



# A Radial-Axial (Raxial) Flux PMSM Design for a Compact Prosthetic Actuator

## Project Brief

Conventional motor topologies often face challenges when high torque must be generated within very limited space. Prosthetic finger joints require compact actuators with high torque density, low weight, and good dynamic performance. While radial- and axial-flux machines have individual advantages, combining both flux paths may improve electromagnetic utilization without increasing overall dimensions.

This work investigates a compact Radial-Axial (Raxial) permanent magnet synchronous motor (PMSM) for metacarpophalangeal (MCP) joint actuation.

## Design targets:

- Compact dimensions for MCP integration
- High torque density
- Low weight
- Potential for gearless actuation

## Methodology

- Designed three baseline machine configurations: Outer-radial machine, Inner-radial machine and Axial-flux machine.
- Maintained identical geometric and electrical constraints for fair comparison
- Performed three-dimensional finite-element simulations using ANSYS Maxwell
- Evaluated no-load back-EMF to compare electromagnetic behaviour of individual configurations
- Kept stator MMF fixed and swept rotor position to identify the maximum torque angle

- Integrated radial and axial active regions into a single Raxial topology and compared results with standalone configurations

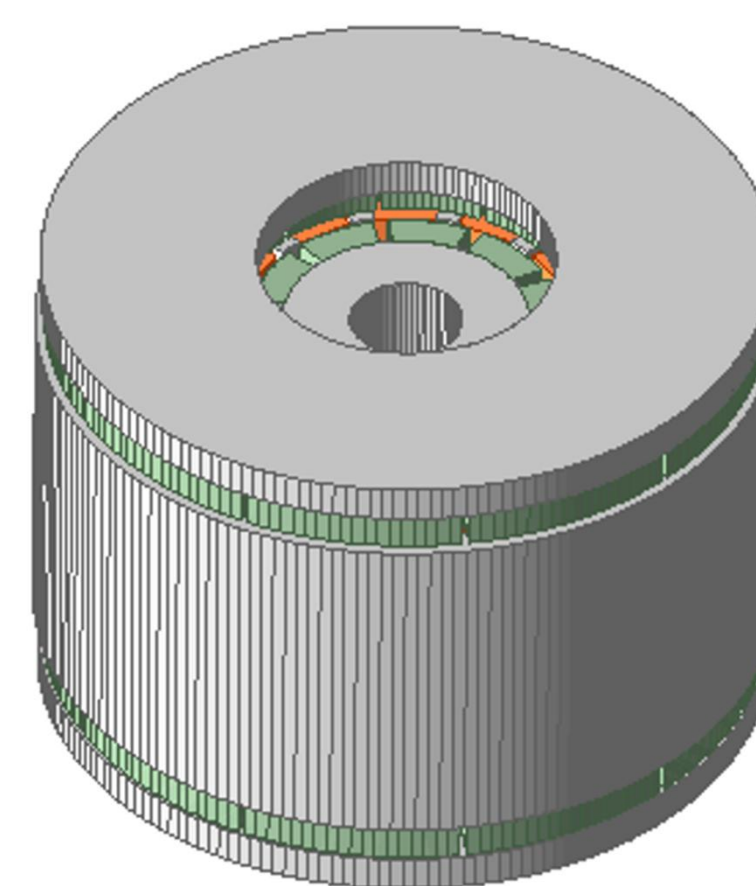


Figure 1. Full 3D view of the proposed Raxial PMSM

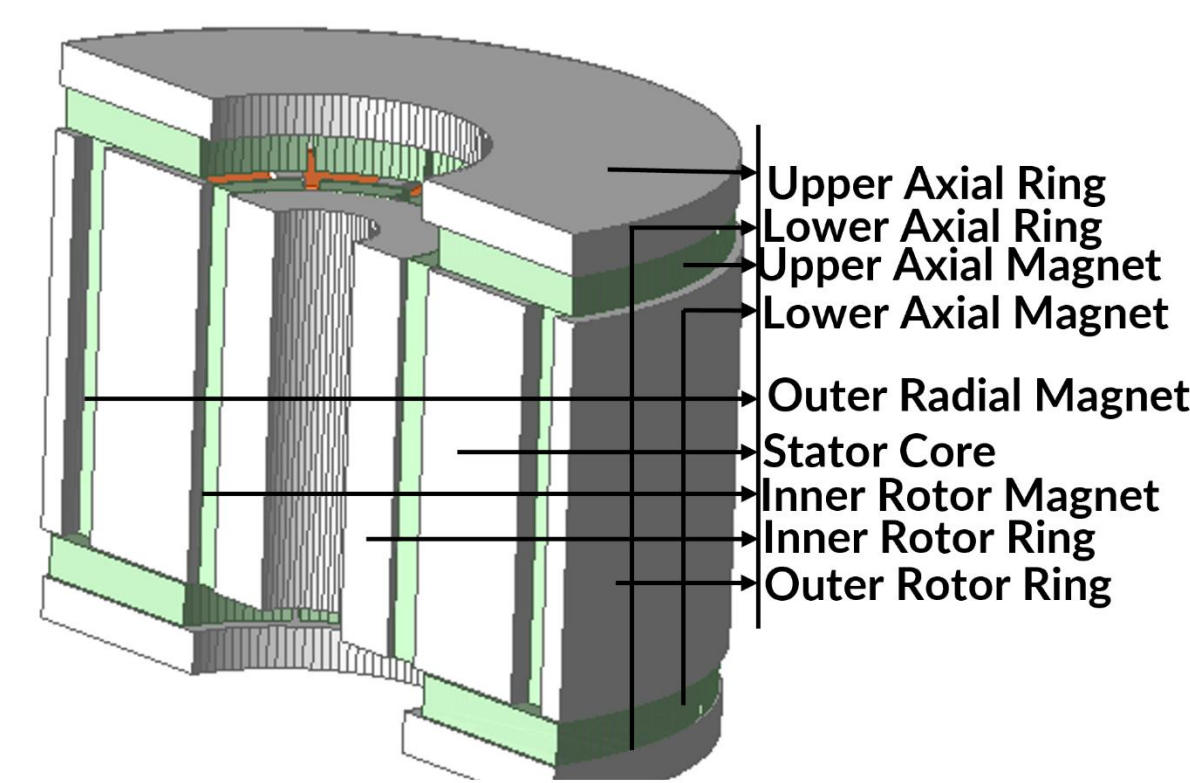


Figure 2. Axial cross-sectional view showing radial and axial flux region

## Results

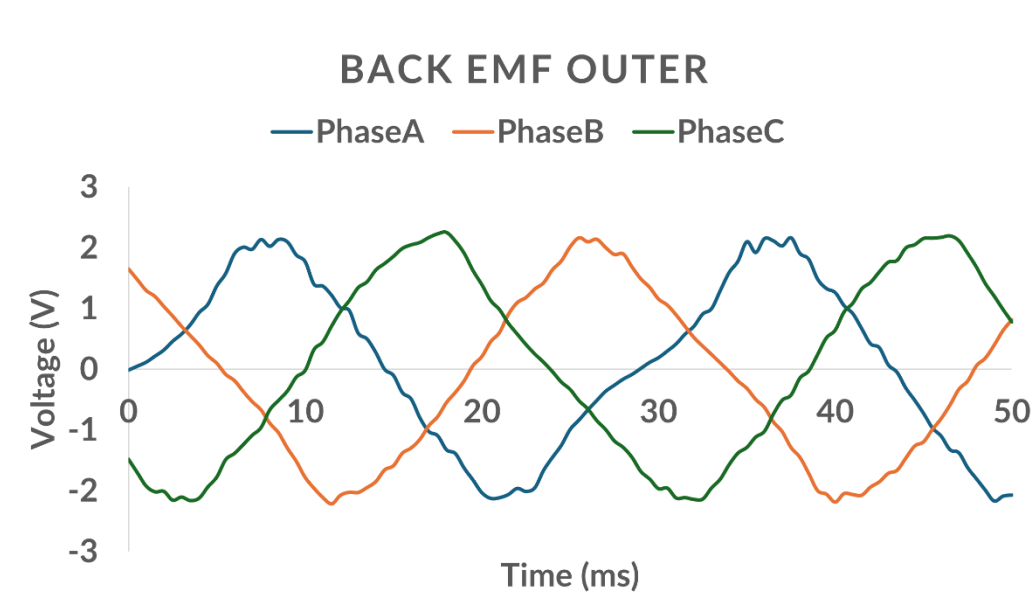


Figure 1: Outer Radial Back EMF

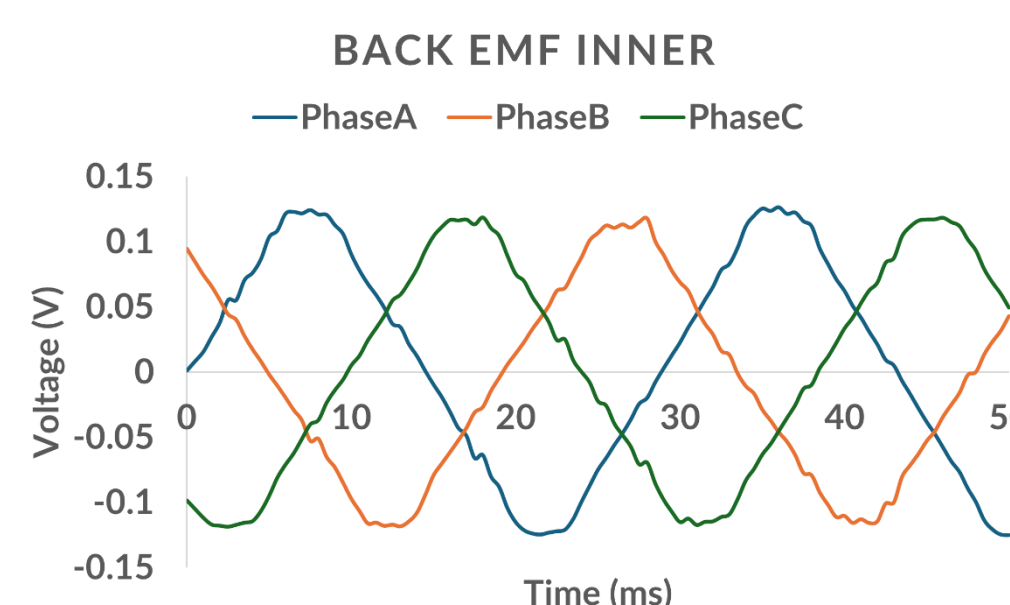


Figure 2: Inner Radial Back EMF

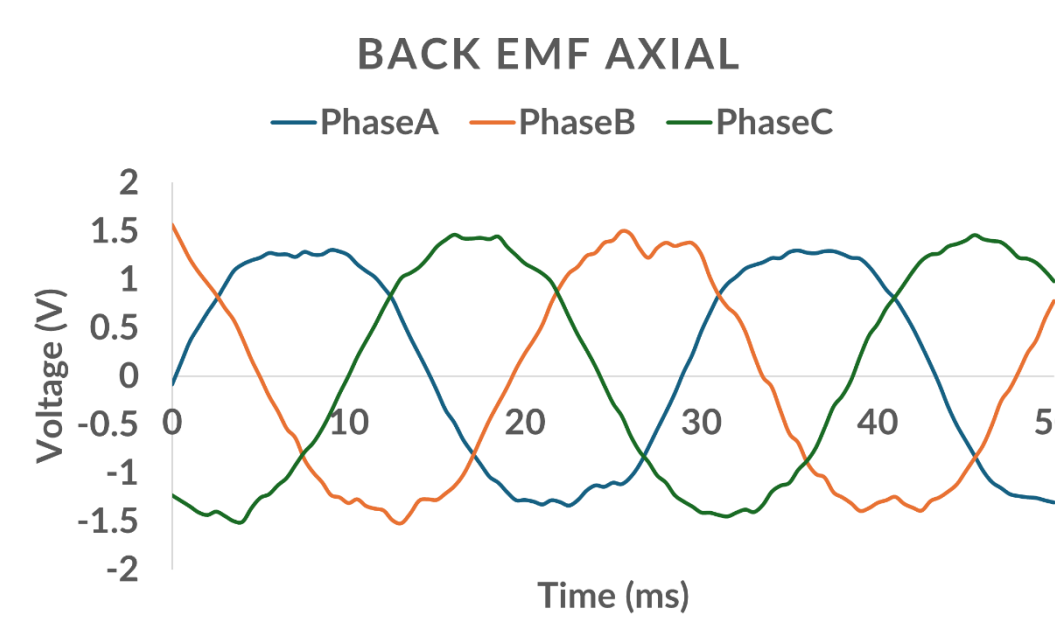


Figure 3: Axial Flux Back EMF

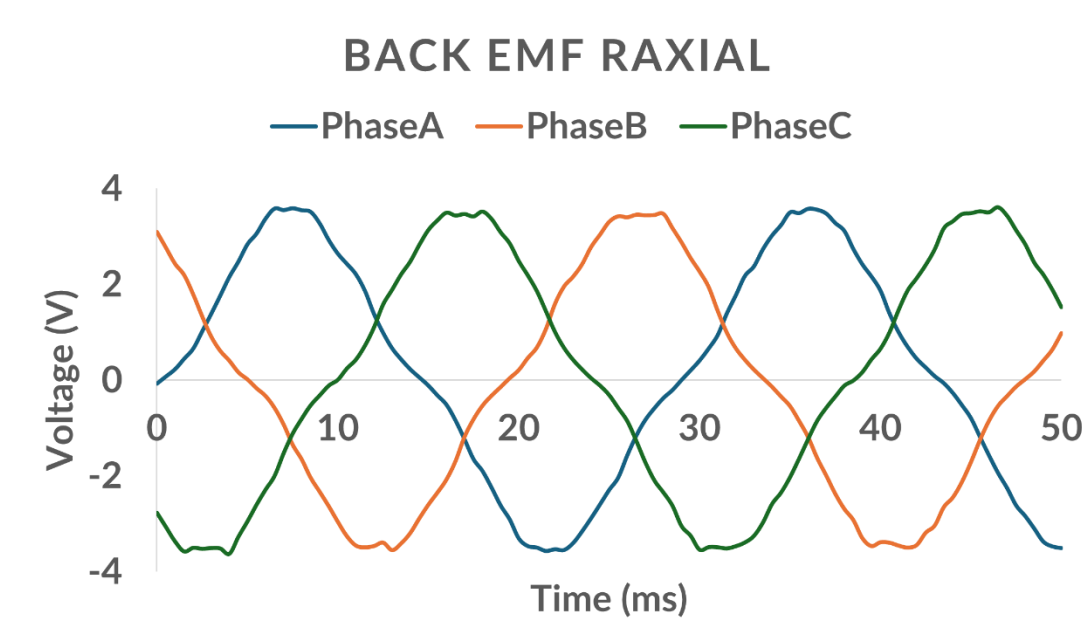


Figure 4: Raxial Back EMF

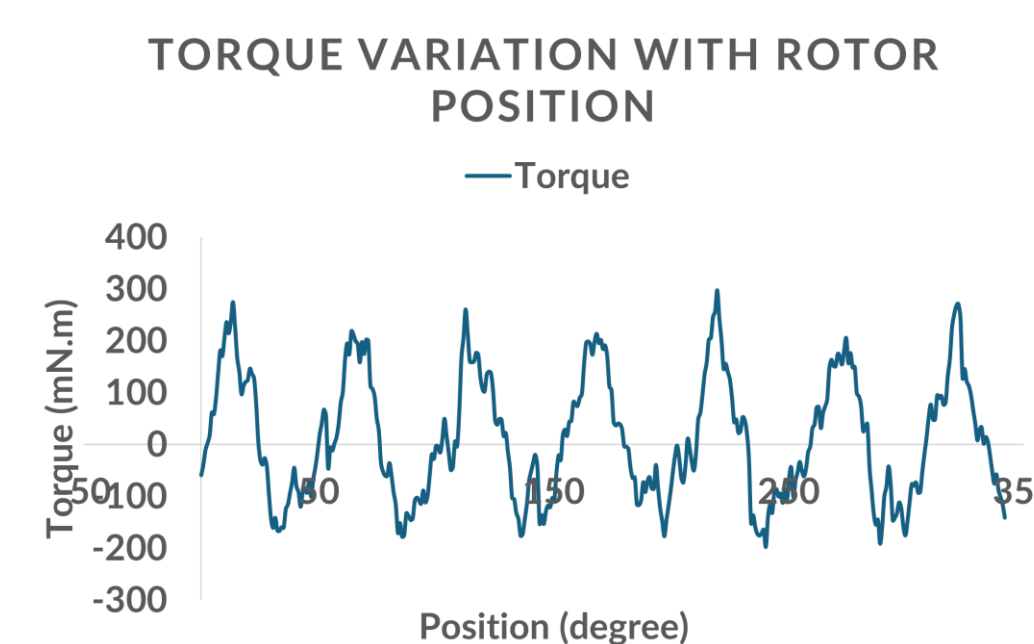


Figure 5: Torque Variation with rotor position

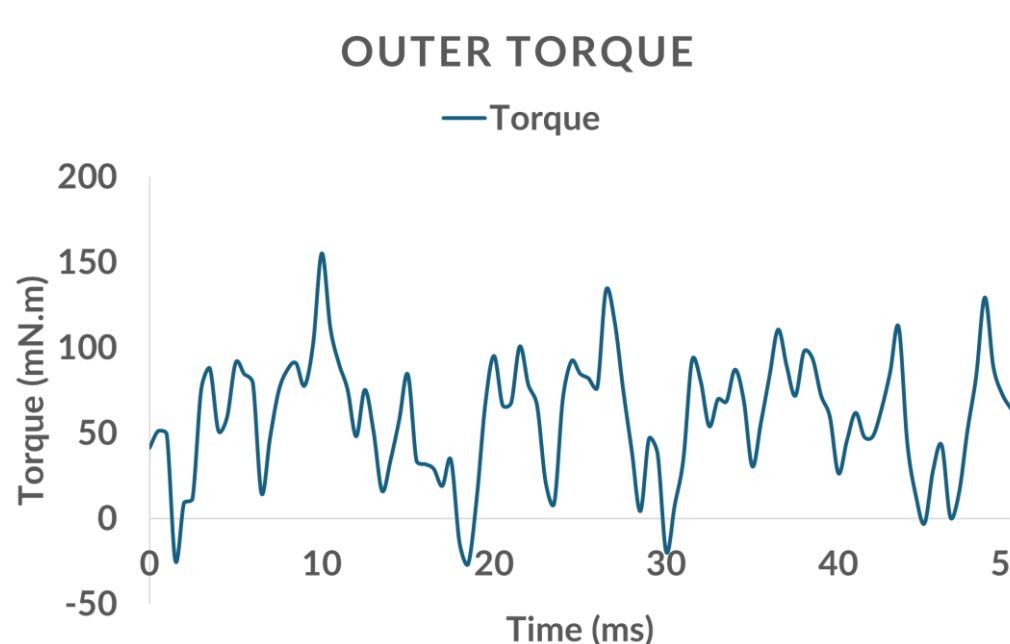


Figure 6: Outer Radial Torque

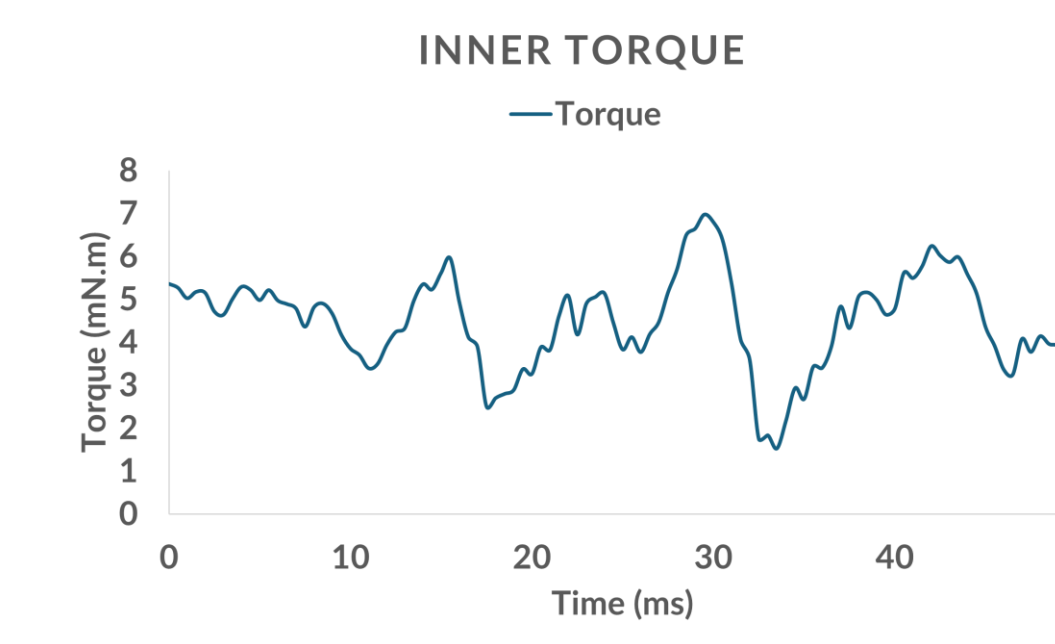


Figure 7: Inner Radial Torque

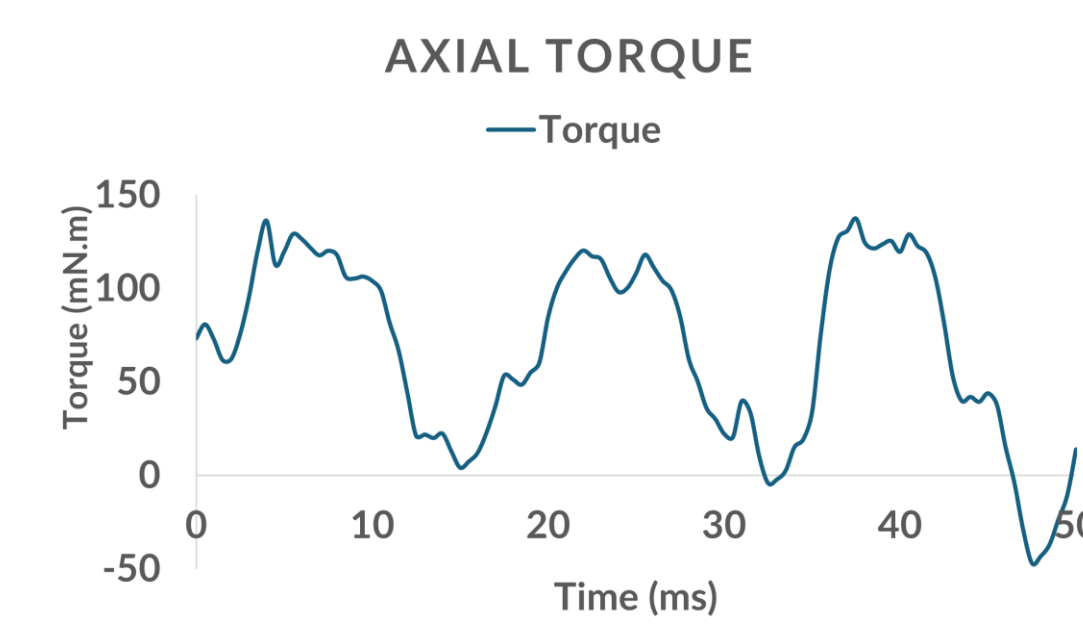


Figure 7: Axial Side Torque

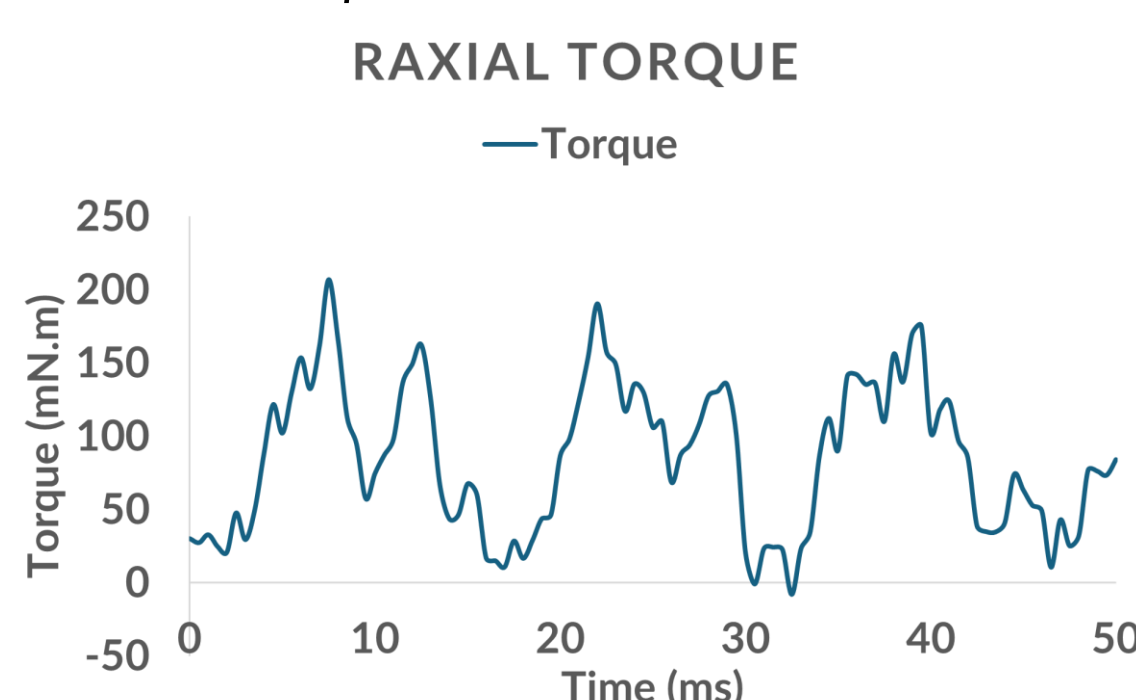


Figure 8: Raxial Torque

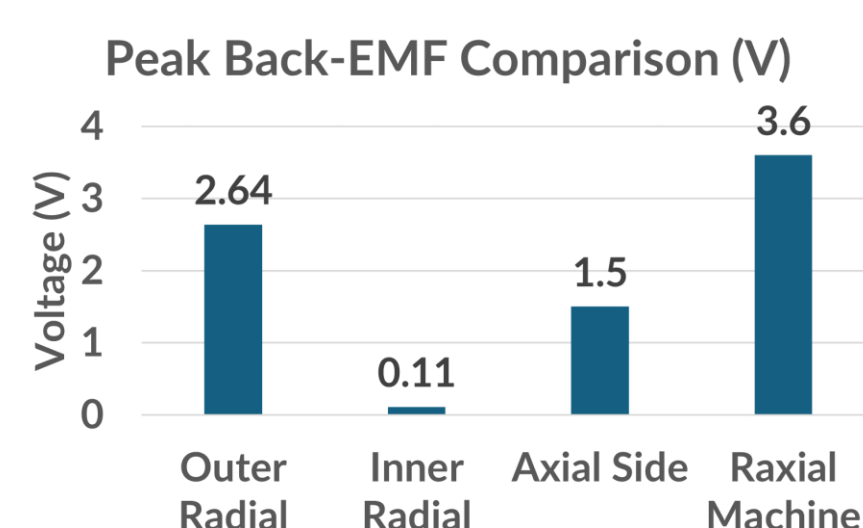


Figure 9: Summary of Back EMF

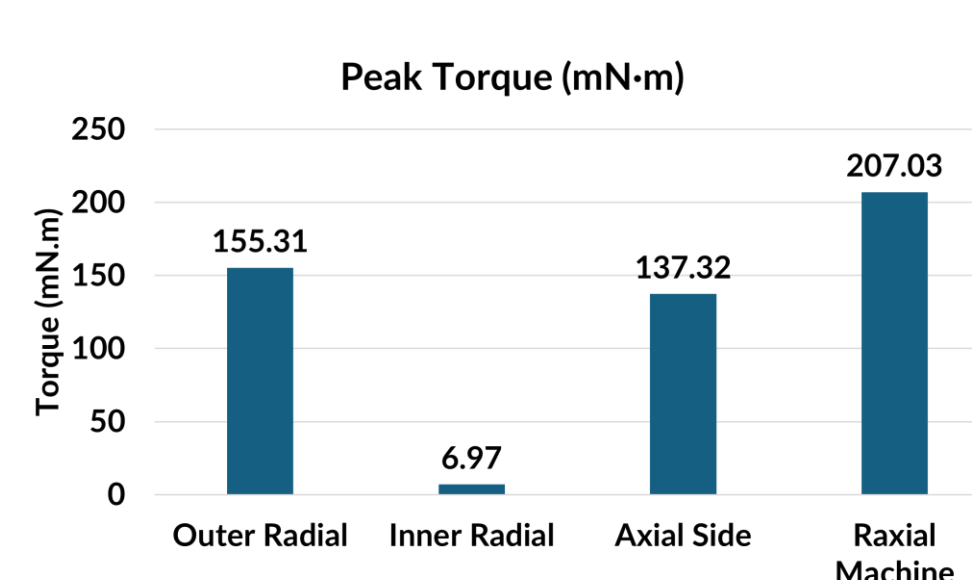


Figure 10: Summary of Torque

## Conclusion

- Developed a compact Raxial PMSM by combining outer-radial, inner-radial, and axial flux regions within a single structure
- Future work includes torque optimization, prototype fabrication, and experimental validation