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Innovative Hub Motor Architecture Featuring Dual Lamination Structure to Minimize Core Loss – For Electric Two Wheeler Application

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Abstract:

Electric two-wheelers for low- to medium-speed applications often use hub motors for their compactness and direct-drive capability. Conventional designs with a laminated stator and solid rotor ring featuring surface-mounted magnets suffer from high core losses, increased rotor inertia, and poor thermal management, limiting torque and efficiency. This paper introduces a novel hub motor architecture inspired by PMSM principles, featuring both a laminated stator and a laminated rotor with embedded magnets. The stacks are assembled by the welding method and it reduces eddy current losses in the rotor. This design reduces core losses, lowers inertia, and improves heat dissipation, enhancing torque density and overall efficiency. Preliminary simulations indicate its potential as a next-generation solution for electric two-wheeler hub motors.

Keywords — **Hub Motor, PMSM, Laminated Rotor, Core Loss Reduction, Electric Two-Wheeler, Thermal Management, High Torque.**

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1. INTRODUCTION

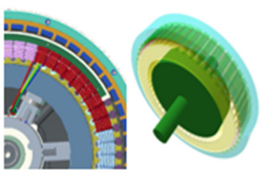
The growing demand for environmentally friendly transportation has accelerated the adoption of electric two-wheelers, particularly for slow/medium-speed applications. Hub motors have emerged as a preferred solution for these vehicles due to their compact design, direct-drive capability, and ease of integration. Conventional hub motors typically employ a laminated stator winding and a solid steel rotor ring embedded with surface-mounted permanent magnets, operating on the Brushless DC (BLDC) principle. While widely used, this configuration presents several limitations, including high core losses, increased rotor inertia, poor heat dissipation, and restricted torque density. These drawbacks adversely affect efficiency, thermal performance, and dynamic response, posing challenges for next-generation electric mobility solutions. To address these issues, this research introduces a novel hub motor architecture inspired by Permanent Magnet Synchronous Motor (PMSM) design principles. In conventional hub motors, the Stator hub is typically formed using sheet metal, whereas the proposed design employs aluminum die casting, which improves heat dissipation, enhances efficiency, and reduces overall weight. The proposed design incorporates dual lamination in both the stator and rotor, replacing the conventional Cold-Drawn Electric Welded (CEW) steel tube rotor with Cold Rolled Non-Oriented (CRNO) electrical steel laminations. Specifically, the rotor employs grade 50C350 material, which offers excellent wear resistance, moderate corrosion resistance, good machinability, high hardness, toughness, and ductility, with a typical tensile strength of approximately 350 MPa.[5] The laminated rotor structure is engineered with dedicated slots for magnet insertion, ensuring secure placement and eliminating the risk of magnet slippage commonly observed in surface-mounted designs [2]. This innovative approach significantly reduces eddy current and core losses, lowers rotor inertia, and enhances heat dissipation. These improvements collectively contribute to higher torque output, improved efficiency, and superior thermal management, making the design highly suitable for next-generation electric two-wheelers. Preliminary simulation and analysis indicate that the proposed rotor construction offers a promising solution to overcome the limitations of conventional hub motor designs.

2. PROBLEM STATEMENT

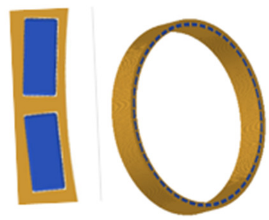
Conventional BLDC hub motors used in electric two-wheelers rely on a laminated stator and a solid CEW steel rotor ring with surface-mounted magnets. Although this approach is, not mechanically locked; instead, the magnets are retained by welding, it imposes constraints that limit further improvements in hub motor performance. The solid rotor structure restricts optimization of magnetic flux paths, resulting in lower torque density and reduced overall electromagnetic efficiency.

Despite advancements in PMSM traction motor architecture, the application of laminated rotor cores in hub motors remains largely unexplored. Current commercial designs continue to use CEW steel tubes due to manufacturing convenience, leaving a significant research opportunity to investigate how laminated electrical steel rotors — with material grades tailored for motor applications can enhance magnetic performance, reduce losses, and improve torque production in compact hub motor topologies

3.Motor Specifications

Motor Details	Size: 10inch	
	Rated Power: 1500Watt	
	Operating Voltage: 48V	
	Air gap: 0.6mm	

Stator Design	No. of slot: 54	
	Sator OD: 193.8mm	
	Material Grade: 50C350	
	Sheet Thickness: 0.5mm	

Rotor Design	No. of slot: 50	
	Rotor ID: 195mm	
	Material Grade: 50C350	
	sheet Thickness: 0.5mm	
	Magnet: NdFe30	

Winding Details	No. of Phase: 3	
	Connection: Star	
	Conductor: Copper	
	No. of layers: 2	
	Fill factor: 0.55	

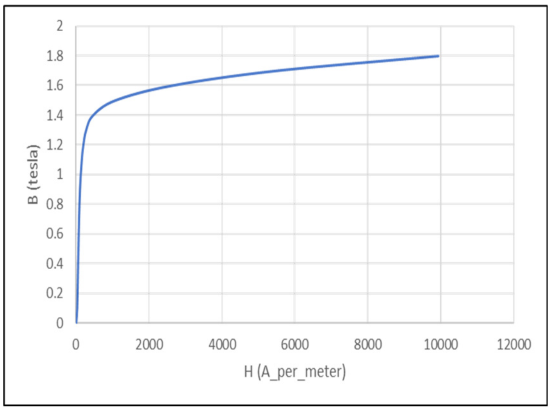


Figure 1: B-H curve for the 50C350

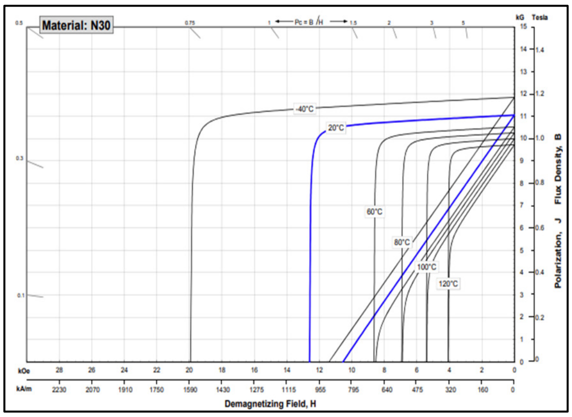


Figure 2: B-H curve for the NdFe30

4. Comparison

Feature	Conventional Hub Motor	New Gen. Hub Motor
Rotor Construction	Solid steel ring with embedded magnets, notch is Mechanically locked	Laminated steel sheets with magnet insertion, Welded for retention.
Core Loss	High (due to solid rotor causing eddy currents)	Low (laminated rotor reduces eddy current and hysteresis losses)
Heat Dissipation	Poor (solid rotor traps heat)	Improved (laminated rotor allows better thermal flow)
Stator Hub	Sheet-metal formed	Aluminium die-cast improves heat dissipation, efficiency, and reduces weight
Torque Output	Moderate	Higher (optimized flux path and reduced losses)
Efficiency	Lower (due to core loss and heat buildup)	Higher (better magnetic performance and cooling)
Dynamic Response	Slower (due to high inertia)	Faster (lower inertia improves acceleration)
Application Suitability	Common in low-cost hub motors	Suitable for high-performance EV hub motors

10-inch PMSM configuration under a 48 V nominal operating condition. The electromagnetic simulation results indicate that the designed motor achieves high torque density, high efficiency, and reduced losses, making it suitable for electric two-wheeler traction applications.

5.1 Analysis of Electromagnetic Losses

The total losses were divided into copper losses and core losses.

Copper Loss = 6.83%

It indicates that the armature design and current density are well within acceptable limits. Lower copper loss improves thermal stability and efficiency.

Core Loss = 2%

The low percentage confirms minimal hysteresis and eddy current effects in the stator and rotor cores. Proper lamination thickness selection and flux distribution optimization contribute to this result.

Total losses <10% validate that the motor operates within a high-efficiency range.

5.2 Power Factor Evaluation

The motor demonstrates a Power Factor of 0.98558, which is extremely close to unity.

A high PF indicates:

- Less reactive current required
- Reduced copper losses
- Better torque per ampere
- Improved controller efficiency

Such PF values are typical only in well-optimized interior magnet designs with strong d-axis inductance contribution.

5.3 Back-EMF Characteristics

The induced voltage (rms) is: 18.3 V at rated speed, this is ideal for a 48 V system because:

- it allows sufficient margin for field weakening
- inverter modulation index remains in optimal range
- Current control stability is improved

5.4 Thermal Safety and Current Density

The current density = 7 A/mm² is within recommended EV motor limits (6–10 A/mm²).

This ensures:

- no thermal runaway
- longer insulation life
- stable operating temperature

The high efficiency (>93%) also minimizes heat generation.

5.5 Material Optimization

Material consumption is extremely important for cost-sensitive EV markets.

Table 6: Material Consumption

Material	Weight / Explanation
Stator Core – 2.27 kg	Optimal for 10-inch motor size; ensures magnetic rigidity.
Copper – 1.36 kg	Balanced for thermal and torque performance.
Rotor Core – 0.81 kg	Indicates lightweight design for quick dynamic response.
Magnet – 0.53 kg	Sufficient magnet mass for strong torque without over-saturation.

5.6 Performance of Motor

Table 7: Output Parameters

Parameter	Value
Motor Size	10 inches
Slots / Poles	54 Slots / 50 Poles
System Voltage	48 V
Input Power	1550 W
Output Power	2300 W
Rated Torque	25 Nm
Peak Torque	48 Nm
Impulse Torque	100 Nm
Rated Current	32 A
Efficiency	≥93%
Core Loss	2%
Copper Loss	6.83%
Torque Ripple	6.5%
Rotor Inertia	0.0227 kg·m²
Power Factor	0.98558
Induced Voltage (rms)	18.3 V
Current Density	7 A/mm²

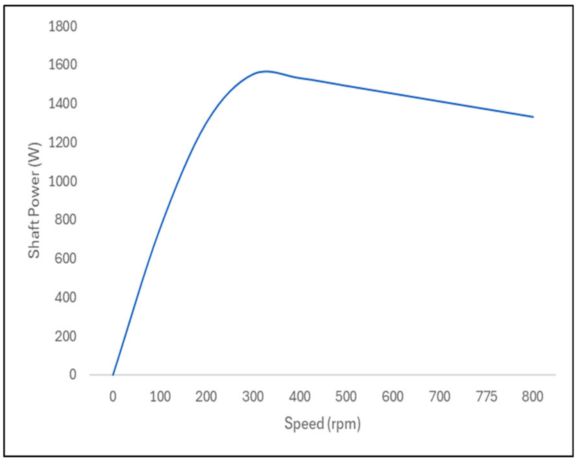


Figure 3: Speed vs Power [Rated]

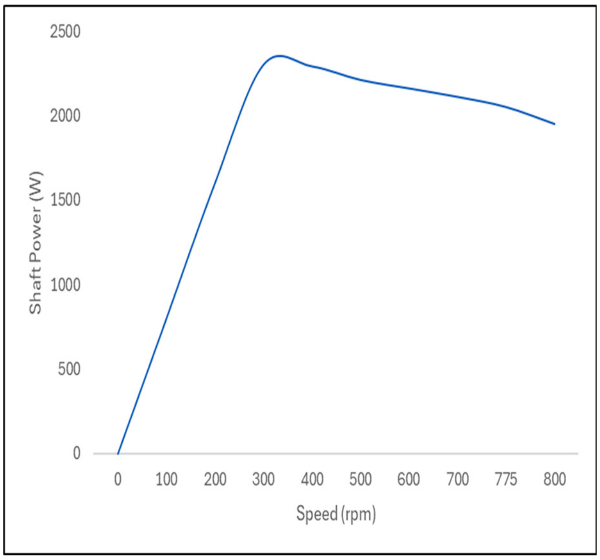


Figure 4: Speed vs Power [Peak]

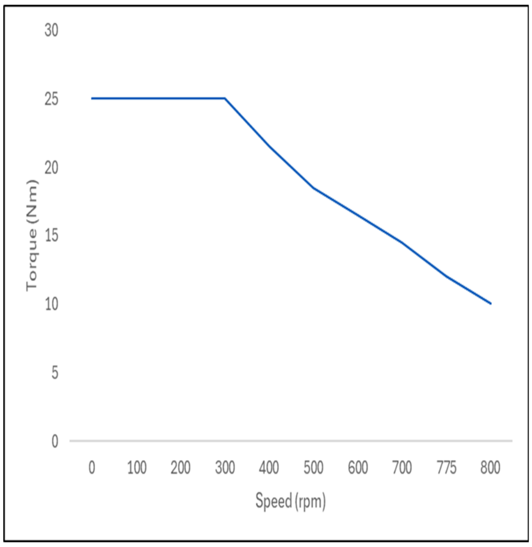


Figure 5: Speed vs Torque [Rated]

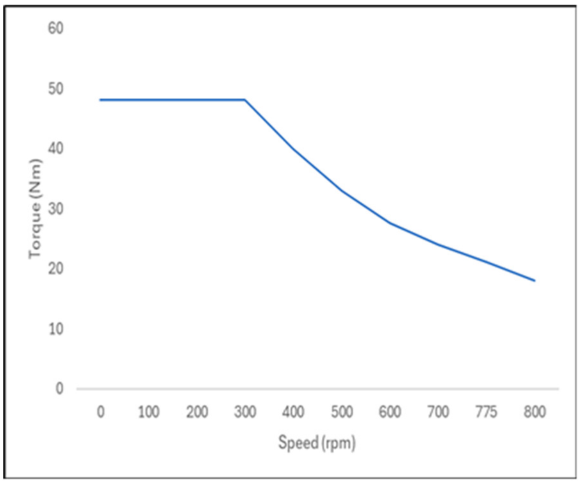


Figure 6: Speed vs Torque [Peak]

5.7 Final Element Analysis:

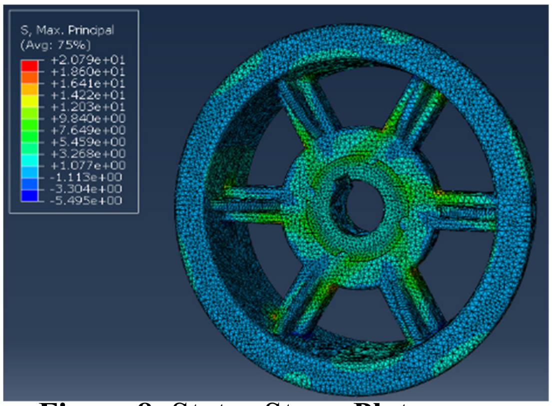


Figure 8: Stator Stress Plot

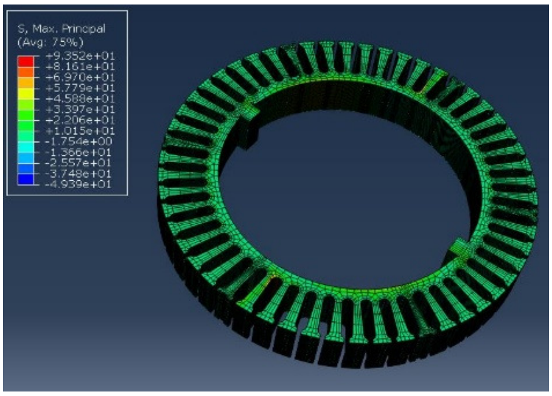


Figure 9: Stator Lamination Stress Plot

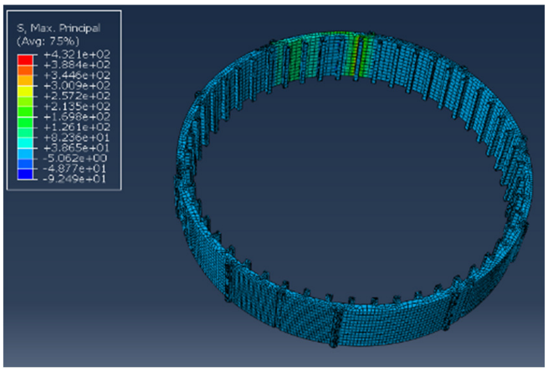


Figure 10: Rotor Lamination Stress Plot

5.8 Thermal Analysis:

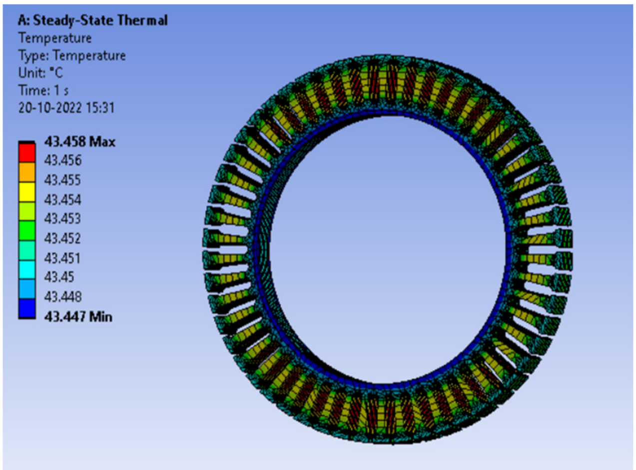


Figure 7: Rated Condition

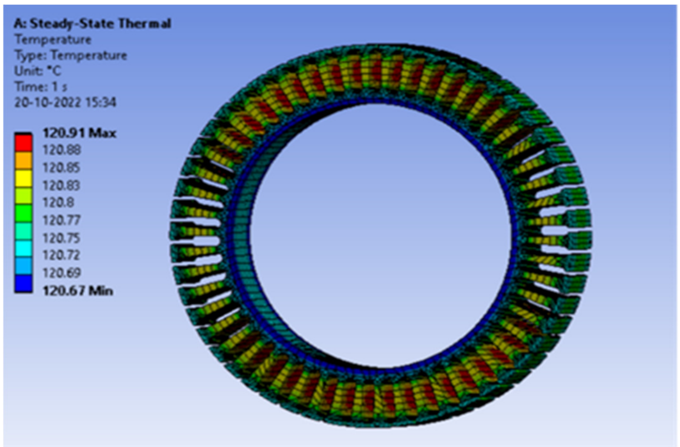


Figure 8: Peak Condition

6. Advantages of New Gen. Hub Motor

- Advanced Rotor Construction: Laminated steel sheets with magnet insertion instead of a solid steel ring. This reduces eddy current losses and improves magnetic performance.
- Lower Core Loss: Laminated rotor significantly reduces eddy current and hysteresis losses, leading to higher efficiency.
- Reduced Rotor Inertia: Laminated structure is lighter than a solid ring, resulting in lower inertia and better dynamic response.
- Improved Heat Dissipation: Laminated rotor allows better thermal flow, preventing heat buildup and improving reliability.
- Higher Torque Output: Optimized flux path and reduced losses enable greater torque density, making it suitable for high-performance applications.
- Higher Efficiency: Better magnetic performance and cooling lead to higher overall efficiency, reducing energy consumption.
- Faster Dynamic Response: Lower inertia improves acceleration and responsiveness, which is critical for EV performance.

1. Suitable Application of New Gen. Hub Motor

- E-bikes, Mopeds, Trikes.
- Wheelchair.
- Automated Guided vehicle for cargo shipment.
- Retro-fitted vehicle
- Delivery vehicles

8. Conclusion

This study presents a novel hub motor architecture for electric two-wheelers, addressing the limitations of conventional designs that rely on solid rotor rings with surface-mounted magnets. By introducing a laminated rotor structure with dedicated slots for magnet insertion, combined with a laminated stator, the proposed design significantly reduces core and eddy current losses, lowers rotor inertia, and improves thermal management. These enhancements collectively lead to higher torque density, improved efficiency, and better dynamic performance, making the motor highly suitable for low- to medium-speed electric two-wheeler applications. Preliminary simulations confirm the potential of this approach as a next-generation solution for hub motors. Future work will focus on detailed electromagnetic analysis, thermal modeling, and experimental validation to further optimize the design for commercial implementation.

References

[1] Ozturk Tosun, "The Design, Optimization, and Experimental Study of Hub and Axial Flux BLDC Motor Under Operating Conditions For Light Electric Vehicles," Journal Advances in Science, Technology and Engineering Systems Journal Vol. 8, No. 3, 272-282 (2023)

[2] A. Joss, Design and Optimization of a Hub Drive Electrical Motor for an L2 Class Electrical Vehicle for Sustainable Urban Transport Applications.

[3] Thenmozhi GANESAN, "Design conversion, and performance estimation of BLDC motor in hybrid electric vehicle BULLETIN OF THE POLISH ACADEMY OF SCIENCES TECHNICAL SCIENCES, Vol. 73(2), 2025, Article number: e153424

[4] Irfan Güven Çömezo˘glu, "Implementation and Experimental Validation of Efficiency Improvement in PM Synchronous Hub Motors for Light Electric Vehicles,

[5] Rohith raj N, Arun Sundar S "Formula Electric Vehicle Wheel Hub Design and Optimization for in-Hub Motor in Rear Wheeldrive Configuration, International Journal of Engineering Research & Technology (IJERT)

[6] Wolfgang Gruber, Wolfgang Bäck and Wolfgang Amrhein "Design and Implementation of a Wheel Hub Motor for an Electric Scooter,"

[7] Bianchi, N.; Bolognani, S.; Zigliotto, M.; "High-performance PM synchronous motor drive for an electrical scooter," IEEE Transactions on Industry Applications, vol. 37, no. 5, pp. 1348-1355, Sep/Oct 2001

[8] Aditya Khotte, 2Shravani Gaikwad, 3Sanat Deodhar "Design And Development Of An Efficient System For Affordable Retrofitting Of Internal Combustion Engine Vehicle To Hybrid Electric Vehicle" International Journal of Creative Research Thoughts. Volume 11, Issue 4 April 2023 | ISSN: 2320-2882

