Stator Coreless Winding Performance Metrics for Electrical Machines: Implications from Previous Studies

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Background

- Coreless stator winding has become a revolutionary method in contemporary electrical machine development, requiring a lightweight framework, decreased electromagnetic losses and superior performances.
- While coreless design is appealing for renewable energy systems, electric vehicles, and aerospace actuation, where efficiency and reliability are crucial design factors.

Problem Statement

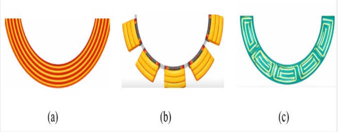
- Stator coreless windings have attracted significant research interest due to their compact structure.
- Despite that, achieving optimal performance remains challenging due to winding materials, design and orientation.
- Previous research has not adequately synthesized and presented an insightful review guide for a state-of-the-art study.

Objectives

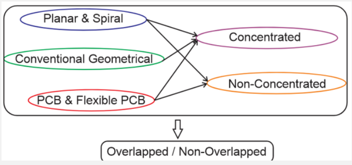
- To present a performance metrics overview, utilizing findings from previous analytical, numerical, and experimental research.
- To deliver design-focused advice for enhancing coreless winding arrangements in contemporary electrical devices.
- To interpret the design implications and improve the transparency of the developed framework for future analysis.

Coreless Winding Topologies

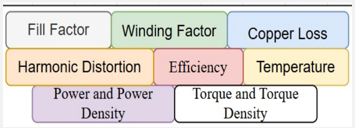
(a)Planar & Spiral (b) Conventional Geometrical (c) PCB and Flexible PCB



Configuration mapping for the stator coreless topologies.



Block of the key performance metric for the stator coreless windings framework



- Increased fill factor typically results in enhanced current capability.
- Advanced winding geometries are often adopted to maximize the winding factor & reduce distortion.
- Optimizing coil geometry & material selection is crucial for minimizing copper losses & temperature.
- The configurations have no rigid thermal conduction path.

Design Implications

Design implication gives a pathway for future research and analysis

1. **Trade-Off Between Metrics and Fill Factor Analysis:** Improving the fill factor directly influences the magnitude of the current-carrying capacity within the given area
2. **Inner vs Outer Region Constraints:** The inner diameter section of coreless windings has significant performance constraints.

Comparison of the performance of the stator coreless winding topologies

Parameters / Coils	Planar & Spiral Windings	Conventional Geometrical Winding	PCB & Flexible Printed Windings
Fill Factor	Low –Moderate	High	Low
Winding Factor	Moderate	High	Moderate
THD	Moderate – High	Low – Moderate	Moderate
Copper loss	High	Moderate	High
Eddy current loss	Low	Low	Moderate
Temperature	Moderate – High	Moderate	High
Torque	Low – Moderate	High	Moderate
Power	Moderate	High	Moderate
Efficiency	Moderate	High	Moderate

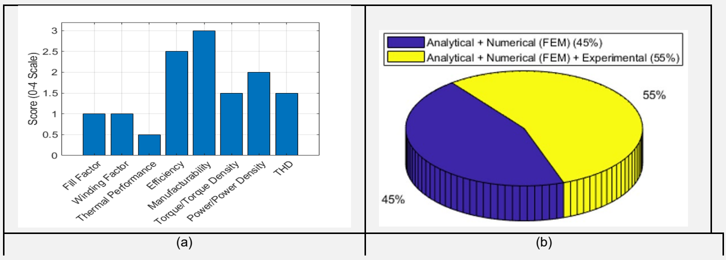
Practical Design Considerations

Practical design considerations focus on ensuring that the proposed machine is not only efficient but also manufacturable and reliable under real operating conditions.

Mechanical support: Non-ferromagnetic material (epoxy resins, binder & composite reinforcements) employed to provide adequate geometric integrity of the winding	Thermal management: adoption of natural air cooling, forced convection, integration of heat sinks or novel substrates, among others.	Insulation and manufacturing: play a significant role in determining the uniformity of winding geometry, which directly impacts electromagnetic

General Performance Metrics

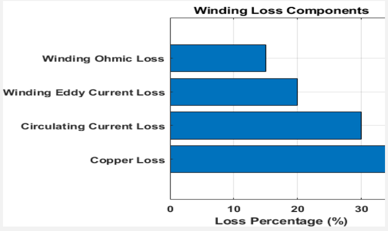
The bar and pie chart plots show the implications of studies for stator coreless windings. **(a)** Normalize performance scale, **(b)** Study methodological approaches



(a)

(b)

Stator winding losses plot highlighting the contribution of each loss component. Copper at 35%, indicating dominant loss. Circulating current loss contributes 30% due to induced currents. Winding eddy current loss accounts for 20%, while winding ohmic loss is the lowest at 15%.



Conclusion

Coreless stator windings offer significant advantages in reducing electromagnetic losses and improving efficiency. However, their performance is highly dependent on winding topology, thermal behaviour, and geometric optimization. This study highlights that fill factor distribution, winding factor, and thermal constraints are the most critical determinants of performance.

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