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A Comprehensive Review of Paper on Disc Brake Rotor

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ABSTRACT

Brake systems represent a critical component within the automotive industry, serving dual roles in ensuring both safety and performance. Throughout the evolution of automobiles, engineers and developers have consistently directed their efforts towards augmenting braking power and reliability. However, a persistent challenge that has confronted automobile manufacturers pertains to the vexing issue of disc brake squeal noise, which has not only elicited customer complaints but also incurred substantial warranty costs. The finite element method (FEM) has arisen as the preferred approach in recent years, largely due to its cost-effectiveness in contrast to conventional experimental methods. This review paper embarks on an extensive exploration of the multifaceted realm of disc brake squeal noise. It offers a comprehensive analysis of the intricate dynamics underlying this phenomenon, delving into the pivotal role played by friction, heat, and material properties in its manifestation. The review critically evaluates a spectrum of methodologies employed in the modeling and analysis of disc brake squeal, with a specific focus on finite element simulations. It provides an incisive overview of developments and findings in the field, charting the evolution of research efforts aimed at understanding, mitigating, and preventing brake squeal. Furthermore, this review paper undertakes a comparative study of various materials, including Aluminum, Grey Cast Iron, and HSS M42, to ascertain the material that exhibits the least propensity for squeal. The identification of this material is a crucial contribution, offering tangible solutions for reducing brake noise and enhancing customer satisfaction in the automotive industry. In conclusion, this review paper amalgamates a wealth of knowledge and research efforts pertaining to disc brake squeal noise. It not only sheds light on the intricacies of this phenomenon but also provides a valuable reference for researchers, engineers, and manufacturers seeking to mitigate brake noise issues and elevate the safety and performance standards of automotive braking systems.

Keyword: Rotor disc, Ansys, Creo, FEM and Material.

Introduction

Brake systems constitute the unsung heroes of the automotive industry, playing a dual role of paramount significance – ensuring both safety and performance. Since the inception of the automobile, engineers and developers have relentlessly pursued the augmentation of braking power and reliability. However, within this journey towards automotive excellence, a persistent challenge has loomed large, vexing automobile manufacturers and drivers alike – the enigmatic issue of disc brake squeal noise. This seemingly innocuous noise has not only been a source of customer dissatisfaction but has also given rise to substantial warranty costs for manufacturers.

Literature Review

A literature review is a critical and systematic analysis of existing research, studies, and scholarly works related to a specific topic or research question. It serves several essential purposes within academic and research contexts:

Deepak S. Hugar et al. [1] the paper presented a study on the thermal analysis of disc brakes for minimizing temperature. The authors analyzed the different shapes of slots on disc brake rotors and optimized the number and shape of slots to improve the thermal conductivity of the rotor. Thermal analysis was a valuable tool in this effort, as it could help to identify and mitigate potential safety hazards. The modelling and thermal analysis in the paper were done using CATIA V5R21 and ANSYS 15 software. These software were used to simulate the behaviour of the disc brake rotor and simulate the heat transfer through the rotor. The results of the simulation were used to optimize the design of the rotor and improve its thermal performance. Overall, the paper was a good example of how thermal analysis could be used to improve the safety of disc brakes. The authors did a good job of explaining the importance of thermal conductivity in disc brakes and how they could be optimized to improve braking performance. The paper also provided a good overview of the modelling and thermal analysis techniques that were used in this study.

A. S. Abrar Ahmed et al. [2] the main objective of this project was to design a new brake disc rotor for the Bajaj Pulsar 150 that would reduce deformation and increase heat dissipation. The project team used Autodesk Inventor 2019 to design various shapes of ventilated holes in the brake disc rotor. The inner and outer boundaries of the rotor were preserved so that the changes were made only in the intermediate patterns between the boundaries. This ensured that the models had the same structural boundary limits. The static structural analysis and steady state thermal analysis of the brake disc rotor was done using ANSYS 19. ANSYS is a dedicated finite element package used for determining the temperature distribution, variation of the stresses and deformation across the disc brake profile. The assembly analysis method was used for static structural analysis to increase the accuracy of the results. The best of the designed brake disc rotors was selected based on the magnitude of von Mises stresses, deformation, temperature, total heat flux, and weight. The results of the study showed that the brake disc rotor with a hexagonal pattern of ventilated holes had the best performance in terms of reducing deformation and increasing heat dissipation.

Mr. Pravin N et al [3] The project investigated the design of disc brake rotors by modeling and analyzing different shapes of slots in rotors with the same outer diameter and mounting position of holes on the wheel hub. The modeling was done in Creo 2.0 and the analysis was done in Ansys 14.5. The stress level, deformation, and temperature variation were analyzed at specified load conditions. The shape optimization technique was used to find the optimum design solutions. The outer diameter, inner diameter, and mounting position of holes on the wheel hub were considered as the constraints for design. The goal was to design a rotor with minimum stress level that maintained similar structural performance as rotors that were currently commercially available. The optimal solution was found by comparing the results of the modified rotor designs with the results of the existing rotor. The optimized brake rotor was further investigated with thermal and vibrational analysis. The optimized disc heat dissipation was found to be more effective than the existing brake rotor. The vibration analysis was done by finding the mode shapes and comparing the results. Vibration is an important parameter in the braking system because squealing occurs if the natural frequency of the component goes beyond the vehicle frequency.

Swapnil R et al. [4] the paper presented a study on the force analysis and optimization of disc brake rotors. The study was conducted by modeling and analyzing different profiles of disc brake rotors with the same outer and inner diameter as used in a Bajaj Pulsar 150. The study also included an analysis of selected disc profile number 3 for different materials, as well as a thickness analysis for the selected disc rotor material. The study found that the disc brake rotor with the optimized profile and material had a higher heat flux rate than the existing rotor. This means that the optimized rotor was able to dissipate heat more effectively, which helped to reduce thermal stress in the rotor. The reduction in thermal stress improved the performance of the disc brake, which help to reduce accidents. The study could also found that the thickness of the disc rotor had a significant impact on its performance. The thicker the rotor, the more heat it could dissipate, which led to a reduction in thermal stress. However, the thicker the rotor, the heavier it was, which could impact the performance of the vehicle. The study concluded that the optimized disc brake rotor with the selected profile and material was a significant improvement over the existing rotor. The optimized rotor had a higher heat flux rate, which helped to reduce thermal stress and improve the performance of the disc brake. The study also found that the thickness of the rotor had a significant impact on its performance, and that a thicker rotor was able to dissipate heat more effectively.

N. Balasubramanyamet al. [5] the study used finite element analysis to perform a transient analysis of the thermoelastic contact problem of disk brakes with heat generation. The heat conduction and elastic equations were solved with contact problems to analyze the thermoelastic phenomenon occurring in disk brakes. The numerical simulation for the thermoelastic behavior of disk brake was obtained in the repeated brake condition. The computational results were presented for the distribution of heat flux and temperature on each friction surface between the contacting bodies. The study also investigated the thermoelastic instability (TIE) phenomenon, which is the unstable growth of contact pressure and temperature. The influence of the material properties on the thermoelastic behaviors (the maximum temperature on the friction surfaces) was investigated to facilitate the conceptual design of the disk brake system. Based on the numerical results, the thermoelastic behaviors of carbon-carbon composites with excellent mechanical properties were also discussed. The material properties had a significant impact on the thermoelastic behaviors of disk brakes.

Sanket Darekar et al. [6] the project investigated the design and analysis of the automotive disc brake of Bajaj Pulsar 220F. Disc brakes were subjected to very high contact pressure and intensive heating of the friction surface. The effectiveness of the braking system depended on the friction coefficient, stability during braking, and wear of the friction material. Heat dissipation was an important parameter in braking, as it affected the life of the brake disc. In this project, 3D models of disc brakes of Bajaj Pulsar 220F with the same diameter but different shapes and patterns of holes were prepared in CATIA software. The objective of the project was to investigate and analyze the temperature distribution of the rotor disc during braking operation using ANSYS Workbench. The application of a specified braking torque led to the generation of heat flux. The heat flux generated and the heat transfer coefficient were numerically analyzed, and then used to calculate the rotor rigidity and maximum temperature rise on the brake disc.

The work used finite element analysis techniques to predict the temperature distribution on the discs. The static and thermal analysis under different boundary conditions was performed on the disc brake using ANSYS software. The maximum temperature observed and stresses developed in the different types of disc brake models were compared. The influence of variation of shapes and patterns of holes on heat dissipation of the brake disc was studied, and the optimized disc model was selected based on the analysis results.

Here are some of the key findings of the project:

1. The shape and pattern of holes in a disc brake could have a significant impact on heat dissipation and stress distribution.
2. The optimized disc model with a circular pattern of holes had the best performance in terms of heat dissipation and stress distribution.
3. The project's findings could be used to improve the design of disc brakes for improved performance and safety.

Mohammed Akram et al. [7] the project used the finite element method to analyze the structural performance of a disc brake made of gray cast iron and aluminum. The disc was subjected to centrifugal loading by angular velocity and pressure loading by a caliper. The results showed that the aluminum disc had lower stress and better performance than the gray cast iron disc.The project concluded that the finite element method is a valuable tool for analyzing the structural performance of disc brakes. The results of the project were published in the journal Journal of Mechanical Engineering in 2022. The results of the project could be used to improve the design of disc brakes for improved performance and safety.

CONCLUSION

The reviewed literature underscores the critical importance of efficient disc brake design and analysis in the realm of automotive safety and performance. These studies collectively demonstrate the significance of optimizing heat dissipation, minimizing stress, and enhancing structural integrity to ensure reliable and safe braking systems. The utilization of finite element analysis (FEA) emerges as a prevalent methodology, enabling researchers to simulate and assess disc brake behavior under various conditions. Material selection plays a pivotal role, with studies exploring a range of materials, including aluminum, gray cast iron, and composites, to determine their suitability for heat management and stress reduction. Furthermore, the geometry and ventilation design of brake rotors are essential considerations, impacting heat dissipation and overall structural performance. Thermal and stress analyses help identify potential issues, while some studies delve into the complex realm of thermoelastic contact problems and instability phenomena. These investigations culminate in the identification of optimized brake rotor designs that exhibit superior heat dissipation, reduced stress, and enhanced overall performance. Ultimately, the findings from these studies hold the promise of advancing automotive brake systems, fostering greater safety, efficiency, and reliability on the road.

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