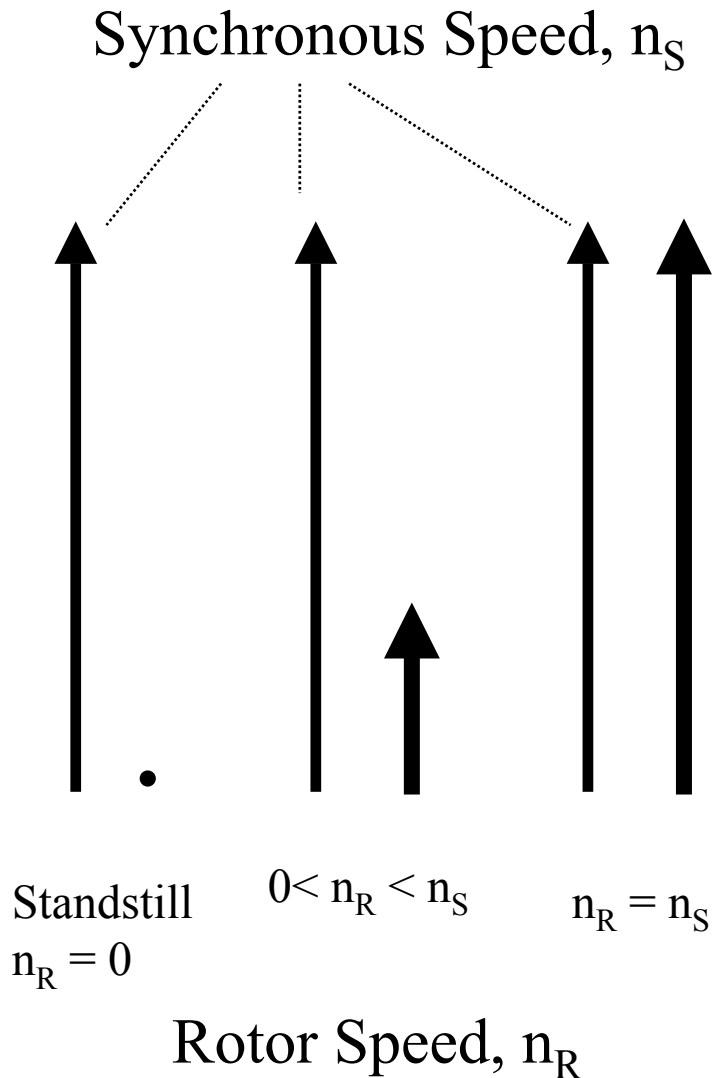
- The stator currents establish a rotating mmf (not shown). This rotating mmf causes an emf to be induced in the rotor which, because the rotor bars are essentially single turn coils, cause currents to flow in the rotor bars. These rotor currents establish their own mmf which interacts with the stator mmf to produce a torque.



# Motion!

- The induction motor will self-start!
- The rotor will turn when the interaction, torque, produced by the stator and rotor mmfs is sufficient to overcome the inertia etc of the rotor... this is dependent on the level of induced rotor current being high enough.
- Once the rotor has started turning the motor acts like a 'rotating transformer'.
- The rate the rotating stator mmf passes the rotor bars now begins to reduce compared to the stationary or locked rotor case.
- The worst case is if the rotor is turning at synchronous speed ... then there is no relative speed difference and the rotor bars are not experiencing a changing magnetic field... therefore there can be no torque!!

# Relative Motion - Slip!



- At standstill the relative speed of the rotating mmf is at a maximum, therefore the frequency of the induced emfs is at a maximum
- Once the rotor is turning the relative speed, and hence frequency, of the induced emf decreases
- If the rotor is turning at synchronous speed, there is **no** relative speed and therefore **no** induced rotor emf or rotor current flow.
- Therefore there is **no torque** produced
- This is an impossible situation that cannot be achieved by normal motor action

# Slip

- For induction motors a very important parameter is the **slip** of the motor
- The slip,  $s$ , defines the relative speed difference between synchronous speed and rotor speed and is given by:

$$s = \frac{\omega_S - \omega_R}{\omega_S} \quad \text{or} \quad \frac{n_S - n_R}{n_S}$$

where  $\omega$  is expressed in rads/s and  $n$  is expressed in rpm.

- From the definition it is clear that at standstill  $s = 1$  and that at synchronous speed  $s = 0$

# Slip versus Speed

