

# Copper v/s Aluminium (Squirrel) Cage Rotor (of Induction Motor)

The induction motor (*especially in Mines*); is required to operate under frequent Start - Stop conditions, Poor to Moderate Supply Grid Strength leading to substantial dip in Starting Power, etc. .

## 1. Superior Starting Performance

1.1. Aluminium cage rotors inherently possess **higher rotor resistance** compared to Copper cages, which results in:

- 1.1.1. **Higher Starting Torque**, enabling reliable acceleration of high-inertia loads
- 1.1.2. **Smoother Torque-Speed characteristic** during run-up

## 2. Reduced Starting Current

2.1. The higher rotor resistance of aluminium cages also leads to:

- 2.1.1. **Lower locked-rotor current**, typically 10–20% lower than equivalent copper cage designs
- 2.1.2. Reduced voltage dip on the power supply
- 2.1.3. Lower stress on upstream electrical infrastructure such as transformers, cables, and starters
- 2.1.4. This makes fabricated aluminium cage motors particularly suitable for **weak grids, DG-backed supplies, and frequent start-stop applications.**

## 3. Lower Rotor Weight and Inertia

3.1. Aluminium has significantly Lower Density than copper, resulting in:

- 3.1.1. **Substantially reduced rotor Mass**
- 3.1.2. Lower moment of inertia ( $GD^2$ )
- 3.1.3. Faster acceleration and deceleration
- 3.1.4. Reduced transient mechanical stresses on shaft and coupling
- 3.1.5. This contributes to improved dynamic behaviour and enhanced mechanical reliability of the motor.

## 4. Improved Bearing Life and Mechanical Reliability

4.1. Reduced rotor mass / weight directly translates into:

- 4.1.1. **Lower radial and dynamic loads on bearings**
- 4.1.2. Reduced bearing temperature rise
- 4.1.3. Improved bearing L10 life expectancy

## 5. Centrifugal Stresses on Rotor Bar Short Circuit Ring End Joints :

- 5.1. When Large Rating x High / Medium Speed Motor's Rotors are rotating, they experience substantial Centrifugal Stress which can cause the Rotor Bars & it's Short Circuiting Ring (*the End Section of the Bars*) to behave Dynamically Differently which in Turn imposes Tensile & Shear Stresses onto the Bar – Short Circuit Ring Joint.
- 5.2. This Joint can be made either by Brazing or by Casting or by Welding. The key difference is Type & Depth of **Melting** :
  - 5.2.1. Casting melts the Entire Metal – the Bars as well as the Short Circuiting Ring & then Cools them – needless to say, it has Excellent Electrical Conductivity as well as Strong Mechanical Joint.
  - 5.2.2. Welding melts the base metals Locally to fuse them & then cool them - creating the Strongest Mechanical Joint as well as Good Electrical Conductivity
  - 5.2.3. But, Brazing melts only a Filler metal (*often a Tin Silver Bronze composition*), without melting the Copper Bars or Copper Short Circuiting Ring - making it Acceptable for Electrical Conductivity but has Poor Mechanical Strength.
  - 5.2.4. Aluminium Joints of Rotors are made from Molten Aluminium itself (*-i.e. either Welding or Casting*); the Strength of this Joint is 100% equal to that of the Parent Material -i.e. Aluminium.
    - 5.2.4.1. Aluminium has a very favourable Strength to Weight Ratio as proven by a Century of Aircrafts which are now exclusively made from Aluminium.
    - 5.2.4.2. Hence Aluminium Rotors are Superior for Frequent Start Stops & have Lower Problems associated with Bar Ring End Joint Stresses as compared to Copper Rotors.
  - 5.2.5. However, Copper Joints of Large x High Speed Motors cannot be made by Welding or Casting – it has to be made only by Brazing & hence is inherently a Weak Mechanical Joint.
  - 5.2.6. Additionally, with the recent Supply Chain Issues in Copper, Silver, etc; Quality of Brazing Rods is (& will continue to) Deteriorating rising even more questions on reliability of Copper Bar (*Brazed*) Rotors.

## 6. Copper Rotors

### 6.1 Find Favour In :

- 6.1.1. Ultra Large motors,
- 6.1.2. Custom Built x Small Batch motors,
- 6.1.3. Water Filled Motors &
- 6.1.4. Ultra High Efficiency (*say IE4 beyond*) of Motors is demanded

6.2 But Need to have a :

- 6.2.1. Strong Power Supply Line to cater to Larger *(than Aluminium)* InRush Current during Starting.
- 6.2.2 Reinforced Bearings due to Larger Mass *((than Aluminium) for Same kW)*
- 6.2.3. Strong Supply Chain *(given the recent disruptions/volatility in Copper, Silver)*

## 7. Conclusion

- 7.1. Nearly 90%+ Motors World Wide are built with Aluminium Rotors & they work well & so do the 10% with Copper.
- 7.2. As a **Rule of Thumb**, for most Pumping Applications; Motor Rotors can either be specified **Either with Aluminium** *(except Water or Oil Filled Motors)* **Or Copper** *(based on the Manufacturer's Design against the very specific demand)* – **however, for Motors of :**
  - 7.2.1. High Speed -i.e. **2P 3000rpm** *(@ 50Hz & Any Voltage level),*
  - 7.2.2. **LT** *(upto 1000V)* **of Any kW &**
  - 7.2.3. **Up to IE3** Motor Efficiencies

**Aluminium Rotors are Techno Commercially much more Economical & Safer Choice.**