EPEi 2024
13th International Conference and Exposition on Electrical and Power Engineering
IASI, ROMANIA, October 17 – 19, 2024

The research presented in this conference is part of the MAXIMA project.

MAXIMA

Design of an Axial Flux Machine with Distributed Winding for Automotive Applications: Comparison of Different Rotor Structures

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Abstract

This poster outlines a design methodology for axial flux permanent magnet synchronous machines (AFPMs) aimed at electric vehicle applications.

A simplified analytical model for electromagnetic design is proposed, also the design choices related to machine topology: stator, and rotor structures.

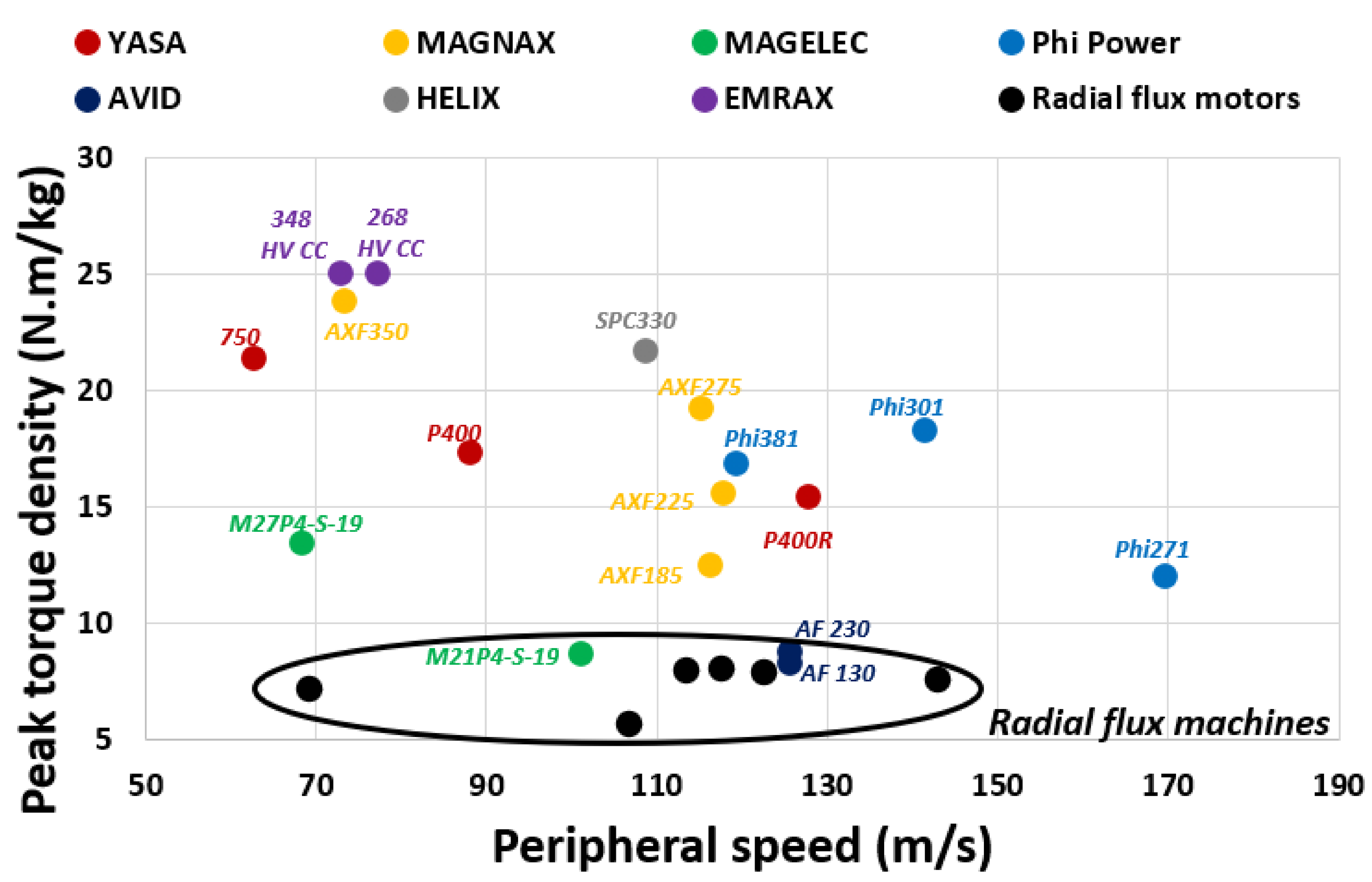
Three rotor configurations: SPM, flux-concentrating IPM, and V-shaped IPM are compared based on peak and continuous performance, magnetic attraction forces, and demagnetization risk. The findings provide insights into optimizing AFPM design for electric drivetrains.

Comparative Review of Axial Flux Machines for Automotive Applications

(scientific articles, manufacturer docs & websites)

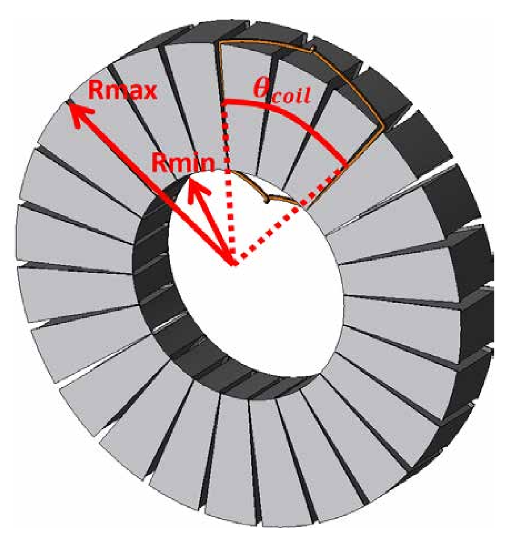
Marketed axial flux electric machines:

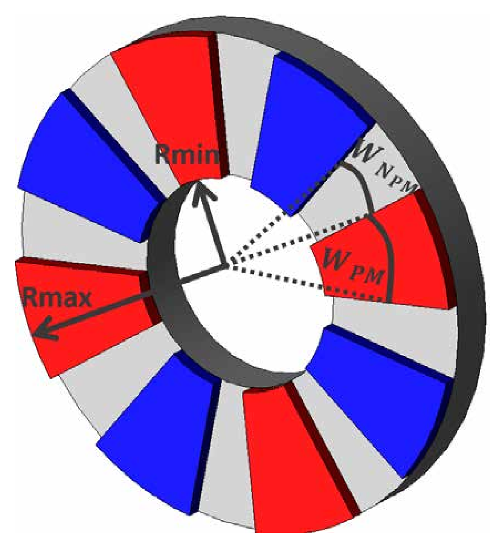
- **Surface mounted permanent magnet-based**
- **Dual-rotor or dual-stator structures**
- **high compactness (low axial length) & high torque density**



Sizing methodology and design choices for axial flux electric machines

Simplified analytical model: based on the calculation of the winding function and virtual work for torque computation.

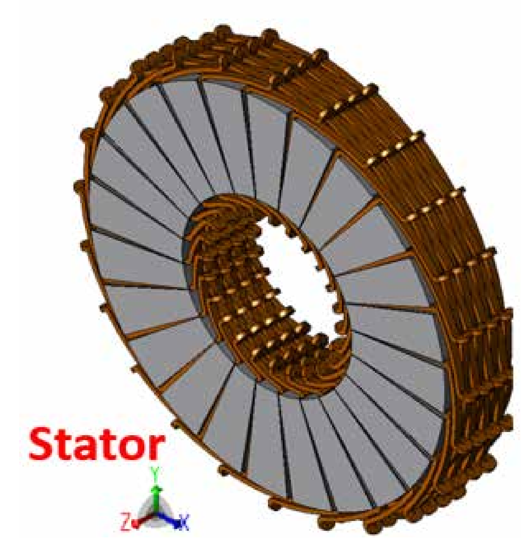




$$Torque = \frac{2\sqrt{2}}{\pi} \cdot \left(R_{max}^2 - R_{min}^2 \right) \cdot B_o \cdot m \cdot N_{turns} \cdot I_{rms} \cdot k_{wind_1}$$

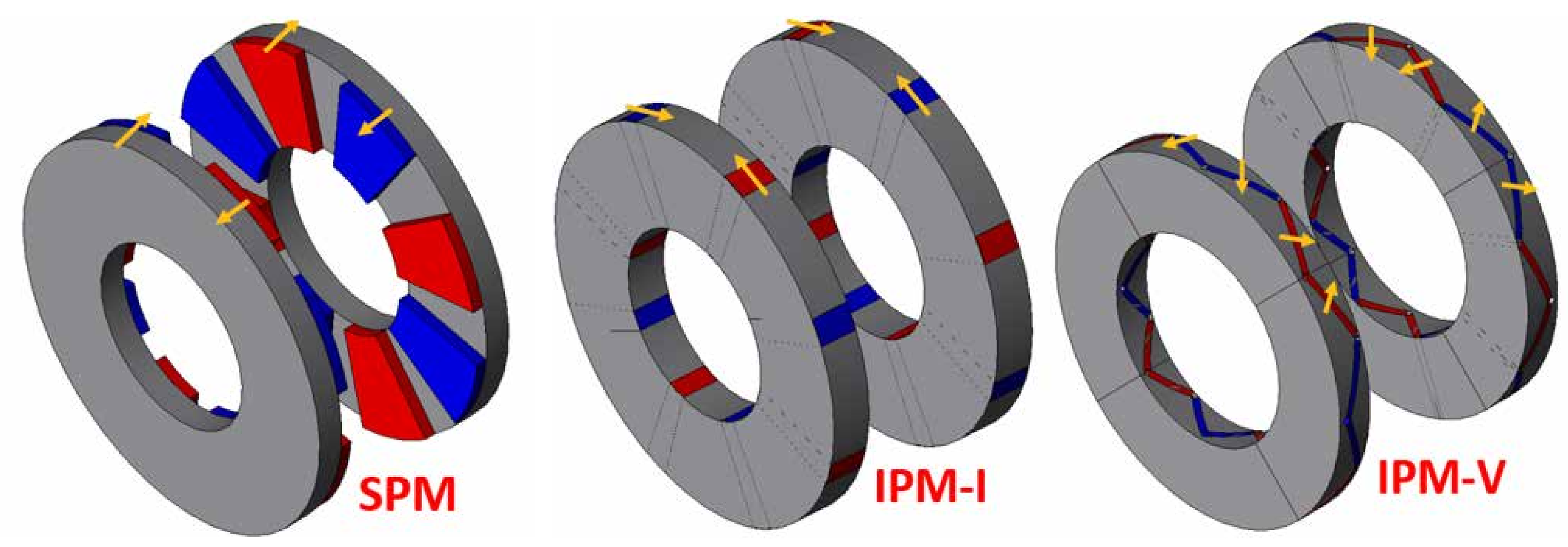
Structure		Advantages	Disadvantages
1 airgap		Easy to make Low cost	High attraction force Low power
2 airgaps	2 rotors	Low Joule / iron losses High power/torque density: yokeless stator possible Balancing of attraction forces Ease of rotor cooling	High PM quantity Complex manufacturing process Less mechanical rigidity Stator cooling: challenge High cost
	2 stators	Low PM quantity High torque density: easy cooling of the stator Possibility: core-less rotor Balancing of attraction forces Simple manufacturing process	High Joule / iron losses High weight: copper & stator yokes Difficult to cool the rotor

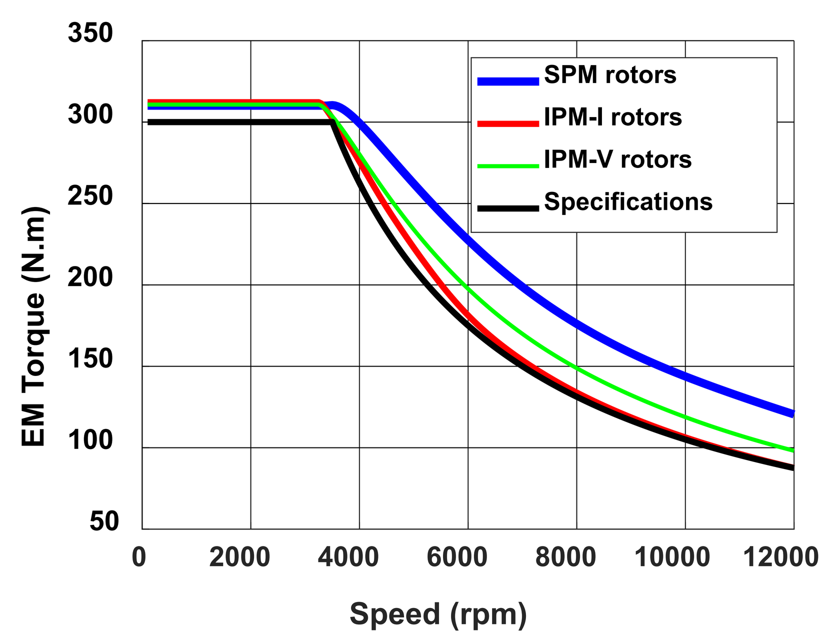
Studied structures and 3D FEA results comparison

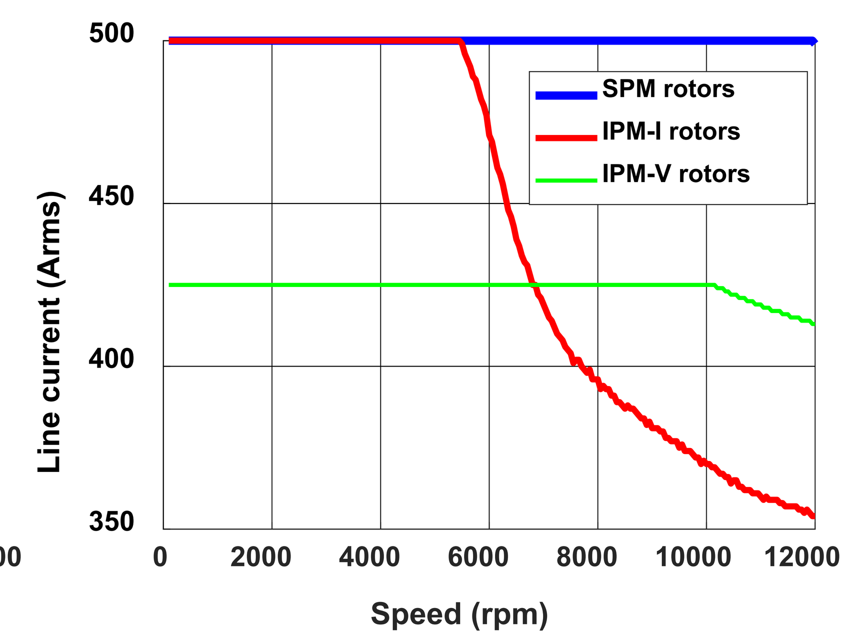


Same stator structure:

- Lowest axial length: SPM
- Lowest total weight: SPM







Cont. perfos	SPM	IPM-I	IPM-V
Stator losses @ low speed	😊	😐	😊😊
Rotor losses @ low speed	😐	😊	😊😊
Stator losses @ high speed	☹️	😊😊	😊
Rotor losses @ high speed	☹️	😊	😊
Mag Attraction force	😊😊	☹️	☹️
Demag risk	☹️	😊	😐

Conclusions

- A simplified analytical model gives an overview of key parameters.
- Machine structure selection depends on stator, rotor design, and topology, each with pros and cons.
- Buried magnets reduce losses and risk of demagnetization.
- SPM rotors are easier to industrialize, making them widely use.

ACKNOWLEDGEMENT

This project has received funding from the European Union's Horizon Europe research and innovation program under grant agreement No GA 101096097. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.