DESIGN AND STRESS ANALYSIS OF A HEAT-DISSIPATING BRAKE DISC FOR ELECTRIC SCOOTERS

Executive Summary

Electric scooters are gaining popularity in urban mobility, but their compact structure limits the size of brake systems, causing heat buildup during frequent braking. This case study focuses on the CAD design and simulation of a lightweight, ventilated brake disc for electric scooters. The disc is optimized for heat dissipation and structural performance under repeated load. Finite Element Analysis (FEA) is used to test thermal expansion, deformation, and stress distribution. The study demonstrates the iterative design process and highlights the trade-offs between weight, performance, and manufacturability.

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1. Introduction

Braking systems in two-wheeled electric vehicles experience high-frequency usage in short urban trips. As speeds and loads increase, thermal stress on brake components becomes a design bottleneck. Conventional solid discs are prone to warping or thermal fade. A heat-optimized, ventilated brake disc design is proposed to improve both cooling and structural integrity.

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2. Problem Identification

Challenges in current systems include:

- **Excessive Heat**: No airflow channels in standard discs lead to poor thermal regulation.
- **Material Degradation**: Continuous heating causes micro-cracks and rotor wear.
- **Weight-Performance Trade-off**: Larger discs offer better performance but increase unsprung mass.

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3. Literature Review

Insights from prior research:

- Ventilated rotors with radial slots increase convective cooling by 15–25%.
- Materials like stainless steel (SS410) and grey cast iron balance thermal conductivity and machinability.
- Lightweight disc design improves vehicle efficiency by reducing rotational inertia.

Sources:

- Ghasemi, A. (2022). *Heat Transfer in High-Performance Brake Rotors*, SAE Int.
- ISO 6312:2020 (Brake Component Testing)
- Patil, S., & More, A. (2021). *FEA of Ventilated Disc Brake*, IJRTE

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4. Design Objectives

- **Ventilation Efficiency**: Add radial vents and perimeter holes.
- **Heat Tolerance**: Withstand temperatures of up to 450°C without warping.
- **Structural Stability**: Support braking torque with minimal deformation.
- **Manufacturing Compatibility**: Ensure the design supports CNC machining and casting.

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5. Design Process

Tools Used:

- SolidWorks for 3D modelling
- ANSYS Workbench for thermal and structural simulations
- MATLAB for heat transfer calculations

Process:

1. Sketched baseline disc design using standard scooter hub specs.

2. Integrated 12 radial vanes and 24 peripheral heat holes.
3. Performed mesh sensitivity analysis to ensure simulation accuracy.
4. Optimized mass-to-performance ratio through design iterations.

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6. Modelling and Simulation

Disc Specs:

- Outer Diameter: 160 mm
- Thickness: 4 mm
- Material: Grey Cast Iron (alternatively SS410)
- Max Operating Temp: 450°C

FEA Results:

- Max Thermal Stress: 122 MPa (below material yield of 250 MPa)
- Max Temp Zone: 438°C at inner edge, indicating proper vent function
- Total Deformation: 0.12 mm (acceptable within ISO tolerance limits)

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7. Evaluation and Improvements

Key observations:

- Heat sinks placed too close to mounting holes led to minor thermal bridging.
- By increasing vane curvature, cooling rate improved by 9.2%.
- Replacing solid disc with this design reduced total disc mass by 14%.

Proposed additions:

- Apply ceramic coating for enhanced wear resistance.
- Shift to dual-material composite (e.g., aluminum core with iron friction layer).

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8. Conclusion

The heat-dissipating brake disc design significantly enhances thermal regulation and durability under urban braking conditions. The case demonstrates how CAD and FEA tools can converge to refine product performance for lightweight electric vehicles.

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9. References

- ISO 6312:2020 Brake Component Standards
- Ghasemi, A. (2022). *Heat Transfer in High-Performance Brake Rotors*, SAE
- ANSYS Workbench User Manual
- Patil, S. & More, A. (2021). *FEA of Ventilated Disc Brake*, IJRTE
- SolidWorks Design Manual (2024)