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Copper Alliance

## Copper Rotors for Induction Motors: New Technologies Make Copper Die-Casting Economically Feasible

Copper Alliance  
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# Copper Rotors for Induction Motors: A New Era is Beginning

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## Copper: The material of choice for rotors

Copper's significant advantages over aluminium – such as its high conductivity (57 MS/m vs. 37 MS/m) – make it the material of choice for a number of induction motor applications worldwide.

The high melting point of copper has historically led to die-casting problems.

However, new yet fully proven copper die-casting technologies are now leading to possibilities for industrial copper rotor production.

Market potential is high, meeting end user requirements for regulation, cost and environmental compliance.

Manufacturing is low risk with minimal barriers and significant economic and environmental advantages.

# What is a copper rotor?

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## Introducing the (copper) rotor

The rotor is the non-stationary part of a rotary electric motor, electric generator or alternator.

A copper rotor is a rotor made of electrical steel (laminations) where the slots and end rings are filled with copper instead of the traditional material (aluminium).

The use of copper in place of aluminium can lead to improvements in motor energy efficiency due to a significant reduction in  $I^2R$  losses (the power lost in an electrical device due to the current flowing through the motor's windings).



# The end user advantages of copper rotors vs. aluminium rotors

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## A) Copper leads to cost savings over aluminium

Two avenues to adopt copper rotor technology:

### 1) Same dimensions Higher efficiency

- Energy savings which will pay back the higher cost of copper within a reasonable time
- A lower Total Cost of Ownership

### 2) Same efficiency Smaller and Lighter

- The motor can be made lighter and smaller (compensating for the higher cost of copper)
- A lower purchase cost in some sizes is possible

# The end user advantages of copper rotors vs. aluminium rotors

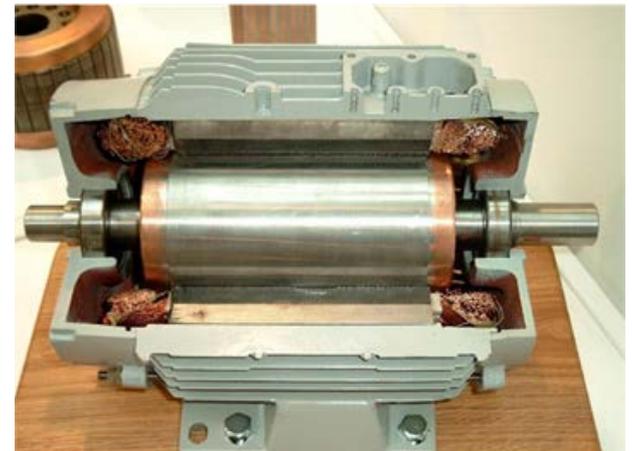
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## Avenue 1: Design for higher efficiency

Copper has the second highest electrical conductivity of all metals. It is 70% more conductive than aluminium. So replacing aluminium with copper lets the rotor conduct heat and electrical current more efficiently.

The increased efficiency pays back the extra investment, lowering the costs over the life cycle. Payback times will depend on the kind of application (load and operating hours)

The resulting lower temperatures let the motor run cooler and extend its life – motor life is generally halved for every 10°C rise in operating temperature. Some copper rotor induction motors generate so little heat that they don't need the cooling fans.



# The end user advantages of copper rotors vs. aluminium rotors

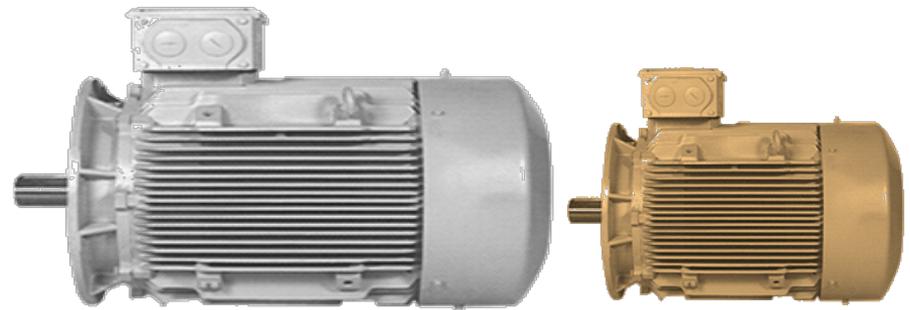
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## Avenue 2: Design for same efficiency

Although counterintuitive, the overall weight of a copper rotor can be reduced by replacing an aluminium rotor with one cast using copper.

This is because the higher efficiency of the copper rotor allows the overall length of the rotor (and motor) to be decreased, while still matching the performance of a motor utilizing an aluminium rotor. Shortening the motor:

- Eliminates some of the rotor and stator laminations.
- Decreases the number of stator windings.
- Reduces the length of the shaft.



# The end user advantages of copper rotors vs. aluminium rotors

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## B) Copper offers superior thermal capacity to aluminium

Copper has higher conductivity and higher thermal capacity than aluminum, which translates into the following benefits:

- A lower temperature rise during operation.
- Fewer cooling facilities are required.
- A more compact and lighter machine is possible.
- An easier fit into a monoblock motor system.

# The end user advantages of copper rotors vs. aluminium rotors

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## C) The use of copper enhances the surrounding steel

The higher melting point of copper compared to aluminium means that the surrounding steel parts become hotter, which in turn changes the structure and characteristics of the steel.

Surprisingly, the influence is positive. The steel is more energy-efficient and has a higher electromagnetic permeability.

# The end user advantages of copper rotors vs. aluminium rotors

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## D) Copper increases a motor's reliability

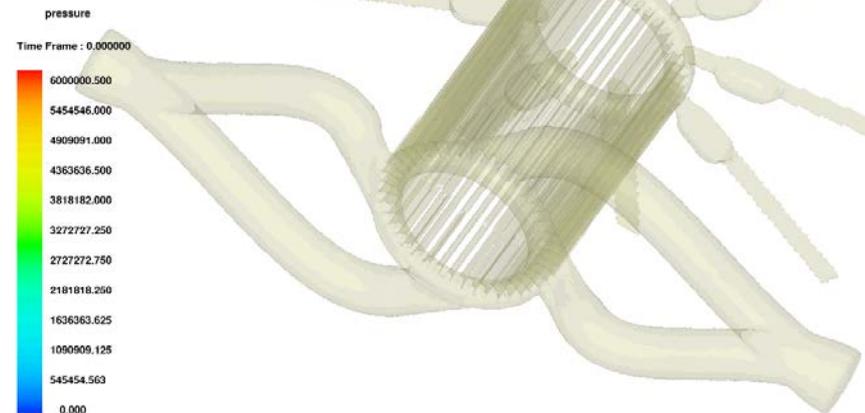
**The increased reliability of a copper rotor motor is due to:**

- The higher strength of copper.
- Lower temperature differences during operation.
- The positive influence of high temperature die-casting on the surrounding steel parts.

## Overcoming the high melting point of copper

Melting points: Copper = 1083°C / Aluminum = 660°C.

This made die-casting of (pure) copper technically difficult or virtually impossible for a long time. Recently, several breakthroughs in copper die-casting have removed the previous die-casting problems. The technology has been fine-tuned to make it economically viable.



## Global interest in copper die-casting is growing

Companies in Europe, US and Asia are now up and running with copper die-casting, including:

- Europe: Breuckmann (Germany) / Favi (France) / Kienle+Spiess (Germany).
- US: Ramco / Remy / THT / Vforge.
- Asia: Akashi (Japan) / Fukuta (Taiwan) / Yunnan Copper Die-casting (China).



## Be prepared for significant global growth

The market for copper die-cast rotors is expected to grow significantly:

- Medium-scale, regular production is now taking place.
- New die-casting technology is becoming more accepted.
- Around 1 million copper die-cast units are in use worldwide.
- Mass production is now possible and economically viable.



Current and future applications are under development

Initial interesting applications include industrial low voltage induction motors (100 W – 100 kW) and traction applications. More applications will follow in niche sectors, such as corrosive atmospheres, special cooling needs, cranes, and maintenance with rotor replacement (increasing efficiency of existing motors in heavy-duty applications).



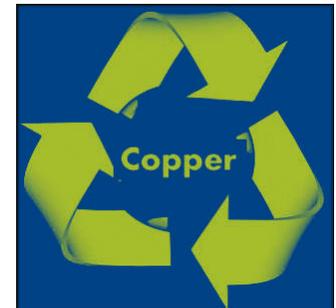
## Technologically and economically feasible

A number of sorting techniques are being tested and proved, such as X-ray fluorescence.

The large-scale recycling of copper is considered to be technologically feasible.

The high scrap value of copper makes recycling economically feasible:

- For 1 ton of rotor scrap with 25% copper, the value of copper is about 10 times higher than steel.
- At 8000 USD/ton, copper value is 1500 USD. At 200 USD/ton, steel value is 150 USD (discount for copper in copper rotor scrap = 25%).



## The benefits of recycling copper

- **Environmental** – Recycling of copper leads to the emission of few, if any, harmful gases.
- **Landfill costs** – Recycling of copper avoids its expensive disposal in landfills.
- **Energy saving** – To extract copper from copper ore, the energy required is approximately 100 GJ/tonne. Recycling copper uses much less energy, about 10 GJ/tonne. This energy saving leads to the conservation of valuable reserves of fossil fuels and consequent reduction of CO2 emissions.
- **Conservation of copper ore** – To date only about 12% of known copper resources have been mined. However copper ore is a finite resource and it makes sense to conserve ore by recycling.



## The future for the copper rotor is highly promising

**Copper is the natural choice for a rotor due to its high conductivity.**

**Thanks to new die-casting techniques, copper rotors can now be manufactured on an industrial scale.**

**Main advantages: cost savings, higher efficiency, weight and space savings, improved thermal capacity, improved steel properties, increased reliability.**

**Recycling of copper rotors is technologically and economically feasible.**



## Copper Rotors for Induction Motors: New Technologies Make Copper Die-Casting Economically Feasible

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