



**R. C. Patel College of Engineering and Polytechnic,
Shirpur**

Class: TYEE (EE5K)

Course:

A.C. MACHINES PERFORMANCE (ACM)

(Course Code: 315333)

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Unit - V

Special Purpose Machines (10 Marks)

Course Outcome:

**CO5 - Use Special Purpose
Electrical Machines for Industrial
Applications.**

* Universal motor: (W-14, B-15) (4M)

The motor which can be operated satisfactorily on a.c. as well as d.c. supply is universal motor.

The universal motor is small fractional HP motor.

→ Types of universal motors:

1. Uncompensated type universal motors
2. compensated universal motors.

→ Windings:

There are three types of windings used, namely armature, main field winding and compensating winding. out of which the compensating winding is used only for the compensated universal motors. All the windings are connected in series with each other since this is basically a series motor.

① Uncompensated Universal Motor:

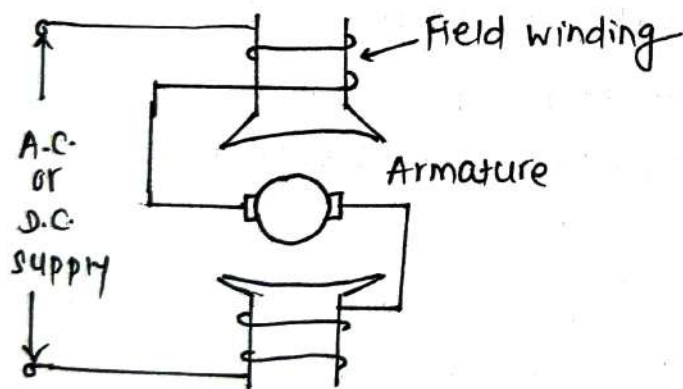


Fig. a) construction

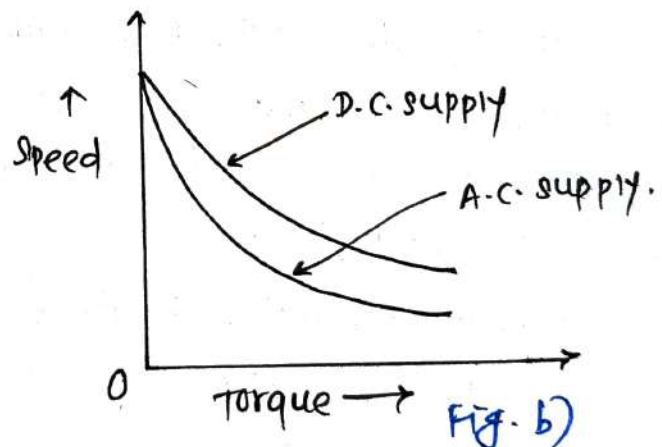


Fig. b)

Fig: Non compensated type universal motor.

The construction of uncompensated universal motor is shown in Fig. a) and its torque speed characteristics is shown in Fig. b)

Field winding produces flux. It is a stationary winding. Armature is a rotary winding.

Operating principle is same as that of dc series motor.

These motor produce a high starting torque but their speed decreases with increase in load. Their speed regulation is not very good.

- The torque speed characteristics of uncompensated universal motors differ a lot for DC and AC supply characteristics. In non compensated type motor the capacity is low. Normally it is designed for two pole structure. pole and pole shoe both are laminated to reduce eddy current losses. Armature is similar to d.c. motor armature.

* Compensated Universal Motor: (W-14, S-15)

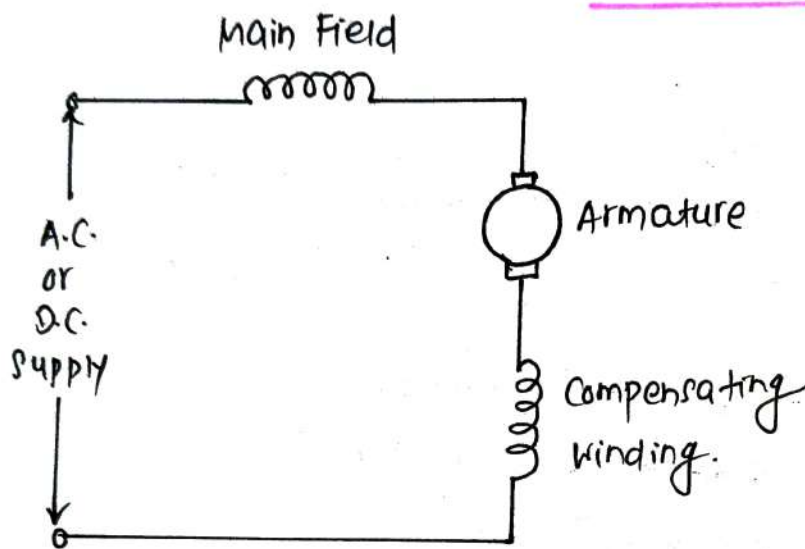


Fig a) construction

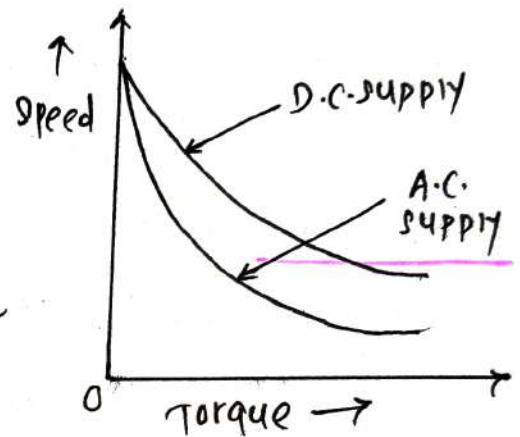


Fig b) Torque speed ch's.

In compensated type motor main Field winding and compensating winding are distributed over entire stator. (21-W, 21-S, 41-W)

Fig. a) shows the schematic diagram for the compensated type universal motor and Fig. b) shows its speed-torque characteristics.

The motor characteristics can be modified as per requirement with the help of the compensating winding.

It is seen that speed-torque characteristics on d.c. and a.c. supply almost coincide.

Hence this type of motor is better suited even for higher speeds.

Compensated motors are more expensive due to complicated construction.

Hence they are preferred for higher capacity loads. Non compensated universal motor is cheaper due to simple construction. It is therefore preferred even its d.c. and a.c. supply characteristics differ by large margin.

* Advantage of Universal Motor:

1. Simple construction
2. Low cost
3. Small size
4. They can be operated on DC as well as AC supply
5. High starting torque.

* Disadvantages of Universal Motors:

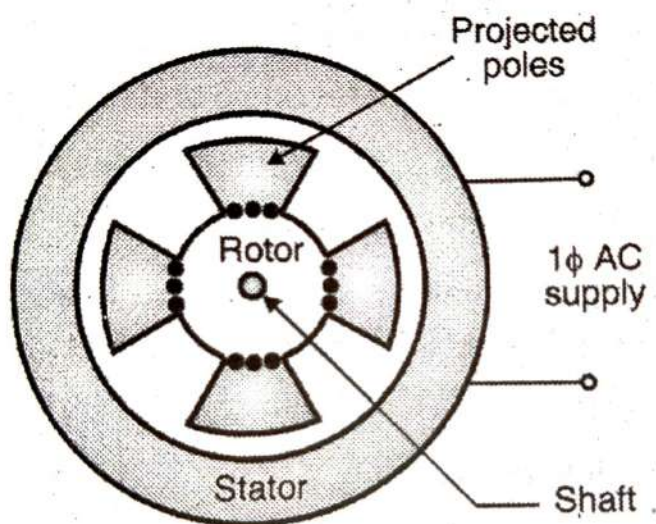
1. poor speed regulation
2. They are fractional H.P. motors
3. Construction of compensated universal motors is complicated.

* Applications:

- | | |
|---------------------|----------------------------|
| 1. Washing machines | 2. Mixes and grinders |
| 3. Food process | 4. Small drilling machines |
| 5. Vacuum cleaner | 6. Sewing machines. |
| 7. Hair driers. | 8) Electric shavers. |

* Synchronous Reluctance motor:

* Construction:



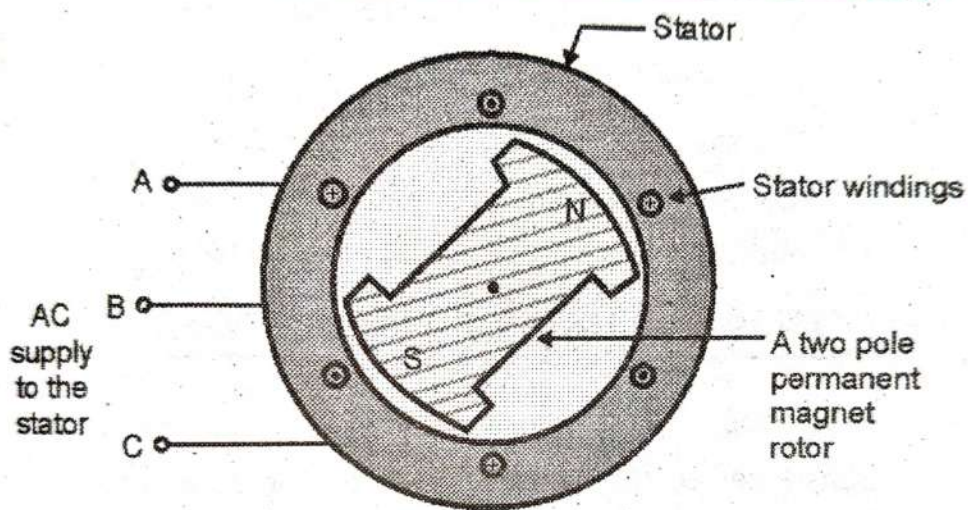
1. Reluctance motor is basically same as 3ϕ or 1ϕ Induction motor with modification in rotor design.
2. It consists of a slotted stator carrying uniformly distributed 3ϕ winding (for 3ϕ motor) or both the main & starting winding (for 1ϕ motor).
3. The rotor in this motor does not include any field winding but the rotor core presents unsymmetrical reluctance to stator rotating magnetic field.
4. Many rotor designs are available to offer unsymmetrical reluctance.
5. Typical rotor is cage type having poles projecting out as shown in fig. above.
6. The rotor bars are kept intact even in the spaces from where teeth are removed, the two end rings short circuit these bars as in a cage rotor.

* Working:

1. When the stator windings (1ϕ or 3ϕ) are connected to AC supply, the rotating magnetic field is produced. This RMF is cut by rotor conductors (bars), emf is induced and currents are produced in rotor bars as they are shorted.
2. According to basic motor principle, force is exerted on current carrying rotor conductors (bars) placed in rotating magnetic field. Thus the motor starts as an induction motor.
3. The rotating magnetic field experiences unsymmetrical reluctance as it sweeps over the rotor surface (toothed and non-toothed portion).
4. Since the magnetic flux always follow the path of minimum reluctance, the induced magnetic field in rotor core creates magnetic pole in toothed portion of the rotor.
5. The rotating magnetic field poles attract the rotor induced opposite poles. The torque so produced is called reluctance torque.
6. During starting period, when motor is started as induction motor and the speed reaches close to the synchronous speed, reluctance torque produced causes tendency of the rotor to align itself in the minimum reluctance position with respect to the synchronously rotating magnetic field of stator.
7. As a result, rotor is pulled into synchronism and then rotates at synchronous speed with rotating magnetic field of stator.

8. Once rotor starts rotating with synchronous speed, the relative motion between rotor and RMF of stator becomes zero, so no induced EMF, no rotor current and no induction motor torque.
9. The rotor continues constant synchronous speed operation due to reluctance torque only. Hence it is called "synchronous reluctance motor".

* permanent magnet synchronous motors (PMSM):



- The permanent magnet synchronous motor (PMSM) is basically a synchronous motor in which field excitation is provided by permanent magnets.
- The stator is similar to that of an induction motor.
- It has slotted stator core construction & 3 ϕ or 2 ϕ winding is accommodated in the slots.
- A PMSM uses permanent magnets embedded in the steel rotor to create a constant magnetic field.
- These motor do not have rotor winding instead they have PM rotor so no external DC excitation is needed.

1) Stator Construction:

- The stator consists of an outer frame and a core with windings.
- The most common design comes with two-phase winding (1 ϕ motor) and three-phase winding (3 ϕ motor).
- Depending on the stator design, a permanent magnet synchronous motor can be:
 - PMSM with distributed winding
 - PMSM with concentrated winding.

2) Stator Windings:

- Distributed winding has the number of slots per pole and phase.
- $Q = 2, 3, \dots, K$
- Concentrated winding has the number of slots per pole and phase $Q = 1$.

3) Stator & Rotor Construction:

- The rotor consists of permanent magnets.
- Materials with high coercive force are used as permanent magnets.
- According to the rotor design, synchronous motors are divided into:
 - PMSM with salient pole rotor.
 - PMSM with non-salient pole rotor.
- As there is no field winding, no external dc excitation is needed.
- This will eliminate the need for slip rings and brushes.
- This reduces the winding losses and necessity of maintenance.

* operation:

1. When a 3ϕ AC supply is given to the stator winding, it produces a rotating magnetic field (RMF).
2. The rotating magnetic fields rotates at synchronous speed.

$$N_s = \frac{120F}{P} \quad \text{where } F = \text{Frequency in Hz}$$

$P = \text{NO. OF poles.}$

3. The rotor contains permanent magnets, which produce a constant magnetic field.
4. The magnetic field of the rotor interacts with rotating magnetic field of the stator.
5. Due to this magnetic attraction, the rotor starts rotating in the same direction as the rotating magnetic field.
6. When the rotor reaches synchronous speed, its magnetic field locks with the rotating magnetic field.
7. Therefore, the rotor rotates at exactly synchronous speed.
8. Hence, the PMSM operates with zero slip.

$$\boxed{N_r = N_s}$$

where, $N_r = \text{rotor speed.}$

* Advantages:

- 1) High efficiency
- 2) High power density
- 3) High torque
- 4) Constant speed
- 5) Low maintenance
- 6) Compact and lightweight
- 7) Good power factor
- 8) Low noise and vibration
- 9) Good dynamic performance

* Disadvantages

1. High initial cost
2. Difficult starting as they are not self starting.
3. Requires a controller for operation.
4. Control is more complex.
5. Difficult to repair.

* Application:

1. Electric vehicle
2. Hybrid electric vehicles
3. Robotics
4. Industrial Automation.
5. CNC machines
6. Servo drives
7. Elevators and lifts.

* stepper motor:

Defn: A stepper motor is an electromechanical device that converts electrical pulses into discrete mechanical movements (steps).

- For each input pulse, the rotor moves through a fixed angular step, allowing accurate control of position and speed.

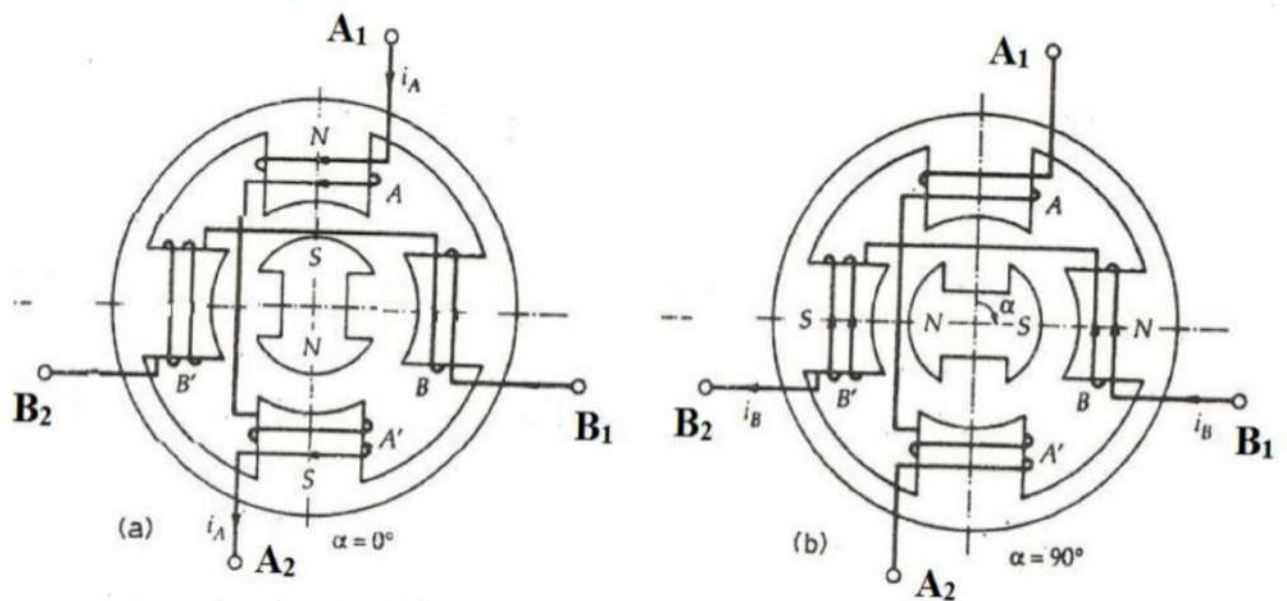
* Permanent Magnet stepper motor:

Construction:

- The constructional diagram of permanent magnet stepper motor is shown in fig. below.

- The rotor consists of permanent magnet poles of high retentivity steel and is cylindrical in shape.
- The concentrating windings on diametrically opposite poles are connected in series to form a two phase winding on the stator.
- The rotor poles align with the stator teeth depending on the excitation of winding.
- The two coils AA' connected in series to form a winding of phase A with terminals A_1 and A_2 .
- Similarly the two coil BB' is connected in series forming a phase B windings with terminals B_1 and B_2 .

* Working / operation:



- In Fig. (a), the phase A is excited, causing current i_A flowing from A_1 to A_2 of phase A, where phase B is not excited.
- Due to the current i_A , the poles are created on stator as shown.
- The south pole of the rotor is attracted by the north pole of stator phase A.
- Thus, the magnetic axis of the stator and rotor coincide and $\alpha = 0^\circ$.

- In Fig. (b) the phase B is excited, causing current i_B flowing from B_1 to B_2 of phase B, where phase A is not excited.
- Due to the current i_B the poles are created on stator as shown.
- The south pole of rotor is attracted by the north pole of stator phase B and the rotor moves by 90° in the clockwise direction.
- Thus, the magnetic axis of the stator and rotor coincide & $\alpha = 90^\circ$.
- Similarly, if phase A alone is excited with reversed current I_A , the rotor moves further by 90° and when the magnetic axis of stator and rotor coincide, we get $\alpha = 180^\circ$.
- Further if only B phase is excited with reversed current i_B , the rotor moves further by 90° and when the magnetic axis of the stator and rotor coincide, we get $\alpha = 270^\circ$.
- In this way, the sequential excitation of phases A and B with forward and reverse current, the rotor movements in steps of 90° can be obtained.
- It is also possible to obtain steps of 45° by exciting both the phases simultaneously.

* Advantages:

1. Accurate position control
2. Simple control
3. Good starting and stopping
4. No feedback required.

5. low maintenance
6. Good reliability

* Disadvantages:

1. low efficiency
2. Low torque at high-speed.
3. Vibration and noise.
4. limited high-speed operations
5. Heating problems.
6. Requires a driver circuit.

* Applications:

1. Printers and scanners.
2. CNC machines
3. 3 D printers
4. Robotic system
5. Computer disk drives
6. Camera system
7. Automatic control system
8. Textile machines
9. Medical Equipments.

* Linear Induction Motor: (W-14, S-15, W-15)

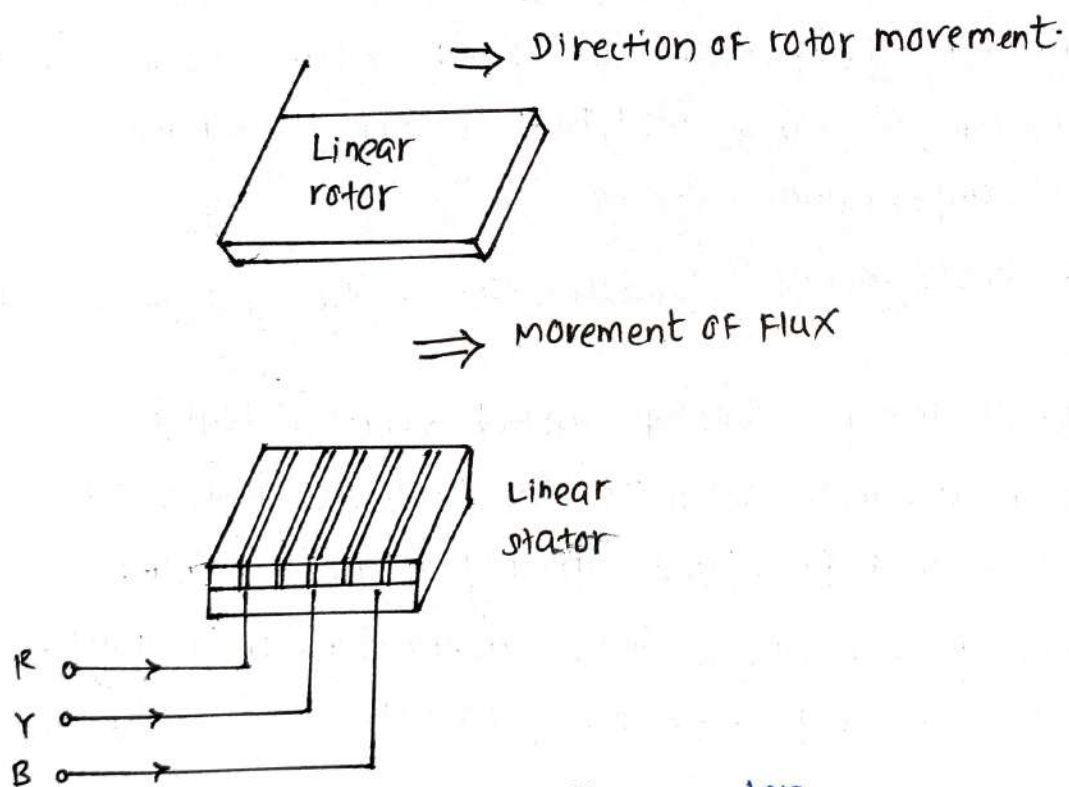


Fig a) Linear induction motor.

- Fig. a) shows the construction of a linear induction motor.
- In a sector induction motor, if the sector is opened up and made flat and a flat squirrel cage winding is brought close to it, then we get the linear induction motor.

Practically, they do not use the flat squirrel cage winding. Instead a plate made of aluminium, copper or iron is used as a rotor as shown in Fig. a)

The flat stator produces a flux that moves in a straight line from its one end to other.

The speed of this flux is called the linear synchronous speed which is given by,

$$V_s = 2 \pi \cdot F \cdot \lambda \quad \text{--- (1)}$$

where F = Supply Frequency (Hz)

λ = Width of one pole pitch (m)

The linear synchronous speed V_s does not depend on the no. of poles, instead it is directly proportional on the stator supply frequency (F) and the pole pitch as shown by eqn (1)

As the flux moves from one end to other, it will force the rotor to move in the same direction as that of the flux. But in most of the practical applications, the rotor is made to be stationary while the stator moves. An application of linear induction motor is high speed train which operates on the principle of linear magnetic levitation.

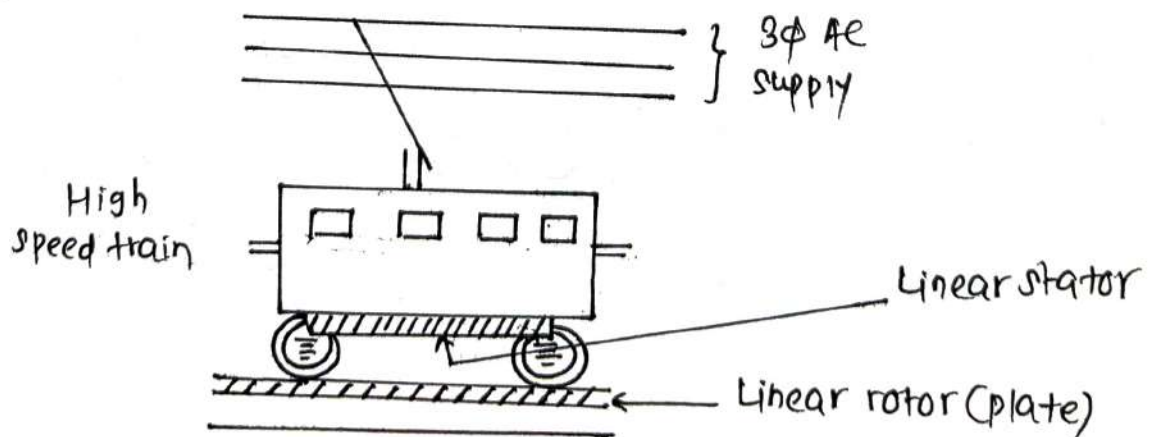


Fig. Application of linear induction motor.

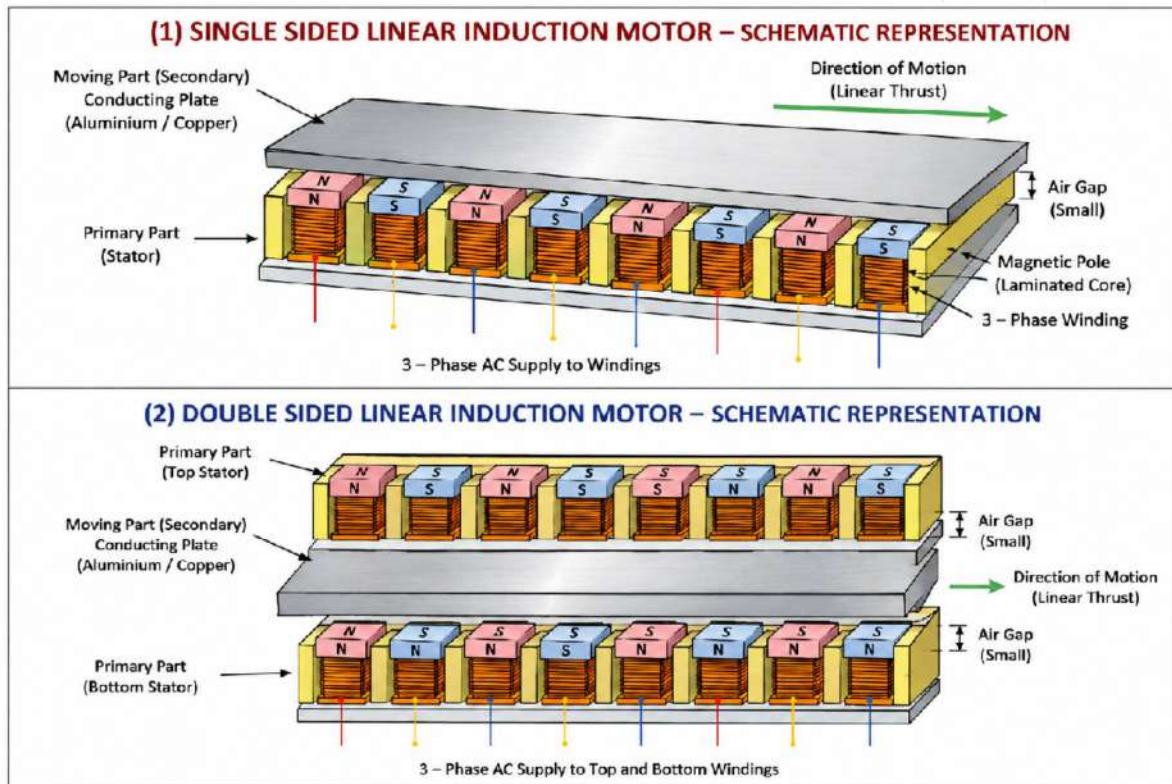
The rotor is made of thick aluminium plates which is fixed to the ground and it is extended over the full length of track.

The linear stator is bolted to the undercarriage of the train. When it is energized by the supply, the stator will start moving which in turn will move the train.

* Application of linear Induction motor:

1. Industrial Automation: Conveyor systems, material handling equipments.
2. Machine tools.
3. Elevators and Escalators.
4. Military applications.
5. Electric trains
6. maglev transportation.
7. conveyor system
8. metro rails system.

* Single sided Linear Induction motor (SLIM):



- The main parts of a single sided linear induction motor are:
 1. primary: It consists of a laminated iron core with 3 ϕ winding placed in slots.
 2. secondary: It is generally a conducting plate made of aluminium or copper. A steel backing may also be provided for mechanical support.
 3. The travelling magnetic field
 3. Air gap: A small air gap is maintained between the primary and secondary.
 4. support: The primary and secondary is mounted on a suitable support depending on the application.
 5. Three-phase supply: The primary winding is connected to a 3 ϕ ac supply.

* Working:

1. When 3ϕ AC supply is given to the primary winding, it produces a travelling magnetic field.
2. This magnetic field travels along the length of the motor.
3. The travelling magnetic field cuts the conducting secondary plate.
4. Due to electromagnetic induction, eddy currents are induced in the secondary.
5. The interaction between travelling magnetic field and induced currents produces a linear force or thrust.
6. This thrust moves the secondary in a straight line in the direction of the travelling magnetic field.
7. Thus, electrical energy is converted into linear mechanical energy.
8. The synchronous linear speed of the travelling magnetic field is

$$\boxed{V_s = 2wf}$$

where V_s = synch. linear speed (m/s)

f = supply frequency (Hz)

w = width of one pole pitch (m)

* Advantages:

1. It produces direct linear motion.
2. No mechanical arrangement is required to convert rotary motion into linear motion.
3. It has simple construction.
4. low maintenance as no brushes or commutator.
5. suitable for high speed linear motion.

* Disadvantages:

1. It has lower efficiency compared with some conventional rotary motors.
2. End effect reduces the performance of the motor.
3. It requires a large amount of primary material for long travel distances.
4. The power factor may be low.
5. There is a large air gap, which increases the magnetizing current.
6. It may produce heating in the secondary due to induced currents.

* Applications:

1. Conveyors system
2. Material Handling system
3. Automatic doors
4. Industrial Automation.
5. Linear actuators.
6. Elevators and lifts.
7. Transportation system.

* Double sided linear Induction Motor: (DLIM)

* Construction:

- The main parts of double-sided linear induction motor are
- 1. Two primary parts:
 - Two identical primary sections with laminated cores and 3ϕ windings are placed on both sides of the secondary.

2. Secondary:

- A conducting plate generally made of aluminium or copper is placed betn the two primaries.

3. Air gaps:

- A small air gap is maintained betn the secondary and each primary.

4. A 3 ϕ supply: Both primary windings are supplied with suitable 3 ϕ Ac supply.

5. Mechanical support:

- The primary and secondary parts are properly supported to maintain the required air gaps.

* Working:

1. When 3 ϕ Ac supply is given to both primary windings, they produce travelling magnetic fields.
2. The magnetic field act on both surfaces of the conducting secondary.
3. These magnetic fields cut the secondary conductor and induce currents in it.
4. The interaction betn the magnetic fields and induced currents produces linear thrust.
5. The thrust produced by both sides acts in the same direction.
6. Therefore, the secondary moves in a straight line.
7. Thus, DLIM converts electrical energy directly into linear mechanical energy.
8. The synch. linear speed $V_s = 2fW$

* Advantages:

1. It produces higher thrust because both sides of the secondary are active.
2. It ~~provides~~ provides direct linear motion.
3. It has better utilisation of secondary compared with a single sided arrangement.
4. The magnetic forces from both sides can be balanced, reducing normal force.
5. Suitable for high speed transportation.
6. Less mechanical maintenance.

* Disadvantage:

1. Construction is more complicated.
2. It requires two primary sections, increasing the cost.
3. Maintaining equal and small air gap on both sides is difficult.
4. It requires a larger amount of material.
5. End effect and losses can reduce efficiency.
6. The initial cost is relatively high.

* Applications:

1. High speed electric trains.
2. Maglev trains.
3. Metro railway system.
4. High speed transportation.
5. Industrial material handling.
6. Linear propulsion system.
7. Industrial Automation.

* Comparison of Single sided and Double sided linear Induction Motor:

Sr. No.	Parameter	Single sided LIM	Double sided LIM.
1.	Construction of Primary winding	primary winding is provided on one side only.	primary winding are provided on both sides of secondary.
2.	Secondary	usually a conducting plate/sheet with or without back iron is used.	A conducting secondary plate is provided/placed betn two primary windings
3.	weight	Lighter	Heavier
4.	Magnetic flux path	Flux travels through the primary, air gap and secondary.	Flux produced by the two primaries forms a more effective path through the secondary.
5.	Efficiency	low efficiency	High efficiency
6.	power factor	lower P.F.	Higher P.F.
7.	End effect	More significant	less significant
8.	Construction	simple and economical.	more complex and costly
9.	cost	low	High
10.	Maintenance	Easy and less costly	difficult and costly.
11.	Applications	conveyors, doors & small transport system	High speed transportation, Advanced propulsion system.