



Copper use in high efficiency electrical rotating machines

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LSEE – (Environment and Electrical Systems research Lab)

Motor Workshop 2017 – European Copper Institute

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Laboratoire Systèmes Electrotechniques
et Environnement



UNIVERSITÉ D'ARTOIS

Lab characteristics



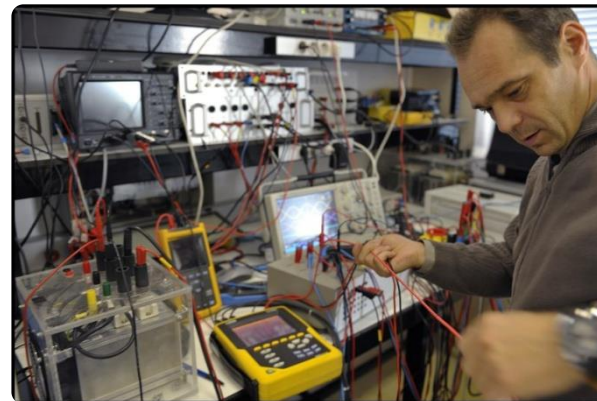
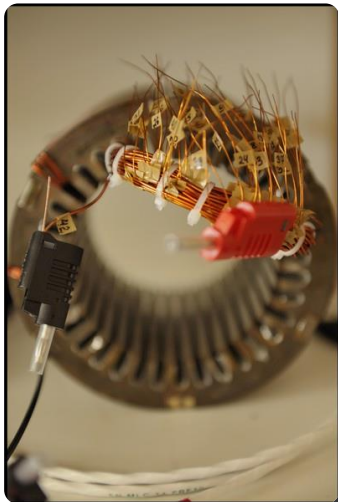
→ Staff :

- 5 full Prof, 9 Associate Professor
- 12 Ph-Students – 4 Post-Doc & Engineers
- 2 technical staff



→ Research Field ⇨ Applied research on :

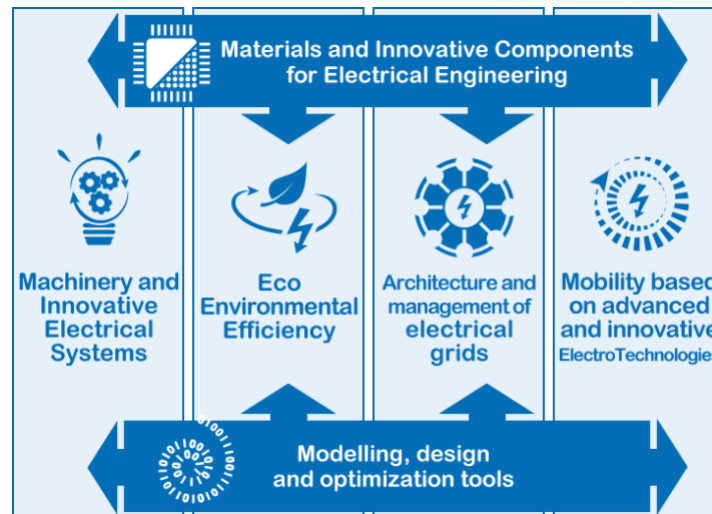
- Electrical machines and transformers
- Constitutive parts : Electrical Steel Windings



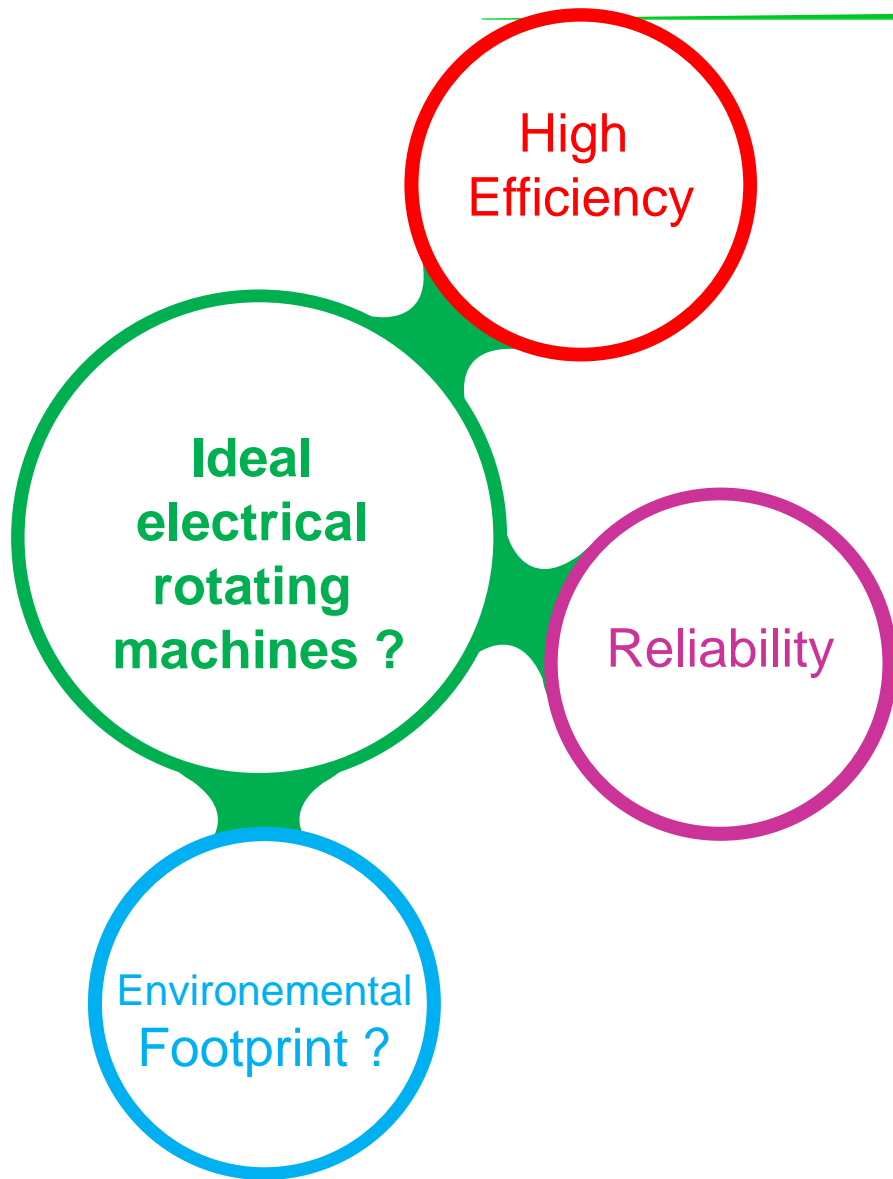
Lab characteristics



- **Location** : North of France (Béthune)
- Research Centre of the **University of Artois**
- Strong support of the cluster **MEDEE**
(Motors and Electrical Devices for Electrical Efficiency)



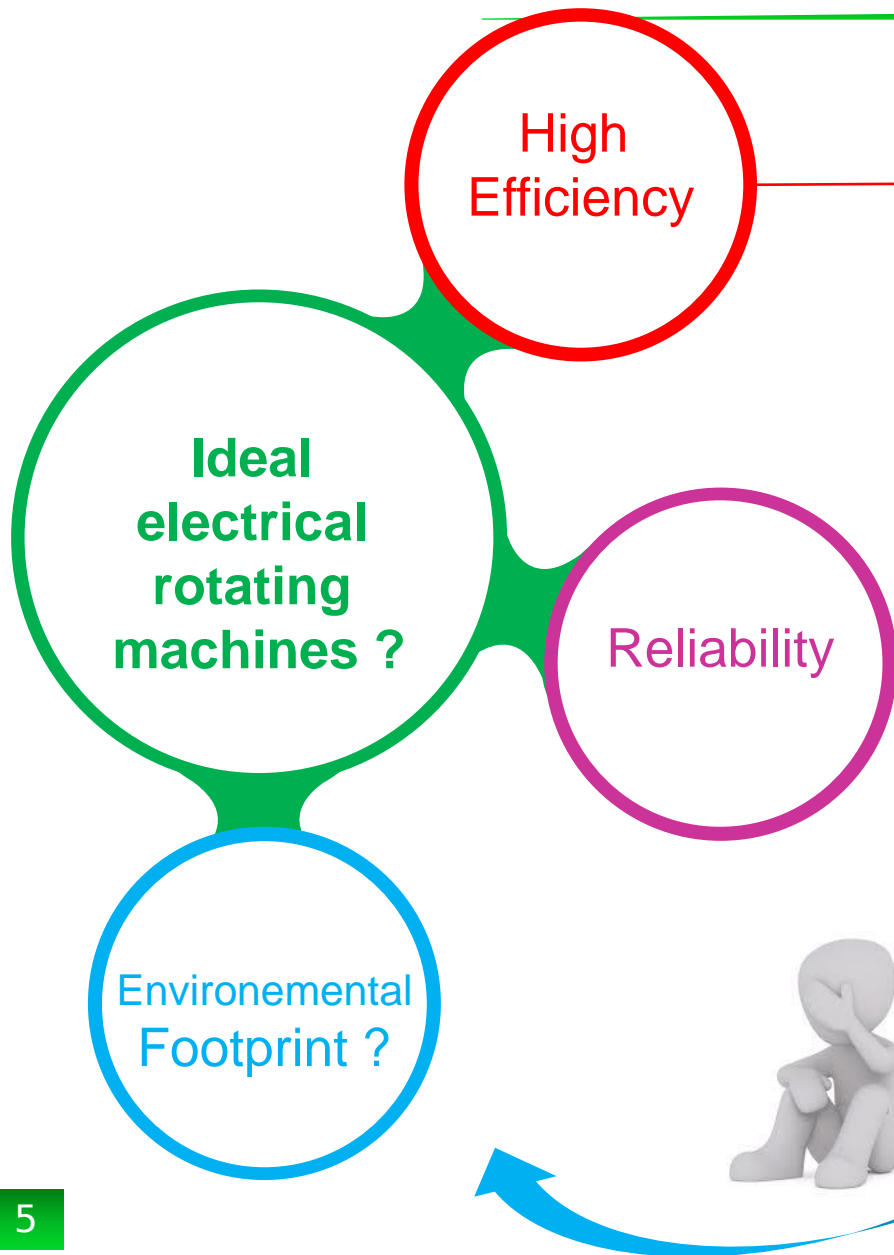
Electrical machines



How copper can be use in this context ?



Electrical machines



High
Efficiency

... of the application !

Example: aircraft

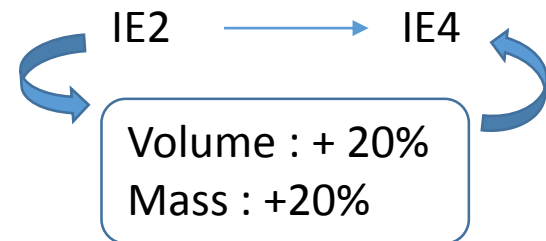


Electrical motor with :

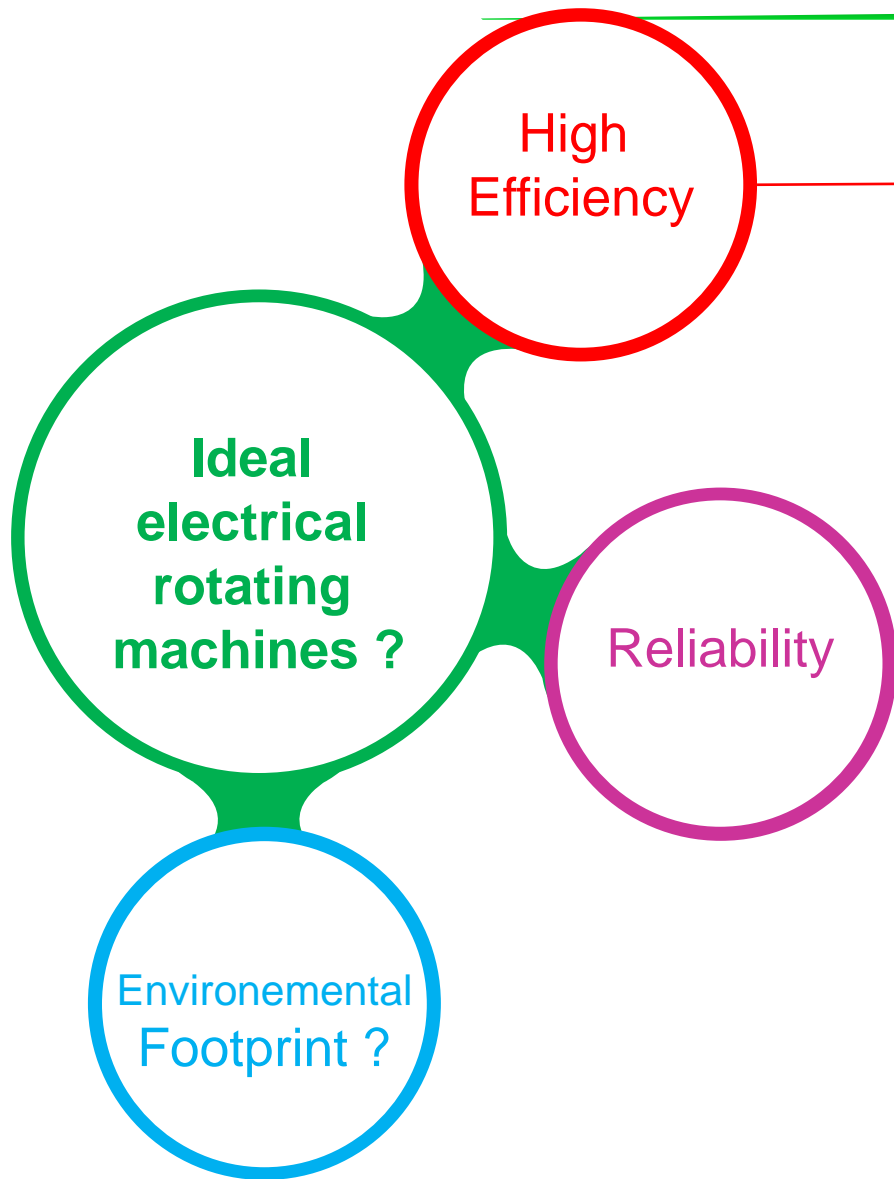
- High efficiency
- High power density



Cases of induction machines



Electrical machines



... of the application !

Example: aircraft



Electrical motor with :

- High efficiency
- High Power to Weight ratio



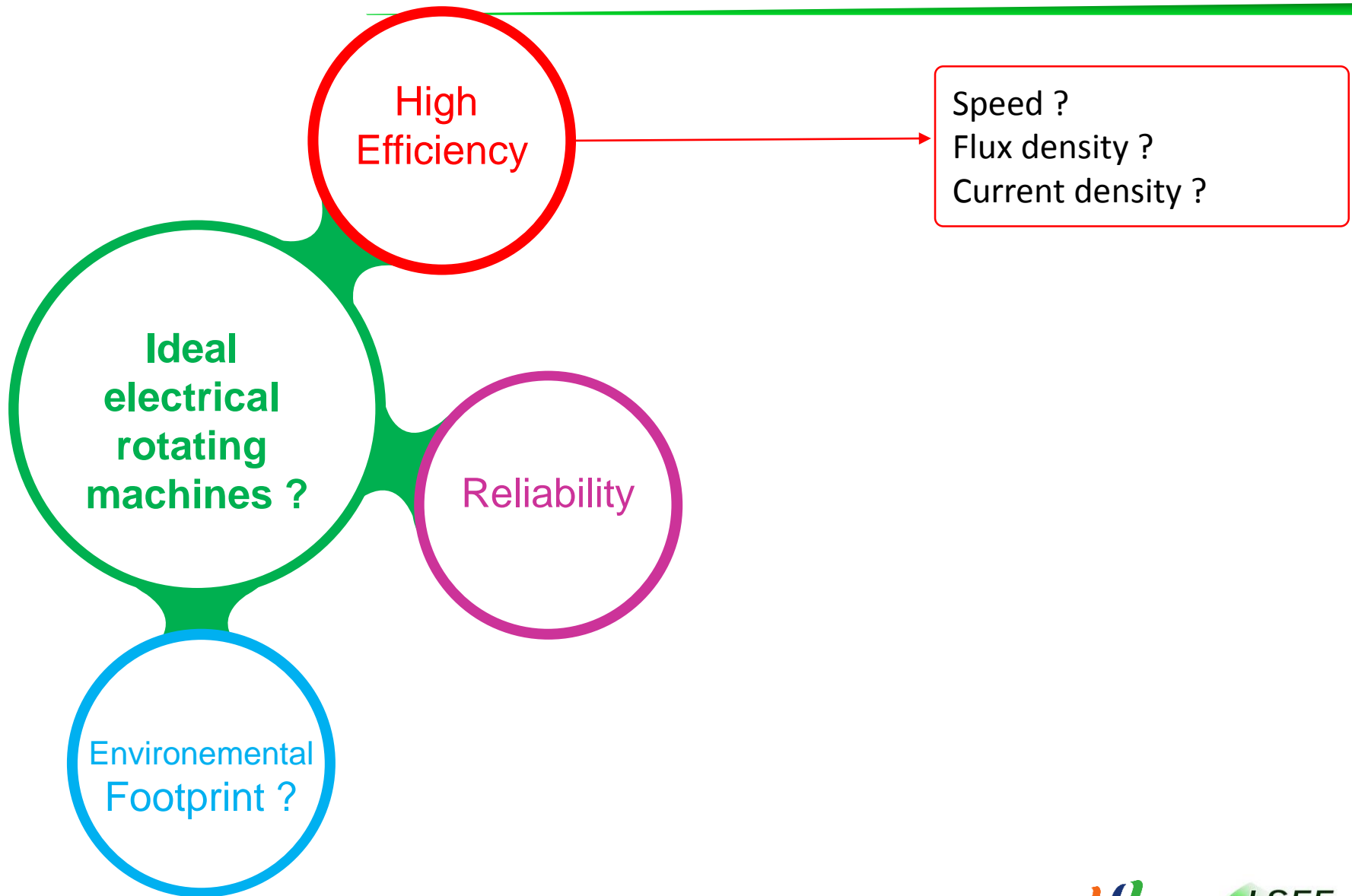
2025 Goal :
15 to 20
kW/kg

Today :
600W/kg
10kW/kg (peak)

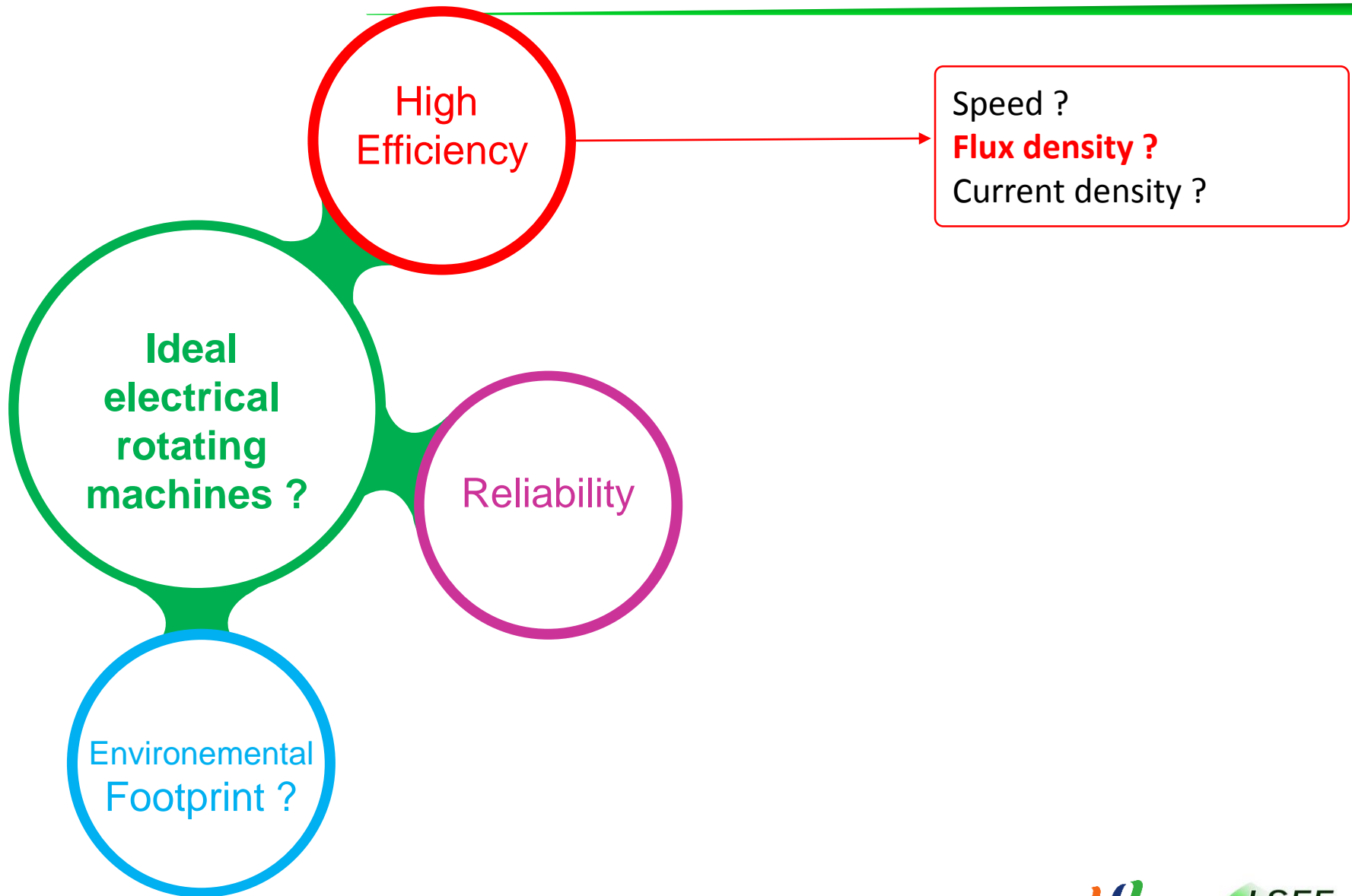
EMRAX 268



Electrical machines



Electrical machines



Electrical steel → in link to copper

Induction machine with Grain Oriented electrical steel : How ? Why ? Partner ? Results ?

- ▶ Induction machines with stator shifted GO sheets to reduce iron losses

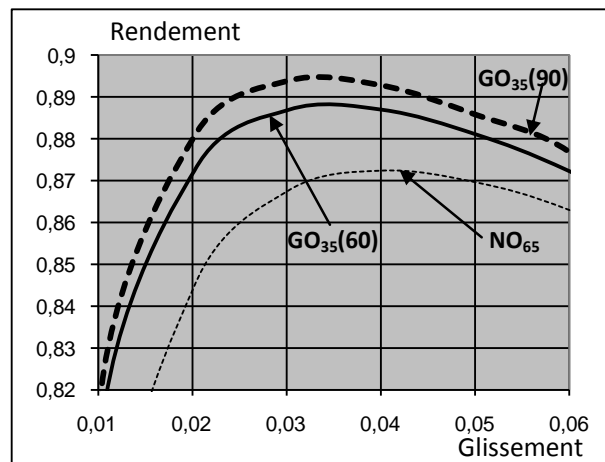
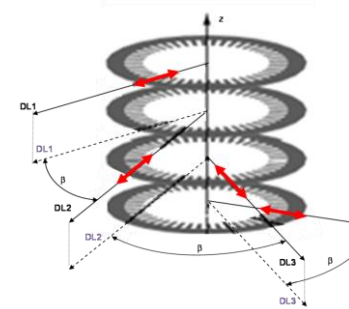
- ▶ Partner :



- ▶ 1 patent : **Magnetic Core and Use of Magnetic Core for Electrical Machines**
WO 2009/030 779 A1, Mar. 12, 2009.

- ▶ Effects ?

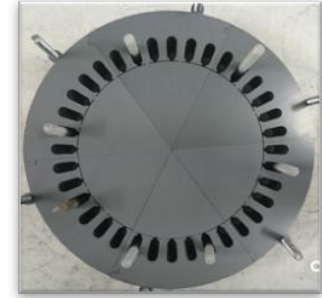
Losses ↘
(iron & copper)
Efficiency ↗
LCA +++



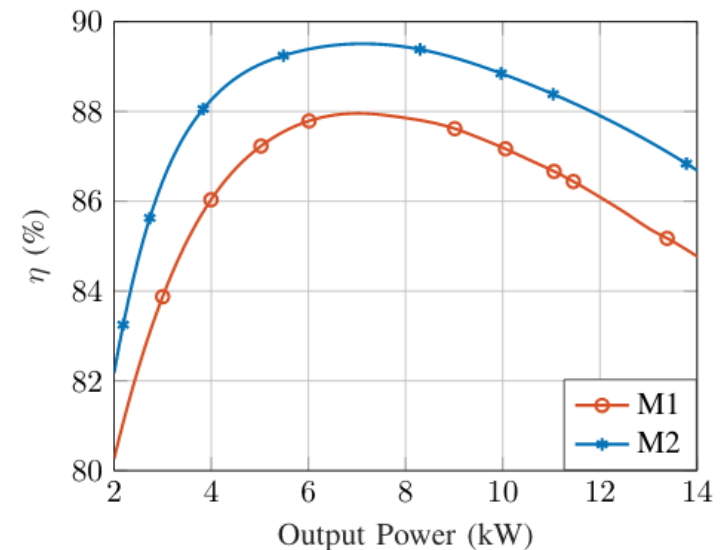
Electrical steel → in link to copper

GO in the rotor !

- ▶ Copper die cast rotor + GO steel : High efficiency

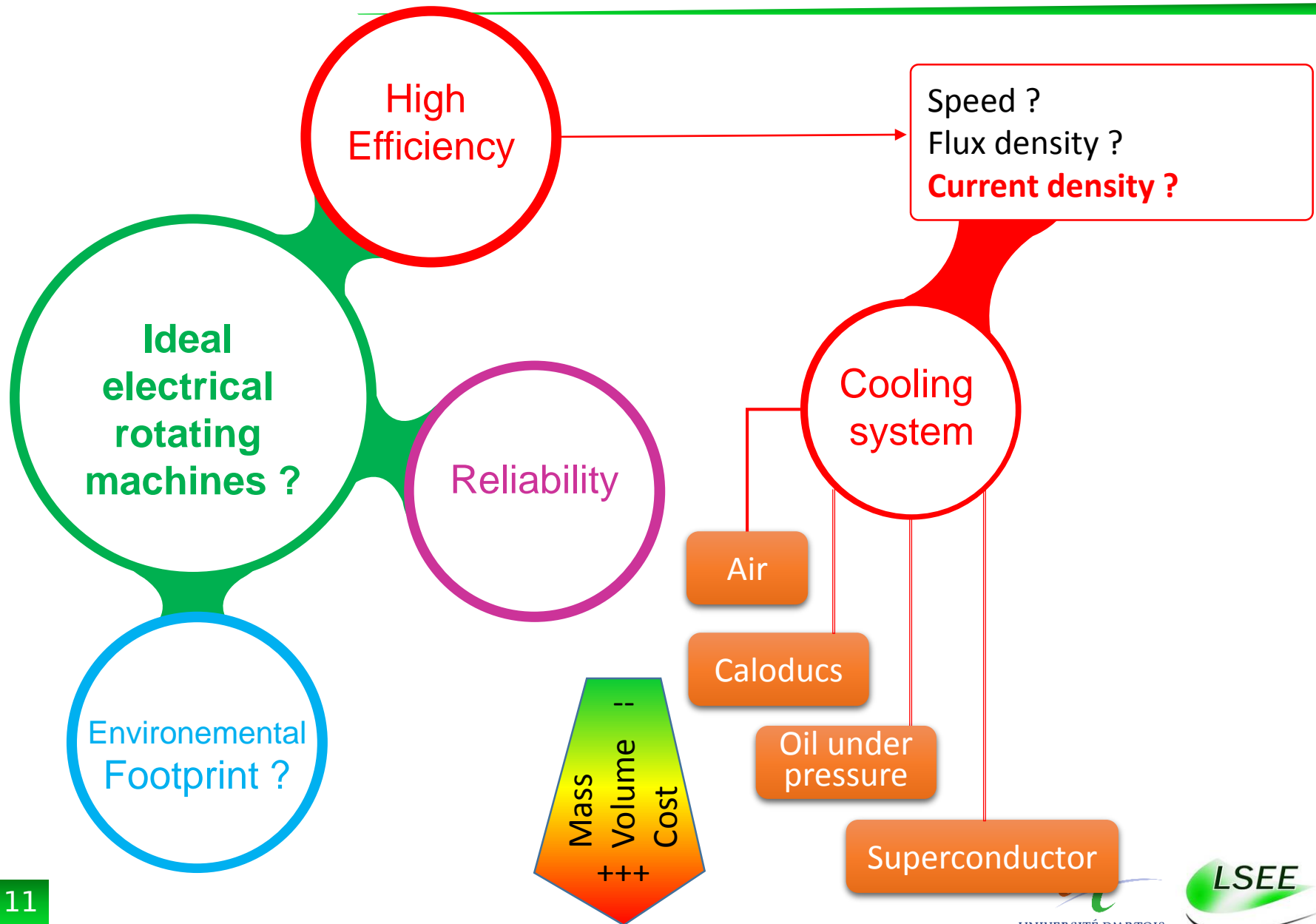


- Implementation of an overmoulded copper cage rotor
- Determination of the impact of a thermal shock on GO sheets
- Comparison of 2 machines :
 - ▷ Induction machine - 11kW – 1500 rpm
 - ▷ Stator electrical steel : Non Oriented Grain (M400)
 - ▷ Only the rotor is modified (Steel + copper)

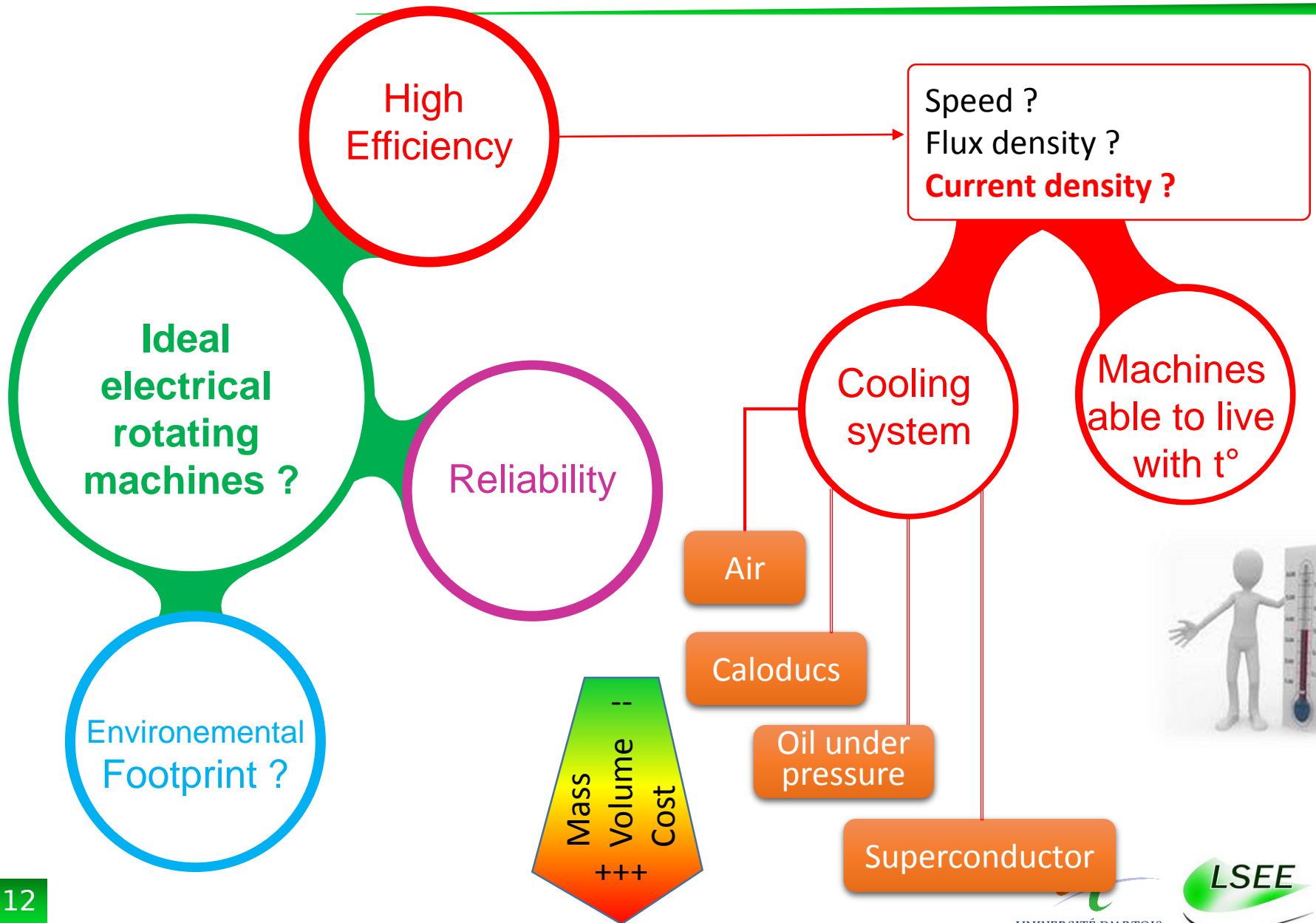


Losses ↗
Efficiency ↗
Internal t° :
↗30°C

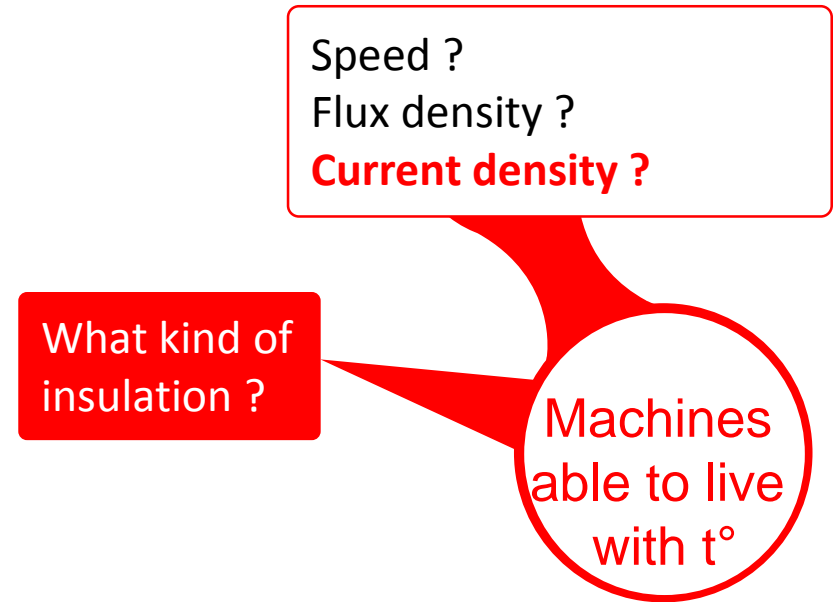
Copper and machines working at high t°



Copper and machines working at high t°



Copper and machines working at high t°



Copper and machines working at high t°

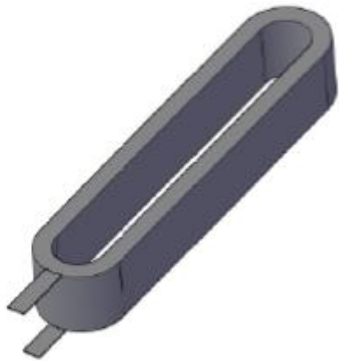
Anodized aluminium strips (Al₂O₃)

- ▷ Up to 350°C
- ▷ Filling factor is excellent
- ▷ Inter-turn voltage 👍
- ▷ 😊 Limitation of the voltage
- ▷ LCA
- ▷ ☹ Connection

Speed ?
Flux density ?
Current density ?

What kind of insulation ?

Machines
able to live
with t°



Copper and machines working at high $t^{\circ}\text{C}$

Anodized aluminium strips

Nickel Clad Copper wires insulated with :

- ▷ Mineral sheet (Mica)
- ▷ Ceramic coat

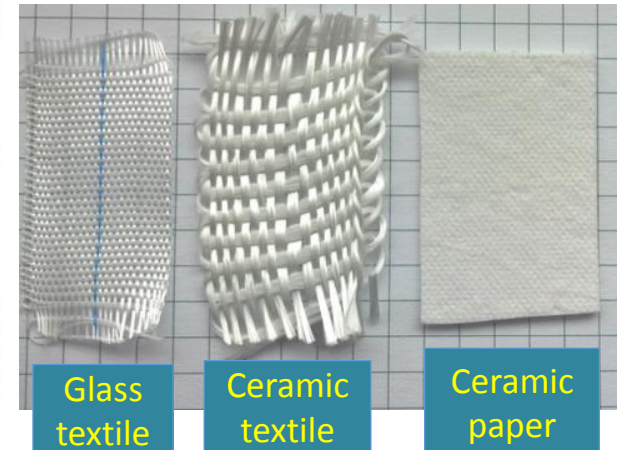
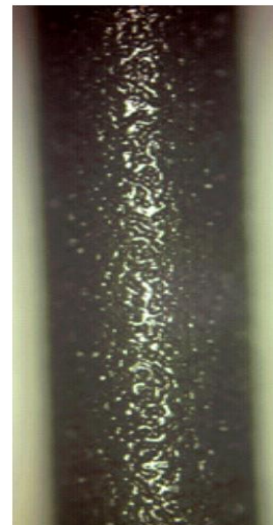
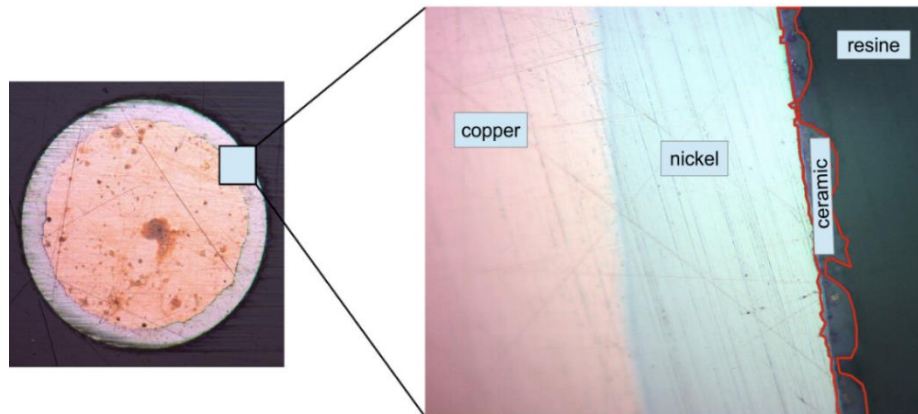
Nickel acts as a buffer used to prevent oxydation

→ 1 PhD student

Speed ?
Flux density ?
Current density ?

What kind of insulation ?

Machines able to live with t°



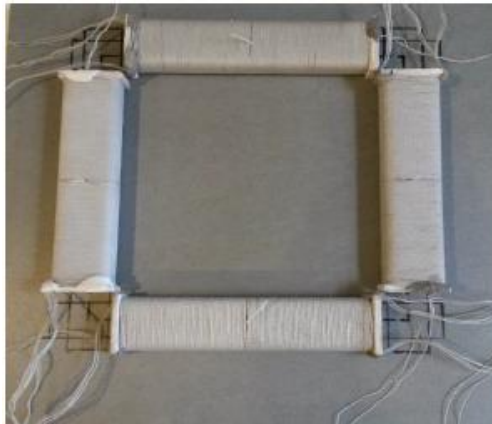
Copper and machines working at high t°

Cobalt-iron : 😊 Price

GO Silicium-iron

- ▷ Bs reduced of 10% at 500°C
- ▷ Iron losses ⚡

↓
Epstein Frame adapted
to measure electrical
steel at high
temperature

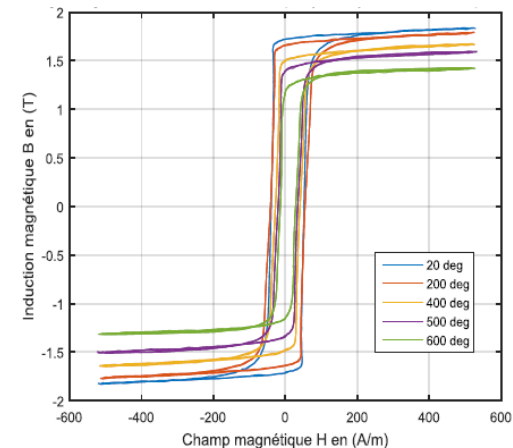


Speed ?
Flux density ?
Current density ?

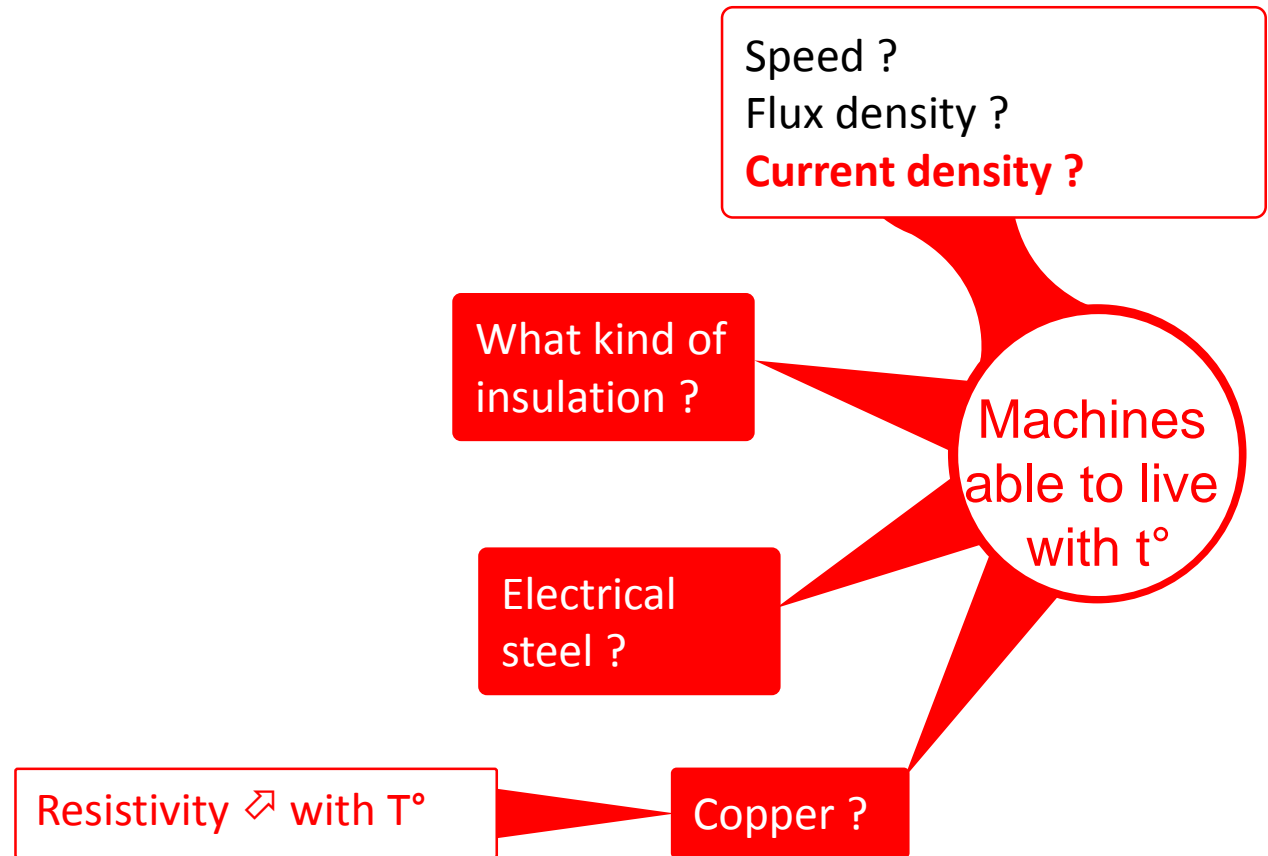
What kind of
insulation ?

Electrical
steel ?

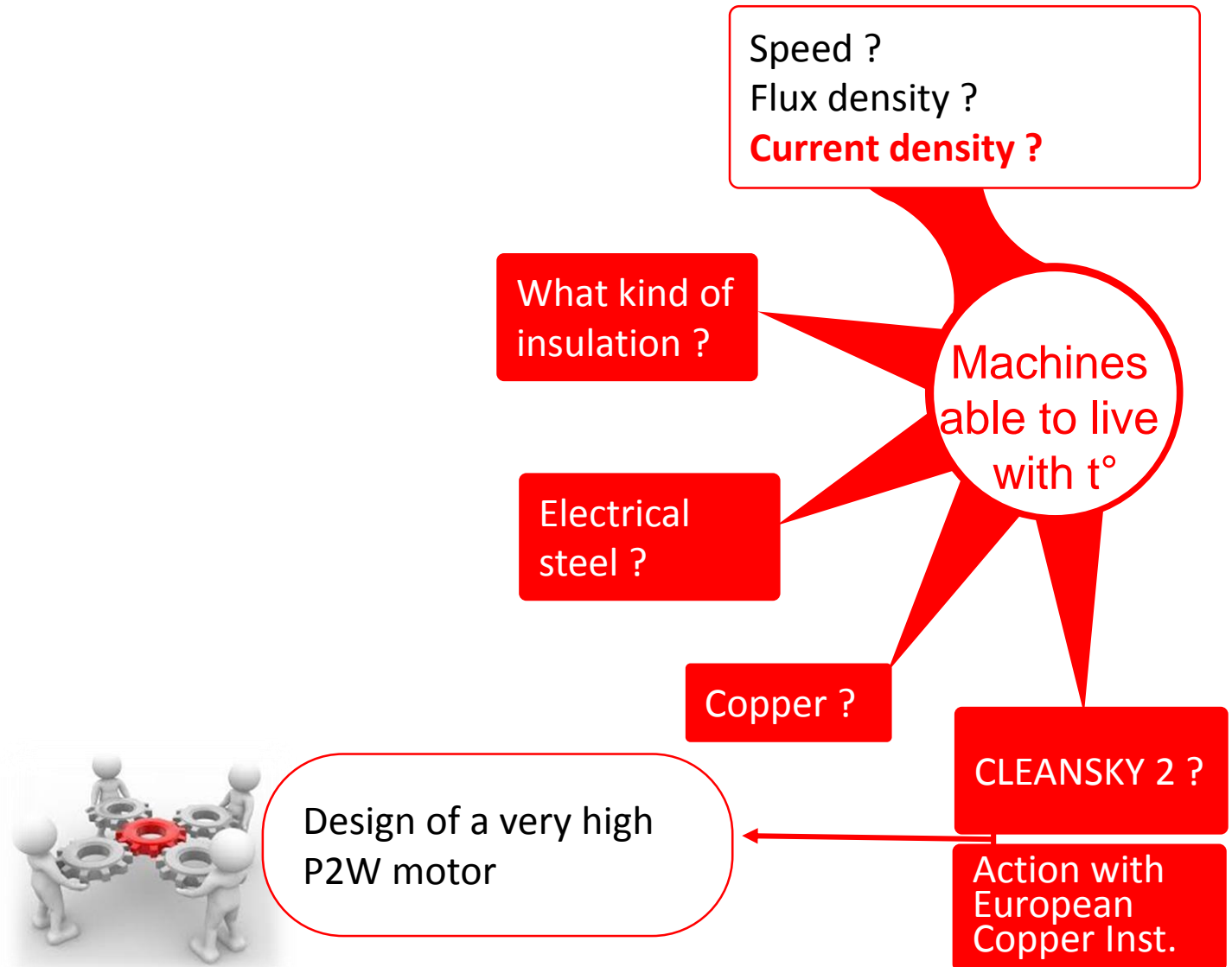
**Machines
able to live
with t°**



Copper and machines working at high t°



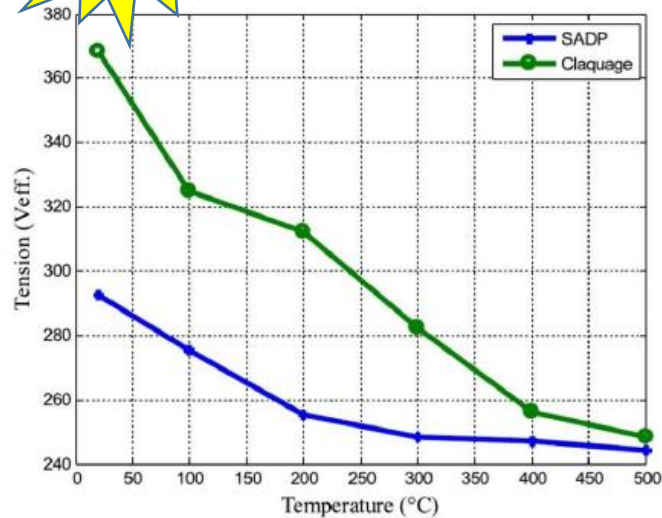
Copper and machines working at high t°



Copper and machines working at high t°

2 motors :

- ▷ Coils around teeth

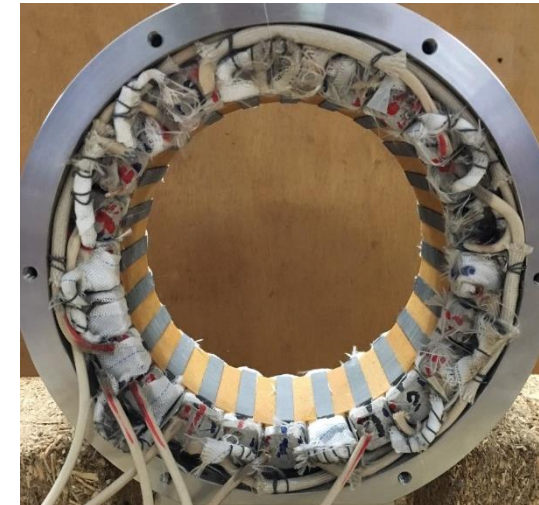


Speed ?

Flux density ?

Current density ?

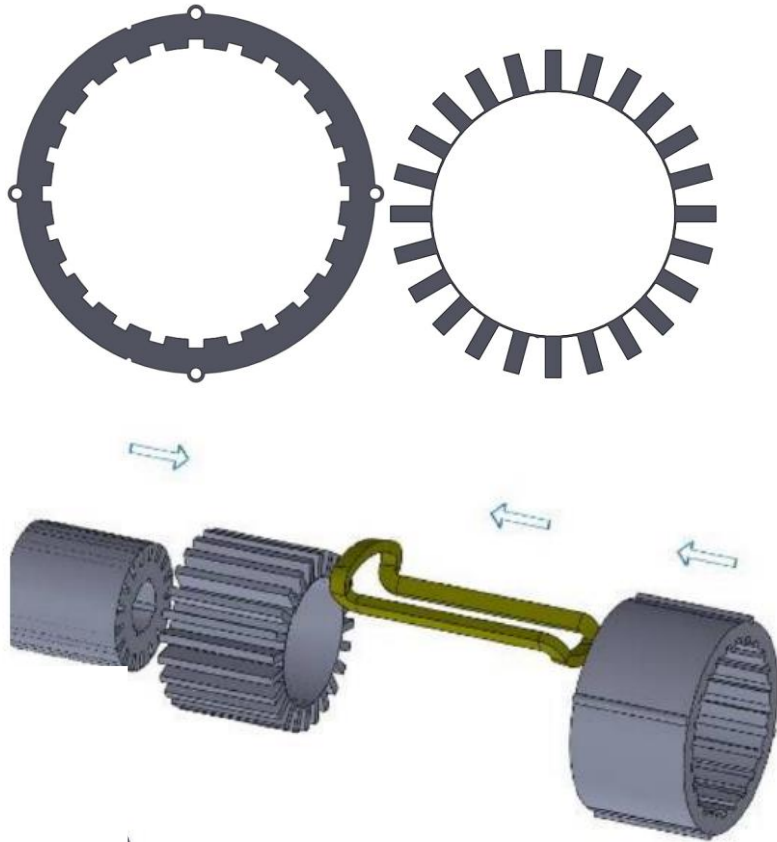
Machines
able to live
with t°



Copper and machines working at high t°

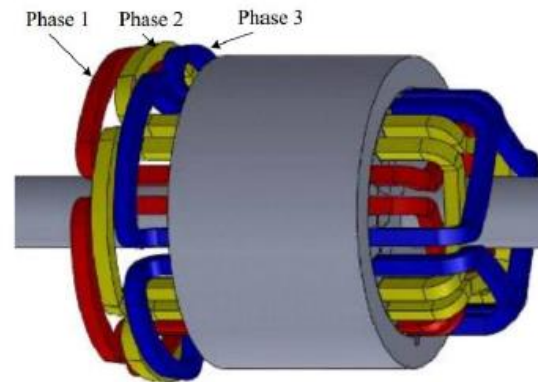
2 motors :

- ▷ Coils around teeth
- ▷ Distributed winding



Speed ?
Flux density ?
Current density ?

Machines
able to live
with t°



An equipment to build and test prototypes

Insulation characterization

- Partial discharges detectors
- Impedance bridge from 20Hz to 100MHz
- PWM sources
- Furnace up to 1200°C with gaz line
- Climatic chamber (-70°C -180°C) and humidity (0% to 95%)
- Device to create fast voltage pulses
 - ▷ Twisted pairs / coils / Windings can be analysed
 - ▷ Number of pulses are counted up to breakdown
 - ▷ PDIV
 - ▷ With partners :



EDF



JEUMONT
Electric

AUXEL



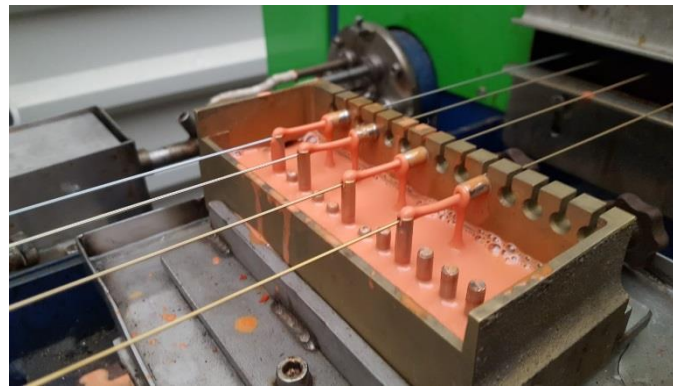
ALSTOM



- Impregnation stand :



Insulation with sol-gel process



An equipment to build and test prototypes

Noise and vibrations



Efficiency of rotating machines and transformers

- Loads
- Probes and fast oscilloscopes

➡ Space for experimentation : 280m² (+ 200m² in 2019)

Possible actions with ECI group

Insulation ?

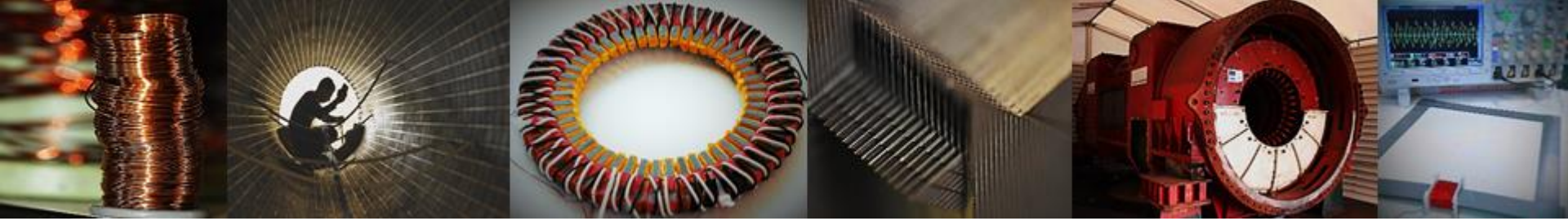
- Test in LSEE ? Platform is for academic and industrial partners
- New kinds of insulation can be developed

Copper ?

- Behavior with temperature : resistivity / Oxydation

Rotating machines

- Design of motor with a very high Power to Weight ratio ?



LSEE : At the heart of the electrical machines !