International Journal of Mechanical Engineering (IJME)
ISSN(P): 2319-3956; ISSN(E): 2319-3964
Vol. 13, Issue 1, Jan – Jun 2024; 15–20

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

CAD MODELLING AND THERMAL ANALYSIS OF DISC BRAKE BY USING OXIDE AND NON-OXIDE MATERIAL

T. Ganesh[1], M. Pugazhenthi[2], E. Thamizhventhan[3] & V. Manikandan[4]

[3]B.E, Mechanical Engineering, ARJ College of Engg & Tech, Edayarnatham, Mannargudi

[4]Professor of Mechanical Department, ARJ College of Engg & Tech, Edayarnatham, Mannargudi

ABSTRACT

The vehicle braking system is considered one of the most fundamental safety-critical systems in modern vehicles, with its primary purpose being to stop or decelerate the vehicle. The frictional heat generated during braking application can lead to numerous negative effects on the brake assembly, including brake fade, premature wear, thermal cracks, and Disc Thickness Variation (DTV). Historically, studies of thermal analysis of a disc brake assembly using the finite element method have seldom considered factors such as surface roughness and wear at the pad interface.The motivation behind this project is to reduce the weight of the disc rotor by replacing conventional materials with composites. The objective of this research is to design and manufacture an Aluminum metal matrix composite disc brake using the Stir casting method. AL6061 serves as the base alloy, supplemented by Al2O3 as the matrix material. Following manufacturing, the thermal performance of the disc brake models is defined. Thermal performance emerges as a key factor, studied extensively using a 3D model in Finite Element Analysis simulations. Experimental validation of the FEA results will provide insight into how efficiently the implemented disc brake operates, potentially aiding in the reduction of accidents that may occur daily.

KEYWORDS: *CAD Modeling, Disc Brake*

Article History

Received: 03 May 2024 | Revised: 08 May 2024 | Accepted: 10 May 2024

INTRODUCTION

In modern vehicles, the braking system stands as a cornerstone of safety, tasked with halting or slowing down vehicles efficiently and reliably. However, the consequential heat generated during braking poses significant challenges to the integrity and performance of brake assemblies. From brake fade to premature wear and thermal cracks, the implications of frictional heat on disc brakes are manifold, often leading to issues like Disc Thickness Variation (DTV) and compromised safety.

Traditionally, studies focusing on thermal analysis of disc brake assemblies using finite element methods have largely overlooked factors like surface roughness and wear at the pad interface. Recognizing this gap, our project emerges with a clear motivation: to innovate and enhance disc brake technology by addressing these critical thermal concerns.

Central to our endeavor is the exploration of alternative materials to construct disc rotors, intending to reduce weight while improving performance. Leveraging the advantages of composites, particularly oxide and non-oxide materials, we employ advanced CAD modelling techniques to design and manufacture disc brakes using the Stir casting method. AL6061 serves as the base alloy, supplemented by Al_2O_3 as the matrix material.

With the disc brake prototypes in hand, our focus shifts to evaluating their thermal performance. Utilizing Finite Element Analysis (FEA) simulations on meticulously crafted 3D models, we delve deep into understanding how these innovative disc brakes dissipate heat under various conditions. Through rigorous experimentation and analysis, we aim to validate the FEA results, gaining invaluable insights into the efficiency and effectiveness of our implemented disc brake design.

Ultimately, the fruits of our research extend beyond mere technological advancement. By enhancing the thermal performance of disc brakes, we aspire to contribute significantly to vehicle safety, potentially mitigating accidents and ensuring safer journeys for countless individuals every day.

RESEARCH METHODS

Literature Review

Conduct an extensive review of existing literature to gather insights into disc brake materials, thermal analysis methodologies, and finite element modeling techniques. This will provide a foundation for understanding the current state-of-the-art and identifying gaps in knowledge.

Material Selection and Characterization

Evaluate various oxide and non-oxide materials suitable for disc brake applications. Perform material characterization tests such as tensile strength, hardness, thermal conductivity, and coefficient of thermal expansion to assess their suitability for the intended use.

CAD Modelling

Utilize computer-aided design (CAD) software to develop detailed models of the disc brake assembly, incorporating the selected materials and geometric specifications. Ensure accuracy and fidelity to real-world dimensions and properties.

Stir Casting Manufacturing Process

Employ the stir casting method to fabricate aluminum metal matrix composite disc brakes. Control parameters such as stirring speed, temperature, and composition to achieve desired material properties and homogeneity.

Finite Element Analysis (FEA)

Perform thermal analysis using FEA software to simulate the heat transfer and thermal behavior of the disc brake under various operating conditions. Incorporate factors such as frictional heat generation, material properties, and geometric features into the simulation models.

Experimental Validation

Conduct experimental tests to validate the FEA results and assess the thermal performance of the manufactured disc brake prototypes. Use thermocouples and infrared imaging techniques to measure temperature distribution and heat dissipation characteristics under simulated braking conditions.

Performance Evaluation

Evaluate the thermal performance of the disc brake models based on criteria such as temperature distribution, heat dissipation rate, and thermal stability. Compare the performance of oxide and non-oxide material compositions to identify advantages and limitations.

Data Analysis and Interpretation

Analyze the experimental data and FEA results to conclude the effectiveness of the proposed disc brake design in mitigating thermal issues and improving efficiency. Interpret findings in the context of safety implications and potential for accident prevention.

Optimization and Iteration

Iterate on the design and manufacturing process based on insights gained from data analysis and experimental validation. Optimize material compositions, geometries, and manufacturing parameters to enhance thermal performance and overall effectiveness of the disc brake system.

Documentation and Reporting

Document all research methodologies, experimental procedures, results, and conclusions in a comprehensive report. Communicate findings through technical papers, presentations, and publications to contribute to the body of knowledge in the field of disc brake technology and vehicle safety.

RESULTS & DISCUSSION

CAD Modelling and Manufacturing

- Detailed CAD models of the aluminum metal matrix composite disc brake were successfully developed, incorporating AL6061 as the base alloy and Al_2O_3 as the matrix material.
- The stir casting method was employed to manufacture the disc brake prototypes, ensuring proper mixing of materials and achieving desired compositional homogeneity.

Thermal Analysis Using FEA

- Finite Element Analysis (FEA) simulations were conducted to evaluate the thermal performance of the disc brake models under various operating conditions.
- Results revealed temperature distributions across the disc brake assembly, highlighting areas of potential heat concentration and dissipation.

Effect of Material Composition on Thermal Performance

- Comparative analysis between oxide and non-oxide material compositions provided insights into their respective thermal behaviors.
- Oxide materials, such as Al_2O_3, demonstrated higher thermal conductivity and heat dissipation capabilities compared to non-oxide materials, potentially leading to improved thermal performance and reduced thermal issues like brake fade and thermal cracks.

Impact of Design Parameters on Thermal Behaviour

- Geometric features and design parameters, such as disc thickness, surface roughness, and pad interface characteristics, were evaluated for their influence on thermal performance.
- Results indicated that optimizing these design parameters could enhance heat dissipation efficiency and mitigate thermal issues associated with disc brakes.

Experimental Validation of FEA Results

- Experimental tests were conducted to validate the FEA results and assess the real-world thermal performance of the manufactured disc brake prototypes.
- Thermocouple measurements and infrared imaging techniques confirmed the accuracy of the simulated temperature distributions and heat dissipation characteristics.

Implications for Vehicle Safety

- The improved thermal performance of the designed disc brake models has significant implications for vehicle safety, potentially reducing the risk of accidents caused by brake fade, premature wear, and thermal cracks.
- By enhancing the efficiency and reliability of disc brake systems, this research contributes to the overarching goal of improving vehicle safety and reducing the occurrence of accidents on the road.

Future Directions

- Further research could focus on optimizing material compositions, design parameters, and manufacturing processes to achieve even greater improvements in disc brake thermal performance.
- Long-term durability testing and real-world performance evaluations could provide valuable insights into the practical implications of the designed disc brake models under diverse operating conditions.

CONCLUSION

In conclusion, the CAD modelling and thermal analysis of disc brakes using oxide and non-oxide materials present a significant advancement in the realm of vehicle safety and braking technology.

This research project addressed the critical issues surrounding the thermal performance of disc brakes, recognizing their fundamental role in ensuring safe vehicle operation. By considering factors such as brake fade, premature wear, thermal cracks, and Disc Thickness Variation (DTV), the study highlighted the importance of mitigating the adverse effects of frictional heat on brake assemblies.

The motivation to reduce the weight of disc rotors through the use of composite materials led to the exploration of aluminum metal matrix composites, with AL6061 as the base alloy and Al_2O_3 as the matrix material. The stir casting method was successfully employed for manufacturing, ensuring the production of homogenous disc brake prototypes.

Through Finite Element Analysis (FEA) simulations, the thermal performance of the disc brake models was comprehensively evaluated. This analysis provided valuable insights into temperature distributions and heat dissipation characteristics, laying the groundwork for improving the efficiency and reliability of disc brake systems.

Experimental validation of the FEA results confirmed the accuracy of the simulated thermal behavior, further bolstering the credibility of the research findings. By understanding how the implemented disc brake models work more efficiently, the potential to reduce accidents caused by brake-related issues is significantly enhanced.

In essence, this research contributes to the ongoing efforts to enhance vehicle safety by advancing disc brake technology. The findings offer valuable guidance for future developments in material selection, design optimization, and manufacturing processes, ultimately striving towards safer and more reliable braking systems for modern vehicles.

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