Continental
The Future in Motion

Continental Engineering Services

Linear Winding: Design and Industrialisation

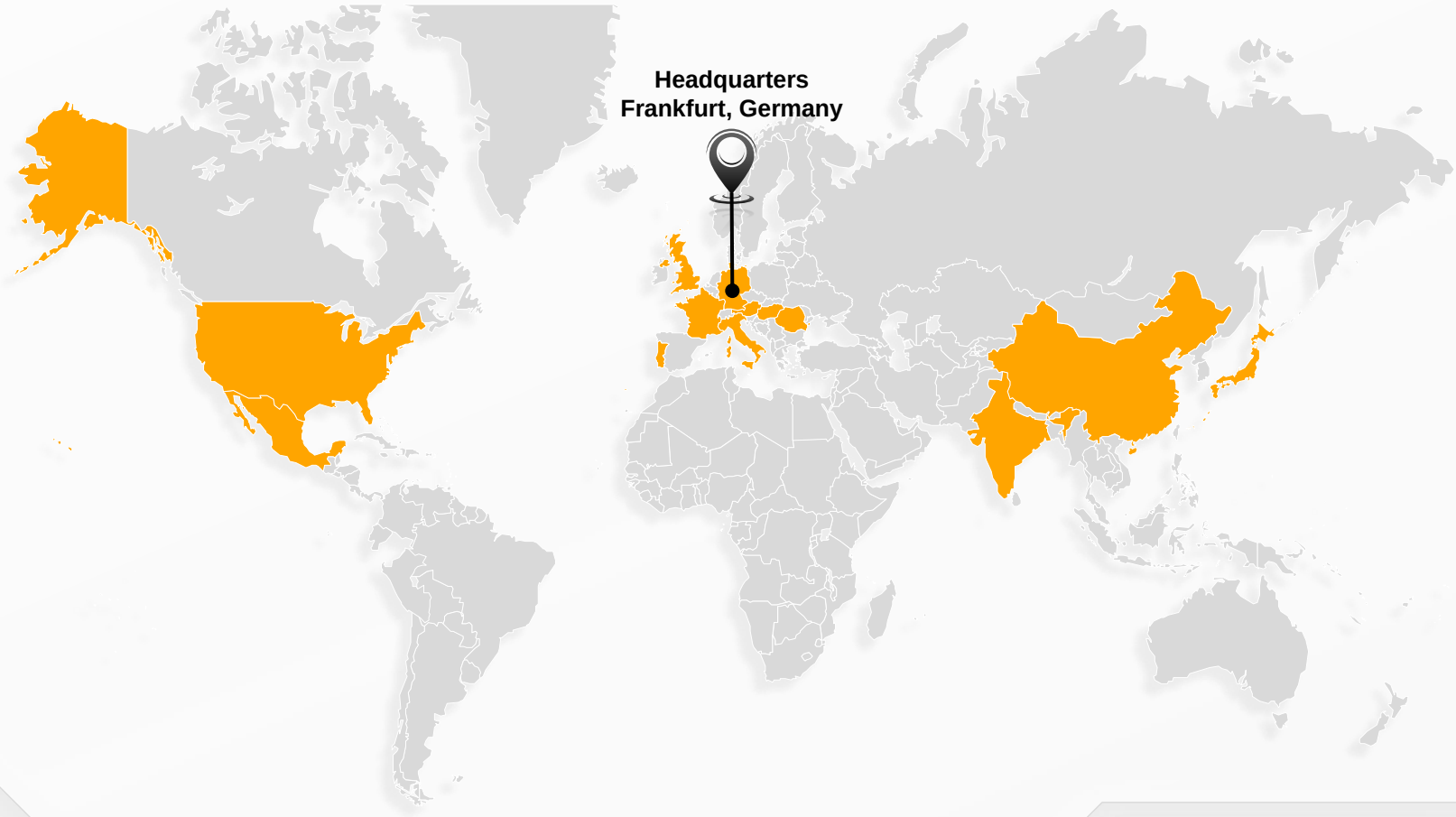
Neil Cheeseman, Segment Chief Engineer – Driveline & Electrification, Continental Engineering Services
Lorenzo Veglia, Sales manager – Electric Motor division, GROB Italy

www.conti-engineering.com

Continental Engineering Services

An Engineering Service Provider with a Global Footprint

Continental Engineering Services



2600+
Employees

21
Locations

European Union
- **Frankfurt (DEU)**
- Babenhausen (DEU)
- Ingolstadt (DEU)
- Karben (DEU)
- Markdorf (DEU)
- Nuremberg (DEU)
- Regensburg (DEU)
- Stuttgart (DEU)
- Vienna (AUT)
- Turin (ITA)
- Veszprém (HUN)
- Timisoara (ROU)
- Toulouse (FRA)
- Porto (PRT)

United Kingdom
- Lichfield (GBR)
- Burgess Hill (GBR)

North America
- Auburn Hills (USA)
- Guadalajara (MEX)

Asia
- Bengaluru (IND)
- Shanghai (CHN)
- Yokohama (JPN)

Continental Engineering Services

SERVICE PORTFOLIO

Consulting & Specialist Support
- Software Consulting
- Data Services
- Simulation Engineering
- Security & Privacy
- Research & Development Process Consulting
- Functional Safety Management
- Cloud
- Data Literacy

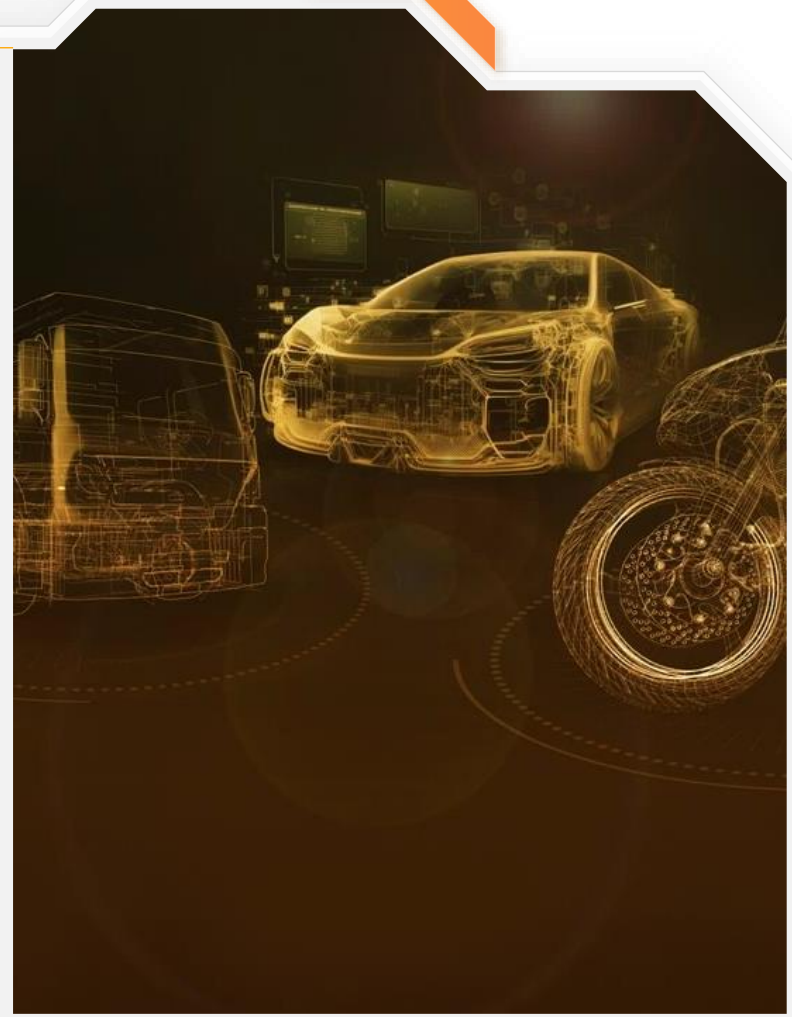
Manufacturing
- Samples, Electronics & Mechanics
- Series Production
- Build-to-print
- Special projects (automotive & beyond)

Integration
- System Integration
- Virtual Integration
- Vehicle Integration & Workshops
- Software Integration

Development
- System Engineering
- Software Engineering
- Electric Machine Design
- Hardware & Mechanical Engineering
- Noise-Vibration-Harshness

Concept Creation
- System Conception
- Requirement Engineering
- E/E Architecture
- Innovation Engineering

Testing & Simulation
- 3D Thermal Simulation and Structure Analysis
- Test Consulting Services
- Driveline Performance Simulation
- Brake Systems Test and Validation
- Virtual Vehicle Testing



Neil Cheeseman © Continental AG

Machine Topology and Optimization

Generally, comparing different electrical machine types is not a straightforward task since for each machine many variables exist, and it is difficult to define which variables should be kept constant and which may vary

Axial Flux Machine (AF) vs Radial Flux Machines (RF)	
Torque density @ 1–3 krpm speed	AF > RF
Performance @ high speed	AF < RF
Better heat dissipation	AF < RF
Enhanced durability & Demanding industrial applications	AF < RF
Better performance for Poles > 10	AF > RF
Mechanical – limited axial length	AF > RF
High Speed application	AF < RF

Fractional Slot Machine (FS) vs Integer Slot Machine (IS)	
Efficiency (low speed)	FS > IS
Torque density	FS > IS
Short End-Winding	FS > IS
NVH Issues	FS > IS

Thin Wire Winding (TW) vs Bar Wire Winding (BW)	
High Speed (High Freq.) Operation (AC Loss dependent)	TW > BW
Low Speed (Low Freq.) Operation (DC Loss dependent)	TW < BW
Variable Speed (Variable Freq.) Operation (AC vs DC Loss dependent)	Case-dependent
Slot Fill Factor	TW < BW (TW up to 44% / 62%) (BW up to 65-75%)
Production cost	TW < BW

Optimization and Machine Topology

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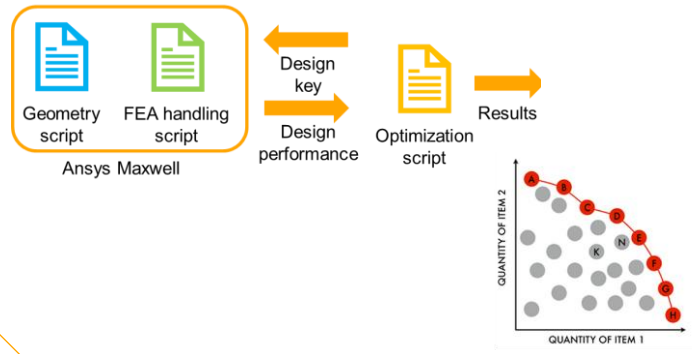
Optimisation

- Finding a good design to meet the costumer performance requirements within a target volume
- Evolutionary Computation provide efficient algorithms that may find a set of optimal designs in some hours to a few days



Segmented stator benefits

A. Back iron & set of teeth.
It does make sense mainly for high performance & high-speed & high frequency & compressed coils

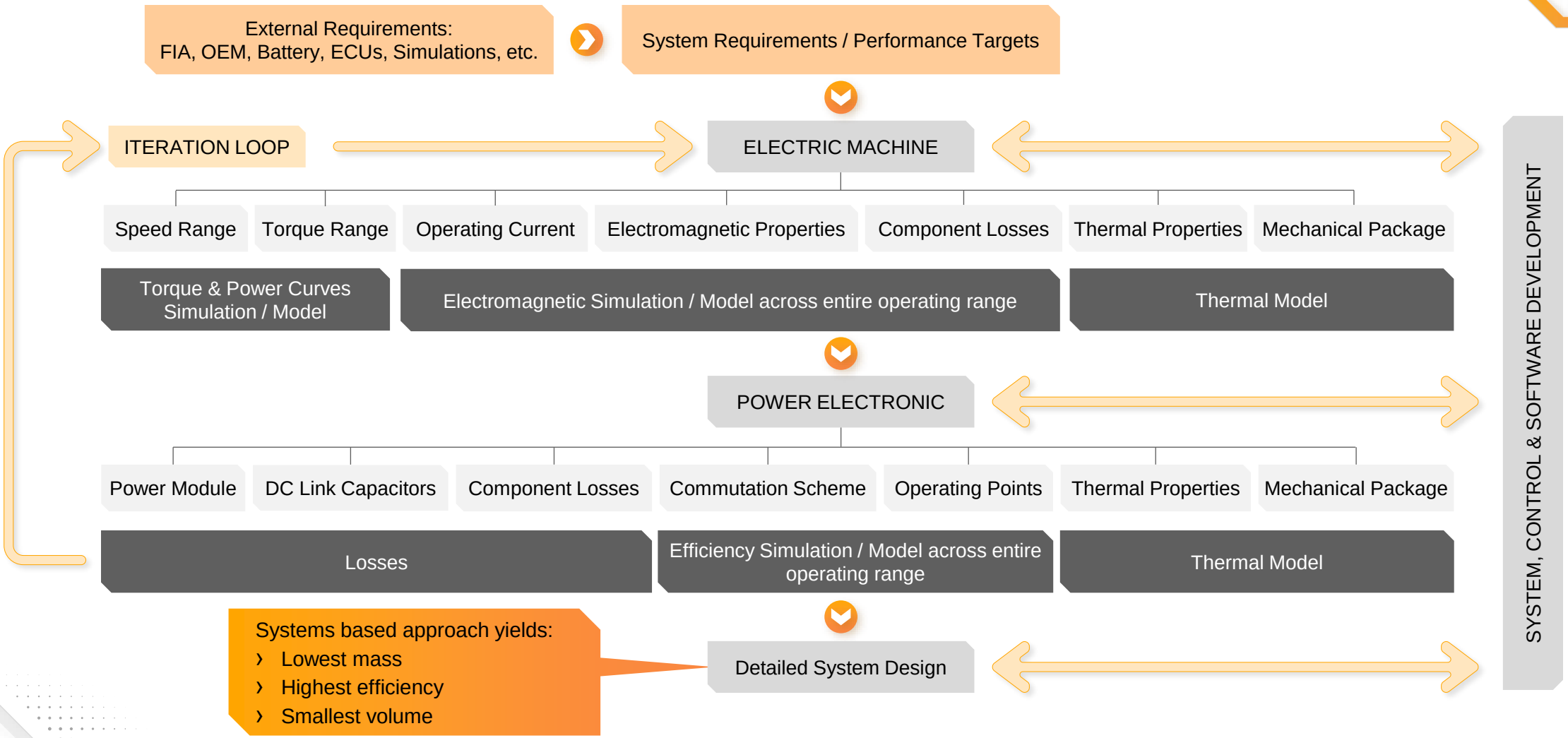
B. T-segmented stator
T-segment stator & precision wound coils solutions. Stator does not have a separate back iron. Each tooth has a part of back iron, the segment shape reminds letter T

Winding construction images

Back iron & teeth & compressed coils

Bar & hairpin winding

Machine Topology and Optimization



Machine Topology and Optimization

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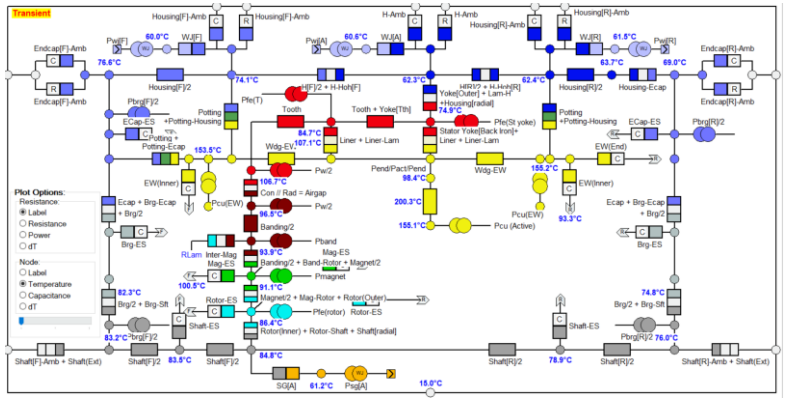
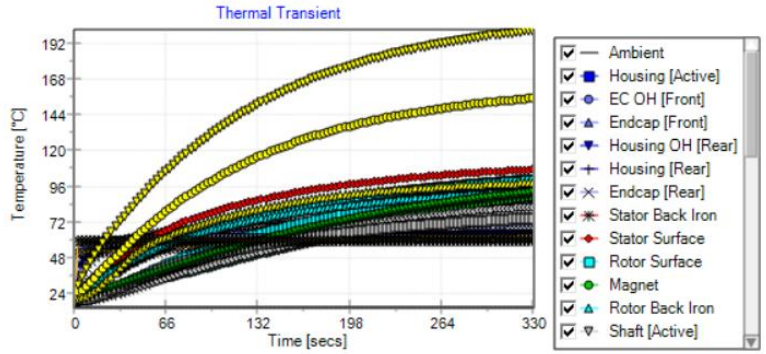
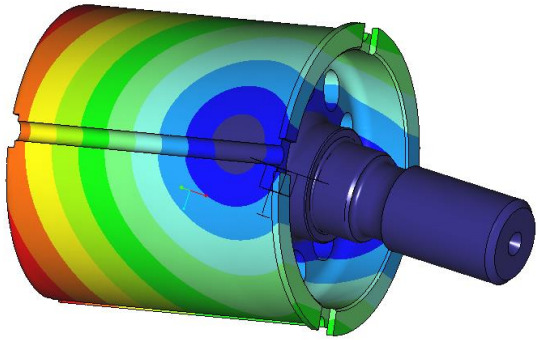
Thermal model – thermal network

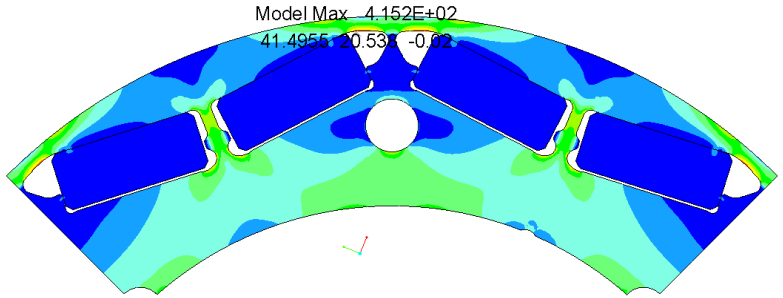




Temperatures vs time

Von Misses stress distribution – mechanical model





Services To Support Linear Winding Industrialisation

Continental Engineering Services

- Customer’s specification discussion
- Entire design process discussion
- Electric machine design: Electromagnetics
  - Permanent Magnet Motors
  - Induction Motors
  - Wound Rotor Synchronous Motors
- Electric machine design: Mechanics
- Electric machine design: Power Electronics
- Electric machine design: Systems
- Electric machine design: Thermo-Magnetics

Winding design and analysis

- Coil design
- End-winding design
- Winding design
- Thermal simulation
- Thermal measurement
- Electric test and measurements
- Compressed coils manufacturing
- Failure diagnosis

Linear Winding Webinar

Development – Experience - Reliability

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Excellence in sustainable technology

Linear Winding Webinar

CONTENT

GROB OVERVIEW

- **Processes for electric transition**
- **Technologies for stators**
- **Technologies for rotors**

LINEAR WINDING PROCESSES

- **Radial flux round wire on core**
- **Axial flux round wire on core**
- **Radial flux flat wire air coil**
- **Axial flux flat wire air coil**

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GROB GROUP AT A GLANCE

Employees
~ 8,800

Orders received
EUR 2.0 billion

Total output
EUR 1.8 billion

6 plants

15 sales & service subsidiaries

MINDELHEIM, Germany
Output: EUR 1.3 billion
Employees: 5,800 (in Mindelheim since 1968)

SAO PAULO, Brazil
Output: EUR 117 million
Employees: 622

BLUFFTON, USA
Output: EUR 249 million
Employees: 814

DALIAN, China
Output: EUR 245 million
Employees: 1,186

PIANEZZA, Italy
Output: EUR 22 million
Employees: 140

BANGALORE, India
Output: EUR 18 million
Employees: 81

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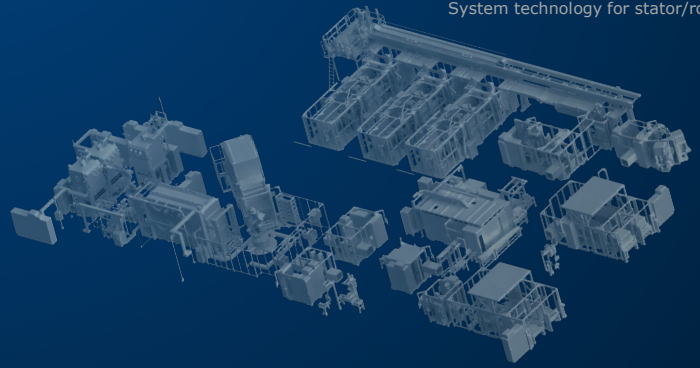
GROB PROCESSES FOR ELECTRIC TRANSITION

MOTOR PRODUCTION:

- **Stator lines**
- **Impregnation systems**
- **Rotor lines**

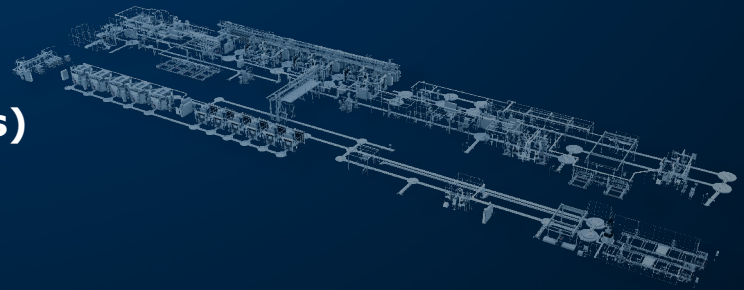
System technology for stator/rotor assembly



Layout examples

POWER SOURCES PRODUCTION:

- **Batteries assembly lines (cell, modules, packs)**
- **Fuel cell stacking lines**



System technology for battery pack assembly

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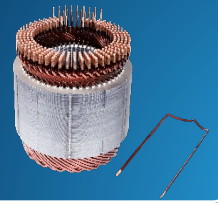
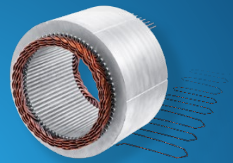
GROB WINDING TECHNOLOGIES STATOR AND ROTOR

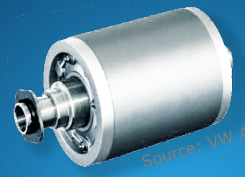
Hairpin technology



Continuous hairpin



Rotor production with permanent magnets



Insertion technology

Axial flow motors

Rotor production with needle winding

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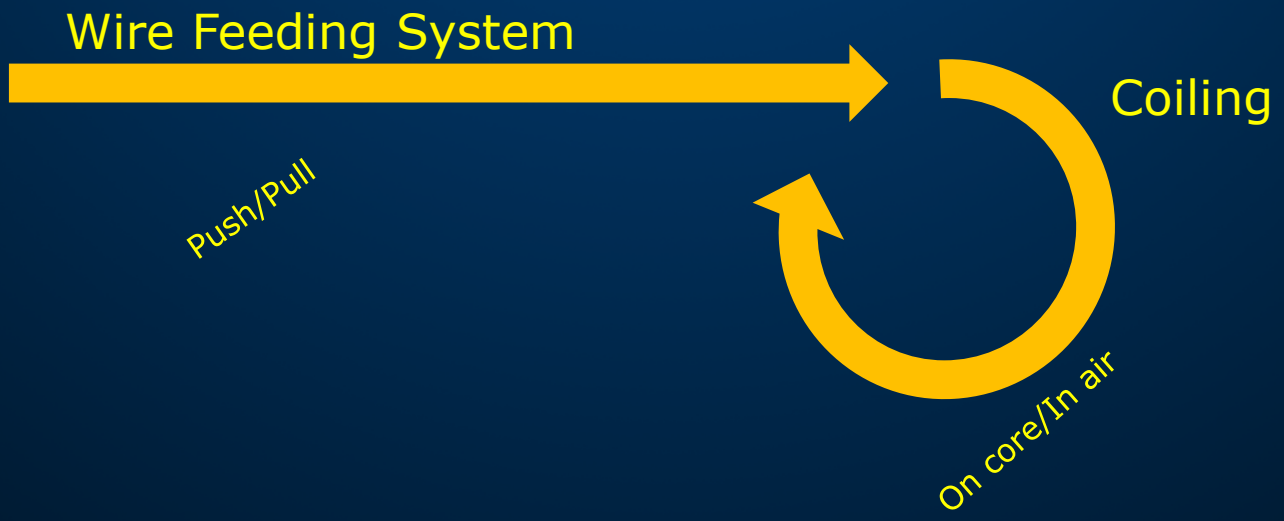
Meaning of Linear Winding:
Winding of single coils with linear feeding of the wire



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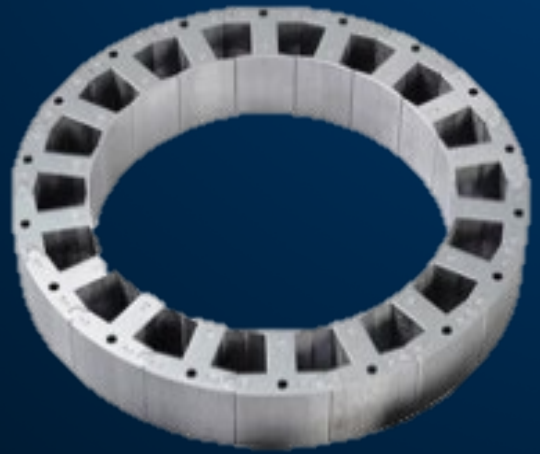
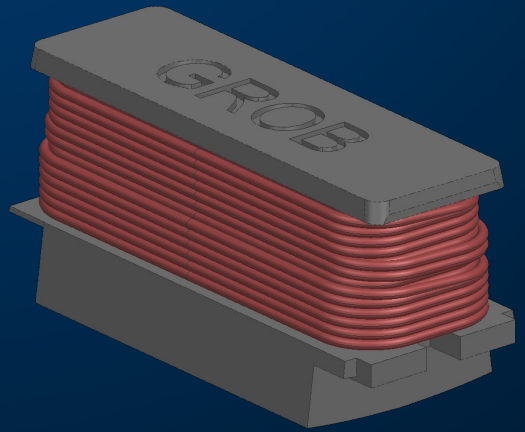
RADIAL FLUX ROUND WIRE ON CORE

Stator type	Segmented
Wire type	Round





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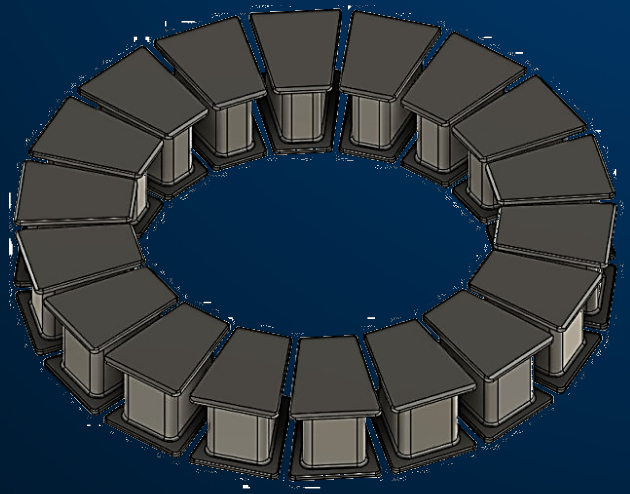
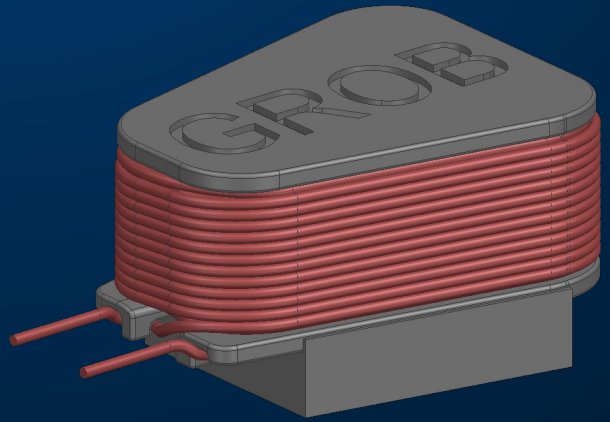
AXIAL FLUX ROUND WIRE ON CORE

Stator type	**Segmented**
Wire type	**Round**





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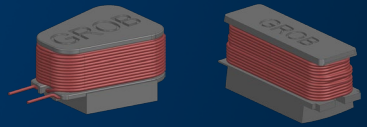
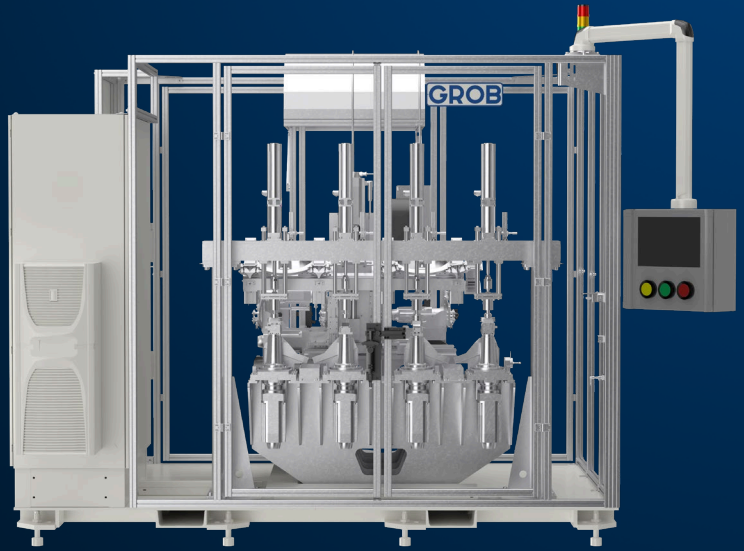
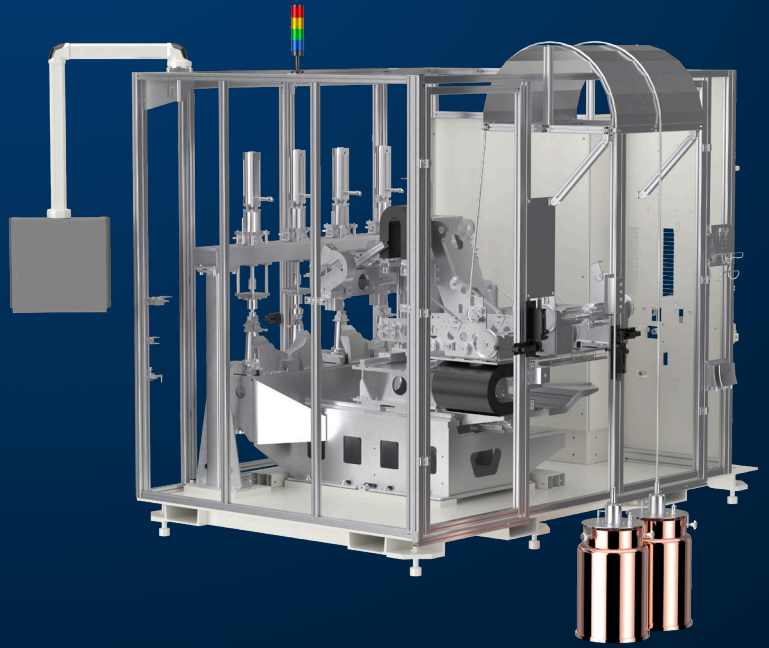
RADIAL FLUX/AXIAL FLUX ROUND WIRE ON CORE







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RADIAL FLUX/AXIAL FLUX ROUND WIRE ON CORE

Stand-alone machine

- with manual or automatic loading/unloading
- with Light curtain / Automatic door / Manual

Full-automatic line

Flexibility at its highest with 3-axis concept with servo motors, ball screws, and ball rail systems

Up to four winding spindles

Multiple part-clamping options

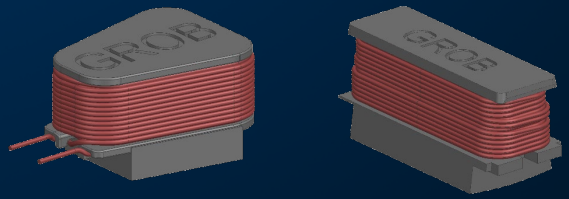
- Fixed clamping system
- Fast changeable clamping system via indexing unit
- Clamping via form closure on tooling and the pressing

Multiple gripping and cutting options

- Independent gripping and cutting system with servo drives
- Gripping and cutting unit moves with the needle winding

Wire tensioner in-house developed

Insulation with plastic support or paper



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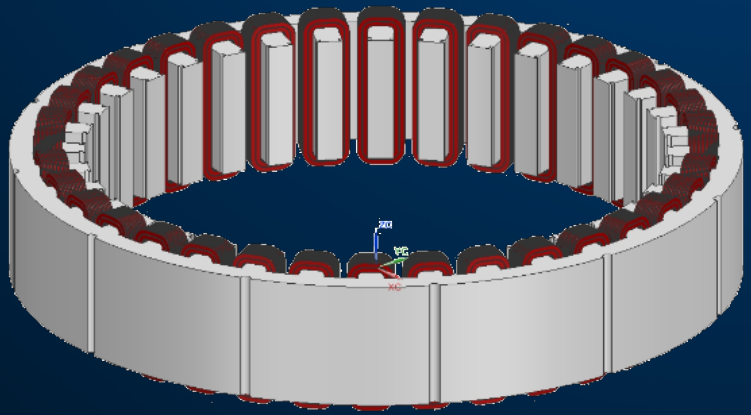
RADIAL FLUX FLAT WIRE AIR COIL

Stator type	**Solid**
Wire type	**Flat**



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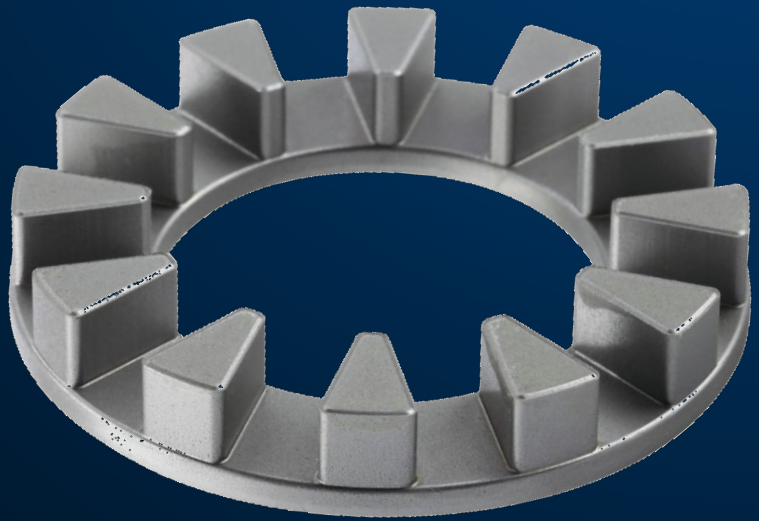
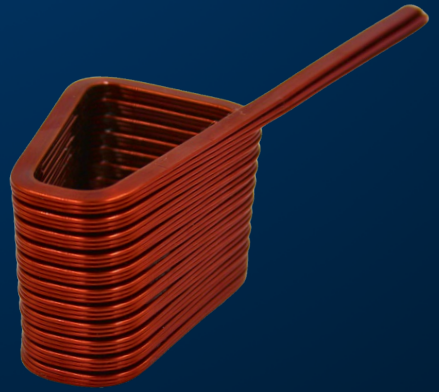
AXIAL FLUX/RADIAL FLAT WIRE AIR COIL

Stator type	**Solid**
Wire type	**Flat**





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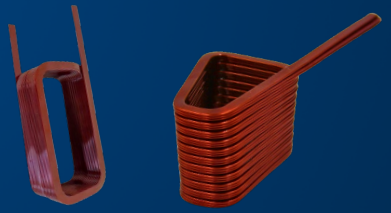
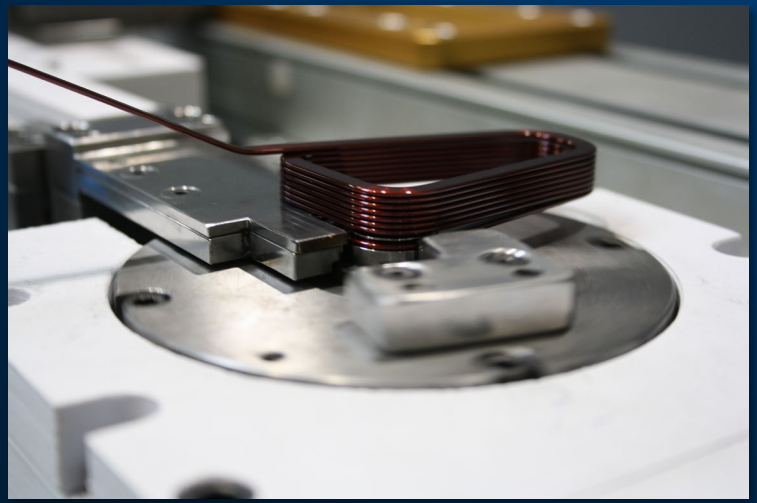
AXIAL FLUX FLAT WIRE AIR COILS





- ✓ **Stand-alone machine**
  - ➢ with manual or automatic unloading
  - ➢ with Light curtain / Automatic door / Manual door
- ✓ **Suitable to be inserted in Full-automatic line**
- ✓ **Flflexibility at its highest, change of coil shape by pressing one button**
- ✓ **Possibility to install many machines in parallel**
- ✓ **Stripping can be included in the feeding line (masked time)**
- ✓ **Wire straightening in-house developed**

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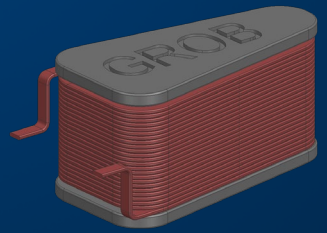
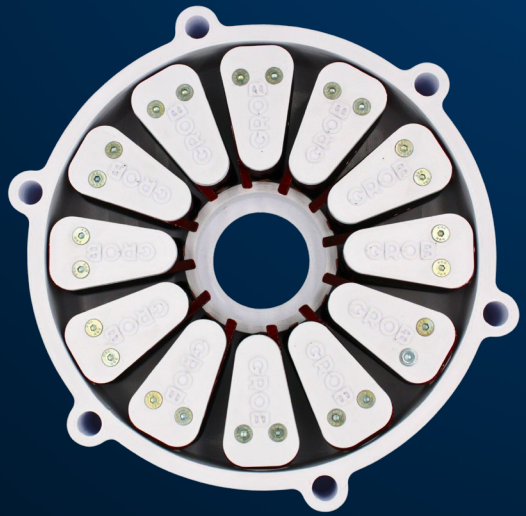
AXIAL FLUX FLAT WIRE ON CORE

Stator type	**Segmented**
Wire type	**Flat**





Technology in development at
GROB Italy

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CONCLUSION

RELIABILITY

GROB Group aim to stay in deep contact with all customers involved in the electric transition.

EXPERIENCE

Engineering support is available by **GROB Italy**, for samples, process/product industrialization.

DEVELOPMENT

Other technologies for linear winding are **in development.**

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GROB ITALY S.R.L.
Via Sergio Marchionne 3
11040 Pianezza (TO)
Italy

GROB-WERKE GMBH & CO. KG
Industriestraße 4
87719 Mindelheim
Deutschland

www.grobgroup.com

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