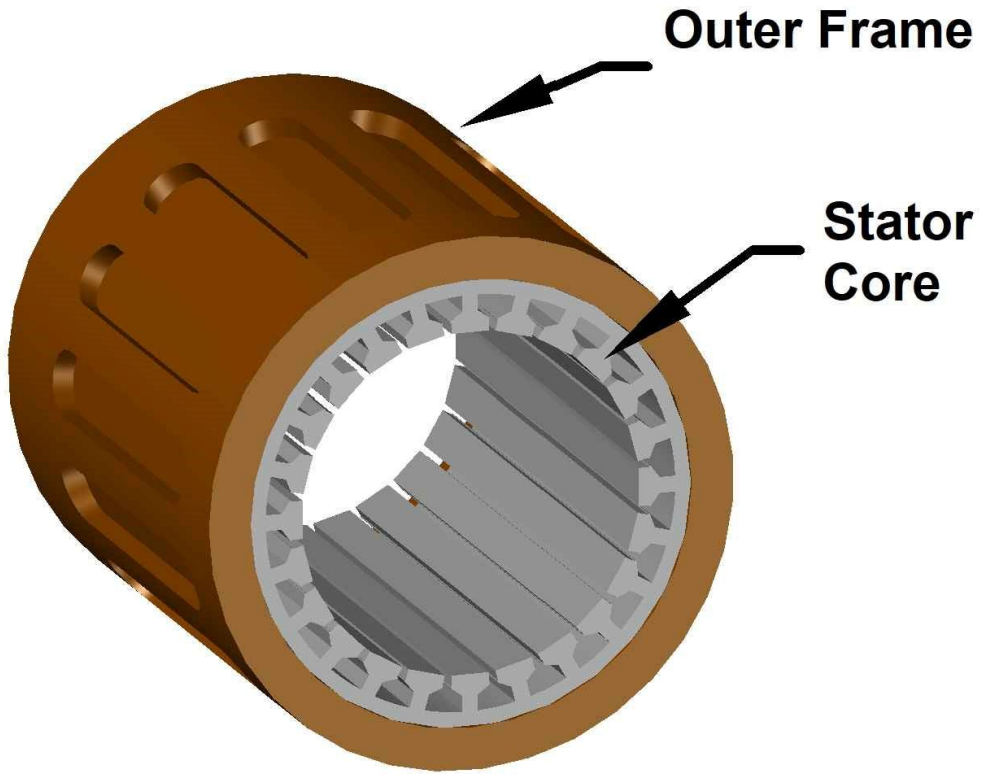
AC Motors

What is an AC motor

- An AC motor has the same purpose as a DC motor
- 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

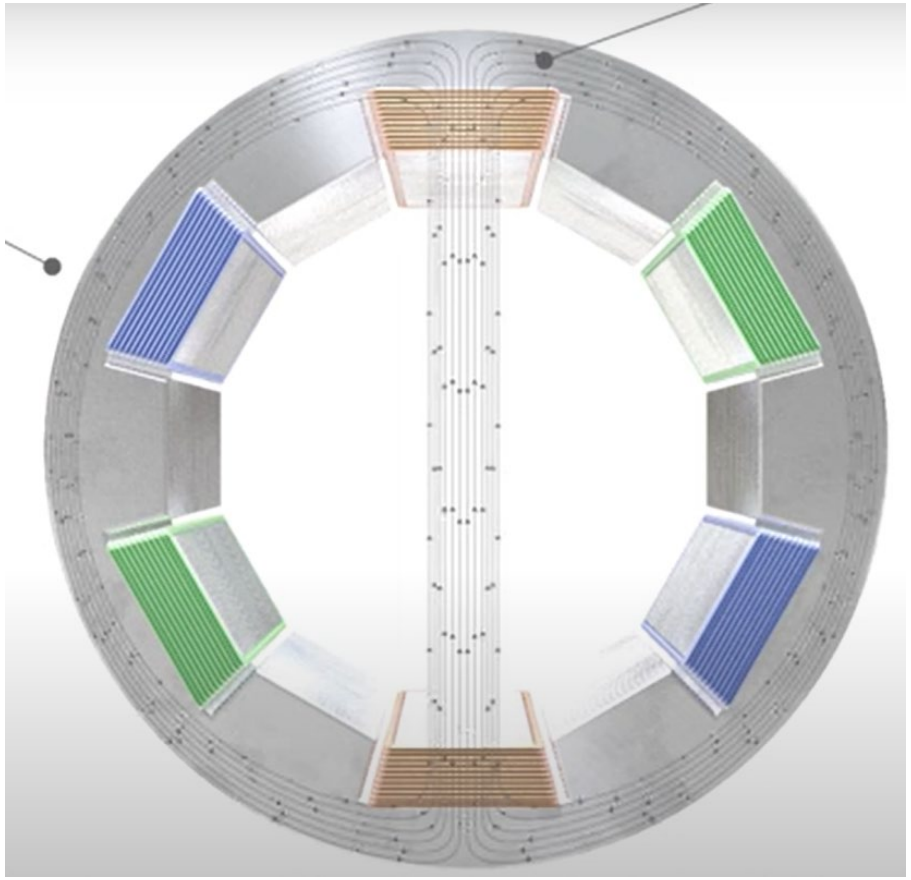
Stator

- 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.
- The more slots for windings there are the slower the motor's speed and the same vice-versa



Stator

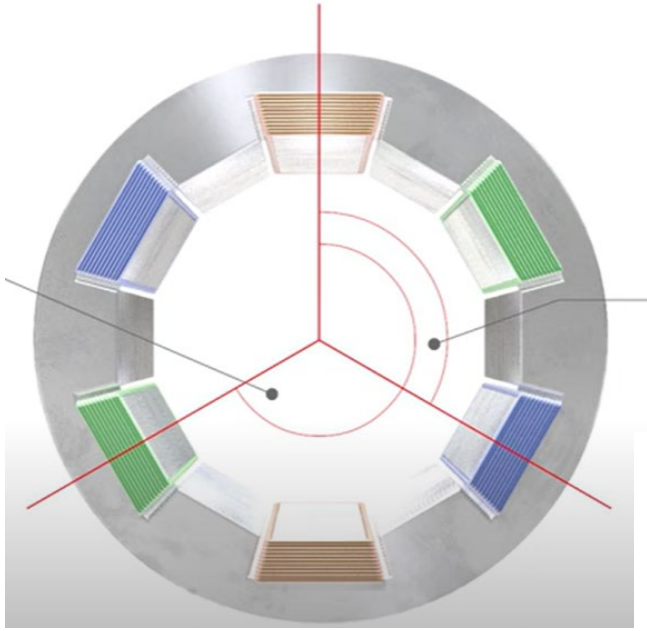
- When the windings have power put through them, they form a magnetic field
- The stator contains and conducts the field while also controlling the electrical field

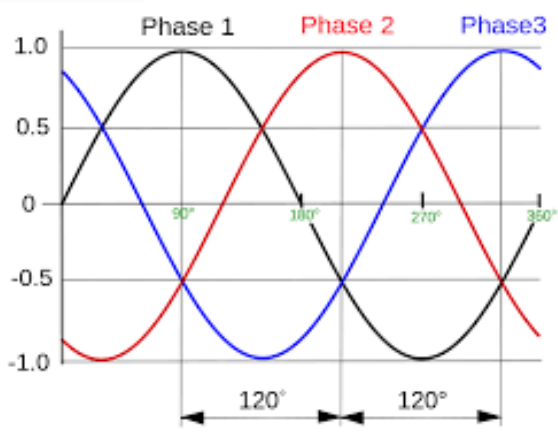


Stator

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

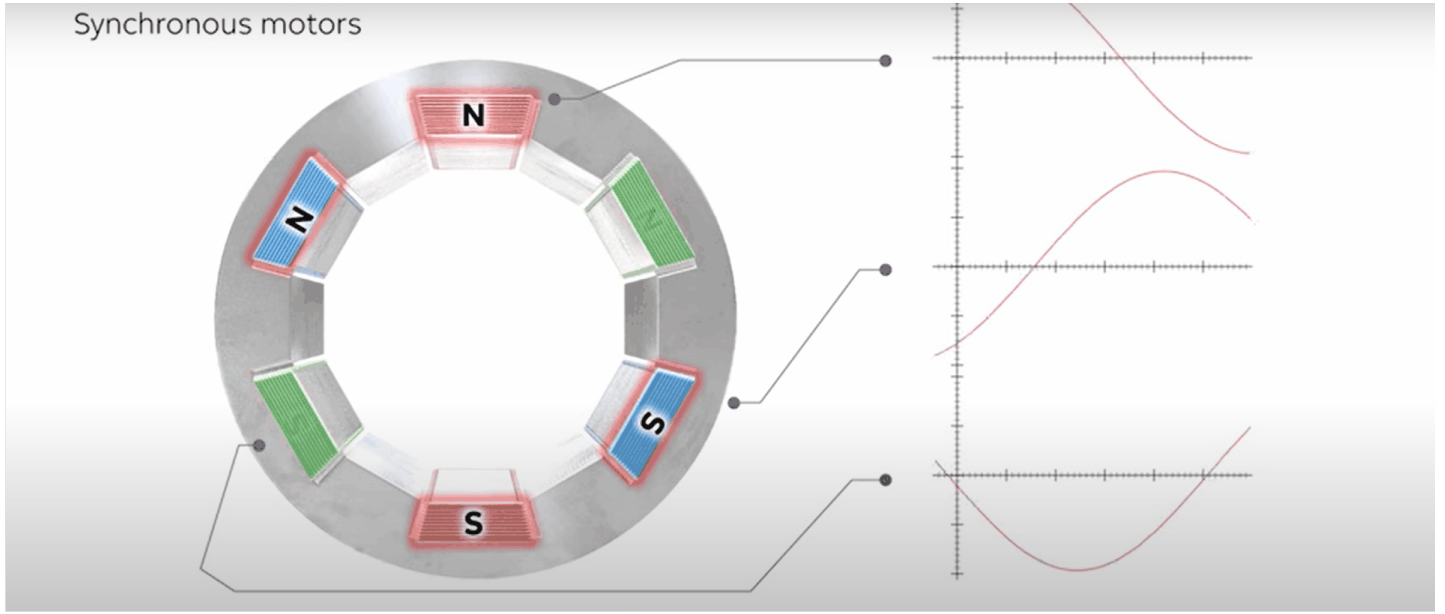
- As the 3 phases fluctuate their respective pairs of windings create their own magnetic fields taking turns





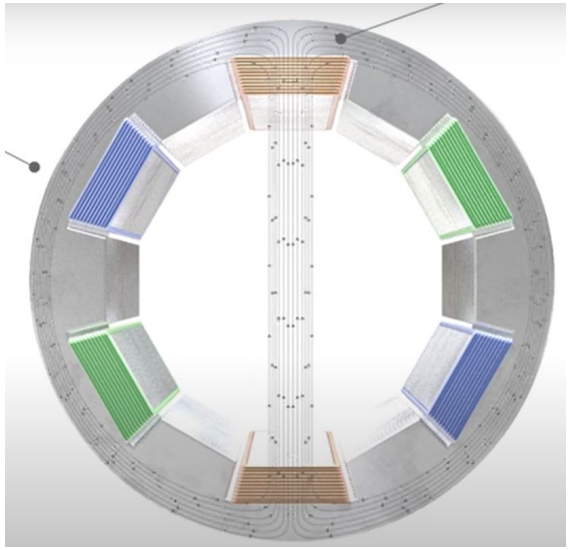
Stator

- This creates a rotating magnetic flux around the stator



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.



Equation for Speed of an AC motor

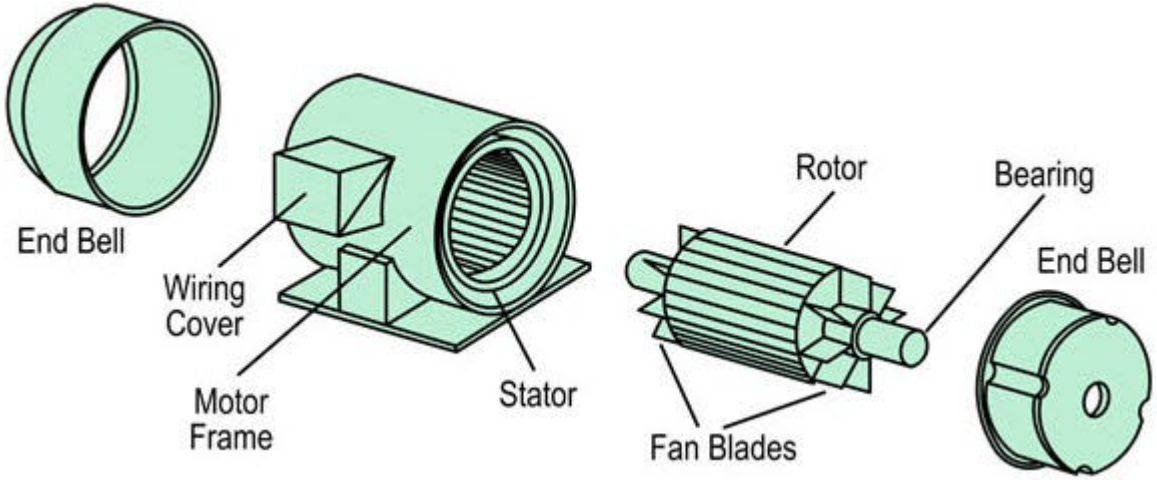
$$N_s = \frac{120 \times f}{P}$$

Where:

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

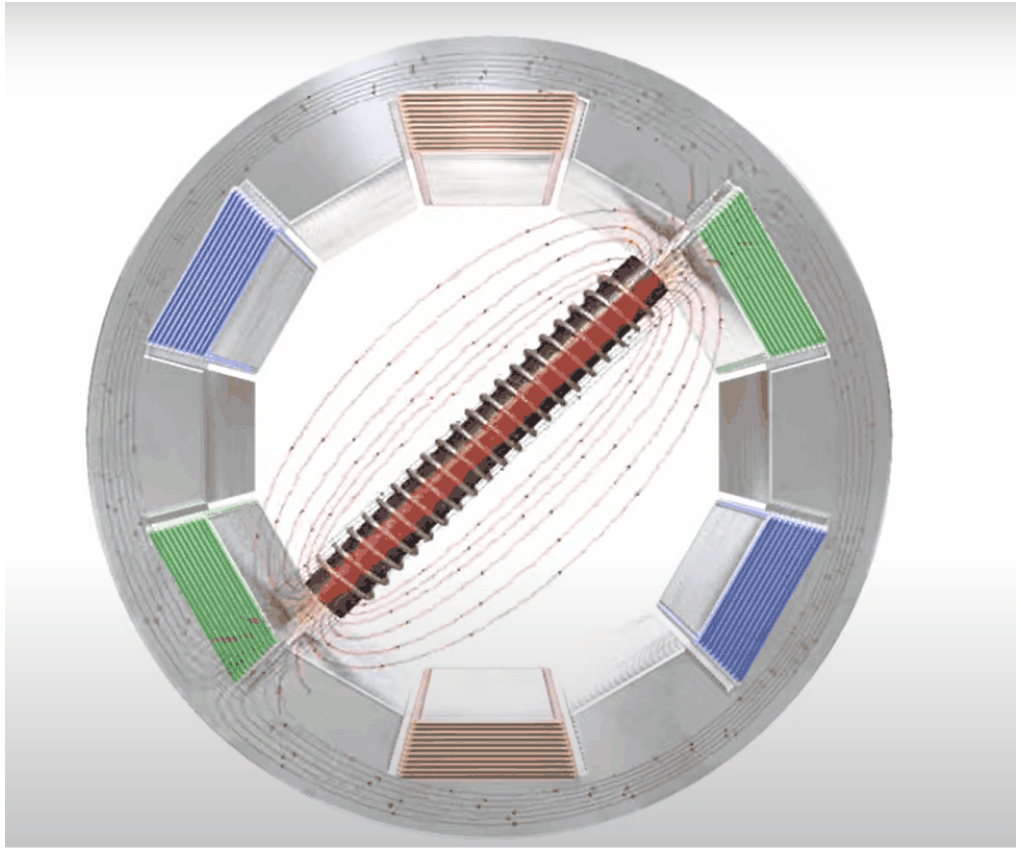
Synchronous Motor

- 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

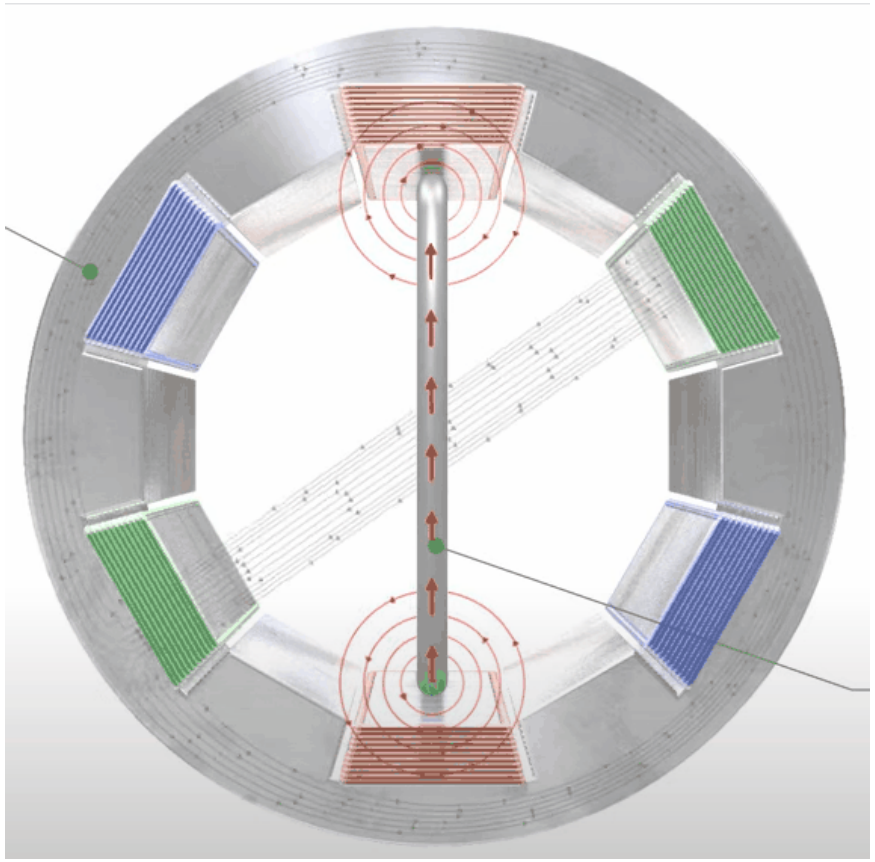
- **Constant Speed Operation** – Runs at a fixed speed (synchronous speed) regardless of load variations, making it ideal for precise speed applications.
- **High Efficiency at Full Load** – More efficient than induction motors at full load due to lower rotor losses.
- **Power Factor Correction** – Can 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.

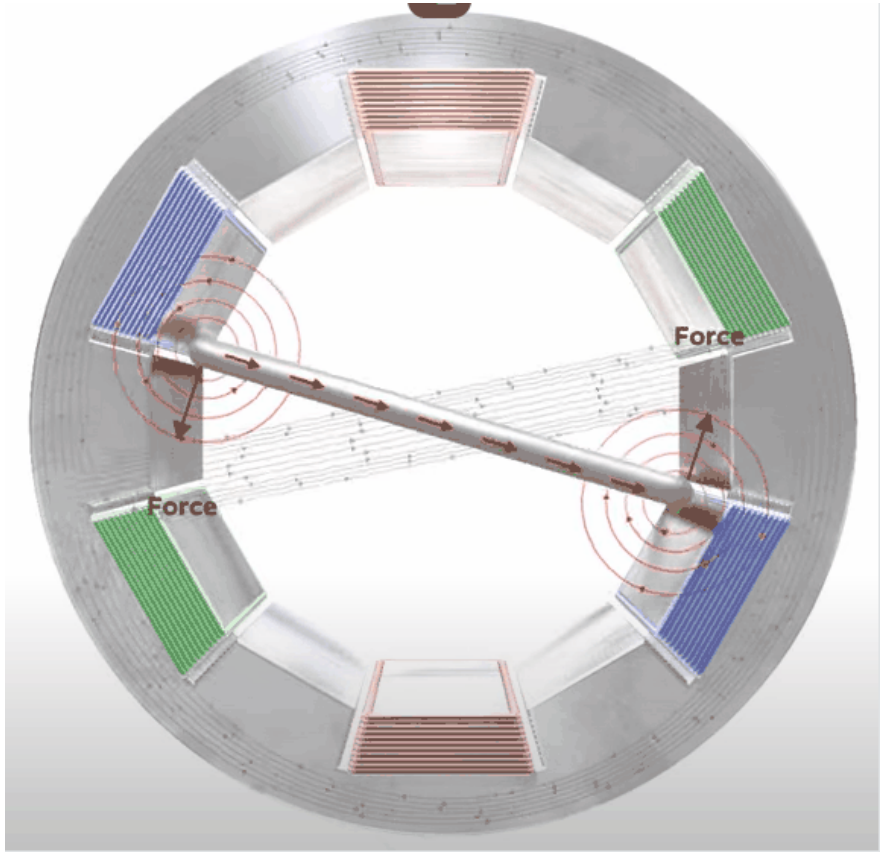
Induction motors

- 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



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**”



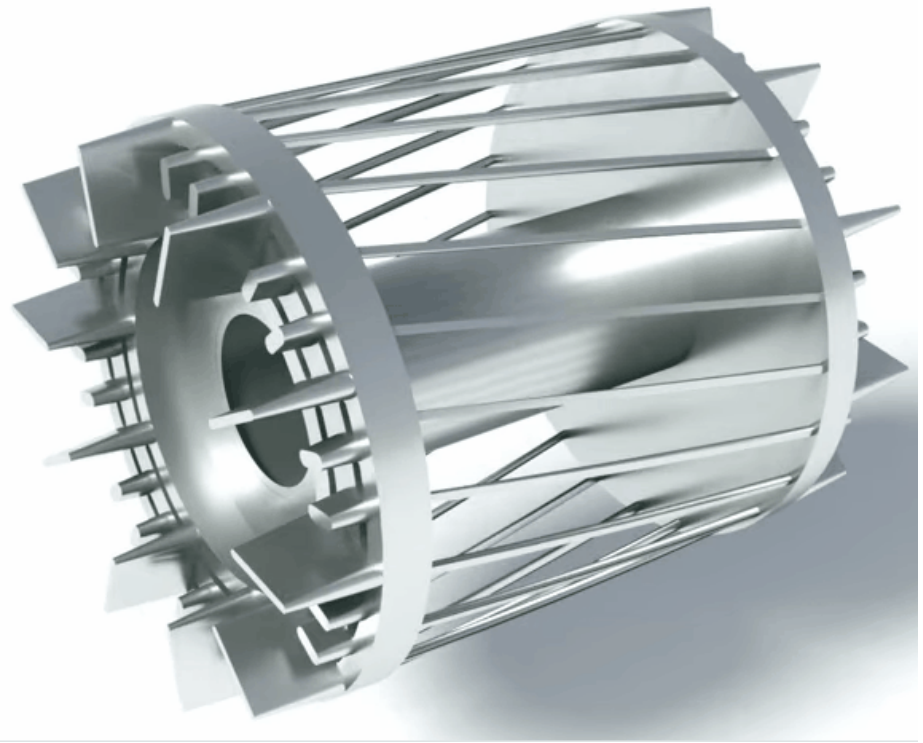
Equation for slip (Induction Only)

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

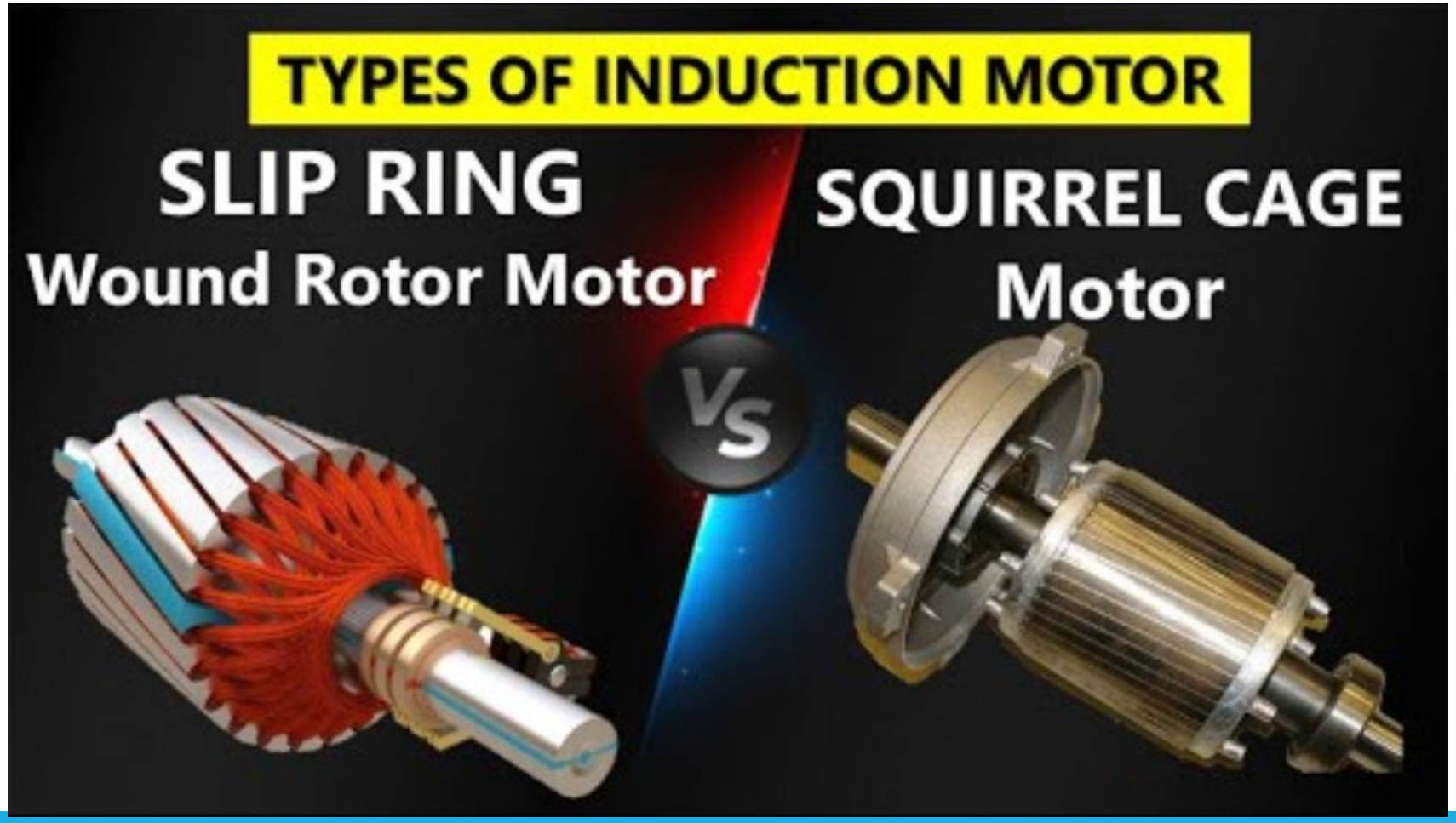
- Where:
- S = slip (%)
- N_s = synchronous speed (RPM)
- N_r = motor speed (RPM)
- 100% converts from decimal to %

Modern Induction Motors

- Modern induction motors use multiple parallel conductors to form their rotors
- This allows more the motor to have more power (torque)
- These are commonly referred to as squirrel cage motors



Squirrel Cage vs Wound Rotor (slip ring) Induction motors



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.