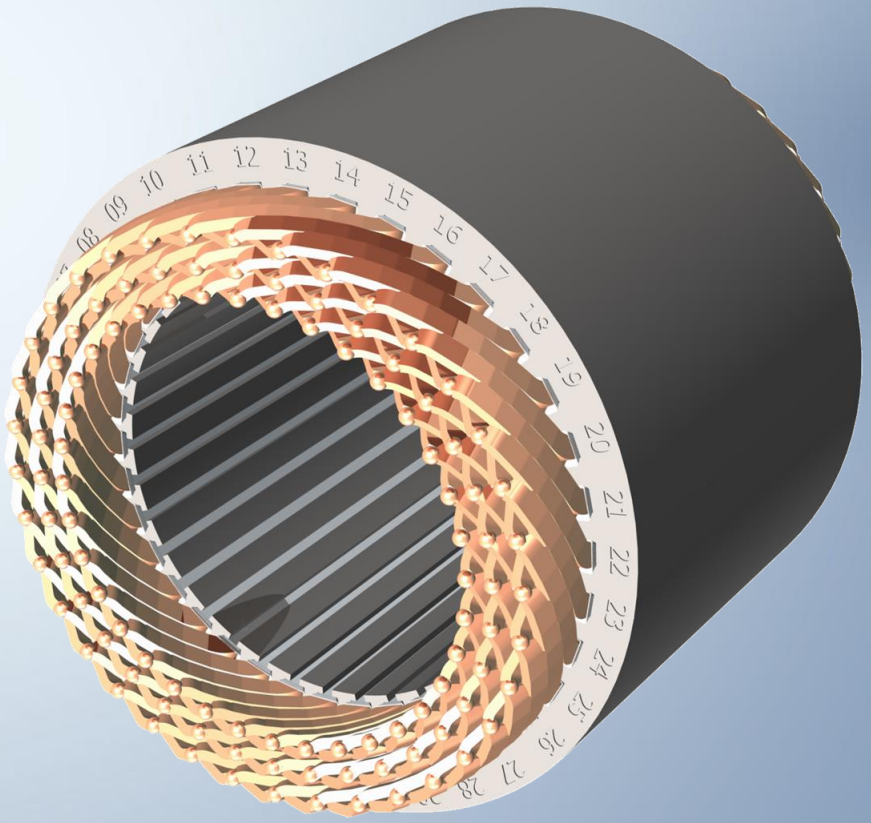
Innovation in Motion

Technology Trends in eMotor Components for Automotive Applications

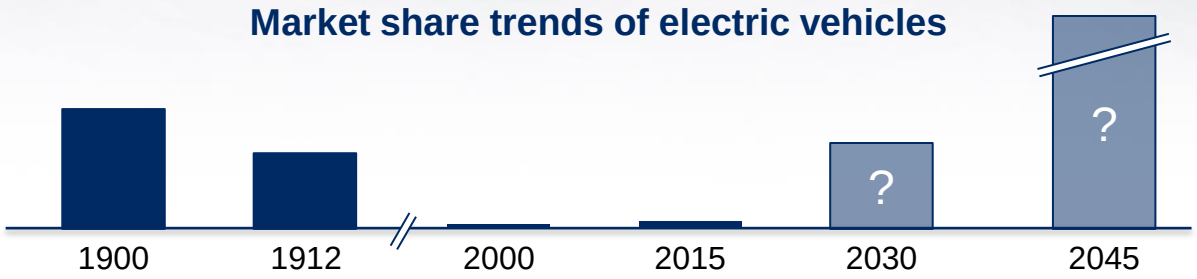
Mateo Primorac
09.11.2017, Miba AG



Introduction

Innovation in Motion

Relevant market shares of electric vehicles about to happen in near future …



… increasing the requirements for automotive eMotors

Focus of today's presentation

Technology Trends in eMotor Components for Automotive Applications

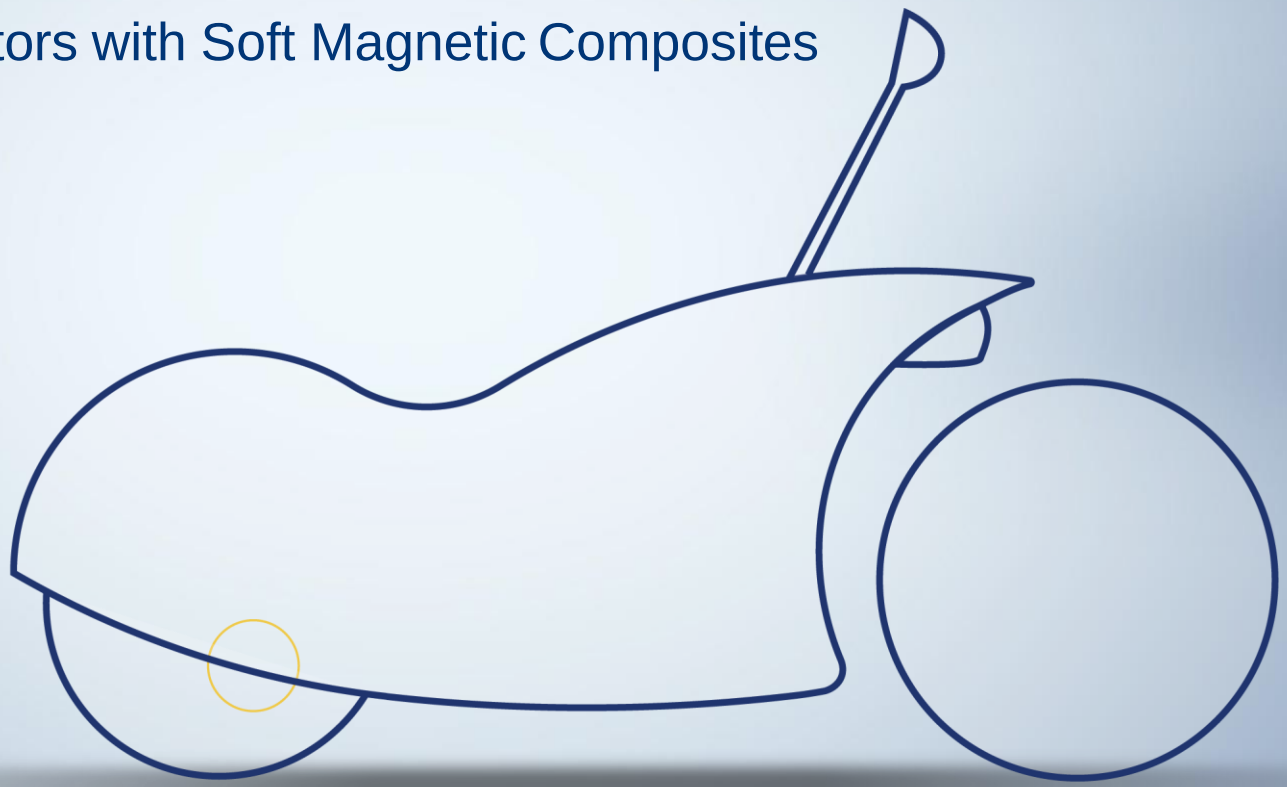
Part 1 – Development Trends of **Axial and Transversal Flux Machines**

Part 2 – Technology Trends of **Radial Flux Machines** (Focus: Stator Assemblies)

Innovation in Motion

Part 1 – Development Trends of Axial and Transversal Flux Machines

eMotors with Soft Magnetic Composites



Introduction

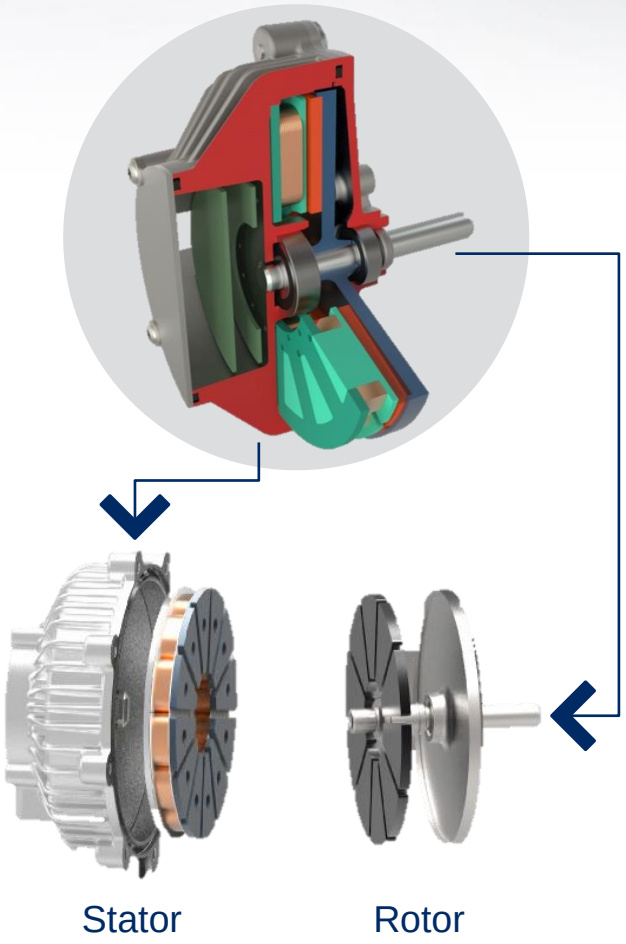
Part 1 – Development Trends of Axial and Transversal Flux Machines

Innovation in Motion

Axial Flux Machines

- Dedicated for short length requirement (“Pancake” Motor)
- Increased torque due increase of loaded radius and superficial thrust
- Increased magnetic active surface

	Axial Flux Machine	Radial Flux Machine
Dimension		
Torque	$M \sim r^3$	$M \sim r^2$



Introduction

Part 1 – Development Trends of Axial and Transversal Flux Machines

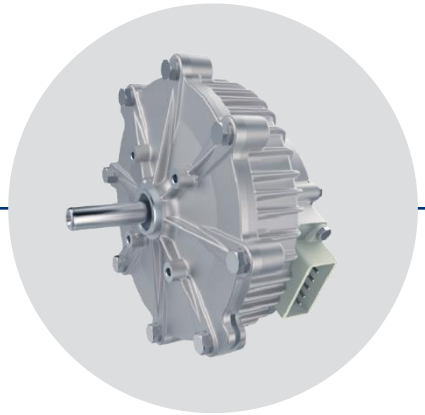
Innovation in Motion

Miba **Soft Magnetic Composite** (SMC) allows to conduct the magnetic field in all three dimensions without losses.

This makes it possible to design compact and powerful electric motors with **high power and torque density → M ~ r^3**

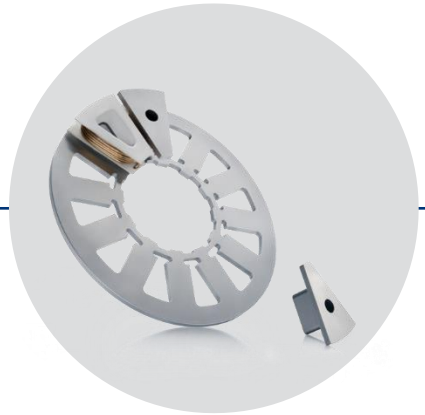
- Axial Flux Machine (AFM)
- Transversal Flux Machine (TFM): Claw Pole

3D magnetic flux of SMC



Customized solutions for electromagnetic components

- Auxiliary Drives
- Traction Drives



Miba SMC components

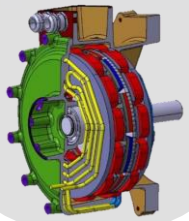
Cooling Concepts

Part 1 – Development Trends of Axial and Transversal Flux Machines

Innovation in Motion Miba

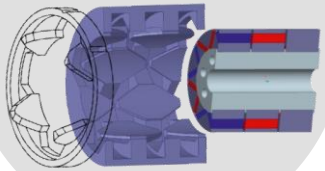
eMotors with SMC: Axial and Transversal Flux Machines

Double sided Axial Flux Motor



- high efficiency
- high performance cost / ratio
- use of ferrites instead of rare earth magnets

Claw Pole Motor



- 30% more torque in the same installation space
- high overload capability

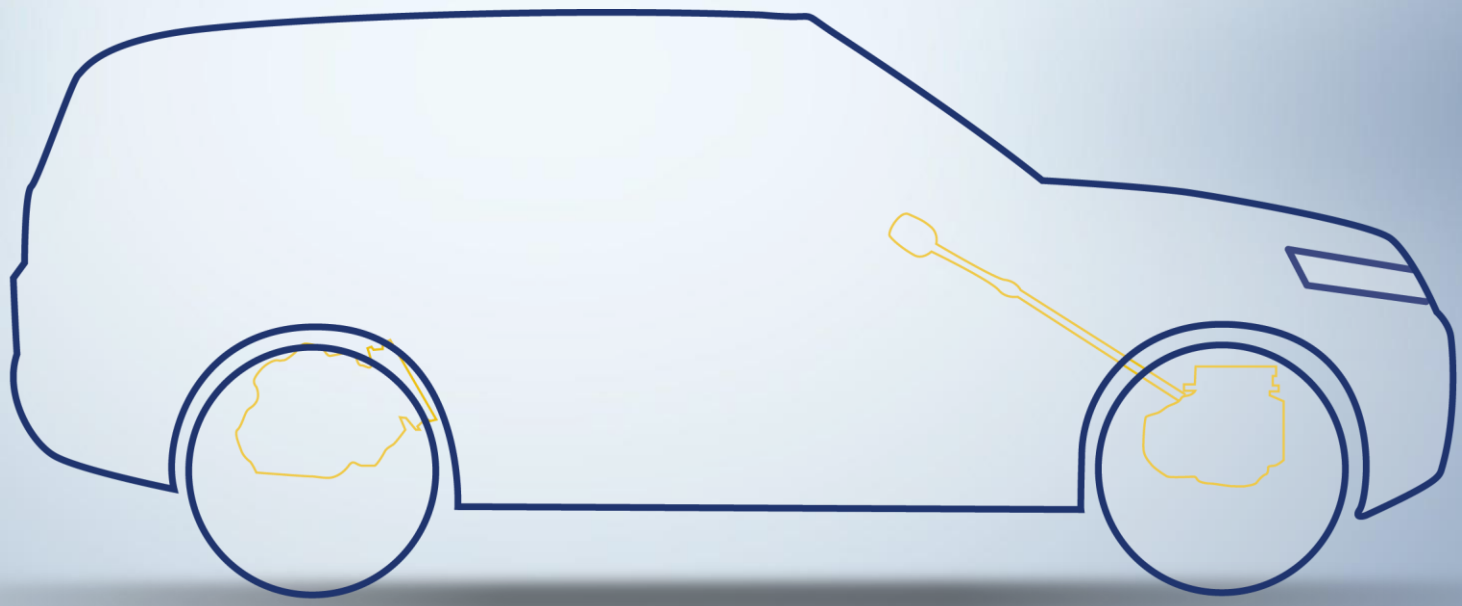
Single sided Axial Flux Motor

- use as auxiliary drive (e.g. electric water pump)
- in-sensitive to environment temperature
- easy to assemble / disassemble / recycle

Innovation in Motion

Part 2 – Technology Trends of Radial Flux Machines

Focus: Stator Assembly

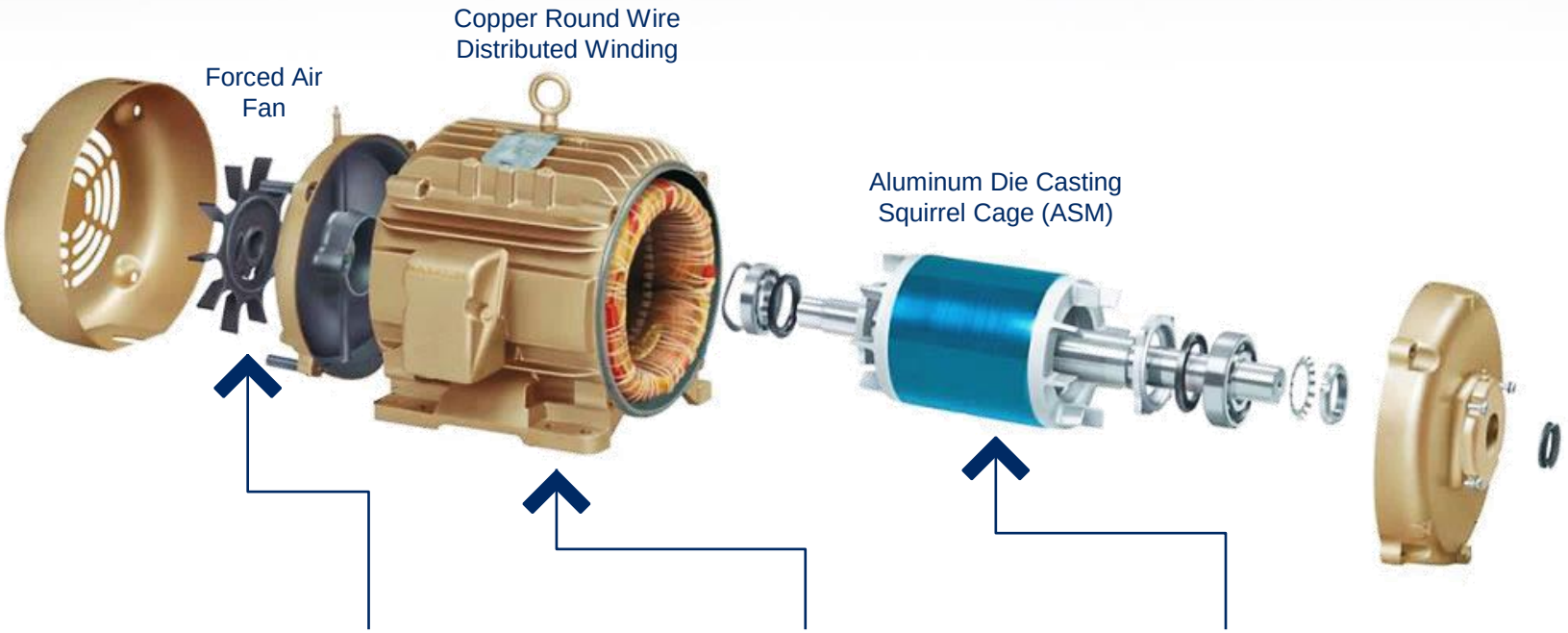


Introduction

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion

A representative industrial electric motor as Radial Flux Machine (RFM) not applicable for usage in automotive applications …



- **Cooling Concepts**
- **Stator Assembly**
- **Rotor Assembly**

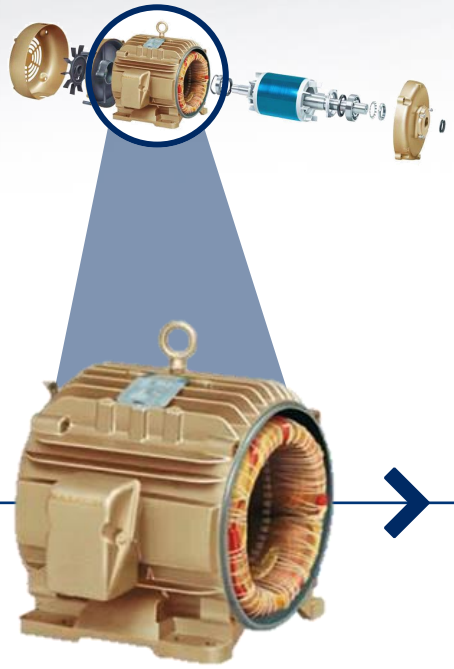
Additionally, mentions for

- **Functional Integration**
- **High RPM Concepts**

Stator Assembly

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion



Technology Trends: Stator Assembly

Connection
Wiring with circuit boards

Lamination
Improved magnetic materials

Winding
Flat wire copper winding

Insulation
optimized materials & process

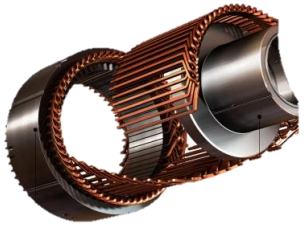
Integration
Power electronics

Source: Kienle Spiess

- Space
- Efficiency
- Performance

Back paint lamination cores

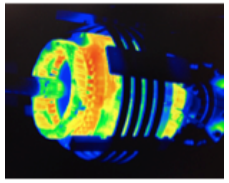
Source: General Motors



- Quality
- Efficiency
- Cost savings

Hair-Pin stator

Source: Coppering



- Process quality
- Cycle time
- Space

Inductive heating

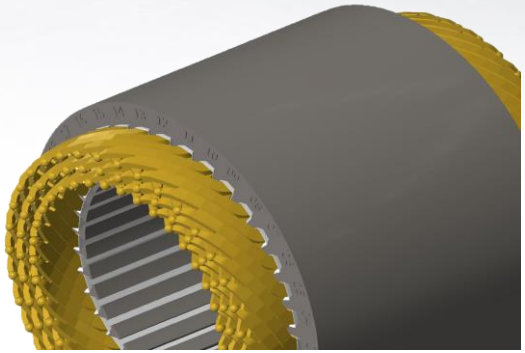
Stator Assembly

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion

Winding: Flat wire compared to Round wire

- Higher copper fill factor → high efficiency
- Higher thermal conductivity → improved cooling
- No windings → stable process & quality increase
- Full automation → lower cost for high volumes



Flat wire types:	Continuous Hair-Pin	Hair-Pin	i-Pin
Image			
Process	**Avoid process steps** +: twist, weld, insulation -: complex preparation	**Maturity level** +: one side process steps -: insertion, tolerance	**Low cycle time** +: easy insertion, speed -: double sided process
Winding head	**Low on both sides** +: installation space	**Low on Hair-Pin side:** ~: space / cooling	**Higher on both sides** +: cooling surface
Magnetic behavior	↓ **variation, slot opening**	**Flexible winding**	**Flexible widing, Roebel**

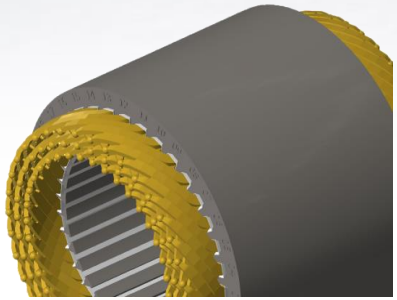
Stator Assembly

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion

Miba
New Technology
Pin Windings

- **Hair-Pin**
- **i-Pin**



Miba as component supplier

- **Material experience**
- **Product know-how**

Copper

Insulation paper

Steel core laminations

Full assembled eMotor stators

+

Miba as equipment supplier

- **Process development**
- **Equipment design**

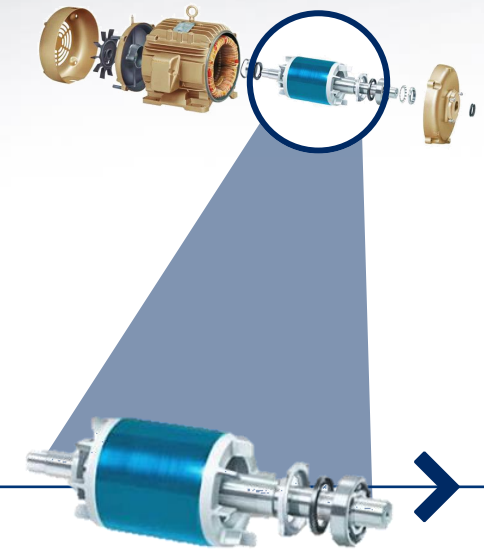
Full automated Stator Assembly Lines in 3rd Generation

Holistic approach for stator assemblies

Rotor Assembly

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion



Technology Trends: Rotor Assembly

Bearings
High RPM possibility

Shaft
Innovative materials & functions

High RPM
Optimized processes

Improved magnetic behavior

Integration
Sensors & transmission

Source: Xperion Components

CFK shafts

Source: Thyssen Krupp

“InCar Plus”

Source: Wieland-Werke

- High RPM ASM
- Mech. strength
- Cost savings

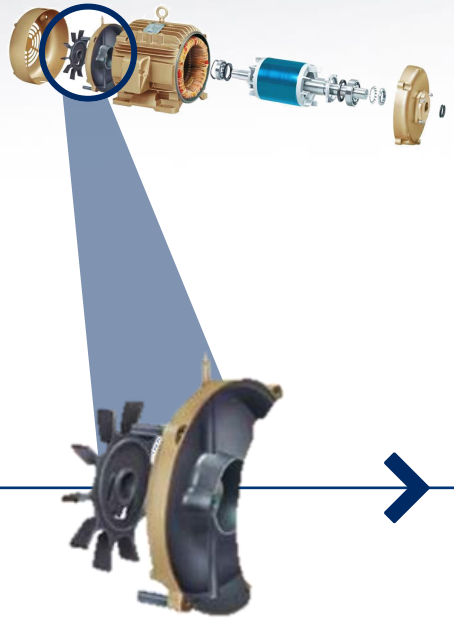
- Die casted Copper
- Assemblied Copper Bars

1. Optimized coupling rotor and stator
2. New designs for permanent magnets
3. Foreign-excited synchronous motors
4. Increase of reluctance moment

Cooling Concepts

Part 2 – Technology Trends of Radial Flux Machines

Innovation in Motion



Technology Trends: Cooling Concepts

Rotor
Spray mist cooling

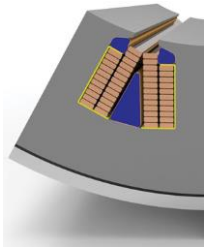
Stator
Fluid winding head cooling

Source: General Electric

- Transmission fluid
- Efficiency increase
- Space

Stator
Direct slot cooling

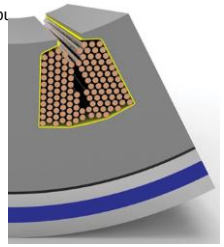
Source: Karlsruhe Institute of Technology



- Performance
- Efficiency
- Installation space

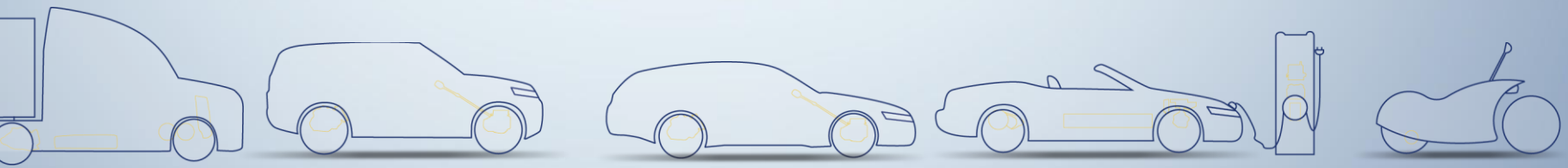
Stator
Optimized housing cooling

Shaft
Hollow shafts & bearing cooling



- Extruded profile
- Efficiency
- NVH

Conclusion



Conclusion

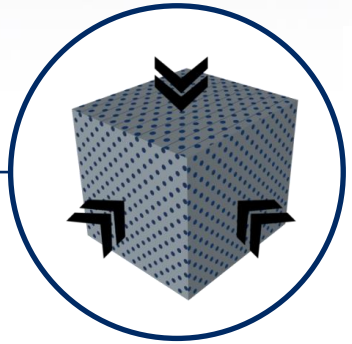
Innovation in Motion

Axial and Transversal Flux Machines

Axial Flux Machine

- High torque
- Short length (disc shape)
- Easy assembly

SMC Technology



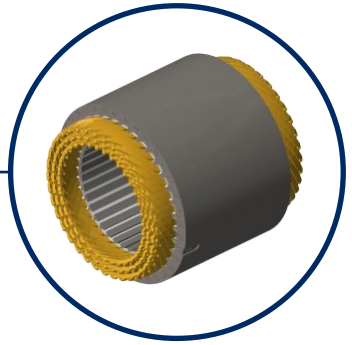
- 3D-flux → flux collector
- Cost efficiency (optional ferrites)

Radial Flux Machines (Stator Assemblies)

Radial Flux Machine

- Change from industry to automotive
- Various trends, different players

Stator Assemblies



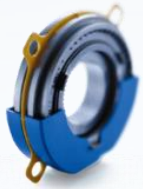
- Material experience
- Automated high volume lines
- Holistic approach

Miba Parts for electric Vehicles

Innovation in Motion

Clutches

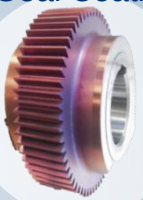
Synchronizer



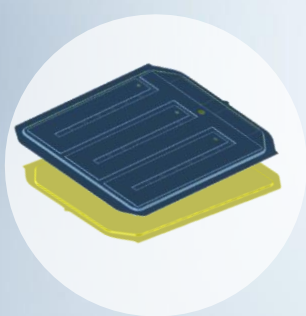
High strength Ring Gears

Lightweight and NVH optimized Gears

Adaptocoat silent Gear Coating



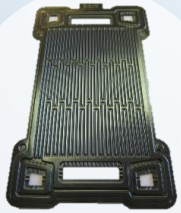
Power Resistors



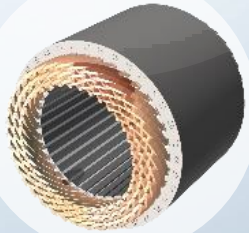
Battery Cooling

Questions?

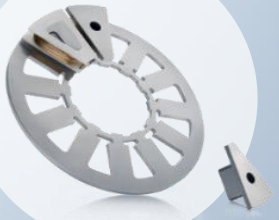
Heat Sinks for Power Electronics



Coatings for Fuel Cells



Stator assemblies



SMC parts