AC Motors

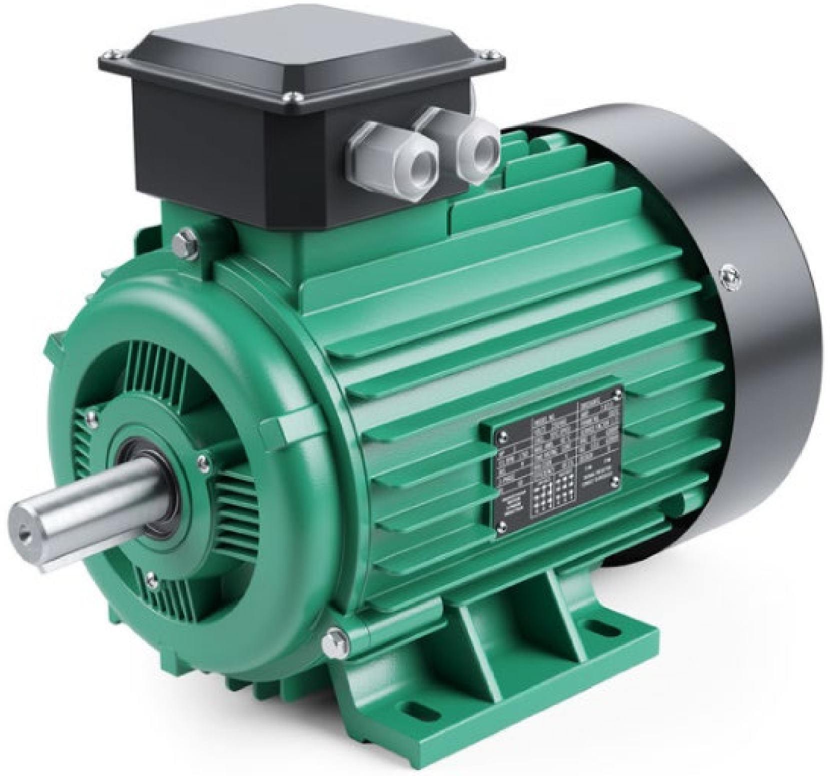
YORK COLLEGE & UNIVERSITY CENTRE

What is an AC motor

- An AC motor takes a sinusoidal AC current and turns it into a mechanical movement

- AC motors are much more common in heavy industry because they can be attached to mains power as it is distributed in the form of AC

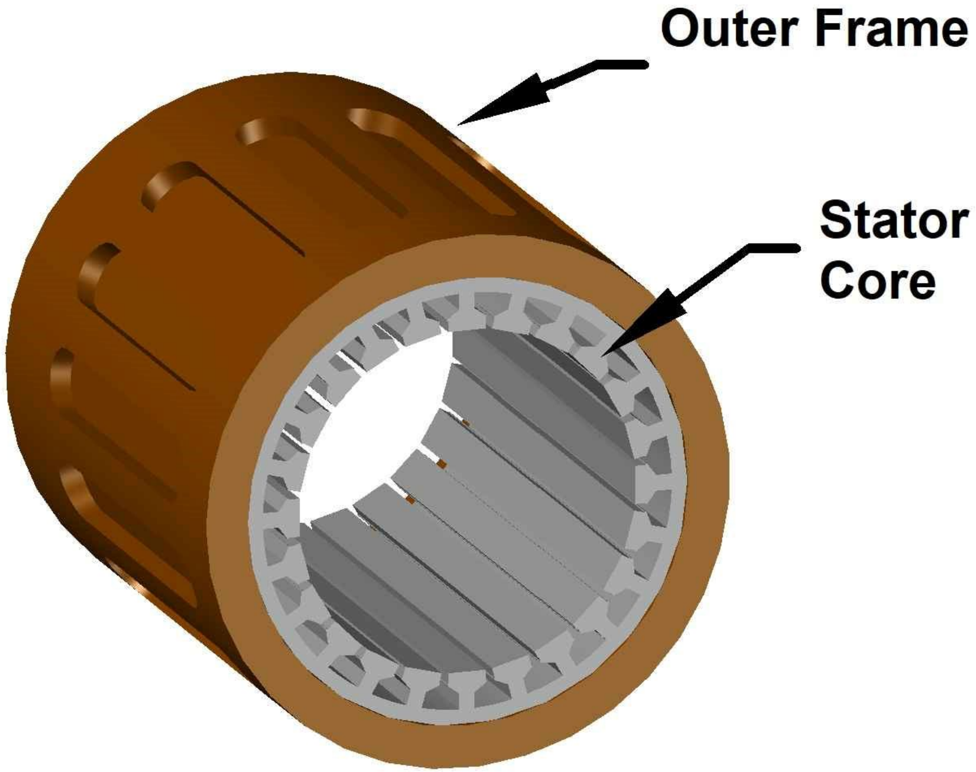
- This is helpful as it means you don’t have to convert between AC and DC for your motors



Construction - Stator

- The stator of an AC motor is built up of many thin layers (laminations) of iron which is packed tightly together

- There are slots that run down the length of the stator core into which coils of insulated wire or strands known as windings are inserted.



Windings in the stator

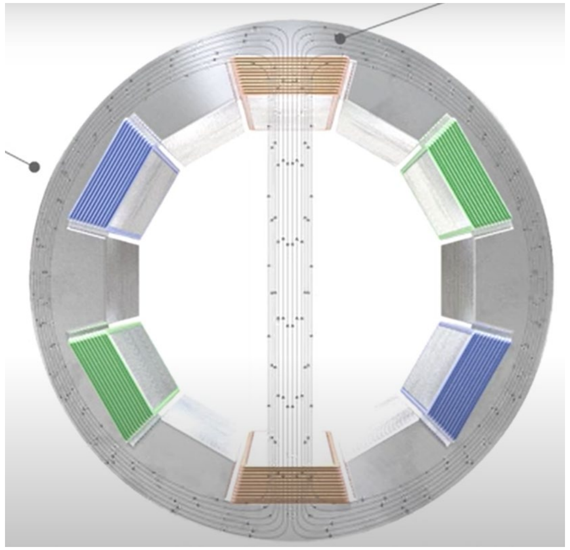
- As you add more windings to the stator more poles are created this has several effects:

- **Lower Motor Speed** – The more slots for windings, the lower the synchronous speed of the motor.

- **Higher Torque at Lower Speeds** – More poles mean the motor can produce higher torque at lower speeds, making it useful for applications like conveyors and cranes.

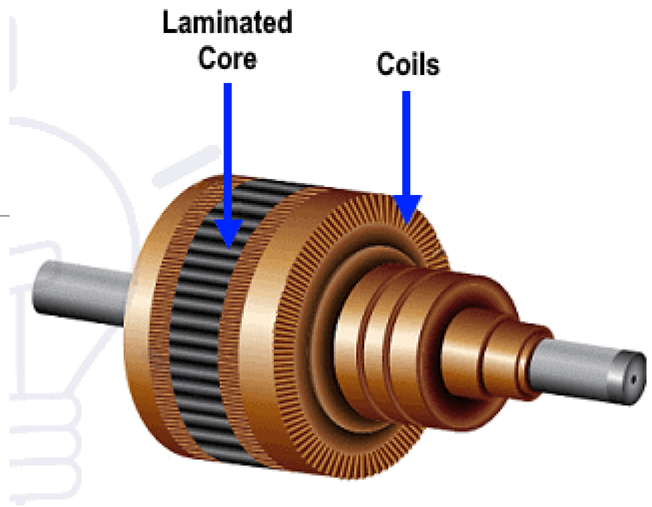
- **Improved Efficiency in Some Cases** – More windings can improve the motor's efficiency by reducing losses, but only if properly designed.

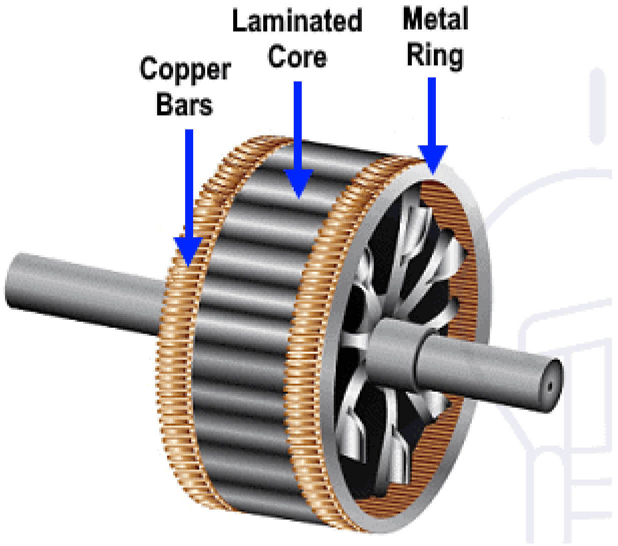
- **Increased Cost & Size** – More windings require more copper, increasing manufacturing costs and making the motor physically larger.



Construction - Rotor

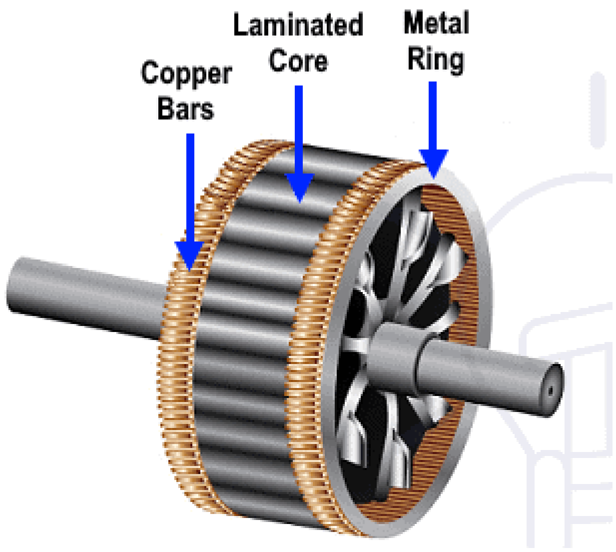
- The rotor is the rotating part of an AC motor.
- Located inside the stator and mounted on a shaft.
- Produces mechanical output (rotation) when magnetic fields interact.
- Made of laminated iron core to reduce eddy current losses.
- Conductors (bars or windings) carry induced current from the stator's magnetic field.
- Connected to load through the motor shaft.





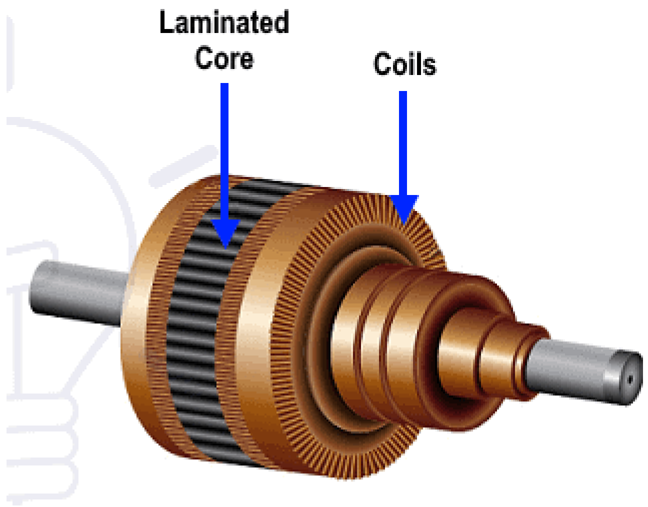
Construction – Squirrel Cage Rotor

- Most common type (used in induction motors)
- Made of conductive bars (aluminium or copper) short-circuited by end rings → looks like a hamster wheel
- Simple, rugged, low-cost design
- No electrical connection to external circuits
- Used in fans, pumps, conveyors, etc.



Construction – Wound Rotor

- Windings placed on rotor core (similar to stator windings)
- Connected to external resistors via slip rings & brushes
- Resistance can be varied → controls starting torque and speed
- More complex and expensive, requires maintenance
- Used in heavy-duty applications (cranes, mills, hoists)



Construction – Shaft

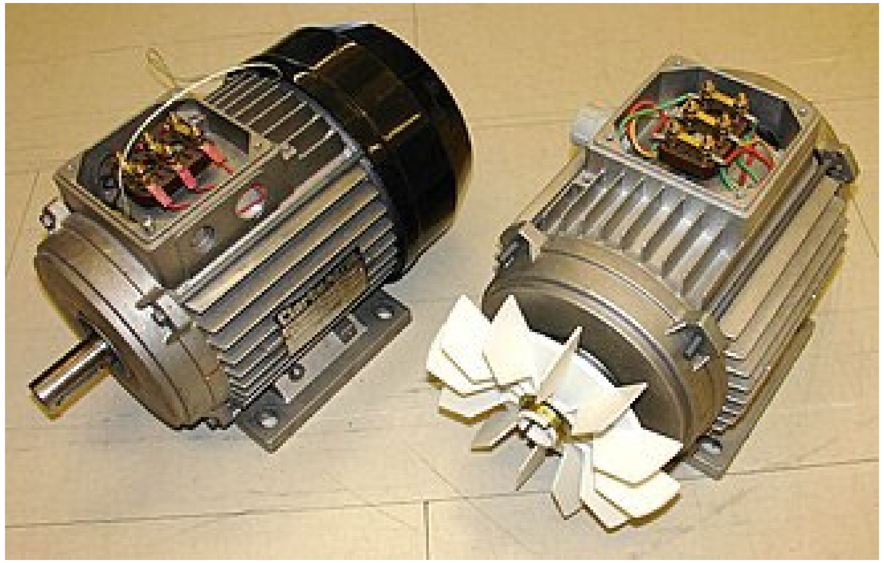
- A steel rod connected to the rotor.
- Transfers the motor's rotational motion to the load (e.g., pump, fan, conveyor).
- Must be strong, rigid, and precisely balanced.
- Can include a keyway or coupling for attaching pulleys, gears, or direct drives.

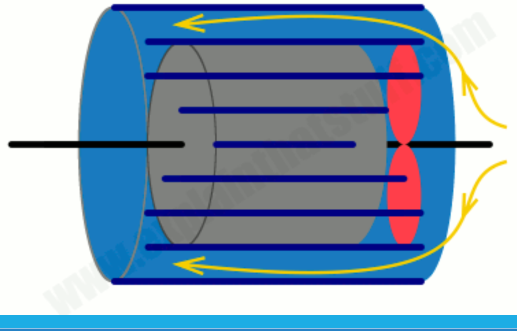
Construction – Shaft and Bearings

- Support the rotor and allow smooth, low-friction rotation of the shaft.
- Keep the rotor aligned in the stator air gap.
- Types commonly used:
  - Ball bearings – smooth, low friction, general purpose.
  - Roller bearings – for heavy loads.
  - Sleeve bearings – simple, used in small motors.
- Proper lubrication is critical for reducing wear and noise.

Construction – Internal Fan

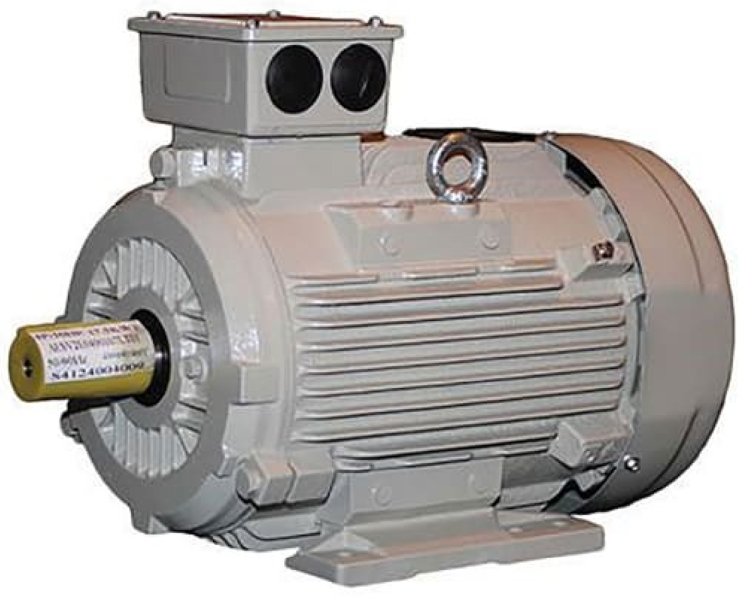
- Mounted on the motor shaft inside the housing.
- Spins with the rotor, forcing air over the motor windings.
- Provides cooling, preventing overheating during operation.
- Ensures longer motor life and efficiency.



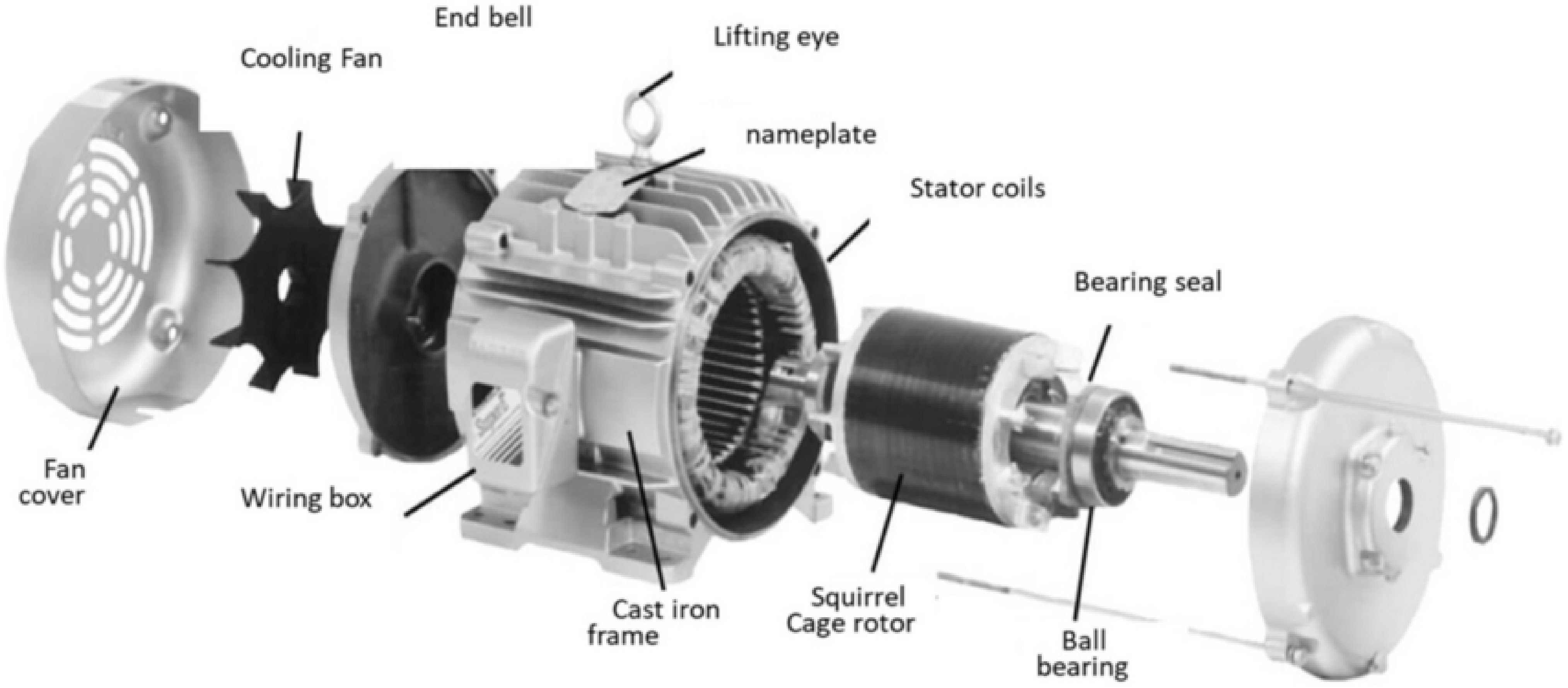


Construction – Motor Housing

- Outer casing of the motor, usually cast iron, aluminium, or steel.
- Protects internal components from dust, moisture, and mechanical damage.
- Designed with cooling fins to help dissipate heat.
- Provides mounting points for fixing the motor to a frame or machine.



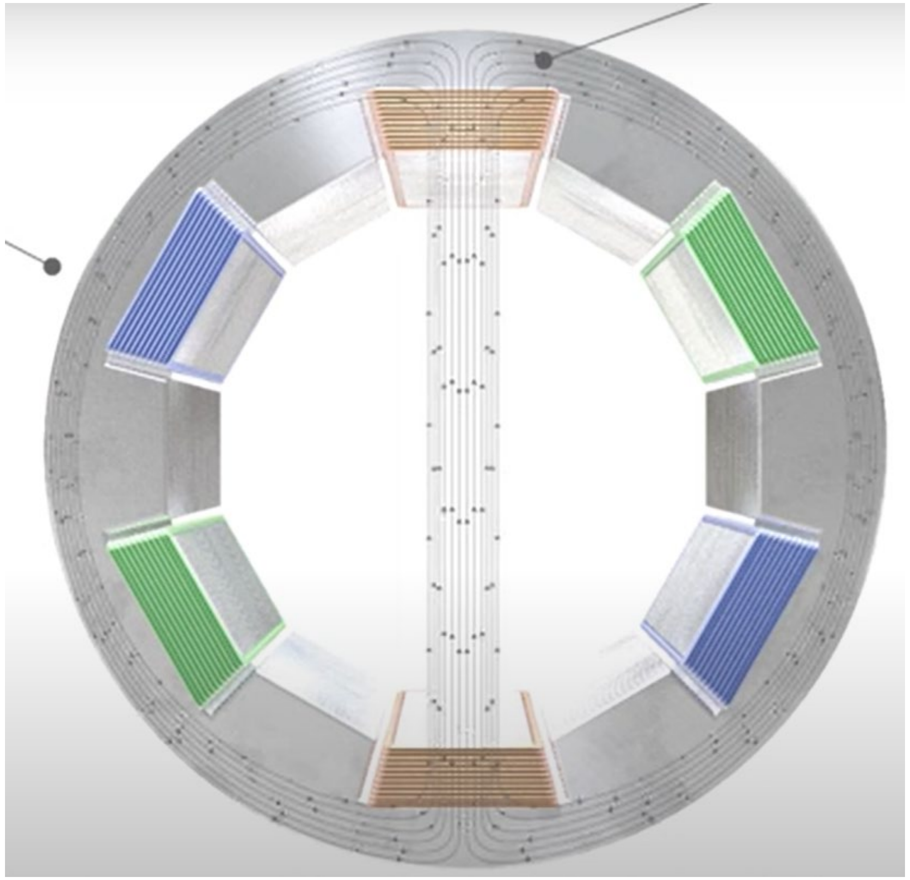
AC Motor Exploded Diagram



Operation - Stator

- When the windings have power put through them, they form a magnetic field

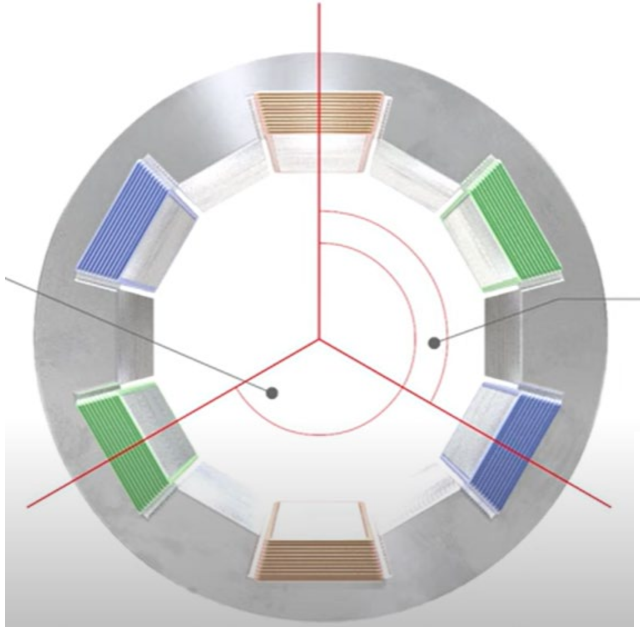
- The stator contains and conducts the field while also controlling the electrical field

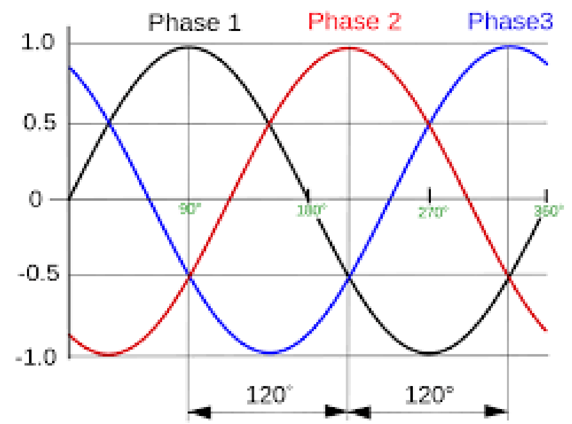


Operation – Stator (multi phase)

- In multi phase windings are evenly distributed across the stator in pairs, each pair being 120 degrees from the previous one

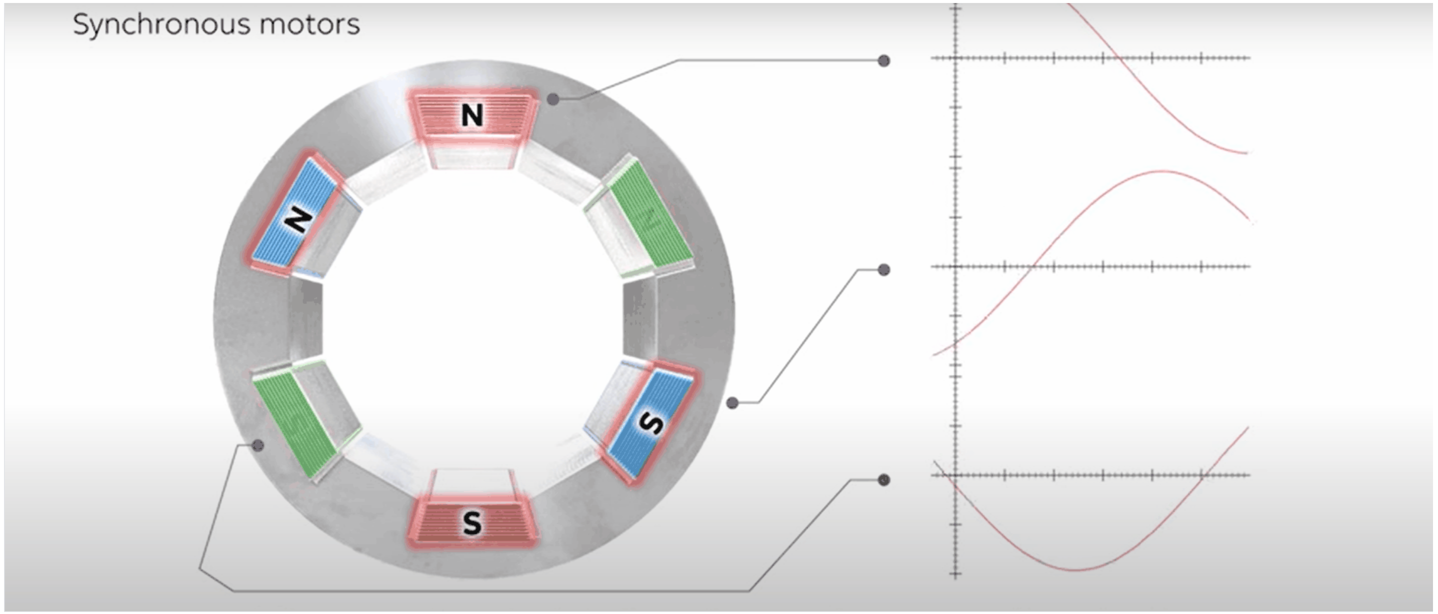
- As the 3 phases fluctuate their respective pairs of windings create their own magnetic fields taking turns



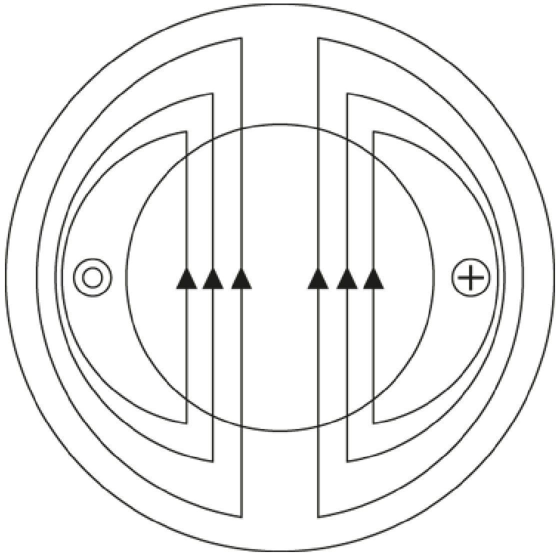


Operation – Stator (multi phase)

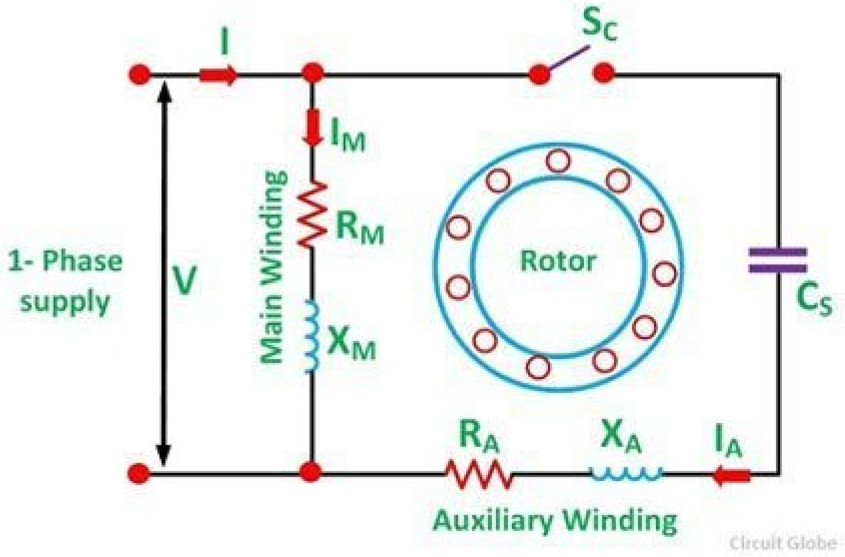
- This creates a rotating magnetic flux around the stator



Operation – Stator (Single Phase)

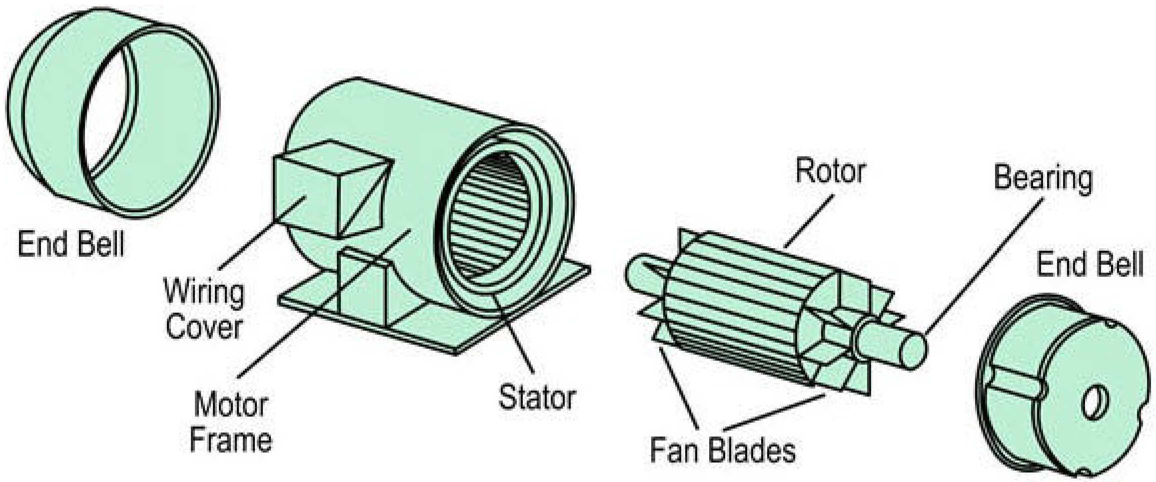


- With only one sinusoidal supply, the stator produces a magnetic field that pulses back and forth, not a true rotating field.
- This means a single-phase motor cannot start on its own.
- To create rotation, an auxiliary (starter) winding is added.
- A capacitor shifts the phase of the current in this winding, making its magnetic field slightly out of step with the main winding.
- The two fields combine to produce a rotating magnetic field, allowing the rotor to start turning even with only one phase of supply.



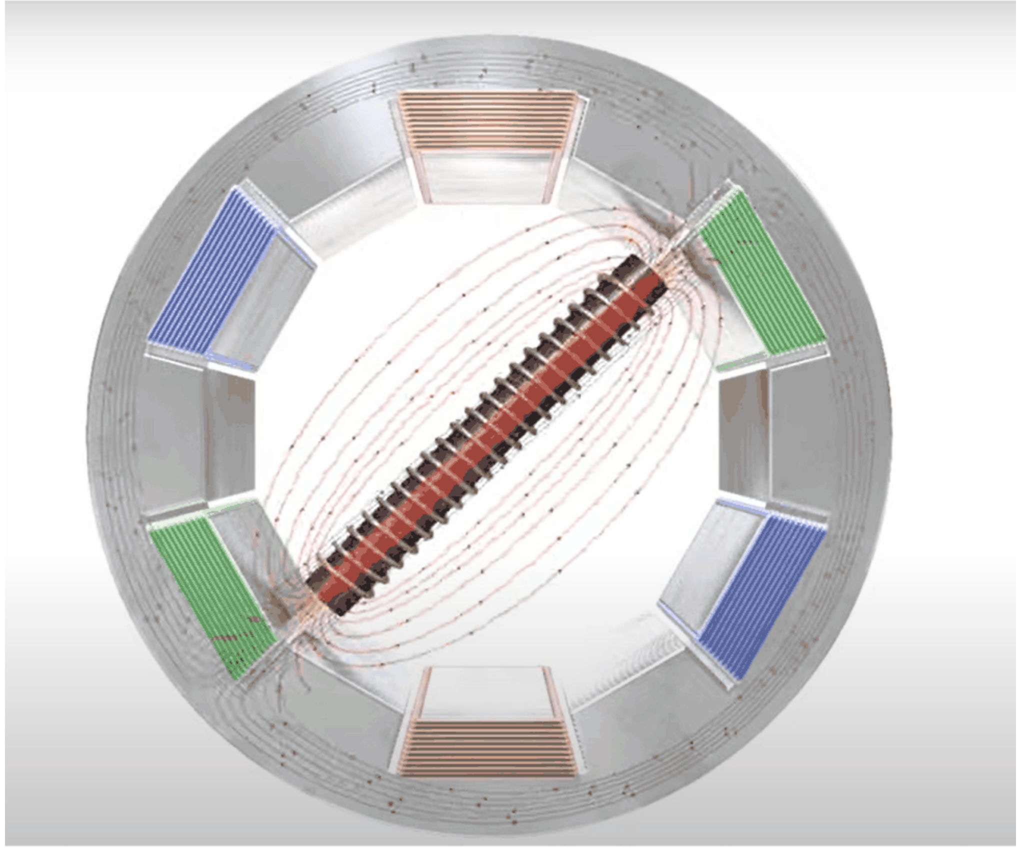
Synchronous Motor

- If you put a magnet inside a powered stator the magnetic fields will interact with each other and cause the magnet to spin
- The magnet in the middle can either be a DC electromagnet or a permanent magnet



Synchronous Motor

- This magnet will spin at the same speed as the flux does due to the interacting magnetic fields



Advantages of a Synchronous AC Motor

- **Constant Speed Operation** – Runs at a fixed speed (synchronous speed) regardless of load variations, making it ideal for precise speed applications.
- **High Efficiency at Full Load** – More efficient than induction motors at full load due to lower rotor losses.
- **Power Factor Correction** – Can operate at a leading power factor (over-excited condition), helping to improve the power factor of the entire system.
- **Stable and Reliable Performance** – No slip, which is beneficial for applications needing precise timing and synchronisation.
- **High Torque at Low Speeds** – Unlike induction motors, synchronous motors can deliver high torque at low speeds, useful in applications like rolling mills and crushers.

Disadvantages of a Synchronous AC Motor

- **Requires External Excitation** – Needs a separate DC source (exciter or permanent magnets) to magnetise the rotor.
- **Not Self-Starting** – Unlike induction motors, it requires an external starting mechanism (e.g., damper windings or a separate induction motor).
- **More Complex and Expensive** – Due to the excitation system and additional control components, it is costlier to manufacture and maintain.
- **Less Efficient at Partial Loads** – Efficiency can drop at lower loads, making them less suitable for varying load applications.
- **More Sensitive to Load Fluctuations** – Sudden load changes can cause instability, and if overloaded, the motor may lose synchronism and stop functioning properly.

Equation for Speed of an AC motor

$$N_s = \frac{120 \times f}{P}$$

Where:

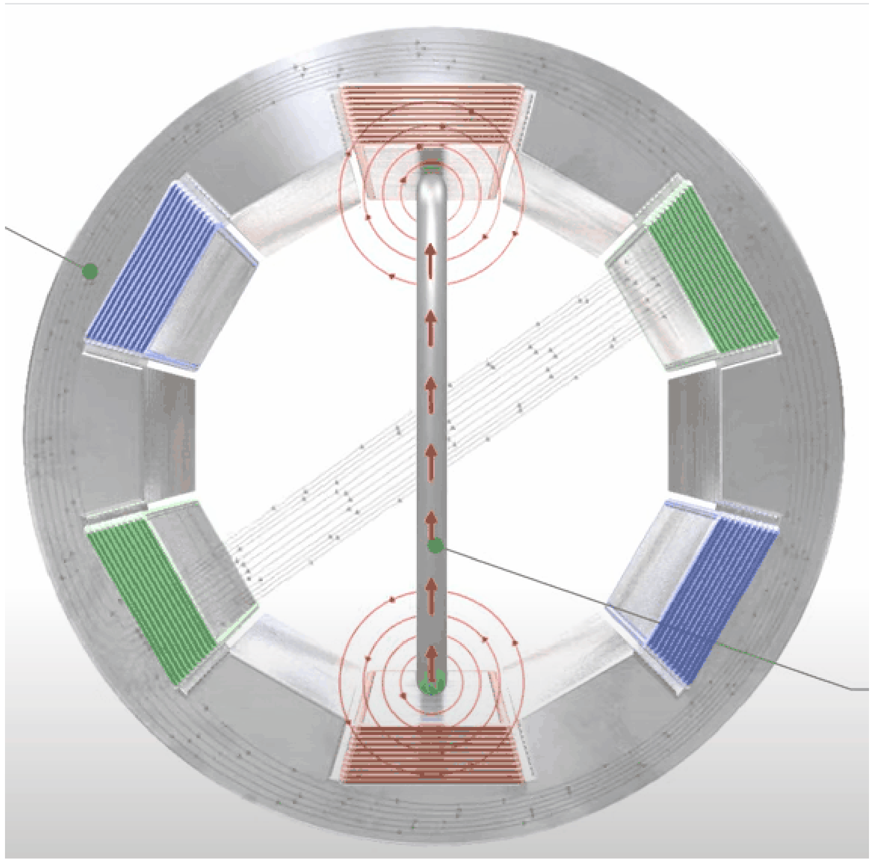
- N_s is synchronous speed (RPM)
- f is supply frequency (Hz)
- P is the number of poles

Asynchronous (Induction) motors

- Induction motors work differently from synchronous motors

- They rely on the idea of electromagnetic induction

- This means that the magnetic field from the stator induces an electrical current in the rotor which then generates its own magnetic field which interacts with the stator's producing rotational movement



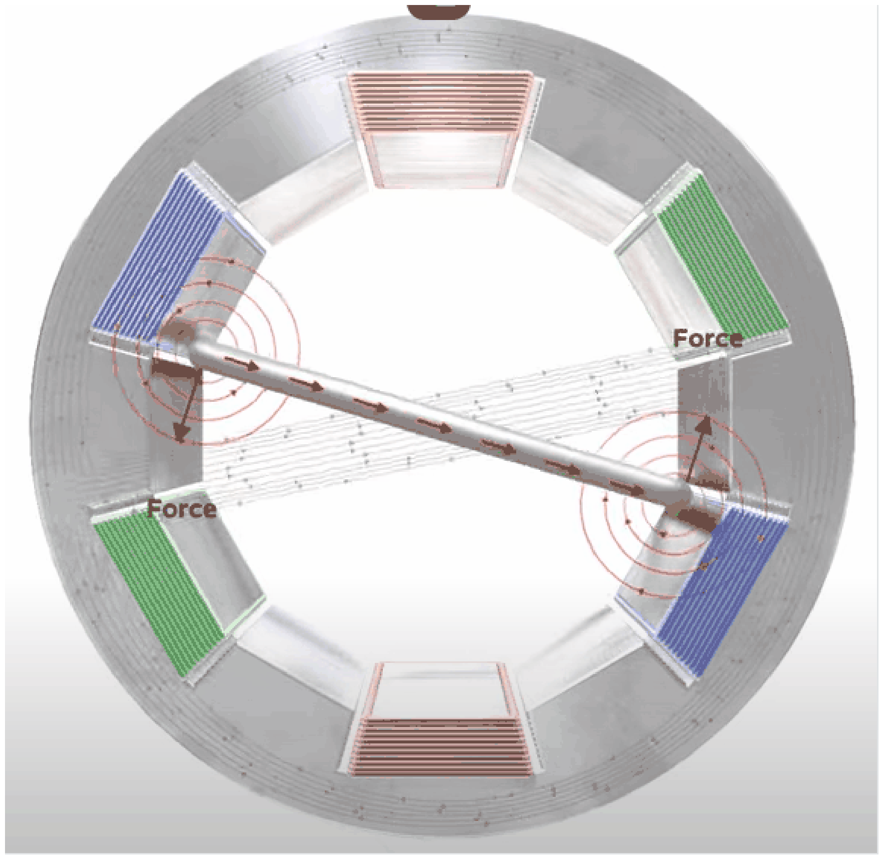
Asynchronous (Induction) motors

- For induction motors to work the rotor must turn slower than the rotation of the flux from the stator

- The rotor must turn slower as otherwise there would be no induced current in the rotor as the magnetic field interacting with it would not be changing

- This is okay because friction will cause the rotor to turn slower anyways

- The difference between the flux rotation and rotor rotation is called "**Slip**"



Equation for slip (Induction Only)

$$S = \frac{N_s - N_r}{N_s} \times 100\%$$

- Where:
- S = slip (%)
- N_s = synchronous speed (RPM)
- N_r = motor speed (RPM)
- 100% converts from decimal to %

Advantages of Induction Motors

- **Simple and Robust Design** – No brushes, commutators, or slip rings (in squirrel cage type), making them highly durable and low-maintenance.
- **Self-Starting** – No need for external excitation or starting mechanisms in most cases.
- **Cost-Effective** – Relatively cheap to manufacture due to simple construction.
- **Efficient and Reliable** – High efficiency at full load and long operational life.
- **Good Speed Regulation** – While not as precise as synchronous motors, induction motors maintain stable speeds under varying loads.
- **No Need for Separate Excitation** – Rotor current is induced by electromagnetic induction, eliminating the need for an external DC source.

Disadvantages of Induction Motors

- **Lower Efficiency at Partial Loads** – Efficiency drops significantly under light loads.
- **Lower Power Factor** – Operates at a lagging power factor, requiring power factor correction in large installations.
- **Speed Variation with Load** – Unlike synchronous motors, speed slightly decreases with increasing load due to slip.
- **High Starting Current** – Draws a large inrush current during startup, requiring additional starting methods (e.g., star-delta starters, autotransformers).
- **Limited Speed Control** – Speed control is less efficient and more complex compared to DC or synchronous motors.