ASEC 2025 Conference

The 6th International Electronic Conference on Applied Sciences

09–11 December 2025 | Online

MDPI

Impact of Stator Winding Insulation on Thermal Behavior in Switched Reluctance Machines

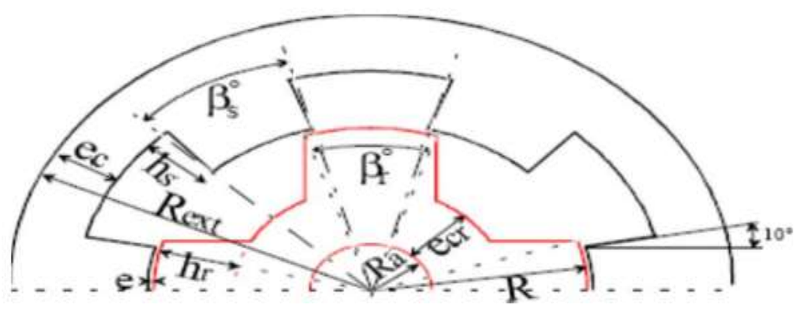
Mama CHOUITEK 1; Houaria NEDDAR 2,

1Department of Industrial Engineering, University of Oran, Oran, Algeria

2 Department of Electrical Engineering, University of Mostaganem, Mostaganem,Algeria

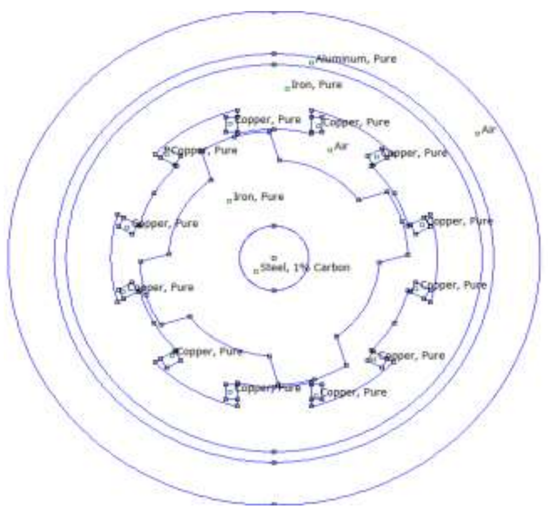
INTRODUCTION & AIM

Our study examines a 6/4 double-saliency switched reluctance machine (SRM), featuring six stator teeth and four rotor teeth. This double-saliency structure is well suited for high-speed operation thanks to its rotor without active components, and for low-speed operation since increasing the number of teeth reduces rotational speed without additional windings.

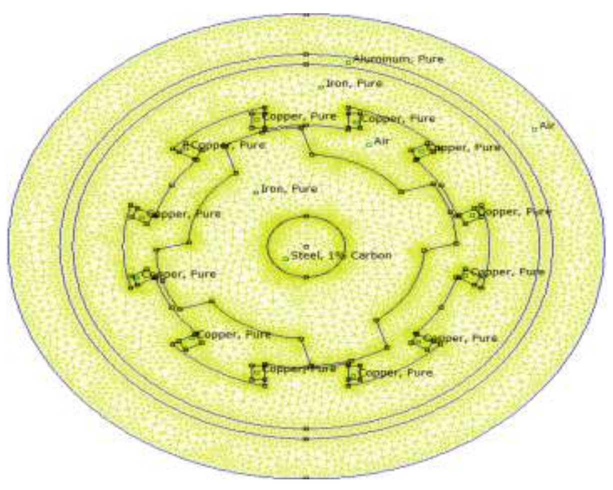


METHOD

In the first step, we created the equivalent model of the machine. We then defined the materials for each part, as shown in the figure below, which represents the cross-section of a type 6/4 variable reluctance machine.We cut this model into finite elements, which we see in the figure below



Section of a type 6/4 switched reluctance machine

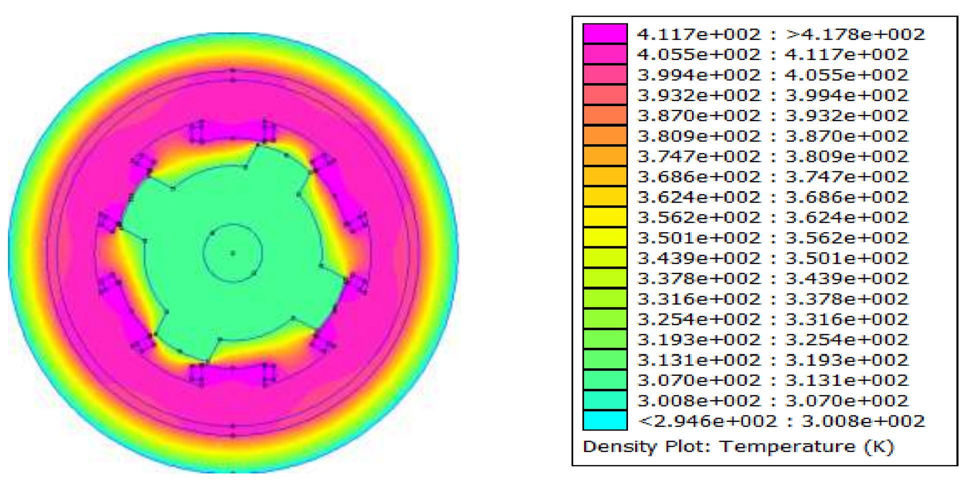


Cross section of the MRV type 6/4

RESULTS & DISCUSSION

We first study uninsulated coils to establish baseline thermal behavior, identify key heating factors, and provide a reference for assessing insulation effects on reliability.

1-Non-insulated winding



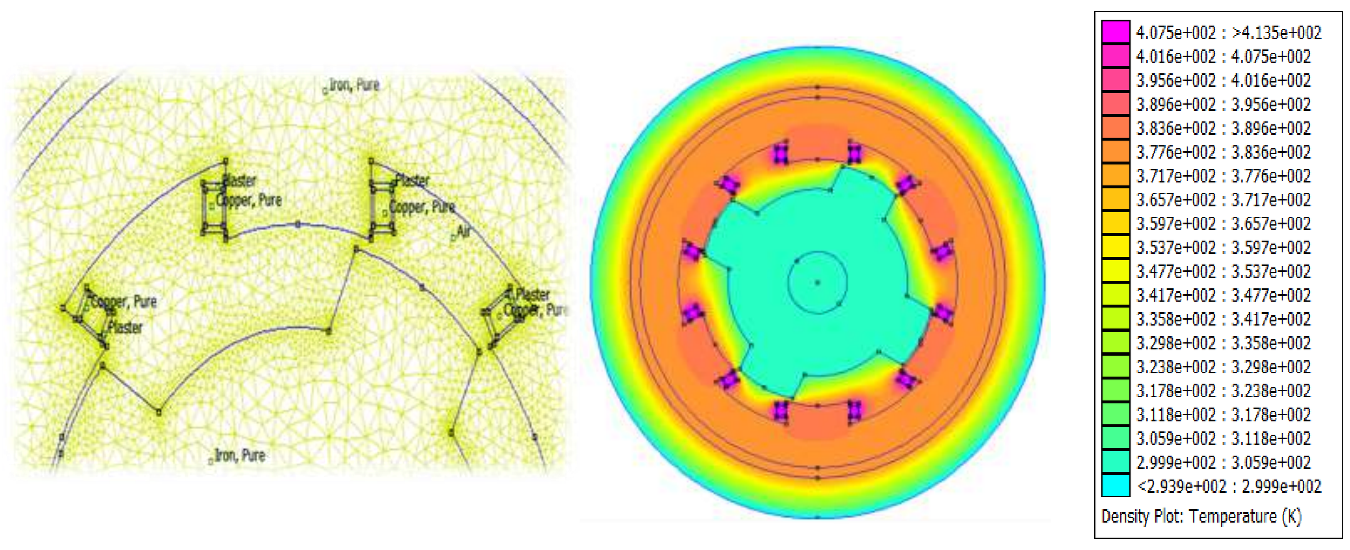
Temperature propagation in an MRV (without insulation).

The results show a decreasing thermal gradient from the winding (450.3 K) toward the outside of the machine. The windings reach the highest temperature due to Joule losses. The close temperatures of the stator teeth (411.7 K) and stator yoke (405.5 K) indicate good heat conduction through the ferromagnetic structure. Despite its low conductivity, the air gap still transfers heat to the rotor, as reflected in the temperatures of the rotor teeth (325.4 K) and rotor yoke (319.3 K). The lower shaft temperature (313.1 K)

2-Insulated Winding

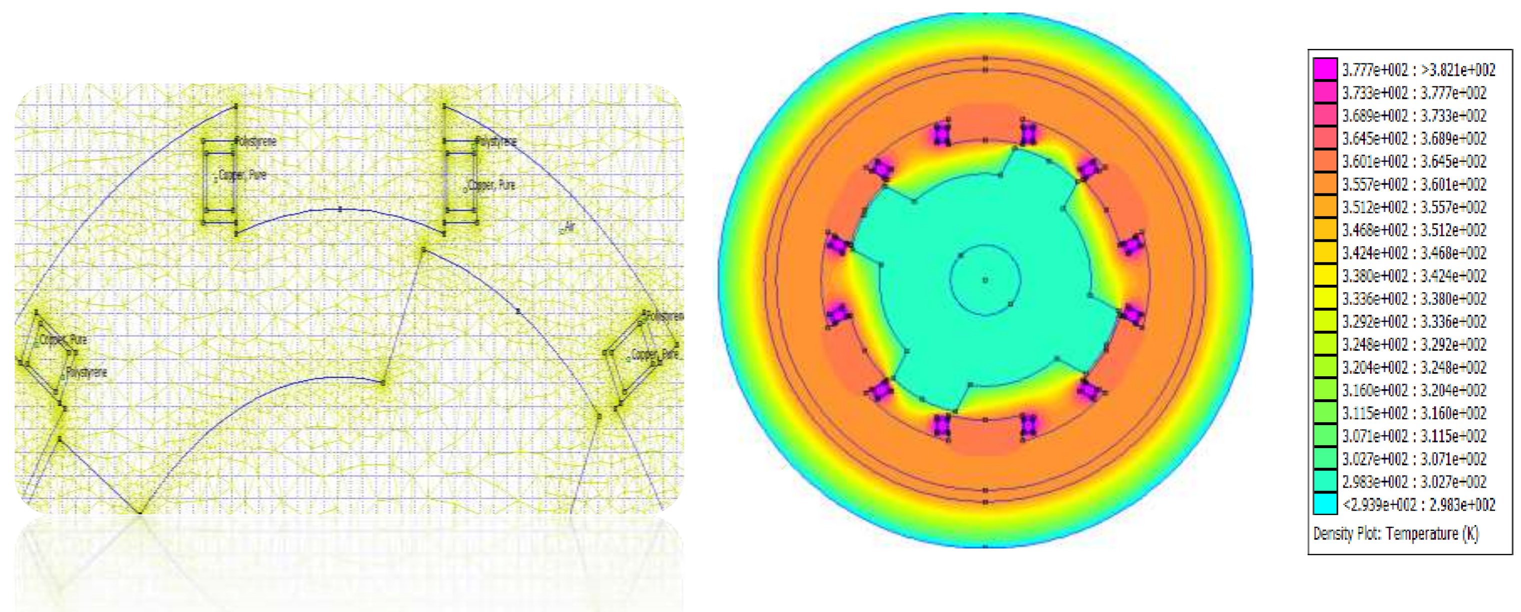
In this experiment, insulating materials are added around the windings to assess their effect on thermal management. Plaster was first tested for its thermal and electrical properties, followed by polystyrene, chosen for its high electrical resistivity to ensure effective coil insulation under high stress.

a)Use of plaster as an insulator:



Steady-state temperatures (without insulation) decrease progressively from the windings towards the outside of the machine. The windings reach the highest temperature (413.5 K), followed by the stator teeth (383.6 K) and the stator yoke (380.6 K). The frame reaches 377.6 K, the air gap 371.7 K, while the rotor teeth (310 K), the rotor yoke (305.9 K), and the shaft (300.1 K) exhibit lower temperatures, indicating heat dissipation towards the peripheral parts.

b)Use of Polystyrene as an Insulator.



In steady-state without insulation, temperatures decrease from the windings (382.1 K) to the shaft (298.3 K). The stator teeth (364 K) and yoke (360 K) remain relatively hot, while the case (355.7 K) and air gap (351.2 K) show moderate temperatures. The rotor teeth (302.7 K) and yoke (300 K) are cooler, with the shaft being the coolest region, indicating progressive heat dissipation toward the machine's periphery. Plaster provides moderate insulation, allowing some heat to escape from the windings. Polystyrene, with lower thermal conductivity, more effectively traps heat and protects the machine. Overall, polystyrene is better for high thermal loads, while plaster suits less demanding conditions.

CONCLSION

This study confirms the importance of developing a reliable thermal model to predict and control overheating risks that may compromise both the performance and the durability of the Switched Reluctance Machine. The insulating properties of materials have a direct impact on thermal resistance and therefore on the overall efficiency of heat dissipation. These results emphasize the close relationship between design choices and thermal behavior, highlighting the necessity of careful material selection in SRM construction. The steady-state simulations provided a clear quantification of heat flows in each component, while the transient analysis offered valuable insight into temperature rise and the machine's response under varying loads.

FUTURE WORK / REFERENCES

Future work will focus on refining meshing strategies, incorporating experimental validation to improve model accuracy, and investigating advanced insulating materials to further enhance thermal management

1 N. A. Rahman, E. Bostancı, and B. Fahimi, "Thermal analysis of switched reluctance motor with direct in-winding cooling system," in *Conference / Seminar*, 2016, DOI: 10.1109/CEFC.2016.7816110. open.metu.edu.tr

2 R. Hemmati, F. Wu, and A. M. El-Refaie, "Survey of Insulation Systems in Electrical Machines," in *Proc. IEEE Int. Electric Machines & Drives Conf. (IEMDC)*, 2019, pp. 2069-2076, DOI: 10.1109/IEMDC.2019.8785099. epublications.marquette.edu+1

3 E. Elhomdy, Z. Liu, and G. Li, "Thermal and Mechanical Analysis of a 72/48 Switched Reluctance Motor for Low-Speed Direct-Drive Mining Applications," *Applied Sciences*, vol. 9, no. 13, Article 2722, 2019, DOI: 10.3390/app9132722. MDPI

4 Hira Raziqa, Munira Batoola, Fawad Nawaz, Ali Akgül, et al., "A review on analysis and modeling of electrical machine insulation system," *Cogent Engineering*, vol. 11, no. 1, 2024, DOI: 10.1080/23311916.2024.2400614. Taylor & Francis Online