Copper Rotor Motors – White Paper
For: European Copper Institute

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Plan Design Enable

Summary

- To make the most of CRM technology, a full re-design of the motor is needed.
- CRM technology makes it possible to design more efficient motors in the same frame size and stack length.
- For the same efficiency, CRM technology can offer a lower cost solution than is possible with the use of aluminium rotor bars.
- CRM offers the designer the options of greater efficiency and lower temperature operation. It may also be more compact.
- Part load performance will vary according to the detail of the design
- Copper inherently allows more frequent start:stops.

What are the intrinsic properties of cast copper rotors?

Better thermal conductivity

Rotors cool down faster and so more frequent starts is possible.

Lower Porosity

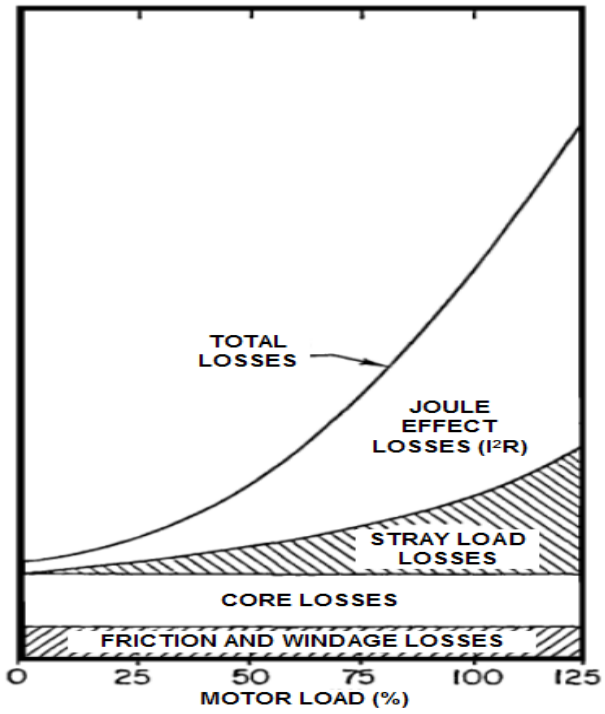
But would aluminium rotors be as good if they had heated dies?

This gives a better balanced rotor.

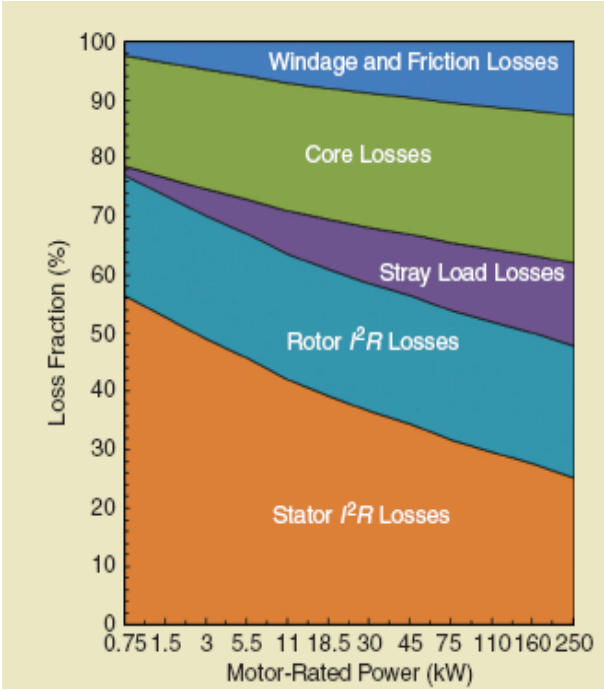
Model based analysis

- Lots of good papers showing the benefits of CRM technology. For this exercise, the interest was to understand the relative costs for the same performance.
- University Of L'Aquila created model optimising copper and aluminium rotor motors for the **same** technical performance.

Breakdown of losses



... As a function of load



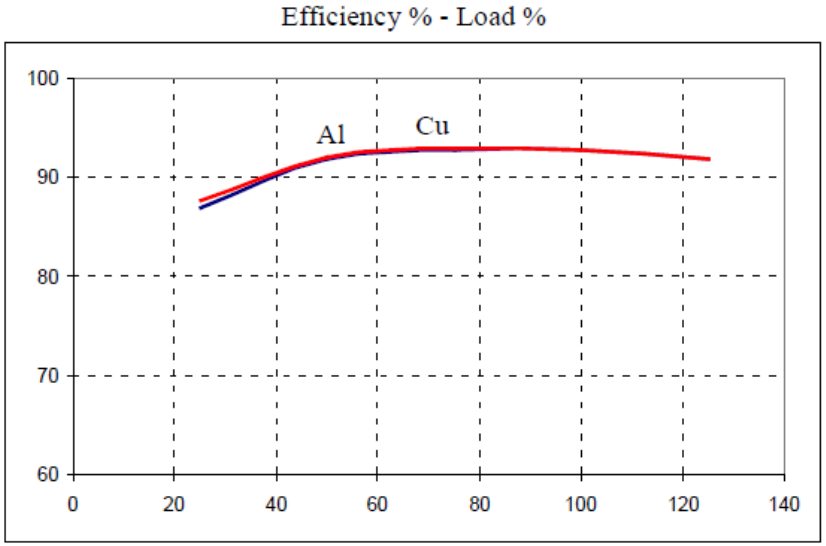
... As a function of size

Model assumptions

- Number of stator and rotor slots
- Air gap length
- Slot fill factor
- Stator slot opening
- Rotor skewing
- Shaft diameter
- Winding distribution
- Winding factor
- Stator slot insulation
- Thermal coefficients (for the modelling)
- Stray losses (assumed to be 2% of the output power)
- Laminations 330-50 AP (0.5mm thickness).

Material	Cost (€/kg)
Copper wire	7.08
Copper pellets (for rotor)	6.16
Steel laminations (inc pressing scrap)	0.911
Aluminium	1.76

Example – A cost Optimised 22kW Motor using CRM vs ARM Technology



η = 92.7% (IE3)		Al	Cu
Electrical steel		330-50 AP	330-50 AP
Stack length	(mm)	215	205
Outer stator diameter	(mm)	290	285
N. of turns x phase		84	84
Wire size	(mm^2)	6.36	4.80
Stator slot area	(mm^2)	200	164
Rotor slot area	(mm^2)	122	83
Phase current	(A)	20.3	20.2
Speed	(rpm)	2933	2939
Power factor		0.93	0.93
Temperature (°C):	Stat. winding	60	62
	Rotor cage	70	72
Joule losses (W)	Stat. winding	414	510
	Rotor cage	516	467
Iron losses	(W)	390	360
Starting Current/Rated Current		9.0	9.0
Starting Torque/Rated Torque		4.4	4.2
Max Torque/Rated Torque		4.8	4.7
Weight (kg);	Gross iron	135	124
	Stator winding	17.37	12.69
	Rotor cage	2.45	5.18
Active Material Cost (∈):			
	Scenario_1	232.6	217.2
	Scenario_2	250.1	234.6
	Scenario_3	267.9	252.1

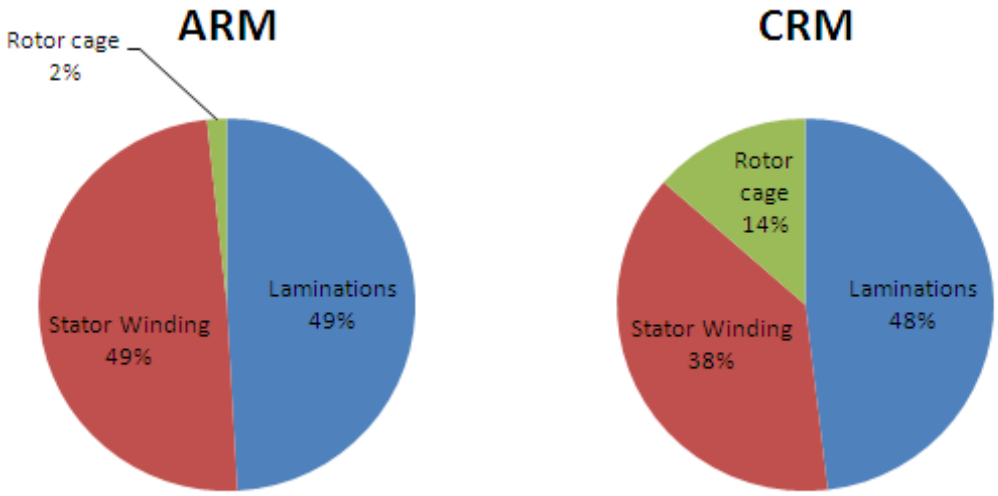
Different rotor material, different material cost distribution

Key Observations

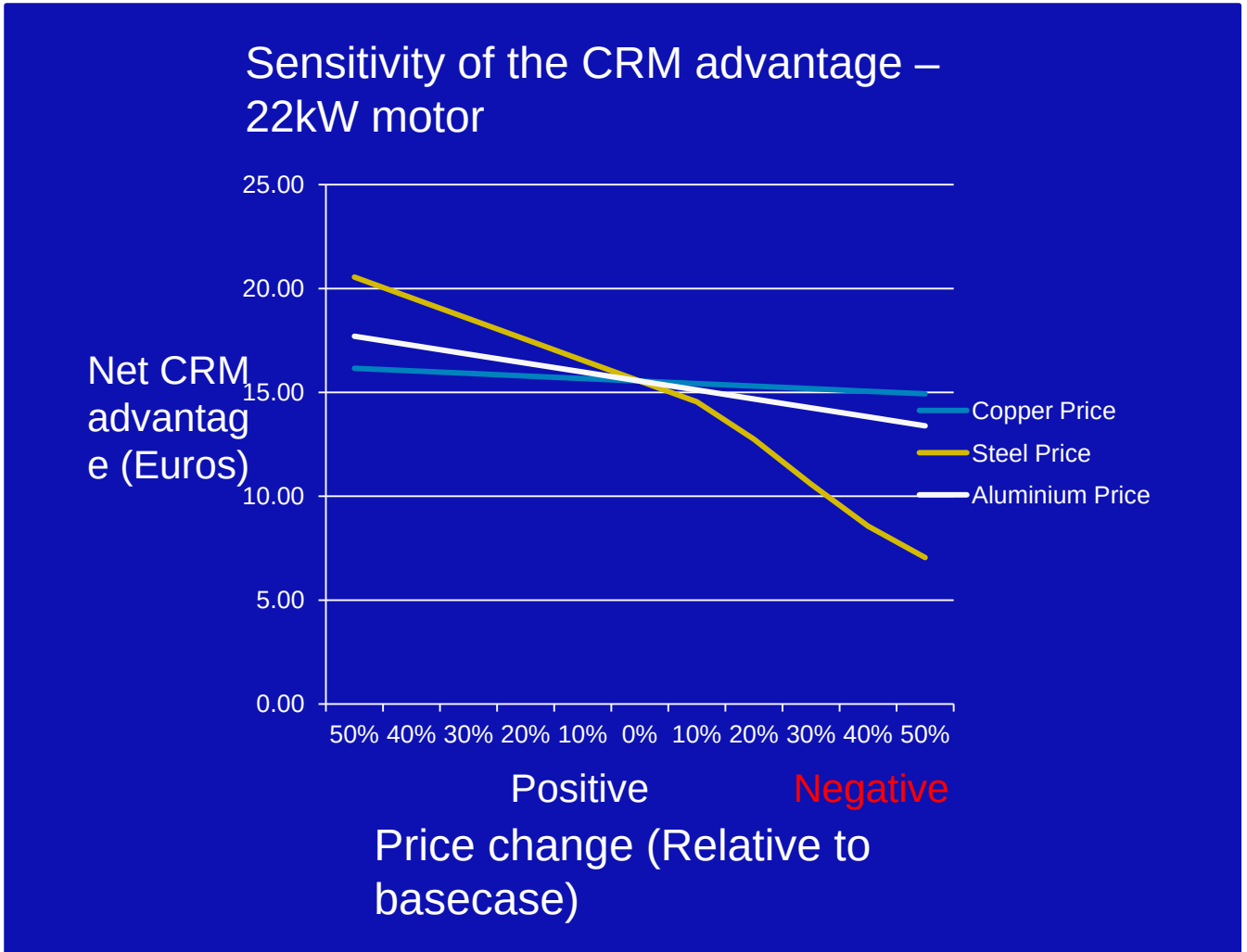
Its the smaller lamination stack that pays for the cost of the copper.

In this model, it was economic to increase stator losses.

The cost of the Aluminium rotor is negligible.



Cost sensitivity of CRM



Lower Slip

- Induction motors rely on the slip (the small difference in speed between the rotor and stator field) for their torque. If there was no slip, there would be no torque. Lower rotor resistance inherently gives less slip, and so the motor will run slightly faster.
- Greater shaft stiffness.
- Higher running speed, meaning that adjustment of the load may be necessary in some circumstances.

Conclusions

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